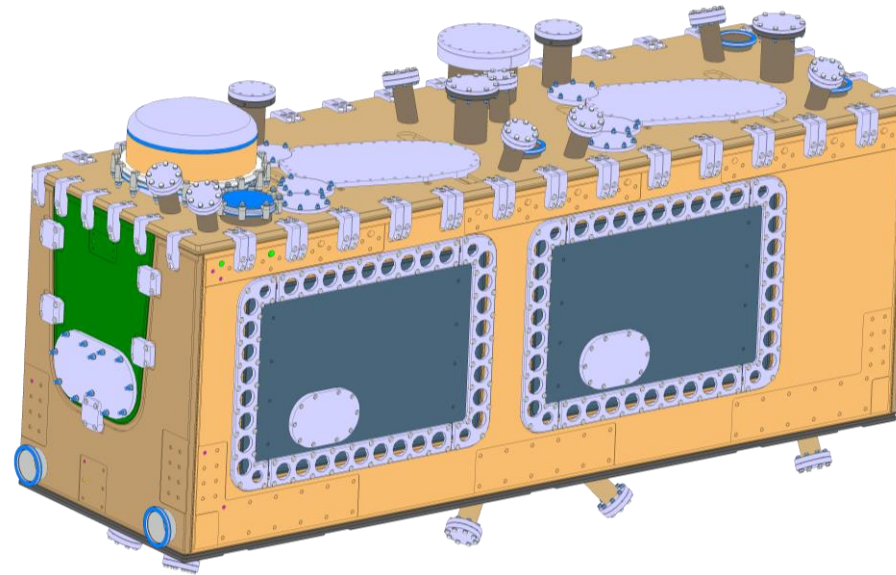


Industrial experience with cryomodule components



11th HL-LHC collaboration meeting

Joel Sauza Bedolla

Lancaster University – UK Collaboration

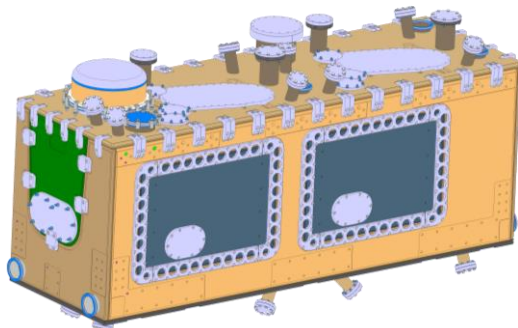
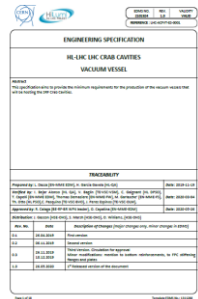
Summary



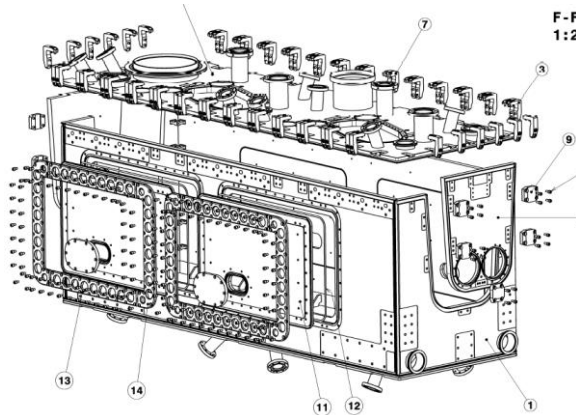
Technical specifications

Procurement Quality

Fabrication



HCACFVT004-UK000001



Material Specification
 N° 510 - Ed. 5
 EDPS No: 1306227

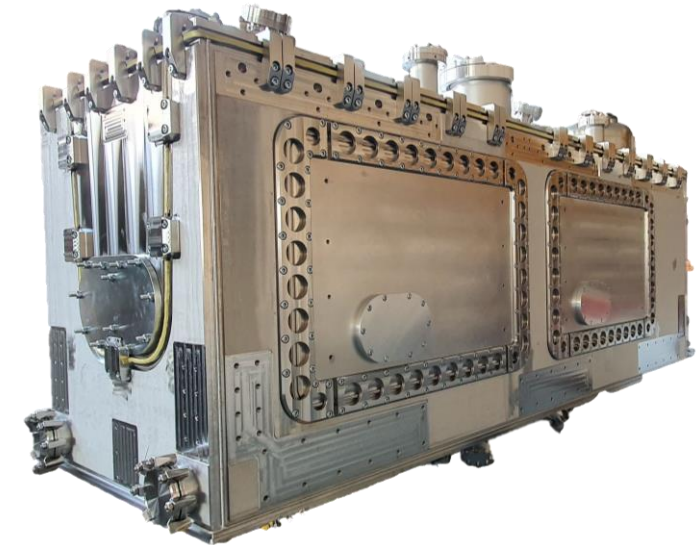
Welded and seamless stainless steel tubes

