MQXF Q1/Q3 Conductor Procurement

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MQXF Conductor Review
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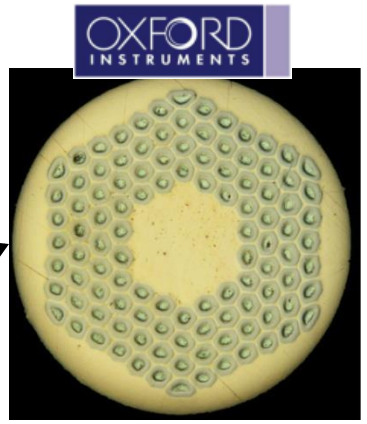
CERN

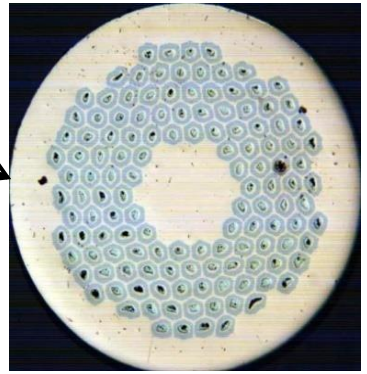
Outline

- Introduction
- MQXFS and MQXFL Magnet Strand and Cable
  - Strand procurement for the prototype magnet (qualification phase or pre-production phase)
- MQXF Strand Production/Procurement Plan
  - Phase I followed by Phase II production
  - QA/QC plan at vendor and within the project
- MQXF Cable
  - Cabling,
  - Insulation and Testing
  - QA
- Summary

Introduction

- For the MQXF Q1/Q3 Magnets we will likely use RRP® wire from Oxford Superconducting Technology
- Strand diameter 0.85 mm
  - Ti-Ternary Nb_3Sn
- Cable is a 40- strand Rutherford Cable with stainless steel core
- The 1st Short model MQXFS magnet is using coils made with 108/127 strand.
- Subsequent Short and Long MQXF magnets will use 132/169 design wire (smaller filament diameter)
- Final Specification Documents for the MQXF magnet strand will be released in June'2015.
  - It will be a performance based specification as is currently being used for LARP strand procurements.





LARP-MAG-M-8004-Rev. B (Present spec.)

Process	Ti-Ternary RRP® Nb_3Sn
Strand Diameter, mm	0.85 ± .003
I_c(12 T) at 4.2 K, A	≥ 684
I_c(15 T) at 4.2 K, A	> 361
n-value	> 30
D_s, µm (sub-element diameter)	< 60
Cu-fraction, %	> 53
RRR (after full reaction)	≥ 150
Twist Pitch, mm	14 ± 2
Twist Direction	Right-hand screw
Minimum Piece length, m	750
High temperature HT duration, h	≥ 48

D_s sub-element diameter
I_c Critical Current
RRR residual resistivity ratio

MQXF Strand Specification

Process	RRP® or PIT Nb3Sn
Strand Diameter, mm	0.850 ± .003
I_c(15 T) at 4.2 K, A	> 361
n-value	> 30
I_c(12 T) at 4.2 K, A (Reference Only)	(> 632)
D_s, µm (sub-element diameter)	< 50
Cu : Non-Cu volume Ratio	1.2 ± 0.1
RRR (after full reaction)	≥ 150
Twist Pitch, mm	19 ± 2
Twist Direction	Right-hand screw
Strand Spring Back, deg.	< 720
Magnetization Width at 3 T, 4.2 K, mT	< 300
Minimum Piece length, m	TBD

LARP-MAG-M-8007 Rev.0 (TBR)

Process	Ti-Ternary RRP® Nb_3Sn
Strand Diameter, mm	0.85 ± .003
I_c(15 T) at 4.2 K, A	> 361
I_c(12 T) at 4.2 K, A (for reference)	(≥ 632)
n-value	> 30
D_s, µm (sub-element diameter)	< 50
Cu : Non-Cu volume Ratio	1.2 ± 0.1
RRR (after full reaction)	≥ 150
Twist Pitch, mm	19 ± 2
Twist Direction	Right-hand screw
Strand Spring Back, deg.	< 720
Magnetization Width at 3 T, 4.2 K, mT	< 300
Minimum Piece length, m	550
High temperature HT duration, h	≥ 48

