



Production of SQXF Magnet Components: Return on experience

P.MOYRET
EN-MME-FS

Introduction

Design Optimization

Production Processes

Results

Cost Analysis

Production option for 10 MQXF

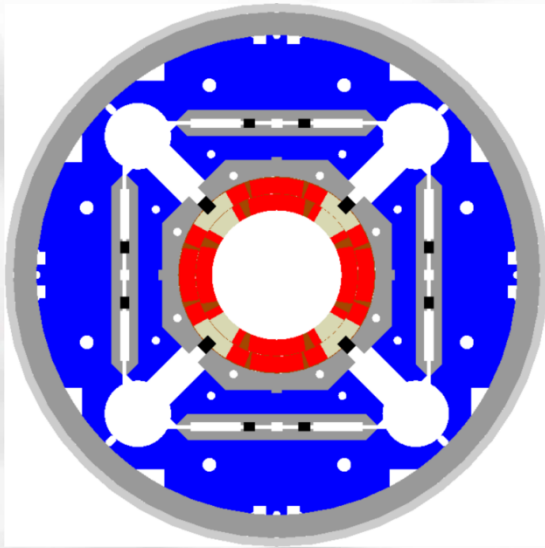
SQXF magnet 150 mm



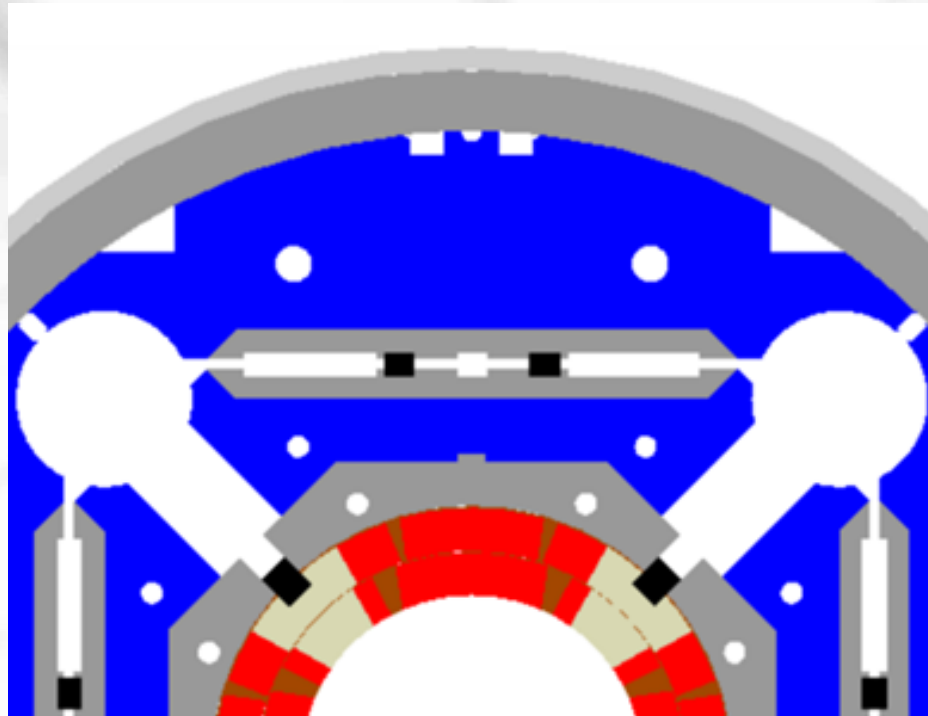
INTRODUCTION

- ✓ Request from TE-MSU (received in March 2014) to supply 2 SQXF magnets (length 1.5 m) plus 1 magnet mock-up of 150 mm.
- ✓ Agreed Date of delivery: End of October 2014 (7 months available for production)

