

Engineering Specification

ULTRASONIC WELDING OF SPOOL PIECE AND LATTICE CORRECTOR CABLES IN THE DFB INTERCONNECTIONS

Abstract

The **auxiliary** bus bars are used to power the auxiliary superconducting magnets of the LHC machine. The ultrasonic welding technique was chosen to perform some 3000 connections taking place in the cryogenic Feed Boxes (DFB). This Functional Specification explains how to use the ultrasonic welding machine to splice two types of wires (type Spool Piece and type Lattice Corrector) used in the DFB.

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1. INTRODUCTION

The auxiliary bus bars are used to power the auxiliary superconducting magnets of the LHC machine with nominal electrical currents up to 600A. The chosen jointing method is ultrasonic welding. Some 3000 welds will have to be made in the DFB. This Functional Specification gives the requirements and specifications for the ultrasonic welding machines, which will be of two types (type spool-piece and type Lattice Corrector).

2. SCOPE OF THIS DOCUMENT

2.1 TYPES OF CABLES

This Engineering Specification deals with the electrical connections of the Lattice Corrector cables (2 mm² wires) and the Spool Piece cables (3 mm² wires) present in the Cryogenic Feed Boxes (DFB). The types of bus bars concerned are :

Cable code	Description
DCAD	42 wire-cable for Lattice Corrector Circuits (2 mm ²)
DCED	48 wire-cable for Lattice Corrector Circuits (2 mm ²)
DCFD	4 wire-cable for Lattice Corrector Circuits (2 mm ²)
DCGD	4 wire-cable for Spool Piece Corrector Circuits (3 mm ²)
DCHD	22 wire-cable for Spool Piece Corrector Circuits (3 mm ²)
DCID	14 wire-cable for Lattice Corrector Circuits (2 mm ²)

2.2 TYPES OF WIRES

Two types of 120/600A superconducting wires are present in the DFB:

- the Lattice Corrector Cable (LCC) wire which is circular with a 1.6mm diameter;
- the Spool Piece Cable (SPC) wire which is circular with a 2mm diameter.



Figure 1: section views of the two types of wires

2.3 CABLE LOOPS

Though the welding operations sequence is identical, this document does not deal with the making of cable loops for test purposes. For more information, refer to the document LHC-DFB-ES-xxxx [].

2.4 LOCATION OF THE CONNECTIONS

The concerned interconnections take place inside the DFBA, DFBL and DFBM []. They also appear between the DFBL or DFBM and the stand alone magnets.

This document does not explain the jointing method for the connection of these cables to the current leads interface ("pigtail").

2.5 RELATED SPECIFICATIONS

All the specifications concerning the positions of cables extremities are exposed in the Engineering Specification LHC-LI-ES-000x [].

2.6 CHOICE OF THE TECHNOLOGY

On the basis of the LHC requirements and the study of various techniques, the AT-CRI group has chosen the ultrasonic welding for the LHC cryomagnet auxiliary bus bars connection. Its principle is explained in [1].

The bus bar types available in the DFB are similar to the ones in the cryomagnets and this soldering technique complies with the DFB environmental constraints [2]. Consequently, it was decided to use this technique by adapting it to the DFB requirements.

3. EQUIPMENT DESCRIPTION

The ultrasonic welding equipment is composed of :

- An **adjustable frame with positioner** that will be used to modify the height (Z) and the position (X, Y). This system will rest on the tunnel ground and, due to floor imperfections it must be adaptable for any configuration.
- An **ultrasonic welding machine**. The ultrasonic welding machine contains the "active" part of the process and carries a support for the tooling. It transforms the high frequency electric signal generated by the power supply and transmits the ultrasonic movement to the tools.
- Ultrasonic vibrations are produced by a **high frequency generator** connected to the machine.
- The **tooling** consists of two main pieces, which are the sonotrode and the anvil. The sonotrode remains the same whatever the type of wires to connect. The anvil is equipped with two sets of clamps. The choice of the clamps depends on the wire type (Spool Piece or Lattice Corrector) to maintain the wires in position.
- The complete system will be controlled via a PC, with the dedicated software "Mecawin" installed, that will act as a user interface to control the parameters.

