CORDLESS STUD FUSION

Technical Manual

International version

September 2025

Contents

Preface

At Hilti, we are committed to invest in technology to support and further drive productivity of the construction industry. Hilti Cordless Stud Fusion (CSF) provides customers with a fully cordless system with built-in process controls to install high quality stud welds consistently and safely.

The objectives of this Technical Manual are the following:
- Introduce the CSF system and technology
- Provide guidance to ensure the quality of surface preparation
- Provide guidance to ensure the quality of stud welding
- Offer technical specifications and load data for the F-BT studs
- Provide guidance and resources for implementation of CSF on jobsites

This Technical Manual covers stud fusion of metallic materials subject to static loading. It provides requirements and recommendations relating to stud fusion, including preparation, installation, product specification, welding procedure specification and qualification, process control, and qualification testing of operators.

This manual provides guidance for project specific design, qualification, and installation in keeping with the following welding standards, however CSF is not solely limited to use with these standards:
- EN ISO 14555 [5]
- AWS D1.6/D1.6M [15]

The parent materials covered in this Technical Manual are the following standardized materials:
- 1.1, 1.2, 1.3 and 2.1 according to CEN ISO/TR 15608 [8]
- Steel grades according to AWS B2.1 [13]
- American Bureau of Shipping (ABS) steel grades

Parent materials not identified to the standard nominated above may be used provided one of the following requirements are met:
- Testing parent materials, to determine compliance with before mentioned steel grades.
- Comparing parent material test certificates, to determine compliance with the nominated steel grades.

This Technical Manual is intended for use in all fields of the metal-working industry.

1. Introduction

Engineers, manufacturers, contractors, and a range of other professionals use stud welding to attach studs to steel of varying materials and thicknesses.

The Cordless Stud Fusion (CSF) welding process is classified as a drawn arc (DA) stud welding process with shielding gas (welding process 783 according to EN ISO 14555). The drawn arc stud weld process utilizes a welding power supply to create an electric arc along a circuit created between the stud and parent material. The electric arc travels between the two materials via an air gap, generating an intense, concentrated heat used to melt the stud's base and a small area of the parent material. Once the materials are melted appropriately, the stud is plunged into the molten area and held in place as the metals solidify to form the welded connection.
The timing, voltage, current, plunge and other aspects of the weld process are fully controlled by the CSF system, with power turning off automatically, negating the need for fine tuning by an operator.

Benefits of CSF:
- Compact and portable system, with no need for external power source
- Adjustment free hand tool and fully automated welding process
- Consistent and spark free process
- Lightweight and convenient shielding gas
- Easy to learn welding process
- No ferrule required

Welding codes and standards address all aspects of design and fabrication of welded components, including welding procedure qualification, testing methods, process control, and operator qualifications.

It is therefore important to understand the requirements of the relevant welding codes and standards to ensure stud welding is completed effectively and safely. This technical manual provides guidance relative to these standards.

The Cordless Stud Fusion System is qualified through testing by following authorities:
- Det Norske Veritas (DNV)
- gbd Lab GmbH (gbd)
- Lloyd's Register (LR)
- RINA Services S.p.A. (RINA)

The Cordless Stud Fusion System holds type approvals from following authorities:
- American Bureau of Shipping (ABS)
- Bureau Veritas (BV)
- Det Norske Veritas (DNV)
- ICC Evalution Service (ICC-ES)
- Lloyd's Register (LR)

2. Application information

The purpose of CSF is to weld studs to construction steel workpieces. Modern fastening technology is increasingly important in shipbuilding, on- and off-shore structures, modern construction industry and structural engineering worldwide. Among others, CSF is used in following application groups:

- Multi-disciplinary support
- Welded support for cable trays
- Modular support for cable trays
- Individual support
- Welded support for pipe trays
- Modular support for pipes
- Suspended ceiling
- Equipment fastening
- Shipbuilding fastening

2.1 Applications

Representative services within the applications groups are pipes, conduits electrical services, control services, instrumental services and telecommunication services. Typical shipbuilding fastenings are false ceiling fastening, outfitting and inspection grids. Figure 2.1-1 shows various application examples.

Applications

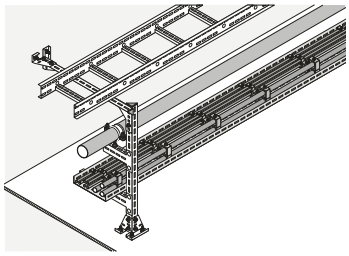
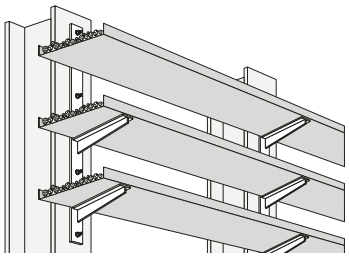
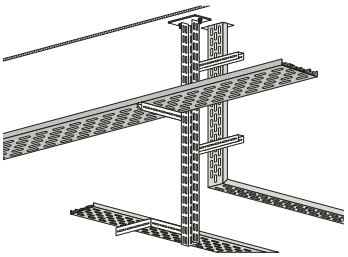
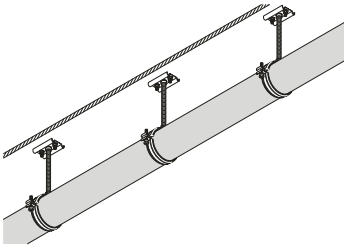
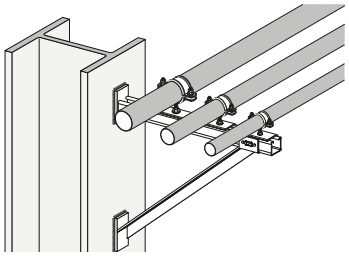
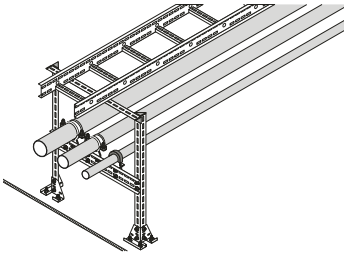
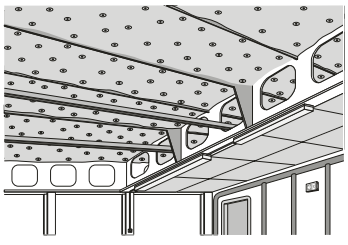
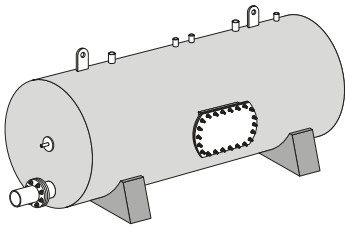
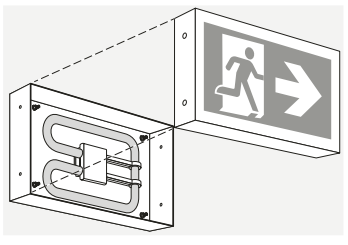
		
Multi-disciplinary support	Welded support for cable trays	Modular support for cable trays
		
Individual support	Welded support for pipe trays	Modular support for pipes
		
Suspended ceilings	Shipbuilding fastenings	Equipment fastenings

Figure 2.1-1: Applications

3. Cordless Stud Fusion (CSF)

This section gives an overview on the CSF technology.

3.1 CSF equipment

In this section an overview of CSF equipment is given. It is subdivided as follows:
- Surface preparation equipment when installing with surfacing tools
- Surface preparation equipment when installing with grinding tools
- Stud fusion equipment
- Installation equipment
- Testing equipment

The correct functioning of the CSF equipment shall be ensured by the manufacturer. During production, a function check shall be performed at fixed intervals.
Cables, connection elements, mechanical guides and fixtures and stud holders shall be regularly checked and replaced if excessive wear or damage has occured.

Surface preparation equipment when installing with surfacing tools	
	Cordless drill driver: SF 8M-A22 • It is recommended to hold the drill with the other hand at the back of the drill.
	Cordless hammer drill driver: SF 6H-22 • It is recommended to hold the drill with the other hand at the back of the drill.
	Surface tool FX 3-ST d14, for preparing surfaces with: • Mill scale on bare (uncoated) steel • Weldable primer with maximum coating thickness: 25 µm
	Surface tool FX 3-ST d20, for preparing surface with: • Non-weldable primer • HDG coating • Multi-layer coating • Maximum coating thickness: 1000 µm

Figure 3.1-1: Surface preparation equipment when installing with surfacing tools

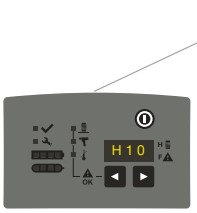
Surface preparation equipment when installing with grinding tools

	AG 5D-22 NURON Cordless angle grinder (125 mm) • Cordless brushless angle grinder with dead man's switch for everyday cutting and grinding with discs up to 125 mm (Nuron battery platform).
	AG 4S-22 NURON Cordless angle grinder (125 mm) • Cordless brushless angle grinder with adjustable speed for everyday cutting and grinding with discs up to 125 mm (Nuron battery platform).
	AG 6D-22 NURON Cordless angle grinder (125 mm) • Powerful cordless angle grinder with brushless motor, SensTech control and advanced safety features for discs up to 125 mm (Nuron battery platform).
	AG-D SP Grinding discs • Extra-long lifetime and high stock removal rate. • For use on regular or stainless steel. • Complies with EN 12413 and Organization for the Safety of abrasives (oSa) safety standards.
	AG-D SPX Grinding discs • Hilti's ultimate abrasive grinding disc offering super-high removal rate and extra-long lifetime. • For use on regular or stainless steel. • Complies with EN 12413 and Organization for the Safety of abrasives (oSa) safety standards.

Figure 3.1-2: Surface preparation equipment when installing with grinding tools

Stud fusion equipment

Cordless stud fusion unit FX 3-A
- Battery powered
- Fully automatic
- Cordless stud fusion unit with one touch control panel
- Based on selected welding code H1, H2, H3 or H10, all welding parameters are set



Stud stamp

One touch control panel
- Electrical and mechanical process parameters are pre-set based on selected H-code
- Required H-code is stamped on top of each stud

Gas can FX 3-GC for use in the Cordless stud fusion unit
- Shielding gas (SG): ISO 14175 – M21 – ArC-18:
  - 82% Ar (CAS 7440-37-1)
  - 18% CO2 (CAS 124-38-9)

Stud fusion hand tool FX 3-HT
- All studs work on the same hand tool
- Stud holder is changed to adjust stud diameter
- Auto adjustment to stud length

Stud holder X-SH F3 M6-1/4"
- For use with F-BT studs featuring M6 thread diameters

Stud holder X-SH F3 M8-5/16"
- For use with F-BT studs featuring M8 thread diameters

Figure 3.1-3: Stud fusion equipment – part I

Stud fusion equipment

Stud holder X-SH F3 M10-3/8"
- For use with F-BT studs featuring M10 thread diameters

Stud holder X-SH F3 M12-1/2"
- For use with F-BT studs featuring M12 thread diameters

Support leg X-SL F3
- Support leg for keeping tool perpendicular to base steel while welding

Charger C 53
- For charging the cordless stud fusion unit
- Quick charge button available

Ground cable X-GC F3
- For connecting FX 3-A to grounding point on steel plate

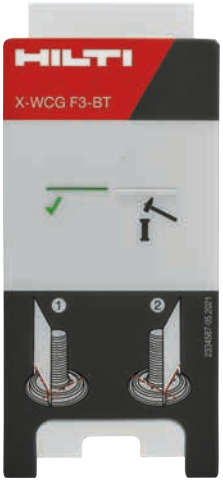
Magnetic ground clamp X-MC F3
- May be used as a temporarily installed grounding point

Stud holder change tool X-SHT F3
- Used to exchange the stud holder on the FX 3-HT

Figure 3.1-4: Stud fusion equipment – part II

Post weld installation equipment

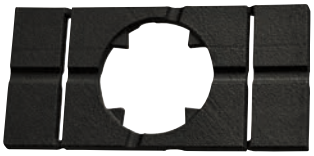
Sealing washer setting tool X-WST F3-BT
- Setting tool with different adapters can be used for metric (M6, M8, M10, M12) and imperial (3/8”, 1/2”) studs
  - M6: green
  - M8: yellow
  - M10/ 3/8": red
  - M12/ 1/2": blue



Washer Check Gauge X-WCG F3-BT
- For verifying sealing washer installation

Figure 3.1-5: Post weld installation equipment

Support plate



Support plates are available as an option to help with load distribution for F-BT-MR SN studs with sealing washers.
The plate is installed at the base of the stud around the washer, to provide an even surface for the fastened material to act upon. This helps to transfer bending moment effects to the base or parent material.

Figure 3.1-6: Support plate

Sealing washer

Sealing washer
- Included with F-BT-MR SN studs to provide a seal over the prepared surface and weld joint to help prevent corrosion. For more information regarding corrosion resistance and sealing, reference Sections 4.4 and 4.5.

Figure 3.1-7: Sealing washer

Measuring and testing equipment

Pull Tester HAT 28-FX

- The HAT 28-FX is a system for applying tensile loads to installed studs. It consists of a mechanical screw jack passing through a hydraulic load cell, which directly measure the load applied to the stud. For more information regarding testing of studs see Section 8.

Bending bar X-BB F3

- For bend testing studs during qualification and production activities. For more information regarding testing of studs see Section 8.

Figure 3.1-8: Measuring and testing equipment

3.2 CSF surface preparation

Surface preparation before welding is a mandatory step to ensure the integrity of the welded joint. It is necessary to ensure that the parent material surface is clean, free from scale and coatings, dry and free from organic materials. The surface preparation process not only cleans the steel, but also provides a suitable surface profile to achieve acceptable welding results. To provide reliable weld performance across variance of coatings and steel surfaces, the welding surface needs to be prepared with the recommended Hilti FX 3 surface tools or Hilti grinding tools and discs. This section provides the surface preparation steps, tool selection and the surface inspection guidelines for different parent material coating types. CSF surface tools may be used to prepare both coated and uncoated base steels, while grinding tools may only be used for uncoated base steels. For grinding processes new software version is required (see table 3.9-1).

3.2.1 Surface preparation with surfacing tools

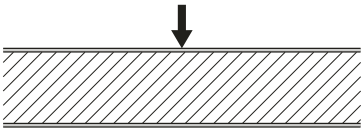
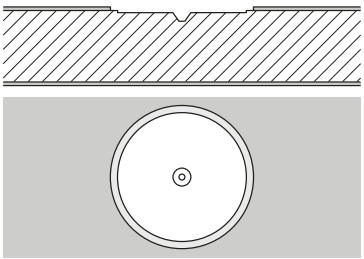
Surface preparation	
	Mark stud location • Use a center punch to mark the stud location
	Prepare surface • Coated parent material: remove coating • Uncoated parent material: remove rust, dirt, contaminants • Use drilling tool SF 8M-A22 or SF6(H)-22 • Adjust cordless screwdriver to correct speed • Select gear according to Instructions for Use (IFU)/Operators Instructions (OI): – SF 8M-A22: gear 3 (1’250 rpm) – SF 6H-22: gear 2 (2’000 rpm) • Insert the recommended surface tool appropriate to the parent material based on Figure 3.2-2. • For more details, please refer to the Instruction for Use (IFU).

Figure 3.2.1-1: Surface preparation with surfacing tools

Figure 3.2.1-2 shows the surface tool selection for different parent material, coating types and thicknesses with an assignment to the corresponding studs.

Surface tool selection			
Preparation tool and insert	Surfacing tool		
	SF 8M-A22: Gear 3, SF 6H-22: Gear 2		
	FX 3-ST d14	FX 3-ST d20	
Parent material coating	Type I	Type II	
	Weldable primer, Black steel with mill scale	Non-weldable primer HDG coating Duplex coating Multi-layer coating	Non-weldable primer HDG coating Duplex coating Multi-layer coating
Coating thickness	t_c ≤ 25 µm (0.025 mm)	t_c ≤ 1000 µm (1 mm)	t_c ≤ 1000 µm (1 mm)
Stud type	F-BT-MR	F-BT-MR	F-BT-MR SN

Figure 3.2.1-2: Surface tool selection

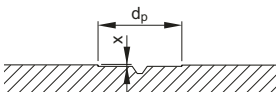
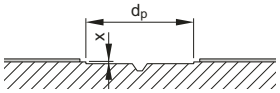
Surface preparation dimensions			
Parent material coating type I		Designation	Diameter of prepared surface, d_p
		FX 3-ST d14	14 mm (0.551")
Parent material coating type II		Designation	Diameter of prepared surface, d_p
		FX 3-ST d20	20 mm (0.787")

Figure 3.2.1-3: Surface preparation dimensions

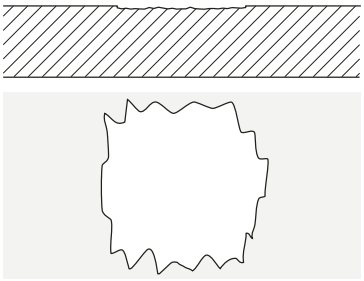
Surface preparation removes only a small amount of the base steel material, with a typical depth, x, of 0.2 mm (0.008") relative to the base steel surface.

3.2.2 Surface preparation quality assessment

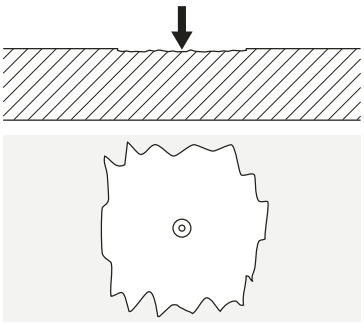
All surface preparations should be visually inspected according to the following technical documents: Hilti F-BT visual examination catalogue [10] and Instructions for use (IFU).

