ELECTRIC-DISCHARGE-BREAKDOWN PHENOMENA OF A GLASS WINDOW USED IN A FLUORESCENT SCREEN MONITOR

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Abstract

A vacuum leakage occurred from a glass window (viewing window) used in a fluorescent screen monitor close to the summer shutdown of the KEKB operation this year, while the injector linac has been favorably under operation. We have had no experience accompanied by such a vacuum breakdown of the glass window due to an electric discharge during four years of operation ever since the commissioning of the KEKB injector linac started in 1997. In this report we describe in detail the observational result and its cure on the vacuum breakdown of a glass window used for the screen monitor.

1 INTRODUCTION

The KEK B-Factory (KEKB) project[1] started in 1994 to investigate CP violation in the decay of B mesons. The KEKB injector linac[2] injects 8-GeV electrons and 3.5-GeV positrons directly into the KEKB rings with asymmetric energies. One hundred and fourteen fluorescent screen monitors in total are located along the injector linac. They are utilized in daily operation in order to easily check the transverse beam sizes and the beam optics matching. Almost all of the screen monitors (old type) were replaced by new compact monitors with an axial length of 85mm between the flanges. They were newly developed for the KEKB injector linac[3]. Thirteen of the old-type screen monitors with the axial length of 160mm are being reused in the J-arc and energy-analyzer lines. The new screen monitors were firstly designed and manufactured in 1994, and were finally installed in 1998 (started in 1994). The beam commissioning of the injector linac started in October 1997 and also started in full scale in 1998.

We found a vacuum leakage from a viewing window of a certain screen monitor, which is located at an electron beam energy of about 6 GeV, during the KEKB operation, close to this summer shutdown. After a detailed investigation, it was found that the vacuum leakage was caused by a breakdown of the viewing window due to an intense electric discharge. Such a breakdown for the viewing window occurred for the first time four years after the beam commissioning started. While we have no clear explanation for this phenomenon, it is important to summarize our detailed observational results in order to better cure the vacuum breakdown.

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2 ELECTRIC-DISCHARGE BREAKDOWN PHENOMENA

2.1 Vacuum Leakage from a Viewing Window

Figure 1 shows the variation of a vacuum pressure measured by an ion pump located at sector 3 during about four days up to the start of the vacuum leakage from the viewing window. The degree of the vacuum started to become worse in 18th in April and, after that, a rapid growth of the degree of the vacuum continued until 19th, and finally the linac operation became impossible due to the interlock-system operation over the vacuum limit. This vacuum leakage was identified from the viewing window of the screen monitor located at sector 3 after an immediate leakage test using a helium detector. After replacing the viewing window by a new one, linac operation was started again without feeding RF power into the accelerator structures.

2.2 Observational Results

The viewing window used in the screen monitor comprises a silica glass (SiO_2:68%, B_2O_3:18%, K_2O:9%, Al_2O_3:3%, other:2% [wt%]) with a thickness of 4.5 mm and with a diameter of 38 mm based on the ICF70 standard. Figures 2 (a) and (b) show photo pictures of this viewing window broken down due to the electric discharge. Both pictures were taken from the window surface in the vacuum side. Figure 2 (a) shows about twenty main traces with a clear symmetry caused by the electric discharge. Two kinds of the discharge traces are found in the figure. One is a trace group generated from the glass centre; it grows in the direction of the inner side of the metal flange with many fine branch traces. The other trace group is also generated with many fine branch traces from the inner corner of the metal flange; it grows in the direction of the glass centre. Figure 2 (b) shows a microscopic picture of the breakdown point penetrating the window glass in which a thick main trace is seen at the centre of the picture. It was located about 11mm apart from the glass centre. We found only one discharge trace penetrating the window, which caused the vacuum leakage. This penetrating trace is not a straight line, but a loosely curved line. The thickness of the penetrating trace is barely observable by human eye and it is around a few hundred μm. We can also find several narrow discharge traces developing transversely from the main discharge point to the metal flange; they also have several narrow branch traces. No transverse traces were found on the atmospheric surface side of the window glass.

