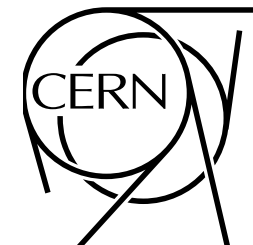


## Structural tests – Production & Fasteners

Dimitar MLADENOV - CERN EP/NU

LBNF Cryostat, final design review

SURF, 21-22 August 2017



# Introduction

The results from the main calculations demonstrated that the fasteners needed were simply:

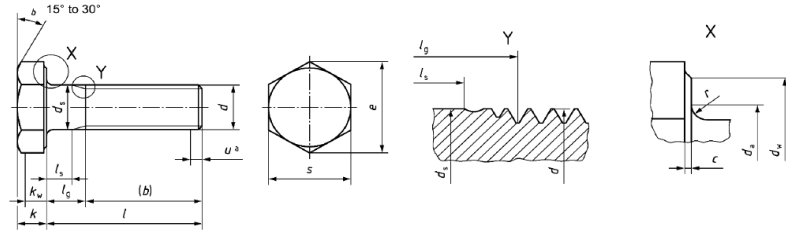
- **M48** from **10.9** grade.

But during the discussions with the supplier it became clear that more detailed information is needed. For example:

- the exact shape of the nut, the washer and the bolts itself. The main reason was that the standards are not covering the geometry for pre-stressed bolts bigger than M36.
- the exact length of the thread, to guarantee:
  - ✓ the shear plane always pass through the non threaded part of the bolt
  - ✓ and at the same time, the non threaded part is still sufficiently away from the nut
- the exact materials used, especially to guarantee the friction coefficient, which will be very important during the tightening.
- the precise manufacturing methods, geometrical tolerances, traceability and markings, surface treatment, chemical composition, testing and qualification requirements, validation procedures, testing reports, etc.

# Fasteners - Geometry and shape

## M48 HR 10.9 Bolt (based on EN 14399-3)



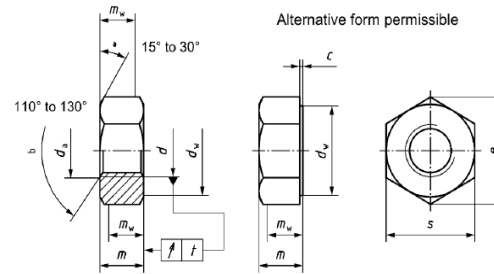
Nominal size and thread diameter	Pitch of thread	Thread	Washer face		Shank diameter			Washer face diameter	Width across corners, AC		Width across flats, AF		Head thickness			
			c, max	c, min	da, max	ds, max	ds, min		dw, min	e, min	s, max	s, min	k, nom	k, max	k, min	kw
48	5	108	1	0.6	56.6	49	47	74.2	88.25	80	78.1	33	33.5	32.5	22.75	3.2

lg max	42	ls min	17
b, min	108	u+1p	10
		b, max,1	123

Connection	Thread Pitch	Washer thickness	Nut thickness	Steelwork		Thread above the nut (1p)	Incomplete thread [u<2p] (1p)	Steelwork Connection, grip	Clamp Length	Calculated bolt length	Calculated bolt length	Shank	Thread inc. run-out
				S1	S2								
M48	p	h, max	m, max	S1	S2	P1 (2p)		S1+S2	CL1	l	l, rounded		
1<>2	5	9	42	35	45	10		80	98	150	160	83	77
1.2<>1.3				35	35			70	88	140	140	63	77
3<>1.2				45	35			80	98	150	160	83	77
1.3<>3				35	45			80	98	150	160	83	77
6<>7				30	22			52	70	122	130	45	85
8.1<>9				45	45			90	108	160	160	83	77
9<>8.2				45	45			90	108	160	160	83	77