3.2.3 Surface preparation with grinding tools

Surface preparation



Prepare surface
- For uncoated base materials or those with weldable primer: remove rust, dirt contaminants, primer
- Use angle grinder AG 5D -22 Nuron, AG 4S- 22 Nuron, AG 6D-22 Nuron
- Adjust angle grinder to correct speed
- Select gear according to instruction of use (IFU)/ Operator instruction (OI):
  - AG 4S-22: Gear 6 (7’600 rpm)
  - AG 5D-22: Gear 1 (9’000 rpm)
  - AG 6D-22: Gear 1 (8’500 rpm)
- Insert the recommended grinding disc based on figure 3.2.3.1
- For more detail refer to the F-BT-MR instruction of use (IFU)



Mark stud location
- Use a center punch to mark the stud location on the grinded surface.
- Attention: Apply the center punch always after grinding

Figure 3.2.3-1: Surface preparation with grinding tools

Surface tool recommendation

Preparation tool and insert	Grinding tool
	AG 4S-22: Gear 6, AG 5D-22: Gear 1, AG 6D-22: Gear 1
	AG-D SP: 125x6.4, AG-D SPX: 125x6.4
Parent material coating	Type I
	Weldable primer, Black steel with mill scale
Coating thickness	$t_c \leq 25$ µm
Stud type	F-BT-MR

Figure 3.2.3-2: Surface tool recommendation

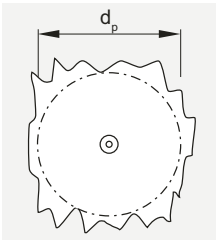
Surface preparation dimensions		
Parent material coating type I		Diameter of prepared surface d_p
		≥ 0.787"/20 mm

Figure 3.2.3-3: Surface preparation dimensions

The inspection in detail is provided in following technical documents: Hilti F-BT visual examination catalogue [10] and Instructions for use (IFU).

3.3 CSF welding process

CSF is a drawn-arc technique (EN ISO 4063-783) where a stud is welded onto a steel parent material by heating both parts with an arc. It is carried out with shielding gas.

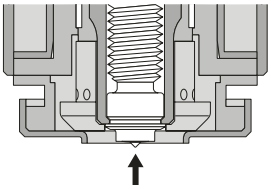
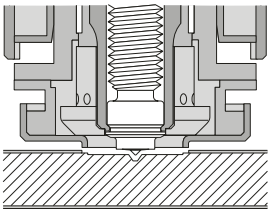
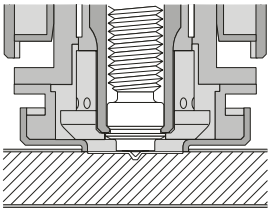
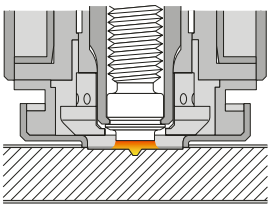
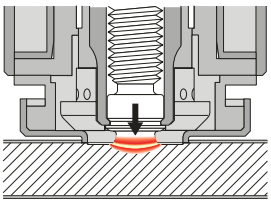
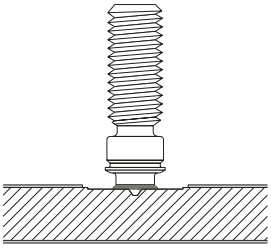
Stud fusion	
• Easy and ergonomic operation. • Fully computer-controlled and automated cordless stud fusion unit. • Ability to change stud holder allows for one hand tool to accommodate various stud sizes.	
	Prepare stud fusion • Identify stud H-code • Adjust the tool by selecting the welding code (H-code) • Press stud into tool front until it clearly clicks into place
	Position stud • Position stud tip over the center of the prepared surface
	Compress hand tool to base material
	Start stud fusion process • Trigger the tool • Welding process is automatically started • Stud is automatically lifted • Arc is automatically ignited • Arc melts stud base and parent material • Stud is automatically plunged into the molten material • Arc is extinguished and metal cools down
	
	Inspect stud • Remove tool • Inspect weld joint

Figure 3.3-1: CSF welding process

3.4 CSF welding parameters

The basic parameters to describe the Cordless Stud Fusion (CSF) process are as follows:

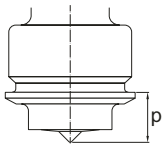
- **Polarity:** In welding, polarity is the property of each piece metal used to form a circuit, which determines the flow of electrons within a circuit. The CSF system is a direct current (DC) system in which the stud acts as the negative pole and the base material acts as the positive pole, resulting in flow of electrons from the stud to the base material.
- **Welding current:** Electric current is the rate of charge flow in an electric circuit, measured in Amperes (A).
- **Welding time:** The amount of time for which the welding current is applied.
- **Protrusion:** The distance between the tip of the F-BT stud facing the base material and where the FX 3-HT tool grips the stud at the stud holder interface. See figure 3.4-1.
- **Lift:** The distance between the tip of the stud and the base material during the welding process. The FX 3-HT hand tool automatically lifts the stud to the appropriate distance prior to igniting the electrical arc.
- **Welding protective:** The method used to protect the weld process from outside environmental influence. The CSF system uses a combination of shielding gas and a magnetic field to provide protection for the weld.

Basic parameter of CSF welding process

Designation	H-Code	Welding Current	Welding time	Protrusion	Lift
Metric					
F-BT-MR M6 x L (6)	H2	250 to 280 A	150 to 180 ms	4.2 to 4.6 mm	2.3 to 2.8 mm
F-BT-MR M8 x L (8)	H3		245 to 285 ms	4.4 to 4.8 mm	
F-BT-MR M10 x L (10)	H10		390 to 440 ms	4.4 to 4.8 mm	
F-BT-MR M12 x L (10)	H10		390 to 440 ms	4.4 to 4.8 mm	
F-BT-MR M6 x L SN (4)	H1	250 to 280 A	80 to 110 ms	4.2 to 4.6 mm	2.3 to 2.8 mm
F-BT-MR M8 x L SN (4)	H1		80 to 110 ms	4.2 to 4.6 mm	
F-BT-MR M6 x L SN (6)	H2		150 to 180 ms	4.2 to 4.6 mm	
F-BT-MR M8 x L SN (8)	H3		245 to 285 ms	4.4 to 4.8 mm	
F-BT-MR M10 x L SN (10)	H10		390 to 440 ms	4.4 to 4.8 mm	
F-BT-MR M12 x L SN (10)	H10		390 to 440 ms	4.4 to 4.8 mm	
Imperial					
F-BT-MR 3/8 x L SN (5/32)	H1	250 to 280 A	80 to 110 ms	4.2 to 4.6 mm	2.3 to 2.8 mm
F-BT-MR 3/8 x L (3/8)	H10		390 to 440 ms	4.4 to 4.8 mm	
F-BT-MR 1/2 x L (3/8)	H10		390 to 440 ms	4.4 to 4.8 mm	
F-BT-MR 3/8 x L SN (3/8)	H10	250 to 280 A	390 to 440 ms	4.4 to 4.8 mm	2.3 to 2.8 mm
F-BT-MR 1/2 x L SN (3/8)	H10		390 to 440 ms	4.4 to 4.8 mm	

Table 3.4-1: Basic parameters

Protrusion



Protrusion p
- Distance between the tip of the stud and the stud holder interface

Figure 3.4-1: Protrusion

3.5 CSF energy regulation

The FX 3-A energy source supplies consistent power through the weld process to deliver appropriate energy is delivered into the materials. This is achieved by regulating the current and voltage. Below is a sample of energy regulation.

If a change in resistance occurs, the energy source automatically responds by adjusting the current and voltage accordingly, therefore regulating the power delivered.

Power regulation over time for weld process

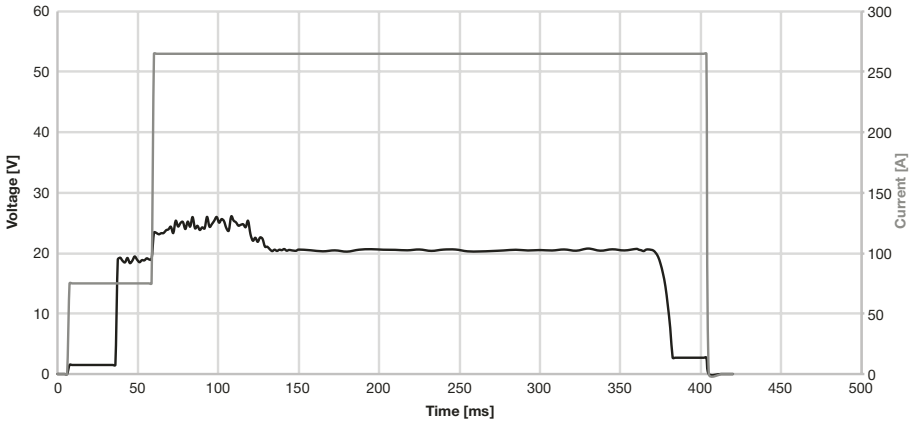
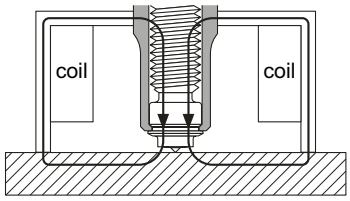


Figure 3.5-1: Power regulation over time for weld process

3.6 CSF magnetic arc control

Arc control by magnetic field



When stud welding, magnetic blowing effects due to irregular current distribution in the base material can reduce weld quality. To minimize and control magnetic blowing effects, the CSF system provides arc control through the use of a magnetic field.

Figure 3.6-1: Arc control by magnetic field

3.7 CSF welding protection

The welding protection is ensured by a shielding gas system. The main features of the shielding gas system are the gas itself, the gas flow distribution, and the distribution ring.

Shielding gas	
M21-ArC-18 according to EN ISO 14175 [4]	The shielding gas has a composition of 18 % carbon dioxide and 82 % argon. The gas is denoted as M21-ArC-18 and is standardized to EN ISO 14175 Group M21. Argon is a noble gas with low reactivity, which helps to protect the welding process from reacting with the surrounding atmosphere.

Table 3.7-1: Shielding gas

The gas flow rate is 3 l/min. Figure 3.7-1 shows the gas flow distribution.

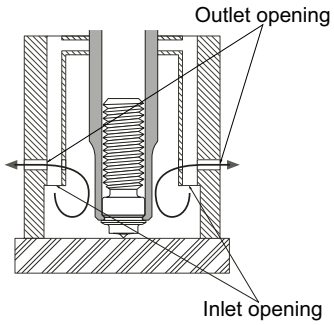
Gas flow distribution	
	The gas flow is constant and flows as shown in the diagram to the left. It covers the welding zone through the complete welding process.

Figure 3.7-1: Gas flow distribution

Figure 3.7-2 shows the distribution ring.

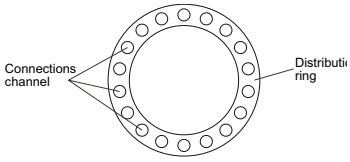
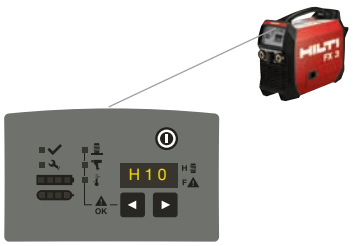
Distribution ring	
	The distribution ring function as a gas diffuser to ensure uniform gas distribution over the stud element connected with the parent material. It is designed for lower pressure so that the shielding can be achieved with the gas can FX 3-GC implemented in the CSF unit FX 3-A.

Figure 3.7-2: Distribution ring

3.8 Active Fusion Indicator (AFI)

One Touch Panel with Active Fusion Indicator (AFI)



The FX-3 A features the One Touch Control Panel, which provides the following:

- Allows user to select required H-Code, which is stamped on the top of each stud.
- Electrical and mechanical weld process parameters are preset based on selected H-Code
- Provides installation and status feedback to users via the AFI system.

The AFI system provides the following:

- Built in process control and sensors help to detect errors and failures before, during, or after the welding process.
- Failure is indicated via status lights and/or an F-Code on the display. Please reference the FX-3 A Instructions for Use (IFU) for more information.

Figure 3.8-1: One Touch Panel with Active Fusion Indicator (AFI)

Failure Codes

F-Code	Failure case	Required action
F06	Hand tool inner mechanics	Test inspected stud with HAT 28-FX (see chapter 8.4.3). **Alternative:** Remove and reinstall the stud directly without testing.
F07	Electrical connection bad	
F10	Stud embedment not proper	
F14	Operator interrupted process	
F16	Spot contaminated	
F17	Process aborted	

- For corrective actions to avoid repeated occurrence of F-Codes see sticker inside of the Kit box or see the quick start guide on the tool. Additionally, check that the software installed on the tool is the latest version available, see chapter 3.9.
- For troubleshooting of F-Codes not listed here see Sticker inside of the Kit box or on the tool or in operating instructions of the FX 3-A.
- Recommendation on how to remove and reinstall F-BT can be found in the repair procedure for F-BT.

Table 3.8-2: Failure Codes

3.9 Checking Software Version

Display software version

Step 1: Power on the tool

Step 2: Press both arrow buttons simultaneously, twice

Step 3: The Software version will appear on the display

Step 4: Press left arrow button to view the additional digits

Figure 3.9-1: Display software version

Supported features by software version

Features		V1.12.1	V1.12.15
Stainless steel studs	F-BT-MR	●	●
	F-BT-MR SN	●	●
Surface preparation methods	Surfacing tool ST-d14	●	●
	Surfacing tool ST-d20	●	●
	Grinding disc AG-D SP		●
	Grinding disc AG-D SPX		●
Additional features	Heating function for Thermal bag X-TB F3 accessory		●

Table 3.9-1: Supported features by software version

4. F-BT stud description

4.1 Stud designation

F - BT - M R __x__ __ (_)

Technology
F: Fusion

Fastening principle
BT: Blunt tip

Application
M: Multi purpose

Stud material
R : Stainless steel (CRC III)

Base material
(_): Minimum thickness (metric or imperial) of coated base material For getting full performance and no rework on the back side

Sealing
SN: Stud for use with sealing washer
_ _: Stud for use without sealing washer

Stud size
_ _ X _ _: Diameter x Length (metric or imperial)

4.2 Stud design principles

The F-BT stud terminology is found in figure 4.2-1 below.

F-BT stud terminology

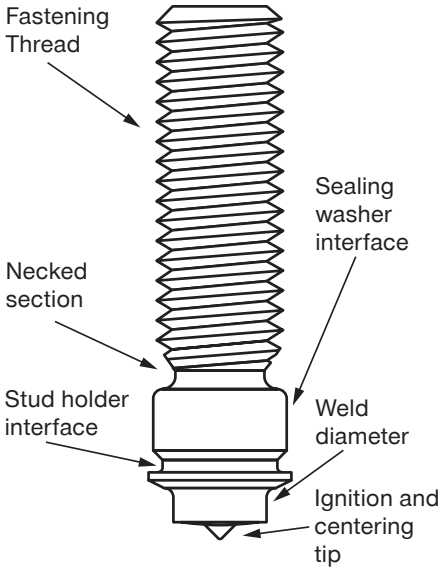
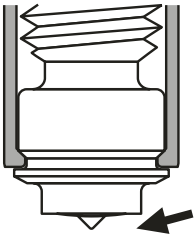


Figure 4.2-1: F-BT stud terminology

The following features of the F-BT studs combined with the CSF tooling and accessories, help provide more consistent welding and installation:

Stud design includes a centering and ignition tip and an interface holder to ensure correct stud positioning and proper stud fusion.

Centering and ignition tip

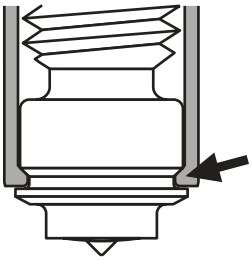


- Centering tip required for positioning
- Ignition tip required for arc striking

Figure 4.2-2: Centering and ignition tip

The stud feeding system consists mainly of a specialized stud holder interface as part of the hand tool. This interface ensures the mechanical and the electrical interlock. The stud connection at the stud front allows the use for different stud lengths with the same stud holder interface. Figure 4.2-2 shows the stud holder interface as part of the stud feeding system.

Stud holder interface

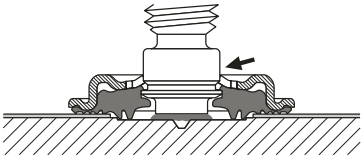


- Provides mechanical and electrical interlock
- Front connection allows use of different stud lengths
- Interface integrated in the hand tool

Figure 4.2-3: Stud holder interface

The sealing washer protects the parent material against corrosion. The sealing washer grips the stud at the sealing washer interface.

Sealing washer interface



- Provides a clamping lock between stud and sealing washer

Figure 4.2-4: Sealing washer interface

4.3 Stud selection and specifications

F-BT studs are divided into two primary categories:
- F-BT-MR SN studs, which are available with sealing washers and flange nuts supplied by Hilti and are intended for installation on coated materials, with sealing achieved via the provided sealing washer. These studs are intended for use only with the supplied flange nuts.
- F-BT-MR studs, which do not include nuts and washers, and are intended for use on uncoated base materials or base materials in which a coating will be used for sealing after stud installation.

The F-BT-MR SN portfolio features studs for use with thin base materials with minimum thicknesses 4 mm (5/32"). These studs feature smaller neck and weld diameters and are designed to avoid damage of the coatings on the backside of the base material during installation.

Drawings to scale of the F-BT studs are provided in the following figures below:
- Figure 4.3-2 for F-BT-MR SN for thin base materials
- Figure 4.3-3 for F-BT-MR SN studs for standard base material thicknesses
- Figure 4.3-4 for F-BT-MR studs

For full dimensional information of the F-BT-MR SN and F-BT-MR portfolios, please reference sections 5.1 and 6.1 respectively.

