Accelerator Technology Department

SM-18 Operation & Related Issues

V.Chohan
CERN, Geneva, Switzerland

Review of the Tests of Superconducting Magnets in SM18
14 January 2005

Accelerator Technology Department

Talk Outline

- The Environment
  - Present Working Conditions
  - Consequences
- Current Status
  - Summary 2004
  - Further Statistics
- Future & Outlook

Accelerator Technology Department

The Environment

Accelerator Technology Department

Environment

- **Fixed**
  - 12 Test Benches arranged in pairs so, 6 clusters(A to F)
  - 6 Main Power Converters
  - 6 sets of Electronics for testing 1 per cluster
- **Mobile**
  - For Q-location & MM we need to install Special 15 m Shafts
  - Shafts require Anticryostat mounting in magnets
  - Mobile Racks for HV insulation tests & Magnetic Measurements
- **Utilities**
  - Water for 4 magnet powering at the same time
  - Cryogenics capacity and limits
- **Manpower [24 hr Tests Operation Staff special arrangements]**
  - 7 CERN staff on loan from CERN Accelerator Operation
  - 15-20 persons on exact 1 year contracts from India & constantly rotating
  - Cryogenic Support staff (3 per shift) from Industrial Support contract
  - ICS "Magnet connectors" working 24 hours since June 2004, but not ROCLA operators
- **Support**

  Generalized Equipment support as opposed to specialized support as found in 24 Hr. OPERATION in CERN & "physics" is not at stake if specialist 'fixing' is delayed

Accelerator Technology Department

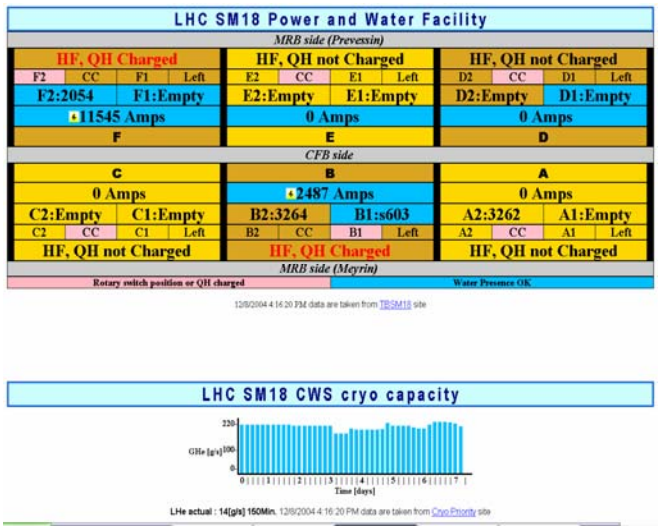
The Environment and Consequences

All the Above implies that to test the LHC magnets at 1.9K and in advancing the tests work, we have a constant juggling exercise in the optimal usage of resources, namely :

1. **Equipment for Testing** (Benches, Electronics, specialised equipment for Quench location & Magnetic Measurement)
2. **Utilities** (Water, Power & Cryogenics)
3. **Staff with frequent & rapid turnover** (hence constant vigilance on Knowledge Management Issues and Facilitation – always on "learning curve")

Accelerator Technology Department

Utilities: Water,Power & Cryo-CWS



Resource Monitoring

Accelerator Technology Department

Utilities : Cryogenics Capacity

- **Cryogenics capacity (in 2004) and limits :**
  - **3 to 5** Magnets @ 1.9K and under cold tests,
  - **1** magnet in 300K to 90 K phase ,
  - **1** magnet in Last (Warm up) Quench to 300K phase,
  - **1** magnet in 90K to 1.9 K phase

with a further capacity constraint of not exceeding 9 recoveries of high field quenches or initial cooling from 4.2 K to 1.9 K per 24 h

We need to ensure that the magnets under the tests programme follow the cryogenic phase distribution as above, within the limits of possibilities due to the varying training performance (a priori not known) and respecting all the other environment constraints mentioned earlier

Accelerator Technology Department

Shared Resources & Priorities as seen from Cryogenic Operation

CRYOGENICS PRIORITIES & RESOURCES USAGE ON Sunday 17 October 2004 5:34:33 PM

MAIN PRIORITY				CWS [g/s]			PRIORITIES			COMMON RESOURCES
LEVEL	MAIN	MAGNET	T Mag[K]	COOL	WARM		CWS	LHe	1.9 [K]	
1	D1	ss62	1.9				E2	D1	D1	
2	F2	3227	1.93				D1	F2	F2	
3	A2	3224	1.9				F2	A2	A2	
4	B1	ss53	1.9				A2	B1	B1	LHe DEWAR LEVEL: 61 %
5	E2	3207	195		92		B1	C1	E2	LN2 DEWAR LEVEL: 58 %
6	C1	3234	18.7				C1	B2	C1	BALLON VOLUME: 58 m^3
7	E1	1075	298				E1	E2	E1	
8	A1	3131	297				A1	E1	B2	1.9 [K] Pumping Resources: 5(WPU1) + 0(WPU2) = 5 [g/s]
9	B2	ss64	89				B2	D2	D2	
10	D2	ss66	296				D2	C2	C2	
11	C2	3164	298				C2	F1	F1	
12	F1	1156	296				F1	A1	A1	

