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~~APPENDIX E~~

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RADIATION PROTECTION ASPECTS OF THE DECOMMISSIONING OF THE CERN INTERSECTING STORAGE RINGS

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ABSTRACT

The CERN Intersecting Storage Rings (ISR) operated from 1971 to 1984. During that time high-energy physics experiments were carried out with 30 GeV colliding proton beams. At the end of this period the machine was decommissioned and dismantled. This involved the movement of about 1000 machine elements, e.g. magnets, vacuum pumps, RF cavities, etc., 2500 racks, 7000 shielding blocks, 3500 km of cables and 7 km of beam piping. All these items were considered to be radioactive until the contrary was proven. They were then sorted, either for storage and reuse or for radioactive or non-radioactive waste. The paper describes the radiation protection surveillance of this project which lasted for five months. It includes the radiation protection standards, the control of personnel and materials, typical radioactivity levels and isotopes, as well as final cleaning and decommissioning of an originally restricted radiation area to a free, accessible area.

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1. INTRODUCTION

The CERN Intersecting Storage Rings (ISR) came into operation in 1971. Studies of proton-proton interactions were carried out at energies up to 31.4 GeV per proton beam for over 13 years. A typical proton beam current was 25 A corresponding to 5 x 10^{14} protons, which were stored for two to three days. The machine elements which were exposed to radiation were installed in a rectangular tunnel, 15 m wide and 6.5 m high. During machine operation access to this tunnel was prohibited; during shut-downs it was a controlled radiation area with typical dose rates of induced radioactivity of 10 to 50 µSv/h 48 hours after the end of operation, reaching up to 1000 µSv/h in the dump and injection areas. Due to the low loss rates during operation the radioactivity of air and water was negligible and there were also, as for high-energy particle accelerators in general, no problems with contamination.

In order to make resources, equipment and manpower available for the Large Electron Positron (LEP) accelerator and storage rings, it was decided to stop the ISR programme in 1983 and to dismantle the machine. The radiation protection services took an active part in a working group which surveyed these tasks during 1984 with the aim of ensuring that the decommissioning was done in a safe way.

2. RADIATION SAFETY STANDARDS AND ORGANIZATION

The objectives of radiation safety for the ISR decommissioning were:

- limitation of personal doses,
- control of radioactive materials either for reuse or for disposal,
- prevention of dispersion of radioactive material outside CERN.

The limit for personal doses and radioactive materials were taken from the CERN Radiation Protection Manual 1983 edition, as follows: the reference dose for persons who work in radiation controlled areas is 15 mSv per year (0.3 mSv per week), and a material is considered to be radioactive with a specific β/γ activity exceeding 2 Bq/g (50 pCi/g).

In view of the rather low values of induced radioactivity no problems were expected as regards personal doses. By far the biggest concern as regards radiation protection was the dispersion of radioactive materials outside the tunnel and outside the site. A priori each machine item was considered to be radioactive until the contrary was proven. At the exit of the tunnel all materials were checked with hand-held instruments* : on non-radioactive materials a green self-adhesive tape was applied and the radioactive material was marked with the trefoil and stored at specially

* IPAB 7-1 type E500 (Nardeux) and Ratemeter RM 2/1 (EMI) with plastic scintillator probes.

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created provisonal areas. In case of doubt, samples were taken for gamma spectrometry. A further last check was carried out on the lorry before it left the site, both manually and by fixed installed gate monitors at the exit. For the radioactive materials which remained at CERN for reuse, special storage areas were created within the ISR tunnel and those items intended for disposal were finally transported to the CERN radioactive waste area.

During working hours one radiation protection technician was permanently on the work site and one on stand-by.

3. DISMANTLING OF THE MACHINE ELEMENTS

3.1 Shielding and beam dumps

One of the first tasks after the shut-down of the ISR was the removal of mobile shielding blocks including 350 concrete blocks and 300 steel blocks of various sizes (standard 40 x 80 x 160 cm^3 and multiples thereof). Due to the low beam losses in the ISR only a few of them were radioactive near the dump area (10-40 μSv/h at 10 cm). The beam dumps themselves were the most radioactive parts of the machine (~1000 μSv/h at 40 cm, 10-100 mSv/h inside). It was decided to leave them in the ISR tunnel and create a radioactive storage area around them, for magnets and other equipment which might be reused (see following sections). Dust samples collected for contamination tests in the dump area showed a very low specific activity of 0.6 Bq/g (see Table 1).