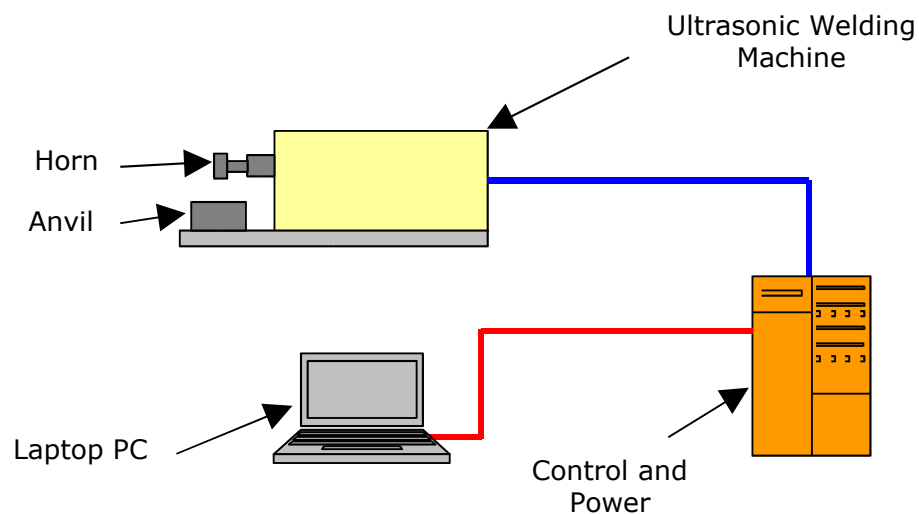


Figure 2 : Scheme of ultrasonic welding installation

3.1 ADJUSTABLE SUPPORT FRAME

The height adjustable support frame consists of a rigid part resting on a rolling cart that will be used to position the welding machine to the correct position to weld the N line superconducting cables. It must be rigid and robust enough to carry the welding machine as well as to protect it during manipulations. An example of a support frame that has been used for the assembly of LHC prototype cell (String 2) is given in figure X.



Figure 3 : Welding machine on its support frame

The main parameters of the support frame must ensure the following requirements:

- possible movements of the welding machine in three dimensions to adjust the welding positions and to remove the machine for the bus bars preparation operations;
- stability of the welding machine during operations insured;
- Complete equipment as compact as possible so as to permit passage in the tunnel. If necessary, the ultrasonic welding equipment should be removed from the passage after an official requirement two hours before removing it;
- System to tighten the cables during operation integrated in the tooling.

3.2 ULTRASONIC WELDING EQUIPMENT

The ultrasonic welding machine transforms the electrical power in a mechanical ultrasonic movement, which is transmitted by the horn to the pieces to weld. The "box" integrates a transducer (power transformation), a booster (amplification of movement) and the horn.

picture of the welding machine

3.3 ULTRASOUND GENERATOR AND CONTROL BOX

These two components are the heart of the machine.

3.3.1 CONTROL BOX

The aim of the control box is to provide a dialogue interface to the operator. All the US welding process related parameters will be controlled via this box.



Figure 4 : Front view of the ultrasound generator (left) and the control box (right)



Figure 5 : Back view of the ultrasound generator (right) and the control box (left)

