Experience with the KEKB/SuperKEKB magnet cooling water system

Mika Masuzawa, KEK, Japan

T15 : Strategies for Continuous Reliable Operations

Stringent reliability requirements are driving the need for perpetual operation. How do you design or adapt systems in situations where even short interruptions to operations are unacceptable. Building facilities using active redundant systems, and automated compensation systems to ensure continuous operations and avoid system shutdown.

KEKB/SuperKEKB is one such example

KEKB 1998~2010, SuperKEKB 2016~

There are ~1700 water-cooled magnets.
Stable operation of the magnet system (along with the others, of course) is VERY important.

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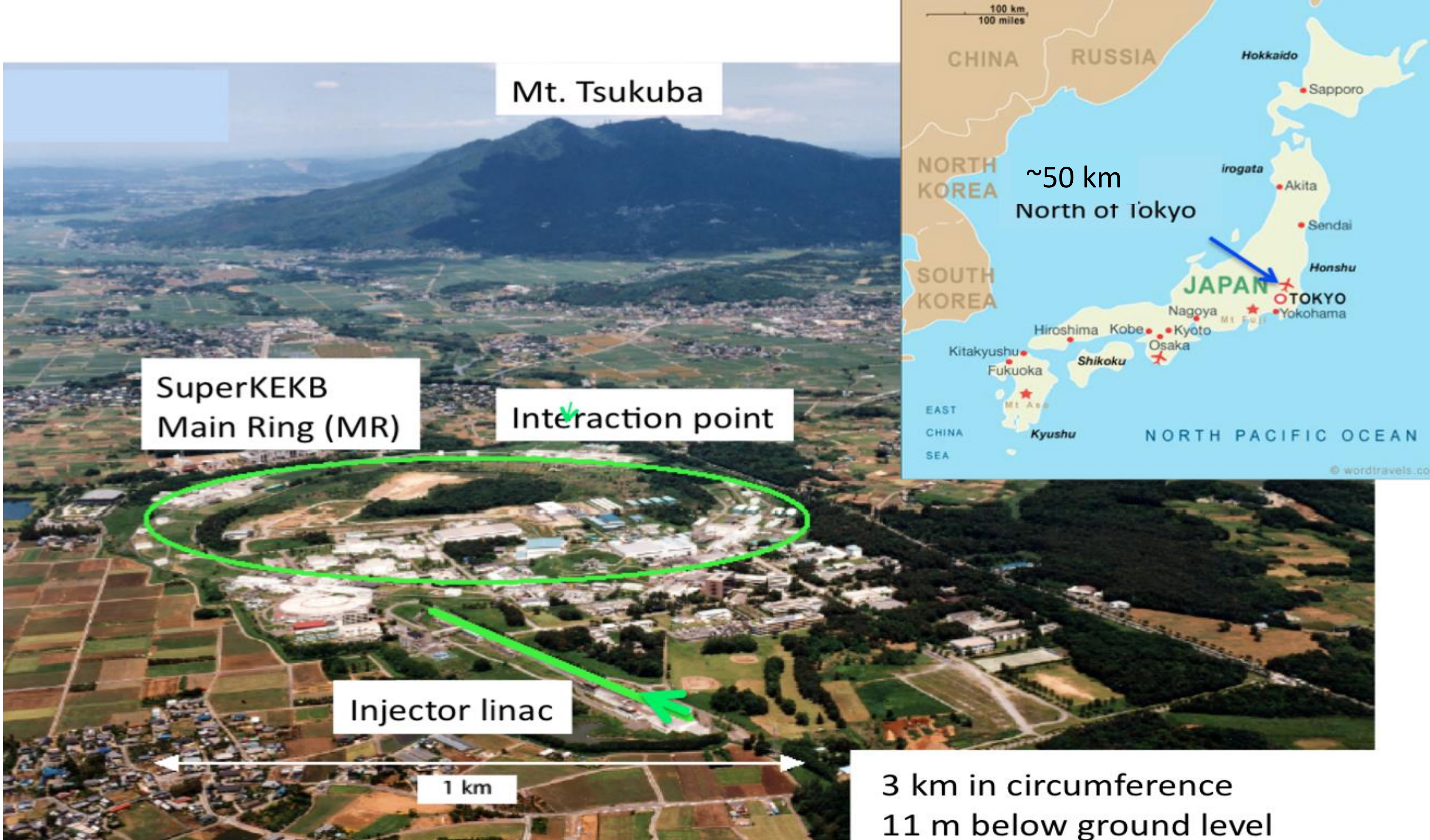
Introduction