Lots of simplification & ease thanks to ACR team of :Tovar, Axensalva & Lamboy

Accelerator Technology Department

Setting Priorities from Tests Operation

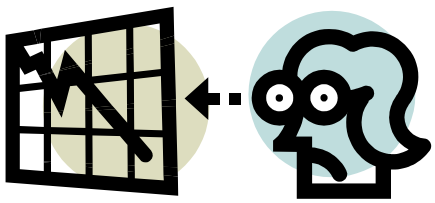
Cold Tests	Bench	Temp.	Priority
10 - 1.9 [K] since 4h 55' (PT 6.6 Training 6)	TBA2	1.9	3
10 - 1.9 [K] since 12h 39' (powering IJ)	TBB1	1.9	4
10 - 1.9 [K] since 57h 9' (Stretched Wire Cold SC23)	TBD1	1.9	1
10 - 1.9 [K] since 53' (PT 6.2 Training 2)	TBF2	3.2	2
Warming up or Cooling Down	**Bench**	**Temp.**	**Priority**
6 - COOLDOWN TO 80 [K] since 4h 53' (Prep 5 Pumping + Cool Down)	TBB2	89	9
13 - WARM UP TO 300 [K] since 5h 17' (PT 12 Warm Up)	TBE2	183.1	5
Cooling 80 K to 4K	**Bench**	**Temp.**	**Priority**
9 - LHe FILLING since 5h 18' (Prep 5 Pumping + Cool Down)	TBC1	49	6
Warm	**Bench**	**Temp.**	**Priority**
6 - COOLDOWN TO 80 [K] since 4h 53' (CR 1 Leak Test)	TBA1	296.4	8
2 - CONNECTING MAGNET since 1h 5' (ICS 2 Connect Magnet (ICS))	TBC2	298	11
52 - OVC PURGE since 9h 9' (ICS 4 Final connection)	TBD2	296.3	10
52 - OVC PURGE since 53' (ICS 4 Final connection)	TBE1	297.1	7
2 - CONNECTING MAGNET since 2h 1' (ICS 2 Connect Magnet (ICS))	TBF1	295.2	12
Other	**Bench**	**Temp.**	**Priority**

Send those priorities to Cryo team

10/17/2004 5:04:35 PM data are taken from TBSM18 site

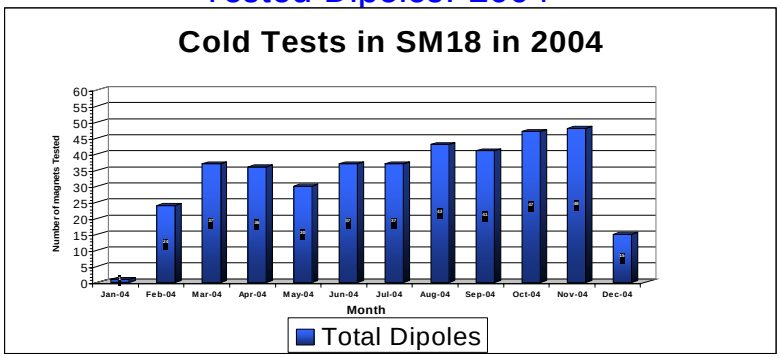
Accelerator Technology Department

Current Status to end December 2004



Accelerator Technology Department

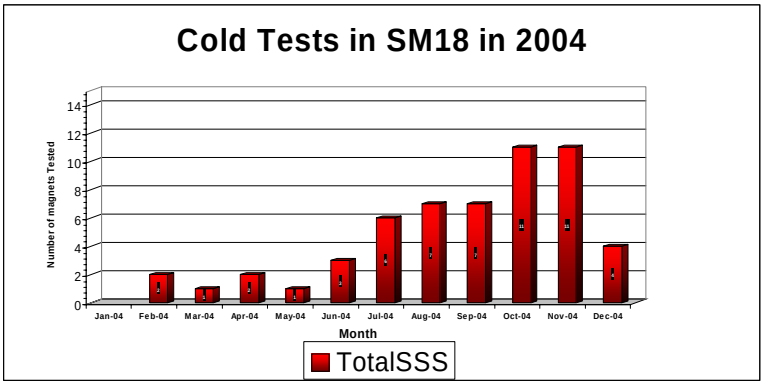
Tested Dipoles: 2004



- A total of **396 Dipole** magnets were tested during the year 2004, these include repeat magnets
- A conservative estimate of **45 Dipole** magnets per month could be expected during year 2005, with the present environmental / test conditions

