SPECIFIC TECHNICAL PRESCRIPTIONS FOR THE DRAWINGS AND MANUFACTURE OF THE EMITTANCE METER UNIT FOR THE ESS MEBT

MEBT-BI-EM90

Content of the document

1 Object

The purpose of this document is to define the technical and functional characteristics of the Emittance Unit Meter (EMU), together with its actuators, which must be delivered by the contractor. The EMU is part of the MEBT that ESS-Bilbao will deliver as part of the "in-kind" contribution to the European Spallation Source project.

ESS Bilbao will deliver the complete 3D model, which should be taken as the final conceptual model from which the contractor should make the tolerance adjustments and the manufacturing blueprints before launching the manufacturing itself. Any modification the contractor needs to make in the design to comply with the requirements and functionality of the instrument must be consulted and approved by ESS-Bilbao.

This document includes the following list of tasks to be carried out by the contractor:

- Design review of the slit (see section 2.3.3).
- Realization of the manufacturing blueprints of all the pieces in the 3D model.
- Study of manufacturing procedures based on the specification given on this document.
- Procurement and supply of all materials
- Machining and manufacturing of all the components.
- Realization of all the measurements and tests to ensure compliance with the specifications.
- The guarantee of the geometrical conformity of the components following the specifications.
- Cabling in and out vacuum.
- Cleaning and storage according to specifications.
- Packing and shipping to ESS-Bilbao facilities.
- Complete manufacturing documentation and verifications including complete metrology reports.

2 Technical requirements

ESS-Bilbao is responsible for the final conceptual design of EMU actuators, Slit head and Grid hedad; and will provide the 3D files for all the components. The vacuum vessels design and manufactruing are out of the scope of this contract. The contractor will be responsible for the tolerance adjustment of the final 3D models; for the slight modifications needed to make, when necessary, in the conceptual design to reach the final 3D model to mechanize fulfilling the functionality of the instrument; and for defining the manufacturing

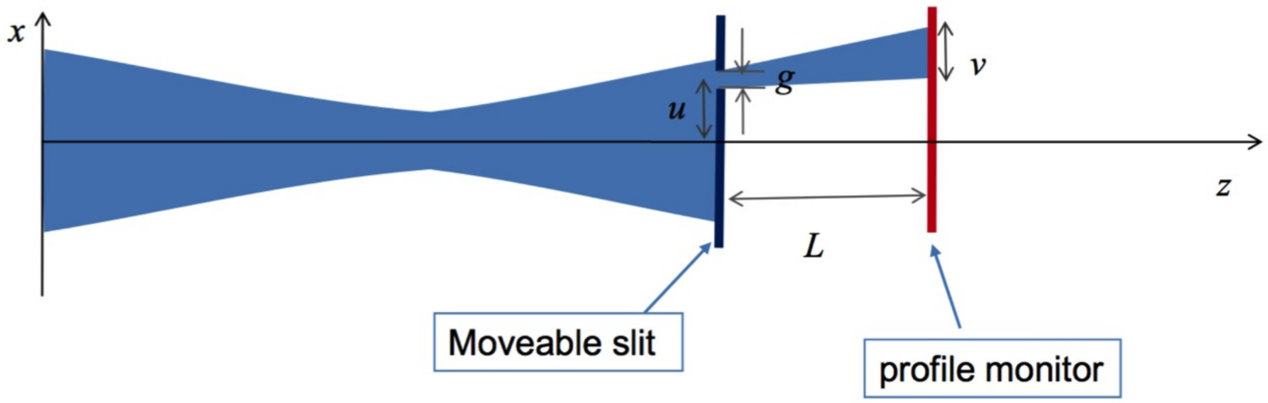


Figure 1 Slit Grid

requirements to fulfil the specifications. The contractor will be also responsible for the definition and application of the necessary controls to ensure a quality assurance plan during the manufacturing. **Once the instrument has been machined and assembled the contractor should assure the positioning of the Slit apperture of the Slit Head and the positioning Grid Head with the specifications described on section 2.2**.

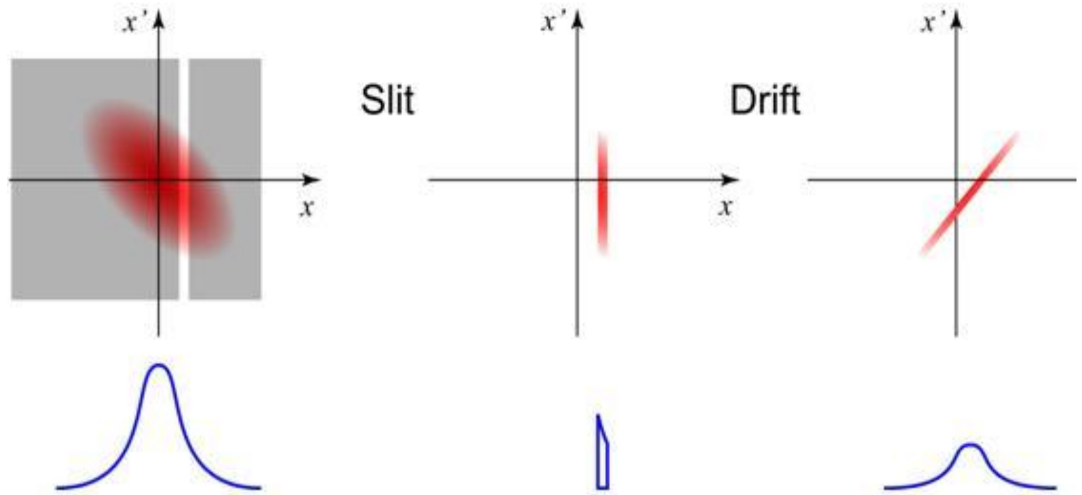


Figure 2 Phase-space sampling using a slit and grid system (sampling of the beam divergence after the beamlet rotation in phase space along the drift from the slit to the profile monitor

2.1 Slit and Grid Emittance Meter Unit

For low energy linacs, a typical method for measuring the transverse emittance consists in a slit and grid system, as schematically shown in Figure 1. For each slit position, the narrow aperture allows the passage of a beamlet populated by particles that have an almost equal position x (y) and a certain angular distribution. Due to the phase space rotation in the following drift space (see Figure 2), the beamlet angular distribution is transformed into a position distribution and sampled using a profile monitor, in our case a wire grid. Therefore, the profile measurement gives the angle x' (y') for a certain position x (y) and by scanning the slit across the beam, the whole phase-space can be reconstructed.

To assure a proper reconstruction of the emittance, the EMU is based on the design parameters specified in the ESS-0020535 document [1]: The distance between the Slit and the Grid will be 400 mm. The slit aperture is 100 µm and the thcikness 200 µm. The grid is will have 24 tugnsten wires, 33 µm diameter. The pitch of the grid is 500 µm. By design, the resolution of the actuadors wil be 25 µm. The feasibility of these parameters regarding thermomecanical considerations have been studied in the document MEBT-BI-EM01-01 for the Slit [2] and MEBT-BI-EM02-02 for the Grid [3]. The requirements that need to be fulfiled are collected in Table 1.

Table 1: EMU requirements to be fulfilled.

User Defined ID	DOORS-ID	Name	Description
		MEBT transverse phase space measurement	The beam distribution in transverse phase space shall be measured in the MEBT section. The measurement can be invasive.
MEBT-L4-PBI-110	MEBT.PBI-54	MEBT transverse phase space measurement planes	The transverse phase space measurement shall consist of one horizontal and one vertical measurement. Both measurements shall independently fulfil all requirements.
MEBT-L4-PBI-120	MEBT.PBI-55	MEBT transverse phase space 95% emittance measurement error	The transverse emittance containing 95% of the beam shall be measured with a total measurement error of less than ±10 % of the measured value.

		MEBT transverse phase space RMS emittance measurement error	The transverse RMS emittance shall be measured with a total measurement error of less than ±10 % of the measured value.
		MEBT transverse phase space measurement dynamic range	The transverse phase space measurement shall have a dynamic range of 1000.

Each EMU is composed of two independent subsystems: The *Slit Subsystem* and the *Grid Subsystem*. In this document, the Slit Subsystem (see schematic of the Slit in Figure 3) is divided in two components: Actuator (Motor, Encoder, Guides, …) and the Slit arm (Slit Head and Schaft). The 'Grid subsystem (see schematic of the Grid in Figure 4) is divided, again, in two components: Actuator (Motor, Encoder, Guides, …) and Grid arm (Grid Head and Shaft).

The scope of this contract covers the Grid Head, the Slit Head, the actuators, the motors, the encoders, the corresponding grips. The Grid PCB and the Front-End electronics are *excluded* from this contract and they are shown only for orientation and understanding of the requirements. *The contractor should build two identical EMU systems; that is, two Grid subsystems and two Slit subsystems. One system will be horizontally mounted and the other vertically mounted.*

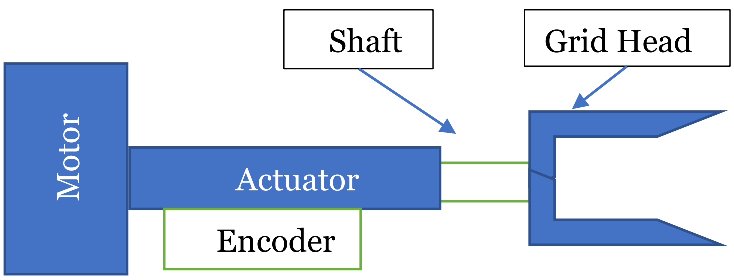


Figure 3 Schematic design of the Slit Subsystem

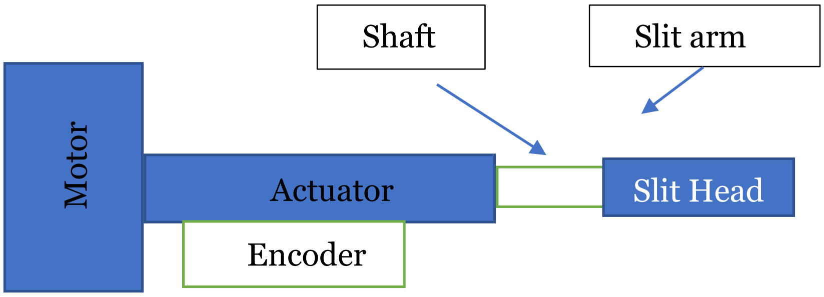


Figure 4 Schematic design of the Slit Subsystem.

2.2 Mechanical Errors

Each of the subsystems is composed by a Head (either the Grid Head or the Slit Head) and an Actuator. The contractor shall guarantee that the relative error between the angular postiion of the head and its correspondant fixed flnage is bellow a certain limit. The next two sections define this errors for each subsytem

2.2.1 Mechanical error for the Slit Subsytem

Figure 5 shows the main parts of the Slit Subsystem to calculate the accumulated mechanical errors. Table 2 describe the meaning of each of these partial errors. The contractor may assign a value to each of the partial error based on its experience, but it should guarantee a relative error between the angular position of Slit apperture and the angular position of its correspondant fixed flange no bigger than **0.5 degrees** in all the axis for each Slit Subsystems (horizontal and vertical).

The contractor shall also guarantee that the Slit apperture mechanical error shall be within ±20μm (see section 2.3.3).

Table 2 Parameters for the calculation of the ***slit*** *mechanical errors*

Error	Description	Responsable
$\Delta\alpha_{fg}$	Angular error between the fixed flange of the actuator (f) and the linear guides (g)	Contractor
$\Delta\alpha_{gm}$	Angular error between the guides (g) and the mobile flange of the actuator (m)	Contractor
$\Delta\alpha_{me}$	Angular error between the mobile flange (m) and the shaft (e)	Contractor

$\Delta\alpha_{es}$	Perpendicularity between the shaft (e) and the Slit apperture (s)	Contractor
$\Delta\alpha_{fs}$	Total angular error between the fixed flange of the actuator and the reference plane of the Slit apperture	Contractor

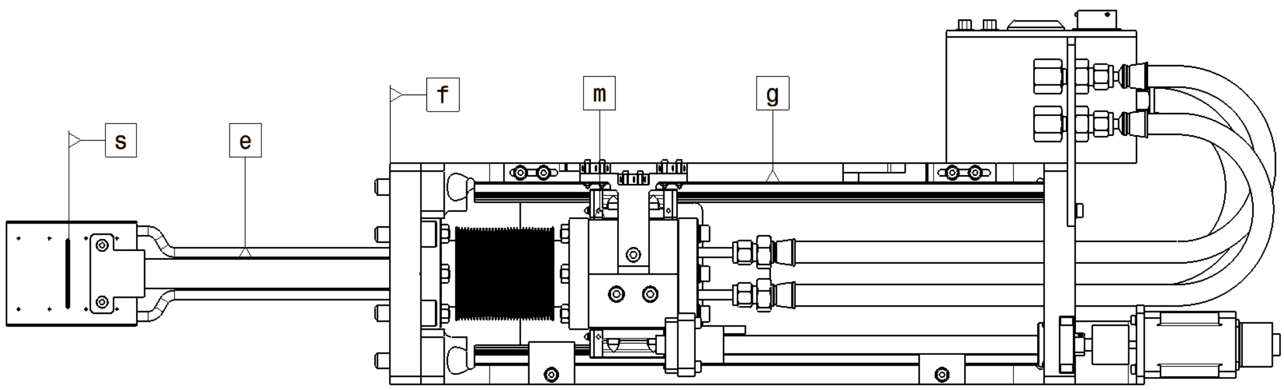


Figure 5 General view of the Slit subsystem for the calculation of mechanical errors

2.2.2 Mechanical error for the Grid Subsytem

Figure 6 shows the main parts of the Slit Subsystem to calculate the accumulated mechanical errors. Table 3 describe the meaning of each of these partial errors. The contractor may assign a value to each of the partial error based on its experience, but it should guarantee a relative error between the angular position of Grid head and the angular position of its correspondant fixed flange no bigger than **0.5 degrees** in all the axis for each Slit Subsystems (horizontal and vertical).