3.2 Electrical equipment

By far the largest amount of equipment to be dismantled was electrotechnical equipment such as magnets and cables. All of the 300 or more magnet units containing some 9000 tons of steel and 1100 tons of copper were dismantled and stored, including their vacuum chambers and supports in the area around the beam dumps mentioned above. The induced radioactivity varied between 5 and 50 μSv/h at 10 cm. As this equipment did not leave the ISR tunnel, no further radiation safety measures were required other than the surveillance of the transport and the labelling of each magnet with its level of induced radioactivity.

With the more than 3500 km of cables the matter was entirely different. Because they were not halogen-free and therefore no longer in conformity with the CERN safety rules, they all had to be disposed of. Temporary storage areas were created on parking lots outside the ISR tunnel to separate the radioactive from the inactive cables (see Fig. 1). Mainly the cables coming from the dump and kicker magnet areas were radioactive with a specific activity of 10-50 Bq/g (see Table 1). Those were cut into one metre long pieces, put into special containers and sent to the CERN radioactive waste area. The others were put on a lorry and sent to the scrap dealer directly.

The main power supplies were in auxiliary buildings outside the radiation areas and therefore not radioactive. This is of course also true for the cables linking them to the ISR tunnel. Also the oil used for cooling of power cables could be considered as being non-radioactive (0.8 Bq/g).

All of the radiofrequency equipment was recuperated for reuse either inside or outside CERN; most of it was not radioactive. The beam observation equipment, on the contrary, was all radioactive (up to 100 μSv/h at 10 cm); it was all labelled and stored for reuse at CERN.

3.3 Vacuum equipment

The vacuum chamber of the ISR had a total length of about 2 km in which successively 35 turbomolecular pumps, 144 sputter ion pumps and 250 titanium sublimation pumps reduced the pressure to 10^{-11} torr. The whole vacuum chamber was wound with heating tapes or surrounded by heating jackets. The latter were the first to be taken apart; they were slightly radioactive (3 Bq/g) and were compressed to radioactive waste.

The vacuum pumps were all radioactive (up to 100 μSv/h at 10 cm) and were stored together with the magnets for reuse at CERN. On the other hand the specific activity of the stainless steel vacuum chambers themselves was, at 8 Bq/g, rather low (see Table 2). Most of them were stored together with the magnets (see above), some were stored for reuse separately, and some disposed of as radioactive waste.

3.4 Ventilation, cooling and ancillary equipment

The air conditioning system of the ISR was kept in operation during and after the decommissioning. As already said earlier, there was never a problem of radioactive air, nor of contamination during operation. Also the air ducts that were installed on the lateral walls of the tunnel were not activated to such an extent that they could become a radiation hazard.

The galvanised and stainless steel water pipes were all dismantled and temporarily stored on a fenced parking lot for later reuse (see Fig. 2). Only a small part of the 7 km of pipe was radioactive, with specific activities between 2 and 10 Bq/g (see Table 1); the highest value found was 300 Bq/g. These pipes were set aside already at the time when they left the ISR tunnel, and were placed in the radioactive storage area.

Of the ancillary equipment large quantities of cable trays and metal plates which had been used as floor covers and on passage ways were sent for disposal. Most of these were below the 2 Bq/g limit (see Table 1). Further, radiation and fire detectors, fire extinguishers, passage ways, ladders, and an innumerable amount of cut connectors and open screws had to be checked before disposal or recuperation. Special care had to be taken with these small items to avoid dispersion of radioactive material.