Accelerator Technology Department

Tested SSS: 2004



- A total of **55 SSS** magnets were tested during the year 2004, these include repeat magnets & Special SSS
- A conservative estimate of **10 SSS** magnets per month could be expected during year 2005, with the present environmental / test conditions

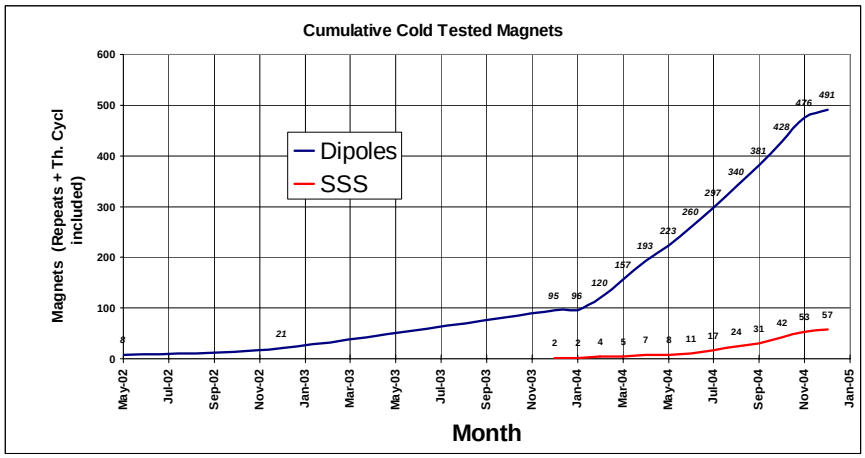
Accelerator Technology Department

Summary: Raw Cold Tests

	Dipoles	Dipoles Repeated	ARC-SSS	IR-SSS	SSS Repeated
Year 2003	95	**Not Applicable**	2	**Not Applicable**	**Not Applicable**
Year 2004	358	38 (about 11%)	49	3	3 (about 6 %)
TOTAL 2004	396 **Includes Rejects & Repeats**		55 **Includes Rejects & Repeats**		
Cumulative Total	**491**		**57**		

