AGEING OF AIRIX ACCELERATING UNITS

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Abstract

Airix is a linear accelerator producing a 60ns, 2kA, 19MeV electron beam. It has been operated in a single shot mode by the "Commissariat à l'Energie Atomique et aux Energies Alternatives" (CEA) for flash X-ray radiography purposes for 10 years [1].

Its modular architecture increases the beam energy by quarter of a megavolt step: each cell delivers a 75ns impulsion of 250kV amplitude.

Our aim is to guarantee a minimum lifetime for the cells and their pulse driver. To achieve it, we are operating a test-bed at a moderately low repetition rate (a couple of pulse per minute) for tens of thousands of pulses.

Afterwards, we will run a series of both non-destructive and destructive analysis to identify the most stressed parts, and, if necessary, the means of increasing the cell lifetime.

This paper describes the test-bed: a pair of cells and its driver, and the first results of these ageing tests.

TEST BED

Cells

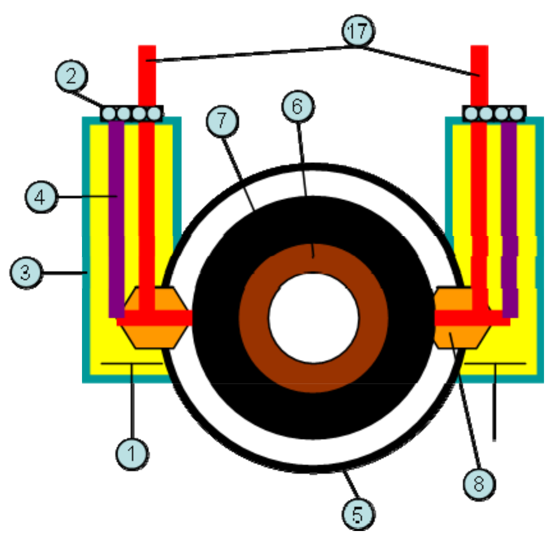

Figure 1: Airix accelerating cell scheme

Each cell is an assembly of an inductive core (7), two matched oil-insulated high voltage (HV) connexions (3), a water-cooled solenoid (6) and two magnetic dipoles for beam deviation, all of those held together under vacuum (<10^{-5} mbar) in a stainless steel casing (5)[2]. The main points of interest are the ageing of the core and of the insulating parts under electrical stress.

The matching at the HV connexion is realised by a resistor (4) in parallel of the cell, while the feedthrough (8) itself separates the oil from the vacuum.

A pair of cells, taken amidst a block of four (which is the basic unit we operate mechanically), is used in conjunction with a HV driver. The block we have chosen had, previously to testing, already been used 25 000 times on Airix, representative of the cells in use on the accelerator.

Driver

The driver consists of four main parts, the first three forming a HV generator:

- low voltage electronics (16) comprising ancillaries regulation and triggering control-command,
- a slow HV pulsed power part (13) charging a Blumlein line,
- a fast HV pulsed power part (15) triggering a pressurized (4.3 bars) dry air spark gap (11),
- HV junctions, e.g. 4 HV cables (17) and their connectors between the generator and the cell pair.

The generator we have chosen has already been used 30 000 times on test beds, which is more than the generators in place on Airix.

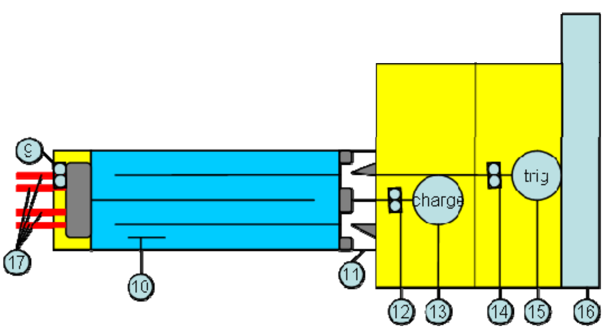

Figure 2: Airix cell driver scheme

The cables are 14m long and 50Ω impedance.

Particular Focus

While our main focus is on the behaviour of the accelerating cells, we are also assessing the lifetime of new elements of the driver, which should be put in place in the future Airix configuration:

- new electrodes for the main spark gap of the generator, designed for use with pressurized dry air, while the actual spark gap is operated in SF_6 at twice the atmospheric pressure.
- new cables and new connectors for the HV junctions.