1,4308	1,4404	1,4425
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X2C018D-13 X2C018M17-12-2 X2C018M18D-14-3
 A312 2041 A312 2161 A312 2164

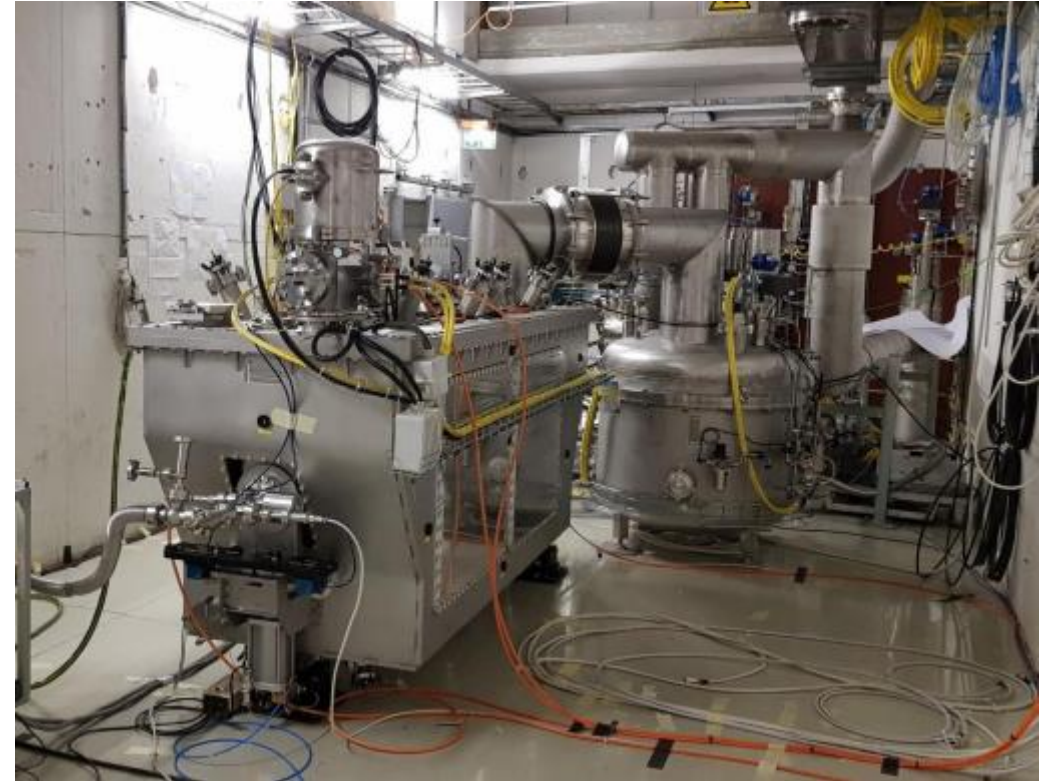


Assembly Coordination



The supplier

- ALCA Technology is located in Schio, north of Vicenza (Italy).
- HV and UHV components
 - Specialized in welding and assembly
 - Machining subcontracted
 - Many suppliers in the range of 10 km
 - Steel procurement included in the order
 - Same supplier of DQW vessel
 - The design of the RFD is significantly different