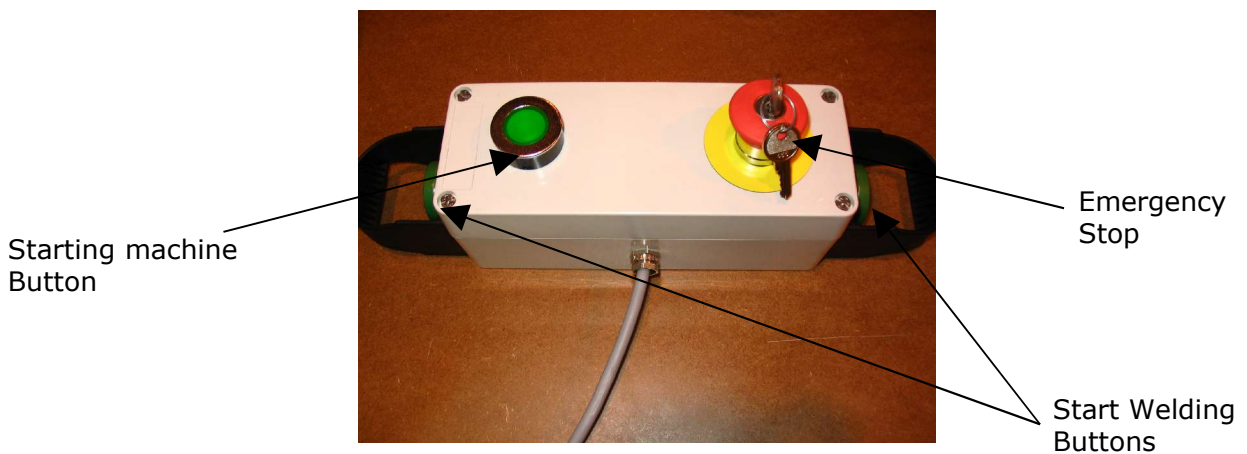


Figure 6 : Control Pad

The main functions of the control box are:

- link between all elements: US generator, welding machine, operator control;
- dialogue between operator and machine;
- check of welding machine positions and related parameters to permit operation;
- measure of dissipated energy and drive in;
- LCD screen that allows to display each chosen parameter;
- Shocks protected box.

3.3.2 ULTRASOUND GENERATOR

The Ultrasound generator will provide the ultrasonic vibrations with the required power to the welding machine.

3.4 SPECIFIC TOOLING

The specific tooling in the ultrasonic welding machine concerns parts which are adapted to the DFB connections purpose. This includes the sonotrode, the anvil and their moving support.

3.4.1 SONOTRODE

The sonotrode, aka horn is the interface between the vibration generator and the wires to connect. To properly transmit the vibration to the wires, the sonotrode has special prints on its contact keys. The dimensions of these prints give the welded zone dimensions.

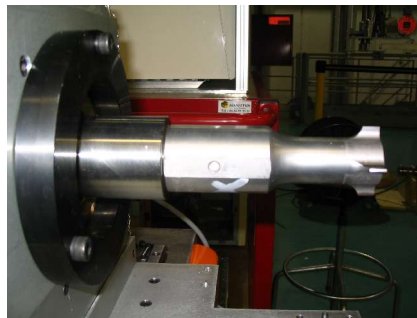


Figure 7 : Sonotrode

3.4.2 ANVIL

The anvil is a metal piece with a the same print as the sonotrode. It supports and fixes the wires to be connected during the welding process. The anvil has the same prints as the sonotrode to maintain the fix wire.

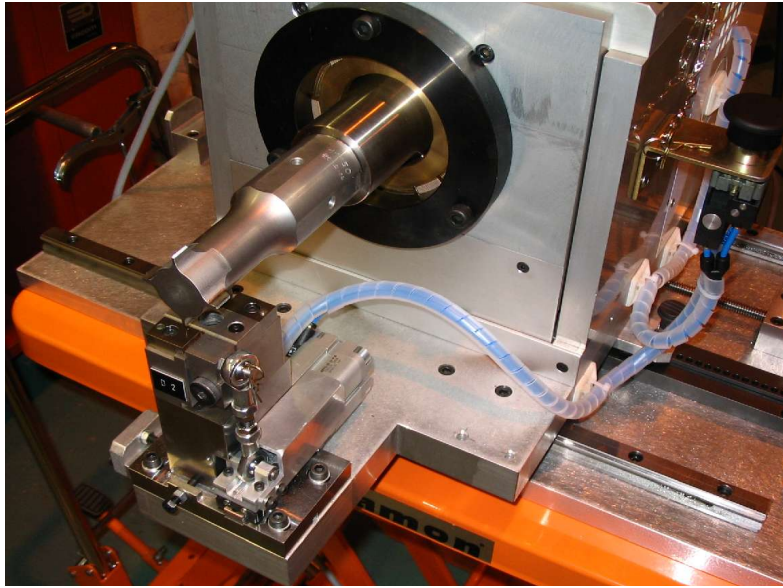


Figure 8 Sonotrode and anvil of the ultrasonic welding machine in DFB configuration

3.4.3 SUPPORT

It is a heavy steel piece linked to the anvil and made to absorb vibrations and position the system in front of the wires to connect. It includes a manual displacement system with a graduation respecting the 7 mm-pitch between each set of wires to connect.