*Table 3 Parameters for the calculation of the **grid** mechanical errors*

Error	Description	Responsable
$\Delta\alpha_{fg}$	Angular error between the fixed flange of the actuator (f) and the linear guides (g)	Contractor
$\Delta\alpha_{gm}$	Angular error between the guides (g) and the mobile flange of the actuator (m)	Contractor
$\Delta\alpha_{me}$	Angular error between the mobile flange (m) and the shaft	Contractor

	(e)	
$\Delta\alpha_{eh}$	Perpendicularity between the shaft (e) and the Grid Head(h)	Contractor
$\Delta\alpha_{fh}$	Total angular error between the fixed flange of the actuator and the reference plane of Grid head.	Contractor

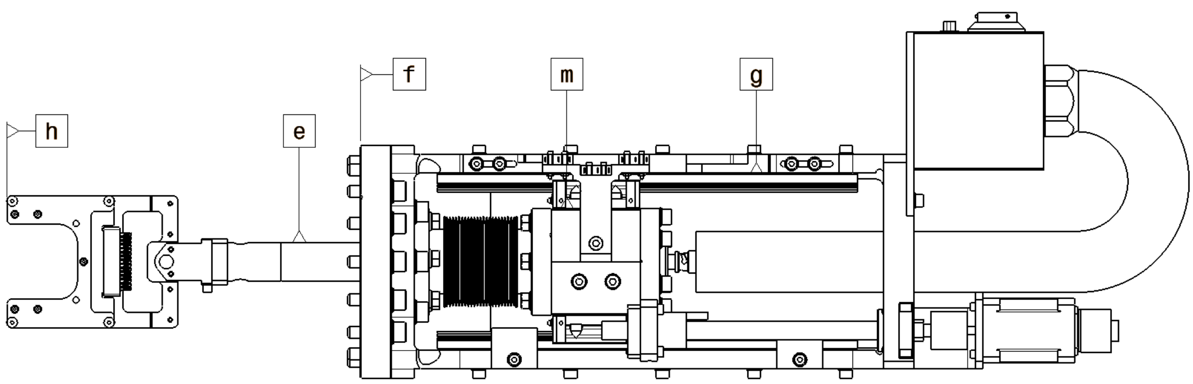


Figure 6 General view of the Grid subsystem for the calculation of mechanical errors

2.3 Mechanical description of the Slit subsystem

A picture of the complete Slit subsystem is shown in Figure 7. The main components of the system are the Slit arm and the Actuator. Due to space limitations with the integration of all the instruments in the MEBT the dimensions of this device should be restricted to a projection volume of a surface of **100 to 140 millimetres**.

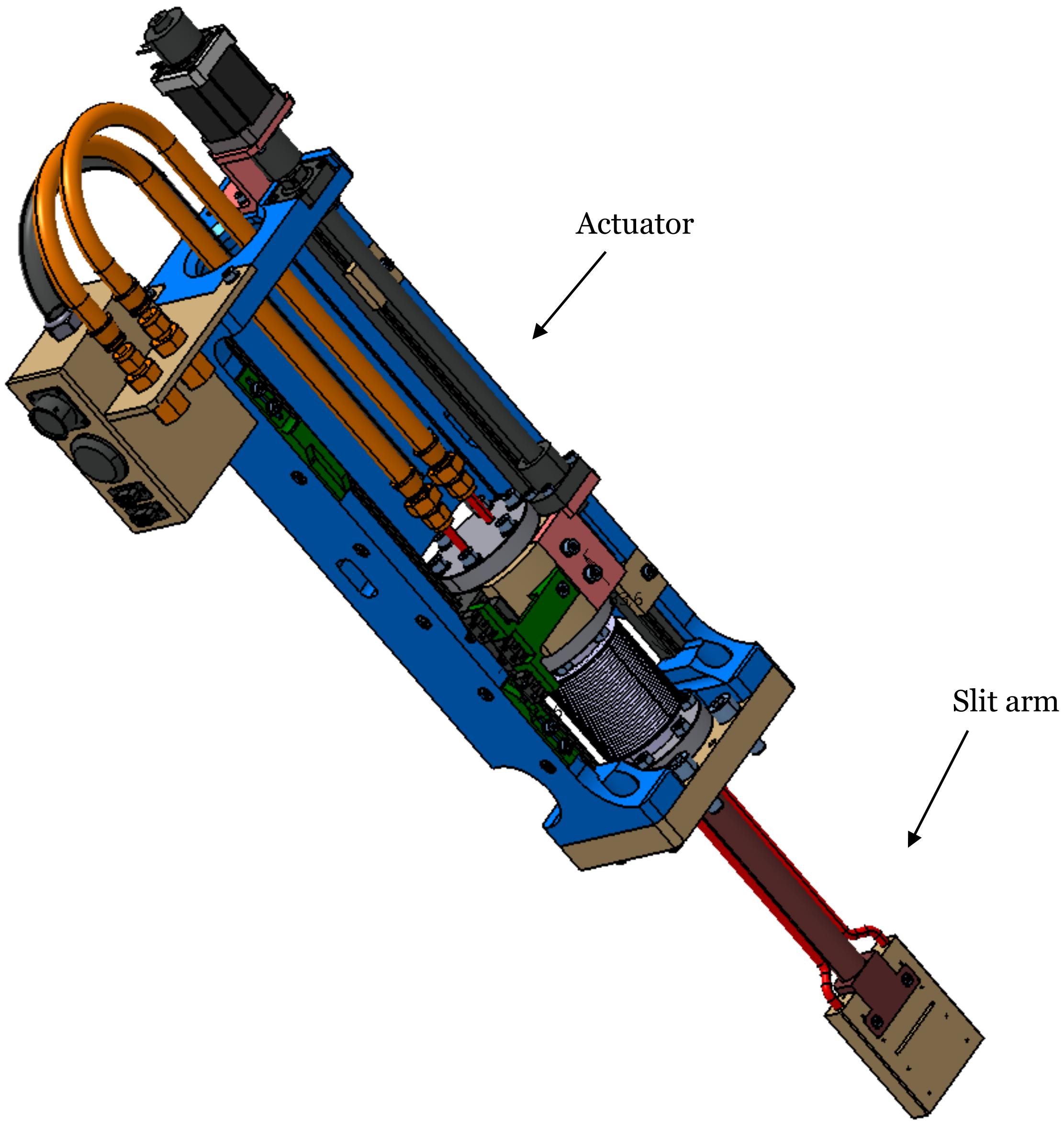


Figure 7 : Actuator and Slit mechanical design

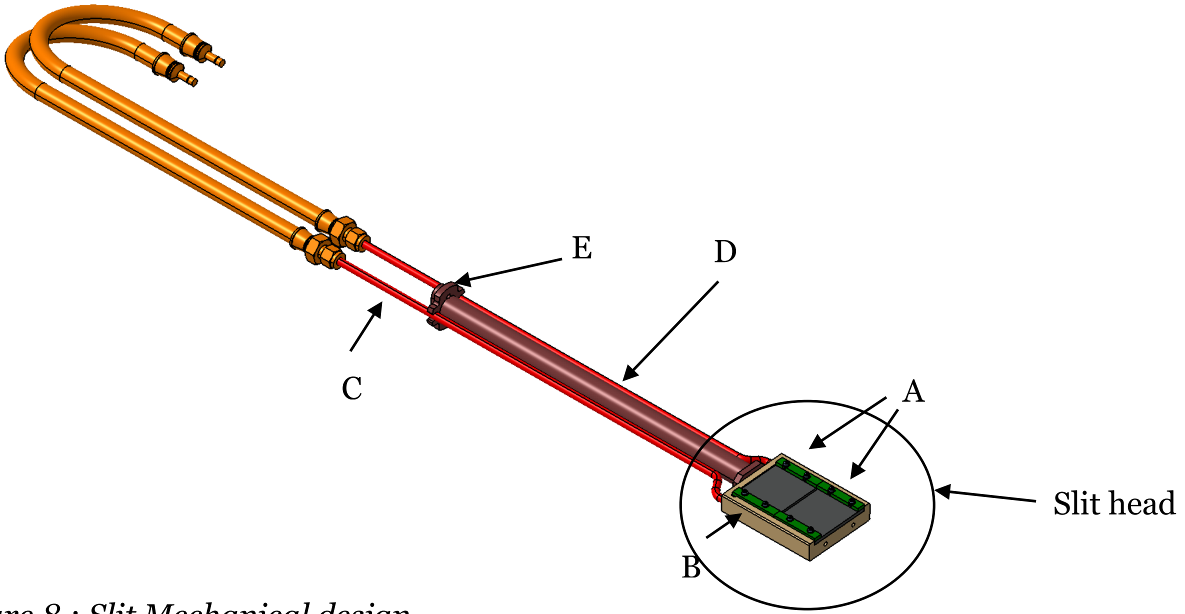


Figure 8 : Slit Mechanical design

2.3.1 Slit arm

A picture of the Slit is shown in Figure 8. The main components of the Slit are:

A) Graphite Plates.
B) Stainless steel back support.
C) Cooling Pipe.
D) Shaft.
E) Shaft Holding Piece.

The Slit head is mainly made of two graphite plates (A) that should be placed in the plane of the actuator (perpendicular to the incoming beam). These plates will be used to collimate the beam that will be measured at the Grid. The graphite should be placed on top of a stainless still holder (B), in such a way that a 100 (±20) µm aperture is obtained. See section 2.3.3 for more details. The purposue of the stainless steel substrate is to allow cooling the graphite plates. The Slit head is screwwed to the shaft (D). The shaft is weleded to the shaft holding piece (E). A water Cooling Pipe (C) is located in both sides of the shaft.

A detailed view of the shaft is shown in Figure 9. The shaft should be welded to the Slit Head support piece in one side and to the holding piece in the other side. The welding should guarantee the relative position of all the components to fulfil the precision requested in Section 2.2.

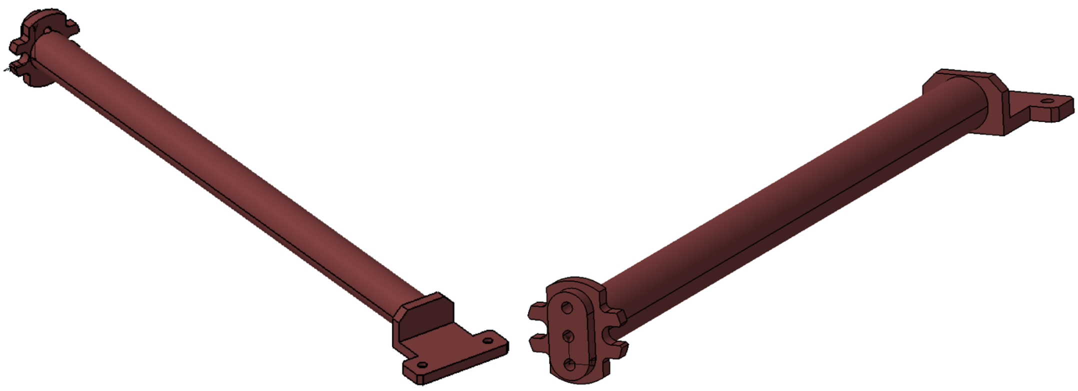


Figure 9 Shaft mechanical design

2.3.2 Actuator of the Slit subsystem

A picture of the Actuator is shown in Figure 10. The main components of the Actuator are:

A) Rectangular Flange
B) Bellow
C) Guides Support
D) Shaft Support
E) Spindle Support
F) Vacuum Feedthrough
G) Linear Guides
H) Spindle
I) Travel Limit Switches
J) MPS Limit Switch
K) Limit Switches support
L) Limit Switch triggers
M) Motor
N) Break
O) Linear Encoder
P) Patch Panel
Q) Cables protections
R) Mechanical Limits
S) Cooling feedthrough