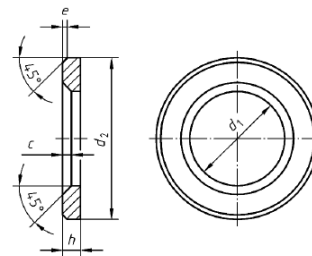
Connection	Thread Pitch	Washer thickness	Nut thickness	Steelwork		Thread above the nut (1p)	Incomplete thread [u<2p] (1p)	Steelwork Connection, grip	Clamp Length	Calculated bolt length	Calculated bolt length	Shank	Thread inc. run-out
				S1	S2								
M36	p	h, max	m, max	S1	S2	P1 (2p)		S1+S2	CL1	l	l, rounded		
4<>5	4	6.6	31	30	40	8		70	83.2	122.2	130	63	67
5<>4				40	30			70	83.2	122.2	130	63	67

## M48 HR 10.9 Nut (based on EN 14399-3)



Nominal size and thread diameter	Pitch of thread	Width across flats, AF		Width across corners, AC	Thickness of nut		Washer face		Washer face diameter	t			
		s, max	s, min		e, min	m, max	m, min	c, max			c, min	da, max	da, min
48	5	80	78.1	88.25	42	40.4	1	0.6	51.8	48	74.2	29.1	1.37

## M48 HR 10.9 Washer (based on EN 14399-6)



### Geometrical data:

- For the bolt
- For the nut
- And for the washer

Nominal size	Internal diameter		External diameter		Outside chamfer	Height			Depth of internal chamfer
	d1, max	d1, min	d2, max	d2, min		e	h, nom	h, max	
48	50	52.74	92	90.6	45 degree	8	9	7	45 degree

# Mechanical Properties

## Mechanical Properties & Material Specifications

- For the bolt
- For the nut
- And for the washer

# M48 HR 10.9 Mechanical Properties

Nominal Stress Area	1473	mm <sup>2</sup>
---------------------	------	-----------------

## Bolt

Chemicals	ISO 898-1	C (0.20-0.55), P (0.025 max), S (0.025 max), B* (0.003 max) <i>If B up to 0.005, non-effective boron is controlled by the addition of titanium and/or aluminium. Approx. 90% of martensite in the core of the threaded section in the "as-hardened" conditions before tempering.</i>			
Hardness	ISO 898-1	320-380 HV <i>Surface hardness shall not be more than 30 Vickers points above the measures base metal hardness of the fasteners. Carried out with HV 0.3</i>			
Decarbonization in thread	ISO 898-1	0.015 mm max			
Tensile strength	1531.92	kN	<i>R<sub>m</sub>, MPa</i>	1040	MPa
Yield, R <sub>p0.2</sub>	ISO 898-1	940			MPa
Elongation, A %	ISO 898-1	9			%
Impact V-notch	27J @ -50C				
Property Class	10.9				
Product Grade	C	<i>except for dimensions c and r</i>		<i>For length:</i>	+/- 4mm
Thread	6g				
Marking	{tbc} 48X150 10.9HR				

## Nut

Chemicals	ISO 898-2	C (0.58 max), Mn (0.30 min), P (0.048 max), S (0.058 max) <i>Alloying element may be added, provided the mechanical properties requires are fulfilled.</i>			
Hardness	ISO 898-2	272-353 HV			
Proof Load	1708.68	kN	<i>R<sub>m</sub>, MPa</i>	1160	MPa
Property Class	10				
Product Grade	B				
Thread - uncoated	6H				
Impact V-notch	27J @ -50C			<i>on reduced test piece</i>	
Lubrication	Customer / Supplier				
Marings	{tbc} 10HR				

## Washer

Hardness	300-370 HV
Markings	{tbc} H

# Manufacturing Company

We have signed a contract with **Cimolai S.p.A** – Italy to produce the testing pieces.

**CERN** Order Number: **CA/6860162**



# Documentation

This company will also develop manufacturing, qualifications and tests procedures, and also a quality assurance plan with special emphasize on the weldings.

They will be the **same ones** later used during the fabrication of the main pieces for the LBNF Cryostat.

The material has been already ordered and delivered to CERN.

Also similar provisions were discussed with the steel manufacturer (*ArcelorMittal*).