KEKB/SuperKEKB

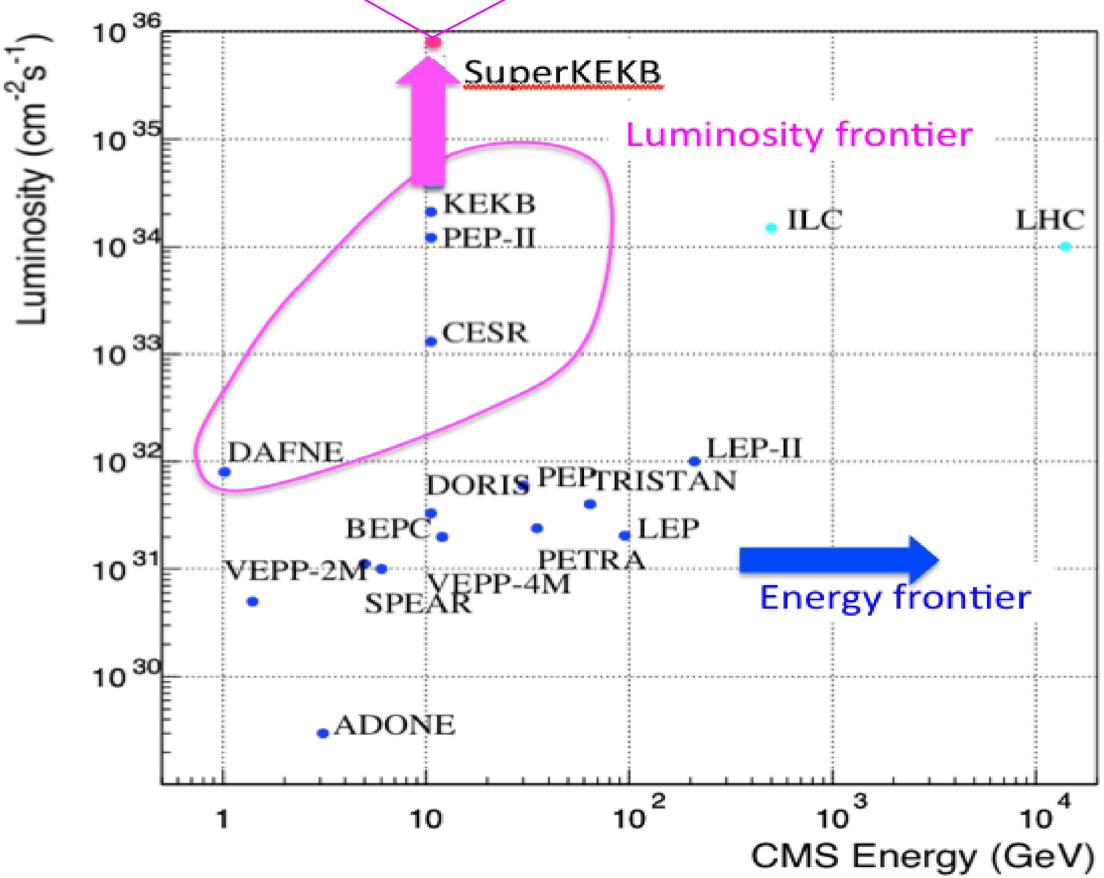
Main Ring (MR) Magnet system



3 km in circumference
11 m below ground level

KEKB/SuperKEKB

Colliding nano-size beams (~60nm in vertical) to realize super high luminosity

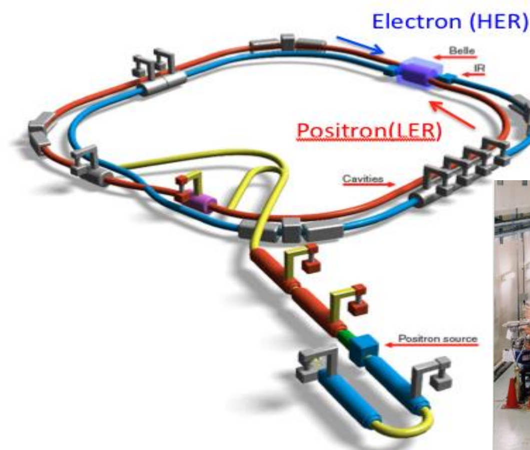


Double ring (side by side)

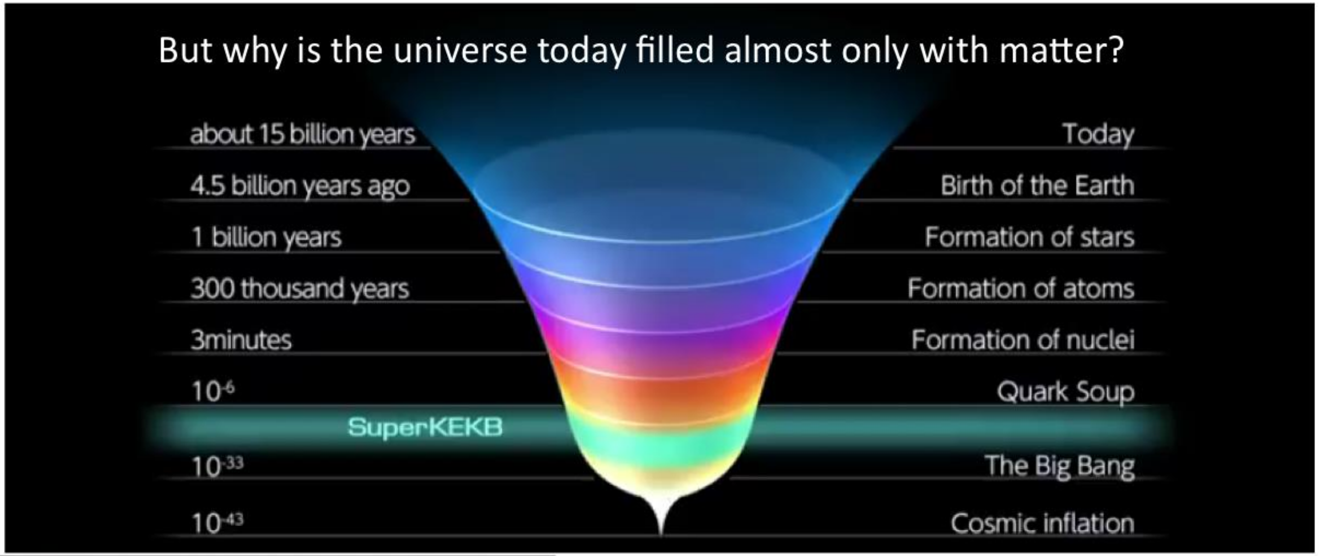
e- (HER) 7GeV, e+(LER) 4GeV

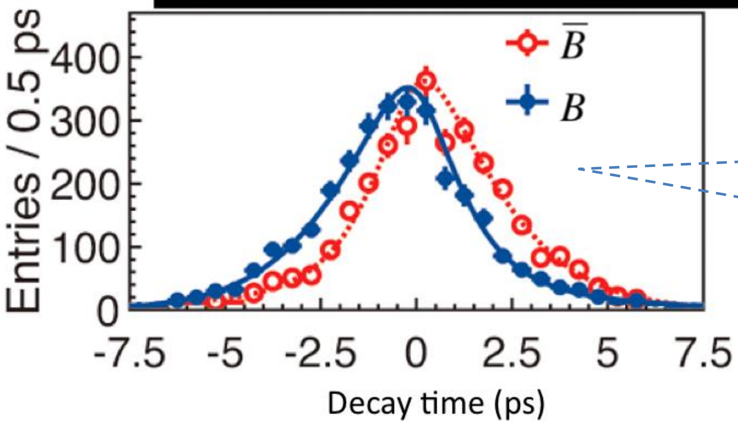
➔10.58GeV

To produce millions of B-mesons ("B-Factory")



KEKB/SuperKEKB





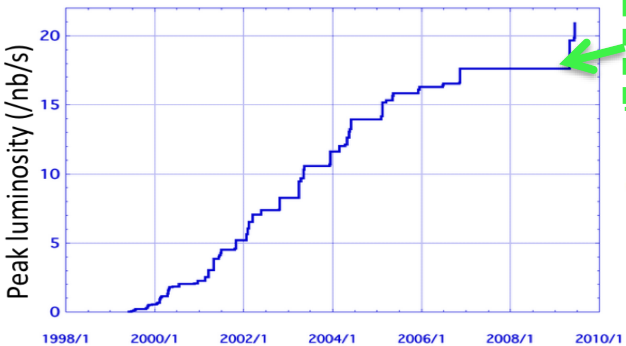
Observed CP violation is not sufficient to explain the actual excess of matter in the universe.
Need much more data (high statistics)
➔ "Super"KEKB

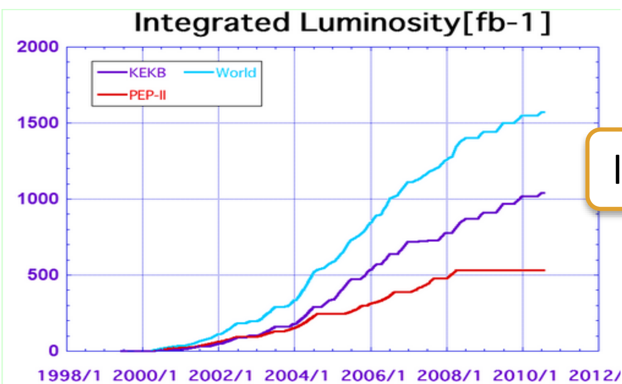
Luminosity × running time
Stable operation of the accelerator is **critical !**