2.3 Fluorescent Screen Monitor and Its Radiation Environment

A mechanical drawing of the screen monitor is shown in Fig. 3 and a typical device arrangement around the screen monitor is shown in Fig. 4. The driving system of the screen monitors used in the injector linac is almost the same as that used in other linac facilities. The driving operation of a fluorescent screen is performed by a pneumatic cylinder controlled by compressed air with a pressure of about 5 kgf/cm^2 using an electromagnetic valve. The initial position of the screen is set to be parallel and 13 mm above to the beam line. The screen is driven at an angle 45 degrees to the beam line by an operator's request. Fluorescent light is sent down through a viewing window mounted 65 mm below from the beam line, and is guided to a CCD camera installed at the floor level by using two aluminium-coated optical mirrors. During the first investigation we had some doubt concerning a bad mechanical drive of the monitor, and thus inferred the generation of a high-radiation environment from the screen due to a beam loss. This inference was immediately rejected after testing the mechanical system both in local control and under remote control.

Next, we checked the dark currents generated from the accelerator structures, which also could cause a high-radiation environment at the monitor position. The radiation environment on the linac beam line is expected to be higher than that before the KEKB project started because the pulsed RF power from a high-power klystron was boosted to be nearly double and the acceleration gradient was also boosted to be 20 MV/m from ~7 MV/m by using a pulse-compression device. Figure 4 shows the arrangement of the accelerator structures around the screen monitor on the beam line. As can be seen from the figure, it is expected to easily generate a high radiation environment due to the dark currents at the monitor position located only 270 mm from an output coupler of the upstream accelerator structure. Figure 5 shows typical fluorescent images (a) for this monitor and (b) for another typical monitor under the typical operational condition without beams. The fluorescent intensity for the former screen is clearly stronger than that for the latter screen.

At present, we understand that such high-intensity dark currents might cause a high radiation environment at this screen monitor and, especially, low-energy electromagnetic radiations might hit the window surface synchronously with a RF pulse having a repetition rate of 50 Hz. It is thus expected that a large amount of soft (relatively low-energy) electromagnetic radiation accumulated on the window surface, which caused electric-discharge breakdown.

3 CURES

For the reason described in the previous section, we found a cure by using a new viewing window with electrical conductivity on its surface in order not to accumulate electrical charge. The new viewing window comprises the same silica glass coated with a thin film of stannic oxide (SnO_2). The thin film was spread out on the window surface by a spray and was fixed by a high-temperature process. The electric resistance between the glass and the metal flange was measured to be about 950 Ω. The new viewing windows will be replaced at three locations under a high-radiation environment during the summer shutdown.

4 CONCLUSION

A vacuum leakage from a viewing window used in a fluorescent screen monitor occurred close to the summer shutdown this year for the KEKB operation, while the operation of the injector linac was progressing well. It was found that this vacuum leakage was caused by an electric-discharge breakdown of the viewing window due to high charged-up on the window surface under a high radiation environment. It was inferred that the high radiation environment was generated by high-intensity dark currents from the accelerator structures. In this report some detailed observational examples and their measurements were summarized. However, at present we have no clear idea concerning the basic physical process for the vacuum breakdown and have also no idea why such a breakdown was caused four years after the installation.

Cures are in progress for a viewing window coated by a thin film with a well conductivity.

5 REFERENCES

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[2] I. Sato, *et al.,* "Design Report on PF Injector Linac Upgrade for KEKB" KEK Report 95-18 (1996).

[3] T.Suwada, A.Enomoto, T.Urano and H.Kobayashi, "Mechanical Design of the New Screen Monitor", *Proc. the 20th Linear Accelerator Meeting in Japan,* Osaka, 1995.