- ✓ Initial design

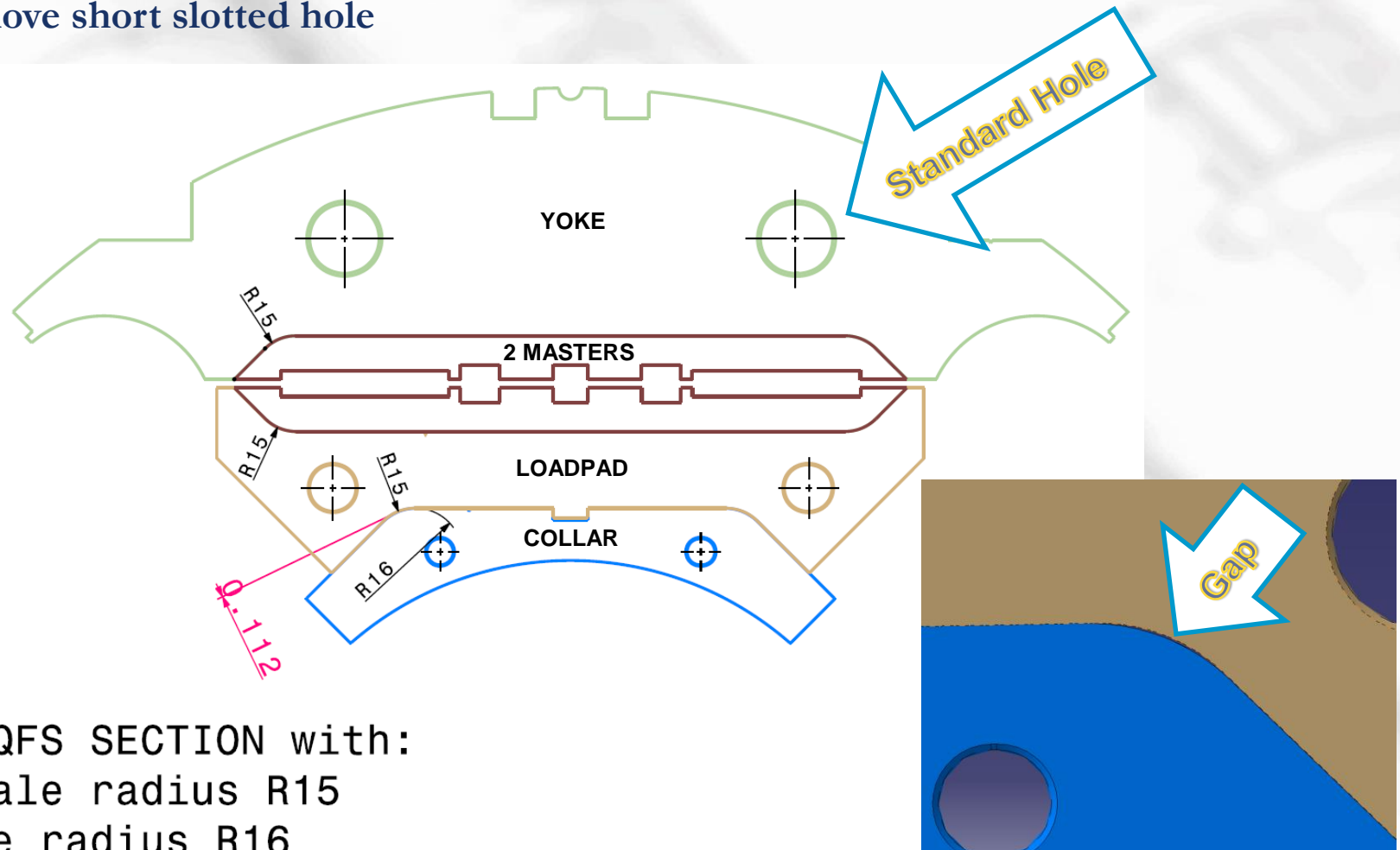


Initial cross section SQXF



Detail initial cross section SQXF

- ✓ Proposal to replace sharp edges with radii for two main reasons...
- ✓ Remove short slotted hole



1/4 MQFS SECTION with:

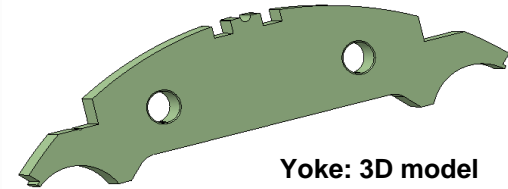
- Female radius R15
- Male radius R16

Detail offset between radius SQXF

✓ Yoke and Load pad:

✓ Detail of the Yoke machining procedure:

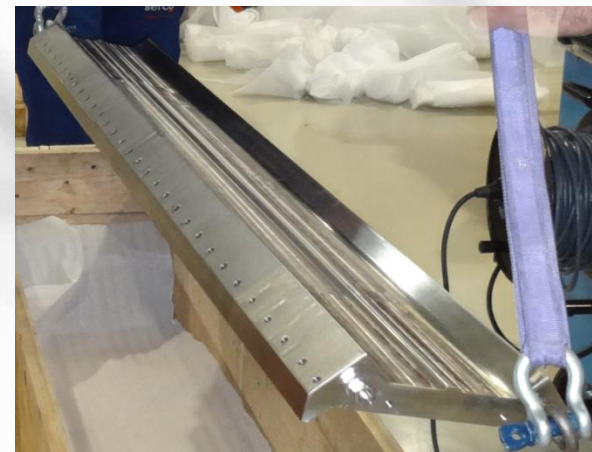
1. Cutting of blocks (sawing) from ARMCO sheet th. 55 mm.
2. Machining using dovetail joints for clamping on both extremities.
3. Milling down to 50mm, drilling holes and rough machining of the lower profile.
4. Rough machining of the upper radius.
5. Assembly.
6. Final machining of the upper radius.
7. Final machining of the lower profile using the side notches for precise positioning.



Yoke: 3D model



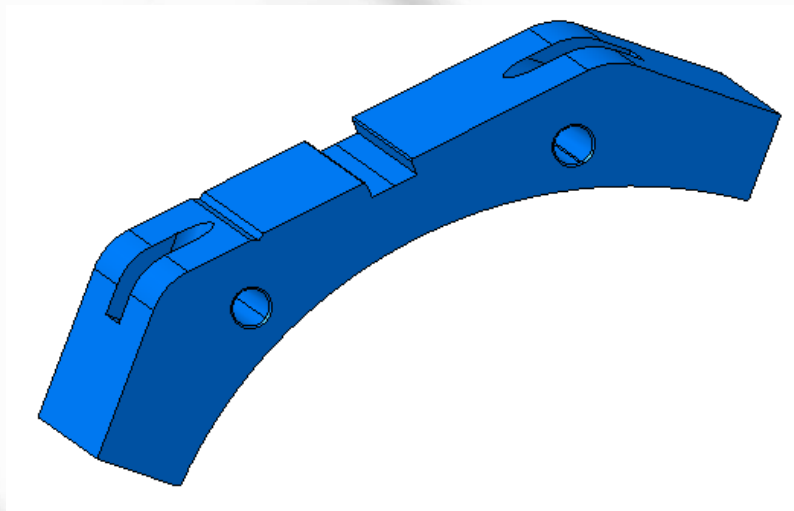
Yoke stack 1.5m



Load-pad stack 1.5m

✓ Collar produced by EDM machining:

1. Cut the Al6082 T6 plate 160x400 mm, thickness 55 mm,
2. Milling both surfaces to thickness 50.3 mm
3. Drilling the holes for the wire erosion
4. Grinding to the final thickness
5. EDM wire cutting. Single step is enough to reach the required tolerance
6. Milling the radial holes



Collar: 3D model

RESULTS AND METROLOGY MEASUREMENTS

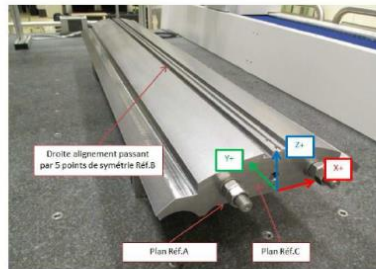
✓ Yoke:

RAPPORT DE CONTROLE

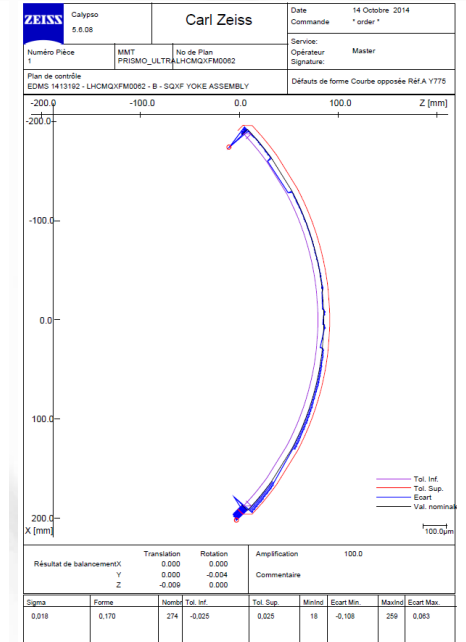
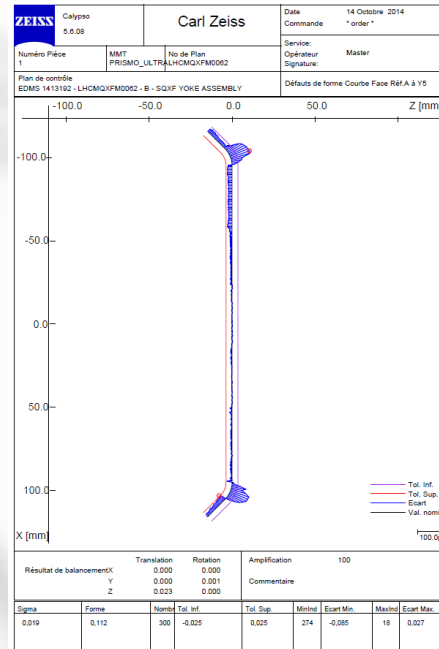
Nom du plan de contrôle: EDMS 1413192 - LHCMQXF0002 - B - SQXF YOKE ASSEMBLY
 N° de plan: SQXF YOKE ASSEMBLY
 Indice du plan: LHCMQXF0002
 Client: PEREZ Juan carlos
 N° de pièce: 1
 N°EDMS: 1413192

Date: 14/10/2014 14:47
 Contrôleur: HAERINCK Caryl
 CMM type: PRISMO_ULTRA
 Incertitude de mesure: 1.2µ + L/500 (L en mm)
 Température: 20°C ±1°C

Informations relatives au référentiel de mesure



Construction du référentiel de base:
 - Orientation primaire: Plan Ref.A
 - Orientation secondaire: Droite alignement passant par 5 points de symétrie
 - Origine: X et Y = Intersection de la droite alignement passant par 5 points de symétrie et le plan Ref.C
 Z = Plan Ref.A



✓ Load pad:

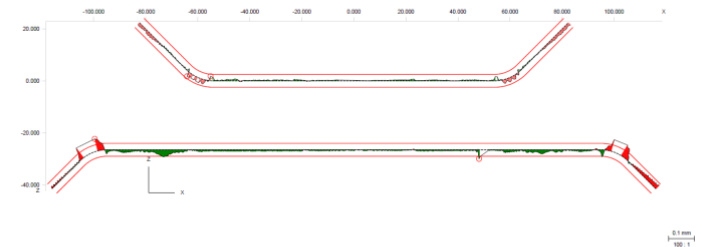


Calypso 5.6.08 Carl Zeiss Date Commande 29 Octobre 2014

Service: Master
 Opérateur: Master
 Signature: Master

N° de Plan: EDMS.1427346-LHCMQXF00056-LOADPAD COU...

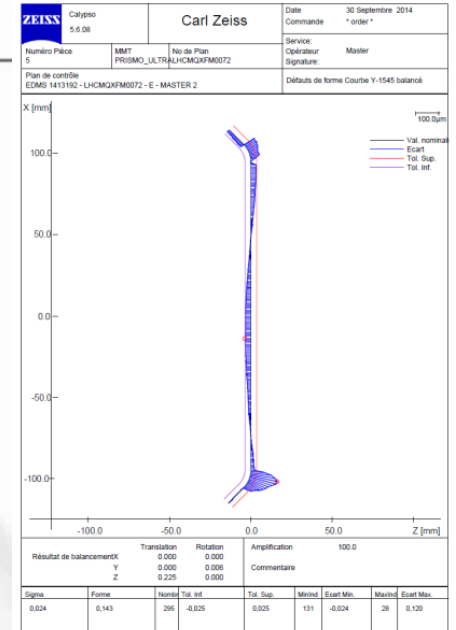
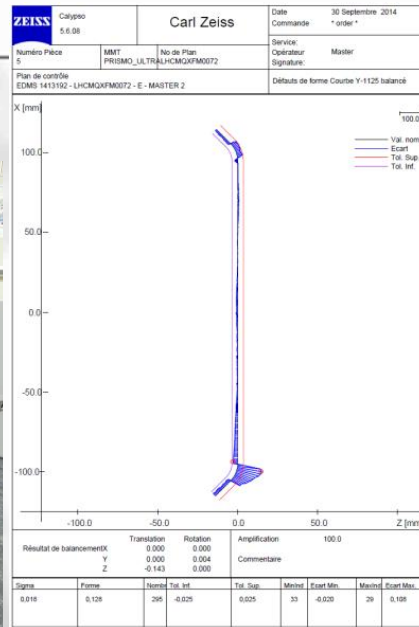
1: Défauts de forme sup 1