Stud with sealing washer for fastening on coated material	Stud without sealing washer for fastening on coated and uncoated material
F-BT-MR SN	F-BT-MR
Metric sizes: M6, M8, M10, M12	Metric sizes: M6, M8, M10, M12
Imperial sizes: 3/8"	Imperial sizes: 3/8", 1/2"
Sealing through washer	Sealing through painting

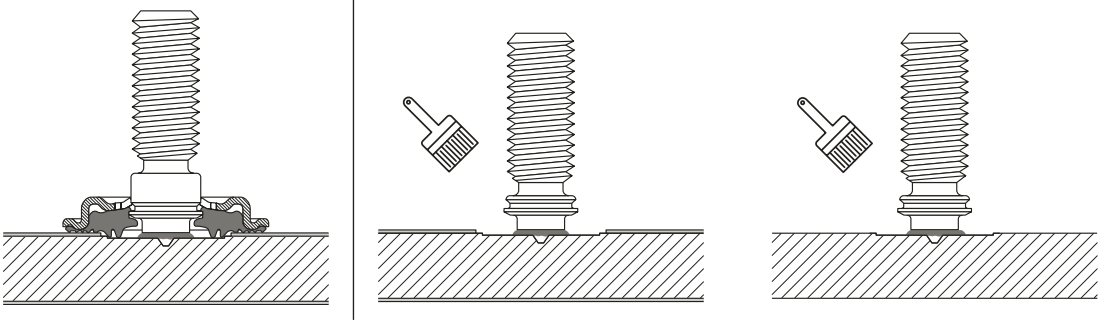


Figure 4.3-1: Stud recommendation

Stainless steel studs F-BT-MR SN with sealing washer for thin parent material

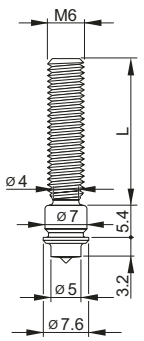
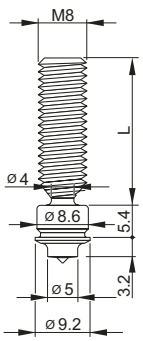
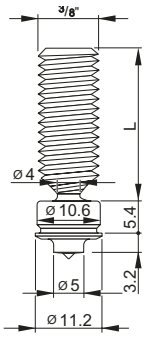
Parent material	Coated material, reduced parent material thickness t_{II} = 4 mm		
Model sketch			
$L_{\text{thread length}}$	25 mm	25 mm	1"
Designation	F-BT-MR M6x25 SN (4)	F-BT-MR M8x25 SN (4)	F-BT-MR 3/8x1 SN (5/32)

Figure 4.3-2: Stainless steel studs F-BT-MR SN with sealing washer for thin parent material

Stainless steel studs F-BT-MR SN with sealing washer

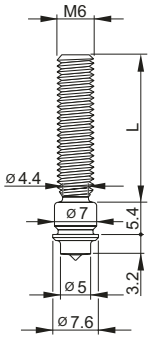
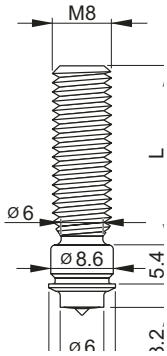
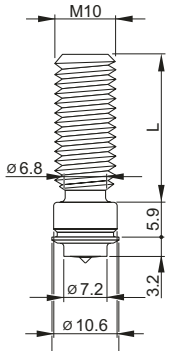
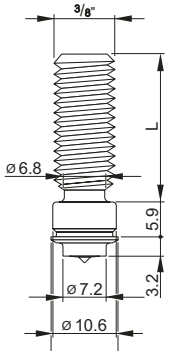
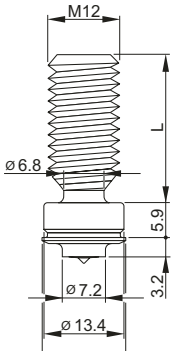
Parent material	Coated material, standard parent material thickness t_{II}				
Model sketch					
$L_{\text{thread length}}$	25 mm	25 mm	25 and 50 mm	1, 1-1/2, 2 and 4"	25 and 50 mm
Designation	F-BT-MR M6x25 SN (6)	F-BT-MR M8x25 SN (8)	F-BT-MR M10x25 SN (10) F-BT-MR M10x50 SN (10)	F-BT-MR 3/8x1 SN (3/8) F-BT-MR 3/8x1-1/2 SN (3/8) F-BT-MR 3/8x2 SN (3/8) F-BT-MR 3/8x4 SN (3/8)	F-BT-MR M12x25 SN (10) F-BT-MR M12x50 SN (10)

Figure 4.3-3: Stainless steel studs F-BT-MR SN with sealing washer

Stainless steel studs F-BT-MR without sealing washer

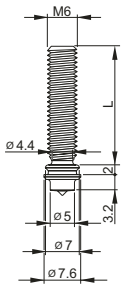
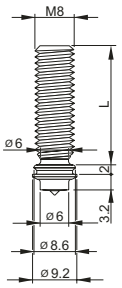
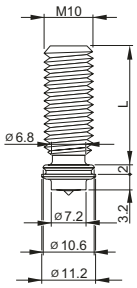
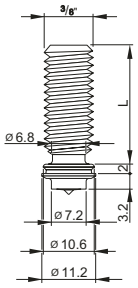
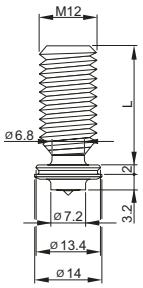
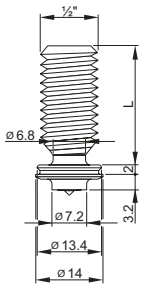
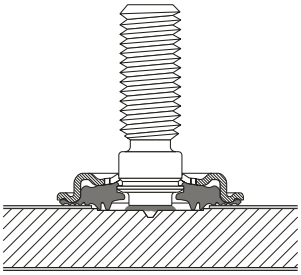
Parent material	Coated and uncoated material, standard parent material thickness t_{II}					
Model sketch						
$L_{thread\ length}$	25 mm	25 mm	25 and 50 mm	1, 1-1/2, 2 and 4"	25 and 50 mm	1-1/2 and 2"
Designation	F-BT-MR M6x25 (6)	F-BT-MR M8x25 (8)	F-BT-MR M10x25 (10) F-BT-MR M10x50 (10)	F-BT-MR 3/8x1 (3/8) F-BT-MR 3/8x1-1/2 (3/8) F-BT-MR 3/8x2 (3/8) F-BT-MR 3/8x4 (3/8)	F-BT-MR M12x25 (10) F-BT-MR M12x50 (10)	F-BT-MR 1/2x1-1/2 (3/8) F-BT-MR 1/2x2 (3/8)

Figure 4.3-4: Stainless steel studs F-BT-MR without sealing washer

4.4 Corrosion resistance and durability through sealing

The corrosion resistance and durability based on the application environment must be taken into account in when designing fastening points. The correct sealing washer installation is the best way to help resist corrosion. Painting is a common sealing method in lieu of the use of sealing washers.

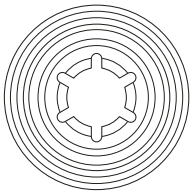
Sealing through sealing washer



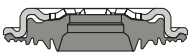
The sealing washer helps to protect the base material and the welded area against corrosion. It consists of a cloroprene rubber bonded to a specially formed stainless steel washer. The sealing washer creates a heavy duty and durable sealing solution for studs.

Applicable parent material coating thickness	≤ 1000 µm
Temperature range in service	–40°C to 60°C (–40°F to 140°F)
Sealing washer water tightness	56d salt spray test according to EN ISO 9227
Sealing washer resistant to	UV, salt water, water ozone, oils, etc.

Based on comprehensive corrosion and durability tests performed in the laboratory, a minimum service life of 25 years can be assumed.



Washer cap
- Stainless steel cap that houses and protects the sealing material
- Clamps the rubber gasket against the base material and stud
- Ensures correct positioning of the sealing washer
- Compression resistant

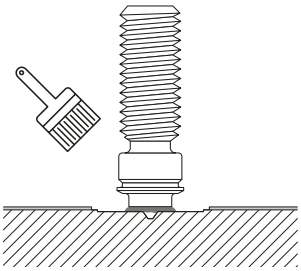


Sealing material
- Chloroprene rubber (CR)

- For more details on installation of the sealing washer, please refer to the Instruction for Use (IFU).

Figure 4.4-1: Sealing through sealing washer

Sealing through painting



- Corrosion resistance and durability through painting varies and must be determined separately.

Figure 4.4-2: Sealing through painting

4.5 Requirements for corrosion protection

In order to meet the respective requirements for corrosion protection, the expected level of exposure to corrosion for the fastening point must be reviewed beforehand. For example, the exposure to corrosion is much higher in environments with seawater than in other areas. Figure 4.5-1 shows a selection of studs for different environmental conditions.

Both the F-BT-MR SN and F-BT-MR fasteners are made of 1.4571 (A5, 316Ti) stainless steel, a Corrosion Resistance Class (CRC III) material, which provides a level of corrosion protection for the fasteners. Due to the unique installation involving surface preparation and welding, it is important to provide additional sealing method for corrosion protection of the prepared surface and weld areas.

Figure 4.5-1 shows a selection of studs and their corresponding sealing methods for different environmental conditions.

		Stud with sealing washer for fastening on coated material	Stud without sealing washer for fastening on coated material
		Sealing through washer	Sealing through painting
Environmental condition	Fastened part	F-BT-MR SN	F-BT-MR
 Dry indoor	zinc-coated steel, painted steel, aluminum, stainless steel	■	■
 Indoor with temporary condensation		■	▪
 Outdoor with low pollution		■	▪
 Outdoor with moderate concentration of pollutants		■	▪
 Coastal areas		■	▪
 Outdoor, areas with heavy industrial pollution		■	▪

■ Recommended solution for corrosion protection when installed according to IFU.
▪ May be suitable for corrosion protection with appropriate coating and sealing of the weld zone. Paint provided by others.

• For more details, please refer to following technical document: Hilti Corrosion Handbook.

Figure 4.5-1: Selection of studs for different environmental conditions

4.6 Structural load types

Load direction types can be classified into five groups: tension load, compression load, shear load, bending moment and load interaction. Examples of these load types are shown in Figure 4.6.1.

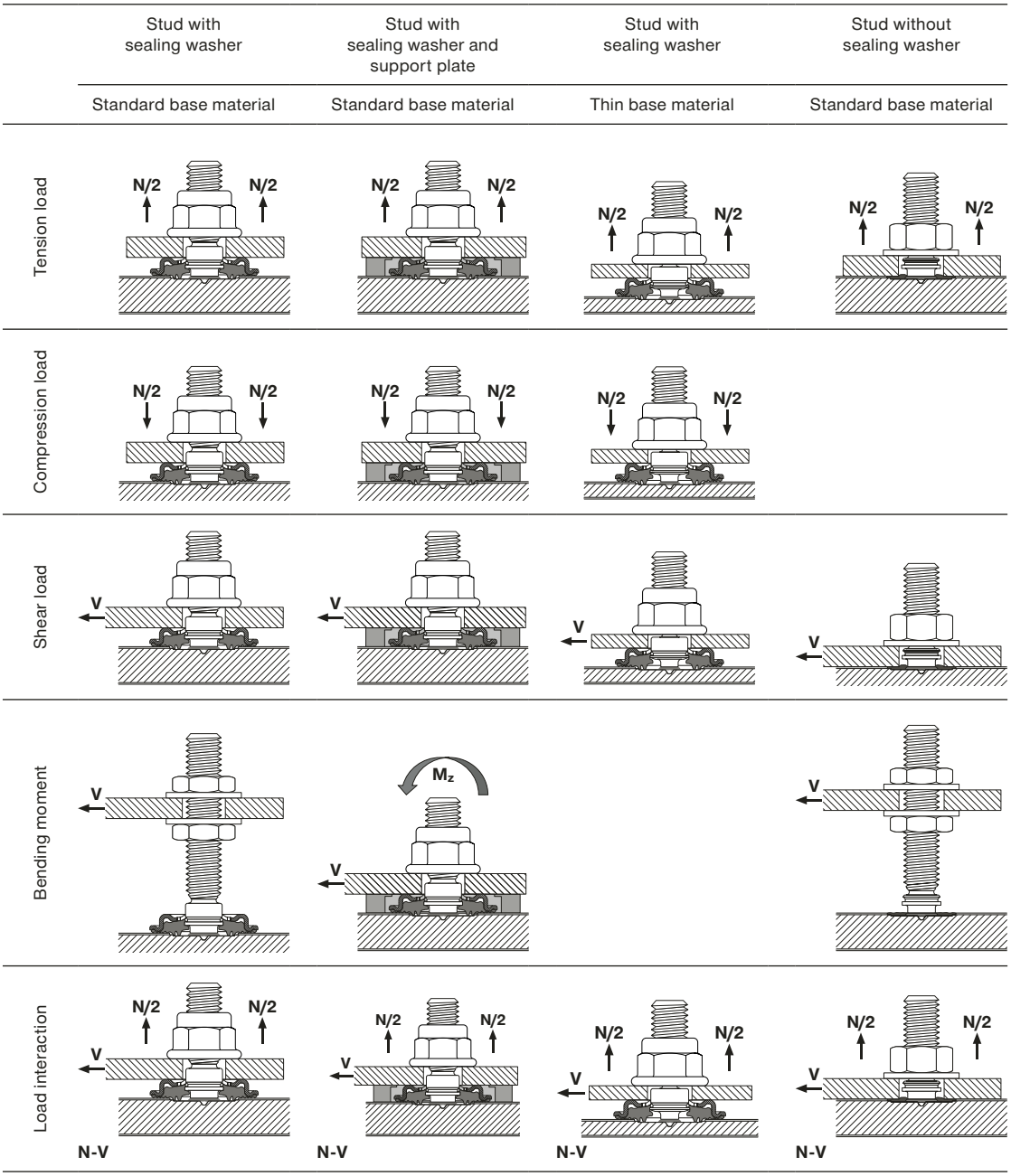
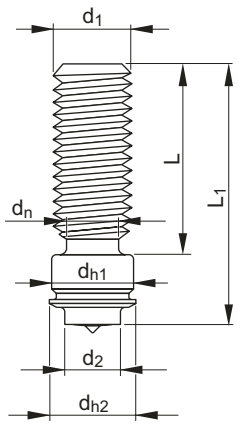


Figure 4.6-1: Load direction types

5. Technical data for F-BT-MR SN

5.1 Stud specification

Stud dimensions



L Thread length
L_1 Nominal stud length
d_1 Nominal diameter, thread diameter
d_2 Diameter of weld area
d_{h1} Diameter of sealing washer interface
d_{h2} Diameter of stud holder interface
d_n Diameter of necking area of stud

Designation	L	L_1	d_1	d_2	d_{h1}	d_{h2}	d_n
Metric size							
F-BT-MR M6x25 SN (4)	25 mm	34 mm	M6	5 mm	7 mm	7.6 mm	4 mm
F-BT-MR M8x25 SN (4)	25 mm	34 mm	M8	5 mm	8.6 mm	9.2 mm	4 mm
F-BT-MR M6x25 SN (6)	25 mm	34 mm	M6	5 mm	7 mm	7.6 mm	4.4 mm
F-BT-MR M8x25 SN (8)	25 mm	34 mm	M8	6 mm	8.6 mm	9.2 mm	6 mm
F-BT-MR M10x25 SN (10)	25 mm	34 mm	M10	7.2 mm	10.6 mm	11.2 mm	6.8 mm
F-BT-MR M10x50 SN (10)	50 mm	59 mm	M10	7.2 mm	10.6 mm	11.2 mm	6.8 mm
F-BT-MR M12x25 SN (10)	25 mm	34 mm	M12	7.2 mm	13.4 mm	14 mm	6.8 mm
F-BT-MR M12x50 SN (10)	50 mm	59 mm	M12	7.2 mm	13.4 mm	14 mm	6.8 mm
Imperial size							
F-BT-MR 3/8x1 SN (5/32)	1"	1.323"/ 34 mm	3/8"	0.197"/ 5 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.157"/ 4 mm
F-BT-MR 3/8x1 SN (3/8)	1"	1.323"/ 34 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8x1 1/2 SN (3/8)	1 1/2"	1.838"/ 47 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8x2 SN (3/8)	2"	2.339"/ 59 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8x4 SN (3/8)	4"	4.213"/ 107 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm

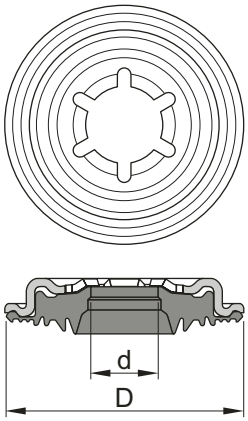
Table 5.1-1: Stud dimensions

Stud material specification and material properties for stainless steel parts

Designation	Element	Material	Steel grade	Standard	Corrosion resistance class	Corrosion resistance standard
F-BT-MR SN	Stud	Stainless steel	1.4571 (A5)	EN 10088-3	CRC III	EN 1993-1-4
			316Ti	ASTM A240/A276	–	–

Table 5.1-2: Stud material specification and material properties for stainless steel parts

Sealing washer dimensions



Sealing washer outer diameter D	Sealing washer inner diameter d	Compatibility	
		Stud	Sealing washer setting tool (Adapter size)
Metric size			
31.5 mm	6.1 mm	F-BT-MR M6xL SN	X-WST F3-BT (M6-1/4")
31.5 mm	7.4 mm	F-BT-MR M8xL SN	X-WST F3-BT (M8-5/16")
31.5 mm	9.2 mm	F-BT-MR M10xL SN	X-WST F3-BT (M10-3/8")
35.1 mm	12.2 mm	F-BT-MR M12xL SN	X-WST F3-BT (M12-1/2")
Imperial size			
1.24"/31.5 mm	0.362"/9.2 mm	F-BT-MR 3/8"xL SN	X-WST F3-BT (M10-3/8")

Figure 5.1-3: Sealing washer dimensions

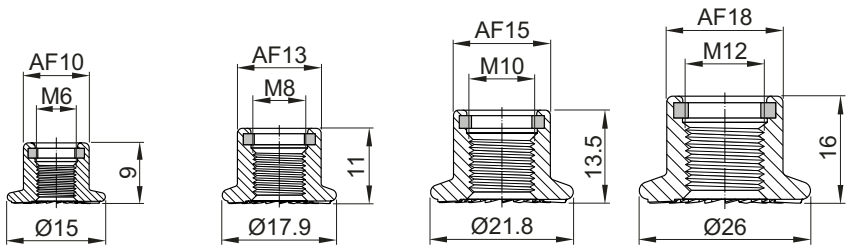
Sealing washer material specification and material properties

Designation	Element	Material	Steel grade	Standard	Corrosion resistance class	Corrosion resistance standard
Sealing ring	Metal cap	Stainless steel	1.4404 (A4)	EN 10088-2	CRC III	EN 1993-1-4
		Stainless steel	316L	ASTM A240	–	–
Sealing ring	Sealing elastomer	Chloroprene rubber (CR)				

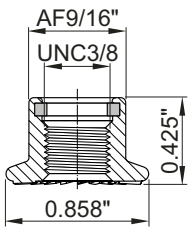
Table 5.1-4: Sealing washer material specification and material properties

Flange lock nut dimensions

Metric size



Imperial size



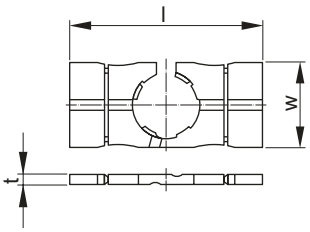
- F-BT-MR SN shall only be used with the provided flange lock nut.