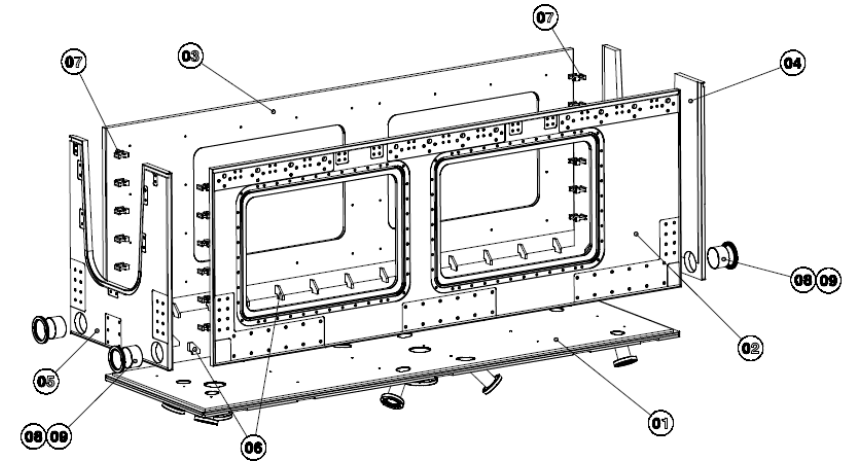


Supplier working method

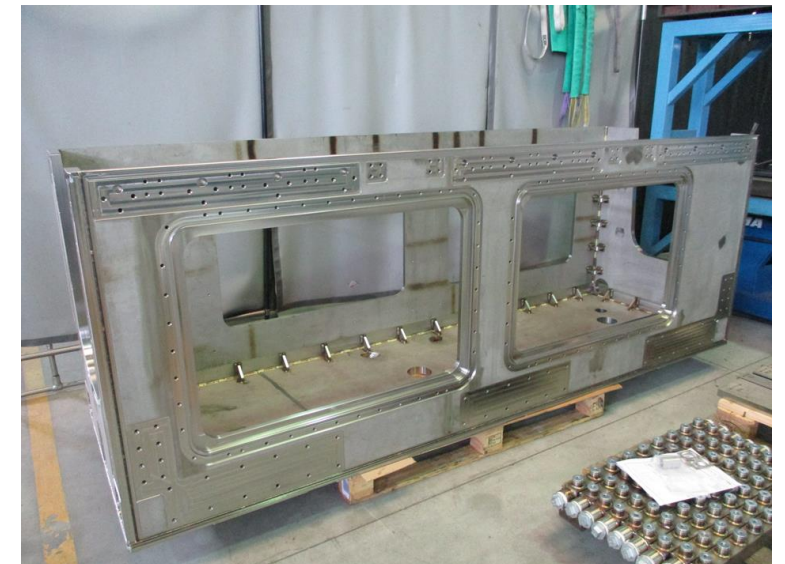


- Finishing of the single part
- Metrology
- Weld
- Metrology

Flexibility for the supplier



- Pre-shape of the parts
- Weld
- Finishing of the parts
- Metrology (See slide [9](#))
 - Part references datums hidden
 - Measurement of both single part drawings and assembly drawing



(Missed) Kick-off

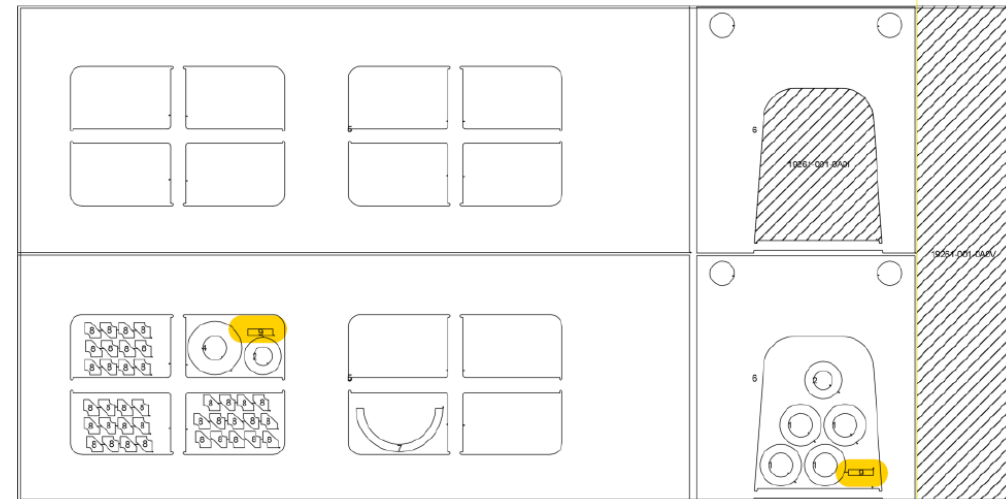
- Due to the pandemic almost all communication was done through mails and calls.
- I asked several times for a thorough kick-off meeting but:
 - Drawings were not officially released when the contract was signed.
 - The company refused to hold the meeting.
 - When the drawings were released they started immediately to work.
- This is key for some of the NC that arose later:
 - Flanges' Material (Slide [11](#)).
 - Screws' material (Slide [13](#)).
 - They had a previous experience working with CERN (and other labs) but in this case it was a different situation.
 - They required QA/QC for this vessel was increased with respect to the DQW. The company failed to realise the difference.

Material supply (1.4435)

- The material was found through the supplier network
- The steel 1.4435 with low Co content ($<0,3\%$)* was “easily” found in Germany.
- Roughing was performed by the same steel supplier (taking some risks)

Kemična Analiza / Chemical Composition / Chemische Zusammensetzung												
Št. Sarže/ Heat No./ Schmelzen Nr.												311266
%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Cu	%Mo	%Ti	%Nb	%N	
0,026	0,487	1,986	0,033	0,0004	17,77	12,82	0,229	2,576	0,003	0,006	0,0705	
%B		%Co										
0,0001		0,133										

Kemična Analiza / Chemical Composition / Chemische Zusammensetzung												
Št. Sarže/ Heat No./ Schmelzen Nr.												314587
%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Cu	%Mo	%Ti	%Nb	%N	
0,029	0,471	1,574	0,034	0,0004	17,66	12,62	0,261	2,502	0,003	0,008	0,0744	
%B		%Co										
0,0003		0,203										



