EU – China collaboration on CFETR and EU-DEMO Reactor Design
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EUROfusion

Remote Handling of EU DEMO breeding blanket pipes

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Contents

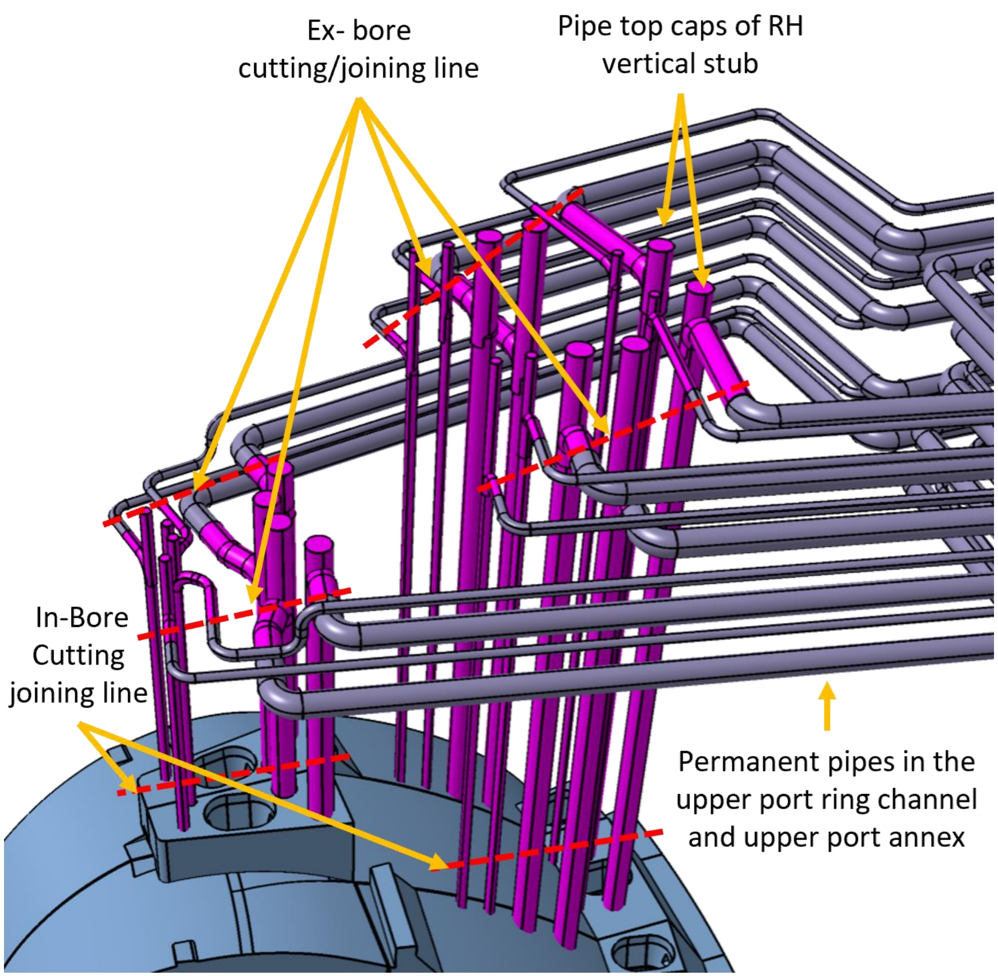
Main Assumptions as base of the pipes RH strategy

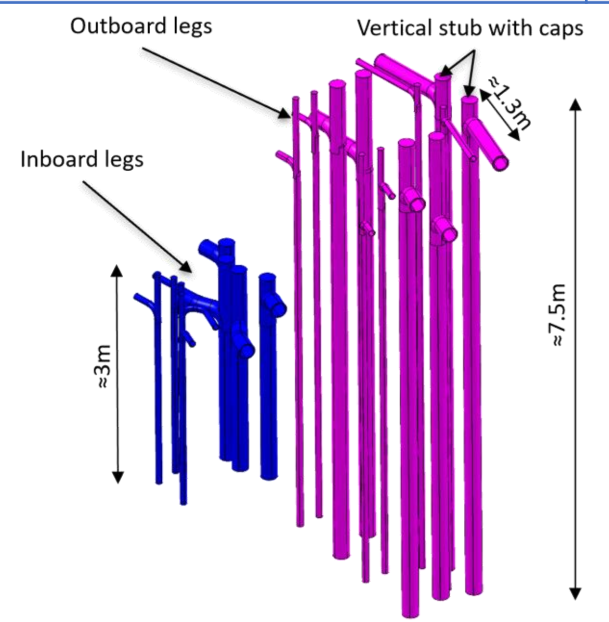
- The removal of the BB pipes is the bottleneck of the maintenance of the machine due to the number of components to be operated.
- The remote replacement of the BB pipes must be operated in a double sealed environment to prevent the spread of contamination into the building and due to the radioactivity caused by neutron irradiation; the *presence of radioactive dust*; the outgassing of the tritium.
- The BB pipes must be removed prior the BB segments (*it means about **400 - WCLL concept** and **316 - HCPB concept pipes** shall be disconnected, removed and then re-joined after the installation of the new BB segments*).
- The RH operations must be parallelized as much as possible to reduce the maintenance time and hence the impact on the plant availability.
- The pipe must be removed prior the removal of the upper port plug.
- The pipes to be removed are grouped in a pipes forest and manipulated as single component.
- Dry parting and beveling in one shot are assumed as reference technology for pipes cutting.
- *Tungsten Inert Gas* (TIG) welding is assumed as reference technology for pipes joining.
- As first attempt, it is currently assumed **the pipes remote handling (RH) is carried out simultaneously in 4 ports**, the remote handling ports, it means that a design of **toroidal in-vessel transporter for the BB segments is needed.**
- Strong reduction of the maintenance times since the **pipe forests in the not RH ports will remain in situ during the remote handling activities**.