Figure 5.1-5: Flange lock nut dimensions

Flange lock nut material specification and material properties			
Designation	Material	Grade	Standard
Flange lock nut	Stainless steel	A4-70	EN 3506-1
		1.4404	EN 10088-2
		316L	ASTM A240

Table 5.1-5: Flange lock nut material specification and material properties

Support plate dimensions



Designation	Length l	Width w	Thickness t
FX 3-SP S	100 mm	44 mm	5.5 mm
FX 3-SP L	100 mm	47 mm	5.5 mm

Figure 5.1-6: Support plate dimensions

Support plate material specification		
Designation	Element	Material
FX 3-SP S	Support plate	PA66-GF50
FX 3-SP L	Support plate	PA66-GF50

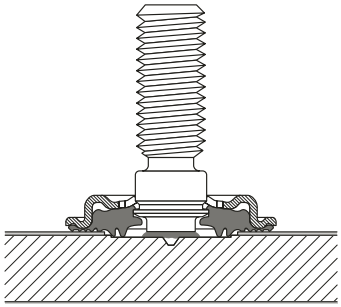
Table 5.1-7: Support plate material specification

- FX 3-SP S is compability with all F-BT-MR SN studs, with the exception of M12 sizes, which require the FX 3-SP L to accomodate the larger washer.

5.2 Specification for installation

5.2.1 Application area

Intended use



- For multipurpose fastening of non-structural components
- Multiple fasteners are recommended for any attachment
- For fastening on coated unalloyed carbon steel
- Conditions during installation:
  - surface to be welded shall be maintained dry and free from condensation
  - temperature of stud and base material temperature: > 0°C (32°F)
- Service temperatures
  –40°C to 60°C (–40°F to 140°F)
- Corrosion resistance class CRC III according to EN 1993-1-4
- Water tightness validated by means of 56 days salt spray test according to EN ISO 9227.
- Based on comprehensive corrosion and durability tests performed in the laboratory, a minimum service life of 25 years can be assumed.

Figure 5.2.1-1: Intended use

5.2.2 Fastened material

Fastened material properties

Designation	Fastened material thickness		Hole tolerance	
	$t_{l,min}$	$t_{l,max}$	$d_{f,min}$	$d_{f,max}$
Metric size				
F-BT-MR M6x25 SN (4)	3.5 mm	10 mm	8 mm	9.5 mm
F-BT-MR M8x25 SN (4)		10 mm	9.5 mm	12 mm
F-BT-MR M6x25 SN (6)		10 mm	8 mm	9.5 mm
F-BT-MR M8x25 SN (8)		10 mm	9.5 mm	12 mm
F-BT-MR M10x25 SN (10)		10 mm	12 mm	15 mm
F-BT-MR M10x50 SN (10)		20 mm	12 mm	15 mm
F-BT-MR M12x25 SN (10)		10 mm	15 mm	18.5 mm
F-BT-MR M12x50 SN (10)		20 mm	15 mm	18.5 mm
Imperial size				
F-BT-MR 3/8x1 SN (5/32)	1/8"/ 3.5 mm	3/8"/ 10 mm	0.472"/ 12 mm	0.571"/ 14.5 mm
F-BT-MR 3/8x1 SN (3/8)		3/8"/ 10 mm		
F-BT-MR 3/8x1 1/2 SN (3/8)		3/4"/ 20 mm		
F-BT-MR 3/8x2 SN (3/8)		3/4"/ 20 mm		
F-BT-MR 3/8x4 SN (3/8)		3/4"/ 20 mm		

- Minimum fastened material thickness $t_{l,min}$ can be achieved by use of multiple layers.

Table 5.2.2-2: Fastened material properties

5.2.3 Parent material

Parent material specification
Subgroup 1.1, 1.2, 1.3 and 2.1 according to CEN ISO/TR 15608

Standard/ application area	Steel grade
EN 10025-2	S235JR +N (or +AR) to S460K2 +N (or +AR)
EN 10025-3	S275N/NL to S460N/NL
EN 10025-4	S275M/ML to S460M/ML
EN 10225	S355NLO/MLO to S460NLO/MLO
Steel grade according to ASTM	ASTM A36, ASTM 572 Grade 50 ASTM A945 Grade 65 , A/SA-487 Grade 1 Cl. B
Shipbuilding steel according to ABS	A, B, D, E, AH 32, DH 32, AH 36, DH 36, EH 36
Extra high strength shipbuilding steel according to ABS	AQ43 N/NR, AQ43 TM, AQ47 N/NR, AQ47 TM, DQ43 N/NR, DQ43 TM, DQ47 N/NR, DQ47 TM
Carbon equivalent value: CEV ≤ 0.45	$CEV=C+\frac{Mn}{6}+\frac{Cr+Mo+V}{5}+\frac{Ni+Cu}{15}$
Deoxidation method	• Stud performance can only be assumed on fully killed material. • If the deoxidation method is not specified on the mill certificate, steel containing nitrogen binding elements in amounts sufficient to bind the available nitrogen (for example min. 0,020 % total aluminium) can be assessed as fully killed. • The usual guideline is a minimum aluminium to nitrogen ratio of 2:1, when no other nitrogen binding elements are present. Such other elements and their content (% mass) shall be reported in the inspection document. • In case of questions in assessing the suitability of base material, contact Hilti for support.

Table 5.2.3-1 Parent material specification

Parent material properties

	Minimum base material thickness	Maximum base material thickness
	$t_{l,min}$	$t_{l,max}$
Metric size		
F-BT-MR M6xL SN (4)	4 mm	40 mm
F-BT-MR M8xL SN (4)		
F-BT-MR M6xL SN (6)	6 mm	40 mm
F-BT-MR M8xL SN (8)	8 mm	40 mm
F-BT-MR M10xL SN (10)	10 mm	40 mm
F-BT-MR M12xL SN (10)		
Imperial size		
F-BT-MR 3/8xL SN (5/32)	5/32"/ 4 mm	1 9/16"/ 40 mm
F-BT-MR 3/8xL SN (3/8)	3/8"/ 10 mm	1 9/16"/ 40 mm

Table 5.2.3-2: Parent material properties

Parent material shape

Designation	Coating thickness t_c [µm]	Installation specification	Material shape	Radius R [mm]
F-BT-MR SN	≤ 1000	Without washer	Concave	890
	≤ 1000	Without washer	Convex	190
	≤ 1000	With washer	Concave	890
	≤ 1000	With washer	Convex	600

Table 5.2.3-3: Parent material shape

Stud positioning in parent material

Designation	Parent material thickness t_{II}	Minimum spacing between studs s_{min}	Minimum edge distance c_{min}
Metric size			
F-BT-MR M6xL SN (4)	< 30 mm 30 ≤ t_{II} ≤ 40 mm	35 mm 35 mm	38 mm 76 mm
F-BT-MR M8xL SN (4)			
F-BT-MR M6xL SN (6)			
F-BT-MR M8xL SN (8)			
F-BT-MR M10xL SN (10)			
F-BT-MR M12xL SN (10)			
Imperial size			
F-BT-MR 3/8xL SN (5/32)	< 1 3/16"/30 mm 1 3/16" ≤ t_{II} ≤ 1 1/2"/40 mm	1 3/8"/35 mm 1 3/8"/35 mm	1 1/2"/38 mm 3"/76 mm
F-BT-MR 3/8xL SN (3/8)			

Table 5.2.3-4: Stud positioning in parent material

5.3 Performance data

In the design of steel structures or vessels, safety factors are applied to account for the uncertainty in applied loads and to provide a margin of safety against failure, and to keep deformations within acceptable limits. Most designs are based on the partial factor method or the working load concept.

Therefore, this section will concentrate on the presentation of the design resistance (partial factor method) and recommended loads (working load concept).

Design resistance under tension load, shear load and bending moment based on partial factor method

Designation	Parent material thickness t_{II}	Tension load N_{Rd}	Compression load N_{Rd}	Shear load V_{Rd}	Bending moment M_{Rd}
Metric size					
F-BT-MR M6xL SN (4)	$4 \le t_{II} < 40$ mm	2.5 kN	11.2 kN	1.4 kN	n. a.
F-BT-MR M8xL SN (4)	$4 \le t_{II} < 40$ mm	2.5 kN	11.2 kN	1.4 kN	
F-BT-MR M6xL SN (6)	$6 \le t_{II} < 40$ mm	4.3 kN	11.2 kN	1.9 kN	
F-BT-MR M8xL SN (8)	$8 \le t_{II} < 40$ mm	6.3 kN	11.2 kN	2.8 kN	
F-BT-MR M10xL SN (10)	$10 \le t_{II} < 40$ mm	11.2 kN	11.2 kN	5 kN	28 Nm
F-BT-MR M12xL SN (10)	$10 \le t_{II} < 40$ mm	11.2 kN	11.2 kN	5 kN	28 Nm
Imperial size					
F-BT-MR 3/8xL SN (5/32)	5/32" ≤ t_{II} < 1 1/2"/ 4 ≤ t_{II} < 40 mm	560 lb/ 2.5 kN	2520 lb/ 11.2 kN	315 lb/ 1.4 kN	n. a.
F-BT-MR 3/8xL SN (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	2520 lb/ 11.2 kN	2520 lb/ 11.2 kN	1125 lb/ 5 kN	20.6 lb-ft/ 28 Nm

Table 5.3-1: Design resistance under tension load, shear load and bending moment based on partial factor method

Recommended tension load, shear load and bending moment based on working load concept

Designation	Parent material thickness t_{II}	Tension load N_{rec}	Compression load N_{rec}	Shear load V_{rec}	Bending moment $M_{rec,z}$
Metric size					
F-BT-MR M6xL SN (4)	$4 \le t_{II} < 40$ mm	1.8 kN	8.0 kN	1.0 kN	n. a.
F-BT-MR M8xL SN (4)	$4 \le t_{II} < 40$ mm	1.8 kN	8.0 kN	1.0 kN	
F-BT-MR M6xL SN (6)	$6 \le t_{II} < 40$ mm	3.1 kN	8.0 kN	1.4 kN	
F-BT-MR M8xL SN (8)	$8 \le t_{II} < 40$ mm	4.5 kN	8.0 kN	2.0 kN	
F-BT-MR M10xL SN (10)	$10 \le t_{II} < 40$ mm	8.0 kN	8.0 kN	3.6 kN	20 Nm
F-BT-MR M12xL SN (10)	$10 \le t_{II} < 40$ mm	8.0 kN	8.0 kN	3.6 kN	20 Nm
Imperial size					
F-BT-MR 3/8xL SN (5/32)	5/32" ≤ t_{II} < 1 1/2"/ 4 ≤ t_{II} < 40 mm	405 lb/ 1.8 kN	1800 lb/ 8.0 kN	225 lb/ 1.0 kN	n. a.
F-BT-MR 3/8xL SN (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	1800 lb/ 8.0 kN	1800 lb/ 8.0 kN	810 lb/ 3.6 kN	14.7 lb-ft/ 20 Nm

Table 5.3-2: Recommended tension load, shear load and bending moment based on working load concept

Group fastenings

Group behaviour is affected by stud ductility and hole clearance. In order to cover unfavorable position of studs in rows or rectangular plates, the following should be taken into consideration for design:

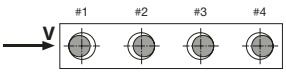
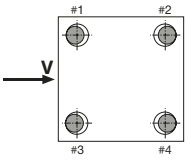
	Studs in rows: • One stud of a row of n (here: n = 4) studs is considered for the total shear load of the row.
	Studs in rectangular plates: • Rectangular plate with 4 studs in the corner and shear load introduction in center of plate. • Two studs of a group of four studs are considered for the total shear load of the group.

Figure 5.3-3: Group fastenings

Bending moment for fastening multi-duty channel system (MT)

Multi-duty channel system (MT)	MT-B-T MT-B-T OC	MT-B-02 MT-B-02-OC	MT-B-02B MT-B-02B OC	MT-BR-40 MT-BR-40 OC
				
	2-hole base plate			Cantilever arm
Multi-duty channel width	42 mm	83 mm	100 mm	60 mm
Support plate	FX 3-SP S	FX 3-SP S	FX 3-SP S	FX 3-SP S
Stud	F-BT-MR M10xL SN (10)	F-BT-MR M10xL SN (10)	F-BT-MR M10xL SN (10)	F-BT-MR M10xL SN (10)
Design bending moment $M_{z,Rd}$	52.8 Nm	232.8 Nm	357.6 Nm	790.0 Nm
Recommended bending moment $M_{z,rec}$	37.7 Nm	166.3 Nm	255.4 Nm	565.0 Nm

- 2-hole base plate and cantilever arm are intended to be used with support plate.
- For the design of the stud linear N-V-M_z interaction applies (with M_z refering to the utilization of the 2-hole base plate).
- Design and recommended bending moments for generic cases of 2-hole base plates, varying stud sizes, plate width and thickness will be published in the upcoming release of this Manual.

Figure 5.3-4: Bending moment for fastening multi-duty channel system (MT)

Figure 5.3-5 shows an installation example for 2-hole base plate.

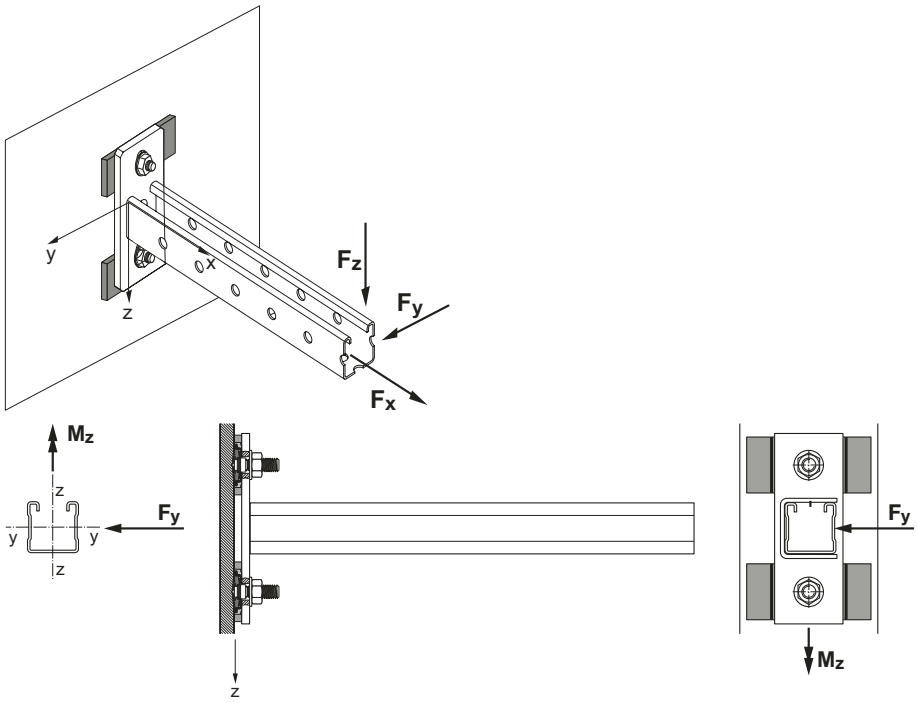


Figure 5.3-5: Installation example for 2-hole base plate

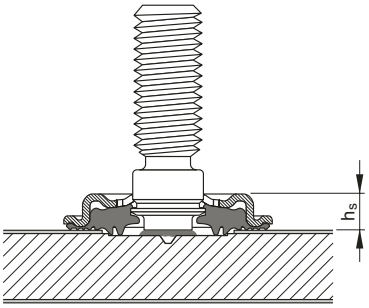
5.4 Installation recommendations

5.4.1 Stud installation

The following guidelines provide the specifications for CSF stud installation. Typically installation will be performed in accordance with a welding code/standard such as EN ISO 14555 or AWS D1.6, which have additional requirements in regards to installation. Please see section 8 for more information regarding processes in keeping with EN ISO 14555.

5.4.2 Sealing washer installation inspection

Sealing washer inspection



Height between the top of installed sealing washer and coating surface, h_s, shall be a maximum of 6 mm (0.236"), which shall be checked with the X-WCG F3-BT washer check gauge.

- For more details, please refer to the Instruction for Use (IFU).

Figure 5.4.2-1: Sealing washer inspection

5.4.3 Installation torque

Installation torque

Designation	Installation torque T_{inst}	Recommended nut type	Tightening tool
Metric size			
F-BT-MR M8xL SN (4)	6 Nm	Flange lock nut according to EN 1663	Tightening tools with torque control function
F-BT-MR M8xL SN (4)	6 Nm		
F-BT-MR M6xL SN (6)	8 Nm		
F-BT-MR M8xL SN (8)	20 Nm		
F-BT-MR M10xL SN (10)	30 Nm		
F-BT-MR M12xL SN (10)	30 Nm		
Imperial size			
F-BT-MR 3/8xL SN (5/32)	4.4 lb-ft/6 Nm	Flange lock nut according to EN 1663	Tightening tools with torque control function
F-BT-MR 3/8xL SN (3/8)	22.1 lb-ft/30 Nm		

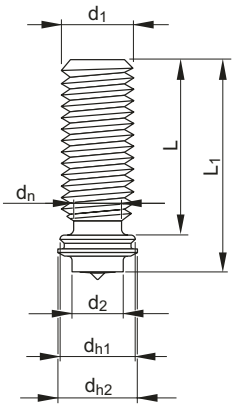
- For more details, please refer to the instructions for use (IFU).
- Only tightening tools with torque control functions shall be used. A powered tightening tool shall not be used.