Accelerator Technology Department

Cumulative Total: All Magnets



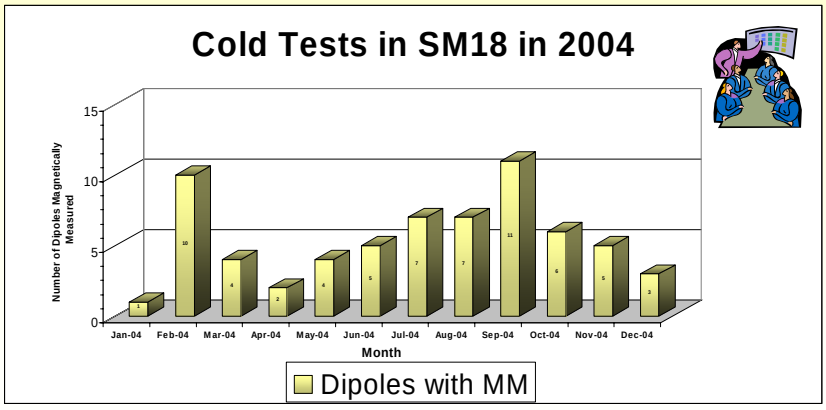
Accelerator Technology Department

Further Statistics

Accelerator Technology Department

Statistics

- Magnetic Measurements

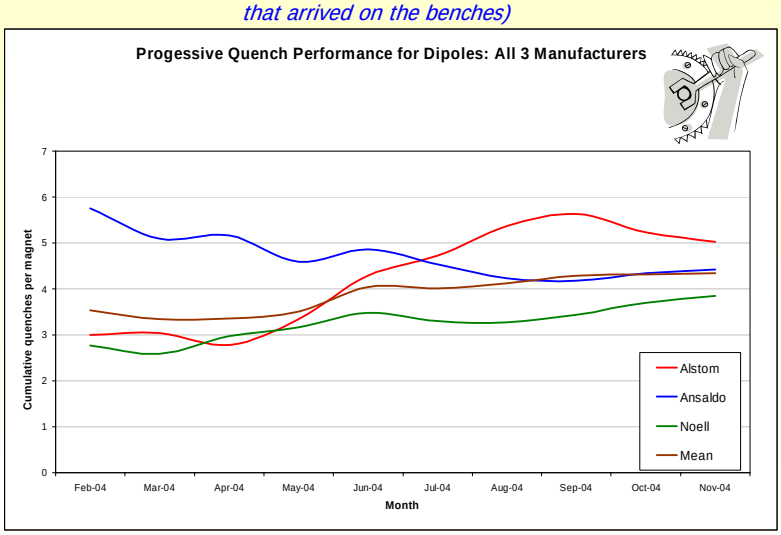


Measurements were done on **65 Dipoles** during 2004 with shafts**(16.41%)**

Accelerator Technology Department

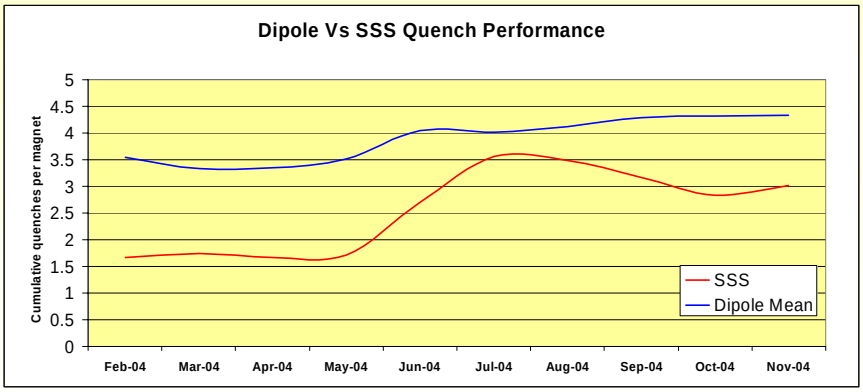
Quench performance- Dipoles

(average seems to worsen during 2004 for magnets that arrived on the benches)