3.4.4 OTHER TOOLING

The machine is carried by a mobile lifting table allowing an easy positioning. This table is equipped with various fittings to hang the cables or carry a bottle of compressed air.

4. CONNECTION OF TWO WIRES

This paragraph shortly describes the sequence of operations to weld two wires with the ultrasonic welding machine.

For more details concerning the use of this machine, refer to the user manual [].

For more details concerning the cables and wires positioning and preparation in a specific interconnection, refer to the corresponding Engineering Specification.

4.1 REQUIRED PERSONNEL AND SKILLS

The connection of the DFB superconducting wires requires 2 technicians. Their skills should include the following:

- electrical techniques
- welding/soldering skills
- use of high-power systems
- safety rules linked to these fields

One more person is required as a responsible person and quality assurance manager.

4.2 NECESSARY MATERIAL

This is a list of the main tools used in the preparation and connection operations.

Various:

White Gloves	CELES (SHOWA gloves)
Isopropil Alcohol	CERN EDMS #58.04.45.300.8
Wiping paper (non fluffing)	CERN EDMS #55.60.82.168.2 or 55.60.82.152.0
Insulating glass-fiber tubings	CERN EDMS #04.86.51.208.3
Black heat shrinkable tubings	RAYCHEM

To cut the wires:

Electric Cable Cutter	CERN EDMS #34.94.20.205.3
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To weld the wires:

Ultrasonic pressure welding machine on its support

To protect and identify the connection:

polyimide tubings \emptyset

Special white heat shrinkable tubings \emptyset marked with the connection ID

4.3 SEQUENCE OF OPERATIONS

Support positioning

It is important to have a proper installation of the machine in front of the interconnection.

Cables preparation

- Check the ID of the two wires to connect thanks to the circuit name they are marked with.
- Cut the two wires to be connected at the adequate overlength.
- Remove the Polyimide protection with the specific machine over the last 15 mm of the wires.
- Clean the wires by use of isopropyl alcohol and position them ready for connection.

Picture of wires ready for connection

Powering and turning on the welding machine (if necessary)

Welding Operation

- The 2 identified wires are tightened together and introduced between the jaws of the adequate anvil.
- The two positioned wires must have the same overlength and both extremities must be in contact with the butee of the anvil.
- One operator maintains the wires in position while the other one presses simultaneously the two buttons on the control pad (refer to the user manual for more information).
- Once the connection is done, push the pneumatic button on the machine to untighten the wires.

Post-welding Operations

- Move the machine in front of the next connection to be performed.
- Clean the connection following the given procedure.
- Surround the connected wires with a 20mm long-polyimide tubing.
- Protect the PI tubing with the specified heat shrinkable tubing marked with the connection ID number.

The connection is done.

5. SPECIAL OPERATIONS**5.1 WIRES AND CONNECTION IDENTIFICATION**

For matters of Quality Assurance, each connection has to be properly identified and the splicing operation data have to be stored in a database.

This identification consists in having cross-references between:

- the identification of the two wires (type, circuit, location of the interconnection)
- the welding operations parameters recorded by the machine
- the operators ID

To cross-link these parameters, a single reference is written with a specially dedicated printer on the heat-shrinkable tubing that protects the connection.

5.2 ROTATING THE ANVIL

The anvil has two tightening systems. Each of them is adapted to one cable type that can be found in the DFB: LCC 1.6mm, or SPC 2mm. Each side of the anvil is marked with the corresponding cable diameter (). Changing the cable type to be welded means the anvil has to be rotated 180°.