Table 5.4.3-1: Installation torque

6. Technical data for F-BT-MR

6.1 Stud specification

Stud dimensions



L Thread length
L_1 Nominal stud length
d_1 Nominal diameter, thread diameter
d_2 Diameter of weld area
d_{h1} Diameter of stud area
d_{h2} Diameter of stud holder interface
d_n Diameter of necking area of stud

Designation	L	L_1	d_1	d_2	d_{h1}	d_{h2}	d_n
Metric size							
F-BT-MR M6x25 (6)	25 mm	30 mm	M6	5 mm	7 mm	7.6 mm	4.4 mm
F-BT-MR M8x25 (8)	25 mm	30 mm	M8	6 mm	8.6 mm	9.2 mm	6 mm
F-BT-MR M10x25 (10)	25 mm	30 mm	M10	7.2 mm	10.6 mm	11.2 mm	6.8 mm
F-BT-MR M10x50 (10)	50 mm	55 mm	M10	7.2 mm	10.6 mm	11.2 mm	6.8 mm
F-BT-MR M12x25 (10)	25 mm	30 mm	M12	7.2 mm	13.4 mm	14 mm	6.8 mm
F-BT-MR M12x50 (10)	50 mm	55 mm	M12	7.2 mm	13.4 mm	14 mm	6.8 mm
Imperial size							
F-BT-MR 3/8x1 (3/8)	1"	1.220"/ 31 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8x1 1/2 (3/8)	1 1/2"	1.693"/ 43 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8"x2 (3/8)	2"	2.205"/ 56 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 3/8x4 (3/8)	4"	4.213"/ 107 mm	3/8"	0.283"/ 7.2 mm	0.417"/ 10.6 mm	0.441"/ 11.2 mm	0.268"/ 6.8 mm
F-BT-MR 1/2x1 1/2 (3/8)	1 1/2"	1.693"/ 43 mm	1/2"	0.283"/ 7.2 mm	0.528"/ 13.4 mm	0.441"/ 14 mm	0.268"/ 6.8 mm
F-BT-MR 1/2x2 (3/8)	2"	2.205"/ 56 mm	1/2"	0.283"/ 7.2 mm	0.528"/ 13.4 mm	0.441"/ 14 mm	0.268"/ 6.8 mm

Table 6.1-1 Stud dimensions

Stud material specification

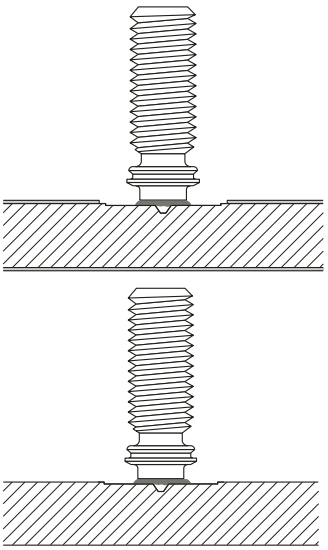
Designation	Element	Material	Steel grade	Standard	Corrosion resistance class	Corrosion resistance standard
F-BT-MR	Stud	Stainless steel	1.4571 (A5)	EN 10088-3	CRC III	EN 1993-1-4
			316Ti	ASTM A240/A276	–	–

Table 6.1-2 Stud material specification

6.2 Specification for installation

6.2.1 Application area

Intended use



- For multipurpose fastening of non-structural components
- Multiple fasteners are recommended for any attachment
- For fastening on coated or un-coated unalloyed carbon steel
- Conditions during installation:
  - Surface to be welded shall be maintained dry and free from condensation
  - Temperature of stud and base material temperature: > 0°C (32°F)
- Service temperatures
  −40°C to 60°C (−40°F to 140°F)
- Corrosion resistance class CRC III according to EN 1993-1-4

Figure 6.2.1-1 Intended use

6.2.2 Fastened material

Fastened material properties

Designation	Fastened material thickness		Hole tolerance	
	$t_{I,min}$	$t_{I,max}$	$d_{f,min}$	$d_{f,max}$
Metric size				
F-BT-MR M6x25 (6)	4.5 mm	10 mm	8.5 mm	10 mm
F-BT-MR M8x25 (8)		10 mm	10 mm	12.5 mm
F-BT-MR M10x25 (10)		10 mm	12.5 mm	15.5 mm
F-BT-MR M10x50 (10)		20 mm	12.5 mm	15.5 mm
F-BT-MR M12x25 (10)		10 mm	15.5 mm	19 mm
F-BT-MR M12x50 (10)		20 mm	15.5 mm	19 mm
Imperial size				
F-BT-MR 3/8x1 (3/8)	3/16" / 4.5 mm	3/8"/ 10 mm	0.492"/ 12.5 mm	0.591"/ 15 mm
F-BT-MR 3/8x1 1/2 (3/8)		3/4"/ 20 mm		
F-BT-MR 3/8x2 (3/8)		3/4"/ 20 mm		
F-BT-MR 3/8x4 (3/8)		3/4"/ 20 mm		
F-BT-MR 1/2x1 1/2 (3/8)		3/4"/ 20 mm	0.591"/ 15 mm	0.768"/ 19.5 mm
F-BT-MR 1/2x2 (3/8)		3/4"/ 20 mm		

- Fastened material thickness $t_{I,min}$ can be achieved by use of multiple layers.

Table 6.2.2-1: Fastened material properties

6.2.3 Parent material

Parent material specification
Subgroup 1.1, 1.2, 1.3 and 2.1 according to CEN ISO/TR 15608

Standard/ application area	Steel grade
EN 10025-2	S235JR +N (or +AR) to S460K2 +N (or +AR)
EN 10025-3	S275N/NL to S460N/NL
EN 10025-4	S275M/ML to S460M/ML
EN 10225	S355NLO/MLO to S460NLO/MLO
Steel grade according to ASTM	ASTM A36, ASTM 572 Grade 50 ASTM A945 Grade 65 , A/SA-487 Grade 1 Cl. B
Shipbuilding steel according to ABS	A, B, D, E, AH 32, DH 32, AH 36, DH 36, EH 36
Extra high strength shipbuilding steel according to ABS	AQ43 N/NR, AQ43 TM, AQ47 N/NR, AQ47 TM, DQ43 N/NR, DQ43 TM, DQ47 N/NR, DQ47 TM
Carbon equivalent value: CEV ≤ 0.45	$CEV=C+\frac{Mn}{6}+\frac{Cr+Mo+V}{5}+\frac{Ni+Cu}{15}$
Deoxidation method	• Stud performance can only be assumed on fully killed material. • If the deoxidation method is not specified on the mill certificate, steel containing nitrogen binding elements in amounts sufficient to bind the available nitrogen (for example min. 0,020 % total aluminium) can be assessed as fully killed. • The usual guideline is a minimum aluminium to nitrogen ratio of 2:1, when no other nitrogen binding elements are present. Such other elements and their content (% mass) shall be reported in the inspection document. • In case of questions in assessing the suitability of base material, contact Hilti for support.

Table 6.2.3-1: Parent material specification

Parent material properties

Designation	Parent material thickness			
	$t_{II,min}$	$t_{II,max}$	$t_{II,min}$	$t_{II,max}$
	(for uncoated parent steel)		(for coated parent steel)	
Metric size				
F-BT-MR M6xL (6)	2 mm	40 mm	6 mm	40 mm
F-BT-MR M8xL (8)	2 mm	40 mm	8 mm	40 mm
F-BT-MR M10xL (10)	2 mm	40 mm	10 mm	40 mm
F-BT-MR M12xL (10)	2 mm	40 mm	10 mm	40 mm
Imperial size				
F-BT-MR 3/8xL (3/8)	0.0787"/ 2 mm	1 9/16"/ 40 mm	3/8"/ 10 mm	1 9/16"/ 40 mm
F-BT-MR 1/2xL (3/8)	0.0787"/ 2 mm	1 9/16"/ 40 mm	3/8"/ 10 mm	1 9/16"/ 40 mm

Table 6.2.3-2: Parent material properties

Parent material shape

Designation	Coating thickness t_c [µm]	Installation specification	Material shape	Radius R [mm]
F-BT-MR	Uncoated	Without washer	Concave	210
	Uncoated	Without washer	Convex	50

Table 6.2.3-3: Parent material shape

Stud positioning in parent material

Designation	Parent material thickness t_{II}	Minimum spacing between studs s_{min}	Minimum edge distance c_{min}
Metric size			
F-BT-MR M6xL (6)	< 30 mm 30 ≤ t_{II} ≤ 40 mm	35 mm 35 mm	38 mm 76 mm
F-BT-MR M8xL (8)			
F-BT-MR M10xL (10)			
F-BT-MR M12xL (10)			
Imperial size			
F-BT-MR 3/8xL (3/8)	< 1 3/16"/30 mm 1 3/16" ≤ t_{II} ≤ 1 1/2"/40 mm	1 3/8"/35 mm 1 3/8"/35 mm	1 1/2"/38 mm 3"/76 mm
F-BT-MR 1/2xL (3/8)			

Table 6.2.3-4: Stud positioning in parent material

6.3 Performance data

In design of steel structures or vessels, safety factors are applied to account for the uncertainty in applied loads and to provide a margin of safety against failure, and to keep deformations within acceptable limits. Most designs are based on the partial factor method or the working load concept.

Therefore, this section will concentrate on the presentation of the design resistance (partial factor method) and the recommended loads (working load concept).

Design resistance under tension load, shear load and bending moment based on partial factor method

Designation	Parent material thickness t_{II}	Tension load N_{Rd}	Shear load V_{Rd}	Bending moment M_{Rd}
Metric size				
F-BT-MR M6xL (6)	6 ≤ t_{II} < 40 mm	4.3 kN	2.5 kN	n.a.
F-BT-MR M8xL (8)	8 ≤ t_{II} < 40 mm	6.3 kN	3.6 kN	
F-BT-MR M10xL (10)	10 ≤ t_{II} < 40 mm	11.2 kN	6.3 kN	28 Nm
F-BT-MR M12xL (10)	10 ≤ t_{II} < 40 mm	11.2 kN	6.3 kN	28 Nm
Imperial size				
F-BT-MR 3/8xL (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	2520 lb/ 11.2 kN	1415 lb/ 6.3 kN	20.6 lb-ft/ 28 Nm
F-BT-MR 1/2xL (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	2520 lb/ 11.2 kN	1415 lb/ 6.3 kN	20.6 lb-ft/ 28 Nm

Table 6.3-1: Design resistance under tension load, shear load and bending moment based on partial factor method

For installing studs to base materials, thinner than those listed within the table, see Section 6.3.1.

Recommended tension load, shear load and bending moment based on working load concept

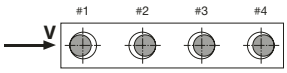
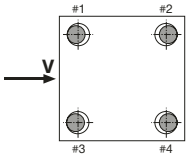
Designation	Parent material thickness t_{II}	Tension load N_{rec}	Shear load V_{rec}	Bending moment M_{rec}
Metric size				
F-BT-MR M6xL (6)	6 ≤ t_{II} < 40 mm	3.1 kN	1.8 kN	n.a.
F-BT-MR M8xL (8)	8 ≤ t_{II} < 40 mm	4.5 kN	2.6 kN	
F-BT-MR M10xL (10)	10 ≤ t_{II} < 40 mm	8.0 kN	4.5 kN	20 Nm
F-BT-MR M12xL (10)	10 ≤ t_{II} < 40 mm	8.0 kN	4.5 kN	20 Nm
Imperial size				
F-BT-MR 3/8xL (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	1800 lb/ 8.0 kN	1010 lb/ 4.5 kN	14.7 lb-ft/ 20 Nm
F-BT-MR 1/2xL (3/8)	3/8" ≤ t_{II} < 1 1/2"/ 10 ≤ t_{II} < 40 mm	1800 lb/ 8.0 kN	1010 lb/ 4.5 kN	14.7 lb-ft/ 20 Nm

Table 6.3-2: Recommended tension load, shear load and bending moment based on working load concept

For installing studs to base materials, thinner than those listed within the table, see Section 6.3.1.

Group fastenings

Group behavior is affected by stud ductility and actual clearance. In order to cover unfavorable position of studs in rows or rectangular plates, the following rule applies:

	Studs in rows: • One stud of a row of n (here: n = 4) studs is considered for the total shear load of the row.
	Studs in rectangular plates: • Rectangular plate with 4 studs in the corner and shear load introduction in center of plate. • Two studs of a group of four studs are considered for the total shear load of the group.

Remark on design and recommended shear values:
group behaviour is affected by stud ductility as well as actual clearances.

Figure 6.3-3: Group fastenings

6.3.1 Installing to thin base materials

When welding onto the minimum defined thicknesses of parent material, the stud's neck is the weakest point, and thus dictates the failure load.

However, when welding on thinner parent material, the parent material rather than the neck is the weakest point. Therefore, the load values are reduced.

Consequently, when welding onto thin parent material, a load reduction factor must be considered when calculating design or recommended load values.

Example:
$N_{rec,\,red}$ = Reduced recommended load
α = Load reduction factor
N_{rec} = Recommended load (on defined parent material thickness)

From test data made as discrete parent material thicknesses, α load reduction factor formula has been derived for each of the stud types.

Load reduction factor for thin parent material

Designation	Thin parent material thickness	Load reduction factor for		
	t_{II}	Tension load	Shear load	Bending
Metric size				
F-BT-MR M6xL (6)	$2 \le t_{II} < 4$ mm	$\alpha = (t_{II} + 4)/8$		n. a.
F-BT-MR M8xL (8)	$2 \le t_{II} < 4$ mm	$\alpha = (t_{II} + 1)/5$		
F-BT-MR M10xL (10)	$2 \le t_{II} < 6$ mm	$\alpha = (t_{II} + 1.5)/7.5$		
F-BT-MR M12xL (10)	$2 \le t_{II} < 6$ mm			
Imperial size				
F-BT-MR 3/8xL (3/8)	$0.0787'' \le t_{II} < 0.236''$	$\alpha = (t_{II} + 0.059)/0.295$		

For metric sizes t_{II} in mm and for imperial sizes in inches.

Figure 6.3.1-1: Load reduction factor for thin parent material

6.4 Installation recommendations

6.4.1 Stud installation

The following guidelines provide the specifications for CSF stud installation. Typically installation will be performed in accordance with a welding code/standard such as EN ISO 14555 or AWS D1.6, which have additional requirements in regards to installation. Please see section 8 for more information regarding processes in keeping with EN ISO 14555.

6.4.2 Installation torque

Installation torque with flange lock nut

Designation	Torque moment T_{inst}	Recommended nut type	Tightening tool
Metric size			
F-BT-MR M6xL (6)	8 Nm	Flange lock nut according to EN 1663	Tightening tools with torque control function
F-BT-MR M8xL (8)	20 Nm		
F-BT-MR M10xL (10)	30 Nm		
F-BT-MR M12xL (10)	30 Nm		
Imperial size			
F-BT-MR 3/8xL (3/8)	22 lb-ft/30 Nm	Flange lock nut with locking teeth according to ASME B 18.16.4	Tightening tools with torque control function
F-BT-MR 1/2xL (3/8)	22 lb-ft/30 Nm		

- For more details, please refer to the instructions for use (IFU).
- A powered tightening tool shall not be used.

Table 6.4.2-1: Installation torque with flange lock nut

Installation torque with Hot Dip Galvanized (HDG) nut

Designation	Torque moment T_{inst}	Possible nut type	Tightening tool
Metric size			
F-BT-MR M6xL (6)	8 Nm	HDG nut	Tightening tools with torque control function
F-BT-MR M8xL (8)	20 Nm		
F-BT-MR M10xL (10)	27 Nm		
F-BT-MR M12xL (10)	27 Nm		
Imperial size			
F-BT-MR 3/8xL (3/8)	20 lbft/ 27 Nm	HDG nut	Tightening tools with torque control function
F-BT-MR 1/2xL (3/8)	20 lbft/ 27 Nm		

- For more details, please refer to the instructions for use (IFU).
- A powered tightening tool shall not be used.

Table 6.4.2-2: Installation torque with Hot Dip Galvanized (HDG) nut

7. Design concept

7.1 Partial factor method

EN 1993-1-1: specifies the use of the partial safety factors to be used in for design. The partial safety factor method is a design method by which safety factors are applied to load and material resistances.

Load type: Quasistatic loading

$S_d \leq R_d$

$S_d = \gamma_F \cdot S_k \leq R_d = R_k / \gamma_{M,\ F\text{-}BT}$

with:
S_d = Design loads acting on the stud (N_{Sd}, V_{Sd} or M_{Sd})
S_k = Characteristic loads acting on the stud (N_{Sk}, V_{Sk} or M_{Sk})
γ_F = Partial safety factor for actions
R_d = Design resistance of the stud (N_{Rd}, V_{Rd} or M_{Rd})
R_k = Characteristic resistance of the stud (N_{Rk}, V_{Rk} or M_{Rk})
$\gamma_{M,\ F\text{-}BT}$ = Partial safety factor of resistance

γ_F = 1.40
$\gamma_{M,\ F\text{-}BT}$ = 2.00

7.2 Working load concept

The working load concept is a design method by which the actual load is used. The safety in the design can be described with a global safety factor for the load and the material.