Reference dimensions of the pipes:

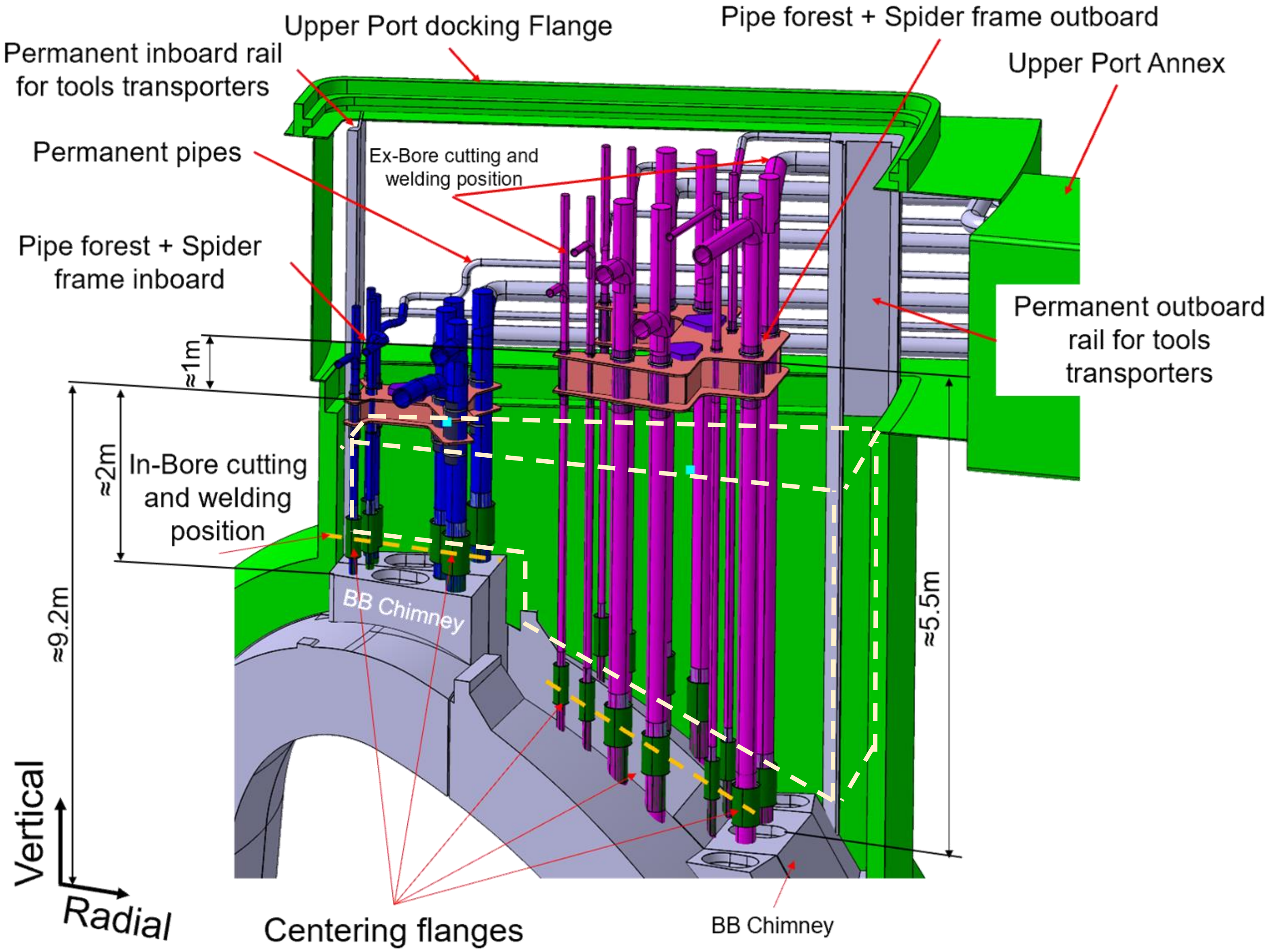
- 10 pipes **DN200** thickness **16 mm**
- 10 pipes **DN80** thickness **6mm**
- Material **AISI 316 L(N)**

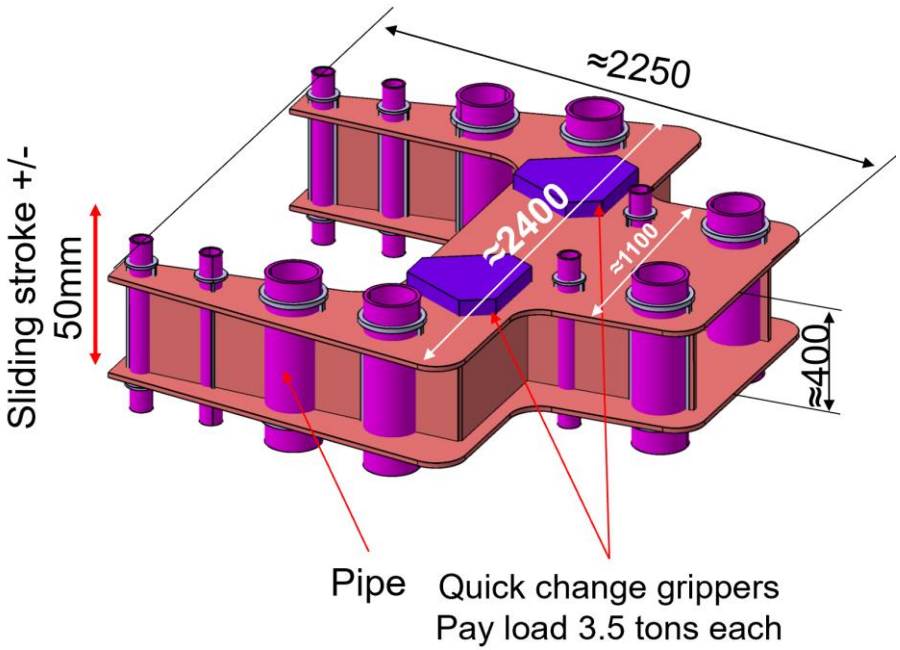
Outboard pipes						
Nominal Diameter	Thickness [mm]	Kg/m	Length [m]	Dead Weight	Qty	Total [Kg]
DN200	16	80	9	705	2	1410
DN200	16	80	8	641	4	2563
DN80	6	10	9	91	2	181
DN80	6	10	8	82	4	330
Total dead weight outboard pipe forest						**4484**
Inboard pipes						
DN200	16	80	4	296	2	593
DN200	16	80	3	240	4	961
DN80	6	10	4	38	2	76
DN80	6	10	3	31	4	124
Total dead weight Inboard Pipe forest						**1754**