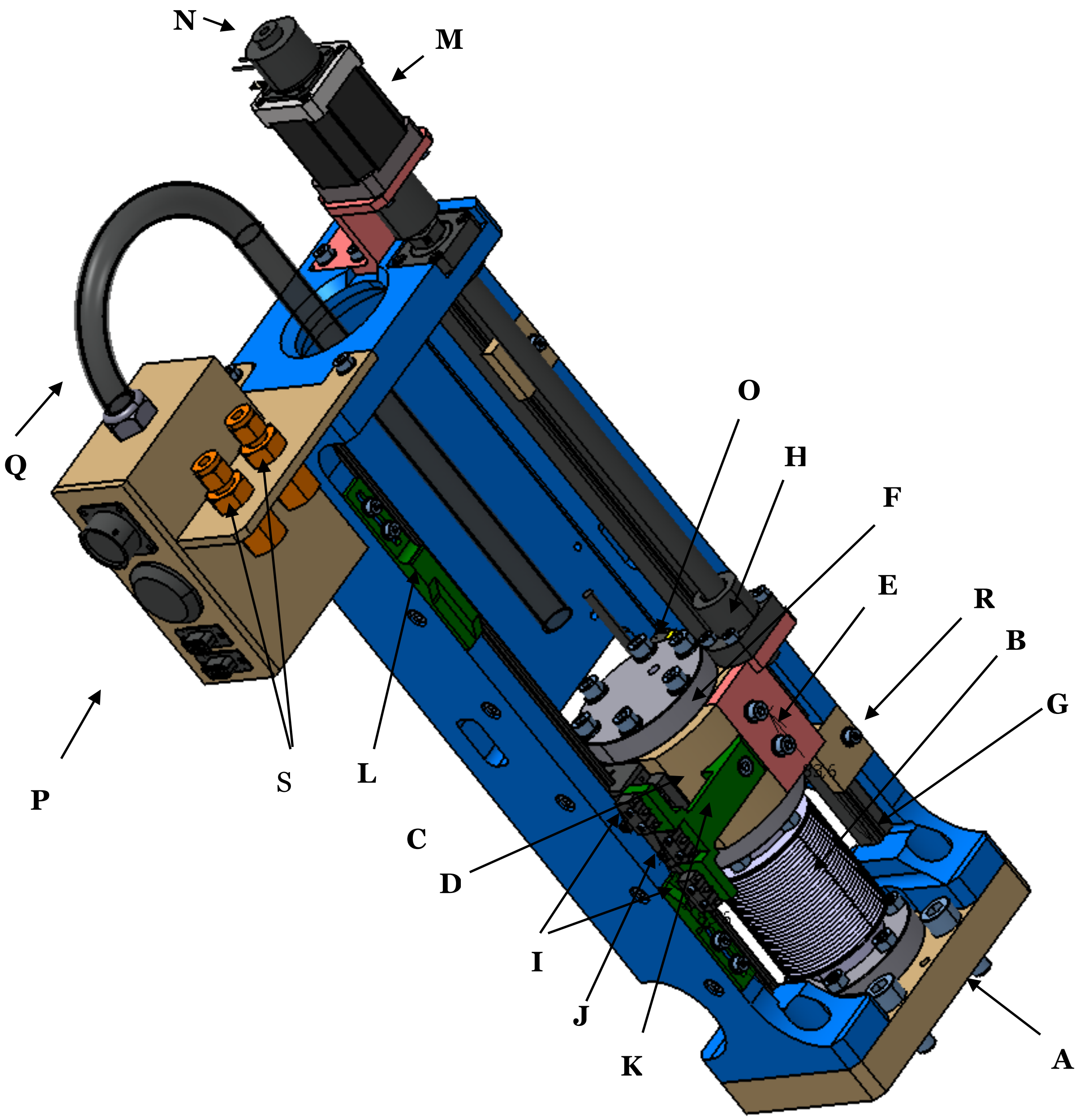


Figure 10 : Actuator and Slit mechanical design showing the different components.

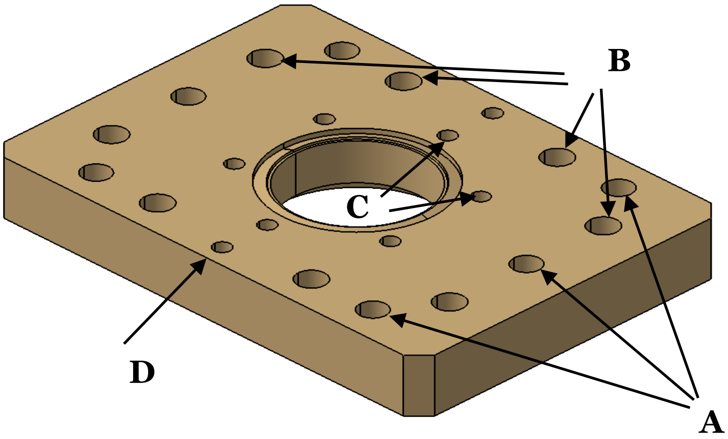


Figure 11 Rectangular Flange mechanical design

The actuator should have a **total axial stroke of 155 mm**. Two limit switches should be placed in the travel limits to indicate the reaching to the final or initial position (I). An additional limit switch (J) should be placed in the beginning of the travel to have an indication of the wire scanner insertion. This last limit switch will be used by Machine Protection System purposes. The limit switches position and functionality is described in Appendix IV. A pair of mechanical limits (R) should be used to protect the integrity of the instrument in case of a failure of the travel limit switches. The bellow (B) is fixed between the rectangular flange (A) and the shaft support (D). The movement of the shaft support is driven by two linear guides (G) placed one in front of the other.

A detailed view of the rectangular flange is shown on Figure 11. This piece has four different screw patterns. The first one (A) is to fix the Guides Support to the Rectangular Flange, the second one (B) is to fix the Rectangular Flange to the Vacuum Vessel, the third one (C) is to fix the Bellow to the Rectangular Flange and the last one (D) is to insert two precision pins to have a reproducibility in the actuator positioning. In the centre of the piece a **CF40 vacuum knife** should be machined in order to close vacuum between the Rectangular Flange and the Bellow. The dimension of the CF40 vacuum knife should be checked with the standard[1], the dimensions including in the 3D model can be considered as a guidance.

A detailed view of the Guide Support is shown in Figure 12. The objective of this piece is to support the linear guides with rigidity and precision. To assure the proper assembly of the linear guides a surface (A) should be grinding during the fabrication to have a good

[1] ISO/TS 3669-2:2007(E)

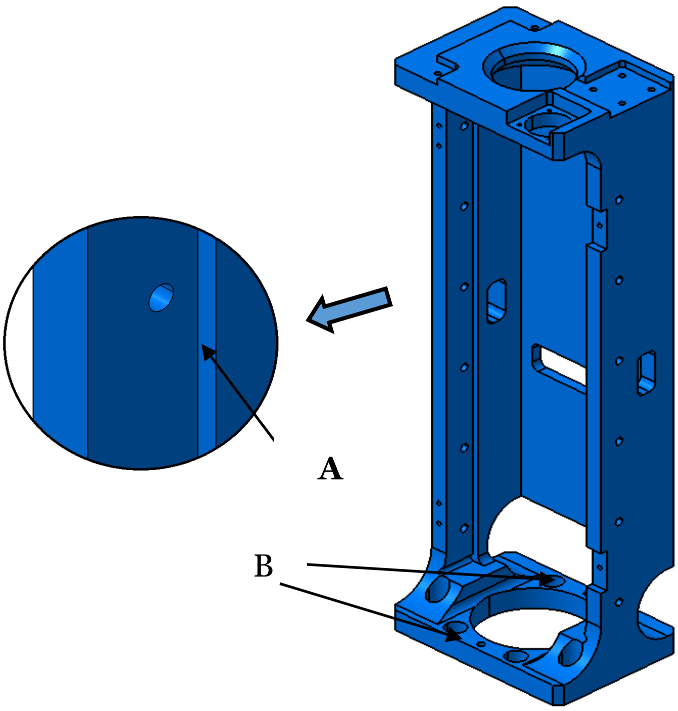


Figure 12 Guides Support mechanical design

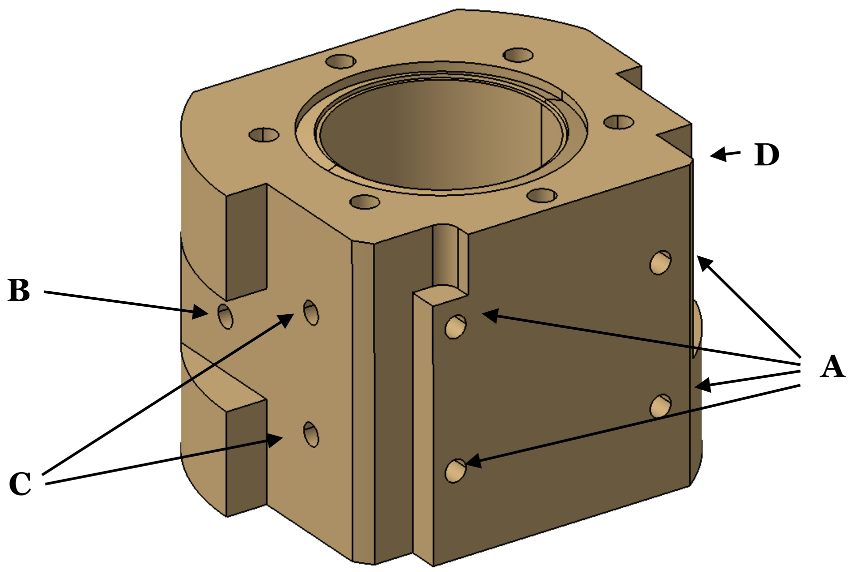


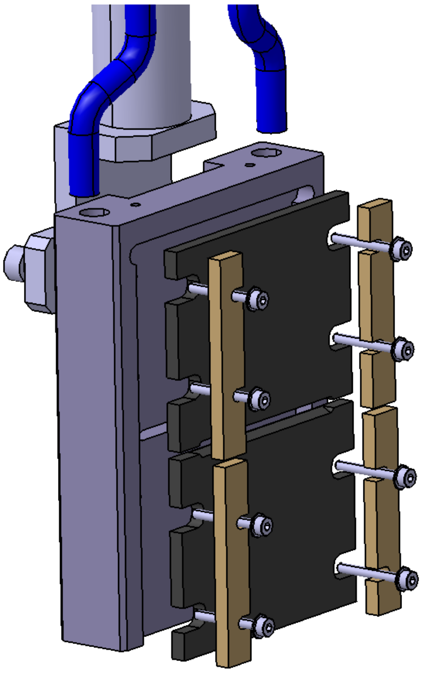
Figure 13 :Shaft Support mechanical design

mechanical precision reference to be used during the linear guides assembly. Two precision holes (B) should be machined in the bottom part of the piece to assure the repeatability during the assembly.

A detailed view of the shaft support is shown in Figure 13. On both sides of the piece a pattern of four holes (A) should be mechanized to fix this piece to the linear guides. In the front side of the piece two patterns of one (B) and two (C) holes should be mechanized to fix the Limit Switches Support and the Spindle Support respectively. On the rear side, a mechanization should be done to place the encoder in position (D). Finally, on the top and bottom faces a CF40 vacuum knife should be machined to close vacuum between Shaft Support and Bellow in one side, and between Shaft Support and Vacuum Feedthrough on the other side. The dimension of the CF40 vacuum knife should be checked with the standard[2], the dimensions including in the 3D model are a guidance.

2.3.3 Slit

Two graphite plates that form the slit are mounted in the slit head. **A possible way of**



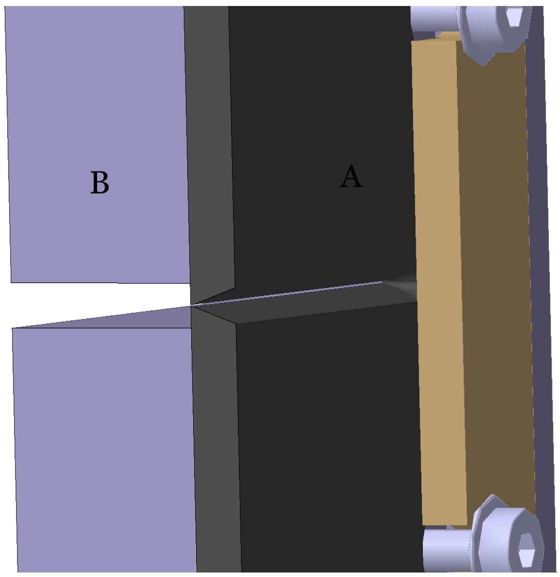


Figure 14 Graphite plate mounting procedure (left). Cut view of the graphite plate on top of the stainless steel substrate (right)

[2] ISO/TS 3669-2:2007(E)

mounting the plates is shown in Figure 14 (left). The graphite plates are 42 mm x 54 mm rectangles. In one of the long side a 42 mm length and 50 µm rabbet should be done. In this way, an 100(±20) µm apperture is formed. In order to maintain the requested performance the slit thickness should be 0.2(±0.02) mm. For the realisation of this thickness, 3 mm graphite plates are foreseen with a local chamfer that allow this 42mm x 100 µm x 200 µm. Figure 14 (right) shows a cut view of the graphite plate (A) on top of the stainless-steel substrate (B). In Figure 15 the main dimensions and tolerances of the graphite piece are shown.

It is responsibility of the contractor to purchase the graphite plates. The graphite should be isostatic fine grain variety. The graphite varieties can be SGL Sigrafine R7550 P5D, Schunk FU2584, Mersen 2220 PT or similar. The graphite variety used for the manufacturing shall be informed to ESS-Bilbao for approval.

To assure a good thermal conductivity between the graphite plates and the substrate a total force of at least 250 N should be applied to the screws. This contact force should be guaranteed by applying recommended fastening torques of ~0.5 Nm.

2.3.4 Slit Cooling Circuit

The Slit cooling circuit consists of 6 mm diameter stainless steel pipe. The substrate should be refrigerated by a water channels with a minimum flow of 2 l/min. The piping shall be welded to both the vacuum gland and the instrument.

