THOUGHTS ON DECOMMISSIONING THE CERN SYNCHRO CYCLOTRON

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ABSTRACT

Solutions proposed on the decommissioning of the CERN Synchro-Cyclotron and thoughts on the construction of future accelerators which in use will become radio-active and which eventually will need to be dismantled to enable their disposal according to the prevailing safety requirements.

1. GENERAL

After 33 years of loyal and active service the 600 MeV CERN Synchrocyclotron (S.C.) was closed down at the end of 1991. Discussions took place concerning the decommissioning and initially it was hoped to start towards the end of 1991 or early 1992, but due to financial restraints it has only been possible to remove the beam lines, including the trolleys upon which they have been built, from the neutron side of the machine. However, in carrying out this work, one of the principal radioactive hot-spots, the electro-mechanical channel has been removed

2. DESCRIPTION

The S.C. machine consists of a conventional 2500 tonnes magnet assembly encompassing a large stainless steel vacuum tank welded to the pole pieces of the magnet. Inside the vacuum tank are the beam control, measurement and beam extraction units : kim coil, regenerator, magnetic channel, electromagnetic channel probe target, diagnostic targets, internal targets, small dees and the accelerating electrode (dee) of the RF system.

External to the vacuum chamber is the vacuum pumping system, the ion source and beam limiter mechanisms. Running on rails between the S.C., and the neutron room were three beam lines (the 125 MeV, 70 MeV and muon) and the electromagnetic channel. It is these latter which have been removed.

3. CONSIDERATIONS

The S.C. was not constructed to be readily dismantled the vacuum tank being welded to the magnet pole pieces and there are also several highly radioactive areas which need special consideration.

It was essential that a decommissioning programme be prepared and in doing so several problems that had not been considered during the construction and exploitation of the S.C. were encountered, to which solutions must be found. The disposal of radioactive waste also needed careful attention.

The two main problems are the induced radiation and/or contamination of major parts of the installation and the need to physically seperate the vacuum tank from the magnet assembly. A subsidiary problem is that all the large steel blocks forming the magnet yoke are tack welded together as well as being bolted.

3.1 Induced radiation

The possibilities for the disposal of radioactive items are governed by the level of the induced activity. At CERN anything below 2 Bq/g is considered non active, between 2 and 40 Bq/g slightly active, between 40 and 400 Bq/g active and over 400 Bq/g highly active. Non-active in this context means that a single piece shall nowhere exceed 2Bq/g and is the limit accepted by the Swiss Authorities for the unrestricted release of scrap. Slightly active items would normally be stored locally until they decay to less than 2Bq/g or be reused. Recently, an alternative possibility, available in France and Germany, is the controlled melting of slightly active steel scrap of less than 74 Bq/g allowing its conversion into shielding blocks at a cost of 4-5 SF/kg. Ref. 1.

Both active and highly active items may be reused in controlled radioactive areas or reduced to a convenient size and placed in concrete containers acceptable to the appropriate Swiss Authorities before they can be considered for disposal at the radioactive waste depository in Switzerland.

The problem of induced radioactivity is created by the presence of long lived radionuclides. The majority of which have half-lives of several years. It has been estimated that one would have to wait until the year 2079 before the specific activity falls below 2 Bq/g. The dose rates inside the vacuum tank and in other areas preclude their dismantling other than by remote procedures.

3.2 Vacuum tank removal

The second problem is the removal of the vacuum chamber, welded to the pole pieces. Should one remove this weld it would still not be possible to withdraw the vacuum chamber in one piece, as the highly active pole pieces protrude inside the vacuum tank. It is therefore necessary to cut up the vacuum chamber in sufficiently small pieces to facilitate their removal and at the same time be small enough to be accepted in the concrete radioactive waste disposal containers. It is a process which will have to be carried our remotely and as some of the walls of the vacuum chamber are 60 mm thick investigations have been carried out on suitable cutting techniques. Methods investigated have been flame cutting, oxy-arc cutting, arc water jet, arc saw cutting, plasma arc cutting, laser cutting and abrasive water jet cutting.

3.2.1 Flame cutting

A burning process consisting of a torch assembly using a mixture of oxygen and usually acetylene gas. The workpiece is preheated by the acetylene flame and when the oxygen is turned on, the metal is burnt away. Cutting ferrous metals presents no specific problem but for non-ferrous metals such as stainless steel, a special technique is necessary. When cutting stainless steel, refractory oxides, with melting points higher than the torch temperature, are formed. However, iron or iron/aluminium in a flowing mixture can be introduced at the torch nozzle to increase the flame temperature enough to melt the refractory oxides and permit the cutting of the stainless steel. The cutting speed is high, even for thick metals, and the torch has a long life; a disadvantage is that the distance from the nozzle to the workpiece is relatively precise.

3.2.2 Oxy-arc cutting

This process uses a hollow rod electrode and an oxygen jet supply. After touching the workpiece, an electric arc is established, the material melts and the kinetic energy of the oxygen jet removes the melted material. It is a simple and cheap process which suffers from the fact that the electrode has to be changed rather frequently.

3.2.3 Arc saw cutting

This is a circular toothless metallic blade which can be used to cut any conducting material without touching the workpiece. The blade rotates at between 300 and 1800 revolutions per minute facilitating the cooling of the blade and the removal of the molten material. The cutting action is obtained by means of an electric arc between the rotating blade and the material being cut. Thick sections can be cut at high speed but as the blade is normally of the order of 1 meter in diameter, it is extremely heavy and cumbersome and very expensive.