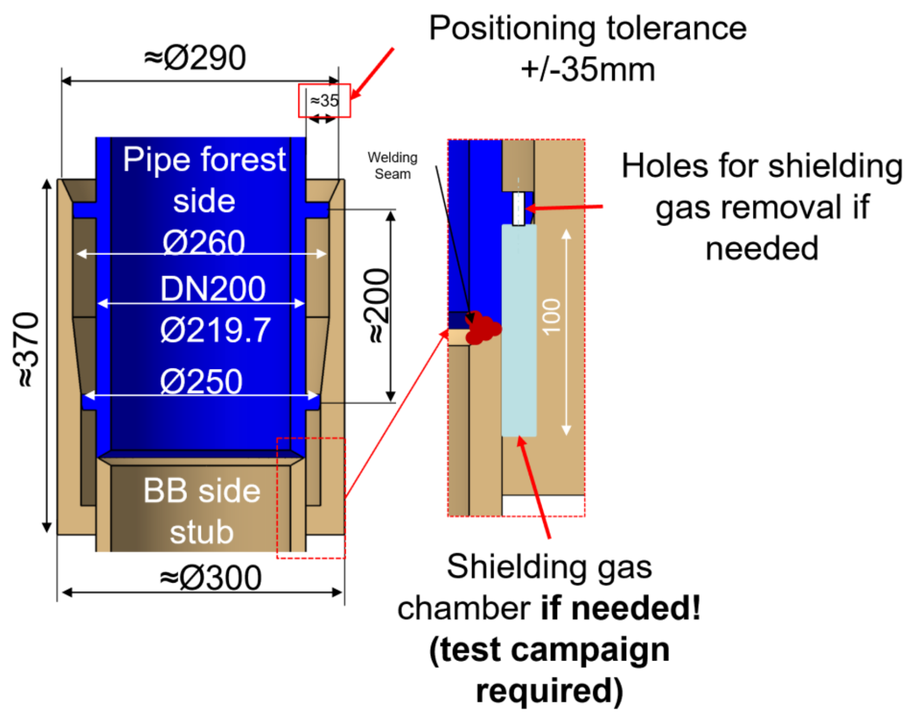


BB Pipe integration in DEMO upper port





Frame structure for pipe forest manipulation - only a short stub of the pipes is shown – dimensions are in mm



Detail of the centering flanges at level of the BB Chimney – Pipe DN200 16mm in thickness

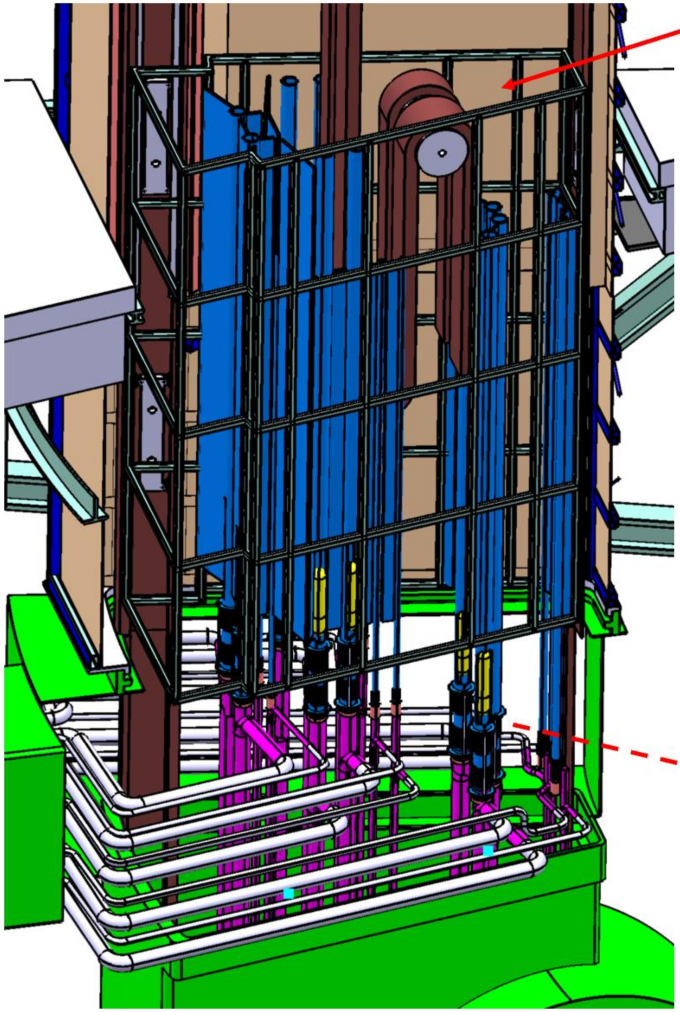
Strategy for pipes replacements & required tool list