- The production started with the certificates of the main components. Material certificates of tubes and flanges to be provided afterwards. The supply is normally done in a different period. See slide [11](#)

* Derogation [2322525](#)

Welding documents

- The specification EDMS [2101924](#) allowed a certain flexibility to choose the filler material.
 - Suggested ER317L. If different the filler, it shall be austenitic and FN <10. Material certificate according to EN 10204 test report 2,2.
 - Supplier initially chose ER316LSi (austenitic with part ferrite)
 - ER317L too austenitic
 - Different methods to calculate the FN. For the same filler: FN 14 (DeLong) or a FN 8 (Schaeffler)
 - Test report EN10204 type 3,1 is also acceptable
 - WQTC not fully conform for ER316LSi
 - Finally, agreed by all partners to use mainly ER316L (ER316LSi just for external welds as per WPQR).
 - Only one WQTC needed requalification.
 - Technical specification corrected for the series.

Certificato 2.2 TRADARC S.r.l. UNIPERSONALE
Test Report 2.2
 secondo / as per : EN 10204 Via Vegrè 11
 No. : 2020-2014551904-00-105233-003 36010 ZANE
 Rev. : Italia

Ordine N°	PO no.	99535	del / of	21.05.2020
Ordine N°	Order no.	1014231637		
Bolle di consegna/Pos./Spitt.	Delivery note/pos./spitt.	2014551904/000000/000090	del / of	04.06.2020
Oggetto test	Product	bacchetta/filo GTAW / GTAW rod/wire		
Denominazione commerciale	Trade name	BÖHLER AWS ER316LSi		
Classificazione norma	Standard designation	EN ISO 14343-A: W 19 12 3 L Si AWS A5.9: ER316LSi		
Dimensione	Dimension	2,4 x 1000 mm		
Colata - Lotto	Heat no.	105233		
Quantità fornita	Quantity	40,0 KG		

Composizione chimica in % del prodotto Chemical composition in % of the product

C	Si	Mn	P	S	Cr	Mo	Ni	Cu				
< 0,01	0,88	1,8	0,023	0,011	18,1	2,5	12,1	0,2				

proprietà meccaniche Mechanical properties

Prova di trazione Tensile test

T	R _{eL} / Rp 0.2	Rp 1.0	Rm	A (Lo = 5d)	Z	WBH	Note
	MPa	MPa	MPa	%	%	PWHT	Remarks
20°C	≥ 380	≥ 420	≥ 560	≥ 35			

Prova di resilienza Impact test

T	Energia di impatto	Medio Average	Espansione lat.	Frattura cristallina	WBH	Note
	Impact energy		Lateral expansion	Shear fracture	PWHT	Remarks
	KV / J	KV / J	mm	%		
-196°C	≥ 32					
20°C	≥ 70					



CERTIFICATO DI COLLAUDO/ INSPECTION CERTIFICATE

in accordo al/acc to EN 10204 - 3.1
 Numero certificato/Cert no.: EC26326299 rev. 0

Data/Date: 2021-02-17

Nostro ordine/Our order: Giovanni Pagliardi
 Nostro riferimento/Our ref: IT1367001
 Codice Cliente/Cust no:
 Data ordine Cliente/Your date:

Vostro ordine/Your order: Stefano
 Vostro riferimento/Your ref:
 Vostro numero fax/Your fax:
 Vostra e-mail/Your e-mail: acquisti@utensileriapornaro.it

Indirizzo di fatturazione/Invoice address: UTENSILERIA PORNARO SRL
 36033 ISOLA VICENTINA VI

Destinatario del certificato/Cert receiver: UTENSILERIA PORNARO SRL
 36033 ISOLA VICENTINA VI

