

CONTINUOUS EB-WELDING OF THE REINFORCEMENTS OF THE CMS SUPER CONDUCTOR

Dr. Peter Oving

OUR EB SOLUTIONS MEET ALL YOUR CHALLENGES

TECHMETA
ELECTRON BEAM EXPERT
Engineering

COMPANY INFORMATION

I. CMS SUPERCONDUCTING SOLENOID COIL

II. EB-WELDING PRODUCTION LINE SET-UP

1. Component handling
2. Electron beam welding
3. High speed machining
4. Final spooling

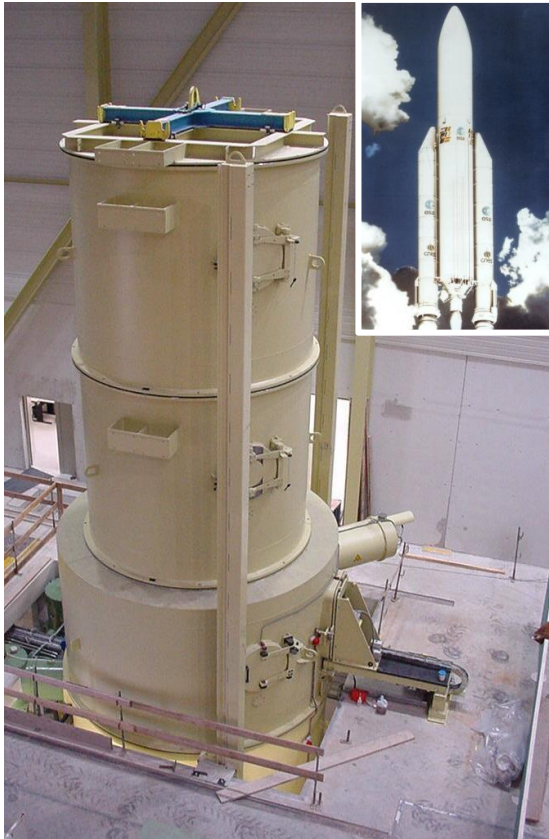
III. PROCESS CONTROL

1. Quality control
2. Ultra-Sonic control
3. Dimension check

IV. EXPERIENCE

CONCLUSION

INTERNATIONAL PROJECT EXPERIENCE



AEROSPACE – ARIANE V
Booster Welding



CERN - CMS
Superconductor Welding



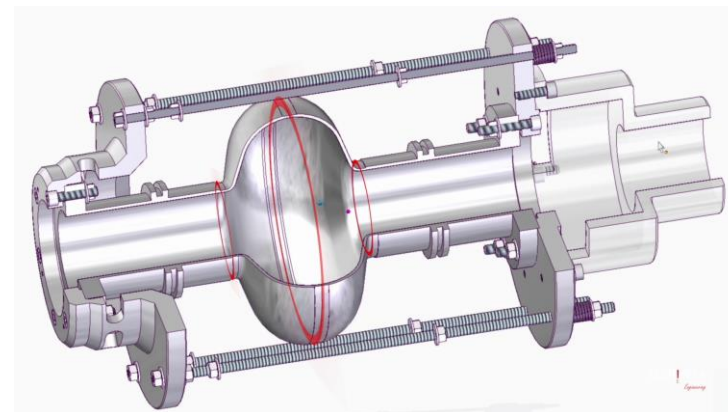
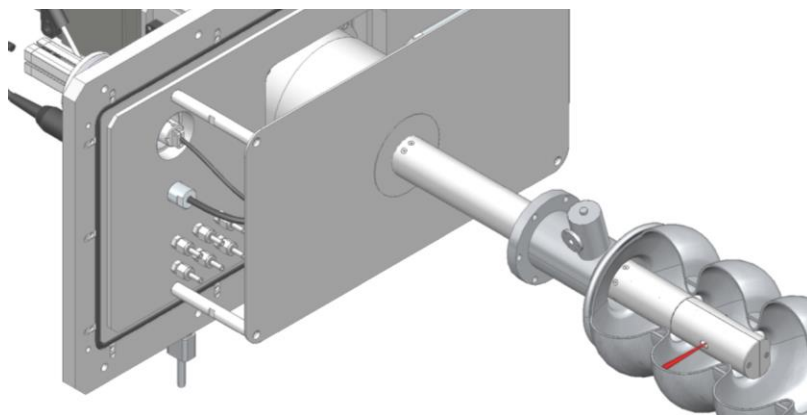
AEROSPACE
Rocket Reservoirs