Load type: Quasistatic loading

$S_k \leq R_{rec}$

$R_{rec} = R_k / \gamma_{tot} = R_k / (\gamma_{M,\ F\text{-}BT} \cdot \gamma_F) = R_k / (2.0 \cdot 1.4) = R_k / 2.8$

with:
S_k = Characteristic loads acting on the stud (N_{Sk}, V_{Sk} or M_{Sk})
γ_{tot} = total (global) safety factor
R_{rec} = Recommended loads (N_{rec}, V_{rec} or M_{Rec})
R_k = Characteristic resistance (N_{Rk}, V_{Rk} or M_{Rk})
$\gamma_{M,\ F\text{-}BT}$ = Partial safety factor of resistance

γ_F = 1.40
$\gamma_{M,\ F\text{-}BT}$ = 2.00

7.3 Load interaction

Table 7.3-1 and 7.3-2 provide interaction equations where studs are loaded with tension, shear, and/or moments simultaneously.

Load combination	Load interaction
Shear – Tension	$\frac{V_{Sd}}{V_{Rd}} + \frac{N_{Sd}}{N_{Rd}} \leq 1.2$ with $\frac{V_{Sd}}{V_{Rd}} \leq 1.0$ and $\frac{N_{Sd}}{N_{Rd}} \leq 1.0$
Shear – Bending moment	$\frac{V_{Sd}}{V_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.0$
Tension – Bending moment	$\frac{N_{Sd}}{N_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.0$
Shear – Tension – Bending moment	$\frac{V_{Sd}}{V_{Rd}} + \frac{N_{Sd}}{N_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.0$

Table 7.3-1: Load interaction for design loads

Load combination	Load interaction
Shear – Tension	$\frac{V_{Sk}}{V_{rec}} + \frac{N_{Sk}}{N_{rec}} \leq 1.2$ with $\frac{V_{Sk}}{V_{rec}} \leq 1.0$ and $\frac{N_{Sk}}{N_{rec}} \leq 1.0$
Shear – Bending moment	$\frac{V_{Sk}}{V_{rec}} + \frac{M_{Sk}}{M_{rec}} \leq 1.0$
Tension – Bending moment	$\frac{N_{Sk}}{N_{rec}} + \frac{M_{Sk}}{M_{rec}} \leq 1.0$
Shear – Tension – Bending moment	$\frac{V_{Sk}}{V_{rec}} + \frac{N_{Sk}}{N_{rec}} + \frac{M_{Sk}}{M_{rec}} \leq 1.0$

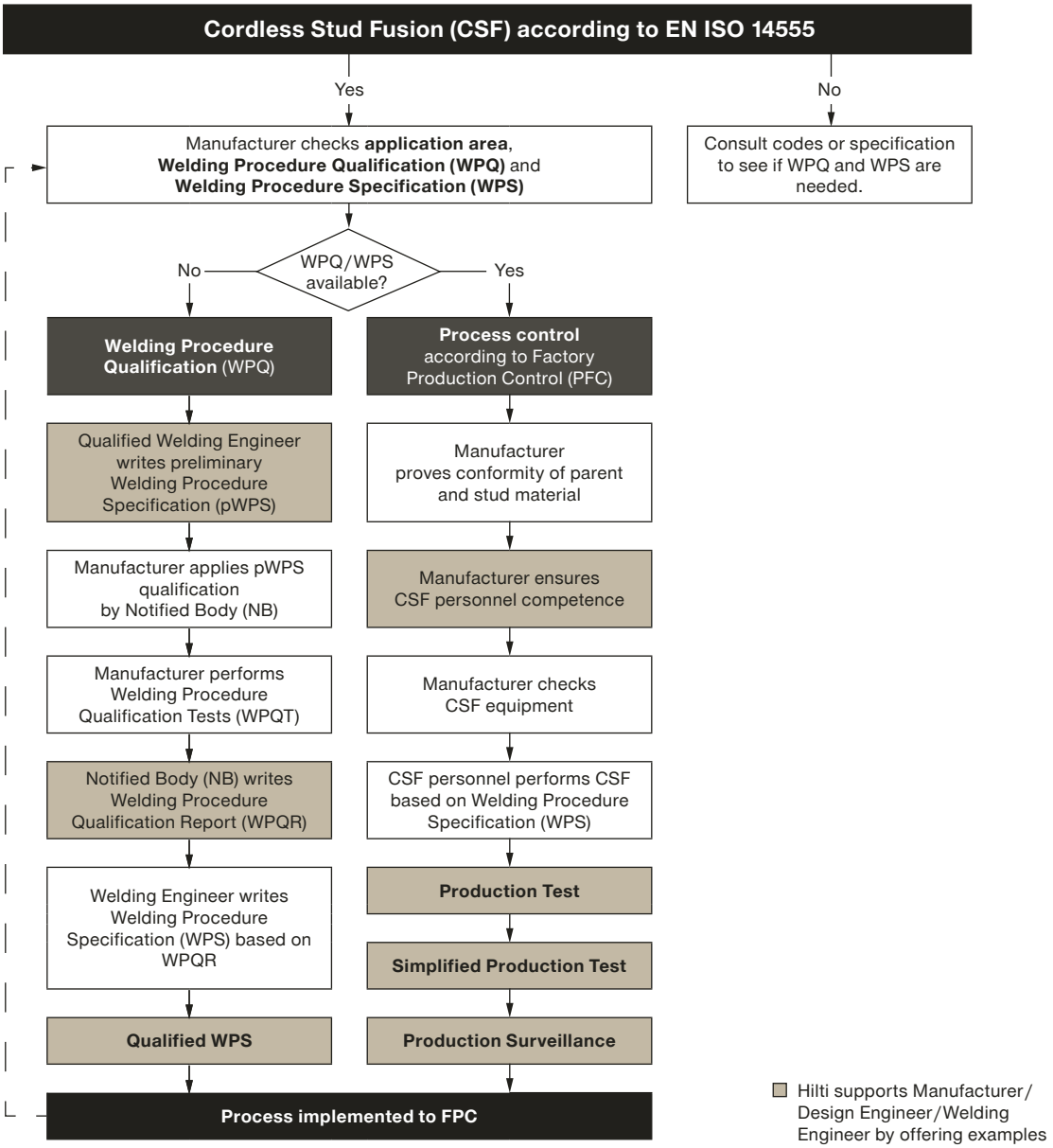
Table 7.3-2: Load interaction for recommended loads

8. CSF in keeping with EN ISO 14555

The purpose of this section is to assist the manufacturer on the Welding Procedure Qualification (WPQ) and the Welding Procedure Specification (WPS) as well as the process control within the Factory Production Control (FPC) according EN ISO 14555 [5].

Admissible application area

- CSF can be used in all fields of metal-working industry
- Structures subjected to specified static loading
- Standard quality requirements in accordance with ISO 3834-3
- Application temperature in service: –40 °C ≤ T ≤ 60 °C



WPQ and process control have to be approved by Notified Body (NB).

Figure 8-1: CSF process implementation to FPC

8.1 Welding Procedure Qualification (WPQ)

Typically, Welding Procedure Qualification results in qualified Welding Procedure Specifications (WPS). WPQ is needed when code or specification requires it. The method should be agreed between the contracting parties. Following methods of qualification are permitted, but specification or application code requirements may restrict the choice of method:

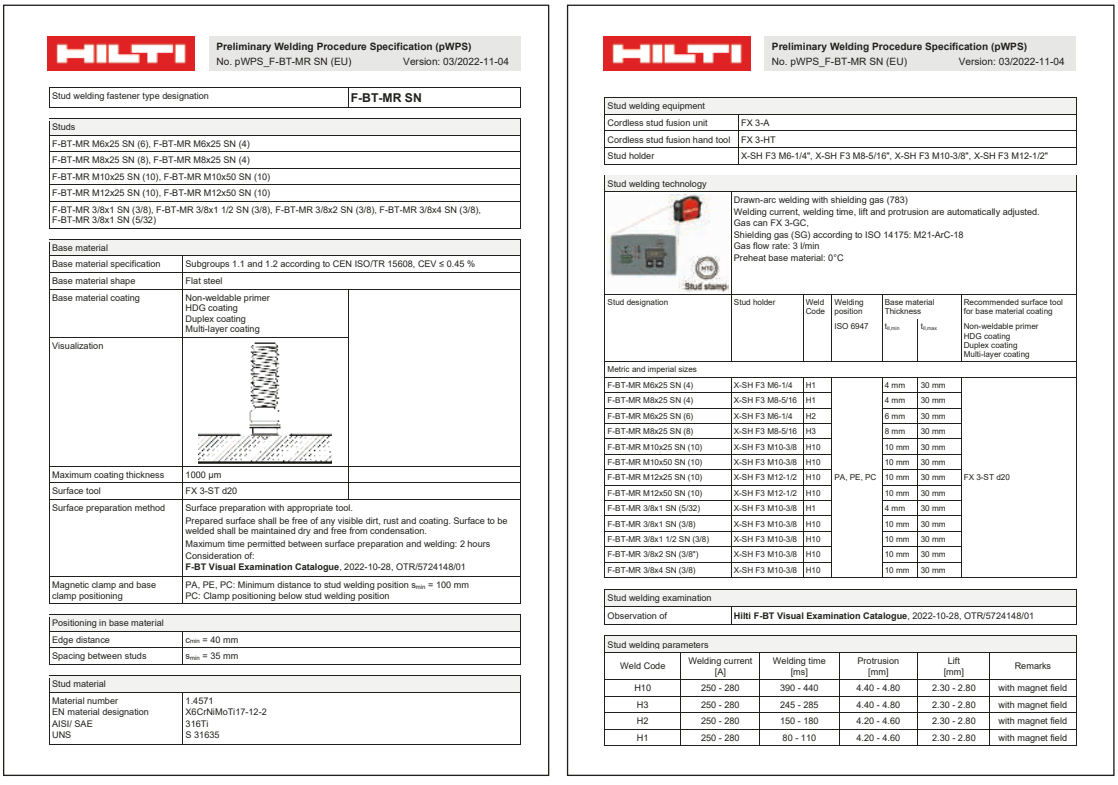
- Qualification by welding procedure test
- Qualification by pre-production tests

8.1.1 Preliminary Welding Procedure Specification (pWPS)

Preliminary Welding Procedure Specification contains the required variables of the welding procedure to be qualified, including the following information:

- Identification of the manufacturer
- Identification of pWPS
- Welding process
- Environmental conditions
- Surface preparation
- Conditions related to parent material
- Conditions related to stud material
- Conditions related to welding positions

For some applications, it may be necessary to supplement or reduce the list.



Preliminary Welding Procedure Specification (pWPS)
No. pWPS_F-BT-MR SN (EU) Version: 03/2022-11-04

Stud welding fastener type designation	F-BT-MR SN

Studs
F-BT-MR M6x25 SN (6), F-BT-MR M6x25 SN (4)
F-BT-MR M8x25 SN (8), F-BT-MR M8x25 SN (4)
F-BT-MR M10x25 SN (10), F-BT-MR M10x50 SN (10)
F-BT-MR M12x25 SN (10), F-BT-MR M12x50 SN (10)
F-BT-MR 3/8x1 SN (3/8), F-BT-MR 3/8x1 1/2 SN (3/8), F-BT-MR 3/8x2 SN (3/8), F-BT-MR 3/8x4 SN (3/8), F-BT-MR 3/8x1 SN (5/32)

Base material	
Base material specification	Subgroups 1.1 and 1.2 according to CEN ISO/TR 15608, CEV ≤ 0.45 %
Base material shape	Flat steel
Base material coating	Non-weldable primer HDG coating Duplex coating Multi-layer coating
Visualization	
Maximum coating thickness	1000 µm
Surface tool	FX 3-ST d20
Surface preparation method	Surface preparation with appropriate tool. Prepared surface shall be free of any visible dirt, rust and coating. Surface to be welded shall be maintained dry and free from condensation. Maximum time permitted between surface preparation and welding: 2 hours Consideration of: **F-BT Visual Examination Catalogue**, 2022-10-28, OTR/5724148/01
Magnetic clamp and base clamp positioning	PA, PE, PC: Minimum distance to stud welding position s_{min} = 100 mm PC: Clamp positioning below stud welding position

Positioning in base material	
Edge distance	c_{min} = 40 mm
Spacing between studs	s_{min} = 35 mm

Stud material	
Material number EN material designation AISI/ SAE UNS	1.4571 X6CrNiMoTi17-12-2 316Ti S 31635

Preliminary Welding Procedure Specification (pWPS)
No. pWPS_F-BT-MR SN (EU) Version: 03/2022-11-04

Stud welding equipment	
Cordless stud fusion unit	FX 3-A
Cordless stud fusion hand tool	FX 3-HT
Stud holder	X-SH F3 M6-1/4", X-SH F3 M8-5/16", X-SH F3 M10-3/8", X-SH F3 M12-1/2"

Stud welding technology	
	Drawn-arc welding with shielding gas (783) Welding current, welding time, lift and protrusion are automatically adjusted. Gas can FX 3-GC, Shielding gas (SG) according to ISO 14175: M21-ArC-18 Gas flow rate: 3 l/min Preheat base material: 0°C

Stud designation	Stud holder	Weld Code	Welding position ISO 6947	Base material Thickness $t_{1,min}$	Base material Thickness $t_{1,max}$	Recommended surface tool for base material coating: Non-weldable primer, HDG coating, Duplex coating, Multi-layer coating
Metric and imperial sizes						
F-BT-MR M6x25 SN (4)	X-SH F3 M6-1/4	H1	PA, PE, PC	4 mm	30 mm	FX 3-ST d20
F-BT-MR M8x25 SN (4)	X-SH F3 M8-5/16	H1		4 mm	30 mm	
F-BT-MR M6x25 SN (6)	X-SH F3 M6-1/4	H2		6 mm	30 mm	
F-BT-MR M8x25 SN (8)	X-SH F3 M8-5/16	H3		8 mm	30 mm	
F-BT-MR M10x25 SN (10)	X-SH F3 M10-3/8	H10		10 mm	30 mm	
F-BT-MR M10x50 SN (10)	X-SH F3 M10-3/8	H10		10 mm	30 mm	
F-BT-MR M12x25 SN (10)	X-SH F3 M12-1/2	H10		10 mm	30 mm	
F-BT-MR M12x50 SN (10)	X-SH F3 M12-1/2	H10		10 mm	30 mm	
F-BT-MR 3/8x1 SN (5/32)	X-SH F3 M10-3/8	H1		4 mm	30 mm	
F-BT-MR 3/8x1 SN (3/8)	X-SH F3 M10-3/8	H10		10 mm	30 mm	
F-BT-MR 3/8x1 1/2 SN (3/8)	X-SH F3 M10-3/8	H10		10 mm	30 mm	
F-BT-MR 3/8x2 SN (3/8")	X-SH F3 M10-3/8	H10		10 mm	30 mm	
F-BT-MR 3/8x4 SN (3/8)	X-SH F3 M10-3/8	H10		10 mm	30 mm	

Stud welding examination	
Observation of	**Hilti F-BT Visual Examination Catalogue**, 2022-10-28, OTR/5724148/01

Stud welding parameters					
Weld Code	Welding current [A]	Welding time [ms]	Protrusion [mm]	Lift [mm]	Remarks
H10	250 - 280	390 - 440	4.40 - 4.80	2.30 - 2.80	with magnet field
H3	250 - 280	245 - 285	4.40 - 4.80	2.30 - 2.80	with magnet field
H2	250 - 280	150 - 180	4.20 - 4.60	2.30 - 2.80	with magnet field
H1	250 - 280	80 - 110	4.20 - 4.60	2.30 - 2.80	with magnet field

Figure 8.1.1-1: Pre-liminary Welding Procedure Specification (pWPS) example

Hilti provide a complete set of qualified WPS examples which can function as basis for the Welding Engineer to write a pWPS.

8.1.2 Welding procedure qualification test (WPQT)

When welding procedure qualification is required, tests shall be carried out. Tests should be agreed between the contracting parties.

Welding procedure qualification tests in keeping with EN ISO 14555

Test type	Test category	Test specimen	Test acceptance criteria
Visual examination	Non-destructive testing (NDT) – surface examination	10 studs	Hilti F-BT visual examination catalogue [10]
	Non-destructive testing (NDT) – stud examination		
	Active Fusion Indicator (AFI) – stud examination		
Physical examination	Destructive testing (DT) – bend testing	10 studs	according to section 8.4.1
	or		
	Destructive testing (DT) – tension testing	5 studs	according to section 8.4.2
Re-testing	If one test fails to meet the requirements, two similar tests can be carried out. If more than one test, or one of the two replacement tests, does not fulfill the acceptance criteria, the test has failed.		

Table 8.1.2-1: Welding procedure qualification tests

- WPQTs shall be performed on coated material if coated material is the use case.
- Tension testing is recommended as physical examination for F-BT-MR M12 and F-BT-MR M12 SN due to the stud geometry.

8.1.3 Welding Procedure Qualification Record (WPQR)

The WPQR is a formally issued document, containing welding procedure details and test results which is written and signed by a Notified Body (NB). The report is required to change a pWPS to a WPS. Hilti supports the manufacturer by providing a complete set of WPQR examples issued by gbd Lab GmbH (gbd), RINA Services S.p.A. (RINA), Lloyd's Register (LR), Det Norske Veritas (DNV) (see section 8.5).

8.1.4 Qualified Welding Procedure Specification (WPS)

The Welding Procedure Specification (WPS) is a qualified pWPS which specifies the range for all relevant parameters and meets the qualification requirements based on welding qualification tests.

Hilti provides examples of qualified WPS according to EN ISO 14555 (see section 8.5):
CSF-WPS F-BT-MR (EU-2), Version: 01/2025-07-24 [11].
CSF-WPS F-BT-MR (EU), Version: 03/2025-07-24 [12].

8.1.5 Conditions related to parent material

For the parent material to be used, proof of conformity shall be available. In the absence of the conformity proof, the parent material shall be subjected to additional material tests before welding. For this purpose, the availability of sufficient parent material from the same melt as being used in the testing shall be guaranteed.

CSF covers material groups in accordance with ISO/TR 15608 [8], see Table 8.1.5-1.