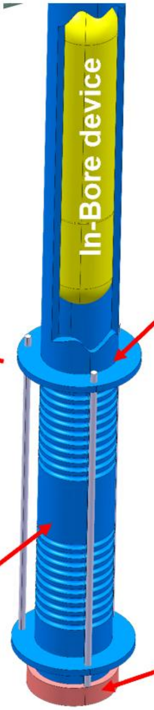
1. Removal of vacuum vessel closure plate (not in the scope of this work)
2. Pipe top caps removal
3. In- Bore cutting (parting and beveling in one shot) of the pipes at level of BB chimney plus edge joint preparation for the subsequent welding
4. Ex-bore parting - beveling of the pipes at level of horizontal leg plus edge joint preparation
5. Pipe forest removal and transportation to the active maintenance facility by mean of a transfer cask
6. Port Plug removal (not in the scope of this work)
7. BB replacement (not in the scope of this work)
8. Port Plug installation (not in the scope of the work)
9. Pipe forest deployment, vertical leg of the pipes engaged in the pipe stubs on the BB chimney by mean of a proper centering system
10. Ex-bore welding at the level of the horizontal legs plus leak checking
11. In-bore welding at the level of the Breeding Blanket chimney plus pipes leak checking
12. Pipes top caps installation plus pipes leak checking

Strategy for pipes replacements & required tool list

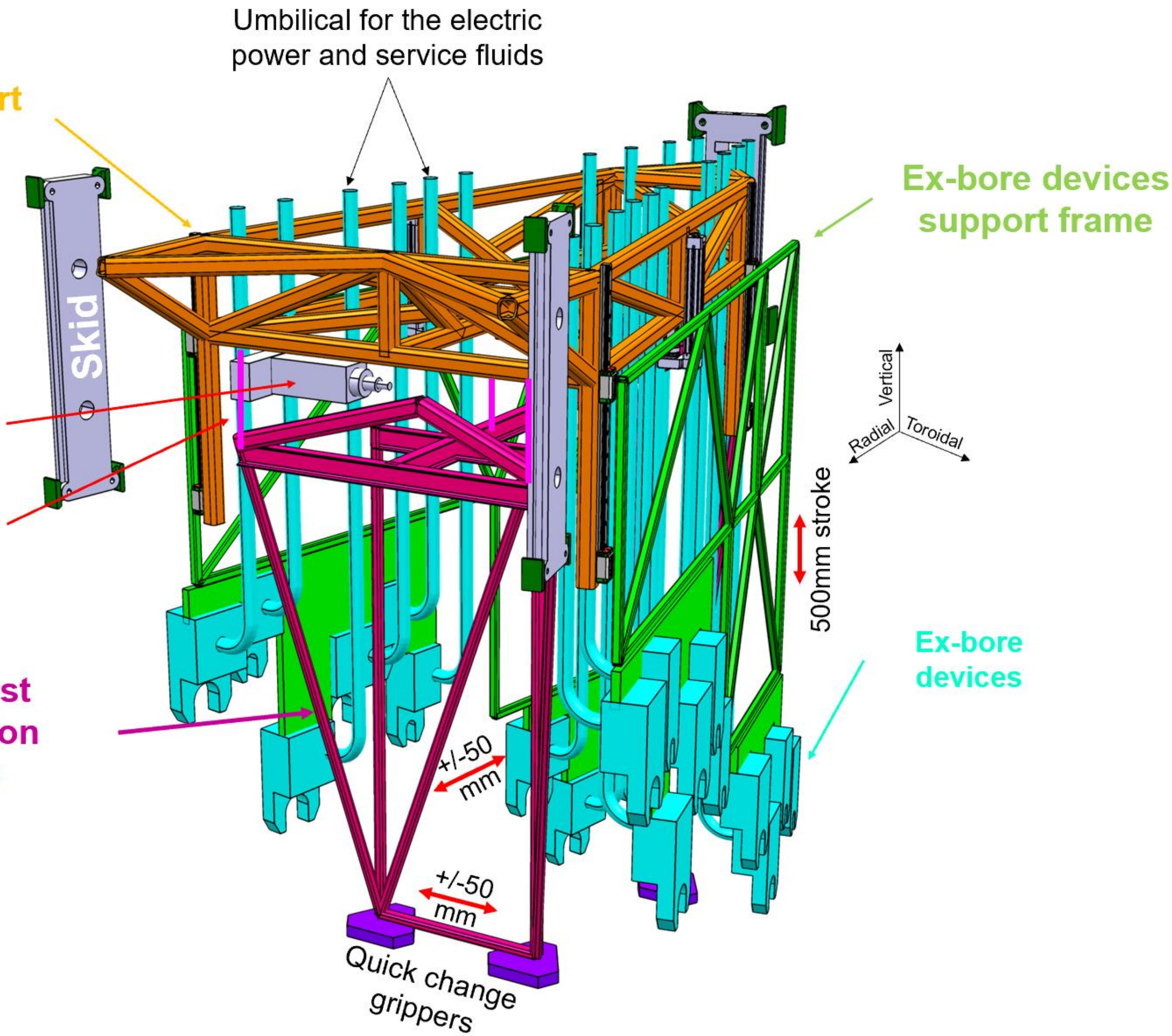
ID	Task	Tool
		Small devices for singles operations (welding, cutting, leak checking)
1	In-Bore Cutting	In-bore cutting devices for pipes DN200 and DN80
2	In-Bore Welding	In-bore welding devices for pipes DN200 and DN80
3	In-Bore pipes caps cutting	Caps In-bore cutting and removal devices for pipes DN200 and DN80
4	In-Bore pipes caps Welding	Caps In-bore welding and installation devices for pipes DN200 and DN80
5	Ex-bore Cutting	Ex-bore cutting devices for pipes DN200 and DN80 + stubs alignment feature
6	Ex-bore Welding	Ex-bore welding devices for pipes DN200 and DN80 + stubs alignment feature
7	Leak detection	Leak detection devices for pipes DN200 and DN80
		Transporters for deployment of the small devices in the working position and manipulation of the pipes forest
1	Pipe caps removal	Pipe caps removal transporter equipped with 20 caps cutting devices (10 for pipes DN200 and 10 DN80) plus features for caps manipulation
2	Pipes caps installation	Pipe caps installation transporter equipped with 20 caps welding devices (10 for pipes DN200 and 10 DN80) plus features for caps manipulation
3	In-bore cutting	In-Bore Cutting transporter equipped with 20 In-Bore cutting devices (10 for pipes DN200 and 10 DN80)
4	Ex-bore cutting	Ex bore cutting tool transporter equipped with 20 ex-bore cutting devices (10 for pipes DN200 and 10 DN80) plus features for pipes deflection and positioning
5	In-Bore welding	In-Bore welding transporter equipped with 20 In-Bore welding devices (10 for pipes DN200 and 10 for pipes DN80) plus features for pipes positioning
6	Ex-bore Welding	Ex-bore welding transporter equipped with 20 orbital welding devices (10 for pipes DN200 and 10 for pipes DN80) plus features for pipes deflection and positioning
7	Leak detection	Leak detection transporter equipped with the leak detection devices (10 for pipes DN200 and 10 for pipes DN80) possibility to equip the welding tool with ND test should be investigated