FRENCH NAVY
Submarine Parts

2021 - DEVELOPMENT – INSIDE CAVITY WELDING

- Equator & Iris Electron Beam welds from the inside



- EB inside welded 1.3GHz Single Cell Tesla Type Cavity
Cryo temperature tested

Quality factor 1.7×10^{10} at 35.0MV/M

Maximal Field Gradient 37.3 MV/m at 1.57×10^{10}

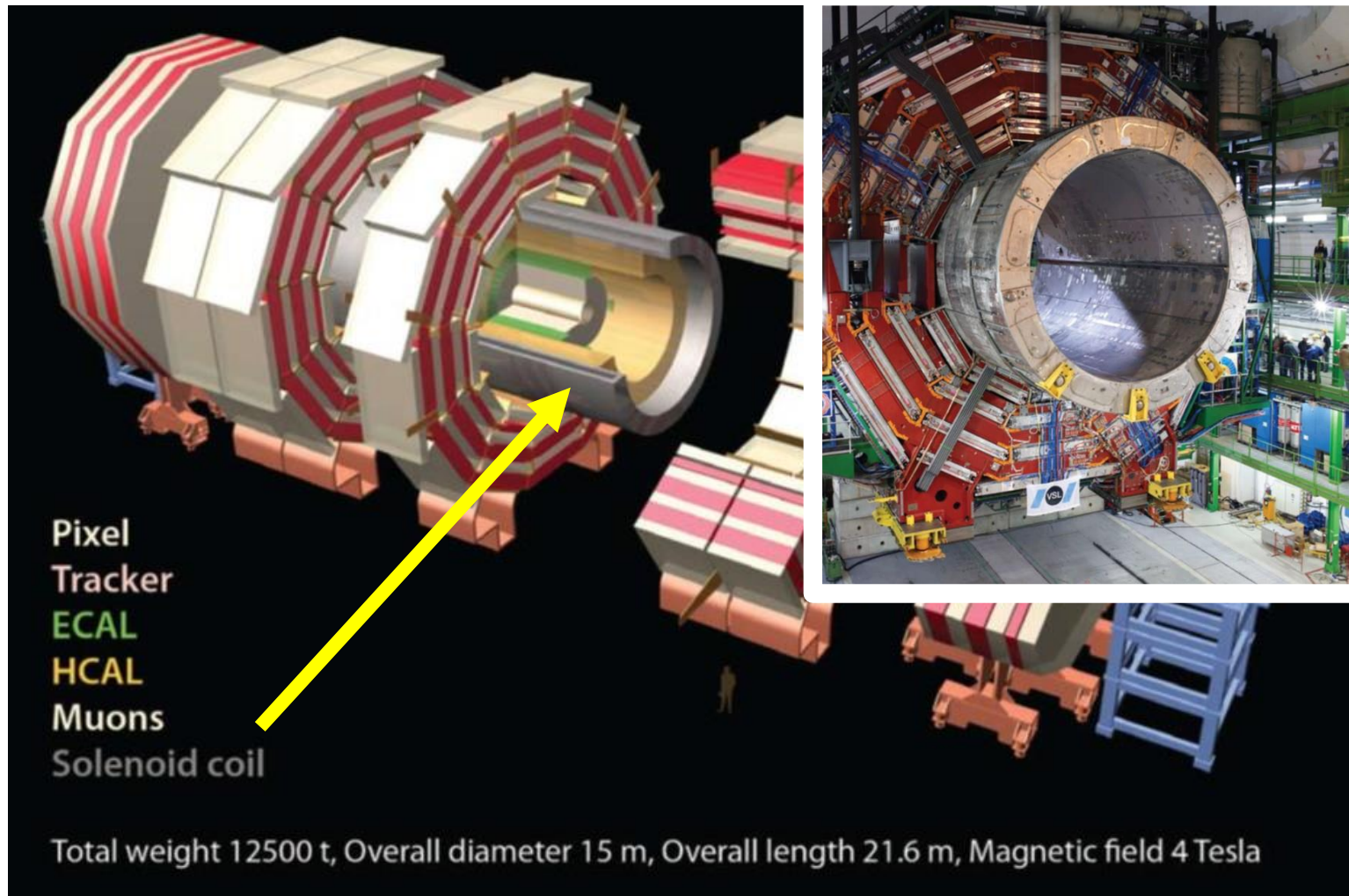


2022 - 2023 – CONTINUOUS STRIP WELDING