Parent material conditions		
Material groups according to	Welding procedure qualification test performed with	Welding procedure qualification test covers
ISO/TR 15608 [8]	1.1	1.1
	1.2	1.1 and 1.2
	1.3	1.1, 1.2 and 1.3
	2.1	2.1

Table 8.1.5-1: Parent material conditions

Table 8.1.5-2 shows the recommended minimum parent material thicknesses which have been investigated within welding procedure tests by Hilti.

Recommended minimum parent material thickness		
Welding process	Designation	Parent material thickness without backside coating damage
Drawn-arc stud welding with shielding gas (783)	F-BT-MR M6x25 SN (4)	4 mm
	F-BT-MR M8x25 SN (4)	4 mm
	F-BT-MR M6x25 SN (6) F-BT-MR M6x25 (6)	6 mm
	F-BT-MR M8x25 SN (8) F-BT-MR M8x25 (8)	8 mm
	F-BT-MR M10x25 SN (10) F-BT-MR M10x50 SN (10) F-BT-MR M10x25 (10) F-BT-MR M10x50 (10) F-BT-MR M12x25 SN (10) F-BT-MR M12x50 SN (10) F-BT-MR M12x25 (10) F-BT-MR M12x50 (10)	10 mm
	F-BT-MR 3/8x1 SN (5/32)	5/32"/4 mm
	F-BT-MR 3/8x1 SN (3/8) F-BT-MR 3/8x1 1/2 SN (3/8) F-BT-MR 3/8x2 SN (3/8) F-BT-MR 3/8x4 SN (3/8) F-BT-MR 3/8x1 (3/8) F-BT-MR 3/8x1 1/2 (3/8) F-BT-MR 3/8x2 (3/8) F-BT-MR 3/8x4 (3/8) F-BT-MR 1/2x1 1/2 (3/8) F-BT-MR 1/2x2 (3/8)	3/8"/10 mm

Table 8.1.5-2: Recommended minimum parent material thickness

8.1.6 Conditions related to stud material

For the stud material the proof of conformity will be provided by Hilti based on request.

A single welding procedure test may cover many different stud designation, but the welding procedure qualification test must consider those with different welding cross sections.
Thus, two welding procedure tests using two stud types with two different welding cross sections will cover all stud designations with a welding cross section within the range of the two stud types tested.

8.1.7 Conditions related to welding positions

The CSF process, including the surface preparation and the CSF itself, can be executed in the following orientations:
- Flat position (PA)
- Horizontal position (PC)
- Overhead position (PE)

Table 8.1.7-1: gives an overview on welding and testing positions.

Welding and testing positions		
Standard	Welding Procedure Qualification Test performed with	Welding Procedure Qualification test covers
EN ISO 6947 [2]	PA	PA
	PC	PA, PC
	PE	PA, PC, PE

Table 8.1.7-1: Welding and testing positions

Welding positions means the orientation of the welded part and the tool and refers to the actual weld position on jobsite.
Testing position means the welding position that is used for Welding Procedure Qualification and operator qualification.

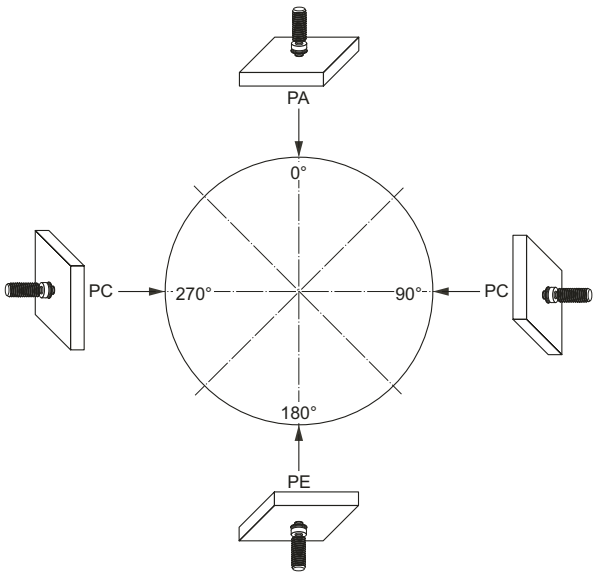


Figure 8.1.7-1: Welding and testing positions

8.2 Process control

For quality assurance, various quality requirements shall be met, depending on the field of application. Table 8.2-1 gives an overview on process control tests.

Application field	Process control test
Process control in keeping with EN ISO 14555	Production test
	Simplified production test
	Production surveillance

Table 8.2-1: Process control

These tests can be carried out by using actual production pieces or by using test specimens. Test specimens shall correspond to production conditions. Repaired studs shall be re-inspected on the same level as originally specified. The visual examination and the physical examination within the process control include non-destructive testing (NDT) and destructive testing (DT). The test category and number of test specimens stated in the following sections shall be used within the process control, unless otherwise specified.

8.2.1 Production test

Production test shall be performed on a construction or group of similar constructions by the manufacturer before the welding and/ or after a specified number of welds. This number shall be taken from the relevant application standard or the specification. The production test is limited to the used stud diameter, stud material and parent material. At least 10 studs shall be welded. For re-testing purposes, additional studs should be welded under the same conditions. Table 9.2.1-1 shows examination and testing which shall be performed, unless otherwise specified.

Test type	Test category	Test specimen	Test acceptance criteria
Visual examination	Non-destructive testing (NDT) – surface examination	10 studs	see Hilti F-BT visual examination catalogue [10]
	Non-destructive testing (NDT) – stud examination		
	Active Fusion Indicator (AFI) – stud examination		
Physical examination	Destructive testing (DT) – bend testing	5 studs	according to section 8.4.1
	or		
	Non-destructive testing (NDT) – tension testing with HAT 28-FX	5 studs	according to section 8.4.3
Re-testing	If one test fails to meet the requirements, two similar tests can be carried out. If more than one test, or one of the two replacement tests, does not fulfill the acceptance criteria, the test has failed. Corrective actions shall be taken. Test shall be repeated.		
Recording	The results shall be documented.		

Table 8.2.1-1: Production test

8.2.2 Simplified production test

Simplified production tests shall be performed by the manufacturer before the start of each shift. Additinal tests may be specified.

Test type	Test category	Test specimen	Test acceptance criteria
Visual examination	Non-destructive testing (NDT) – surface examination	3 studs	see Hilti F-BT visual examination catalogue [10]
	Non-destructive testing (NDT) – stud examination		
	Active Fusion Indicator (AFI) – stud examination		
Physical examination	Destructive testing (DT) – bend testing	3 studs	according to section 8.4.1
	or		
	Non-destructive testing (NDT) – tension testing with HAT 28-FX	3 studs	according to section 8.4.3
Re-testing	If one test fails to meet the requirements, two similar tests can be carried out. If more than one test, or one of the two replacement tests, does not fulfill the acceptance criteria, the test has failed. Corrective actions shall be taken. Test shall be repeated.		
Recording	The results shall be documented.		

Table 8.2.2-1: Simplified production test

8.2.3 Production surveillance

Production surveillance shall be performed by the manufacturer. Generally, visual examination is sufficient for production surveillance. If visual examination fails, physical examination can be carried out in addition.

Test type	Test category	Test specimen	Test acceptance criteria
Visual examination	Non-destructive testing (NDT) – surface examination	all	see Hilti F-BT visual examination catalogue [10]
	Non-destructive testing (NDT) – stud examination		
	Active Fusion Indicator (AFI) – stud examination		
Physical examination	Destructive testing (DT) – bend testing	failed visual examination	according to section 8.4.1
	or		
	Non-destructive testing (NDT) – tension testing with HAT 28-FX	failed visual examination	according to section 8.4.3
Re-testing	If the physical examination does not fulfill the acceptance criteria, the test has failed. Corrective actions shall be taken, see EN ISO 14555 [5], section 14.7.		
Recording	The results shall be documented.		

Table 8.2.3-1: Production surveillance

8.3 CSF personnel

Basic requirements for the manufacturer are to ensure that all the relevant standards and specifications that the CSF personnel need to meet during the fabrication sequence are in place and in order. CSF personnel can be subdivided into inspection and operator personnel.
The CSF personnel shall be qualified in accordance with relevant standards (EN ISO 14731 [6], EN ISO 14732 [7]).

8.3.1 Inspection personnel

When inspection is required by an application standard or by specification, the inspection personnel shall check the following aspects: technical review and inspection report. Carrying out technical reports and inspection reports can be done by qualified inspection personnel.

8.3.2 Technical review

The following aspects have typically to be considered before, during, or after the CSF process:
- Inspect equipment
- Approve parent material specification and parent material properties
- Identify stud location, including accessibility, accessibility for inspection and for non-destructive testing
- Nominate load conditions
- Analyze relevant environmental conditions, e.g. very low ambient temperature conditions
- Provide protection against adverse environmental conditions
- Examine quality requirements and acceptance criteria
- Define approach for the welding procedure qualification, in accordance with Notified Body‘s (NB) requirements
- Define quality control measures, in accordance with Notified Body‘s (NB) requirements
- Provide inspection report, if contractually stipulated
- Ensure operator qualification, in accordance with Notified Body‘s (NB) requirements
- Handle non-conformance(s)
- Define repair work and modification

8.3.3 Inspection record

When an inspection record is contractually stipulated it might be necessary to show that surface preparation and studs have been checked at specified stages and that all acceptance criteria are fulfilled. Form of an inspection record can vary. It is up to the manufacturer to decide.

8.3.4 Operator personnel

The CSF operator qualification can be done within the welding procedure qualification, the process control or as a separate test. CSF operator personnel need to be able to understand Welding Procedure Specifications (WPSs), shall have appropriate knowledge to operate the equipment, and be able to carry out the welding correctly.
The testing shall cover as minimum:

Operator personnel qualification test categories	
Functional knowledge (normative) according to EN ISO 14732, Annex A	basic knowledge about equipment
	basic assessment of imperfections
	carrying out surface preparation and stud fusion
Welding technology (informative) according to EN ISO 14732, Annex B	

Table 8.3.4-1: Operator personnel qualification test categories

As part of the CSF operator training, an example of theoretical testing has been given by Hilti which can function as a guideline for the manufacturers within the operator qualification. The testing shall be in accordance with the specified acceptance criteria.

8.4 Visual examination and physical examination details

The visual examination is described in the separate document Hilti F-BT visual examination catalogue [10]. The examination catologue is identified via the Hilti document number OTR 5724148 current Revision 01, issued October 28, 2022.

Physical examination details are given in section 8.4.1 to 8.4.3. Tests shall be selected according to the application. In certain applications, additional tests may be required by applications standards or specifications.

8.4.1 Destructive testing (DT) – bend testing

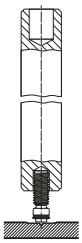
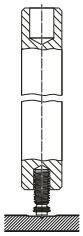
Stud type: F-BT-MR SN	Stud type: F-BT-MR	Description
		• Use bend device X-BB F3 or • Position bending device above the neck at the threaded section • Bending device shall be positioned to allow rotation of necked section

Figure 8.4.1-1: Bend device

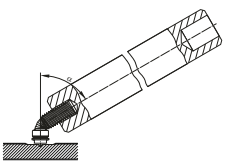
Test description		Acceptance criteria
	• Bend stud to an angle α ≥ 60° according to EN ISO 14555	• Test passes if no cracks are found in the weld after bend

Figure 8.4.1-2: Bend testing

8.4.2 Destructive testing (DT) – tension test

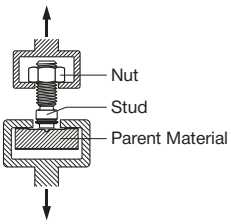
Test description		Acceptance criteria
	• Pull welded stud until fracture	• Fractures in the weld zone or the neck area are permitted if the nominal stud material tensile strength N_{min} is reached: M6, M8, 3/8 (H1): N_{min} = 7.5 kN M6 (H2): N_{min} = 9.0 kN M8 (H3): N_{min} = 17.0 kN M10, M12, 3/8, 1/2 (H10): N_{min} = 22.0 kN • Imperfections in the fracture surface shall be less than 10% of the welded area acc. to EN ISO 14555 [5], 12.1 and 12.4

Figure 8.4.2-1: Destructive tension test

- N_{min} is calculated as the product of the cross sectional neck area of the stud and the minimum specified stud material strength of 600 N/mm^2.

8.4.3 Non-destructive testing (NDT) – tension test (HAT 28-FX)

The HAT 28-FX can be used as a non-destructive test method. The target test load is based on the H-code printed on the stud.

Test description		Acceptance criteria
	• Pull welded stud until tensile proof load is reached	• No fracture until then the proof load is reached: M6, M8, 3/8 (H1): 1130 lb / 5 kN M6 (H2): 1950 lb / 9 kN M8 (H3): 2830 lb / 13 kN M10, M12, 3/8, 1/2 (H10): 5040 lb / 22 kN • See Hilti F-BT visual examination catalogue [10] for more details

Figure 8.4.3-1: Non-destructive tension test

8.5 Technical reports

8.5.1 Welding Procedure Qualification Record (WPQR)

Welding Procedure Qualification Record (WPQR) according to EN ISO 14555: 2017

Document No.	Document subject	Parent material	Issued by	Issue date	Referance documents
L22/0869_01	F-BT-MR M6x25 SN (4)	1.1 and 1.2 according to CEN ISO/TR 15608	gbd Lab GmbH (gbd)	03. Oct 22	F-BT Visual Examination Catalogue, 2025-05-02, OTR/5724148/03 CSF-WPS F-BT-MR (EU)
L22/0868_01	F-BT-MR M6x25 SN (6)			03. Oct 22	
L22/0867_01	F-BT-MR M8x25 SN (8)			03. Oct 22	
L22/1282_01	F-BT-MR M10x50 SN (10)			19. Oct 22	
L22/1281_01	F-BT-MR M12x50 SN (10)			19. Oct 22	
L22/0873_01	F-BT-MR M6x25 (6)			03. Oct 22	
L22/0872_01	F-BT-MR M8x25 (8)			03. Oct 22	
L22/1284_01	F-BT-MR M10x50 (10)			19. Oct 22	
L22/1283_01	F-BT-MR M12x50 (10)			19. Oct 22	
N. 22TO00513PW2-A	F-BT-MR M6x25 SN (6)	1.1 and 1.2 according to CEN ISO/TR 15608	RINA Services S.p.A. (RINA)	12. Oct 22	
	F-BT-MR M10x50 SN (10)				
	F-BT-MR M12x50 SN (10)				
A1339212	F-BT-MR M6x25 SN (6)	1.1 and 1.2 according to CEN ISO/TR 15608	Det Norske Veritas (DNV)	06. Jul 23	
	F-BT-MR M10x50 SN (10)				
	F-BT-MR M12x50 SN (10)				
HAM2303359/3	F-BT-MR M6x25 SN (6)	1.1 and 1.2 according to CEN ISO/TR 15608	Lloyd's Register (LR)	22. Dec 23	
HAM2303359/2	F-BT-MR M10x50 SN (10)			22. Dec 23	
HAM2303359/1	F-BT-MR M12x50 SN (10)			22. Dec 23	
L25/1990_01	F-BT-MR M6x25 SN (6)	1.1, 1.2, 1.3 and 2.1 according to CEN ISO/TR 15608	gbd Lab GmbH (gbd)	16. Jul 25	F-BT Visual Examination Catalogue, 2025-05-02, OTR/5724148/03 CSF-WPS F-BT-MR (EU-2)
L25/1991_01	F-BT-MR M6x25 (6)			14. Jul 25	
L25/1992_01	F-BT-MR M10x25 SN (10)			14. Jul 25	
L25/1993_01	F-BT-MR M10x25 (10)			14. Jul 25	
L25/1994_01	F-BT-MR M12x25 SN (10)			15. Jul 25	

Table 8.5.1-1: Welding Procedure Qualification Record (WPQR)

8.5.2 Test reports

**Hardness test
according to EN ISO 6507-1:2018-03**

Document No.	Document subject	Parent material	Issued by	Issue date
L22/0869_3	F-BT-MR M6x25 SN (4) F-BT-MR M8x25 SN (4) F-BT-MR 3/8x1 SN (5/32)	S355	gbd Lab GmbH (gbd)	08. Oct 22
L22/0868_3	F-BT-MR M6x25 SN (6)	S355	gbd Lab GmbH (gbd)	08. Oct 22
L22/0867_3	F-BT-MR M8x25 SN (8)	S355	gbd Lab GmbH (gbd)	08. Oct 22
L25/1990_05	F-BT-MR M6x25 (6)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1991_05	F-BT-MR M6x25 (6)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1994_05	F-BT-MR M12x50 (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1994_05	F-BT-MR M12x25 SN (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25

Table 8.5.2-1: Hardness test

**Tension test
according to EN ISO 6892: 2019-12**

Document No.	Document subject	Parent material	Issued by	Issue date
L22/0862_01	F-BT-MR M6x25 (6) F-BT-MR M8x25 (8) F-BT-MR M10x25 (10) F-BT-MR M12x25 (10) F-BT-MR M6x25 SN (4) F-BT-MR M6x25 SN (8) F-BT-MR M8x25 SN (8) F-BT-MR M12x25 SN (10) F-BT-MR 3/8x1 SN (3/8)	S355	gbd Lab GmbH (gbd)	27. Jul 22
L22/0862_02	F-BT-MR M10x50 SN (10) F-BT-MR M12x50 SN (10) F-BT-MR M10x50 SN (10) F-BT-MR M12x50 SN (10)	S355	gbd Lab GmbH (gbd)	19. Oct 22
L25/1994_06	F-BT-MR M12x50 (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1995_06	F-BT-MR M12x50 (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25

Table 8.5.2-2: Tension test

Shear test

Document No.	Document subject	Parent material	Issued by	Issue date
L22/0862_03a	F-BT-MR M6x25 SN (4) F-BT-MR M6x25 SN (6} F-BT-MR M8x25 SN (8) F-BT-MR M10x25 (10) F-BT-MR M10x25 SN (10) F-BT-MR M12x25 SN (10) F-BT-MR M6x25 (6) F-BT-MR M8x25 (8) F-BT-MR M10x25 (10) F-BT-MR M12x25 (10)	S355	gbd Lab GmbH (gbd)	13. Dec 22

Table 8.5.2-3: Shear test

Macro examination
according to PA_25_009/02-01;2021-01

Document No.	Document subject	Parent material	Issued by	Issue date
L22/0869_02	F-BT-MR M6x25 SN (4) F-BT-MR M8x25 SN (4) F-BT-MR 3/8x1 SN (5/32)	S355	gbd Lab GmbH (gbd)	10. Aug 22
L22/0868_02	F-BT-MR M6x25 SN (6)	S355	gbd Lab GmbH (gbd)	01. Aug 22
L22/0867_02	F-BT-MR M8x25 SN (8)	S355	gbd Lab GmbH (gbd)	10. Aug 22
L22/1282_02	F-BT-MR M10xL SN (10) F-BT-MR 3/8xL SN (3/8)	S355	gbd Lab GmbH (gbd)	24. Oct 22
L22/1281_02	F-BT-MR M12xL SN (10)	S355	gbd Lab GmbH (gbd)	24. Oct 22
L22/1284_02a	F-BT-MR M10x50 (10)	S355	gbd Lab GmbH (gbd)	25. Oct 22
L22/1283_02a	F-BT-MR M12x50 (10)	S355	gbd Lab GmbH (gbd)	25. Oct 22
L25/1990_04	F-BT-MR M6x25 (6)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1991_04	F-BT-MR M6x25 (6)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1994_04	F-BT-MR M12x50 (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25
L25/1995_04	F-BT-MR M12x50 (10)	S460 ML	gbd Lab GmbH (gbd)	21. Jul 25

Table 8.5.2-4: Macro examination

9. Specific aspects of performance

9.1 General

The performance of the F-BT studs was determined by means of comprehensive experimental investigations performed throughout the development of the system. These internal tests were complemented by test programs performed by accredited external laboratories. Section 8.5 offers a survey of respective test reports.