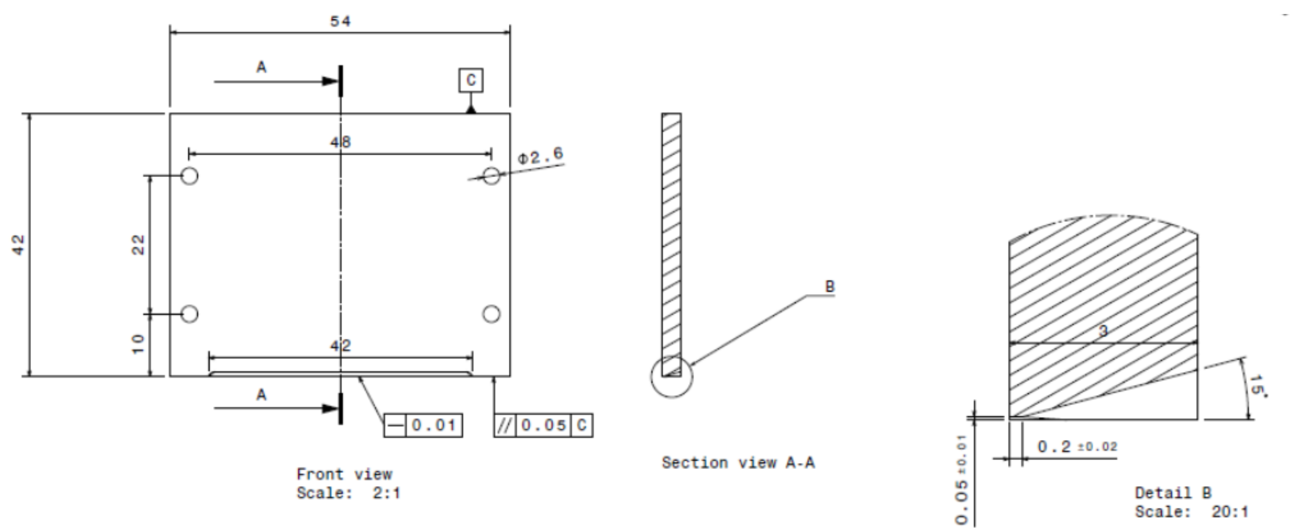


Figure 15 Scheme showing dimensions and tolerances of the graphite piece

2.3.5 Assembly Process

Figure 16 shows a possible assembly process where the contractor can use others based on his experience. The contractor shall in any case ensure compliance with the specifications described in Section 2.2.

The proposed assembly protocol is detailed below:

- It starts with a commercial vacuum feedthrough with two welded stainless steel cooling channels (A).
- The following actuator components are then assembled: Instrument support flange, Bellows and Rectangular flange (B).
- The next step is the welding of a new section of the cooling circuit (C). This section has the radii of curvature required to adapt the cooling circuit to the instrument.
- Next, the slit is assembled with the shaft to the rest of the already installed parts (D). To do this, the bushing of the instrument support flange will be spaced far enough to reach the inside, where the axle fastening screws are located. Once the shaft has been screwed from the inside, the bushing will be returned to its initial position, placing the cooling tubes in their final position.
- Finally, once the shaft is assembled and correctly aligned, the cooling tube is welded to the instrument.

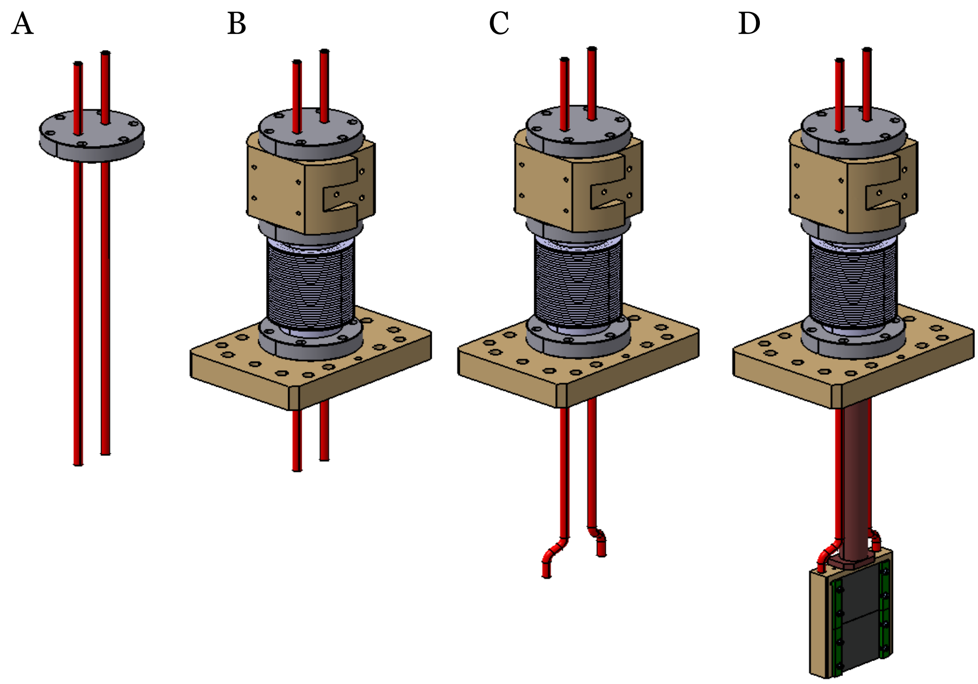


Figure 16 Procedure to mount the cooling system of the Slit

The contractor shall include at the ends of the refrigeration circuit: a flexible tubing with a 6 mm fitting in one side, which will be connected tot the cooling pipe; and a adaptor to a 6 mm pipe on the other side, which will be connected to a freethrought in the actuator. The cooling freethroughts should have a 6 mm tube fitting in one side and a female tapered cylindrical **BSP** connector in the other side. A cooper gasket should be use; Teflon, plastic tubes and quick connectors are not allowd. A recommended supplier for each component is shwon in Table 10.

2.3.6 Cabling & Piping

A general view of the cabling is shown in Figure 17. The limit switches cables are represented in yellow and are placed into the cables protector from the limit switches position (D) to the patch panel (C). The motor and brakes cables are represented in green and are placed from the motor position (A) to the patch panel (C). Finally, the encoder cable is represented in orange and is placed into the cables protector from the encoder position (B) to the patch panel (C).

The patch panel should be configured as indicated in Figure 18. A Souriau type connector should be used for the motor and brake connections (A). For the rest of the elements two DB9 connectors need to be used, one for the travel limit switches (B) and the other one for the encoder (D), and finally a LEMO connector (C) should be used for the MPS Limit Switch. A connection should be placed on top and bottom sides of the patch panel (E) to fix the cables and cables protectors.

The contractor should be responsible of all the cabling and connectors based on the previous indications.The contractor shall ensure that any possible leak of the refrigeration circuit will not affect the electric signals of the product inducing any short-circuit or detrimental effect.

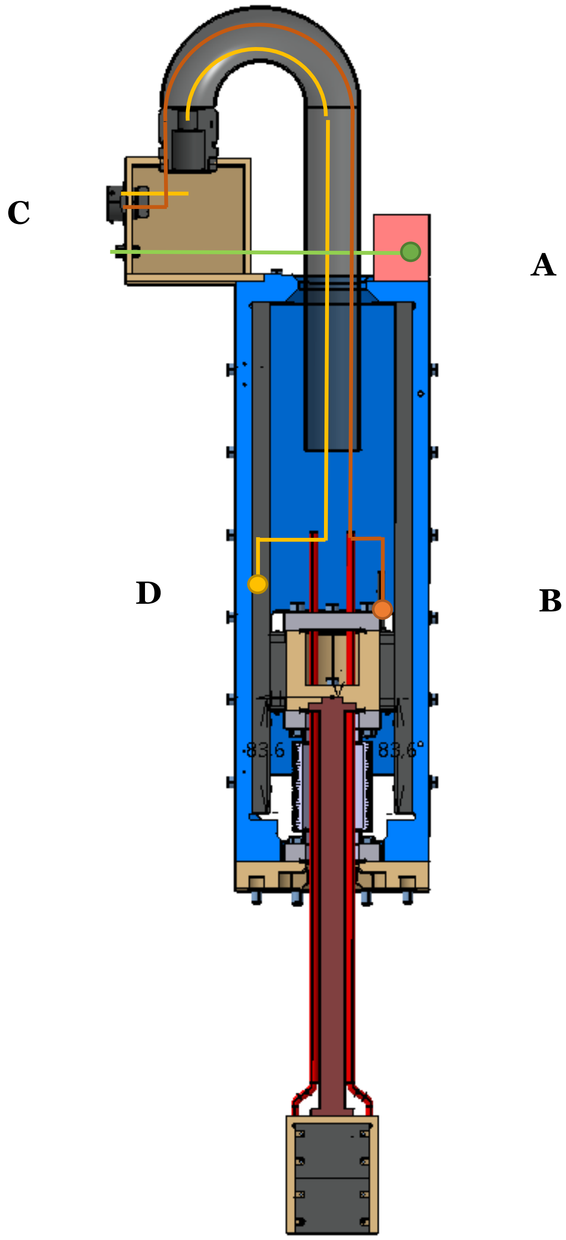


Figure 17 Cabling path general

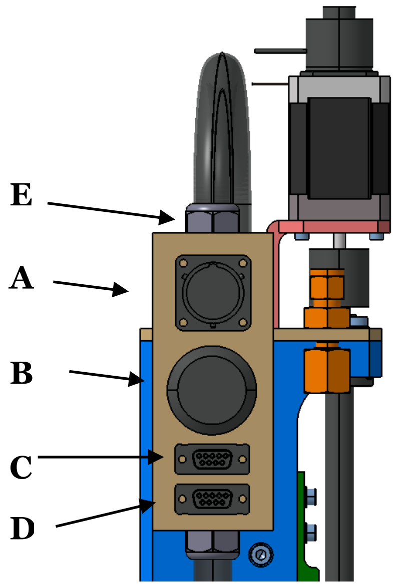


Figure 18 Patch panel connectors configuration

2.4 Description of the Grid subsystem

A picture of the whole system is shown in Figure 19. The main components of the subsystem are the Grid arm and the Actuator.