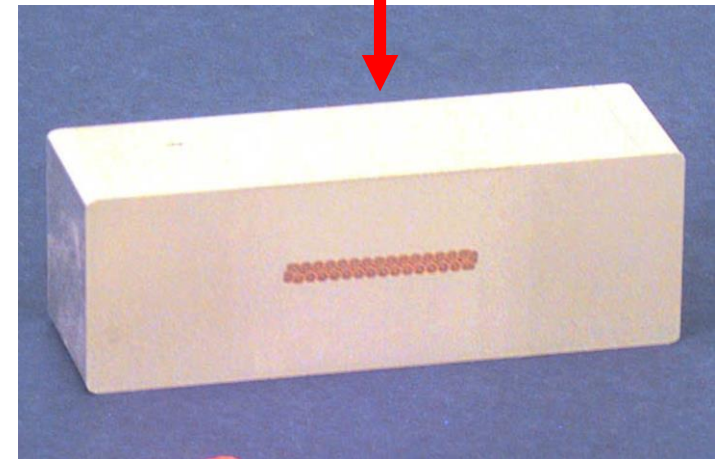
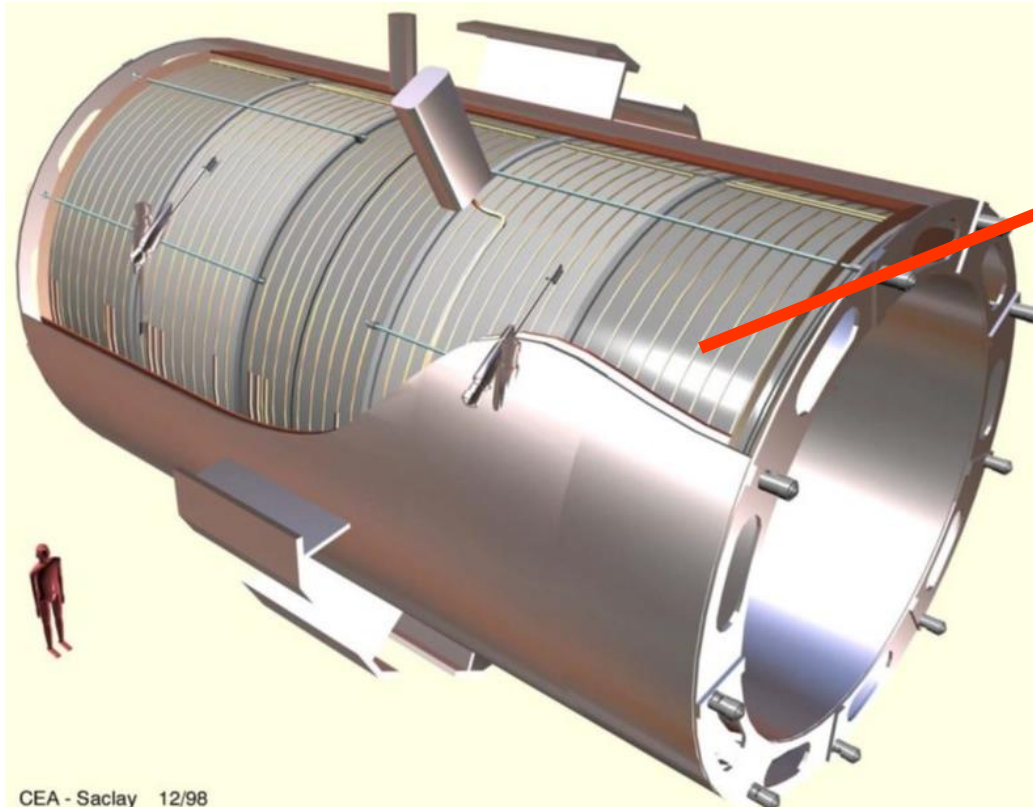
- TECHMETA Strips
- **New jobshop** entity on separate production site
- Dedicated to continuous strip welding > **2 Production Units**
- Operational > Begin **2023**
- Market > Automobile industry / Electrical cars



I CMS SUPERCONDUCTING SOLENOID COIL

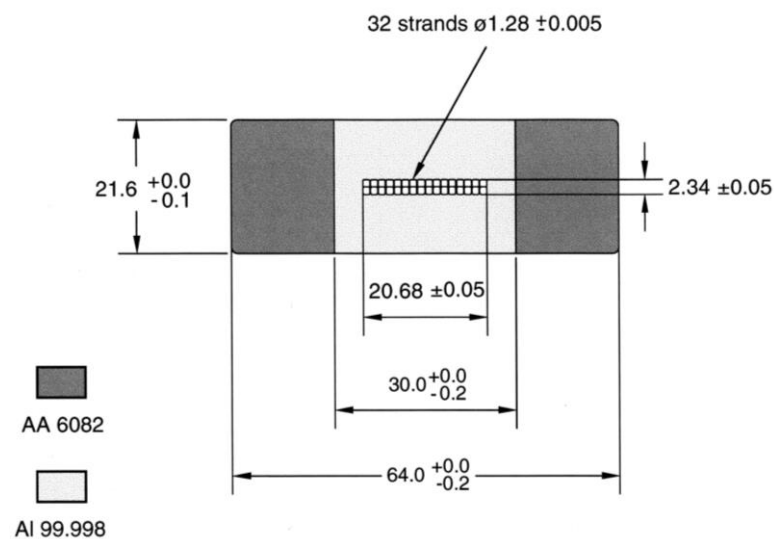
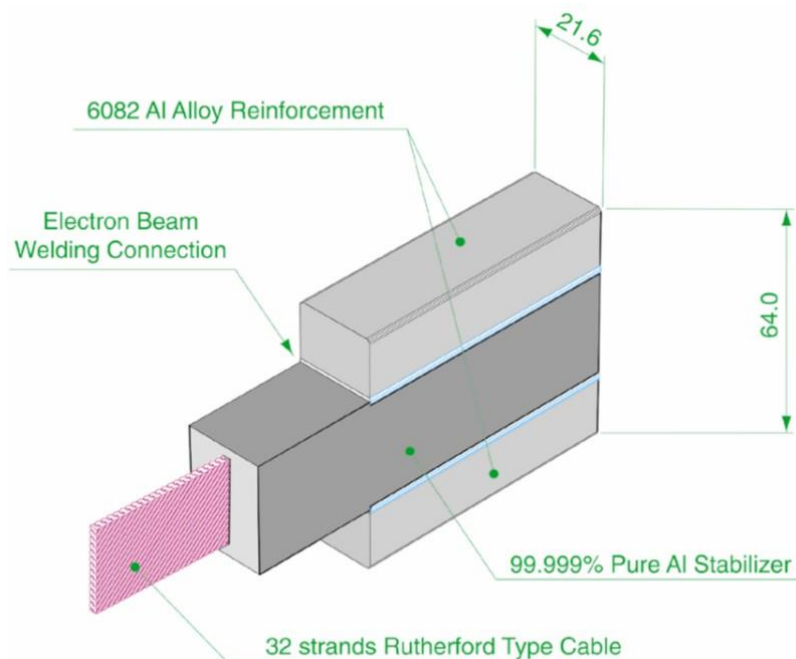


