# KICKERS AND DUMPS

V. Mertens, CERN, Geneva, Switzerland


### *Abstract*

Envisaged major interventions on the systems under the responsibility of TE-ABT include the completion of the staged dilution kicker system in LSS6, upgrade of the extraction protection elements TCDQ and possibly the replacement of a number of injection kickers. The reliability overhaul of the extraction and dilution kicker generators will be completed, and numerous improvements of electronics and controls components of the various systems be carried out, followed by a thorough test and re-qualification programme.


## DUMP SYSTEM

Several activities are foreseen on the beam dumping system, concerning the extraction kickers MKD, the dilution kickers MKB and the protection elements TCDQ. No modifications are presently planned on the dumps itself, i.e. the TDE absorbers with their associated gas handling system, vacuum windows etc.

### *MKD*

Following the initial reliability run, which qualified the dump system kickers up to 7 TeV, a number of teething problems were discovered during the first year of operation. By carefully analysing the results of the post-operational checks slight deviations from the default values were observed, and traced back to various hardware problems in the MKD and MKB high voltage pulse generators. Using a wrong torque when tightening some of the high current connections led to contact erosion and a small but progressive drop of the magnetic field amplitude for a couple of kickers. The addition of a temperature stabilisation inside the generator cabinets (to reduce the variation of the GTO (= Gate Turn-off Thyristors) switch resistance, and thus variation of the magnet field strength, with the operating conditions), increased the risk for corona discharges (which could cause asynchronous dumps). The mechanism leading to this is not entirely clear; one interpretation is [1] that the forced air flow around the GTO stacks causes static charging on insulating pieces. Forced cooling has in the past also caused some condensation and corrosion on metallic parts in the vicinity of the air conditioning units; the working point has meanwhile been raised slightly above the ambient temperature.

Since the construction of the HV generators the specification for the mechanical pressure to be applied when assembling the stack of 10 GTOs (Fig. 1) has been revised downwards by the manufacturer, in the interest of longer component lifetime, from 24 to 20 kN. An improved trigger transformer is also under development which will allow injecting more current into the GTO gates, to ensure more reliable firing and again improve the lifetime of these devices.

A systematic overhaul programme to address the above issues was launched in 2010, to make the generators really fit for 7 TeV without struggling with a higher than expected failure rate or requiring excessive maintenance. Their present state enables reliable operation up to 4.5 TeV. During the various technical stops the 30 MKD and 16 MKB generators are successively replaced by modified spares; the outgoing generators are modified in turn in between the stops. To speed up this process, two additional MKD generators are being constructed (besides the two initial spares), and a second MKD test stand will be built in the new kicker laboratory in building 867. The overhaul programme will be completed during the long stop.

Figure 1: One of two HV switches of an MKD generator: GTO stack (centre), partly hidden behind the voltage distribution resistors; trigger transformer (right); snubber capacitors (left).

Considerations are also being made towards a higher number of GTOs per stack, to increase the margin against breakdowns caused by radiation. The voltage applied across the 10 GTOs at 7 TeV beam energy is about 29 kV. The maximum nominal voltage an individual GTO is able to withstand safely had been revised downwards but meanwhile restored by the manufacturer to 2.8 kV (DC voltage for 100 FIT at ambient cosmic radiation at sea level in open air; 1 FIT = 1 failure in 1e9 device hours). Tests are going on to assess the sensitivity of the GTOs to stray radiation that might leak through the cables ducts into the galleries where the generators are located. Very preliminary findings are rather positive [2], meaning that no or only few GTOs would need to be added per stack. It is noteworthy that in 2010 the increase in radiation from the operation of LHC, at the location of the generators, has been negligible [3]. In case the number of GTOs would need to be increased, up to 12 would still be compatible with the present mechanical layout of the generator cabinet; anything beyond that will require a major reworking. To note that the fabrication of GTOs with identical characteristics is also an activity with long lead time.

### *MKB*

In 2001 it had been decided to stage the manufacturing and installation of the dilution kicker systems in time, because the full dilution was not required for LHC start-up. By now, 4 of the 5 MKB vacuum tanks are installed per beam; each tank comprises 2 magnets. The two remaining MKBV magnets per side are ready and will be installed in the long stop, along with the 4 last pulse generators. Without these two last magnets the dilution system is already sufficient for nominal beam (25 ns) at 7 TeV; the last two tanks will complete the system for ultimate intensity.