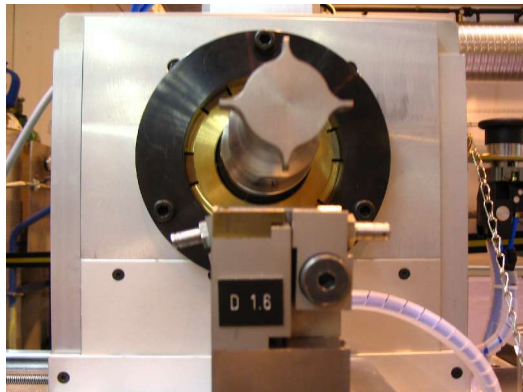


Figure 9 : Front view of the anvil in position for a SPC welding operations

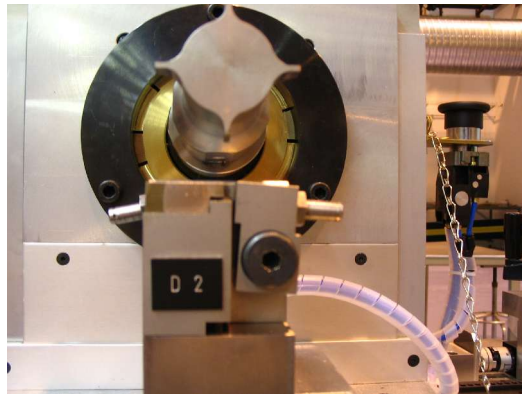


Figure 10 : Front view of the anvil in position for a SPC welding operations

The procedure for this operation consists in:

1. Remove the pin from the untightening system
2. Disconnect the untightening system
3. Use an Allen key to partially unscrew the upper part of the anvil
4. Rotate the anvil 180°
5. Screw the anvil and re-assemble the tightening system.

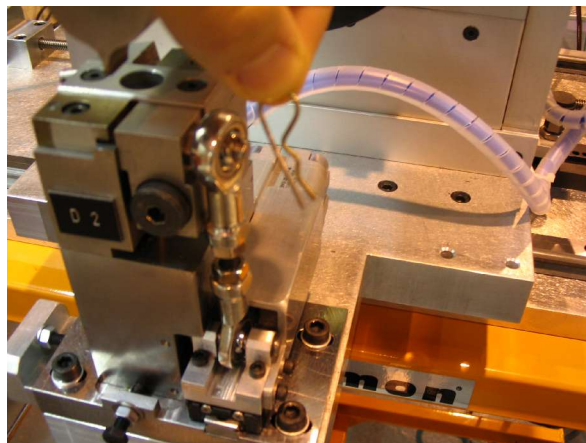


Figure 11 : Pulling the pin away from the upper part of the anvil (pushing the pneumatic button will help during this operation)

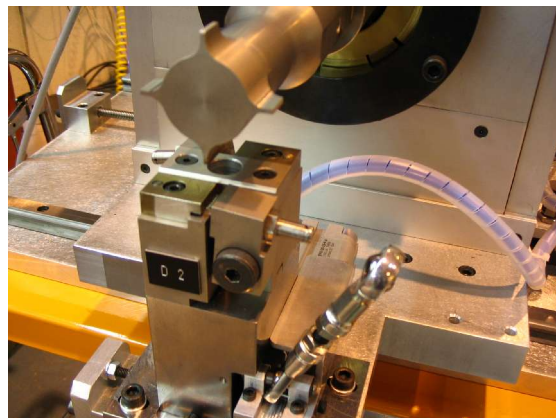


Figure 12 :

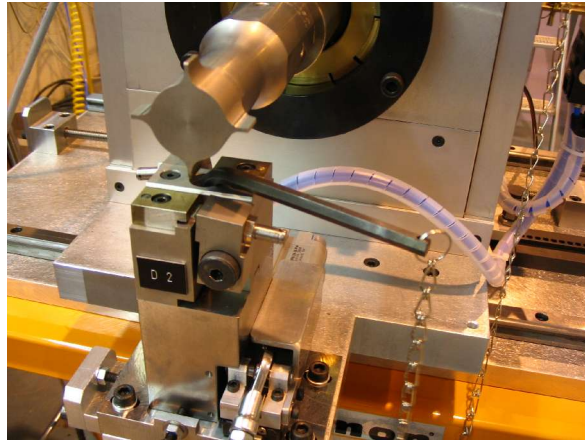


Figure 13 : rotating the anvil 180°. It should adapt in the groove of the lower part.