In case background information related with the performance of the studs or the application itself is requested or needed for product specification, please inquire at Hilti.

Such information may concern aspects like:
- Robustness of F-BT studs to resist dynamic loading.
- Shear-tension interaction behaviour.
- Durability details.
- Effect of welding direction on performance.
- F-BT weld hardness considerations.

9.2 Impact on the fatigue resistance of parent material

9.2.1 Testing program

When F-BT welded studs are applied to structures subjected to fatigue loading, it is essential to understand their impact on the fatigue resistance of the parent material. An initial series of constant amplitude fatigue tests – outlined in Section 9 of the Hilti Cordless Stud Fusion Technical Manual (May 2023) – demonstrated performance significantly exceeding detail category DC 80 for welded headed studs, as defined in Eurocode 3 (EN 1993-1-9:2005) [16]. The fatigue performance is primarily attributed to the reduced heat-affected zones resulting from the CSF welding process, in contrast to conventional fully welded headed studs typically measuring 19 or 22 mm in diameter. To establish a detail category greater than DC 80 additional fatigue tests were executed.
As the use of the fasteners in wind towers is a relevant use case, base material of group 2.1 per CEN ISO/TR 15608 [8] was added into the fatigue test scope, specifically steel grade S460M.

Table 9.2.1-1 presents the test program parameters.

Test series	Threaded studs	Surface tool	Parent material steel grade	Parent material thickness t [mm]	Stress ratio R [–]	Installation Condition	Number of test specimens
355-15-01-w	F-BT-MR 10	FX 3-ST d20	S355J2+N	15	0.1	Correct weld	4
355-15-03-w					0.3		10
355-15-05-w					0.5		10
355-15-03-p					0.3	No weld, only preparation	1
355-15-03-wr					0.3	Stud removed and rewelded	2
460-20-01-w	F-BT-MR 10	FX 3-ST d20	S460G4+M	20	0.1	Correct weld	8
460-20-03-w					0.3		11
460-20-05-w					0.5		7
460-20-08-w					0.8		1
460-40-03-w				40	0.3	Correct weld	6
460-40-05-w					0.5		4

Table 9.2.1-1: Testing program

Testing was carried out at the accredited Hilti Fastening System Research Laboratories (FSRL) and the Swiss Federal Laboratories for Materials Science and Technology (EMPA). Analysis of fatigue test data was carried out at University of Stuttgart, Germany [17].

The key findings can be summarized as follows:
- No significant effect to steel grade
- No notable influence of parent material thickness
- No significant impact from stress ratio
- Test results align well with a slope of m=3, which is typical for welded structural details.

The assumption was substantiated that the impact on fatigue resistance of the parent material – relative to values specified for 19 mm welded headed studs – is reduced when employing Hilti F-BT welded studs. The test result evaluation of all test data resulted in fatigue classification according to EN 1993-1-9:2005 [16] and DNV-RP-C203 [18].

9.2.2 Detail category according to EN 1993-1-9

Table 9.2.2-1 presents the recommended Detail Category in accordance with EN 1993-1-9 [16], while Figure 9.2.2-1 illustrates test data and statistical evaluation.

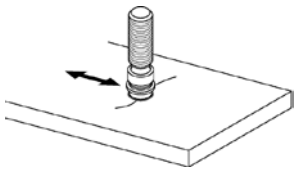
Detail category	Construction detail	Description	Requirements
80		Welded F-BT-MR threaded studs with surface preparation on structural parent material.	Stress range Δσ calculated by the gross cross-section. Parent material steel grade: S235 to S275 according to EN 10025-2 Installation, static loading and spacing of fasteners as described in this manual shall be observed.
100			Stress range Δσ calculated by the gross cross-section. Parent material thickness t ≥ 10 mm Parent material steel grade: S355 to S460 according to EN 10025-2, EN 10025-3, EN 10025-4. Installation, static loading and spacing of fasteners as described in this manual shall be observed.

Table 9.2.2-1: Detail category according to EN 1993-1-9

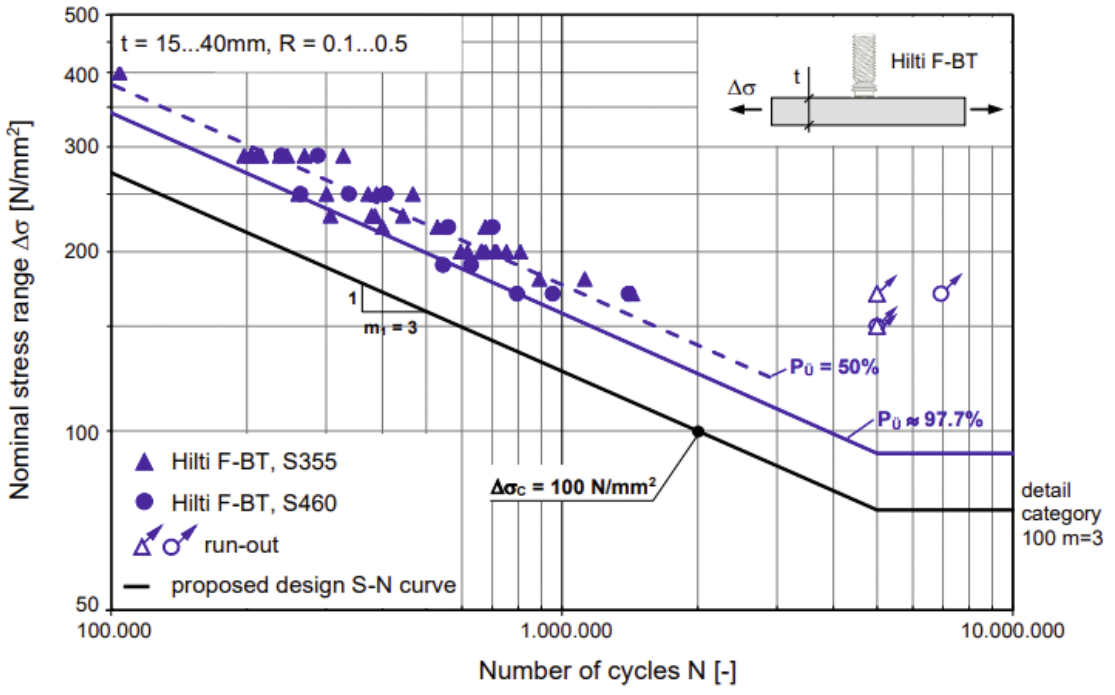


Figure 9.2.2-1: Test data and statistical evaluation according to EN 1993-1-9

9.2.3 Detail category according to DNV-RP-C203

Table 9.2.3-1 presents the recommended Detail Category in accordance with DNV-RP-C203 [18], while Figure 9.2.3-1 illustrates test data and statistical evaluation.

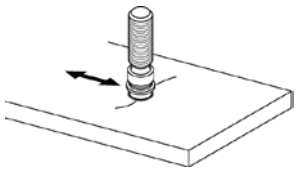
Detail category	Construction detail	Description	Requirements
E		Welded F-BT-MR threaded studs with surface preparation on structural parent material.	Stress range Δσ calculated by the gross cross-section. Parent material steel grade: S235 to S275 according to EN 10025-2 Installation, static loading and spacing of fasteners as described in this manual shall be observed.
C2			Stress range Δσ calculated by the gross cross-section. Parent material thickness t ≥ 10 mm Parent material steel grade: S355 to S460 according to EN 10025-2, EN 10025-3, EN 10025-4. Installation, static loading and spacing of fasteners as described in this manual shall be observed.

Table 9.2.3-1: Detail category according to DNV-RP-C203

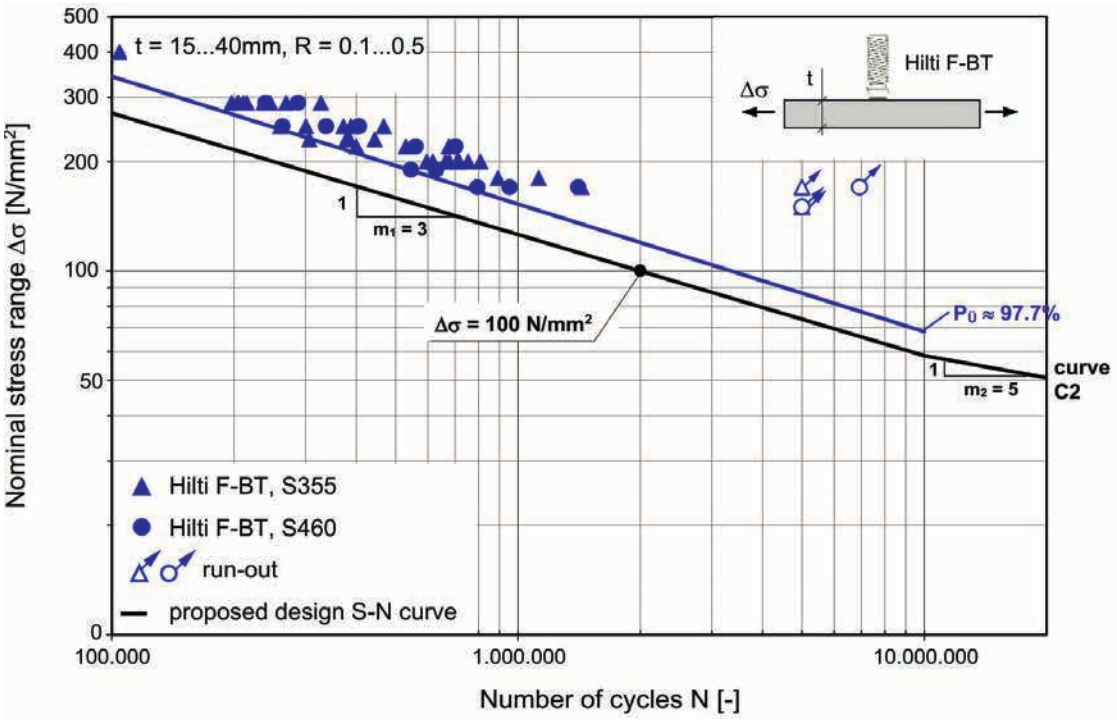


Figure 9.2.3-1: Test data and statistical evaluation according to DNV-RP-C203

10. Terminlogy

10.1 Terms and definitions

For the purpose of this document, the following symbols apply.

Dimensions

d_1	nominal diameter, thread diameter
d_2	diameter of weld area
d_{h1}	diameter of sealing washer interface/diameter of stud area
d_{h2}	diameter of stud holder interface
d_n	diameter of necking area of stud
L	thread length
L_1	nominal stud length

Spacing and distances

c	edge distance
c_{min}	minimum allowable edge distance
s	spacing
s_{min}	minimum allowable spacing

Fastened material and parent material

d_f	diameter of clearance hole in the fixture
t_I	fastened material thickness
t_{II}	parent material thickness
t_c	parent material coating thickness

Forces

F	Force in general
N	Tension force
V	Shear force
M	Moment

T	Torque moment
T_{inst}	Installation torque moment

Basic welding parameters

E	Energy, expressed in Joule (J)
I	Current intensity, expressed in Ampere (A)
U	Charging voltage, expressed in Volt (V)

Assessment

α	Load reduction factor

10.2 Abbreviations

CEV	Carbon equivalent value
EN	European de Normalisation
FPC	Factory Production Control
HAZ	Heat Affected Zone
ISO	International Organisation for Standardisation
NB	Notified Body
pWPS	Pre-liminary Welding Procedure Specification
WPQR	Welding Procedure Qualification Record
WPQT	Welding Procedure Qualification Test
WPS	Welding Procedure Specification

11. CSF equipment, accessories and consumables

11.1 Surface preparation equipment

Item no. and description for stud fusion equipment

Designation	Item no.	Description
SF 8M-A22	Local item: 2061288, 2061305, 2123924	Cordless drill driver
SF 6H-22	2254917	Cordless hammer drill driver
FX 3-ST d14	2270514	Surface tool for uncoated parent material or weldable primer on parent material
FX 3-ST d20	2270512	Surface tool for coated parent material

11.2 Surface preparation equipment for grinding

Item no. and description for stud fusion equipment for grinding

Designation	Item no.	Description
AG 5D-22	2270825	NURON Cordless angle grinder (125 mm)
AG 4S-22	2248009	NURON Cordless angle grinder (125 mm)
AG 6D-22	2215454	NURON Cordless angle grinder (125 mm)
AG-D SP	2119987, 2150740	Grinding discs
AG-D SPX	2150741	Grinding discs

11.3 Stud fusion equipment

Item no. and description for stud fusion equipment

Designation	Item no.	Description
FX 3-BC	2257272	Base clamp
C 53	Local item: 2270518, 2270519, 2270520, 2270521, 2270522, 2270524, 2270525	CSF Charger
FX 3-HT	Local item: 2280108, 2270527, 2270528, 2270529, 2270526	Cordless stud fusion hand tool
FX 3-A	Local item: 2331460, 2270477, 2270478, 2270479, 2270510, 2270511	Cordless stud fusion unit
FX 3-GC	2241926	Gas can
X-SR F3	2331667	Hand tool shielding ring
X-SL F3	2331668	Hand tool support leg
X-GC F3	2257272	FX ground cable
X-MC F3	2259030	Magnetic ground clamp
X-SH F3 M6 – 1/4"	2257273	Stud holder
X-SH F3 M8 – 5/16"	2257274	
X-SH F3 M10 – 3/8"	2257275	
X-SH F3 M12 – 1/2"	2257271	
X-SH F3-MIX	2294502	Stud holder mix
X-SHT F3	2293828	Stud holder change tool

- Local items: based on market regulation, one unique item out of the list would be available.

11.4 Installation equipment

Item no. and description for installation equipment

Designation	Item no.	Description
X-WST F3-BT	2278582	SCF washer setting tool and adaptors for metric (M6, M8, M10, M12) and imperial (3/8", 1/2") studs
X-WCG F3-BT	2331669	Washer check gauge

11.5 Studs

Item no. and description for F-BT-MR studs without sealing washer

Designation	Item no.	Description
Metric sizes		
F-BT-MR M6x25 (6)	2293866	For fastening to standard parent material thickness
F-BT-MR M8x25 (8)	2293867	
F-BT-MR M10x25 (10)	2293868	
F-BT-MR M10x50 (10)	2293869	
F-BT-MR M12x25 (10)	2293870	
F-BT-MR M12x50 (10)	2293871	
Imperial sizes		
F-BT-MR 3/8x1 (3/8)	2293890	For fastening to standard parent material thickness
F-BT-MR 3/8x1 1/2 (3/8)	2293891	
F-BT-MR 3/8x2 (3/8)	2293892	
F-BT-MR 3/8x4 (3/8)	2293893	
F-BT-MR 1/2x1 1/2 (3/8)	2293895	
F-BT-MR 1/2x2 (3/8)	2293896	

Item no. and description for F-BT-MR SN studs with sealing washer

Designation	Item no.	Description
Metric sizes		
F-BT-MR M6x25 SN (4)	2346394	For fastening to thin parent material
F-BT-MR M8x25 SN (4)	2293865	
F-BT-MR M6x25 SN (6)	2293829	For fastening to standard parent material thickness
F-BT-MR M8x25 SN (8)	2293860	
F-BT-MR M10x25 SN (10)	2293861	
F-BT-MR M10x50 SN (10)	2293862	
F-BT-MR M12x25 SN (10)	2293863	
F-BT-MR M12x50 SN (10)	2293864	
Imperial sizes		
F-BT-MR 3/8x1 SN (5/32)	2293887	For fastening to thin parent material
F-BT-MR 3/8x1 SN (3/8)	2293880	For fastening to standard parent material thickness
F-BT-MR 3/8x1 1/2 SN (3/8)	2293881	
F-BT-MR 3/8x2 SN (3/8)	2293882	
F-BT-MR 3/8x4 SN (3/8)	2293883	

11.6 Support plate

Item no. and description for support plate

Designation	Item no.	Description
FX 3-SP S	2360102	CSF support plate for M6, M8, M10
FX 3-SP L	2360103	CSF support plate for M12

11.7 Test equipment

Item no. and description for test equipment

Designation	Item no.	Description
X-BB F3	2401712	Bending bar
HAT 28 M kit	355338	Anchor tester

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