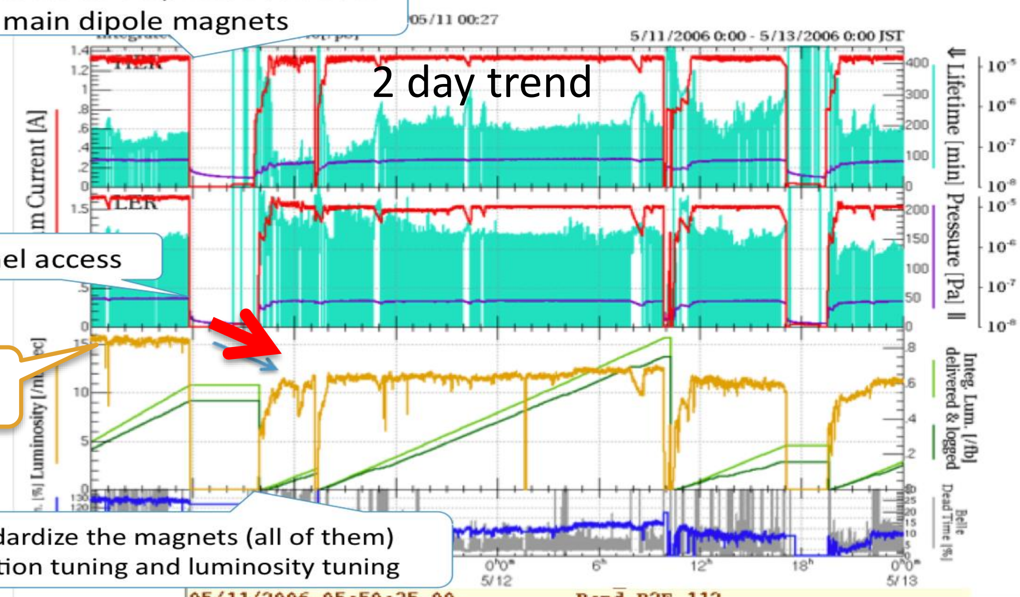
Our experience with KEKB

(1998~2010)

Magnets work as wonderful tuning knobs for boosting luminosity (A set of skew sextupole magnets were introduced here).







But it is often hard to recover good machine conditions after a beam abort caused by the magnets.

Introduction

KEKB/SuperKEKB

Main Ring (MR) Magnet system

Types and number of the SuperKEKB MR magnets

of magnets increased by ~10% from KEKB, mainly by adding more wiggler magnets

Water-cooled magnets

Magnet type	LER	HER
Dipole	159	142
Quadrupole	440	462
Sextupole	108	110
Wiggler	280	36
total	987	750

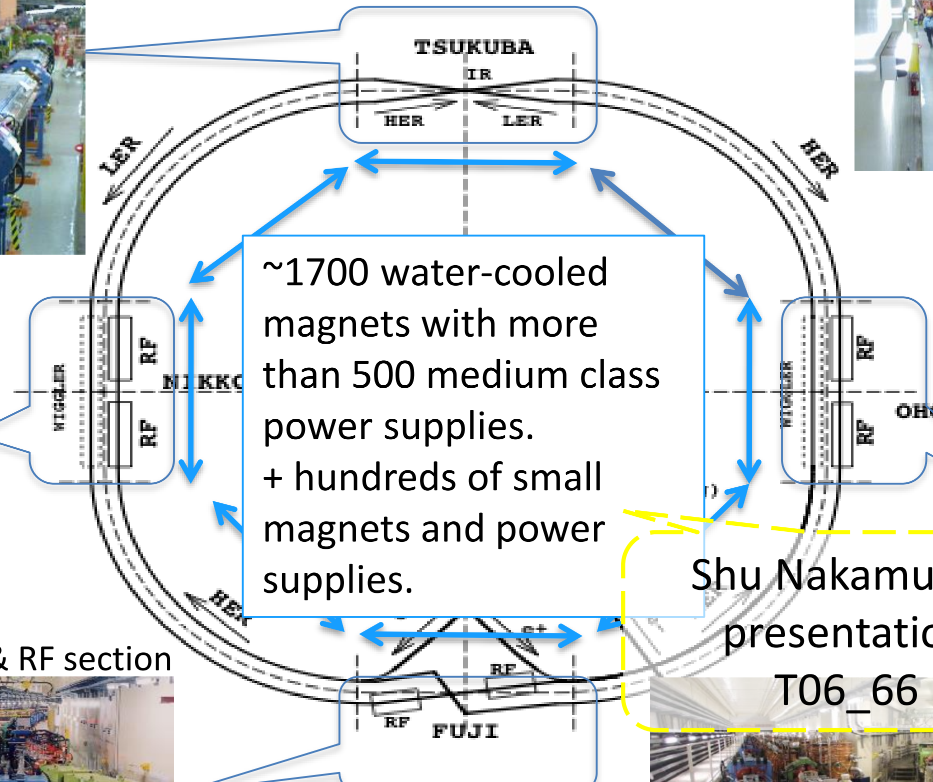
There are more than 1700 water-cooled resistive magnets
& more than 1000 air-cooled corrector magnets that need to be operated stably.

SuperKEKB MR magnet system Overview

IR and local chromaticity correction section

Arc section

Wiggler & RF section

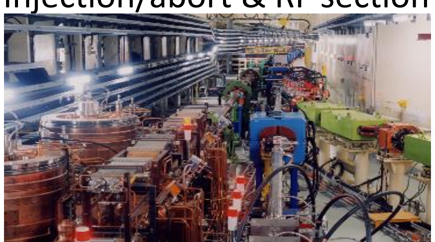


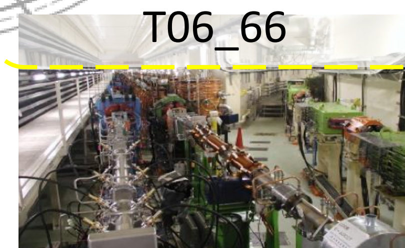
~1700 water-cooled magnets with more than 500 medium class power supplies.
+ hundreds of small magnets and power supplies.

Shu Nakamura's presentation T06_66

Wiggler & RF

Injection/abort & RF section





Each water-cooled magnet is equipped with thermo switches and flow switches.

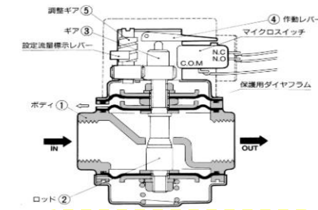
There is no flow meter unfortunately, as they are expensive.

We measure the flow rate using a portable ultrasonic flow meter and the set the flow switch level (interlock level).

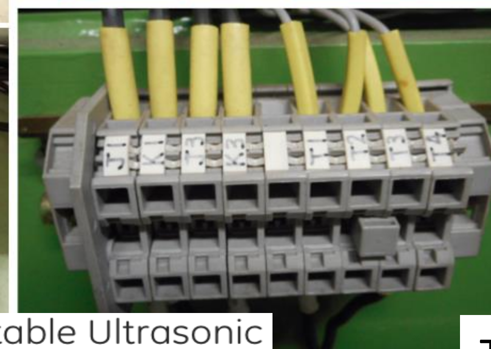
Redundancy

TransPort PT878 Portable Ultrasonic Liquid Flow Meter

GE's TransPort PT878 portable flow meter packs big features into a small, lightweight package.