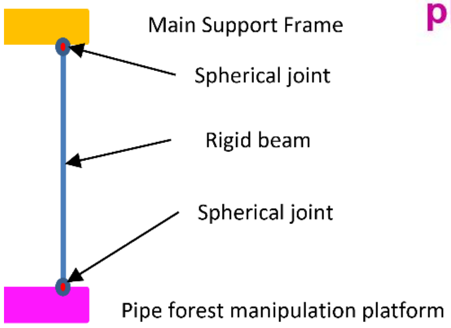
In-Bore tool transporter: main function and conceptual design





Ex-bore tool transporter: main functions and conceptual design





REPLACEMENT STRATEGY FOR EU-DEMO BREEDING BLANKET PIPES

MEDEA

EX-BORE WELDING PROCESS

IN-BORE welding tool (gradual approach):

1. Development a *full-scale prototype in plastic material* - ABS (Acrylonitrile Butadiene Styrene) plus steel and aluminum to develop the control system and to test the actuations :torch movements and engagement in the pipe

2. Development technological tests on **pipes DN200 16mm in thickness in AISI 316 L** in collaboration with industry on available test cell, to set and tuning of the welding process parameters (electrical, electrode diameter, current, voltage, shielding gas, cooling, etc.)

University of Basilicata
SCHOOL of ENGINEERING

PURCHASE SPECIFICATION
IBWT Project - Preliminary Welding Tests
No. IBWT-WT-2023-01 - Rev. 03