D_s sub-element diameter
I_c Critical Current
RRR residual resistivity ratio

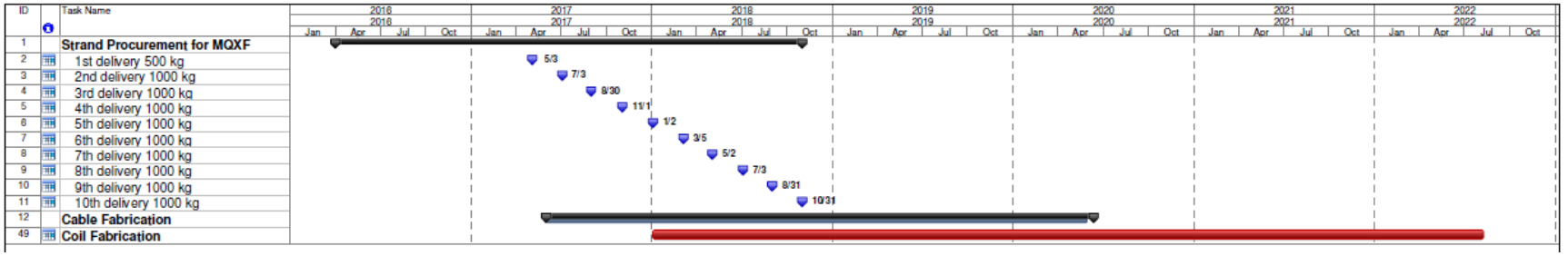
Procurement Plan for MQXF RRP-132/169 strand leading up to the Prototype magnet

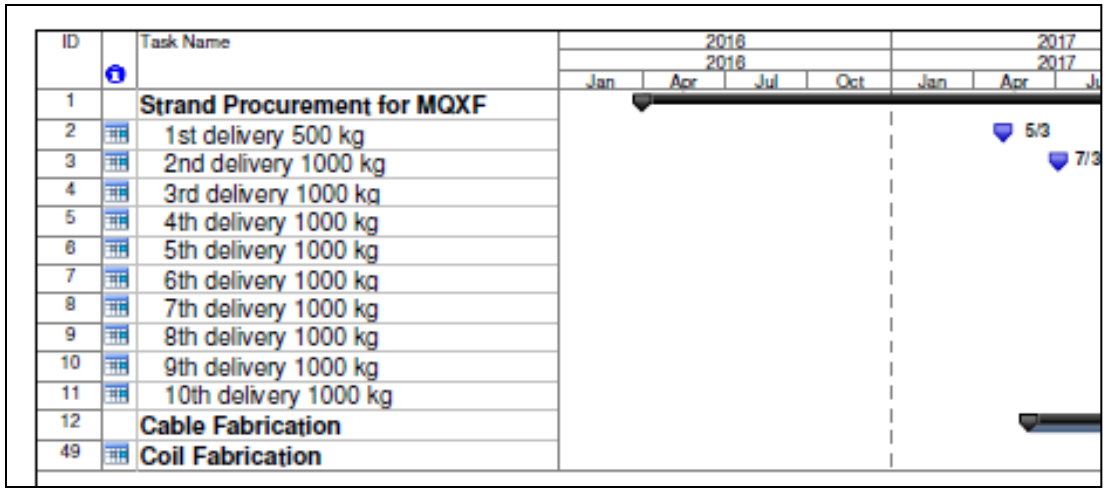
- Require 6 coils for short MQXF; cable unit length 150 m
- Require 16 coils for Long MQXF; cable unit length 450 m
- Assuming 12% loss in strand from cable mapping
- Total length of strand for MQXFS: ~ 50 km (250 Kg)
  - 55 km of strand is in inventory
- Total length required for MQXFL: 350 km (~ 1750 Kg)
  - 12 km in inventory
  - 17 km awaiting delivery pending all tests
  - A total of 320 km has to be procured in FY'15 & FY'16
- Present specification LARP-MAG-M-8004 Rev. B
  - Is being replaced by LARP-MAG-M-8007

Procurement Plan for MQXF Q1/Q3Magnets

- Require 90 coils for Q1 and Q3
- Unit length of cable : 450 m
- Assuming 12% loss in strand from cable mapping
- Total length of strand for UL of cable: 22.4 km
- Total length required for project: 2016 km (~ 10,000 Kg)
  - ~ 225-250 billets depending on yield
  - Present billet size is 45 Kg
- Coil production start: Jan'2018
- Cable Production start: June 2017
  - Final Strand Specification set June'2015
  - RFP sent out Oct'2015
  - Contract placed Apr'2016
  - Phased Production
    - Phase 1 : First delivery of 500 Kg May'2017
    - Phase 2 : Production Phase July'2017 through Oct'2018
  - Delivery complete Oct'2018