## Non Destructive Examination criteria

	VT EN ISO 17637	MT EN ISO 17638	UT EN ISO 17640 Technique A
<i>Fillet Welds (FW)</i>	100 %	5 %	/
<i>Partial Joint Penetration (PJP)</i>	100 %	10 %	/
<i>Complete Joint Penetration (CJP)</i>	100 %	10 %	10 %
<i>Technical Joints, if any (Complete Penetration Splice Joints) and Weld Repairs</i>	100 %	100 %	100 % (if CJP)
<i>Acceptance criteria</i>	EN ISO 5817 Level C	EN ISO 23278 Level 2X	EN ISO 11666 Level 3

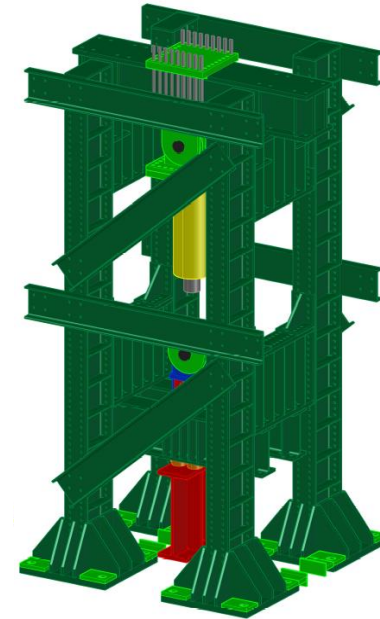
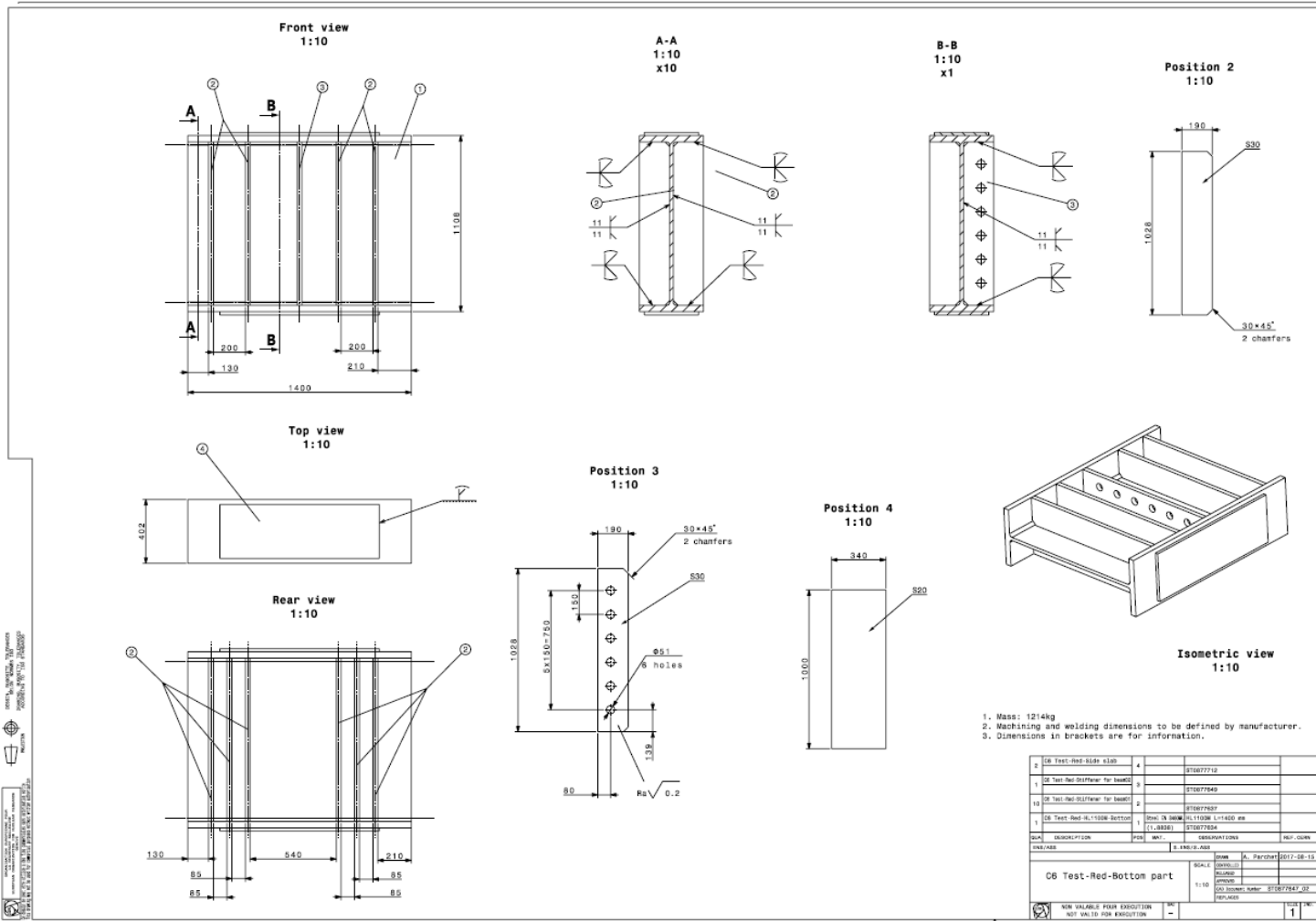
GENERAL									
WPS	04	Rev.	00	Date	01/08/2017				
PQR	ISO-057		Code/ Spec.	EN 15614-1					
Welding process	136 (FCAW)		Automation grade	Partly Mechanized					
FILLER METAL / GAS									
Type	Flux cored wire	Brand	Bohler Ti 52 T-FD		Diameter [mm]	Ø 1.2			
Designation & Class.	EN ISO 17632-A T46 4 P M 1 H5								
Protection gas	EN ISO 14175	M21-ArC-20 (80Ar-20CO <sub>2</sub> )	Nozzle [mm]	12÷16	Gas flow [l/min]	16÷22			
Backing gas	No								
BASE METAL TYPE AND THICKNESS									
Type and grade	EN 10025-2+4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)						Group	1.2÷2.1	
Thickness	Butt weld				Fillet weld				