No	Designation	Sigma [mm]	Forme [mm]	Nombre	Tol. Inf. [mm]	Tol. Sup. [mm]	Minid	Ecart Min. [mm]	Maxid	Ecart Max. [mm]
1	Défauts de forme sup 1	0.005	0,035	588	-0,025	0,025	97	-0,018	120	0,017
2	Défauts de forme inf 1	0.009	0,083	2872	-0,025	0,025	2659	-0,048	825	0,035

RESULTS AND METROLOGY MEASUREMENTS

✓ Master:



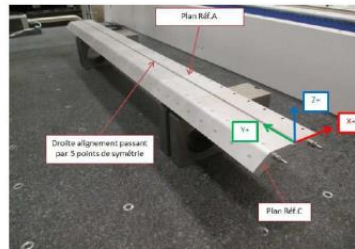
✓ Collar:

RAPPORT DE CONTROLE

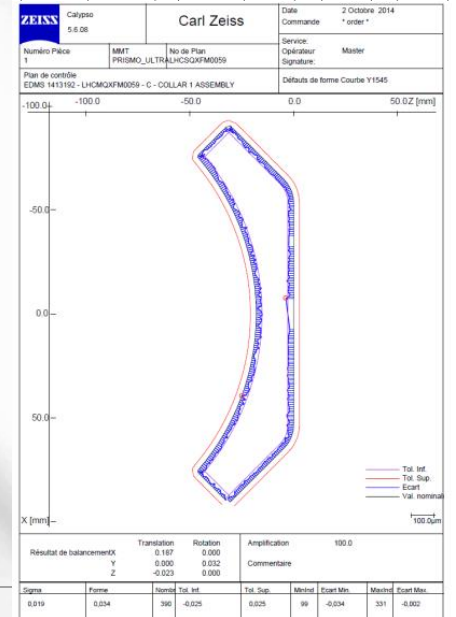
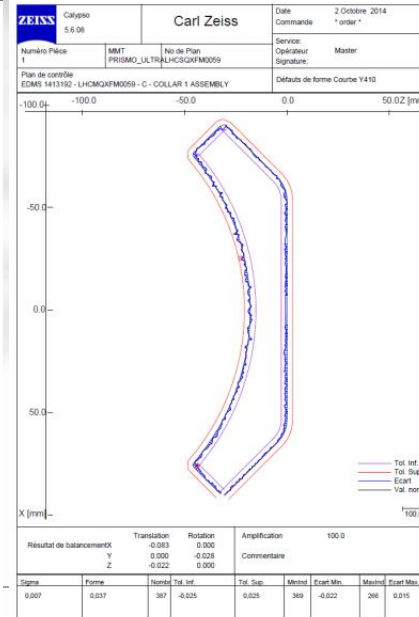
Nom du plan de contrôle: EDM5 1413192 - LHC3QXFM0059 - C - COLLAR 1 ASSEMBLY
 Nom de la pièce: COLLAR 1 ASSEMBLY
 N° de plan: LHC3QXFM0059
 Indice du plan: C
 Client: PEREZ Juan Carlos
 N° de pièce: 1
 N°EDMS: 1413192

