OPERATIONAL EFFICIENCY OF THE AIRIX ACCELERATOR SINCE ITS COMMISSIONING

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Abstract

AIRIX is a high current (20 MeV, 2 kA) electron linear induction accelerator used as a 60 ns single shot X-ray source in order to perform hydrodynamic tests using nonfissile substitution materials within the frame of the so-called CEA Simulation Program.

This accelerator has been running for hydroshot experiments since 1999 and thousands of electron and X-ray beams have been produced so far. The functioning time of the AIRIX machine in the CEA/Moronvilliers test site is now coming to its end. From mid-2012, it will be then refurbished, dismounted and moved to another CEA test site. This paper draws up the report of AIRIX operations over this long eleven-year period : operation key numbers, maintenance policy, X-ray reliability are dealt with.

OPERATIONS OVER 12 YEARS: FACTS AND KEY FIGURES

The AIRIX accelerator has been successfully operated since its commissioning in 1999 [1]. Its operational working in Moronvilliers test site was stopped as scheduled in March 2012. It is now refurbished before its relocation in another test site.

Figure 1: View of the 64 AIRIX induction accelerating cells. Each cell delivers 250 kV to the 2 kA electron beam.

The following key figures may summarize the exploitation of this facility over the 2000-2012 twelve year period:

- 23,000 electron flashes were produced over the functioning period.
- 16,800 electron beams were accelerated up to 20 MeV.
- 4,000 of the 16,800 electron beams were converted into X-ray flashes for hydroshot preparation and the experiments themselves.
- 6,200 electron flashes were produced with the injector alone. After operations such as changing the vacuum insulator panel or the cathode, flashes are needed for the conditioning of these parts and for beam parameters determination [2]. Beam imaging and spectrometry are performed during this phase.
- 10,800 of the 14,500 electron beams were sent to the beam stopper. These ones are mainly used to achieve the beam centering procedure [2].
- The cumulated accelerator operation time is about 11,000 hours.
- There was one shift per day, 140-150 days per year; the remaining time was devoted to maintenance
- About 4,000 preventive maintenance operations per year are carried out.
- The mean preventive operation time is around 2,000 hours per year.
- Mean corrective operation time is about 3,000 hours per year.
- The yearly mean machine downtime for both preventive and corrective maintenance is about 1,200 hours.

MAINTENANCE

Maintenance Strategy

Preventive maintenance operations take place on average four afternoons and one complete day per week. Once a year, there is a five-week maintenance period during which long interventions are run.

As for corrective maintenance, if a failure occurs on the machine, the failing part or subsystem is replaced by a spare. In order to save machine down time, the failure is not fixed in the AIRIX building facility itself but in a devoted maintenance building where various test benches are available to check fixing efficiency. These test benches are also used to perform lifetime tests in order to infer the behavior of sensitive parts such as high voltage cable or accelerating cells when they age [3].

Maintenance Survey Methodology

Each maintenance operation occurring on the AIRIX accelerator is recorded and saved in a database. There are 3 types of maintenance operations:

- Preventive; i.e. operations which are scheduled in the yearly maintenance plan.

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- Corrective; this corresponds to operation to fix failure or to improve a component in order to improve its reliability.
- Support; this mainly corresponds to activities necessary to maintenance operations such as: spare part ordering, maintenance procedure writing, etc…

Each of these maintenance operations have been recorded in the database since half-year 2001. On Fig. 2 the cumulated maintenance operation number per year is shown. It is clearly visible that our maintenance policy is focused on preventive maintenance. The total number of maintenance operation is around 4,000 per year. However the preventive maintenance plan has been continuously modified and optimized over the past twelve years. In fact, the number of maintenance operations has slightly decreased since 2002 and there are between 3,000 and 4,000 maintenance operations per year. Obviously, the amount of operations varies from year to year for some preventive actions only occur every 2 or 3 years.

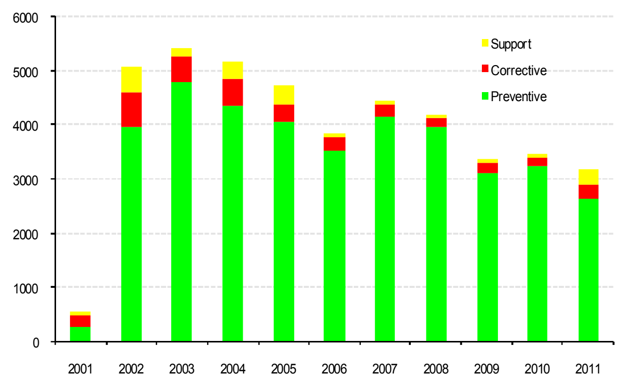

Figure 2: Total number of maintenance operations per year for the whole AIRIX machine. 2001 is incomplete; the database was started after mid-year.