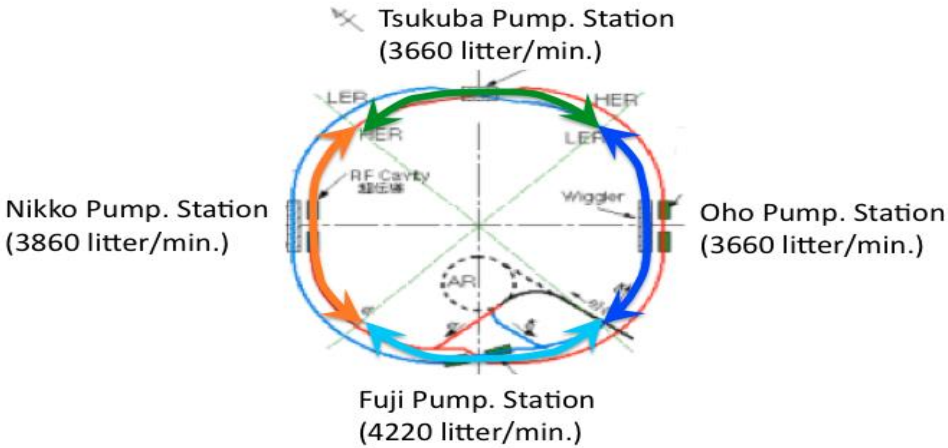


Flow rate varies from 8 to 25 liters/min., depending on magnet type



To PLC

Thermo switch nominally @ 80° C

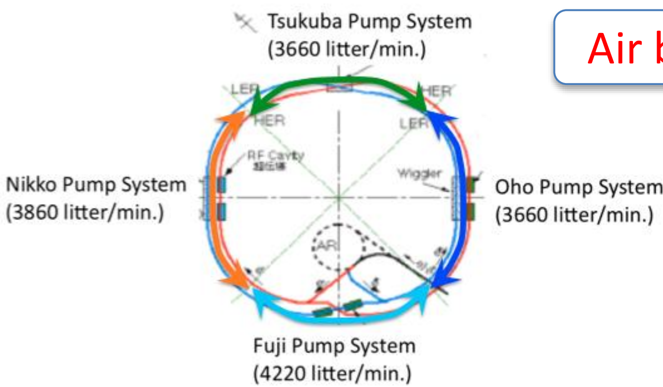


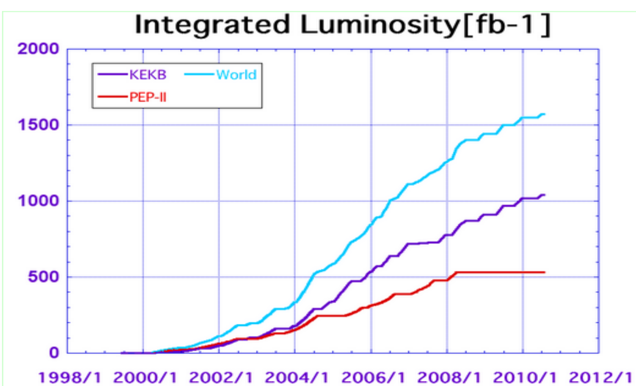
We never liked this idea but.

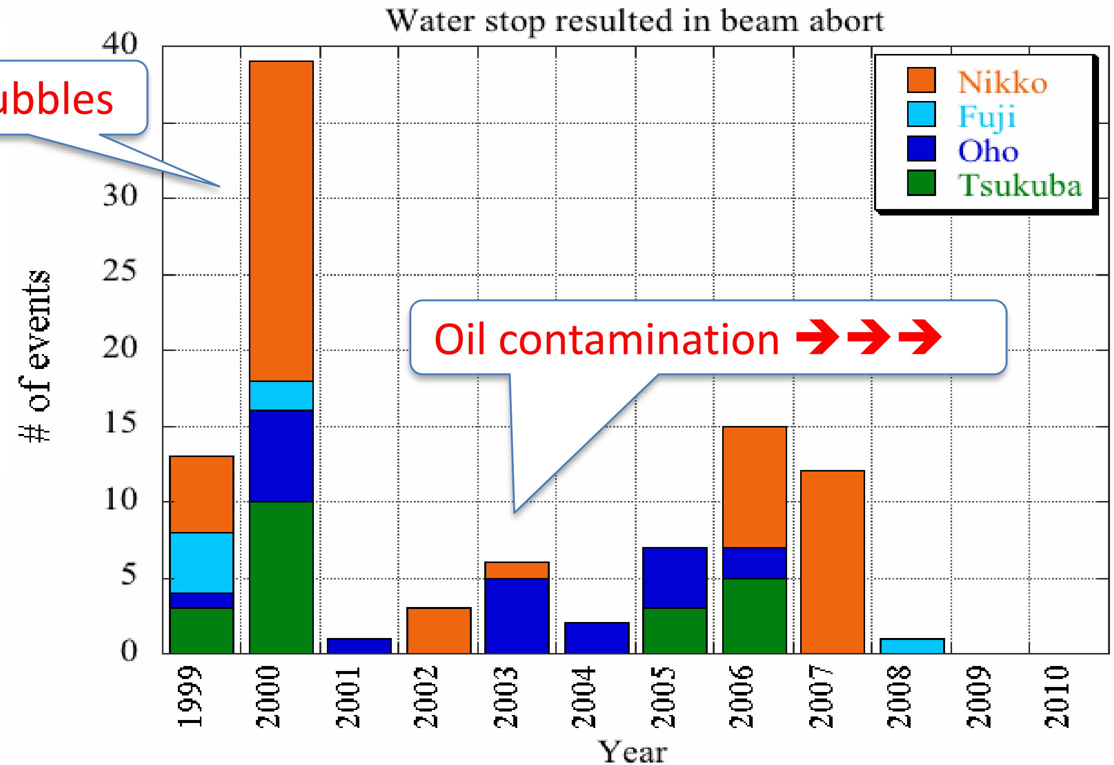
- There were four pumping stations in KEKB, each covering one quadrant of the MR.
- The pumping system was originally designed for the old accelerator (TRISTAN), where the number of magnets was only half that of KEKB➔The system was running at > 90 % of its capacity.
- To keep the total flow rate within its capacity, the water flow to each magnet was needed to be balanced using a globe valve.
  - Some valves were full open, some were merely open a crack (more likely to get clogged when contaminated).

Water stops resulting in beam aborts at KEKB

of water stops resulting in beam aborts during KEKB operation (1998-2010)







~100 water stops/12 years,
half of them in the first 2 years.