Strand Delivery Schedule





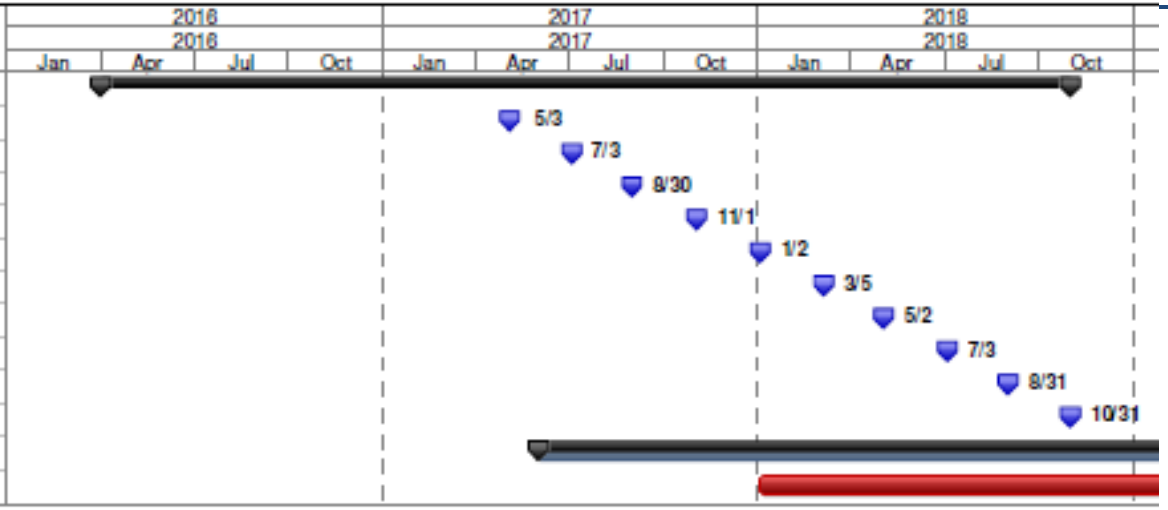
First delivery after 12 months of placing of contract

Cable mapping using first 500 Kg of wire

1 UL will use wire from at least 3 billets

Strand Delivery Schedule

ID	Task Name
1	**Strand Procurement for MQXF**
2	1st delivery 500 kg
3	2nd delivery 1000 kg
4	3rd delivery 1000 kg
5	4th delivery 1000 kg
6	5th delivery 1000 kg
7	6th delivery 1000 kg
8	7th delivery 1000 kg
9	8th delivery 1000 kg
10	9th delivery 1000 kg
11	10th delivery 1000 kg
12	**Cable Fabrication**
49	**Coil Fabrication**