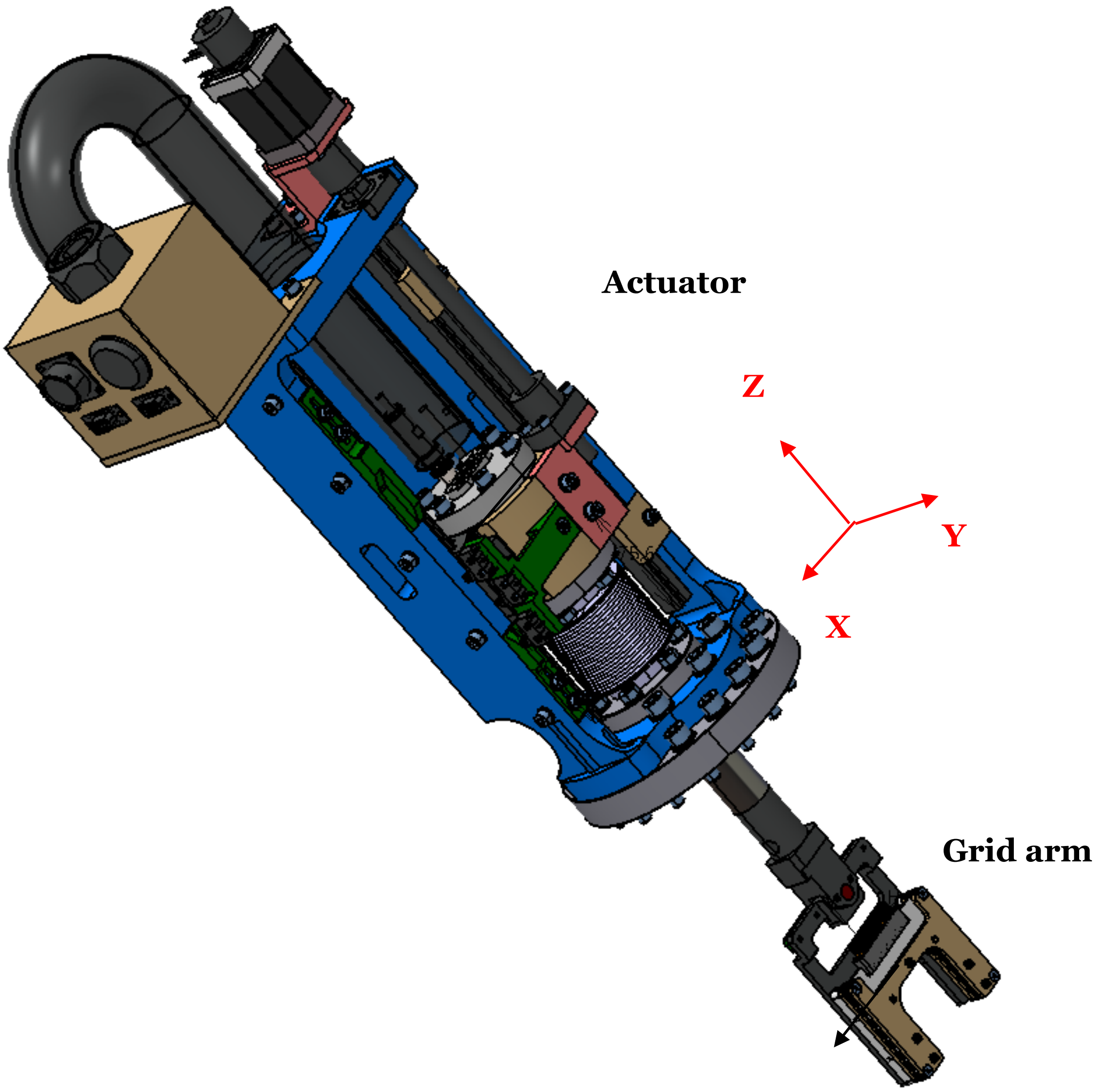


Figure 19 Actuator and Grid arm mechanical design

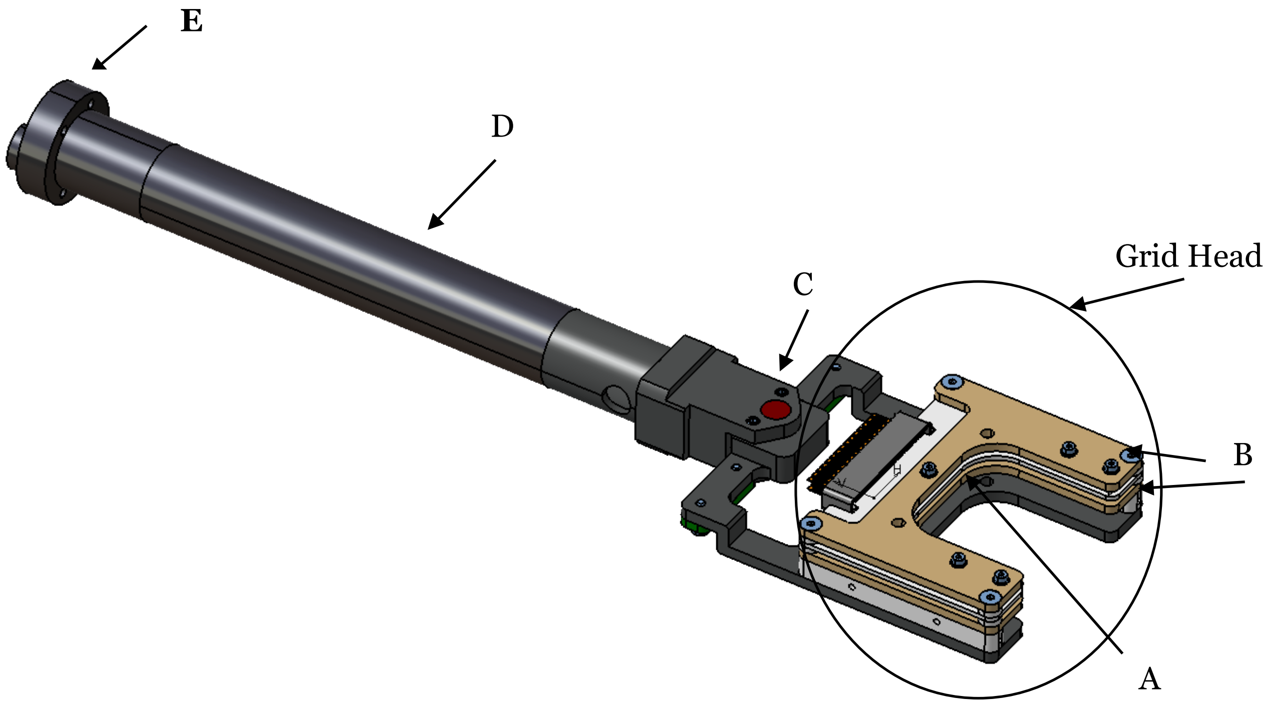


Figure 20 Grid arm Mechanical design

2.4.1 Grid arm

The Grid arm is composed by the shaft that holds the Grid Head and the Grid Head itself. A picture of this part is shown in Figure 20. The main components of the Grid are are:

A) Grid PCB
B) Bias plates
C) Grid Alignment system
D) Shaft
E) Shaft Holding Piece

2.4.1.1 Grid Head

The Grid Head (Figure 21Figure) holds the Grid PCB (A), whose tungsten wires will be in contact with the ion beam to make the measurement The Grid PCB will be provided by ESS-Bilbao and is *excluded* from this contract. The Grid PCB is shown only for orientation and understanding of the requirements.

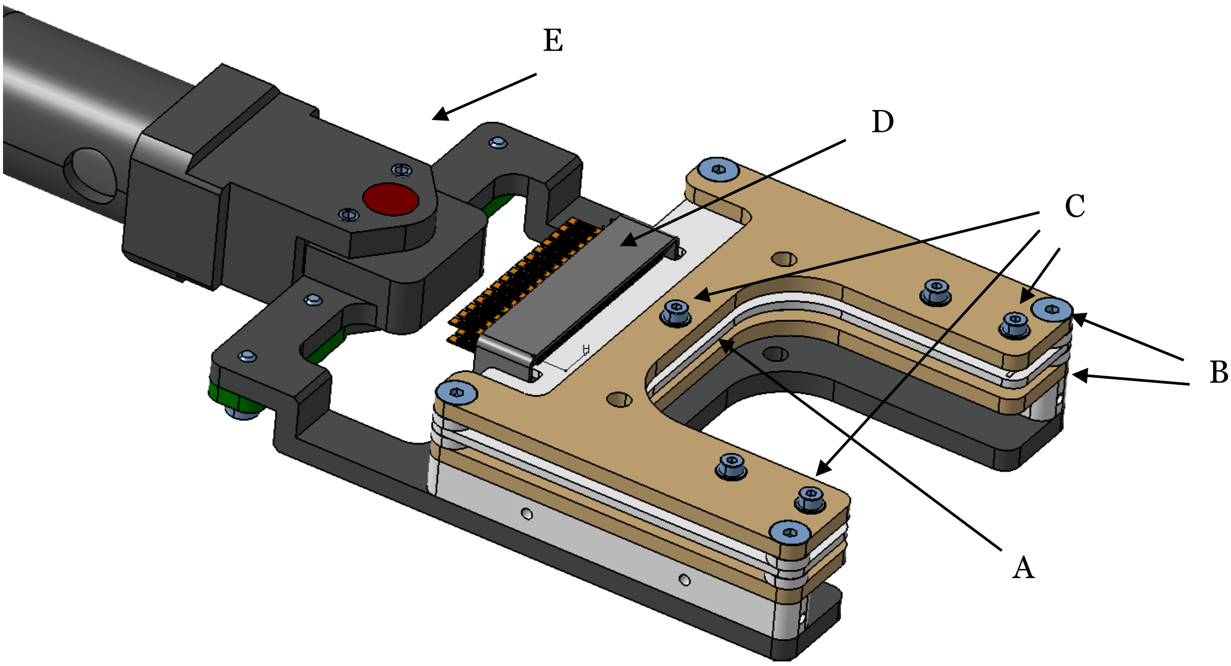


Figure 21 Mechanical design of the Grid Head.

The PCB is surrounded by two plates (B) that will provide a bias voltage to the system. The plates should stand a voltage between -1000 V and 1000 V. The 3 screws in those two plates (C) will allow to wrap tungsten wire around them to enhance the electric field created by the plates. The Signal Connector (D) is part of the Wire PCB. The Grid Wires Head is attached to the shaft with the Alignment System (E).

2.4.1.2 Grid Head mounting

A detailed view of the Alignment System is shown in Figure 22. The whole Grid Head could be rotated with this system to compensate possible misalignment due to errors in the manufactuing or the assembly process. The rotation axis is given by a precision pin (A) and the alignment is driven by a screw (B). When the screw (B) is rotated clockwise the guide (C) is displaced to the up direction, rotating the fork also clockwise with a rotation axis given by the precision pin (A).

A detailed view of the shaft is shown in Figure 23.The shaft should be welded to the alignment system in one side and to the holding piece in the other side. The weld should guarantee the that the errors described in Section 2.2 are fullfiled.

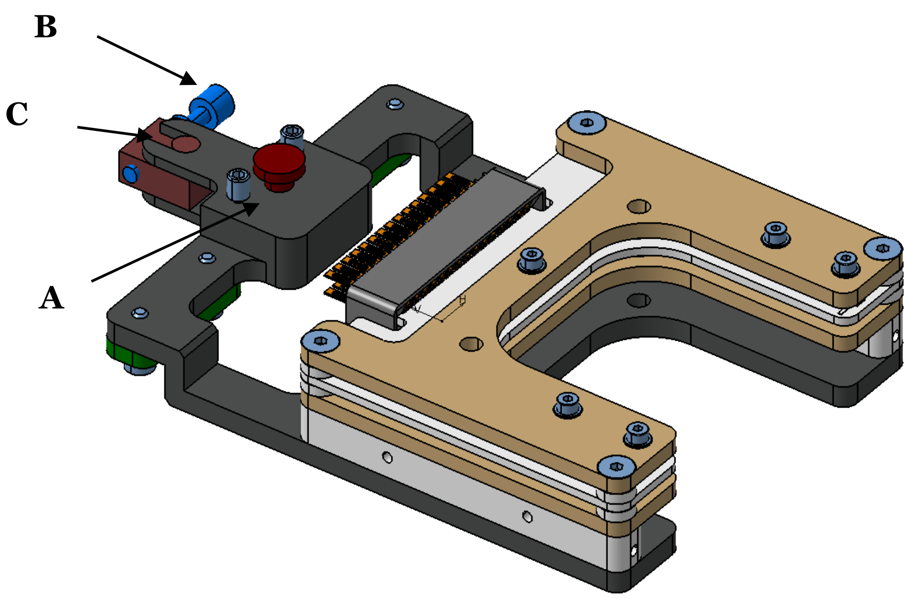


Figure 22 Alignment System without the shaft.

A detailed view of the holding piece is shown in Figure 24. This piece has a pattern (A) with four screws to fix the Grid to the actuator. These four holes should be threaded. A circular shape (B) is also machined in this piece to have only one possible position of fixation.

Figure 23 Shaft mechanical design

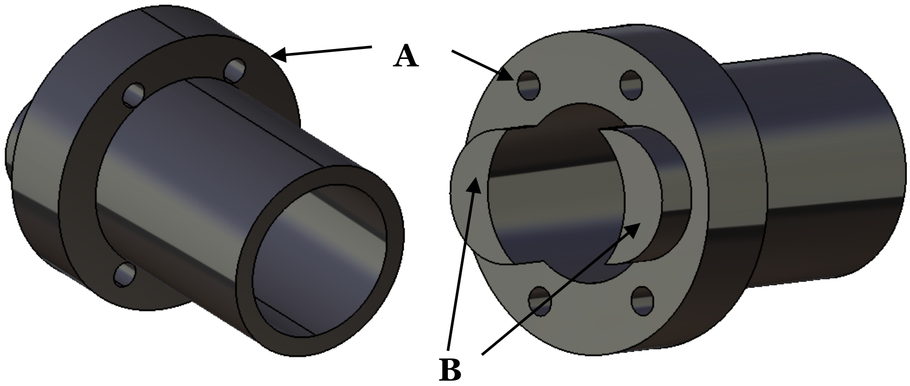


Figure 23 Shaft Holding Piece mechanical design

2.4.2 Actuator of the Grid subsystem

A picture of the Actuator is shown in Figure 25. The main components of the Actuator are:

A) Circular Flange
B) Bellow
C) Guides Support
D) Shaft Support
E) Spindle Support
F) Vacuum Feedthrough
G) Linear Guides
H) Spindle
I) Travel Limit Switches
J) MPS Limit Switch
K) Limit Switches support
L) Limit Switch triggers
M) Motor
N) Break
O) Linear Encoder
P) Patch Panel
Q) Cables protections
R) Mechanical Limits

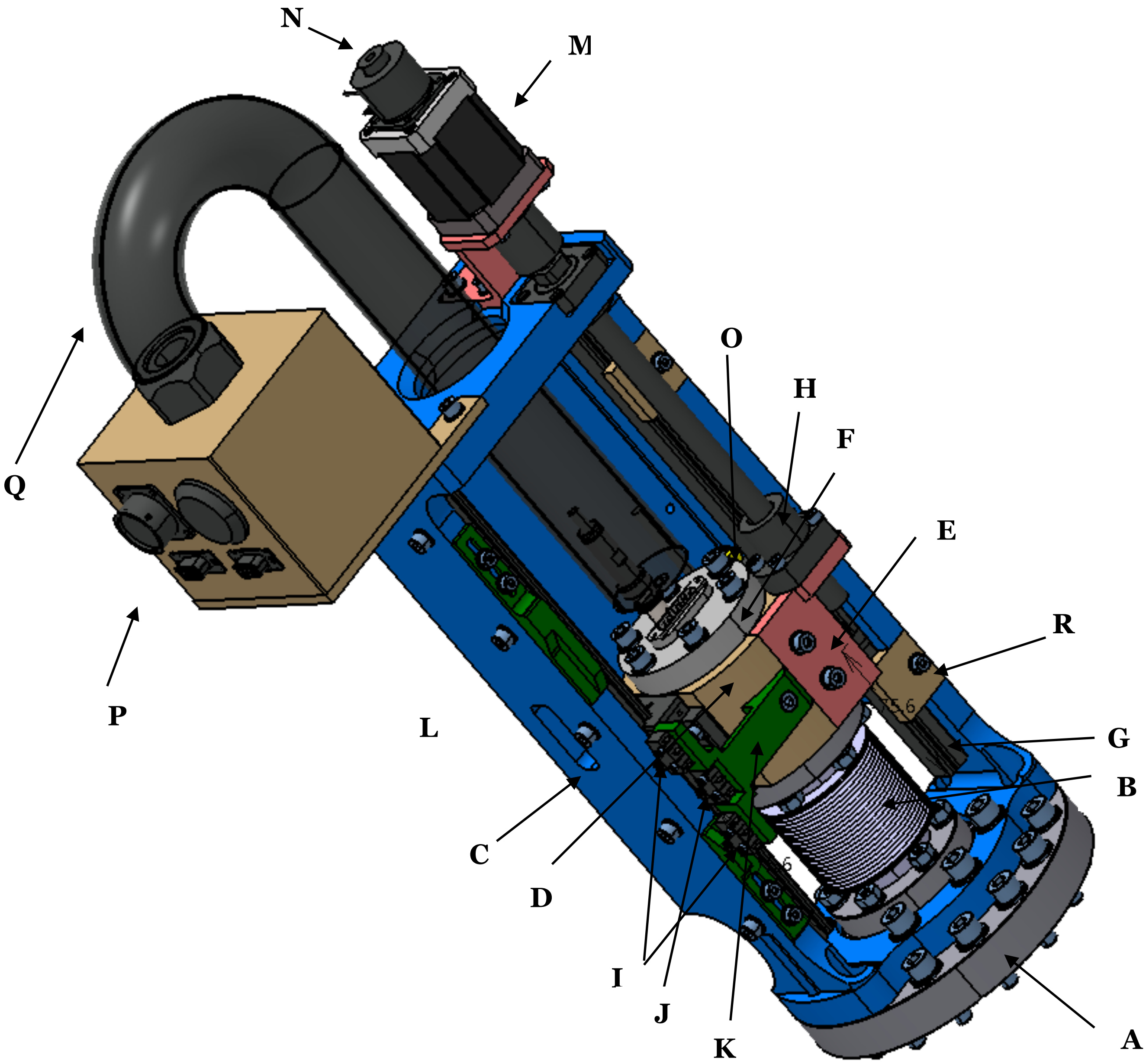


Figure 24 Actuator mechanical design

The actuator should have a **total axial stroke of 80 mm**. Two limit switches should be placed in the travel limits to indicate the reaching to the final or initial position (I). An additional limit switch (J) should be placed in the beginning of the travel to have an indication of the wire scanner insertion. This last limit switch will be used by Machine

Protection System purposes. The limit switches position and functionality is described in Appendix IV. A pair of mechanical limits (R) should be used to protect the integrity of the instrument in case of a failure of the travel limit switches. The bellow (B) is fixed between the rectangular flange (A) and the shaft support (D). The movement of the shaft support is driven by two linear guides (G) placed one in front of the other.