Causes & countermeasures

Air bubbles

Oil contamination

Rubber pieces

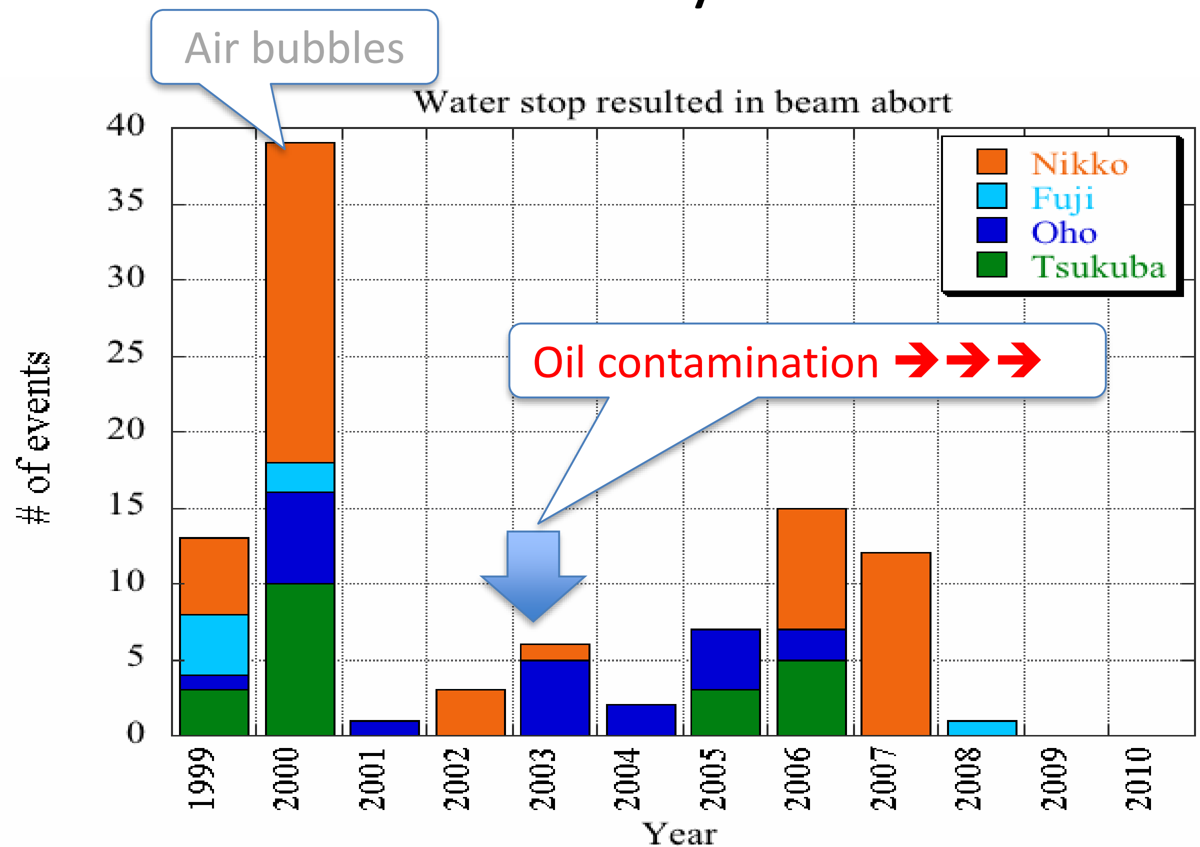
Air bubbles

1999~2000

Air bubbles were not removed from the system because purge valves were not properly located.
We relocated the valves in 2000.

Added more purge valves to the outside cooling tower.
Also control logic was changed from pump discharge pressure control to automated differential pressure control, which resulted in more stable flow.

Air bubble problems were solved in 2000 and we had relatively good years in 2001, 2002… until May 2003.



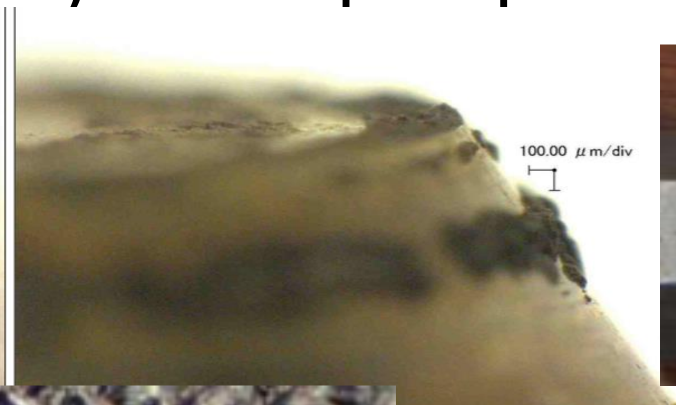
Causes & countermeasures

Air bubbles

Oil contamination

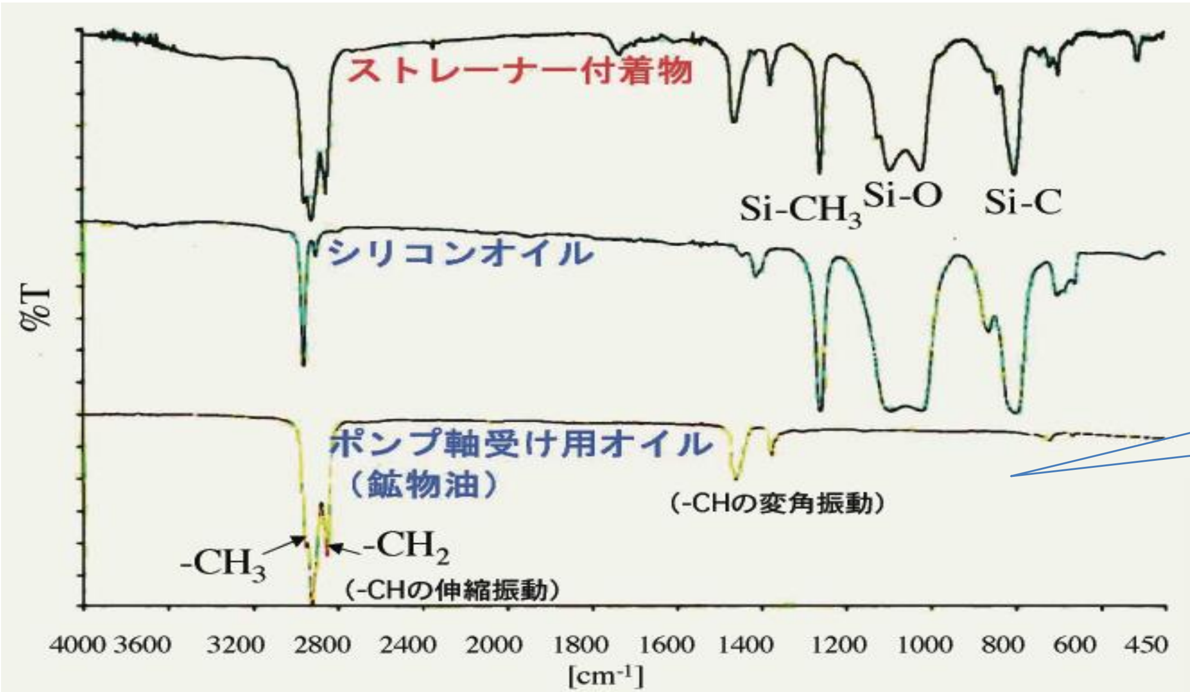
Rubber pieces

Clogging caused by oil contamination caused by maintenance work (by the Facilities Division...) of the pumps!



Copper (from the conductors) is oxidized.
This itself does not cause clogging in the system.
But with grease working as a sort of glue, it makes the situation a lot worse.

Infrared absorption spectrum matched with the machine oil used for pump maintenance