Date: 02/10/2014 10:35
 Contrôleur: HAERNDCK Cyril
 CMM type: PRISMO_ULTRA
 Incertitude de mesure: 1.2µ + L/500 (L en mm)
 Température: 20°C ±1°C

Informations relatives au référentiel de mesure



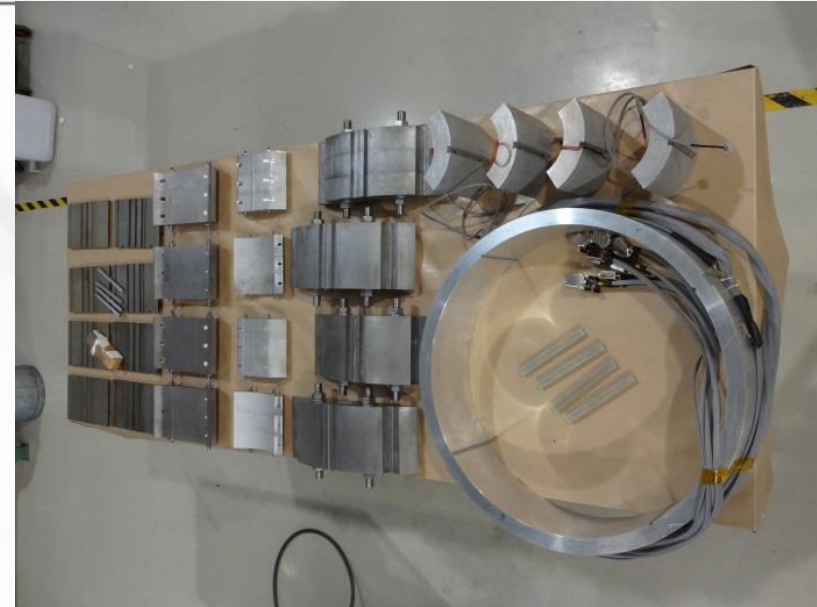
Construction du référentiel de base:
 - Orientation primaire: Plan Ref.A
 - Orientation secondaire: Droite d'alignement passant par 3 points de symétrie
 - Origine: X et Y: intersection de la droite d'alignement passant par 3 points de symétrie et le plan du bout; Z: Plan Ref.A



1 SQXF mock-up 150 mm
with dummy coil:
37 kCHF

2 SQXF lg 1500 mm

- ✓ Yoke and Load pad (ARMCO):
 - ✓ Production by EDM: **(401 kCHF)**
 - ✓ Production by milling:
- ✓ Master, dummy coil and keys by milling:
- ✓ Collar (Aluminium) by EDM (material included):
- ✓ Shell (without raw material), 4x 750 mm:
- ✓ ARMCO material, th 20, 30, 55, 70 mm:



SQXF 150 mm components

206 kCHF
59 kCHF
31 kCHF
20 kCHF
52 kCHF

Total: 368 kCHF (~125 kCHF/m)

- ✓ **Successful results obtained by machining 1,5m long stacks**
- ✓ **Same approach could be extended to an eventual series production**
- ✓ **EDM guarantees very precise components but is competitive only for Aluminium.**

PRODUCTION OPTION FOR 10 MQXF

	BASELINE (1.5 m long stacks)			POSSIBLE ALTERNATIVE (Fine blanking)		
COMPONENTS	RAW MATERIAL	PRODUCTION PROCESS	PROS AND CONS	RAW MATERIAL	PRODUCTION PROCESS	PROS AND CONS
YOKE	ARMCO Sheet th. 55 mm Weight: 110 T	Milling 1.5 m long stacks	<ul style="list-style-type: none"> - Good flatness - Very good quality of the assembly - Limited tolerance dispersion in the production - Standard raw material - Expensive w.r.t Fine blanking 	ARMCO Sheet th. 5 mm Weight: 110 T Specific order Specific corrosion protection	Fine blanking	<ul style="list-style-type: none"> - Cheap process - Specific tool to be developed - Specific raw material - Assembling more difficult - Require s close Follow up - Development: ~1 year
LOADPAD	ARMCO SHEET th. 55 mm Weight: 50 T	Milling 1.5 m long stacks	“	ARMCO SHEET th. 5 mm Weight: 50 T	Fine blanking	“
COLLAR	Aluminium Al 6082 Sheet th. 55 mm Weight: 8 T	EDM single part	<ul style="list-style-type: none"> - Good flatness - Limited tolerance dispersion in the production - Expensive process 	Aluminium Al 6082 Sheet th. 5 mm Weight: 8 T Specific order	Fine blanking	“
MASTER KEY	Bronze Sheet th. 12 mm Weight: 500 Kg	Milling 1.5 m long part	<ul style="list-style-type: none"> - Not expensive - Good flatness - Good geometry 	Bronze Sheet th. 12 mm Weight: 500 Kg	Milling 1.5 m long part or... Extrusion?	<ul style="list-style-type: none"> - Good flatness - Good geometry
MASTER	ARMCO Sheet th. 20 mm Weight: 26 T	Milling 1.5 m long part	<ul style="list-style-type: none"> - Not expensive - Good flatness - Good geometry 	ARMCO Sheet th. 20 mm Weight: 26 T	Milling 1.5 m long part	<ul style="list-style-type: none"> - Not expensive - Good flatness - Good geometry