A detailed view of the Guide Support is shown in Figure 26. The objective of this piece is to support the linear guides with rigidity and precision. To assure the proper assembly of the linear guides a surface (A) should be grinding during the fabrication to have a good mechanical precision reference to be used during the linear guides assembly.

A detailed view of the shaft support is shown in Figure 27. On both sides of the piece a pattern of four holes (A) should be mechanized to fix this piece to the linear guides. In the front side of the piece two patterns of one (B) and two (C) holes should be mechanized to fix the Limit Switches Support and the Spindle Support respectively. On the rear side, a

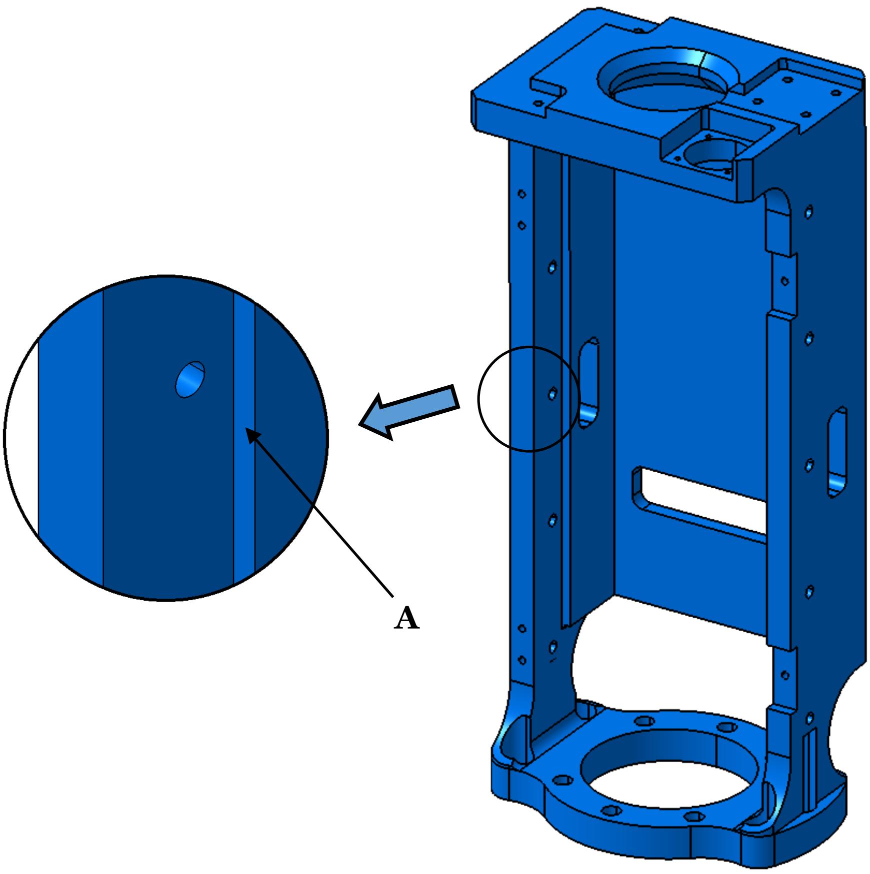


Figure 25 Guides Support mechanical design

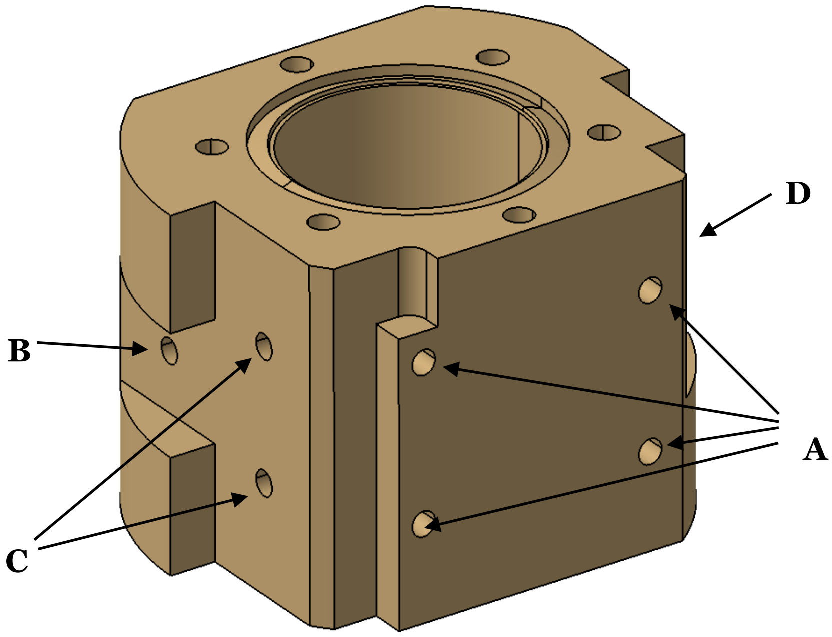


Figure 26 :Shaft Support mechanical design

mechanization should be done to place the encoder in position (D). Finally, on the top and bottom faces a **CF40 vacuum knife** should be machined to close vacuum between Shaft Support and Bellow in one side and between Shaft Support and Vacuum Feedthrough on the other side. The dimension of the CF40 vacuum knife should be checked with the standard[3], the dimensions including in the 3D model are a guidance.

2.4.3 Cabling

The cabling path between the Grid Head connectors to the patch panel passing through the vacuum feedthrough is described in this section All the commercial elements related to the cabling already selected are listed in Table 10.

Figure 28 shows in red the proposal of the Grid Head cabling path. The cables; 24 signal cable coming from the grid connector (A) and the bias voltage cable, should be inserted through the holes (B) into the shaft and connected to the vacuum feedthrough on the other side. The bias voltage cable should allow to apply 1 kV voltage to the bias plates, therefore, it should be appropriate for high voltage. The vacuum feddthrough should have a conector for the 24 signal cables and a SHV connector for the bias voltage cable.

[3] ISO/TS 3669-2:2007(E)

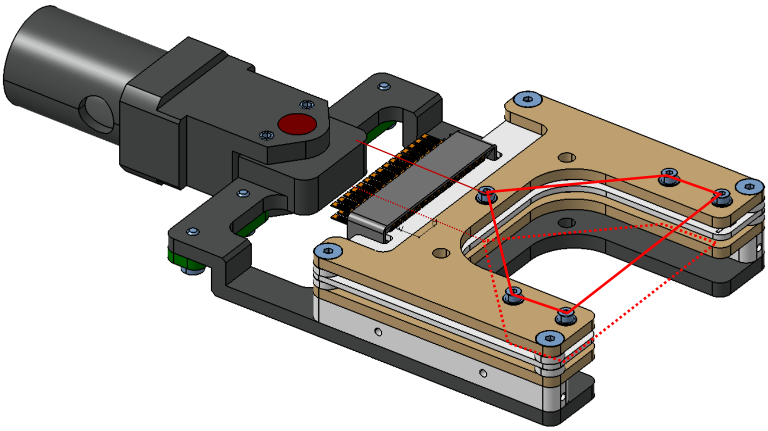


Figure 27 Grid Head cabling path.

A general view of the cabling is shown in Figure 29 The wires signal cables are represented in red and are connected from the Grid connectors to the vacuum feedthrough (A) into the vacuum side and from the vacuum feedthrough (A) to the acquisition box (B) into the air side (the acquisiton box is not part of this process). The signal cables are placed through the patch panel (C) without any connection at this point. A total number of 24 channels are needed, one for each pin. The signal cables should be **suitable to carry 100 µA current**. The bias voltage cable follows the same path as the signal cable.

The limit switches cables are represented in yellow and are placed into the cables protector from the limit switches position (D) to the patch panel (C). The motor and brakes cables are represented in green and are placed from the motor position (E) to the patch panel (C).Finally, the encoder cable is represented in orange and is placed into the cables protector from the encoder position (F) to the patch panel (C).

The patch panel should be configured as indicated in Figure . A Souriau type connector should be used for the motor and brake connections (A). For the rest of the elements two DB9 connectors need to be used, one for the travel limit switches (B) and the other one for the encoder (D), and finally a LEMO connector (C) should be used for the MPS Limit Switch. A connection should be placed on top and bottom sides of the patch panel (E) to fix the cables and cables protectors.

The contractor should be responsible of all the cabling and connectors based on the previous indications[4].

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[4] As specified by the ESS-0064007 [4] and ESS-0034035 [5] documents.

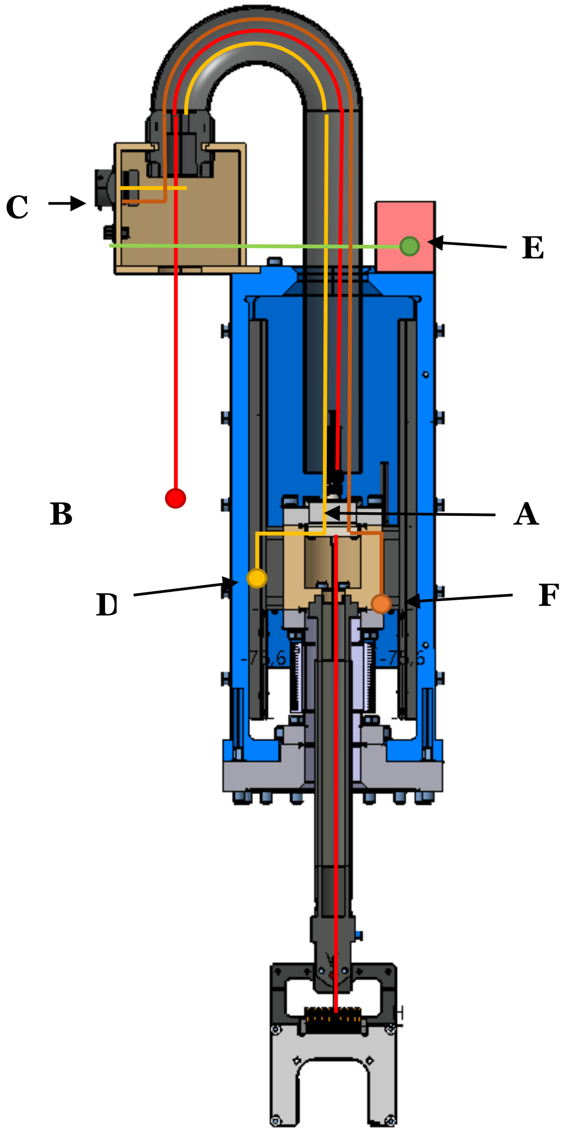

Figure 29 Cabling path general

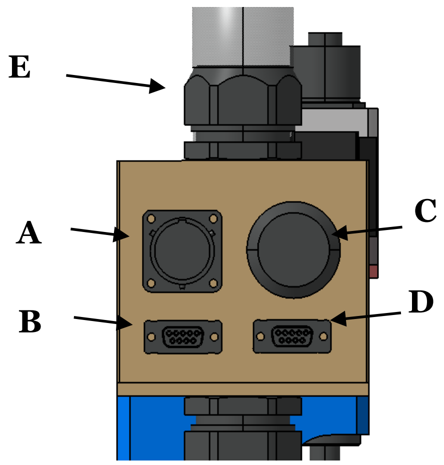

Figure 29 Patch panel connectors configuration

2.5 Components to be supplied by ESS-Bilbao

ESS-Bilbao shall supply a collection of 3D files of all the pieces of the Slit (Table 4), Slit Actuator (Table 5), Grid (Table 6) and the Grid actuator (Table 7).