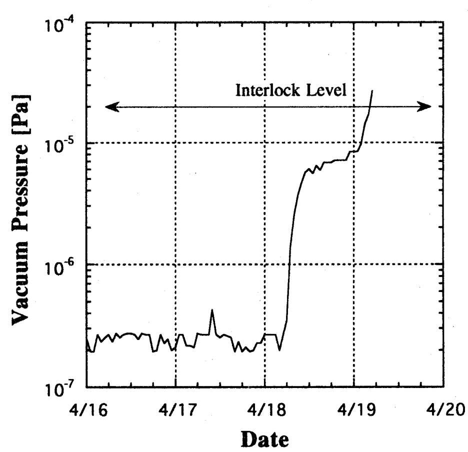

Figure 1: Variation in a degree of the vacuum in sector 3 measured by an ion pump during about four days up to the start of the vacuum leakage from the viewing window.

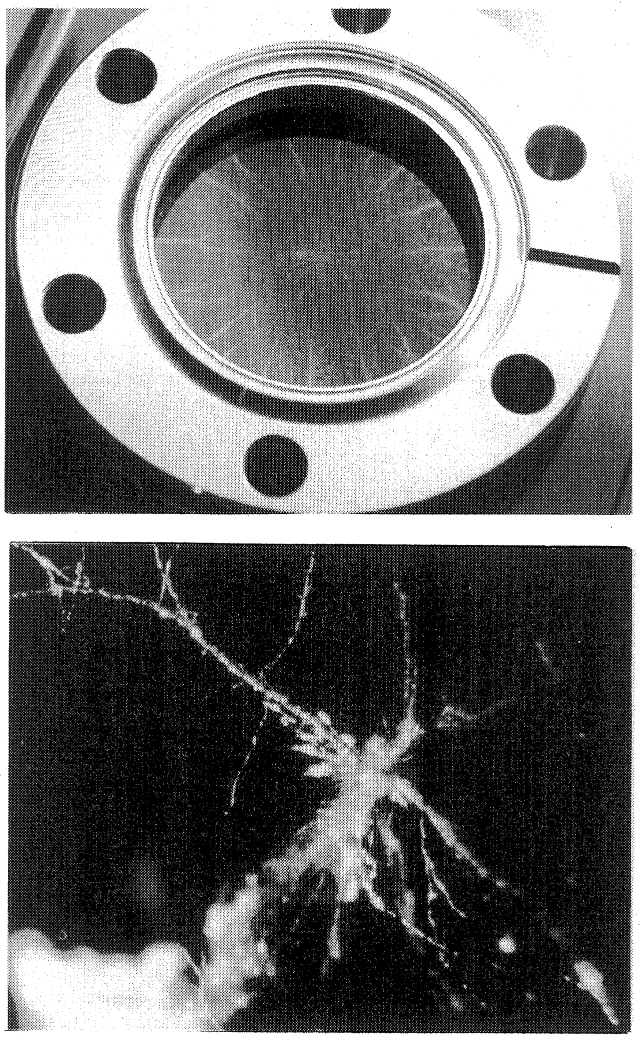

Figure 2: (a) Digital (top) and (b) microscopic photo (bottom) pictures of the generated electric-discharge traces on the glass surface of the viewing window.

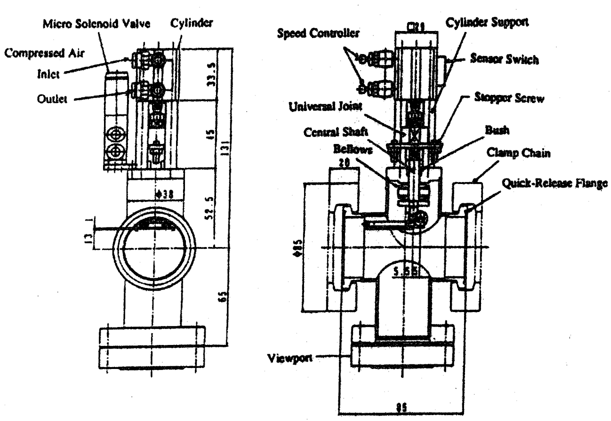

Figure 3: Mechanical drawing of the screen monitor. The beam goes through the monitor from the reverse side to the front in the left drawing, and from the right side to the in the right drawing.