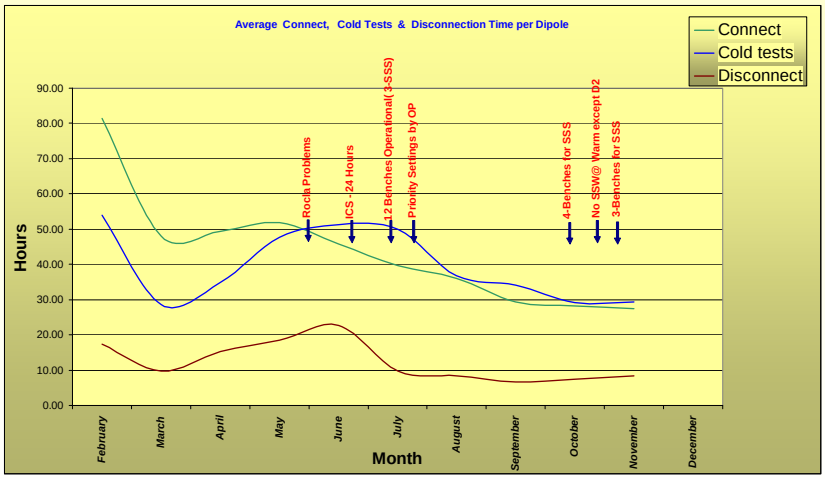
Accelerator Technology Department

Quench performance Dipoles Vs SSS



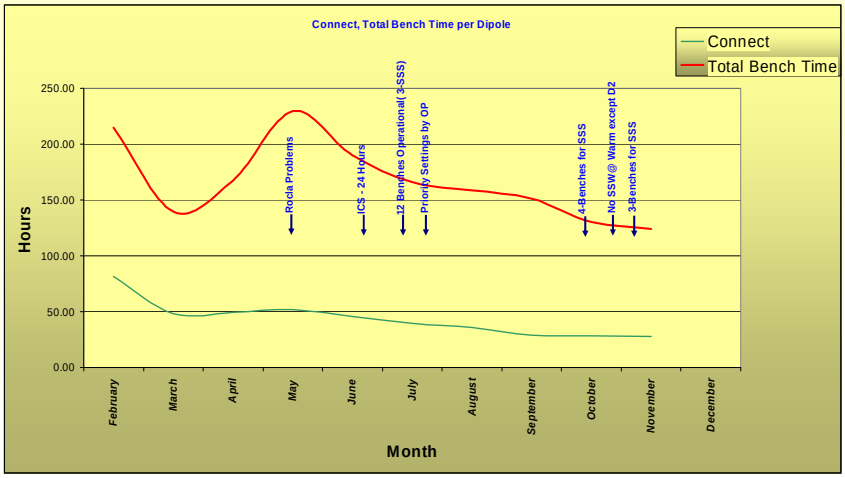
Accelerator Technology Department

Average Connect, Cold test & Disconnect times for Dipoles



Accelerator Technology Department

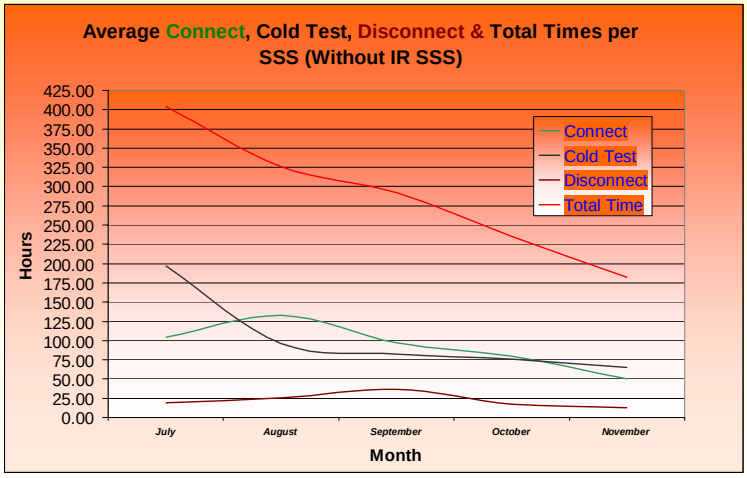
Total Bench Time vs Connect Time



Accelerator Technology Department

Average Connect, Cold test, Disconnect & Total times for SSS

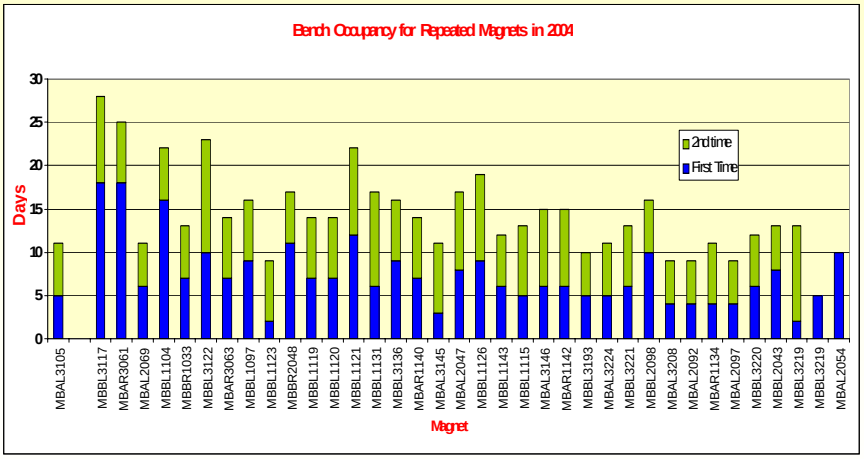
(without IR SSS)



The **BUMP** in **Sept 04** (disconnection) due to ambiguities in definitions in Resistance, HV measurements & SSW @ warm repeated

Accelerator Technology Department

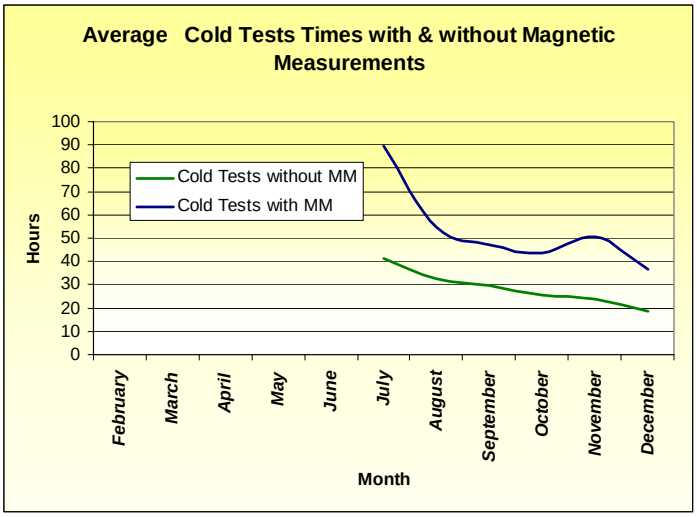
Bench Occupancy for Repeat Dipoles



Accelerator Technology Department

Average Cold Tests Time:

(With & Without Quench Location + Magnetic Measurements)