PURCHASE SPECIFICATION

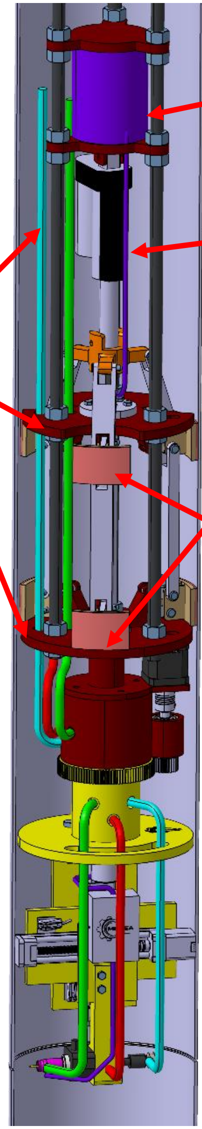
IBWT (In-Bore Welding Tool) *Project*

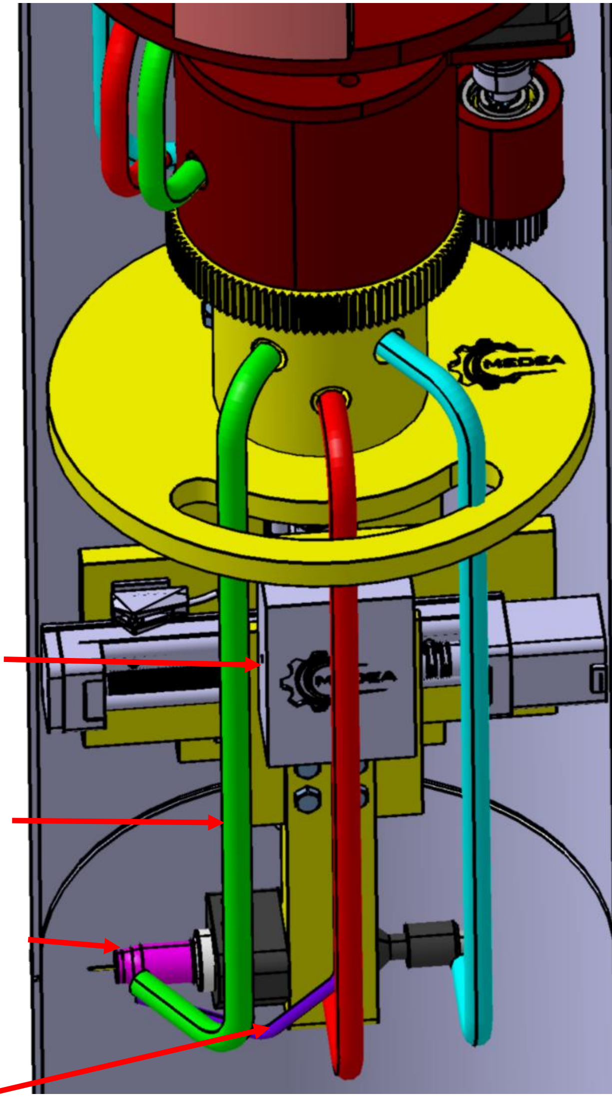
Preliminary Welding Tests

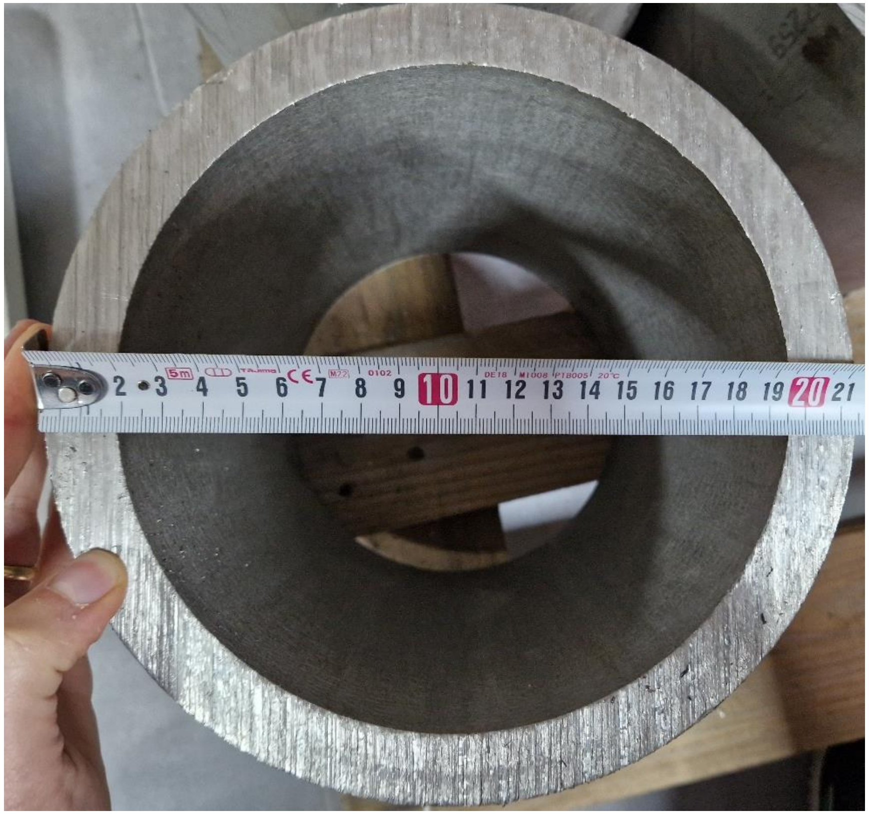
PS N°	Rev.	Issue date	Issued	Approval date	Approved
IBWT-WT-2023-01	03	09/11/2023	R. Salvato	10/11/2023	D. Sorgente R. Mozzillo

Experimental campaign scheduled for the first semester 2024 in the Polysoude welding laboratory in Nantes (France)