3.5 Experimental equipment

In seven out of the eight points of the ISR where the two proton beams intersected at an angle of 14.77°, sophisticated and voluminous apparatus had been installed to carry out high-energy physics experiments. Fortunately, for the purpose of the experiments these areas had been well protected against beam losses in order not to restrict the efficiency of experimental data collection. For this reason the induced radioactivity of all experimental equipment was very low (<2 Bq/g). Large quantities were recuperated for other experiments inside and outside CERN but also very large quantities were disposed of. The largest in volume was the split field magnet comprising 900 tons of iron, 42 tons of copper and 5 tons of aluminium. Samples were taken at different places and depths of the magnet. The specific activity of all of them was below 2 Bq/g (see

Table 1). The magnet was then cut into transportable pieces on the spot, put in a railway truck, and shipped directly to the foundry.

4. FINAL CLEANING

When the dismantling was completed an outside contractor proceeded with the cleaning of the tunnel. In a first stage they collected all metal pieces (screws, connectors, pieces of cable, steel plates, etc.) of which quite a few were radioactive. Then the cleaning service vacuum cleaned the tunnel. None of the collected dust was radioactive (0.6 Bq/g, see Table 1). A few samples taken from the concrete of the walls also showed very low specific activity (0.1 Bq/g). As a next step the part of the ISR tunnel that was used for storage of radioactive items (magnets, vacuum pumps, etc., see above) was fenced off and remained a controlled radiation area; the rest was declassified, from controlled to surveyed radiation area. Then another firm came and flattened the floor with concrete. This crew could already work without radiation control (no personal dosimeters required).

In a last instance radiation protection services carried out a final survey of the tunnel to ensure that nowhere the dose rate exceeded 2.5 μSv/h as required by the CERN Radiation Protection Manual, e.g. from remaining ventilation pipes, cables and cable trays, and from the walls. This survey was also extended to the ISR related auxiliary buildings, office buildings and adjacent roads and parking lots. All even slightly radioactive items (e.g. lead bricks, steel blocks) were recuperated and transported to radioactive storage areas.

5. CONCLUSIONS

1) Following the decision to leave the most radioactive items (the beam dumps) in the ISR tunnel and because the induced radioactivity of the other machine elements was low, the dose to personnel involved in the decommissioning was also very low. It was estimated at about 100 μSv/month (not measurable with the film badge) and the collective dose at about 30 mSv for the whole project.

2) Due to the permanent presence on the site of a qualified radiation protection technician and the good collaboration with the personnel involved in the dismantling of the ISR (to a large extent outside contractors), the movement of radioactive material was kept well under control. In view of the large volume dismantled the amount of radioactive waste was rather low (60 m^3). Large quantities could be eliminated directly and an equally important amount was kept in storage for reuse.

3) The main long-lived isotopes in the machine elements were ^{54}Mn, ^{60}Co and ^{22}Na with specific activities of 1 to 100 Bq/g. There was no risk of contamination from water, oil, concrete or dust.

Table 1

Spectrometric analysis of various materials from
the CERN ISR decommissioning

Samples	Specific activity Bq/g	Percentage of main isotpes				
		^{60}Co	^{57}Co	^{54}Mn	^{22}Na	Others
Copper cable	47	79	13.7	7.3		
Copper cable with PVC sheath	10	72.5	10.6	13.1	1.2	2.6 ^{58}Co
Aluminium cable and bars	1				100	
Vacuum chamber (stainless steel)	8	60	14	23		3.0 ^{44}Ti
Heating tape	3		6.5	4.5	89	
Heating jacket	113			12	88	
Steel cable tray	1.7	18		54		28 ^{65}Zn
Galvanised pipe	2.5	93		7		traces ^{65}Zn
Inox water pipe	7.3	90		10		
Steel plate (floor cover)	1.7	28		72		
Split field magnet iron core 0-105 mm depth	1.5 to 0.6	6		94		
Split field magnet copper coil	0.5	80		20		
Split field magnet aluminium plates	0.1				100	
Concrete (floor)	0.1	31		17		52 ^{137}Cs
Dust (dump area)	0.6			30	9	46 ^{137}Cs Traces of ^{57}Co, ^{140}Ag, ^{134}Cs

Fig. 1. Check of cables for disposal.

Fig. 2. Water pipes for recuperation.