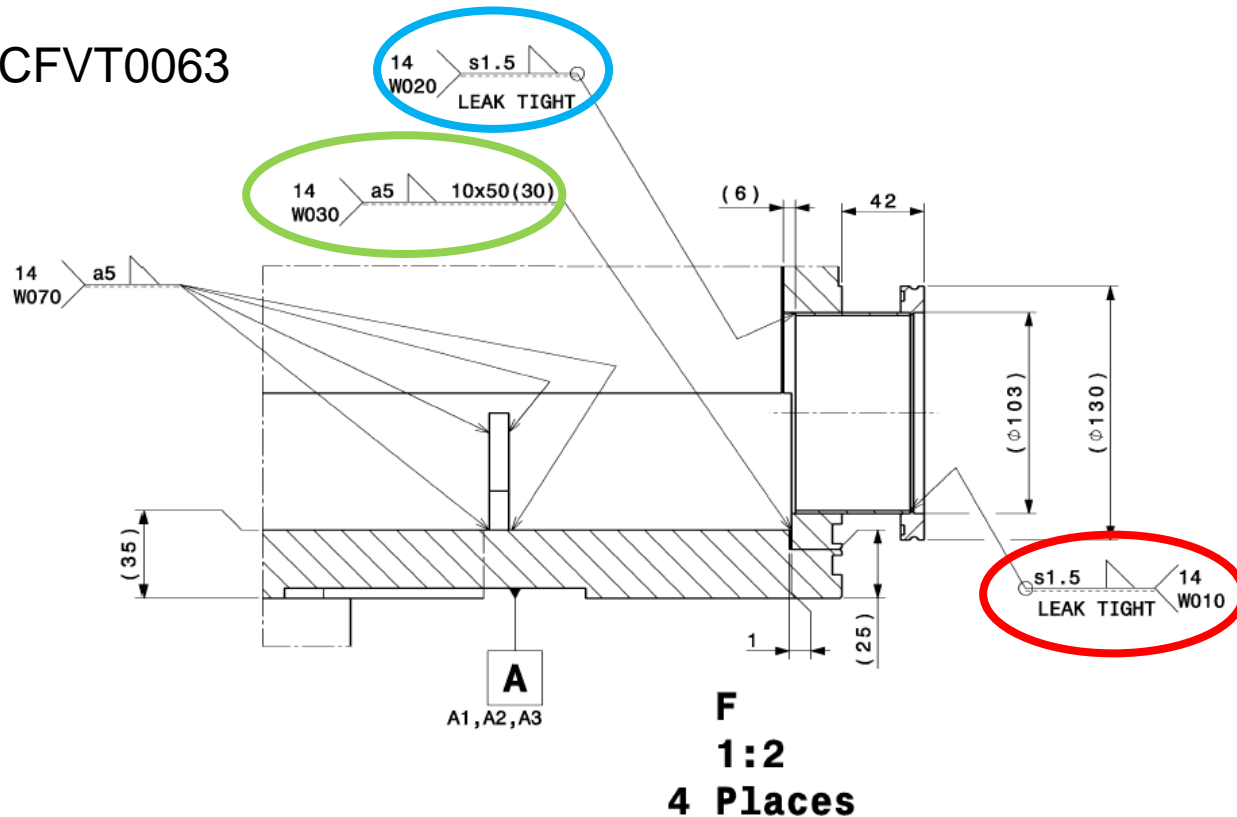
Indirizzo di spedizione/Delivery address: UTENSILERIA PORNARO SRL
 36033 ISOLA VICENTINA VI

PRODOTTO CONSEGNA/DELIVERED PRODUCT	ANALISI CHIMICA/ CHEMICAL ANALYSIS
Marchio/Brand: ESAB	Wire/strip:
Descrizione/Desc: OK Tigred 316LSi 1.6x1000 5kg	Altro/Auxiliary:
Codice/Item no: 163216R150	C 0.02%
Numero di lotto/lot no: pvsu0002380	Si 0.74%
Quantità/Quantity:	Mn 1.8%
	P 0.01%
	S 0.01%
	Cr 18.3%
	Ni 11.3%
	Mo 2.6%
	Cu 0.16%
	N 0.073%
	Co 0.11%
	Ferrite FN 8

CLASSIFICAZIONE/CLASSIFICATIONS

EN ISO 14343-A: W 19 12 3 L Si
 SFA/AWS A5.9: ER316LSi
 Werkstoffnummer: "1.4430

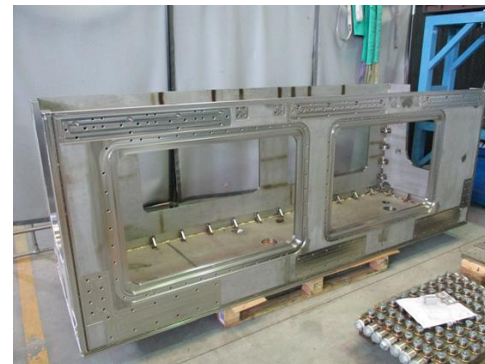
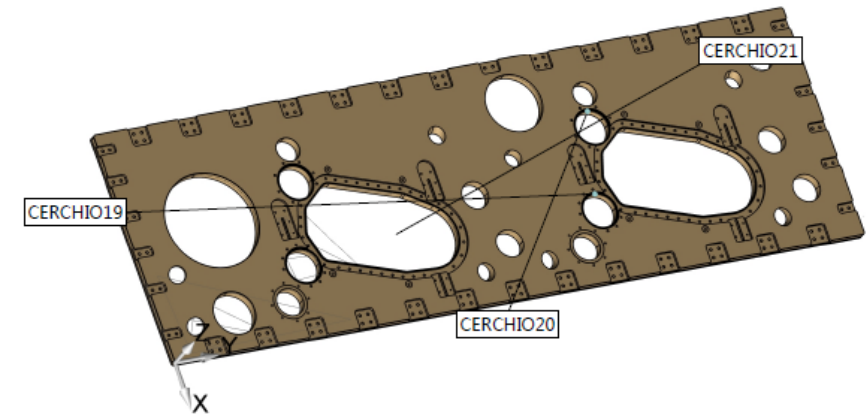
LHCACFVT0063