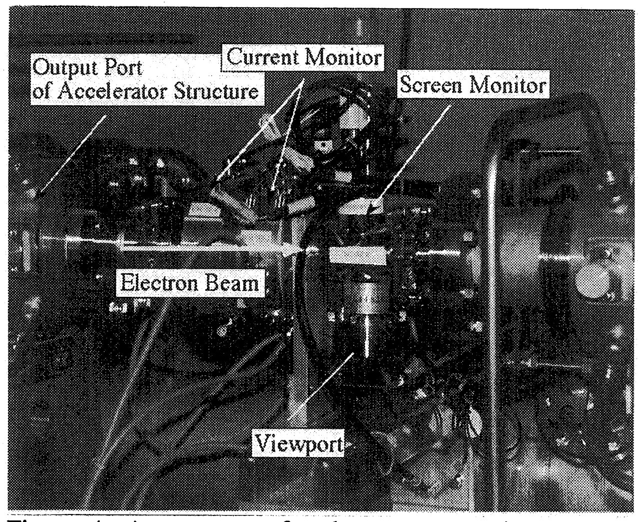

Figure 4: Arrangement for the screen monitor and its peripheral devices. The screen monitor is installed between two 2m-accelerator structures.

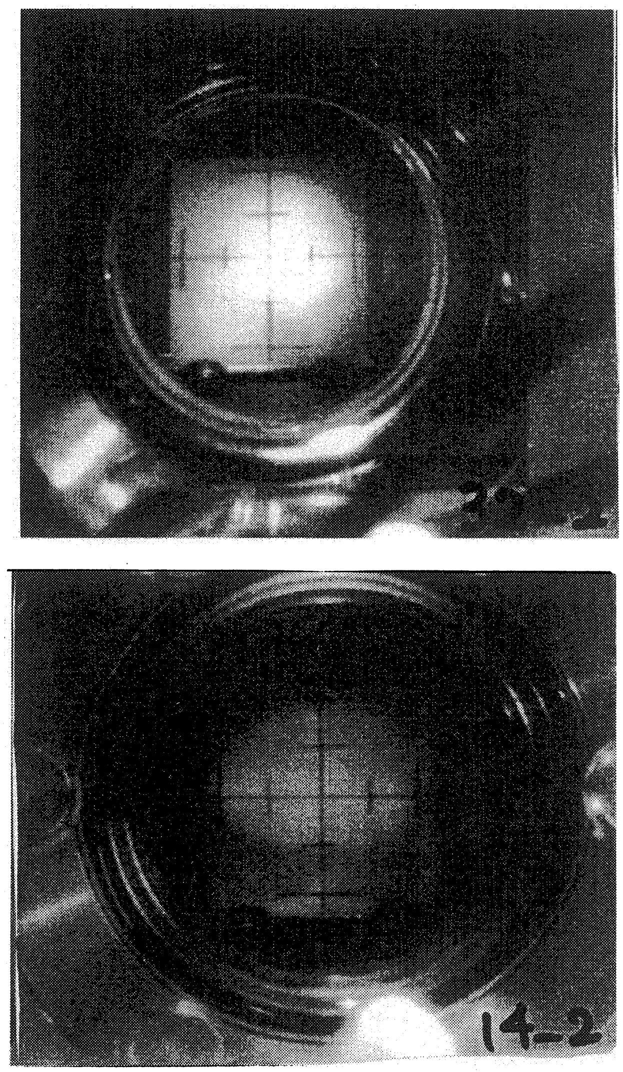

Figure 5: Typical photo pictures of the fluorescent screen images generated by dark currents from the accelerator structures, (a) the screen image (top) of the monitor accompanying by the vacuum breakdown and (b) the screen image (bottom) of another typical monitor.