### *TCDQ*

The protection element TCDQ (Fig. 2) is located upstream of the superconducting quadrupole Q4, and protects it and other downstream elements, in combination with a passive shielding TCDQM and another collimator TCS, against damage (quenches) in case of asynchronous dumps or excessive beam excursions.

The TCDQ features a total single sided absorber length of 6 m, all 1.77 $g/cm^3$ graphite, distributed over two vacuum tanks mounted on a mobile girder. The present TCDQ absorber design is based on the initial static mechanical stress analyses of the TCDS (fixed shielding in front of the extraction septa MSD; the TCDS design parameters were later revised to take also the dynamic stress results into account, and the TCDS were immediately built for ultimate beam intensity). The reassessment of the load to the TCDQ in various failure scenarios, together with the operational experience gained in 2010, led to the conclusion that the TCDQ needs to be upgraded to withstand the impact of bunches at higher energy and intensity. Approximate estimates of the maximum safe limit in the present configuration, for the case that 28 bunches at 7 TeV would impact on the TCDQ during an extraction sweep (asynchronous dump), range between 7e9 and 7e10 protons per bunch. A procedure is being devised to verify as far as possible the integrity of the TCDQ after beam incidents, without having to open the vacuum [4].

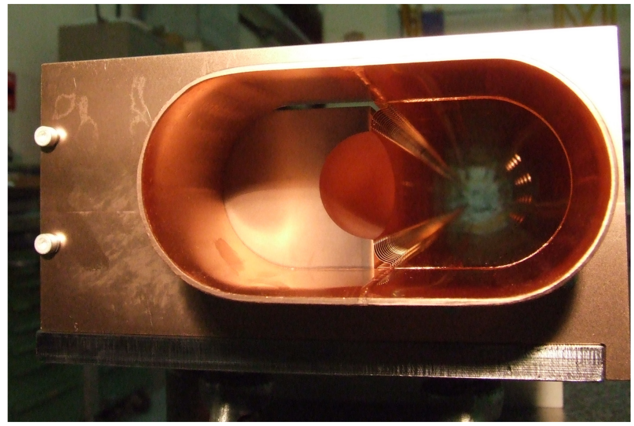

Figure 2: View inside a TCDQ, showing the copper coated tapered graphite jaw to the left. The beam circulates to the right and is shielded from the vacuum tank by a copper beam screen.

The time consuming simulations focus on a C-C absorber, assuming ultimate beam (1.7 p+/b, 25 ns, 7 TeV). Inquiries on the technical feasibility have been started with potential suppliers. Although the present design is deemed to be safe for 50 ns beam with nominal intensity it is desirable to increase the robustness of the TCDQ as soon as possible. If the simulations can be concluded in time and the diluter length does not need to be changed it seems possible to carry out the necessary swap in a short winter stop (2011/12); in the other case one would need one more year for re-design and construction (upgrade in a long stop in 2013).

## INJECTION KICKERS

After the decision to increase the number of spares for the LHC injection kickers, two further magnets are presently under construction and should become ready for use in 2012, thus completing a full injection system comprising 4 magnets, Fig. 3.

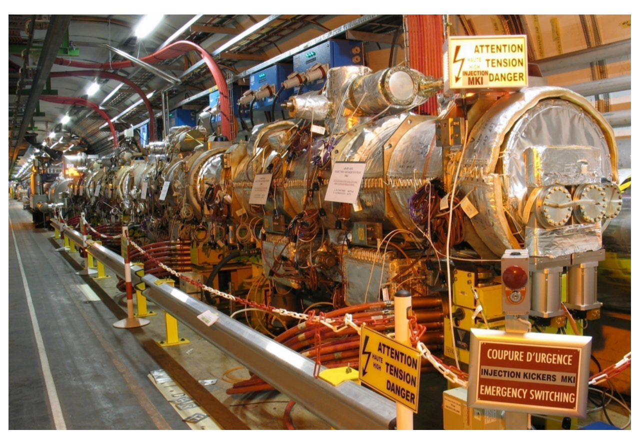


Figure 3: MKI system in LSS8R.

Developments are going on to further improve the voltage holding of the beam screen, and thus to improve the margin against internal flashovers. The manufacturing of the 3 m long ceramic screen support tubes comprises many stages and is therefore a lengthy process. If the new tube version confirms the expected better performance all spare magnets will eventually be equipped with it. Depending on the work progress, the test results, and the operational problems encountered during the coming running period, these spare magnets could replace the operational kickers in future stops. While only up to 2 such replacements look feasible in a long stop in 2012, up to 4 MKI could ideally be upgraded in the course of 2013.