3.2.4 Arc water jet

This consists of a consumable electrode surrounded by a water jet. The electrode touches the workpiece and melts the material and the water jet removes the molten material. It is a relatively cheap and efficient method and can handle large thicknesses but suffers from the fact that the electrodes have to be changed regularly and provision has to be made for water recuperation, which could possibly be radio-active.

3.2.5 Plasma arc cutting

A gas, which is introduced into an electric arc and is constricted by a thermal and magnetic pinch, produces a plasma at approximately 8000°C. The material melts and the kinetic energy of the gas removes the molten metal. It is possible to cut thin sections at high speed but will not handle thick sections.

3.2.6 Plasma arc saw

This process is being developed by the German Government. Several plasma torches are fixed on the periphery of a rotating disc and are oriented in slightly different directions. The blade is rotated at low speed permitting the cutting of very thick metal up to 300 mm. Ref. 2.

3.2.7 Laser cutting

Lasers have been used, especially underwater, to cut extremely thick sections (at least, 1 meter) but they are too bulky and expensive.

3.2.8 Abrasive water jet

A small diameter high velocity water jet and a stream of solid abrasives are introduced into a specially shaped abrasive jet nozzle from seperate entries. Part of the water jet momentum is transferred to the abrasives, whose velocity increases rapidly. This equipment can be used to cut both metal and concrete but is is extremely expensive and the water/abrasive mixture has to be recuperated. It also has a short nozzle life.

3.2.9 Recommendation

After careful consideration, it has been recommended that flame cutting will be used to cut up the CERN vacuum tank and special equipment will need to be designed to retain the torch at an optimum distance from the workpiece.

3.3

Other problems, not without their own importance, are the lack of up-to-date drawings concerning the mechanical assembly of the machine and the fact that equipment used to assemble the S.C. after its reconstruction about 15 years ago, has been destroyed in the interim period. This includes a moving overhead crane in the S.C. building which was dismantled some years ago to facilitate handling in the machine vault - one crane still remains but two are essential for removal of the heavy and cumbersome elements. The grinding away of the yoke element welds will be time consuming and dirty work in a radio-active environment.

4. REFLECTIONS

Finding solutions for these problems at the decommissioning stage tends to be rather more difficult than if, at the design stage, more thought had gone into some of what are typical pit falls.

A safety series published by the International Atomic Energy Agency lays down guide lines concerning all aspects of the decommissioning procedure. Ref. 3.

Every installation one day reaches the end of its useful life and its ultimate fate is either demolition or leaving it to decay (in the radioactive sense). the responsibility rests with the owner for its demolition but more and more Local Authorities and Central Government are insisting that appropriate provision for an orderly and controlled demolition be included in the initial design before allowing planning consent. This particularly applies to electrical power station construction but one can imagine that before long it will become the routine for all similar installations.

In most cases what is needed for efficient demolition is the preservation of adequate information of the original design and its subsequent history. It is also adviseable, even at the design stage to involve a reputable company (or in-house service if available) versed in industrial demolition and decommissioning..It is absolutely essential that the decommissioning operation be planned in outline in advance so that it can be integrated in a way which optimises both safety and costs. Although such a programme could well enhance its selling possibilities in a commercial organisation, it must be remembered that deconstruction is hardly ever the simple reverse of construction.

Not only are complete records of the construction require, supplemented by copious photographs taken during the construction and afterwards, covering every detail required, but also full listings of the isotopic composition of all materials used in the radioactive zones are necessary. All these records must be in a permanent form, since they may remain unused for often 30 years , but they must also be correctly archived and catalogued.

As the timing for the decommissioning cannot be determined at the design stage, it is necessary to think in terms of durable building construction, reliable ventilation, heating, protection systems etc... even if more expensive at the outset, as after the installation has been shut down, the period between this time and decommissioning could be of the order of several tens of years and maintenance must be reduced to a minimum over such a long period.

In the case of shielding, there is a clear case for trying to maximise the amount of mobile shielding used around a machine. One reason is that it gives more flexibility for modifications to machine or beam line layouts during the normal operation of the machine and secondly at the decommissioning stage, it facilitates the removal of the maximum amount of shielding, without the use of pneumatic hammers, and in doing so reduces the amount of exposure time for personnel in radioactive zones. Consideration should be given to the provision of shielding on the outside of a building, allowing more internal space. Care, however, should be taken to ensure that the seismic design requirements are achieved.

Prestressed concrete is often impossible to distinguish, visually, from ordinary reinforced concrete. It is not unusal to stress up horizontal beams in two seperate stages. The first degree of prestress is applied to the tensile side of the beam to enable it to carry part of its load. As the construction proceeds and the load on the beam increases, the pre-stress is correspondingly increased. Accidents have occured during demolition whereby beams have suddenly and unexpectedly failed upwards, to the great danger of the demolition workers. A much more common accident is the unexpected effect of attempting to cut up a pre-stressed concrete beam believing it to be ordinary concrete . It is thus absolutely necessary that permanent records be kept of this type of construction.

5. CONCLUSION

5.1 Decommissioning a radioactive apparatus should start at the design stage.

5.2 Special attention should be taken in the initial design to try to facilitate the ease by which such a construction can be dismantled.

5.3 Adequate permanent records should be kept up to date concerning all aspects of the construction, including the building.

6. REFERENCES

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