The cumulated preventive maintenance operation number is about 45,000 and the cumulated corrective maintenance operation number is around 3,500.

The total maintenance time for all maintenance operations since AIRIX commissioning is about 100,000 hours.

In order to have an ergonomic list of indicators to follow up the AIRIX working order, the accelerator is divided into 6 sub-systems: injector, accelerator, drift tube, measuring systems and diagnostics, vacuum equipment, high voltage generators. Each sub-system is itself divided into equipment then into components, etc. In this way we have a list of indicators which allow a close survey of the AIRIX accelerator working order.

Failures - Corrective Maintenance

Figure 2 shows the number of corrective operations per year for the whole AIRIX machine. After an initial increase of the corrective operation number mainly due to debugging and correction of the machine teething problems, a regular decrease from 2004 until 2010 may be noticed which allowed the facility to reach a plateau below 200 operations per year. The subsystem where the improvement is most noticeable is the high voltage generator subsystem. The failure number had been divided by about 10 in 8 years, as shown on Figs. 3 and 4.

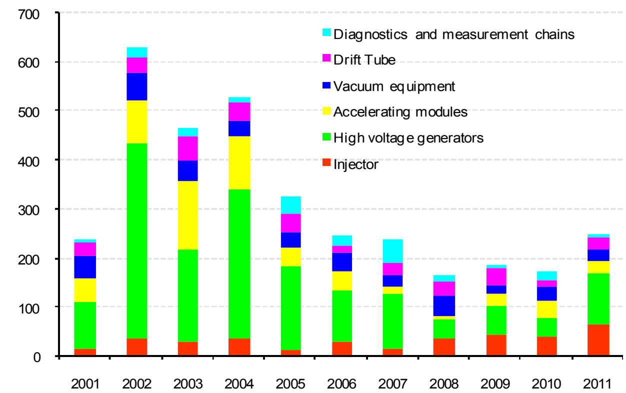

Figure 3: Number of corrective operations per year for the whole AIRIX machine. 2001 is incomplete; the database was started after mid-year.

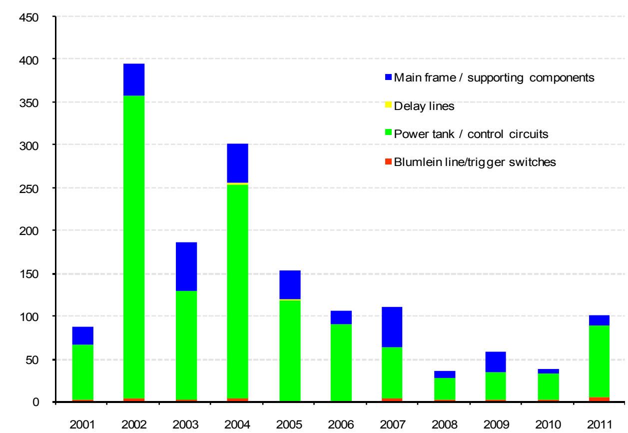

Figure 4: Number of corrective operations per year for the high voltage generator subsystem.

In 2011, an increase is noticeable. It is also due the high voltage generator subsystem (green bars). Figure 4 shows a close view of the high voltage generators subsystem and we can see that there were 100 corrective operations in that year. More precisely, in this subsystem all the high voltage generator triggering circuits were changed in order to improve their reliability. All of them were refurbished in 2011 to improve their reliability and 84 corrective operations, were necessary, hence the significant increase which can be seen.

Thanks to both preventive maintenance plan optimization and continuous technical improvements made since the AIRIX accelerator commissioning the failure rate has been reduced by a factor of about 3.

In order to quantify the maintenance efficiency we can look at the ratio of the number of both preventive and corrective maintenance hours divided by the number of electron beam produced. On Fig. 5 we can clearly see that in 2004 about 5 maintenance hours were necessary to get an electron beam and in 2011 only two were necessary. This notable increase of the electron beam production efficiency is due to operations optimization and reduction of machine downtime due to maintenance operations.