Sample from the clogged strainer mesh

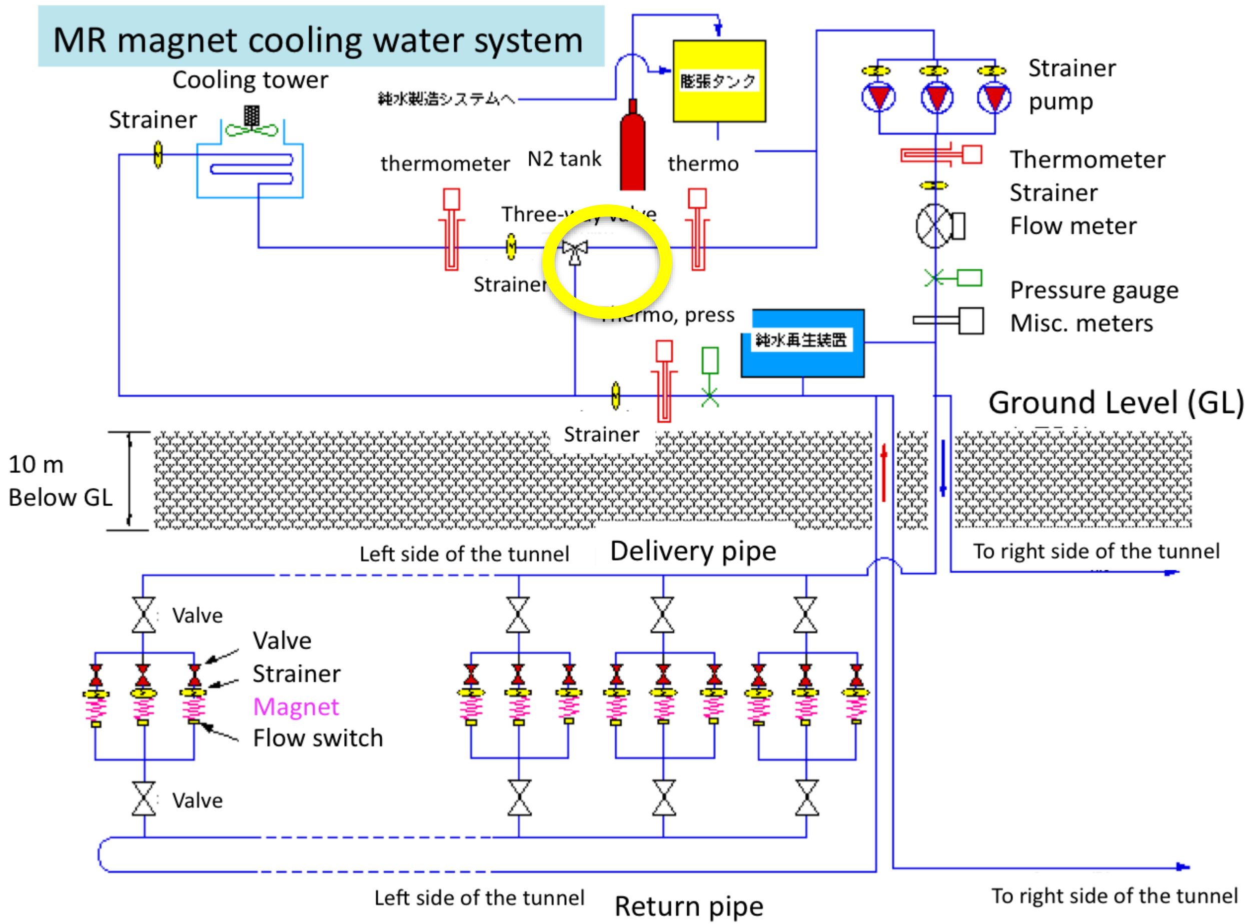
Silicon oil

Pump maintenance oil

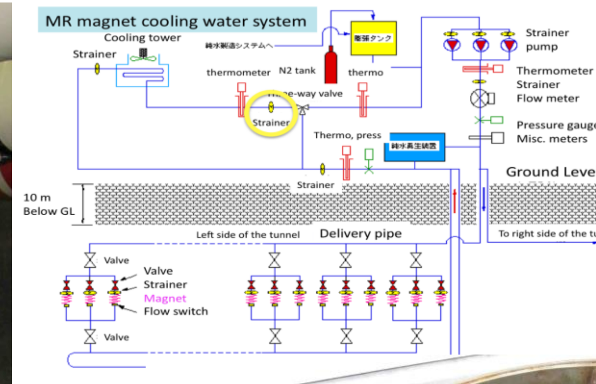
When this problem happened, the Facilities people denied using any oil during maintenance. We interviewed the actual workers (maintenance company people) and learned that it was not the case. Oil in the pure water system… what can I say.

countermeasures

Changed strainer meshes to finer ones
(from #60 to #150 for example) for more effective straining



Cleaning/changing strainer meshes during machine shutdown

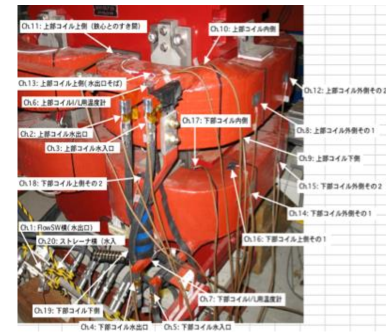


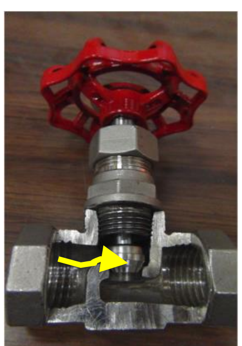
Straining, straining, straining straining, straining, straining, straining, straining, straining, straining, straining, straining, straining, straining, straining, whenever possible.

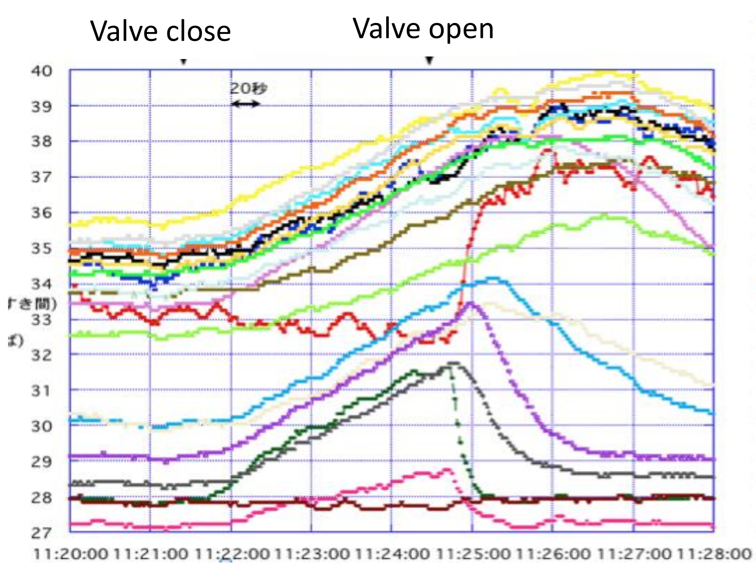
countermeasures

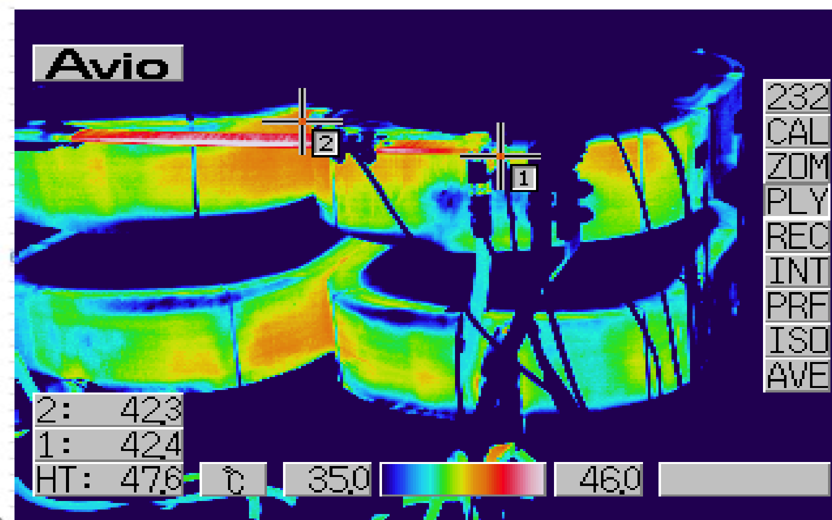
Changed the Interlock decision time from 1 second to 20 seconds

- Sometimes, clogging gets cleared up by water pressure and by the time we go into the tunnel after a water-stop, the flow rate is back to normal.
- So we did an experiment with a wiggler magnet, where the temperature rise is the highest.
- The coils will not be burnt within three minutes after the valve are completely closed.
- So we changed the water-stop decision time from 1 second to 20 seconds.