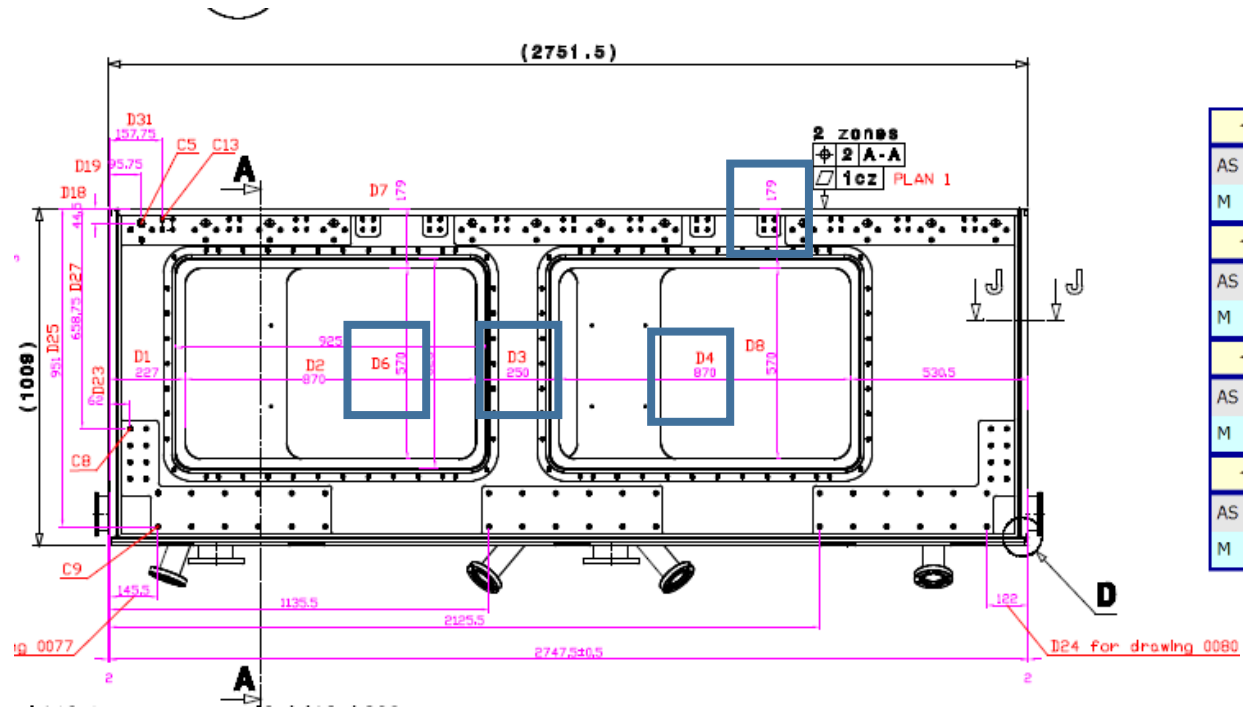
- 33 documents:
 - 3 welding books
 - 21 Manufacturer's Welding Procedure Specification (WPS)
 - 5 Welding Procedure Qualification Record (WPQR)
 - 4 Welder's Qualification Test Certificate (WQTC)

	WELDING BOOK LHCACFVT0063	W.B.21576-01
		Rev.00
W010 	NON-DESTRUCTIVE EXAMS Visual inspection: 100% Leak test: 100% Radiographic examination:/	WPQR: WP-21 WPS: 21576-W10 WATC: WA-034
W020 	NON-DESTRUCTIVE EXAMS Visual inspection: 100% Leak test: 100% Radiographic examination:/	WPQR: WP-21 WPS: 21576-W20 WATC: WA-034
W030-W040 	NON-DESTRUCTIVE EXAMS Visual inspection: 100% Leak test: / Radiographic examination:/	WPQR: WP-015 WPS: 21576-W40 WATC: WA-026
W050 	NON-DESTRUCTIVE EXAMS Visual inspection: 100% Leak test: / Radiographic examination:/	WPQR: WP-015 WPS: 21576-W50 WATC: WA-026

- Top plate was measured first
 - First reports lacked of tolerance identification.
 - Measured dimensions were not in the drawing.
 - Different Datum reference system.
 - Several iterations of corrections.
- Bottom welded assembly
 - Measurements of single parts/assembly drawings
 - Long revision of all the tolerances