Magnetic Measurement+ Quench Location take an extra **~ 20 hrs**

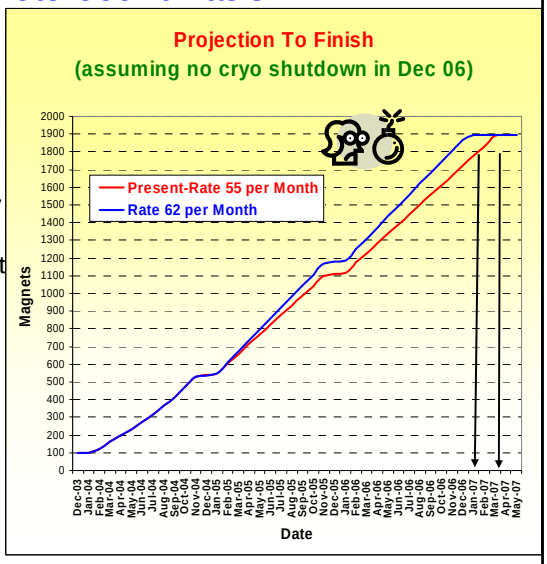
Accelerator Technology Department

Future & Outlook

Accelerator Technology Department

Countdown LHC :Simple Magnets Count Basis

- We are at the rate of **~ 55 Magnets** tested per month (sustainable)
- We need to go up to **~ 62 magnets** per month to finish by end 2006 or early months of 2007
- It all depends on many factors but principally for the sake of this simple calculation, one needs to consider **what % of magnets get repeated** & so forth leading to **raw testing figure of : (1706 + x %)**
- The cut-off around **1893** *as an example* assumes **x =11 %** in this Figure



Accelerator Technology Department

Outlook 2005

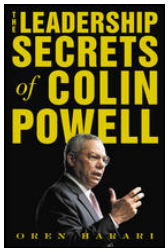
- One needs to **"accelerate"** the testing of magnets to meet the target of **(sustained) 62** magnets per month. It would even be more judicious to attain a figure of **65** magnets (Dipoles+SSS) per **month** because
  - the **testing** of Insertion Region SSS is an **uncharted territory** to date and we need to ensure we have sufficient time for these within the existing boundary conditions
  - We need to permit additional studies in magnetic measurement particularly dynamic behaviour that will aid significantly in **"running-in", "first-turn"** & **first beams** for LHC Operation

Any remaining time would take care of the unforeseen & provide contingency

Accelerator Technology Department

" The people in the field are the closest to the problem, closest to the situation, therefore that is where the real wisdom is."

"Headquarters can support innovation culturally and financially, but it is usually not headquarters that actually comes up with the great innovations and forward leaps- it is the units in the trenches."



Extract from the Book
"The Leadership secrets of Colin Powell" by Oren Harari

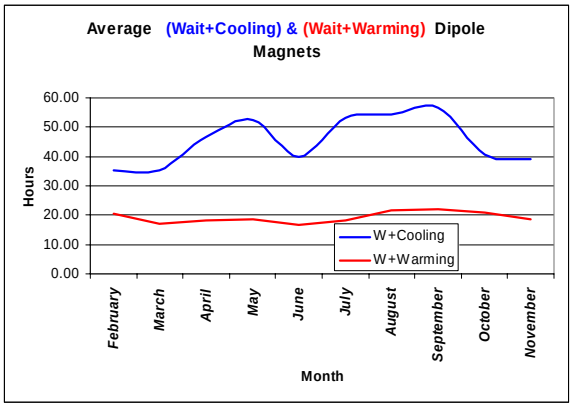
Accelerator Technology Department

How do we accelerate the testing of magnets ?

- Enhanced Cryogenics Capacity in 2005 & resulting optimism
- Reduce the bench occupancy time for ARC SSS magnets
- Other proposals for gaining time

Accelerator Technology Department

Cryo-Capacity 2004 & Estimates 2005

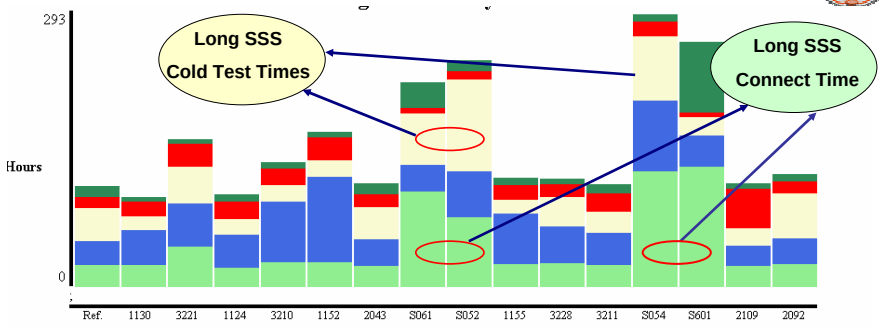


- The Average **Wait+Cooling** time was **45 hours** & **Wait+Warming** time was **20 hours**
- We are told to expect a gain of **50 %** in CWS unit of cryogenics, so at least **1 more magnet** in 300K-90K or 30K-300K phase
- We **predict** a **Wait+Cooling** time of **~ 30 hours** & **Wait+Warming** time of **~12 hours**

Accelerator Technology Department

Example: Weekly Performance

week 42 up to Sat. 16Oct 04



Reference Times

• Light green : Connect (up to Cryo pump down)	24 h
• Blue : Wait + Cool down	26 h
• Ivory: Tests at Cold	36 h
• Red : Wait + Warm up	12 h
• Dark Green: Disconnect	12 h

Accelerator Technology Department

Where is the bench time consumed for ARC SSS ?