Table 4 Slit 3D files

3D file	Descripción	Material	Units
MEBT- SL -1000-ESS	Slit + Actuator.		
MEBT- SL -1100-ESS	Slit.		
MEBT- SL -1101-ESS	Slit substrate (cooling plate)	Stainless steel	1
MEBT- SL -1102-ESS	Shaft.	Stainless steel	1
MEBT- SL -1103-ESS	Graphite plate	Graphite	2
MEBT- SL -1104-ESS	Crimpador	Stainless steel	4

Table 5 Slit actuator 3D files

3D file	Description	Material	Units
MEBT-SL-1200-ESS	Slit assambly		
MEBT- SL -1201-ESS	Guide support	TBD	1
MEBT- SL -1202-ESS	Rectangular flange	Stainless Steel	1
MEBT- SL -1203-ESS	Shaft Support.	Stainless Steel	1
MEBT- SL -1204-ESS	Spindle Support.	Stainless Steel	1
MEBT- SL -1205-ESS	Limit Switches Support	Aluminium	1
MEBT- SL -1206-ESS	Limit Switch trigger 1	Aluminium	1
MEBT- SL -1207-ESS	Limit Switch trigger 2	Aluminium	1
MEBT- SL -1208-ESS	Encoder Support	Aluminium	1
MEBT- SL -1209-ESS	Motor Support	Aluminium	1
MEBT- SL -1210-ESS	Patch panel box	Aluminium	1
MEBT- SL -1211-ESS	Connection box	Aluminium	1

MEBT- SL -1212-ESS	Pneumatic cooling support	Aluminium	1
MEBT- SL -1213-ESS	Mechanical Limit	Aluminium	2

Table 6 Grid 3D files

3D file	Description	Material	Units
MEBT- GR -1000-ESS	Grid + Actuator.		
MEBT- GR -1100-ESS	Grid assambly		
MEBT- GR -1101-ESS	Fork	Stainless Steel	1
MEBT- GR -1102-ESS	Fork alignment	Stainless Steel	1
MEBT- GR -1103-ESS	Shaft	Stainless Steel	1
MEBT- GR -1104-ESS	Shaft holding piece	Stainless Steel	1
MEBT- GR -1105-ESS	Fork alignment screw	Stainless Steel	1
MEBT- GR -1106-ESS	Precision alignment pin	Stainless Steel	1
MEBT- GR -1107-ESS	Alignment guide	Stainless Steel	1
MEBT- GR -1108-ESS	Bias plate 1	Aluminium	1
MEBT- GR -1109-ESS	Bias plate 2	Aluminium	1
MEBT- GR -1110-ESS	Insulating washer	Macor	8
MEBT- GR -1111-ESS	Insulator	Macor	2
MEBT- GR -1112-ESS	Cable flange	Aluminium	2

Table 7 Grid actuator 3D files

3D file	**Description**	**Material**	**Units**
MEBT-GR-1200-ESS	Grid actuator assambly		
MEBT- GR -1201-ESS	Guides Support	TBD	1
MEBT- GR -1202-ESS	Rectangular flange	Stainless Steel	1
MEBT- GR -1203-ESS	Shaft support	Stainless Steel	1
MEBT- GR -1204-ESS	Spindle Support	Stainless Steel	1

MEBT- GR -1205-ESS	Limit Switches Support	Aluminium	1
MEBT- GR -1206-ESS	Limit Switch trigger 1	Aluminium	1
MEBT- GR -1207-ESS	Limit Switch trigger 2	Aluminium	1
MEBT- GR -1208-ESS	Encoder Support	Aluminium	1
MEBT- GR -1209-ESS	Motor Support	Aluminium	1
MEBT- GR -1210-ESS	Patch panel box	Aluminium	1
MEBT- GR -1211-ESS	Patch panel box support	Aluminium	1
MEBT- GR -1212-ESS	Mechanical Limit	Aluminium	2

2.6 Blueprints

The contractor will be responsible of elaborate all the blueprints of every piece of the Emittance Meter Unit and Actuator designs. The contractor will be also responsible of the choosing of all the tolerances to assure the requirements described on section 2.2. The blueprints should be checked and approved by ESS-Bilbao prior to the manufacturing.

2.7 Materials

The Contractor must purchase all the materials for the fabrication of all the components of the two Slit Subsystems and two Grid Subsystems, including the materials required in Table 4, Table 5, Table 6 and Table 7. With the exception of the grid that will be provided by ESS-Bilbao. The materials must be verified according to internationally recognized standards (AISI).

The graphite plate requirements for the Slit Head are described in Section 2.3.3.

The following materials are specifically prohibited for in-vacuum components[5]:

- Brass
- Standard Hard Solder
- Soft Solder
- Electrical Solder
- All Plastics

5 As specified by the ESS Vacuum Handbook Part 1.

- ASTM type 303
- Free cutting stainless steel
- All Glues, Greases
- Silicon or sulphur based machining lubricants when machining any components (only water-soluble machining lubricants are permitted)
- Any material containing: Zinc, Cadmium, Phosphorus, Sodium, Selenium, Potassium or Magnesium
- GE Varnish, Anodized surfaces or any mechanically polished components

2.8 Manufacturing

The Contractor must propose in a conceptual way the manufacturing process to follow to ensure the compliance with the specifications described on section 2.2

For the under vacuum components (see Table 8), the manufacturing method must be compatible with $10e^{-7}$ mbar vacuum applications[6]. To ease preparation for vacuum cleaning, the machining liquids must be free of silicones and halogens to avoid contamination of the material. The contractor must propose the type of cutting oil to be used and the characteristics of it, to ensure that the material is not contaminated.

The surfaces must be milled or turned. No surface of any of the vacuum component shall be terminated any type of mechanical abrasion.

Table 8: Elements under vacuum.

3D File Name	Description
MEBT-SL-1100-ESS	Slit Assembly.
MEBT-SL-1202-ESS	Slit Rectangular Flange.
MEBT-SL-1203-ESS	Slit Shaft Support (Inner faces).
MEBT-GR-1100-ESS	Grid Assembly.
MEBT-GR-1202-ESS	Grid Rectangular Flange.
MEBT-GR-1203-ESS	Grid Shaft Support (Inner faces).

6 As specified by the ESS Vacuum Handbook Part 3 [6].

2.9 Mechanical connections in vacuum

All element for the mechanical connection (screws, ...) must be of silver metal and they must be specially suited for this application. The mechanical connections must be done avoiding the possible air traps.

2.10 Welded joints

The welds will be executed by professional welders, certified according to ISO standards for steel. Vacuum welds shall be made by the TIG method. The use of other welding processes will be notified to ESS-Bilbao for approval.

The standards that apply to welding procedures are:

- ISO 9606-1: 1994 Approval testing of welders — Part 1: Steels
- ISO 15614-1: 2004 Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys
- ISO 5817: 2005 Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections

As a reference, the contractor can consult the document "ESS Vacuum Handbook Part 3 - ESS Vacuum Design & Fabrication."

2.11 Cleaning

Prior to delivery to ESS-Bilbao, all the components must be cleaned in order to be ready for the assembly. All the surface of the pieces to be placed under vacuum listed in Table 8 should be provided free of contamination, grease, or other substances no ultra high vacuum compliance[7].

The Contractor shall establish and deliver together with the tender a detailed cleaning procedure appropriate to its manufacturing facilities. The procedure, including the properties of the cleaning products selected, will be submitted to ESS Bilbao for approval.

[7] As specified by the ESS Vacuum Handbook Part 3.

2.11.1 Storage, packaging and shipping

The contractor is responsible for storage, packaging and transportation to the ESS-Bilbao facilities all the components listed in Table 4, Table 5, Table 6 and Table 7. The Contractor shall ensure that the equipment is stored in an area where the condition of the components is not altered[8].

The Contractor shall propose a packaging system to send the manufactured parts to the ESS Bilbao facilities. The packaging must protect all the components against any types of hazards that may occur during transportation.

3 Verifications and tests

3.1 Verifications to be done by the contractor

ESS-Bilbao reserves the right to be present, or be represented by an external organization of its choice, to follow all the tests carried out by the contractor or one of its subcontractors. The Contractor must notify at least 10 business days prior to the proposed date of any of such test.

The Contractor shall supply all tools, equipment and personnel necessary to perform all the tests required to ensure compliance with the specifications.

Verifications to be carried out by the contractor are specified in the following subsections.

3.1.1 Raw Material

The contractor shall include all the documentation of all the chosen material, including the mechanical properties as well as the chemical composition.

3.1.2 Metrology

The contractor shall deliver a **Manufacturing and Quality Assurance** report including all the measurements and test of the distance with tolerances under 0.1mm of all the pieces directly related to fulfilling the specifications commented in section 2.2.

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[8] As specified by the ESS Vacuum Handbook Part 3.

3.1.3 Hydraulic tests

The cooling circuit must be pressurized up to 16 bar to verify the absence of leaks and the correct assembly of the different components. After one hour, the pressure must be reduced by less than 2% compared to the initial pressure (0.3 bar). After testing, the channel should be emptied and dried properly with compressed air.

3.1.4 Leak Testing

Leak testing must be performed according to EN 1779 - A1 with a calibrated UHV leak detector connected to one of the CF vacuum ports, covered with a helium-filled plastic wrap for 10 minutes. The result should not give an overall leakage rate greater than 2.0 * 10^{-11} Pa * m^3 / s (2.0 * 10^{-10} mbar * l / sec) at room temperature[9]. The Contractor shall submit its proposed leak detection equipment and procedures for approval to ESS-Bilbao.

If before the leakage test the circuit has been subjected to tests of pressure with water, it will be necessary to realize a bake-out. Bake-out is necessary to remove water which will be frozen during the pump down and it could create a temporary barrier making the eventual leak undetectable. The test sequence should be: water pressure test, bake out (100 ° C for 12 hours), leak detection test.

3.1.5 Electric tests

The contractor should test that all cables are properly connected. The contractor shall assess that therefore the signal from the connector in the Wire PCB is correctly carried to the patch panel.

3.2 Verifications to be carried out by ESS-Bilbao

ESS-Bilbao reserves the right to repeat all the tests listed in section 3.1 accepting the specifications. These acceptance tests will be carried out within a maximum of one month from the delivery at the ESS-Bilbao facility.

The Contractor will be informed of any part that does not meet the requirements. In this case and at its cost, the Contractor may send an inspector to verify the findings of ESS-Bilbao.

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9 As specified by the ESS Vacuum Handbook Part 4 [7].

The parts that prove to be unsatisfactory will be returned to the contractor for the repair or replacement according to a written program of mutual agreement.

4 Delivery

4.1 Provisional Delivery Calendar

Table 9: Delivery Calendar

Milestone	Delivery Term
Contract Formalization	T0
Delivery of Blueprints	T1 = T0 + 1 month
Acceptance of Blueprints	T2 = T1 + 1 month
Manufacture and delivery of EMU-H and Verification Documents	T3 = T2 + 3 months
Acceptance of EMU-H	T4 = T3 + 1 month
Manufacture and delivery of EMU-V and Verification Doc.	T5 = T4 + 5 month
Acceptance of EMU-V	T6 = T5 + 1 months
Total Duration of the Project	12 Months

4.2 Acceptance and guarantee

Acceptance will be given by ESS-Bilbao only after all the articles have been delivered in accordance with the conditions of the documentation, all the specified tests have been successfully completed and the complete records of the metrology, tests and other certificates have been supplied to ESS-Bilbao. The Contractor shall supply to ESS-Bilbao the complete documentation within a maximum of **five working days** before each shipment of equipment manufactured for ESS-Bilbao.

5 Other conditions

Compliance with the business obligations established by the Law on the Prevention of Occupational Risks, as well as the regulations and regulations that may be applicable in your case vr. Gratia (Technical Building Code, RD 314/2006 of 17 March, RD 1836/1999 Regulation on nuclear and radioactive facilities, RD 783/2001 Regulation on health protection against ionizing radiations, Regulations on Workplaces, etc.). The process of development of the work or activity, object of the specifications, shall be considered as many measures as are necessary to comply with the Green Public Contracting Plan of the General Administration of the State and its Public Agencies and the Social, Order PRE / 116/2008, of 21 January.

5.1 Follow-up of work in progress

The Contractor shall assign a responsible person for the technical execution of the contract and its monitoring. A one-page written report detailing the progress of the production situation will be sent to ESS Bilbao every two weeks until the end of the contract.

5.2 General Directives

The contractor will follow the following EU directives in the manufacturing of the product:

- 2006/42/EC Machinery's essential health and safety requirements
- 2014/35/EU Low Voltage Directive
- 2014/30/EU EMC emission and immunity
- 2014/68/UE Pressure Equipment
- 2011/65/EU RoHS Restriction of Hazardous Substances in Electrical and Electronic

6 Technical Documentation

The Technical documentation for the tendering offer will be presented in the form required in the Specific Administrative Clauses and signed by the legal representative of the company.

In the technical documentation envelope, in addition to the two copies requested, a copy of this documentation in electronic format will be included. The inclusion of such support does not exempt from the delivery of documentation as required by the Specific Administrative Clauses.

7 Contact

Name	Telephone	E-mail
Zunbeltz Izaola	+34 94 607 68 51	Zunbeltz.izaola@essbilbao.org
Ibon Bustinduy	+34 94 607 68 51	ibustinduy@essbilbao.org

8 Appendix I: Commercial components recommended

All references in this specification or in its appendixes to specific brands, goods or technical specifications must be understood in the sense of art. 117.4 of the Consolidated Text of the Public Sector Contract Law (art. 117.4 del Texto Refundido de la Ley de Contratos del Sector Público), so that the tenderer may propose others, provided that he proves by any suitable means that the solutions he proposes fulfill in an equivalent way the requirements defined in the corresponding technical prescriptions. For this purpose, a technical report by the manufacturer or a test report prepared by an officially recognized technical organization may constitute an appropriate means of proof.

Table 10: Commercial components recommended in 3D design

Name	Supplier	Item Reference	Units per system
Linear Guides	NSK	N1S15	2
Skids	NSK	NAS15EMZ	2
Encoder	SIKO	MSK 1000	1
Encoder Connector	--	DB9 Type	1
Limit Switches	OMRON	SS-01GL2-E	3
Limit Switches Connector	--	DB9 Type	1

MPS Limit Switch Connector	LEMO	EGG.4K.312.CYM	1
Spindle	NSK	VSP1205N1D0500PP	1
Spindle support	NSK	WBK08-11	1
Stepper Motor	NANOTEC	ST4118D3004	1
Motor Connector	SOURIAU	Based on motor spec.	1
Break	NANOTEC	BKE-0.4-5.0	1
Bellow	VACOM	*Custom-made*	1
Feedthrough	ALLECTRA	*Custom-made*	1
Cooling Hoses	SWAGELOCK		
Cooling Feedthrough	SWAGELOCK		

9 Appendix II: Motor axis torque calculations

All the calculation of torque has been done considering the actuator in vertical position as the worst-case scenario.