	<i>T – base metal [mm]</i>		12.5÷50		<i>T – base metal [mm]</i>		n.a.		
	<i>t – weld metal [mm]</i>		12.5÷50		<i>a – throat thickness [mm]</i>		n.a.		
WELDING PARAMETERS									
Runs	Position	Process	Diameter	Current	Voltage	Current tp.	Travel speed	Heat input	
-	-	-	[mm]	[A]	[V]	-	[mm/min]	[kJ/mm]	
1+4; 1R+4R	PC	136	1.2	280÷295	29÷30	DC EP	220÷265	1.47÷1.93	
5+N; 5R+NR				260÷280	27÷29	DC EP	360÷410	0.82÷1.08	
Cap				210÷230	25÷27	DC EP	300÷340	0.74÷0.99	
1÷6; 1R+6R	PF	136	1.2	220÷230	27÷28	DC EP	150÷180	1.58÷2.06	
7+N; 7R+NR				190÷210	27÷28	DC EP	110÷125	1.97÷2.57	
Cap				160÷180	24÷25	DC EP	220÷250	0.74÷0.98	
SKETCH									
Actual dimensions and welding details are represented in the Fabrication Drawings issued for the job.									
PREHEAT / INTERPASS / PWHT									
Min preheat	20 °C					Max interpass	200 °C		
PWHT	No	Temperature	-			Holding time (hrs)	-		
TECHNIQUE									
Joint type	Groove weld				Preparation	thermal cut, grinding or machining			
Cleaning	Grinding and Brushing				Back gouging	Arc-air/grinding (if applicable)			
Nr of runs	Multi Pass								
Single/multi arc	Single				Electrodes spacing [mm]	n.a.			
Oscillation	String				Stick out [mm]	10÷20			