Modifications are also planned on the hydraulic pipework in between the MKI tanks (cooling of terminating resistors), to make all magnet positions compatible with using tanks fitted with 6 vacuum valves (i.e. spares which could be used in either LSS2 or LSS8).

## ELECTRONICS AND CONTROLS

A large number of modifications and upgrades are planned on nearly all of the control systems of equipment under ABT responsibility. These are aimed at further improving performance, reliability and diagnostics capabilities. Examples include the modification of the dump system triggering logic for compensation of the turn-on delays over the complete energy range (induced by the decision to work at a fixed triggering voltage), the re-configuration of the low-level communication networks to increase the data transmission capabilities, and the deployment of a new version of the Trigger Synchronisation Unit (TSU) implementing the improvements recommended by a technical review. Regarding TCDQ the position and interlock logic, presently combined in the same programmable logic controller, will be split into 2 controllers which will be physically separated to reject the probability of common failures induced by single event upsets. The high voltage power supplies and high voltage dividers will also be recalibrated, if needed, to keep the system performance within specification.

In addition enhancements likely to be undertaken by CO, including the replacement of LynxOS by RT-Linux, the upgrade of VME CPUs, or the deployment of FESA version 3, must be accompanied at the equipment level.

After these modifications a thorough test and re-qualification programme will allow to confirm that all systems work well and safely. The pre-conditions for this testing phase, and the resulting constraints, must be carefully accounted for in the overall planning.

## OTHER POTENTIAL WORKS

The addition of a TCT-like collimator, between TCDQM and Q4, has already been considered [5], but the need is not confirmed yet. Based on loss maps for higher intensities and new knowledge on the Q4 quench limits, such a device is supposed to gain a factor 2 in heat load on Q4 for steady state beam losses.

In 2007 a number of elements in LSS6 were installed with inverted tilt. Twelve of those have not been realigned yet (BPM, TCDS, TCDQ, BTVSE). The reading of the BPM has been corrected for in software, and the resulting aperture loss at the TCDS/Q (order of 0.1 – 0.2 mm) is considered marginal with respect to other error sources. Nevertheless, if the vacuum in the relevant zones will be opened anyway one day, the alignment should be corrected to bring it in agreement with the specifications and the corresponding documentation.

The electrical distribution of the AC-dipole in LSS4 (which uses the MKQA magnet to excite the beam) needs to be made more robust to avoid frequent tripping (re-arming the electricity requires tunnel access). The low-level control of the AC-dipole will also be reviewed to improve its integration into the MKQA controls and solve incompatibilities observed in case of failures.

## GENERAL COMMENTS

The work mentioned above will compete for resources with other more standard LHC maintenance activities, not listed, as well as maintenance and project related tasks in other machines. Good planning across the complex should help optimising the use of the workforce and avoid too strong interferences.

Established procedures exist for nearly all of the above mentioned works, and practical experience has already been gathered in earlier interventions. The works should therefore not give surprises in the planning phase or during execution. The required services are typically well defined (see presentation).

The exact plan of interventions depends on the progress until the long stop. Part of the work is already ongoing (MKD overhaul), some parts with long lead-time are either under development (ceramic tubes for MKI), or the requirements need still to be confirmed (GTO stacks). The concrete work programme will also be conditioned by the workload from other activities, and could be affected by new problems which might surface in the meantime.

Most interventions are point-like in time and can be planned in where it fits best; some activities (MKD overhaul) will stretch over extended periods.

Besides unforeseeable mishaps the risks of undertaking the described work consist mainly in not finding easily back the expected performance (vacuum or high voltage). Experience shows that periods of intensive (co-)activity bear a risk by itself (e.g. accidental venting, transport incidents, stepping on equipment). High care should be exercised to preserve the performance of these devices which are vital for the LHC performance.

The risks of *not* doing the work consist in persisting limitations and progressive degradation of the performance (e.g. further contact erosion, requiring unscheduled interventions, or causing more frequent asynchronous dumps).

Postponing the long stop from 2012 to 2013 is likely to be an advantage in terms of ABT equipment, disregarding the foreseeable increase in radiation from the longer operation period (deemed relatively small), and any rapidly progressing performance degradation. It will enable to prepare more thoroughly – or render at all possible – a GTO upgrade of the MKD generators (should this turn out to be necessary), allow more MKIs to be prepared with improved beam screens (should these have significantly superior voltage holding capability), and prepare a layout change of the TCDQ (should this be required).

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