The torque calculation could be divided in two main components: the torque due to inertias during acceleration and the torque due to static forces. In this case, due to a low value of velocity and acceleration, the torque due to static forces will be the dominant factor of the equation so the calculation will be done without the consideration of inertias.

There are two static forces to be considered: the weight of the load and the atmospheric pressure over the vacuum flange. In the worst case, when the motor is pulling the load, the total force applied is the summation of the two.

Considering a total weight of the instrument to move inside the vacuum vessel of $m_L = 4Kg$ the force due to this mass could be calculated as:

$F_L = m_L \cdot g = 39.2N$

The force produce by the atmospheric pressure over the flange could be calculated as $F_P = \Delta P \cdot EA$, where ΔP is the pressure difference between the vacuum and atmospheric pressure (in N/m2 units) and EA is the Effective Area of the selected bellow (m2), in this case a CF40 Bellow.

Considering a pressure difference of $101325 \, {}^{N}\!/_{m^2}$ and an effective area of the bellow of $0.00273m^2$ the force due to the atmospheric pressure over the vacuum flange is:

$F_P = \Delta P \cdot EA = 276N$

The total contribution of static forces is:

$F_T = F_L + F_P = 315.82N$

Considering a pitch of the spindle of $p = 5\, {}^{mm}/_{rev}$ the total torque applied by the motor is:

$T_T = F_T \cdot \frac{p}{2\pi} = 0.251Nm$

With this value of torque a commercial motor and a commercial break from NANOTEC have been selected. The reference of this motor and break can be consulting in Table 10.

The evolution of the torque applied by the motor with respect to the velocity of the instruments is shown in Figure 30.

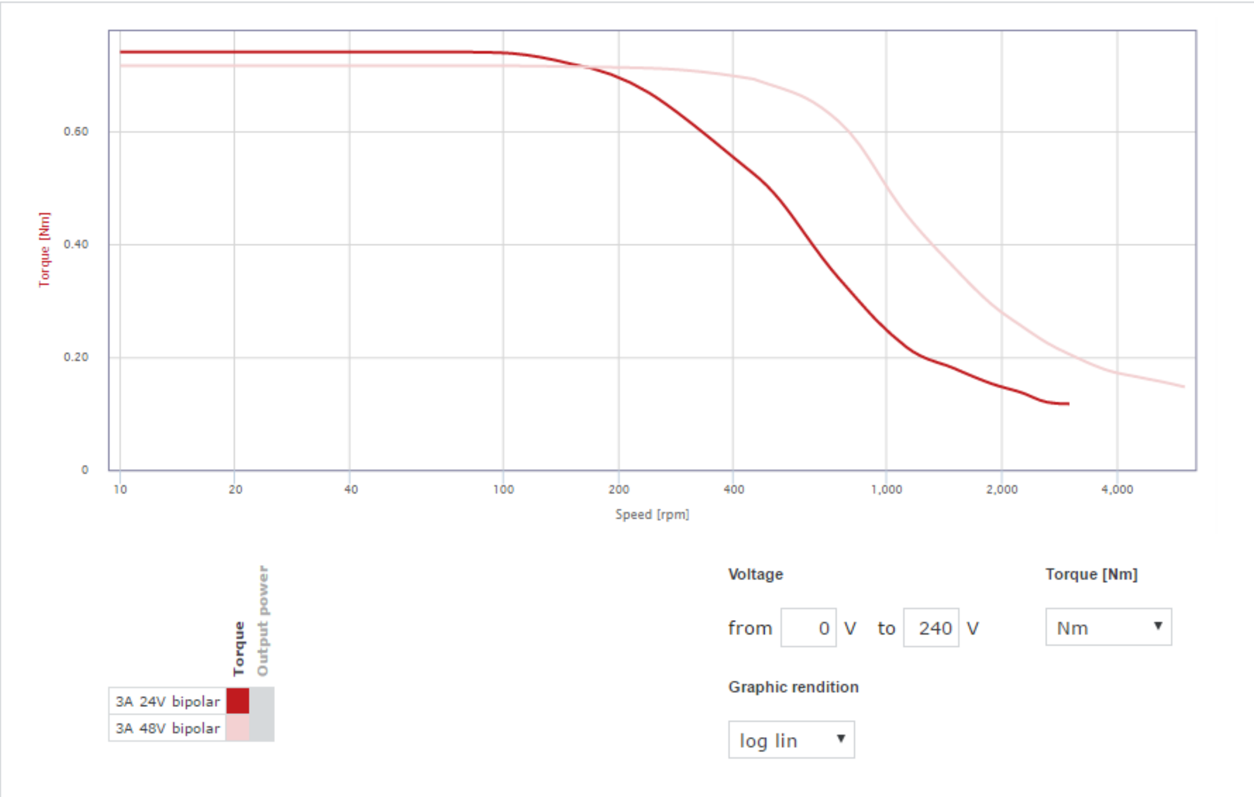

Figure 30: Torque/Velocity curves of motor ST4118D3004

Considering a spindle pitch of $p = 5\, {}^{mm}/_{rev}$ and an instrument linear velocity of $10\, {}^{mm}/_{s}$ the angular velocity of the motor axis is 120 rpm. This angular velocity is in the range of maximum torque of the curve.

The selected break has a holding torque of 0.4 Nm. Considering the calculated value of torque this value of holding torque is enough to maintain the instrument in position during a power failure.

10 Appendix III: Linear guides stiffness considerations

One of the most important parameters of the linear guides is the stiffness, the declination of the instrument with respect to the pitching moment applied to the linear guide.

A simplified calculation has been done to validate the using of this model of linear guide in the particular case of the Wire Scanner actuator. Therefore, a single linear guide has been considered in this calculation to move the instrument inside the vacuum vessel.

The momentum applied to the linear guide by the instrument could be calculated as:

$M = W \cdot D \cdot \sin\theta$

where W is the total weight of the instrument, D the distance between the clamping face and the centre of inertia of the instrument and θ the angle between the vector W and the axis of movement of the instrument.

Considering a total weigh of 3.4 kg, a distance between the clamping face and the centre of inertia of 150 mm and an angle of 45º the momentum applied is:

$M = 34 \cdot 0.15 \cdot \sin(45^{\circ}) = 3.6 Nm$

The Figure 31 shows a graphic with the declination of the instrument with respect to the pitching moment applied to a N1S15 Linear Guide. Using the momentum calculated previously the instrument will have a declination of $1.4 \cdot 10^{-4} rad$.

Considering a total distance of the instrument of 580 mm, the total displacement of the wire scanner tip will be:

$d = 580 \cdot tg(0.008) = 80 \mu m$

With the consideration of using only one linear guide a total displacement of the wire scanner tip of $80 \mu m$ will appear. This value will be reduced in the real model with two linear guides placed one in front of the other.

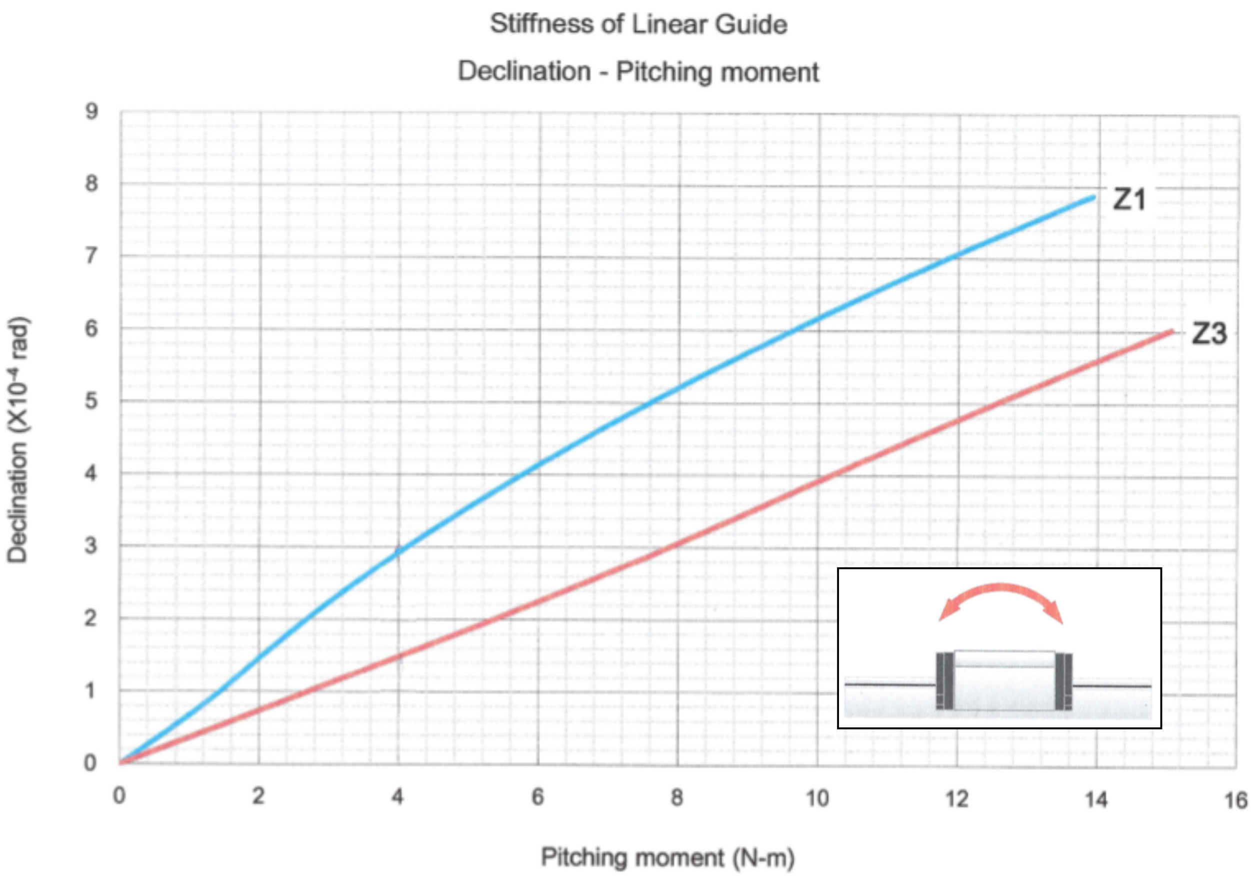

Figure 31: Stiffness of Linear Guide N1S15 from NSK

11 Appendix IV: Limit Switches functionality

The limit switches position and functionality of the actuator are shown in Figure 31. Two limit switches should be used to have a reference of the wire scanner travel between the initial point to the final point. The total distance between this two limit switches should be 240 mm, which is the distance between the parking position and the final scanning position of the instrument. These limit switches should be close in the initial or final position and remain open during the rest of the travel.

An additional limit switch should be added for Machine Protection System purposes. This limit switch should be placed as close as possible of the initial WS travel limit switch. The MPS switch should be close when the wire scanner is in parking position and should remain

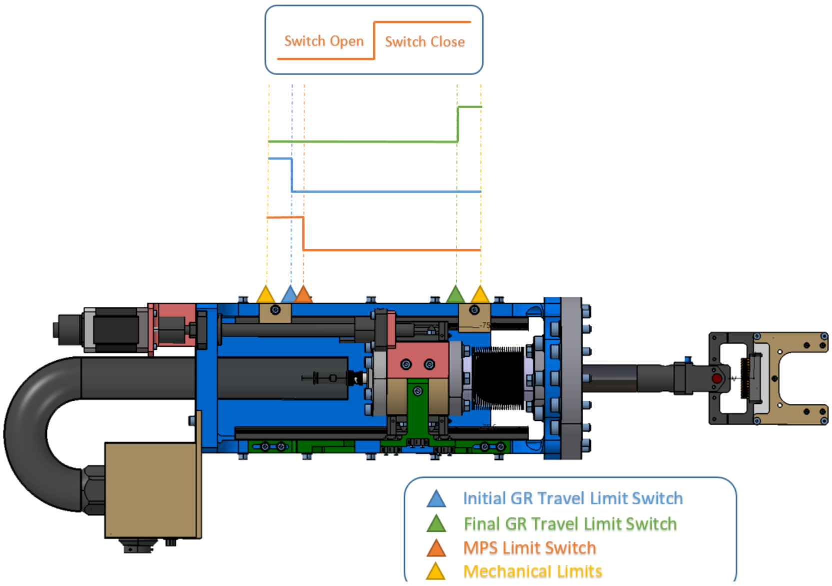

Figure 32: Switches position and functionality

open during the wire scanner travel.

Two mechanical limits should be placed to avoid collisions or bellow damages in case of a limit switch failure. The mechanical limits should be placed with a distance of 260 mm between each other and a distance of 10mm to the initial or final WS travel limit switches.

12 References

[1] B. Cheymol and R. R. Miyamoto, "Preliminary design of the ESS slit and grid system," 2005.

[2] A. R. Páramo, Z. Izaola, Á. Vizcaíno, F. Sordo and I. Bustinduy, "Thermo-Mechanical Analysis of the ESS MEBT EMU/Slit," 2017.

[3] A. R. Páramo, Á. Vizcaíno, Z. Izaola and I. Bustinduy, "Thermo-Mechanical Analysis of MEBT EMU/Grid," 2017.

[4] H. Spoelstra, "ESS cable specifications for the Vacuum System," 2016.

[5] D. Phan and E. Vaena, "AD requirements for the selection of electrical cables with respect to Fire Safety," 2016.

[6] G. Hulla, "ESS Vacuum Handbook: Part 3 - ESS Vacuum Design & Fabrication," 2014.

[7] G. Hulla, "ESS Vacuum Handbook: Part 4 - Vacuum Test Manual," 2016.