- ***Long Connect time for ARC SSS***
  - The Average time to connect an ARC SSS Magnet including the Single Stretched Wire @ warm Tests is **~ 90 hrs** while it is only **60 hrs** without carrying out these Tests

    [for comparison, Dipole connect time is only ~ 32 hrs]
  - The long connect time SSS magnets to date could be attributed to **logistics problems** of **transporting the magnet** to the bench as well as **Single Stretch Wire tests** in initial warm condition and **other warm tests we do which are normally done by ICS for Dipoles**

- ***Long Cold Tests Time for Arc SSS***
  - The Average time to cold test an ARC SSS Magnet including the Single Stretched Wire @ cold Tests is **~ 60 hrs** while it is only **20 hrs** without carrying out these Tests

Accelerator Technology Department

Time Saving Schemes: ARC SSS

1. We are overcoming the real world problems **(since Nov 2004)** of Cranes, Transport, 35 hr week etc in SSS to arrive at the same situation as for Dipoles in fast turnaround in arrivals & departures **(new ROCLA for SSS [Feb 05 ?] ….)**

2. ***[WarmSSW-ColdSSW-WarmMole: Geometry]***
   We should have sufficient statistics by now on the Cold Magnetic axis and Angle Measurements & these, also Correlated to warm measurements done by the Surveyors in Bldg904 by warm mole. (for eventual survey & alignment in the tunnel)

3. ***[ColdSSW: Integral g.dl]***
   With the SSS measured already with SSW@cold, we should have enough statistics to give a 'good' estimate of the field strength and the transfer function required for the operation of the LHC machine.

Hence Stretched Wire Measurements, both warm and cold MUST be reduced dramatically, with significant gain in Bench Occupancy. (Gain in time of 70 to 80 hours per magnet)

Accelerator Technology Department

Other Proposals for Accelerating Magnet Testing

- These proposals are aimed towards achieving the target of testing 65 magnets per month by:

1. Modifications in the Test Programme
   - Quench Rule
   - Diode Test
   - WP04 HV test (ICS)
2. Systematic Mounting of Anticyrostats
3. Dedicated benches for Magnetic Measurements
4. Avoid Q-Loc channels (DC offset & A/C compensation) adjustments except when needed

Accelerator Technology Department

Modifications in Test Programme : Quench Rule

- 2004 Test Programme : 2- Quench Rule (Proposed in Dec 2003 Review)
  - In the **second ramp** if the quench current is greater than **12000 A** then further training quenches are not performed. The magnet is warmed up after the HV insulation at cold (Final), using a 11850 provoked quench.
- Proposed Test Programme : 3- Quench Rule
  - In the **third ramp** if the quench current is greater than **12000 A** then further training quenches are not performed. The magnet is warmed up after the HV insulation at cold (Final), using a 11850 provoked quench.
  - Effects :
    - If this rule was implemented in the year 2004 then
    - **66 magnets** would have passed through without additional quenches
    - **217 extra quenches** would not have been performed on these magnets in 2004
    - The time saved would have been **217 * 5 hours** i.e **1085 hours**

Accelerator Technology Department

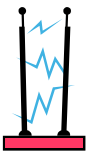
Modifications in Test Programme : Diode Test

- To check the integrity of the diode connection the **"3 kA Diode test" (PTE)** was introduced
- Initially it was stated that these tests were to be conducted on ~ **50** magnets
- In 2004 PTE test were done on **225** magnets i.e an extra **175** magnets
  - Alstom – 67 tests
  - Ansaldo – 53 tests
  - Noell – 105 tests
  - If these tests were restricted to the original scheme, it would mean a saving of **175 * 3 hours** (Test + Recovery time) i.e **525 hours**

Accelerator Technology Department

Modifications in Test Programme : WP04 HV Test (ICS)

- After the magnet comes on the bench and before connection, ICS carry out the HV insulation test. We estimate this test takes at least about **1 hour** (Preparation + Test time)



- In 2004, **396 hours** of extra bench time would have been gained if this test was **not done on the bench OR not carried out at all**.