I SUPERCONDUCTOR INSERT & REINFORCEMENT



I PURE AL INSERT & AL ALLOY REINFORCEMENT

- **Simultaneous double Electron Beam weld of 2.55km length > OK**
- Soft soldering back-up solution
- Alloy co-extrusion > Temperature Critical for Superconductor > NOK
- **Simultaneous machining > +/- 50µm thickness tolerance**



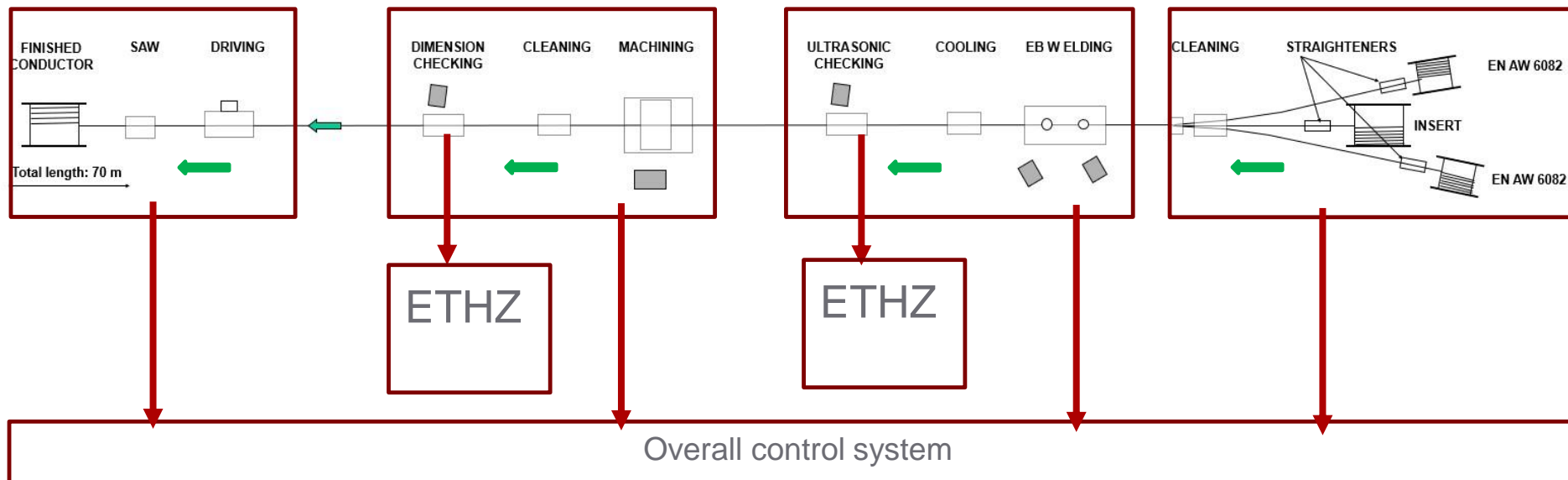
II EB-WELDING PRODUCTION LINE SET-UP

Driving
Cutting Saw
Final coil

Machining
Cleaning
Dimension Checking

EB-Welding
Cooling
US Checking

Initial 3 coils
Straighteners
Cleaners



II-1 COMPONENT HANDLING & PREPARATION



II-1 COMPONENT HANDLING & PREPARATION

Pre-straightening
Straightening



Cleaning



Joining one batch to the other



II-2 ELECTRON BEAM WELDING



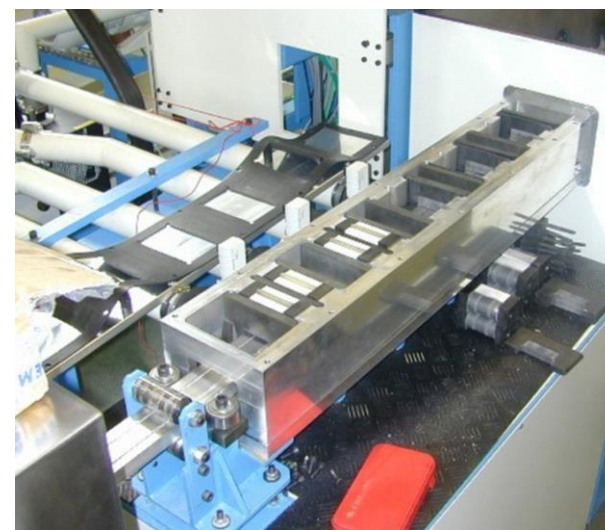
Double gun > Different parameter set

II-2 ELECTRON BEAM WELDING

Entrance Air-Vacuum lock



Exit Air-Vacuum lock



Metal projection management

Strip lamination for exit lock

II-3 DIAMOND TOOL HIGH SPEED MACHINING

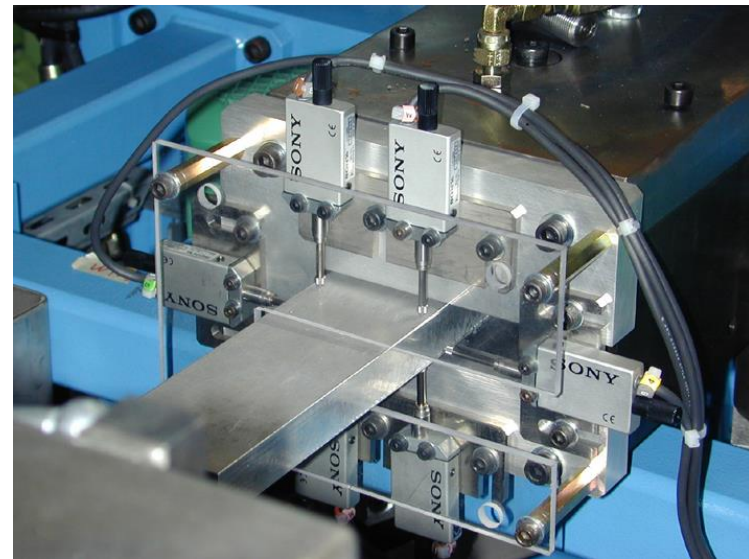


4 side + 4 corner continuous machining

II-3 DIAMOND TOOL HIGH SPEED MACHINING



Machining temperature control



Machining dimensional control

II-4 SPOOLING FINAL REINFORCED STRIP



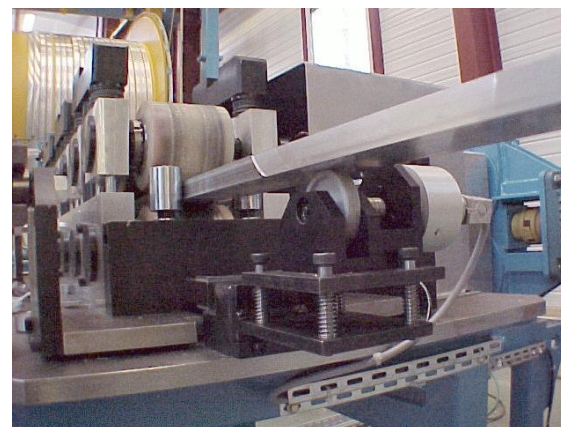
2.55km uninterrupted superconductor reinforced strip

II-4 SPOOLING FINAL REINFORCED STRIP

Caterpillar traction



Coiling control



Speed control

III PROCESS CONTROL & MANAGEMENT

- Control system integrates all synchronised consoles:
 - Commands
 - Signals
 - Alarms
- Man interventions:
 - level 1 Operator attention & Operator OK
 - level 2 Line stop without operator intervention or judgement
- Automatic parameter recording every 500ms
- Samples Begin/End of batch
- Provided by ETH Zurich:
 - EBweld bonding control by US
 - Final dimensional control by laser scanning