PRODUCTION OPTION FOR 10 MQXF

	BASELINE (1.5 m long stacks)			POSSIBLE ALTERNATIVE (Fine blanking)		
COMPONENTS	RAW MATERIAL	PRODUCTION PROCESS	COSTS ESTIMATION	RAW MATERIAL	PRODUCTION PROCESS	COSTS ESTIMATION
YOKE	ARMCO Sheet th. 55 mm Weight: 110 T	Milling 1.5 m long stacks	2.2 MCHF	ARMCO Sheet th. 5 mm Weight: 110 T Specific order Specific corrosion protection	Fine blanking	625 kCHF - Material: 350 kCHF - Tool: 80 kCHF - Parts: 110 kCHF - Assembling + bushings: 85 kCHF
LOADPAD	ARMCO SHEET th. 55 mm Weight: 50 T	Milling 1.5 m long stacks	1.75 MCHF	ARMCO SHEET th. 5 mm Weight: 50 T	Fine blanking	385 kCHF
COLLAR	Aluminium Al 6082 Sheet th. 55 mm Weight: 8 T	EDM single part	675 kCHF	Aluminium Al 6082 Sheet th. 5 mm Weight: 8 T Specific order	Fine blanking	225 kCHF
MASTER KEY	Bronze Sheet th. 12 mm Weight: 500 Kg	Milling 1.5 m long part	65 kCHF	Bronze Sheet th. 12 mm Weight: 500 Kg	Milling 1.5 m long part or... Extrusion?	65 kCHF
MASTER	ARMCO Sheet th. 20 mm Weight: 26 T	Milling 1.5 m long part	475 kCHF	ARMCO Sheet th. 20 mm Weight: 26 T	Milling 1.5 m long part	475 kCHF

✓ Total cost via machining process: 5165 kCHF
(74 kCHF/m)
(SQXF~125 kCHF/m)

✓ Total cost via fine blanking process: 1775 kCHF
(25 kCHF/m)

Add 10% on the total price for the special lamination milled with radial threads

✓ Machining process is a successful approach:

- ✓ “Well known” process.
- ✓ Very good tolerances obtained
- ✓ No step between each part over 1,5m stack assembly.
- ✓ Limited tolerance dispersion in the production.
- ✓ Can be easily extended to the series production.
- ✓ Careful attention to be paid to the assembly of the stacks for 7m long magnets

✓ Fine blanking is cheaper but...:

- ✓ Requires design optimisation for final decision
- ✓ Requires new SQXF prototype to be produced
 - ✓ Validation of the assembly procedure through a proto produced via EDM?
 - ✓ Risk of step between each lamination
- ✓ Specific ARMCO (160T) and Aluminium (8T) sheets necessary
 - ✓ To limit possible perpendicular and flatness defect
 - ✓ Quantity for a special sheet production is quite small!
 - ✓ Possibly regroup orders for other ongoing projects?
- ✓ New development necessary: 1 ÷ 1.5 year (material + manufacturing)
 - ✓ Close follow up required (1 person 100%)
 - ✓ Risk of tolerance dispersion during the production



Thank you for your kind attention

Acknowledgment:

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