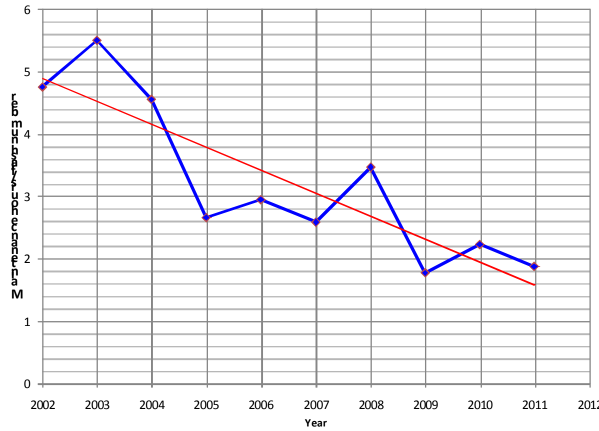

Figure 5: Ratio of the number of maintenance hours over number of electron beam produced.

X-RAY SOURCE RELIABILITY

Survey

All the characteristics of electron beams and X-ray flashes made since 2000 have been stored in and are available from a database. We can study any particular parameter and measure the intrinsic reliability of the X-ray source for hydrodynamic experiments.

The highest occurrence for the known failures that may alter the electron beam and thereby radiographs have been calculated over 4,000 X-flashes. They are listed by order of gravity in the following paragraphs.

Probability of a Total X-ray Source Loss

This could be due to a voltage break-down in the diode and its likelihood is 0.1%. This is a critical event for no electron beam would be produced and thereby the radiographic diagnostic on a hydroshot would in turn be lost. Fortunately the occurrence of such voltage breakdowns is not purely random since they mainly occur after changing vacuum insulator panels and hydroshots are never done after such an operation.

Probability of an X-ray Source Quality Loss

This probability is 1.1%. The two main sources of such a degradation are:

- Voltage breakdowns or rampings in an induction cell: this happens in 0.9% of the flashes. In fact, a closer inspection shows that most of the breakdowns occur in the oil insulated impedance matching connections. The voltage breakdown impact on the beam is strongly dependant upon the cell position. The dose loss is about 3 to 4% and the focal spot is enlarged.
- Loss of one high voltage generator. This occurs in 0.2% of the cases. The impact depends upon the generator position. The dose loss is around 7% and the focal spot size is enlarged.

Probability of Barely Noticeable to No X-ray Source Quality Loss

In 1.7% of the cases post-pulse rampings and/or break-downs in the diode are observed. As these phenomena occur after the main pulse, the impact on the electron beam is barely and in most cases not noticeable on the X-ray source.

On average, 97.1% of the electron beams are produced as expected with nominal characteristics. This figure has in fact increased since AIRIX's commissioning as it is shown on Fig. 6. The probability of having nominal X-ray flashes has on average been increasing over time starting from 94.5% in 2000 to reach about 98% in 2011.

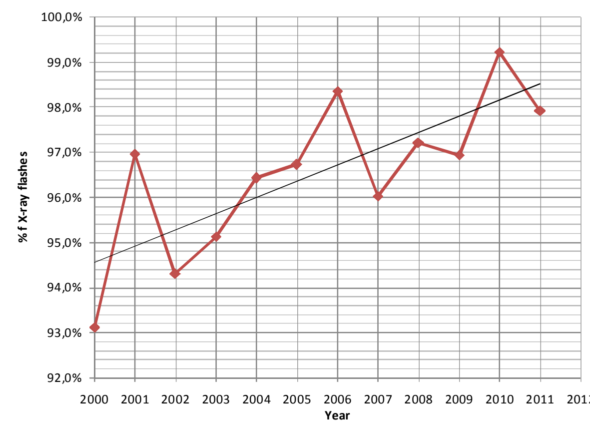

Figure 6: Yearly mean probability of nominal X-ray flashes versus time.

CONCLUSION

All the figures given in this paper are experimental facts, assessed over an entire twelve-year operations period in Moronvilliers test site.

Maintenance and operations are optimized. The maintenance policy has enabled the failure rate per year to be divided by 3 and the maintenance time per electron beam produced to be divided by 2.5.

Meanwhile the probability of having nominal X-ray flashes when hydroshot has increased and is now close to 98%.

AIRIX is a very reliable and available accelerator with stable performances whose ageing is under control.

REFERENCES

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