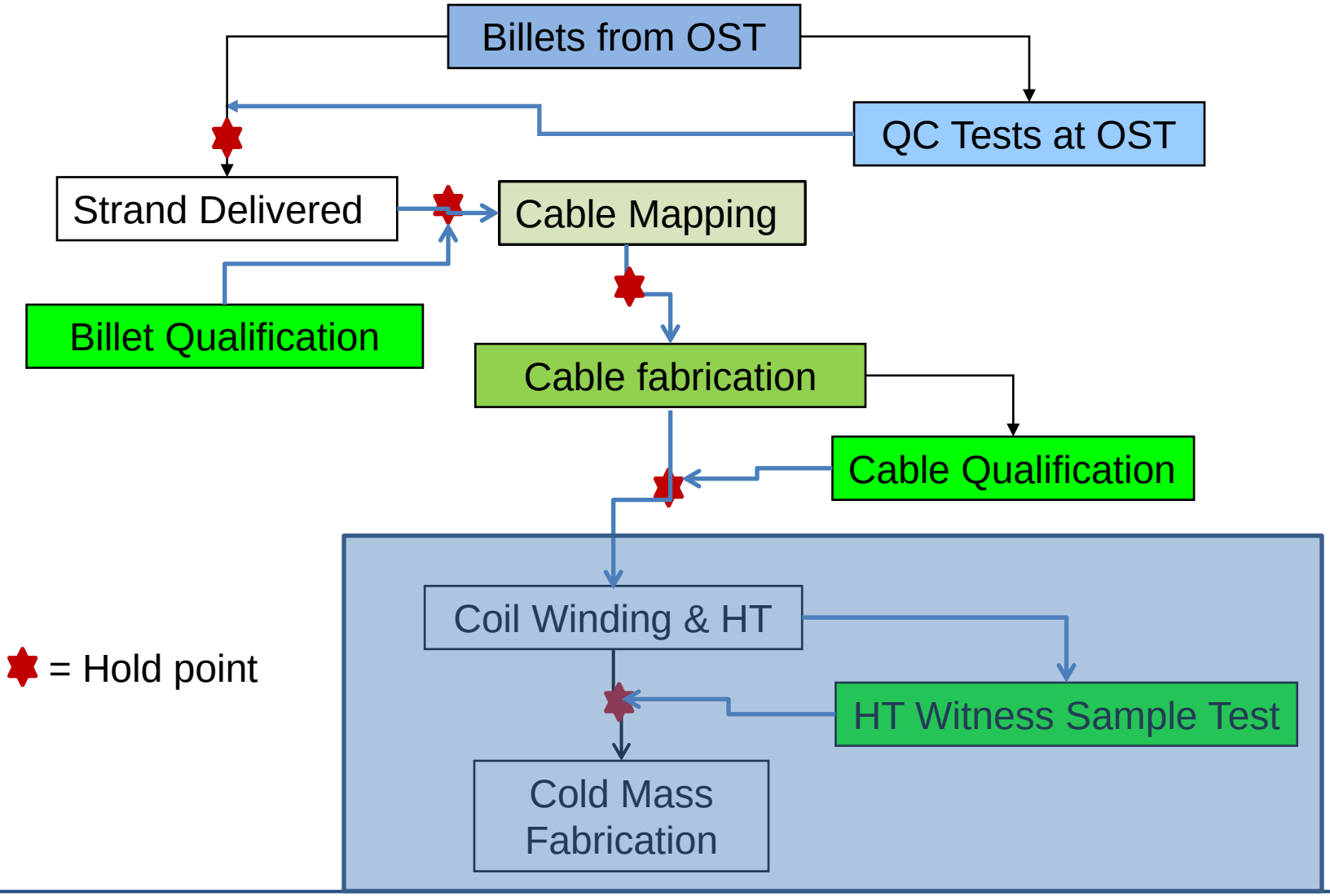


OST (most likely vendor for RRP wire) has sufficient capacity to handle both CERN and US orders in the same time frame. Production rate ~ 1 metric ton/month. During ITER the production rate was ~ 2 tons/month.

Cabling and Insulation Plan

- Cabling at LBNL
- Cabling to start 5-6 months in advance of start of coil winding.
- Cabling Start June 2017
  - Unit length is fabricated within 1 week.
- Cabling throughput required 2 UL's / month at start, ramping to 3 UL's/month by July'2018
- S2 glass Insulation braided directly onto cable
- Vendor: New England Wire Technology (qualified)
  - Sufficient capacity to keep up with cabling rate, 2 braiders available.
  - Unit length insulated within 5 working days.

QA-Plan
Conductor Qualification - 1



Conductor Qualification -2

- Billet Qualification
  - Primarily based on vendor QA/QC
  - Apply SPC to track uniformity of strand production
  - QC tests on a smaller subset of samples at a US lab
  - Phase I will have more extensive checks than Phase 2
  - OST data will be verified periodically with measurements at a US lab.
- Cable Qualification
  - This is important and needs to be completed prior to coil winding.
  - Mechanical tests, metallographic test, insulation thickness
  - I_c and local RRR electrical test: minimum 3 extracted strand and one round wire
    - Heat Treatment schedule (HT) as specified for coil reaction

Strand QC Tests and Reports

- QC Tests and Reports
  - Cu/Non Cu
  - Twist Pitch and Twist Direction
  - Ic, n-Value, RRR
  - Magnetization Width
  - Wire Springback
  - Surface Cleanliness Certification
    - Eddy Current Certification
  - Final Wire Diameter
  - Piece Length
- Material Certifications:
  - Tin Rod
  - Niobium Rod
  - Niobium/Titanium Rod
  - Niobium Sheet
  - Copper Tube

Ian Pong will elaborate on the QA/QC plan

Cable QC Tests and Reports

- QC Tests and reports
  - Cable dimensions from CMM
  - Cable 10-stack measurements
  - Cable cross-section microscopy
  - Cable Residual Twist
  - RRR of Extracted strand
  - Ic, n value of extracted strands
  - Cabling Report
  - Cable Piece Length
  - Insulation thickness
- Material Certifications:
  - Insulation fiber
  - Stainless Steel core

Summary

- Strand procurement has been planned to meet coil winding schedule.
  - Strand production will last for 30 months
  - Phase I used to assess vendor QA/QC and set control limits on full production
- Cabling start is planned for 5 months before coil winding
  - Goal is to be well ahead of cable required for coil winding
- Peak cabling rate of 3 unit lengths/ month during production can be handled at LBNL
  - Cable throughput ramps up after one year of operation.
- Final Specification documents and Strand and Cable production QA plan to be released in time for strand RFP (Request For Proposal) solicitation in Oct'2015.

End of Presentation

Cable Insulation

- Insulation is braided directly on cable
  - New England Wire Technology (NEWT)
- Using S-2® glass (from AGY) with 933 Silane sizing
- 6 lengths of MQXF cable (170 m long) has been insulated
  - Using braiding parameters to yield target specification of 0.145 ± 0.005 mm thickness
  - 10-stack measurements at 5 MPa are used to determine insulation thickness
  - Thickness can be readily adjusted to meet any change to present specification.