Ø	MM	POS19 - CERCHIO19					
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
D	127.000	127.194	0.300	0.000	0.194	0.000	
Ø	MM	POS20 - CERCHIO20					
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
D	127.000	127.190	0.300	0.000	0.190	0.000	
Ø	MM	POS21 - CERCHIO21					
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
X	-289.750	-289.841	0.500	-0.500	-0.091	0.000	
Y	1110.750	1110.667	0.500	-0.500	-0.083	0.000	
R	122.500	122.424	0.300	-0.300	-0.076	0.000	



		MM	DIST3 - PIANO6 SU PIANO7 (ASSEY)				
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
M ✓	250.000	249.792	0.500	-0.500	-0.208	0.000	<div style="width: 100%; height: 10px; background-color: #c8e6c9;"></div>
		MM	DIST4 - PIANO7 SU PIANO8 (ASSEY)				
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
M ✓	870.000	869.956	0.500	-0.500	-0.044	0.000	<div style="width: 100%; height: 10px; background-color: #c8e6c9;"></div>
		MM	DIST5 - PIANO1 SU PIANO9 (ASSEZ)				
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
M ✓	179.000	179.278	0.500	-0.500	0.278	0.000	<div style="width: 100%; height: 10px; background-color: #c8e6c9;"></div>
		MM	DIST6 - PIANO9 SU PIANO10 (ASSEZ)				
AS	NOMINALE	MIS	+TOL	-TOL	DEV	FUORITOL	
M ✓	570.000	569.992	0.500	-0.500	-0.008	0.000	<div style="width: 100%; height: 10px; background-color: #c8e6c9;"></div>

- NC: Welding lip reduction of the Top plate (1 mm) and bottom welded assembly (2 mm overall).
- NC: holes at the bottom/side for the transport
- Metrology still to be improved for the series

- CERN always supplies the material for their orders. All quality checks (chemical composition, certificates, UT) are done at CERN.
- The supplier did not have experience on supplying material certificates to CERN.
- ALCA welded the top plate flanges before sending the material reports.
 - They have used the same flanges for other research institutes.
- The flanges material were not conform to CERN specifications.
- EDMS [790775](#) (CERN spec 1001) Forged blanks for UHV: The process shall include a mandatory Electro Slag Remelting (ESR) step. Multi-directional forged.
 - The report does not include UT inspection (i.e. 100% volumetric inspection) using bars without UT control can entail risks if imperfections are present.
 - The chemical analysis is for the heat only and not to the final product.
 - Inclusion content reported is method A instead of method D.
 - The certificate seems to be for a D115mm bar instead of the final bar diameter. (If the bar has been re-forged to a smaller diameter we would need the certificate of the final state).

Erzeugerform Product		Stab, rund, gewalzt, geschält round bars, rolled, peeled										
Werkstoff / Qty Material		1.4429 X2CrNiMoN17-13-3 (ESU)										
Anforderungen Requirements		TL 1.4429 ESU / 2461 N mod 11 2052 Rev 2 08/18 1.4429 X2CrNiMoN17-13-3 ESU DIN EN 10088 -3 12/14 1.4429 X2CrNiMoN17-13-3 ESU DIN EN 10272 10/16										
Besichtigung und Maßnachprüfung Inspection and dimensional control Inspection et contrôle de dimension ohne Beanstandung without objection		Erschmelzung/Nachbehandlung Melting process/secondary refining Mode d'élaboration/traitement ultérieur E- VOD / ESU					Verwechslungsprüfung (spectroanalytisch) Identification test (spectral-analysis) examination d'identification (analyse spectrale) ohne Beanstandung without objection					
Pos. Item Poste	Anzahl Quantity	Abmessung Dimension		Gewicht Weight		Schmelz-Nr. Heat-No.				No. de coulée		
1	4	115.00 RD		1784 kg		437945						
Schmelz-Heat %	C	Si	Mn	P	S	Cr	Mo	Ni	N	Co		
437945	0,010	0,26	1,65	0,023	0,0003	16,72	2,58	13,69	0,1746	0,046		
Wärmebehandlungszustand Condition of heat treat		Lösungsgeglüht solution annealed										
Probe-Nr. Test-No.	Lage loc.	Temp. °C	Rp0,2 N/mm ²	Rp1,0 N/mm ²	Rm N/mm ²	A5 %	Z %	Kerbschlagarbeit Impact value		Probenform Shape of test piece		Härte Hardness
Soll/Req.	L	RT	>=300	>=315	>=600	>=40		>=100		RT		>=160
	L	RT			<=800							<=200
	L	300	>=155									
091ME1	L	RT	342	385	663	44	77	217	220	217	RT	177
091ME2	L	RT	340	380	660	44	78	219	223	215	RT	
091ME1	L	300	217		507							
Prüfart/test location:		12,5 mm										
Korngröße/grain size		ASTM E 112: 5.5										
Magnetische Permeabilität/magnetic permeability		Sollwert/desired value: <=1,005 µr, Istwert/actual value: 1,004 µr										
Reinheitsgrad/micro purity		DIN 50602/K: K1 = 5										
IK-Beständigkeit/intercrystalline corrosion		DIN EN ISO 3651-2: ohne Beanstandung/without objection.										