(This is in spirit of overall bench efficiency & ICS teams' workload on a 24 hr basis)

Accelerator Technology Department

Anticryostat Mounting

- To ***Locate the quenches*** precisely, we need to ***insert the shafts***. However, in the spirit of the series magnet production (as opposed to the first 90 pre-series production upto 2003) and to advance the tests programme, we do not systematically prepare every magnet with anticryostats since Jan 2004.
- This then leads us to have to prepare "poor" performance magnets with anticryostats ***afterwards & carrying out the retesting.***
- ***Effects :***
  - **Of the 37** magnets that were re-tested (in 2004) for various reasons, **21** had no anticyrostats installed and hence these 21 had to be taken off the bench to equip them with anticryostats
  - If the proposal of **"Anticryostat Mounting on all Dipole magnets"** ***(as proposed in Dec 2003 review)*** were implemented in 2004 , it would have saved **~ 21 * 36 hours** i.e. **756 hours** **(36 hours for connecting and disconnecting the magnet)**

Accelerator Technology Department

Dedicated Benches for Magnetic Measurements

- The major problems that has plagued MMP measurements are related to hardware, software & settings often needing long expert interventions
- The proposal is to dedicate A1 & F1 benches ONLY (or rather A & F cluster) for magnetic measurement with shafts, Hall probes or special systems

Benefits :

- This will enable the support groups to focus on few fixed installations leading to improved reliability.
- Fixed as opposed to Mobile racks assures fewer problems associated with connection / disconnection (The flexibility afforded by mobile racks in an R&D environment has to be offset against limited support available in a serious Production environment)
- This scheme would assure us of testing magnetically at least **(45 x 2) ~ 90** magnets per year

Accelerator Technology Department

Reduced effort in setting up Quench Location Systems

- If the Shafts are used primarily to evaluate the magnetic Performance of the magnet, the proposal is to avoid adjustment of DC offset & A/C compensation of **120** Q-Location channels in the racks. This cumbersome task involves **two people** for **at least 1 hr** depending upon the errors found.

(This is in spirit of overall bench efficiency & OP teams' workload in any one shift and considering that there are a maximum of 4 persons on shift)

Accelerator Technology Department

Accelerator Technology Department

SUMMARY: Time Saved per Magnet including CWS Upgrades & Improvements

Average Time to Test magnets (hrs)				
Details	Dipoles		ARC SSS	
	Present	Future	Present	Future
Connect Time	30	29	82	52
Wait +Cooling Time	45	33	32	30
Cold Test Time	34	28	75	35
Warming Time	20	12	12	10
Disconnect Time	8	8	8	8
Total test Time	***137***	***110***	***209***	***135***

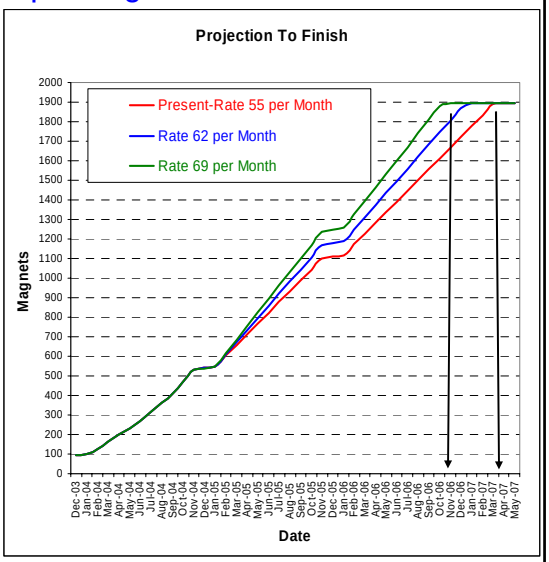
- **WP04 not conducted on Bench – 1 hrs saved from Connect Time (Dipoles)**
- **Diode Test not done – 3 hrs saved from Cold Test Time(Dipoles)**
- **3 Quench Rule - 3 hrs (overall avrg) saved from Cold Test Time (Dipoles)**
- **No SSW @ Warm - 30 hrs saved from Connect Time (SSS)**
- **No SSW @ Cold - 40 hrs saved from Cold Test (SSS)**

This represents 52 Dipoles & 16 ARC SSS could be tested per month, in a bench config. of 8D+3AS+1RS

Accelerator Technology Department

All Projections : 2004, medium and Optimistic based on Simple Magnets Count Basis

- The rate of 69 magnets per month could be obtained by implementing the time saving scheme. This also takes into account the improvement in cryo CWS performance



Accelerator Technology Department

Conclusion

- *An attempt has been made to present an overview of the OPERATION of the SM18 Magnet Tests in 2004, based on the boundary conditions of resources and the RESULTS obtained to date*
- *A PROJECTION, based on management's goals of completing the tests programme so as to permit eventual machine readiness for beam collisions in LHC by 2007 has been made.*
- *This projection requires further increase in testing rates and some PROPOSALS leading to that have been elucidated.*

Accelerator Technology Department

THE END

The Future through tinted glasses.....