III-1 QUALITY CONTROL

- Stepwise process validation
 - 200m
 - 1km
 - Full length

- Acceptance certificate:
 - Provisionnal
 - Final

TECHMETA TESSY 74370 PRINGY	CMS SC FS 0001 : Reinforcement by continuous Electron Beam Welding of the conductor of the CMS MAGNET		
	Order N° B 3137 1239920 May 3 rd 1999		
PROVISIONAL ACCEPTANCE CERTIFICATE			
Data record for conductor N° EBW02 CMS 01 12.12.01			
<u>Basic products :</u>			
	N° spool number	Expected length	Real length
AA Reinforcement right	N° 9	2 690 m	
AA Reinforcement left	N° 10	2 690 m	
Real Insert	CMS 01	2593 m	
Conductor			≈ 2 560 m
<input type="checkbox"/> Welding specification : Left weld : DMOS N° 1573 Right weld : DMOS N° 1574			
PRODUCTION PARAMETERS MONITORING :			
<input type="checkbox"/> Welding parameters : Copy of CD N° EBW02 CMS 01 Welding parameters			
<input type="checkbox"/> Dimensional : Report ETH CD N° EBW02 CMS 01 Dimensional Valeur moyenne largeur:0,364 ep.:21,584			
<input type="checkbox"/> U.S. : report EMPA N° EBW02 CMS 01 US			
<input type="checkbox"/> Destructive testing : Report « Labo » Ref. : N° APAVE report 02.0054			
<u>Mechanical testing :</u>			
Shearing test		Minimum required 30MPa	
See APAVE report 02.0054	Start of spool : Ref. : 1d, 1e, 1f		Conforme
See APAVE report 02.0054	End of spool : Ref. : 4d, 4e, 4f		Conforme
Tensile test		Breaking in pure Al zone	
See APAVE report 02.0054	Start of spool : Ref. : 1a, 1b, 1c		Conforme
See APAVE report 02.0054	End of spool : Ref. : 4a, 4b, 4c		Conforme
Comments : Scratches and surface irregularities have been eliminated by manual interventions.			
Conclusion :			
La bobine du conducteur N° ...EBW02 CMS01 -12.12.01 est acceptée.			
TECHMETA	ETHZ	CERN	
R. CHRISTIN M. VITTEY	P.L. RIBONI	R. FOLCH	
Memo Reference Number : PV N° RF 436		du 15/01/02	1/4