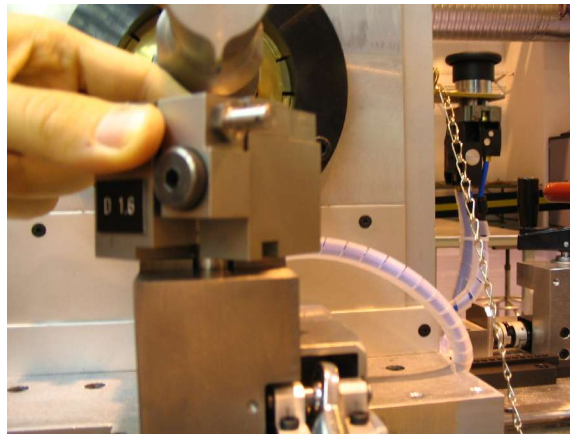


Figure 14 : re-assembling the

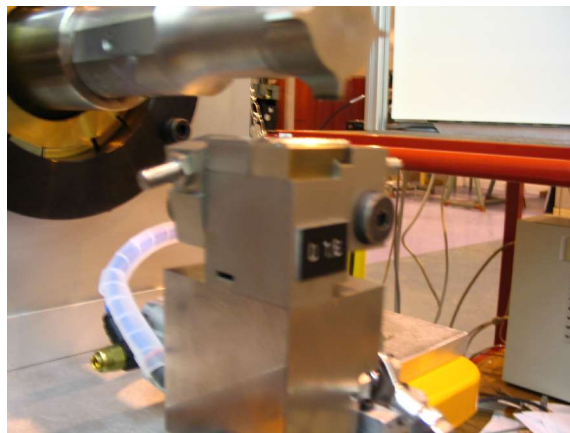


Figure 15 :

5.3 USING THE SOFTWARE MECAWIN 5.3

The normal use of the welding machine does not require an external software. Though it only keeps in memory data concerning the last operation. The Mecawin software enables to store all the data needed to identify and check the quality of the connections.

Due to the required quality level for the LHC assembly, all data concerning each weld and the machine parameters should be recorded. Consequently, during all work and test operations, the control box is linked to a computer through a RS-232 port. The dedicated software "MECAWIN" enables to bypass the control box and fully control the welding parameters.

5.4 REPAIRING A CONNECTION

In some conditions, the quality of a connection may be in doubt. A weld made with ultrasound pressure cannot be repaired. The procedure consists in cutting the connection and making a new one between the same wires.

1. Identify the corresponding connection
2. Disassemble the connection boards to access the connection
3. Bend the connected wires ready for the connection operation (perpendicular to the board)
4. Remove the protection around the connection
5. Cut both wires 2mm before the welded lengths (marked with prints)
6. Perform a new connection (Chapitre 4)

5.5 POSITIONING THE ANVIL

This operation needs to be done only when the anvil is disconnected from its support for reasons of maintenance for example. This happens only at the first installation of the anvil on this support.

This operation should in no circumstance be performed during the normal operations. If needed, please refer to the responsible person and the manual of the welding system.

5.6 CHANGING THE WELDING PARAMETERS

The welding parameters are recorded in the control box for each cable type. They are locked by the responsible person, certified by quality tests and should not be modified. Please refer to the manual of the welding machine for more information.

6. REFERENCE DOCUMENTS

Reference Number	EDMS No. (if any)	Title
LHC-LI-ES-0001	90001	Arc cryomagnet extremities
LHC-DFB-ES-0012		
LHC-DFB-ES-0004		DFB Electrical Connections
SM 4.0 01.28	-	User Manual for the CERN ultrasonic welding machine
		Cable loops