Design of small In-bore Tools: Welding – DN200

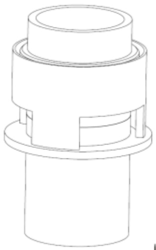




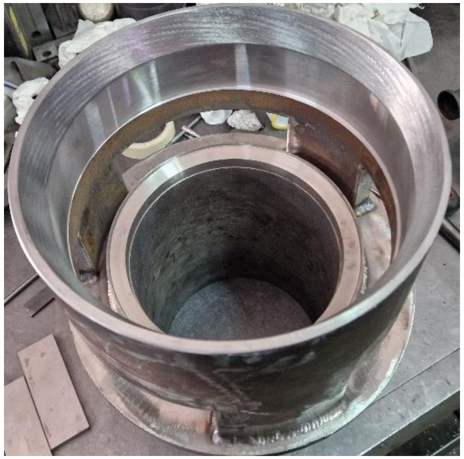


Raw Material for Pipe samples

Status of Test Phase 1 for small welding & cutting tool development

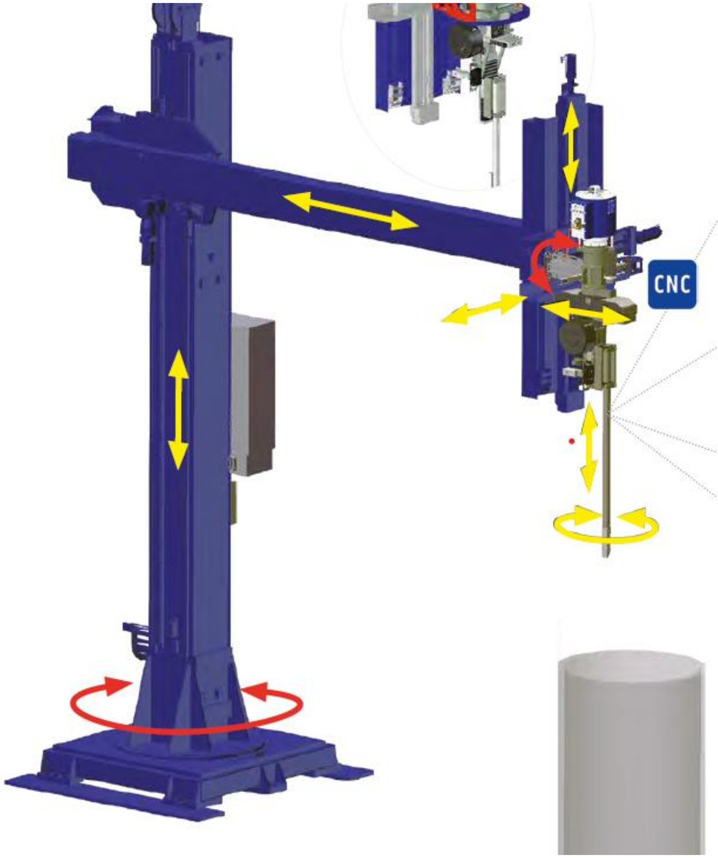


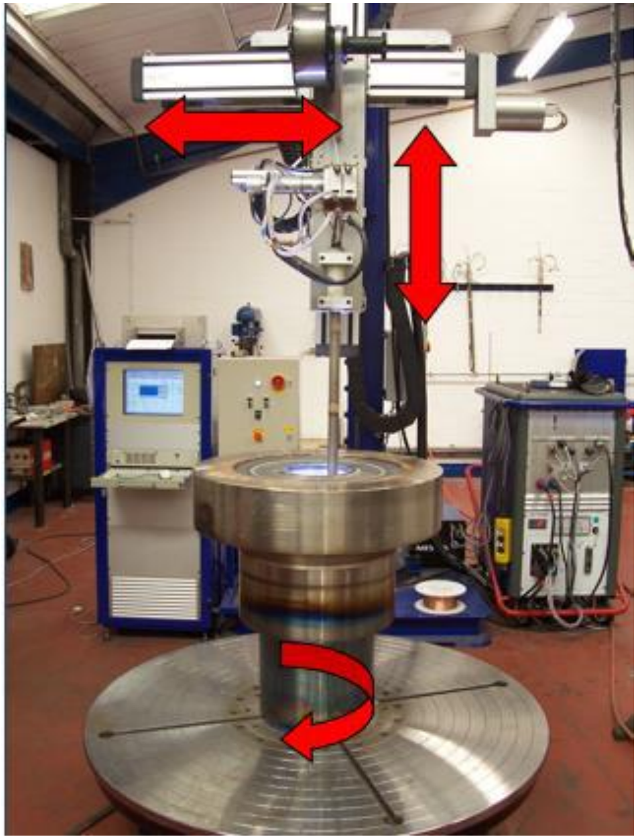
Pipe forest side



Stubs engaged

Next May 2024 welding test in the Polysoude welding laboratory in Nantes (France)!!!





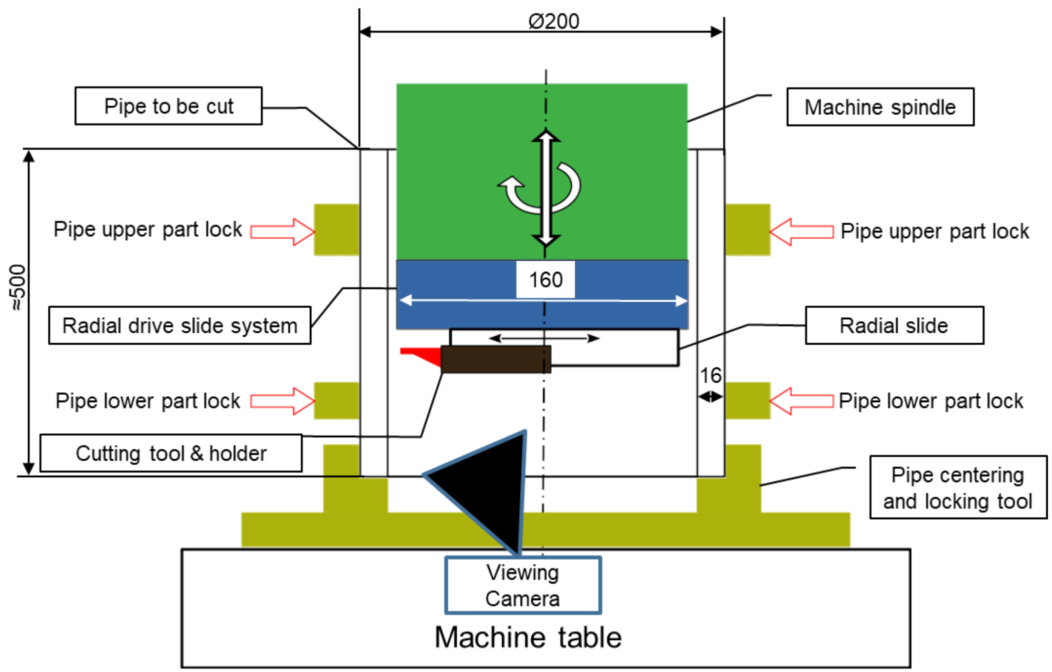
Polysoude Catalogue Weld Overlay Solutions

IN-BORE cutting tool (gradual approach):

1. Development a *full-scale prototype in plastic material* - ABS (Acrylonitrile Butadiene Styrene) plus steel and aluminum to develop the control system and to test the actuations: torch movements and engagement in the pipe

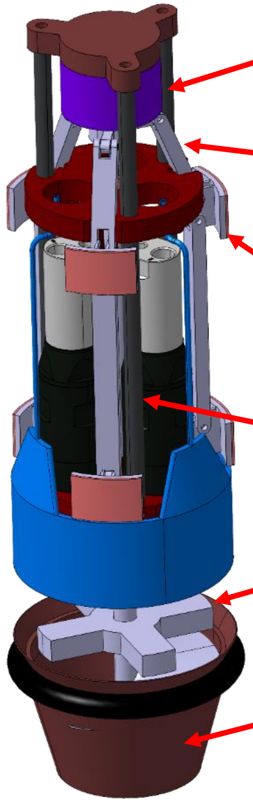
2. Development technological tests in collaboration with industry on available test cell, to set and tuning of the process parameters (*cutting speed, feed, dimensions and geometry of the tools for parting and beveling, etc.)*

Proposed configuration of the test rig on a conventional machine (e.g. vertical lathe)



Scouting activity to find a potential industrial partner is going on!!!