CT 1002 06/0001

CT 1002 06/0001

TECHMETA TESSY 74370 PRINGY	CMS SC FS 0001 : Reinforcement by continuous Electron Beam Welding of the conductor of the CMS MAGNET		
	Order N° B 3137 1239920 May 3 rd 1999		
Distance	Evènement EBW02 CMS 01		
0	- Date : 12/12/01 - Remise à zéro du compteur (longueur de real insert déjà utilisée à cet instant = 16,7 m c'est-à-dire passage du rabotage au delà de la fraiseuse. - Début de soudage pour prise d'échantillon de début de production (10h 11' 04'').		
38,1	- Stop pour accrochage à la bobine après prélèvement des échantillons de début de production. - Go à vitesse établie sur le stop précédent (14h 00' 30'').		
55,0	- Mesure de la température (à égale distance des 2 soudures, sur l'insert) en sortie du sas et après le dispositif de refroidissement (méthode de mesure reproduite lors de toutes les mesures effectuées au cours de la production) sas : 205° C refroidi : 59° C		
339,8	- Repère longueur soudée (16h 32' 30'').		
≈ 356,1	- Début d'une zone de 1,2 m de longueur avec irrégularité en surface du cordon de soudure Tous les paramètres restent constants durant la durée de l'incident, seules les pressions résiduelles enceinte et canon remontent légèrement.		
405,6	- Repère longueur soudée (17h 06' 00'').		
514,7	- Repère longueur soudée (18h 01' 00'').		
≈ 560	- Mesure de la température : sas : 208° C refroidi : 36° C		
≈ 711	- Stop opérateur fin de journée. - Nettoyage sommaire de l'outillage de soudage. - Date : 13/12/01 - Go à vitesse établie sur le stop précédent (7h 54' 15'').		
757,3	- Stop opérateur suite à apparition de rayures post usinage (8h 17' 30''). - Entretien du système de guidage de la fraiseuse. - Go à vitesse établie sur le stop précédent (8h 58' 00'').		
≈ 795	- Mesure de la température : sas : 211° C refroidi : 34° C		
Memo Reference Number : PV N° RF 436		du 15/01/02	2/4

III-2 ULTRA SONIC CONTROL

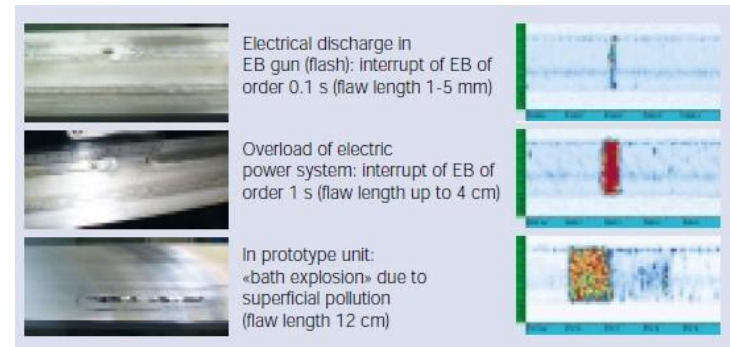
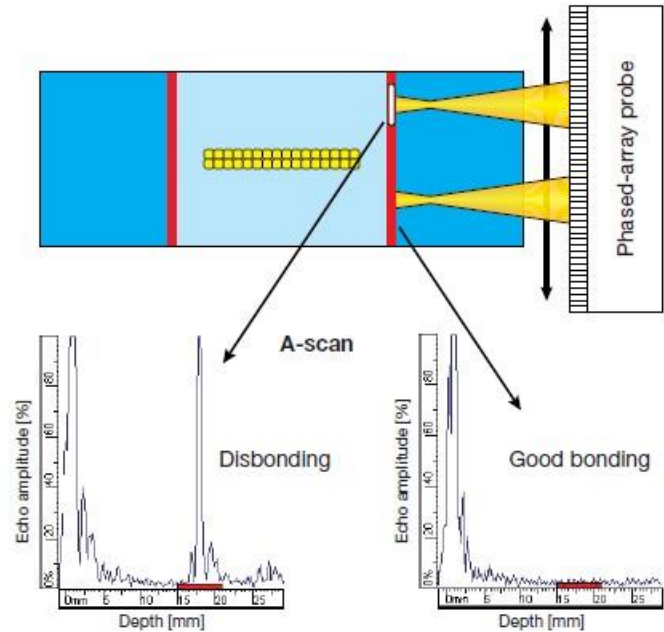
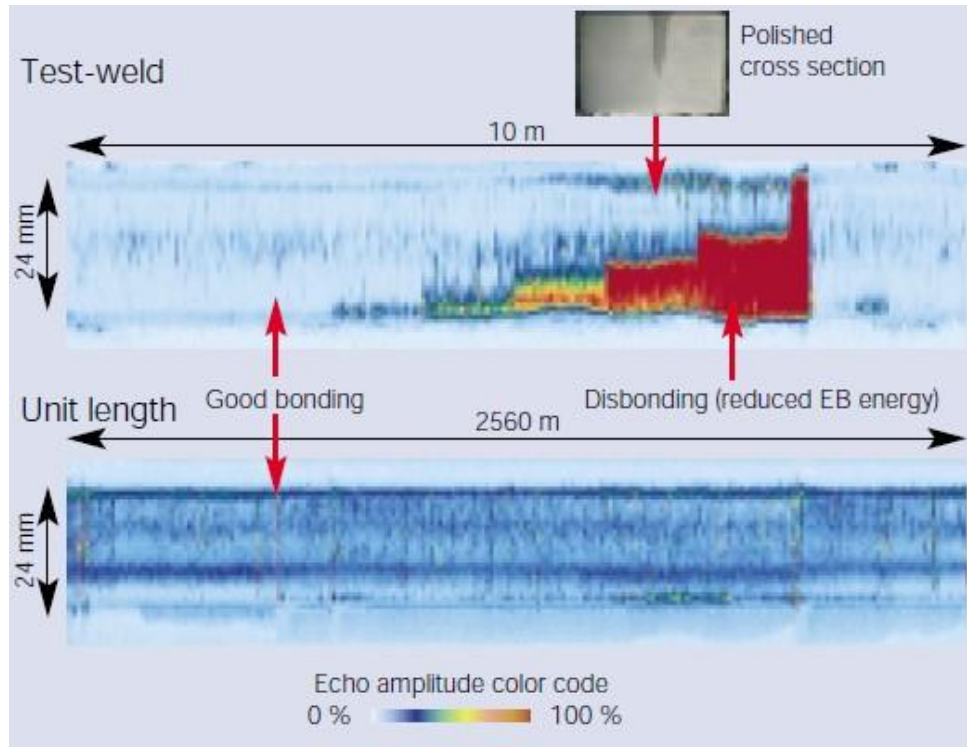