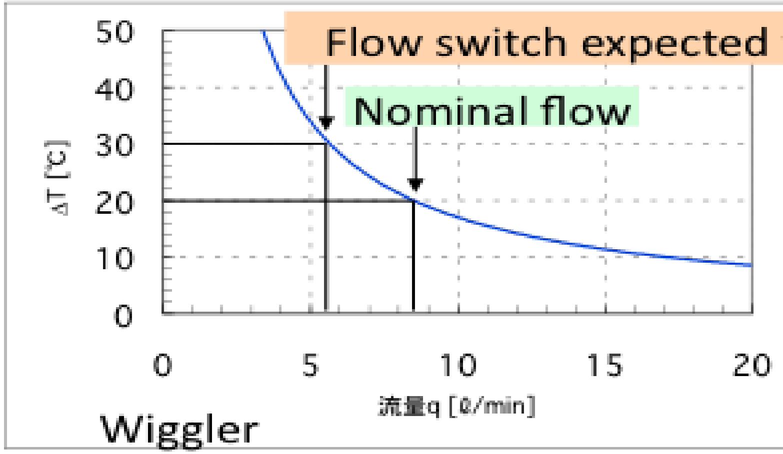


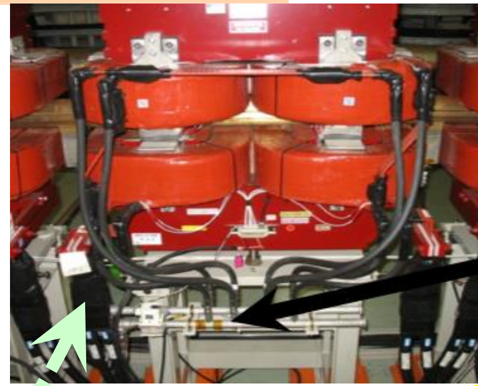


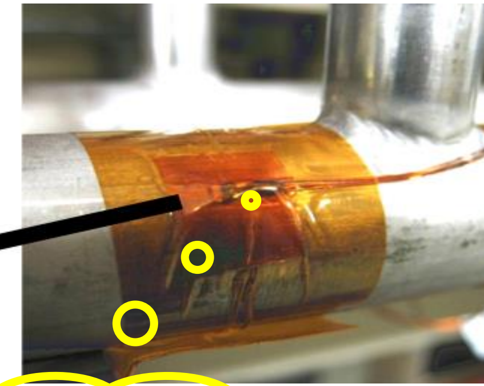


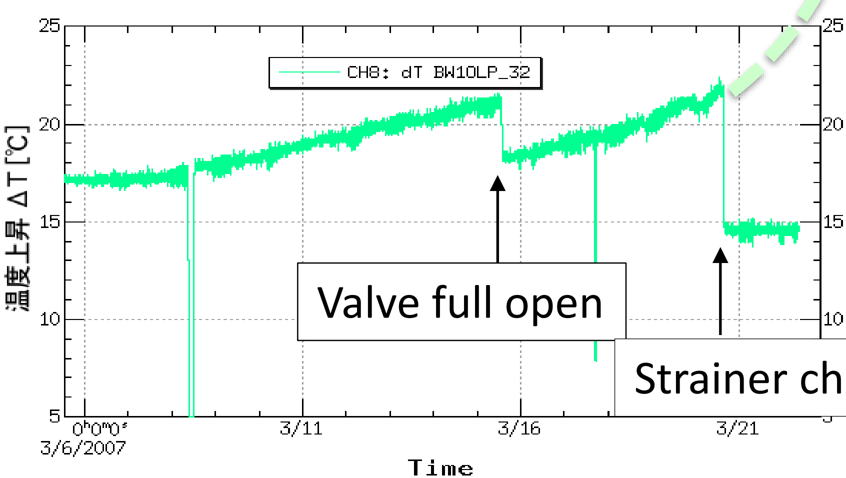


Prevent beam aborts by monitoring temperature rise and looking for the next tunnel access opportunity









Merits:

- Inexpensive
- Attached outside

Sudden beam aborts during luminosity tuning due to water stop were prevented by water temperature monitoring.

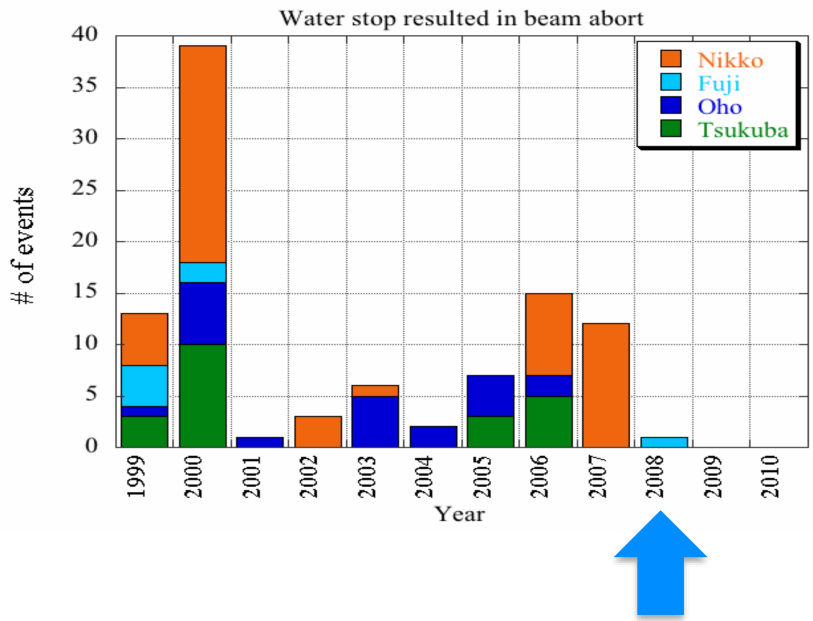
Causes & countermeasures

Air bubbles

Oil contamination

Rubber pieces

Rubber pieces in Fuji pumping station



No water stop in the "Fuji" pumping station, because there was no oil contamination.

But, one water stop in 2008.

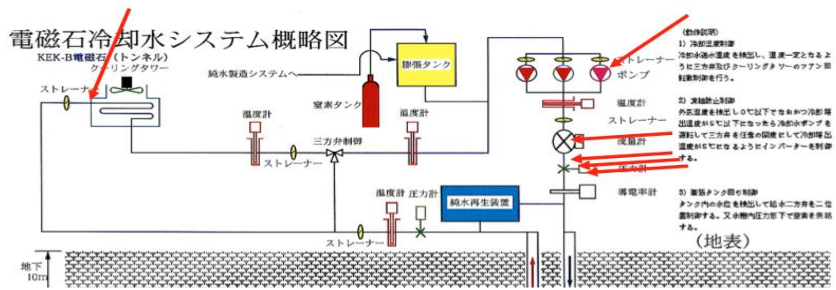
Oil?