Reinheitsgrad/micro purity ASTM E 45, Meth. A:	A dünn/thin: 0	A dick/heavy: 0
	B dünn/thin: 1,0	B dick/heavy: 0
	C dünn/thin: 0	C dick/heavy: 0
	D dünn/thin: 1,3	D dick/heavy: 0,5

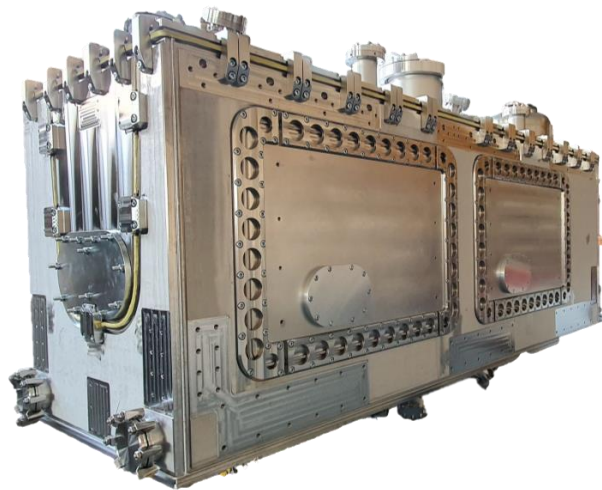
100% Rissprüfung (Wirbelstromprüfung) nach/crack-test (Eddy current test) acc.to
DIN EN 10221 01/96, Klasse/class B: ohne Beanstandung/no objection.

Fertigung nach QM-System ISO 9001: 2015/ QM system in effect is ISO 9001: 2015
Zertifiziert nach / certificated AD2000 W0.

Kontrolle auf Radioaktivität ohne Befund, der Messwert liegt unter der Nachweisgrenze
von 0,1 Bq/g.
Radioactivity inspection without objection, the measured value is below the detection
limit of 0.1 Bq/g.

- It is more than chemical analysis!
- A NC was raised
 - Use granted for this vessel
- For the future
 - Buy the flanges from CERN
 - Buy from CERN suppliers

- The lifting test was not completely defined in the technical specification and in the contract.
- During the mounting of the lifting elements it was noticed that the screws were not of the requested grade (8.8 instead of A4-100)
 - Avoid putting in contact stainless steel with stainless steel
 - The material is not fully specified in the drawings but it was written in the contract and technical specification



Actual

<u>5</u>	Traceability of Materials
<u>10</u>	Cutting and Rough machining
<u>15</u>	Vacuum Vessel Welding
<u>20</u>	Vibrating Stress Relieving
<u>25</u>	Visual check
<u>30</u>	Final Machining
<u>35</u>	Dimensional Control
<u>40</u>	Final Welding (tubes and flanges)
<u>45</u>	Visual check
<u>50</u>	Visual check sealing surfaces after blasting outside and pickling inside
<u>55</u>	Final cleaning and assembly
<u>60</u>	Trial Fitting
<u>65</u>	He Leak Test
<u>70</u>	Lifting Test
<u>75</u>	FAT Test
<u>80</u>	Ready for transportation

Request for series

5	Traceability of Materials (main components)
10	Cutting and rough machining
15	Vacuum Vessel Welding
20	Vibrating Stress Relieving
25	Visual check
30	Final Machining
35	Traceability of Materials (tubes and flanges)
40	Dimensional Control of top plate
45	Final welding (tubes and flanges) top plate
50	Dimension control of tubes and flanges after welding (Top plate)
55	Dimensional Control of bottom welded assembly
60	Final welding (tubes and flanges) top plate
65	Dimension control of tubes and flanges after welding (Bottom welded assembly)
70	Visual check
75	Local pickling
80	Final cleaning
85	Trial Fitting
90	He Leak Test
95	Lifting Test
100	FAT test
105	Ready for transportation

Separate material certificates of main parts and flanges

Top plate

Bottom welded assembly

Conclusions

- The lessons learned will be formalised in EDMS [2641589](#)
- A proper kick-off meeting analysing all related document is necessary even if (especially if) the company has experience working with CERN
- Material certificates are of primary importance and they can delay the project
- Identification of inconsistencies in the technical specifications to be corrected for the series
- NC are not to be hidden. It is better to know the issues, evaluate the impact and correct
- MTF modification proposed for series production

Questions?

- Thanks to (but not only):



- L. Dassa, T. Capelli and M. Garlasche



- T. Jones, C. Guerra Granjeiro, E. Jordan



- G. Burt



- A. Zaltron, A. Lanaro