Equipment and operator by ETH Zurich

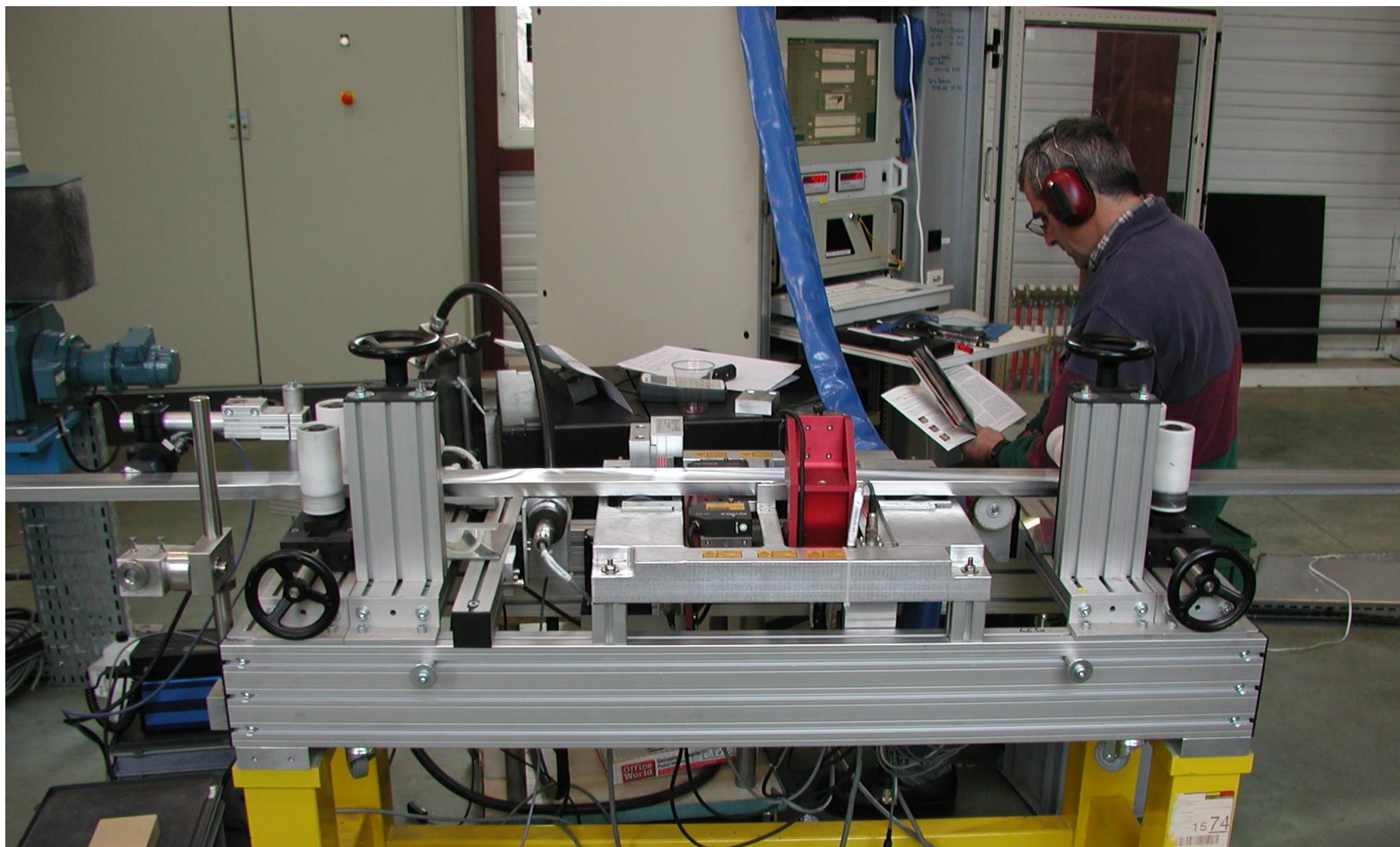
III-2 ULTRA SONIC CONTROL

Phased array Ultra Sonic system

Same control set-up as Co-extrusion control



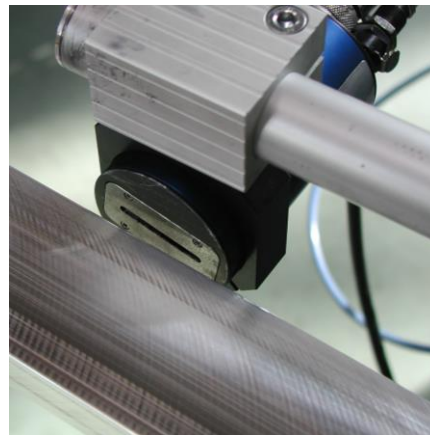
III-3 DIMENSION CHECK



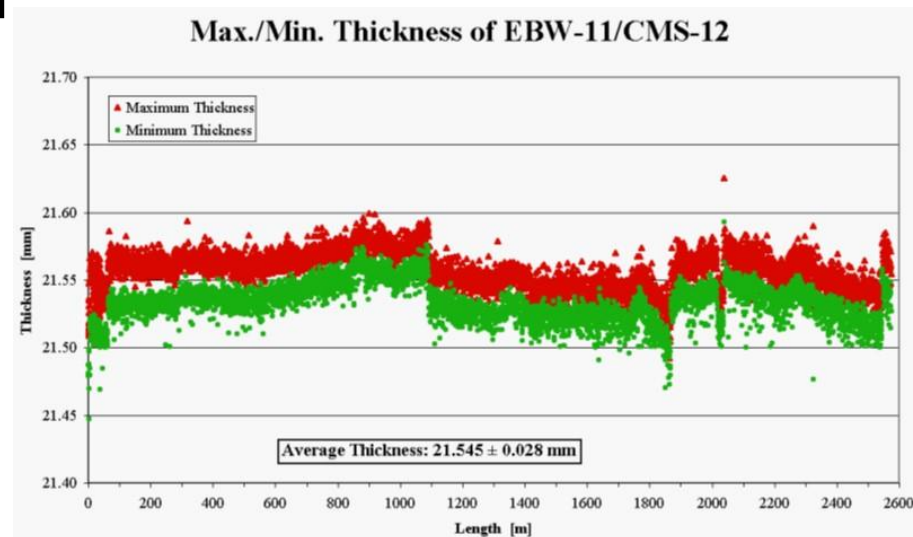
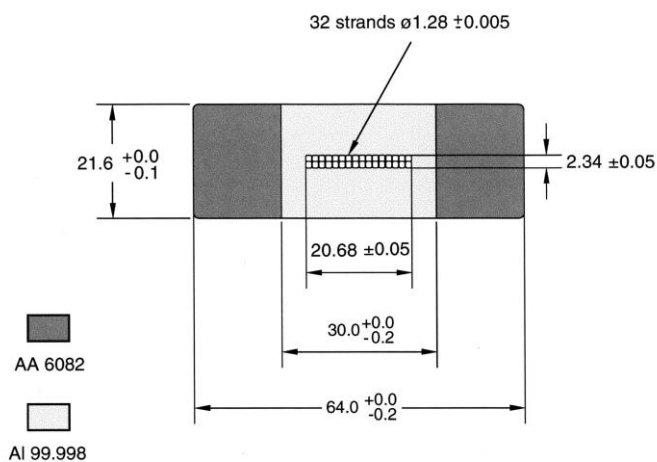
Equipment and operator by ETH Zurich

III-3 DIMENSION CHECK

- 4 inclined laser scanners



- Thickness tolerance 100µm



IV EXPERIENCE

- Processing of stiff bars before and after welding
- Micrometer machining of profile in movement
- Managing the risk of overheating of Rutherford cable
- High quality electron beam welding within specifications
- Managing of large number of operations at synchronised work stations
- Production process management & quality assessment

Greatest challenge → Simultaneous control of work stations

Electronbeam welding → No special issues

**Specification adjustment: → 30mm non bonded allowed
stop & restart after 12h welding**

TIME LINE

- **1999** > **Order** May 3th
- **1999-2000** > **Realisation** of equipment
- **2001-03** > **Production period – Successful cooperation** with ETHZ
20 coils of 2.55km + 1 test coil
No retreatment of complete coil
No major incident
- **2003..** > **TECHMETA: Cristal Globe Award** 2003 from CERN/CM
> **CMS - Successful assembly** of High field coil
- **2003.. 2022** > **TECHMETA's developments and skills:**
Improved Flash management
Improved Beam generation & guidance
High speed seam tracking
Ultra sonic testing
> **CMS - Successful use** of high field coil

Reinforcement EB-welding

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Proven process

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2023 and further on...

TE > Ready for new challenges

OUR EB SOLUTIONS MEET ALL YOUR CHALLENGES

TECHMETA
ELECTRON BEAM EXPERT
Engineering

'Simplicity is complexity resolved' – C. Brancusi

141 route des Machurettes
74370 METZ-TESSY
FRANCE