For both cables and connectors, we have at our disposal an old type, purchased 15 years ago, still in use on Airix, and a newly acquired one, expected to be more resilient to mechanical stress; so we decided to try and test three different combinations:

- nominal cables with nominal connectors
- new cables with nominal connectors
- new cables with new connectors

HV Monitoring

On the cell side, at each HV connexion, we use a capacitive voltage probe (1) to monitor the accelerating pulse, a Rogowski coil (2) to probe the feeding current, and a current transformer to probe the leaking current. We also use B-dots to monitor the magnetising current of each core.

On the generator side, we use current transformers to probe the triggering pulse of the spark gap (14), the charging current of the Blumlein line (12) and the discharging current of said line (9). We also use a capacitive probe to monitor the voltage of the line (10).

Process

We are operating the test bed with Airix command – control hardware and software with upgrades to enable automatic repetitive triggering.

We are operating the test bed at higher repetition rate than Airix, 2 pulses/ minute instead of 1 pulse/ 10 minutes, but still with enough time for the spark gap to be cleaned from degraded gases.

Maintenance operations are scheduled along the tests to assess the state of the systems and to remain coherent with Airix maintenance strategy.

FIRST RESULTS

Particular Layout

The results presented here are products of the first 23000 pulses, which roughly represents 10 years of use.

One cell was connected with nominal cables and nominal connectors and one cell was connected with new cables and nominal connectors.

Both types of cables have been mechanically stressed beforehand.

Maintenance has been performed at the end of these first pulses.

Malfunctions

Three malfunction types have been spotted; they are all cases of insulator breakdown:

- a breakdown of the spark gap before triggering (prefire)
- a breakdown in the oil-insulated matching device of the cell (on the oil side)
- a breakdown in the HV cable

Spark Gap Prefire

The first malfunction is harmless to the hardware, no damage having been detected associated to this event.

It occurred only 6 times amidst 23000 pulses, so there is no recognisable pattern for now.

It is to be noted, however, that no similar event was ever recorded on Airix. Still, there is no clear evidence of a link with SF_6 use or a lower repetition rate.

At the end of the pulse series, we opened the spark gap for maintenance, and we observed a notable contamination with greasy material (perhaps transformer oil). This leak could be the source of very occasional breakdowns.

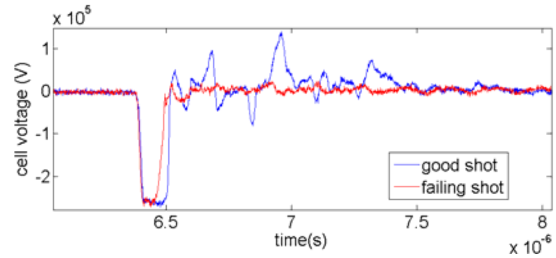

Figure 3: breakdown in oil

Oil Breakdown

23 of these were recorded in 23000 pulses. No correlation between these malfunctions has been made; they seem to appear randomly, with a low probability (p~1/1000). It is to be noted that the same phenomenon with the same probability has been observed on Airix.

Cable Breakdown

The last type of malfunction, on the opposite, is harmful, destroying the affected cable. It occurred four times, all of them with the nominal type cable.

It casts doubts on the ability of this old cable to handle mechanical stress, after 12 years of rest.

Figure 4: cable breakdown

Figure 5: Test bed in use for determination of the lifetime of Airix cells and their driver.

CONCLUSION

Our test bed has been running efficiently to demonstrate the lifetime of Airix accelerating cells and their driver; it has already shown that for 10 years worth of use on Airix, there is little to no dysfunction, provided we choose the right cable.

It also seems that the use of pressurized dry air in the spark gap is very promising.

Detailed studies on performances and reliability are currently completed and at the same time, we continue to perform our testing, increasing our database.

REFERENCES

[1] H.Dzitko et al, "Reliability study of the Airix induction accelerator over a functioning period of ten years (2000-2010)", PAC'2011 Proceedings, New York, March 2011.

[2] E.Merle et al, "Status of the Airix accelerator", PAC'99, New York, August 1999.