Design of small In-bore Tools: Cutting



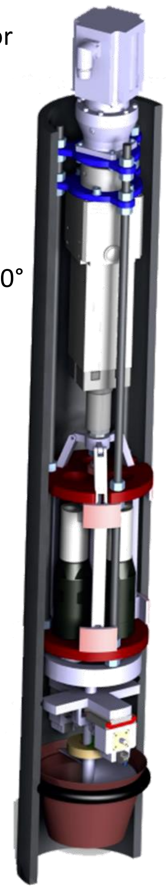
Electric actuator for supporting pads

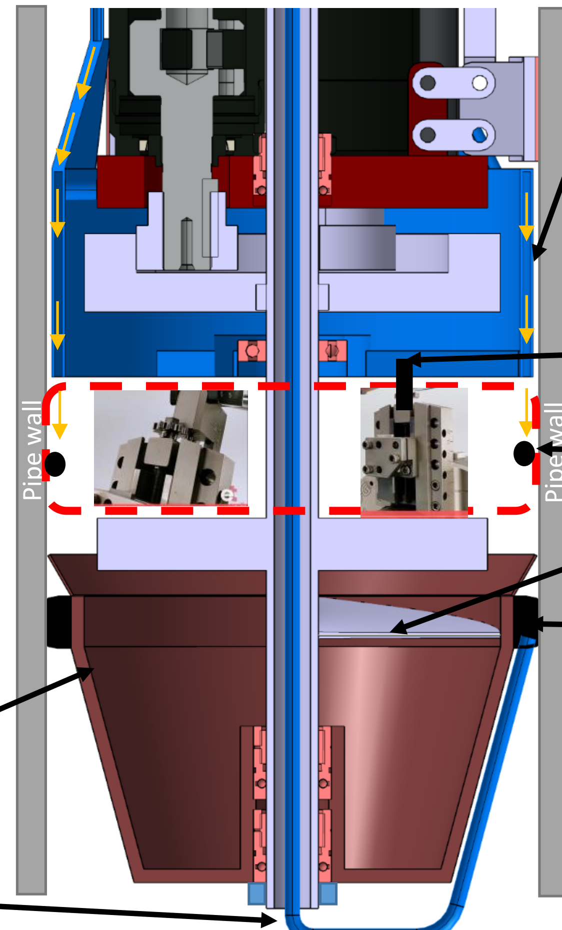
Supporting Pads 120°
3 on top
3 on bottom

Drive + Gear box

Cutting System (tools and radial feed actuators)

Chip collector





Air pressure diffuser to cool and push down the chips with three functions:

- Protect the drives transmission
- Support the fixed pin for the tool bits feeding
- To feed compressed air to cool and clean the cut area pushing down the chips

Fixed pin for tool bits radial feed

Cutting system (ref. Conventional orbital tool)
Not represented

Chip screw compacter

Air Cushion

Chip collector with air cushion and screw compactor.
Chip collector functions:

- To collect the chips from cutting
- Radially support of the hollow shaft (bearings in the centre)
- To block the rotation of the debris collector

Feeding pipe of the air cushion

Conclusion & remarks

1. Finalization of the technological tests for welding at Polysoude in Nantes
2. Finalization of the scouting activities for the cutting tests and definition of the industrial partner
3. Call for cutting tests purchasing by the end of 2024
4. Finalization the conceptual design of both tools: IN-Bore welding and In-Bore Cutting
5. Development of the control system of the tools both for cutting and welding
6. Develop the architecture of the control system of the transporters In-bore and Ex-bore
7. Cost estimation of full-scale prototype of the In-bore welding and In-bore cutting tool hopefully by the end of 2024!!!

BACKUP SLIDES

Backup slides – List of Welding Parameters

The most important information, **welding parameters** and values to be precisely determined at the end of the preliminary test plan can be resumed as follows:

- wire and electrode diameter
- electrical parameters (voltage, current and power)
- flow rates and pressures of water and shielding gas
- joint and surrounding areas temperatures both on pipe side and equipment side
- number of passes, quantity of wire/wire speed, cross section of the deposit per single pass
- torch path (oscillation for filling the joint)
- welding speed
- evaluation of the realization times of the complete joint (possibly with the different welding techniques)
- possibility of making the entire welded joint without interruption of the arc
- otherwise, check that the stop and restart of the welding does not cause defects inside the weld seam which affect the quality of the joint
- check the necessity to use shielding gas also on the opposite side of the root pass (outside of the pipe)
- possibility to complete each joint without replacement or re-sharpening of the tungsten electrode (due to the wear of the electrode itself)
- experiment with different welding techniques (hot / cold wire, shielding gas mixture, wire diameter, other)
- identification of the solutions to be adopted for the correct automatic tracking of the welding joint

- ✓ Main parameters to be defined or acquired shall be:
  - suitable machining parameters (cutting speed, radial feed rate of the knife, dimensions and geometry of the tools for parting and beveling)
  - the torque on the cutting system (with the two tools acting simultaneously)
  - the chip type and chip behavior after being cut (impact of gravity for chip collection)
  - machining vibrations
  - surface quality of the cut edge
  - thermal-related problems
  - machining time
  - tool wear after a complete cutting operation