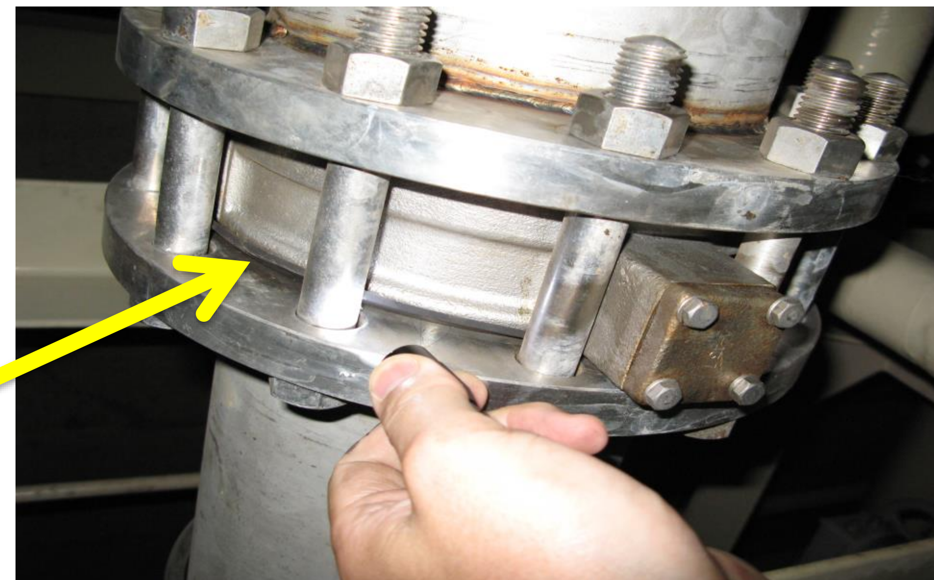
No, it was rubber pieces from old rubber seals.

Rubber pieces in Fuji pumping station

Water stop in the Fuji pumping station area.
It turned out some pieces of rubber triggered a flow switch.

No rubber seals were “supposed” to be used in our





Rubber seals found at many locations.
➔Replaced them with carbon seals.

Others

Our experience with deoxidation devices
Operation log

Proceedings of the 2001 Particle Accelerator Conference, Chicago

THE CHEMISTRY OF COPPER IN WATER AND RELATED STUDIES PLANNED AT THE ADVANCED PHOTON SOURCE*

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E.V. Maughan, College of Knowledge; Duisburg, Germany D-47198

3 DISSOLVED OXYGEN CONCENTRATION

The corrosion rate of copper in water (at neutral pH) as a function of DO is indicted in Fig. 1 [10]. The maximum rate occurs in the range of 200-300 ppb. "Low oxygen" and "high oxygen" operating regimes are defined relative to this maximum. Stator cooling systems can be designed to operate successfully in either regime. The choice is usually specified by the manufacturer but can be changed by the owner if operating experience indicates a benefit [8,13].

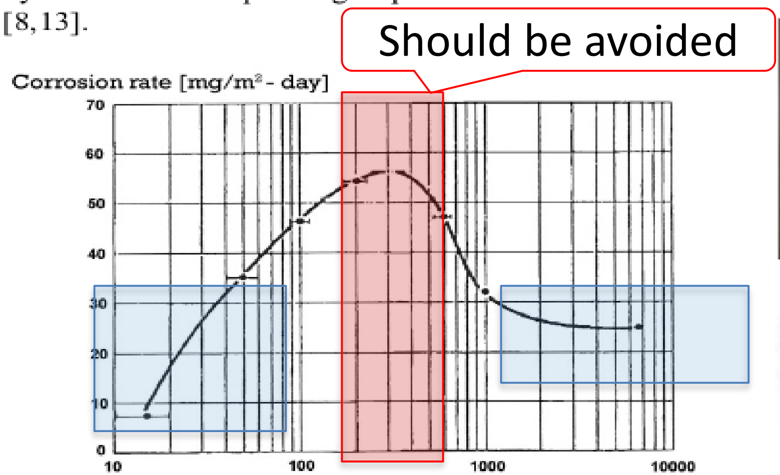
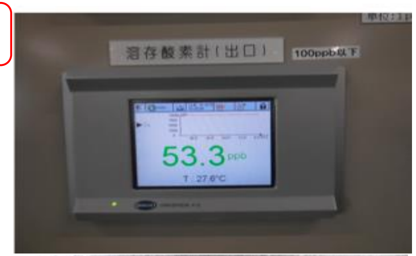
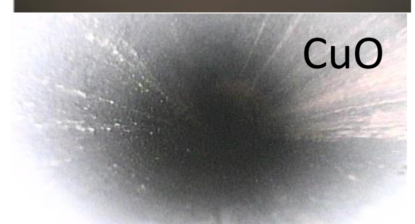


Figure 1: Corrosion rate vs. DO.





Inside of the magnet hollow conductor (Olympus Optical Fiber Scope)

We have a mixed feeling about introducing deoxidation devices

- They are expensive.
- As far as corrosion is concerned we can operate the system in "high oxygen" region.
- The conductors of the recycled magnets are already covered with CuO, so why bother?

- Also we have bad experiences with running the devices with improper parameter sets. At one point they were running in the mid-high region…
- (the devices belong to the Facilities Division, not us)

Operation log

KEKB運転日誌Zlog Viewer

検索 BBS RSS HTML

KEKB トラブル報告 : 2006/11/16 00:00 Thursday

2006/11/16 00:00 Thursday

	C	A	B
一般シフト:	尾崎 俊幸	有永 三洋 久保 忠志	
KCGシフト:	佐藤 政則	家入 孝夫	三増 俊広 池田 仁美
オペレーター:	青山 知寛	飯田 秀一 普家 聡	野口 英明

時間	グループ	障害状況と経過
07:31:11	MG	HER/LER Beam Abort(1357.0/1650.9mA) HER/LER Magnet-Off Abort (B2E_106:TR222 Magnet Water Stop) Abortの件小磯氏、船越氏(所内PHS)連絡するが不在 →船越氏居室にいた為Abortの件連絡 (流量調整後、初期化するとのこと) RF Recover
08:05:30	MG	B2E_106 流量調整実施 →I/L Reset,ON 実施
08:07:00	MG	3C退域(大澤、MSC 青山) B2E_106 流量 6.6L/min でバルブ叩いて 7.7L/min になる。 (I/L はでていない。) 流量調整して 10.9L/min になる。
14:09:30	MG	Solenoid S_ZVQD5E_19(D09_45_13) DC I/L でDown (川本氏に連絡) →I/L Reset, Power ON, 4.5A set にて復旧
16:40:44	MG	Solenoid S_ZVQF2P_30(D06_39_04) DC I/L でDown (川本氏に連絡) →I/L Reset, Power ON, 4.5A set にて復旧
17:20:51	BT	Septum 3 Magnet Water Alarm が出ているのに気が付く(14:24) I/L Reset し復旧(飯田氏)

12時間 画像表示 選択された項目 更新時間 2006年 11月 16日 00:00~24:00 Log表示 Trouble表示

Beam abort by Water stop (Main dipole)

Tunnel access,
6.6 l/min. ➔ 10.9 l/min.

✓Absolutely necessary
Taking statistics and evaluation of the failure are the keys for stable operation.

Summary

Summary (lessons we learned from KEKB)

- We had to make good use of existing infrastructure from the old accelerator:
  the MR tunnel, cooling-water pumping stations, pipes, valves…and so on.
  - ✓This is a constraint when modifying the system.
- Running the system with little margin is bad
  - ✓# of pumping stations increased from 4 to 8.
- Variation in the valve openings among magnets is not good. Narrow valve openings are more vulnerable to clogging.
  - ✓Since the total water capacity was doubled, all the valves are used full open!
- Decision time for water-stop was made longer.

Summary (lessons we learned from KEKB)

- Monitoring is useful to prevent a sudden water-stop.
  - ✓Our choice was to use an inexpensive thermometer attached to the outside of the pipe.
- Grease contamination is nasty. It will stay in the system for a long, long time.
- Mixed feeling about deoxidation devices. We don't feel a need for them now.
- Good communication with the Facilities group and education of the workers who actually maintain the system is critical.
- Any suggestions for more stable and reliable operation of SuperKEKB are appreciated.