Welding Book

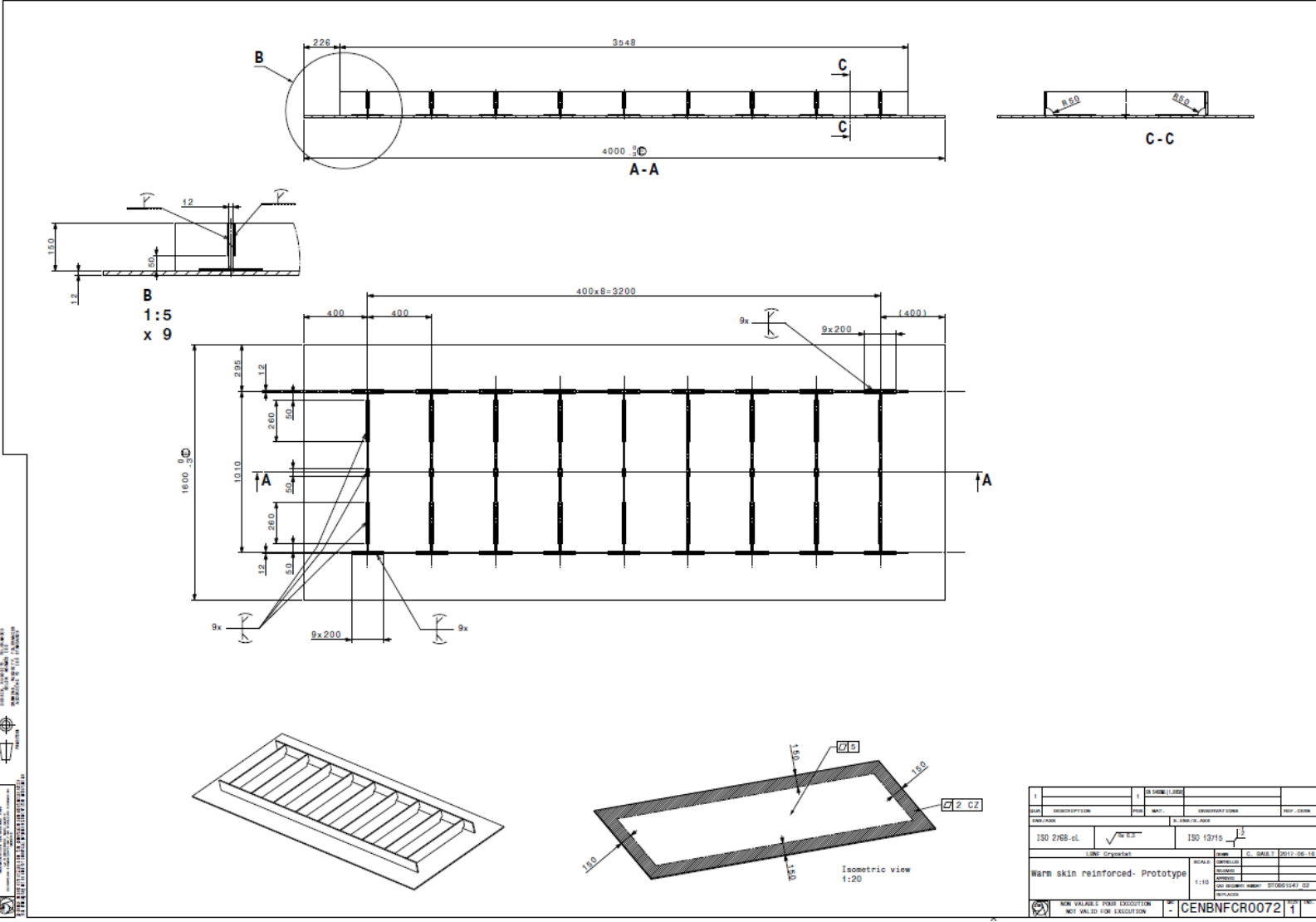
# Production & Testing

## Manufacturing drawings for the test pieces

## Test Set-up



# 2 x Welding test of the warm skin





**Thank you!**