LICENSING AND SAFETY ISSUES OF THE ESS ACCELERATOR

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Abstract

The licensing process for the European Spallation Source (ESS) has started up. The process includes both an application to the Environmental Court in Sweden as well as the application towards the Swedish Radiation Protection Authority (SSM). The applications will be based on an Environmental Impact Assessment (EIA) and a Safety Analysis Report (SAR). One important step has been to define which regulations that apply for ESS [1]. ESS has also set up General Safety Objectives (GSO) [3]. Based on the GSO and the legal requirements, the process design of the whole ESS facility is on going. This paper (presented as poster WEPC166 at IPAC-2011) focus upon the radiation safety issues related to the accelerator.

GENERAL SAFETY OBJECTIVES

The ESS is a complex facility where several hazards might occur. These hazards include radioactive hazards as well as non- radioactive hazards. Although ESS is not defined as a nuclear facility according to the Swedish regulation, ESS emphasizes the objective of setting radiation shielding & safety as a main priority for all phases of the project from design, through construction and operation, to decommissioning.

Table 1: Event Classification in the GSO

Classification	Event	Frequency (per year)
H1	Normal Operation	≤ 1
H2	Incidents	1 to 10^{-2}
H3	Unexpected Events	10^{-2} to 10^{-4}
H4	Design Basis Accidents (DBA)	10^{-4} to 10^{-6}
-	Beyond DBA	$\geq 10^{-6}$

When starting the operation of ESS, there will be no significant radioactive inventory. During operation, penetrating fast neutrons are generated in the target and by proton beam losses in the accelerator. The main inventory of nuclides will be in the target and thus it is in the target station where most radioactivity will be generated. Thus, the main hazards arise from radioactivity sources but other hazards, here named non-radiation hazards must be addressed as well. Examples are hazards originating from cryogenics, high-voltage, electromagnetic fields, heavy equipment, working on high heights, transports etc. Thus, in order to protect the ESS staff, the public and the environment, it is necessary that ESS states and defines specific General Safety Objectives. The GSO will serve as a guiding document at ESS, giving necessary input of how to design the ESS facility.

Table 2: Summary of the Radiation Requirements given by the GSO

Event (unit=mSv)	Radiation workers	Non-exposed workers	Public
H1 (per year)	10	0.05	0.05
H2 (per event)	20	0.50	0.50
H3 (per event)	50	5.0	5.0
H4 (per event)	100	50	50

Concerning radiation, the ALARA principle (As Low As Reasonably Achievable) shall be applied. This means that radioactive doses have to remain as low as possible, or in other words that threshold doses may not be exceeded, if that can be reasonably avoided. For the design process, ESS must have some dose criteria for guidance. A dose budget is given for the different parts of the facility. Thus, a design criterion for the necessary shielding of the accelerator tunnel has been given.

Table 3: Design Criteria (Public) "Facility Dose Budget"

(X = prel. major contributors)	Acc.	Target	Instr.	Waste building
Direct Radiation	X	X	X	X
Activation	X			
Emissions into Air	X	X		
Emissions into Drains		X	X	
ESS_{Total} (mSv)	$\Downarrow$	$\Downarrow$	$\Downarrow$	$\Downarrow$
H1 0.05 /year	0.03	0.01	0.005	0.005
H2 0.50 /event	0.05	0.35	0.05	0.05
H3 5.00 /event	5.00	5.00	5.00	5.00
H4 50.00 /event	50.00	50.00	50.00	50.00

DEFENCE-IN-DEPTH

The ESS shall be designed according to the "defence-in-depth" principle. The International Nuclear Safety Advisory Group (INSAG), part of IAEA, defines five levels of defence in depth for future nuclear facilities:

1. Prevention of abnormal operation and failures
2. Control of abnormal operation and detection of failures
3. Control of accidents within the design basis
4. Control of severe plant conditions, including prevention of accident progression and mitigation of consequences of severe accidents
5. Mitigation of radiological consequences of significant releases of radioactive materials.

An outcome of #1 and #4 is that the ESS facility shall be designed with Safety Barriers (SB). These are physical barriers constructed in order to contain the radioactive inventory of the ESS facility in case of different events. In some sense radiation-shielding material also could be regarded as a barrier. The barriers will not be equal with regard to strength but they will be used in order to mitigate a possible event/incident/accident at different parts of the facility.

Table 4: Proposed Number of Barriers, with respect to the Public

Facility	Examples of Safety Barrier
Target	1. Cladding/crystal lattice 2. Confinement/Crypt vessel 3. Target building
Accelerator	1. LINAC tunnel entrance 2. Accelerator shielding
Neutron Beam Lines	1. Beam Line guides 2. Beam Line Shielding
Instrument Buildings	1. Instrument Shielding 2. Instrument Building
Waste Disposal Building	1. Container/Vessel/Package 2. Building

ANALYSES & CALCULATIONS

Extensive radioprotection studies have been made [2]. Monte Carlo simulations complemented with analytical predictions. PHITS code based on an intra nuclear cascade model to simulate nucleon-induced reactions and a model based on QMD theory for reactions induced by both nucleons and heavy ions. Statistical decay of compound nucleus is calculated with GEM extension of the evaporation model implemented in LAHET code system. In the present calculations default option standing for Bertini intra nuclear cascade (INC) was applied. The use of the PHITS computer code is justified by the fact that at the starting moment of these simulations it was the single available computer code able to estimate the required parameters. Most recent availability of MCNPX code allowed checking the PHITS estimates with good agreement. Presently, simulations using FLUKA code are in progress.

It was concluded from this investigation that a shielding thickness of about eight meters of earth is required for public area designation. Residual field inside the tunnel was further evaluated for beam loss consequences upon the machine structure, concrete wall and air inside. Radioactive isotopes in the air surrounding the beam loss are the short-lived positron emitters that are produced in oxygen and nitrogen by spallation reactions (T1/2 few minutes), 7Be and 3H produced by spallation reactions as well as the 41Ar by thermal neutron capture in the natural argon. Various scenarios of the air radioactivity release from the accelerator tunnel are to be accounted and comparatively analysed. Activation of the concrete wall and adjacent soil shielding was further estimated. Concrete will require final disposal. Also first two meters of soil has to be treated as nuclear waste, at least for 15 years. Contamination of the adjacent soil is not avoided with increased thickness of concrete. Further, ESS accelerator design has to include protective measures to isolate the soil from groundwater in order to prevent contamination.

Detailed studies based on more realistic assumptions are necessary, as well as supplementary studies related to the shielding against “sky shine”.

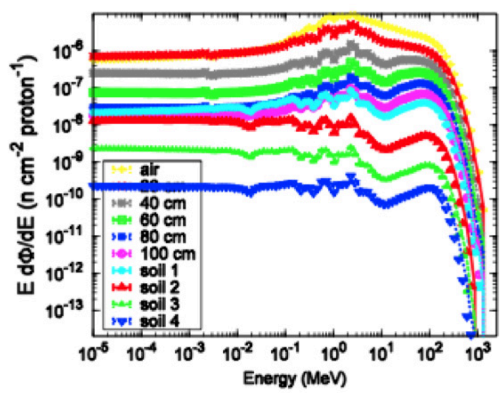

Figure 1: Study of neutron energy distribution at various depths in concrete, and in the subsequent soil.

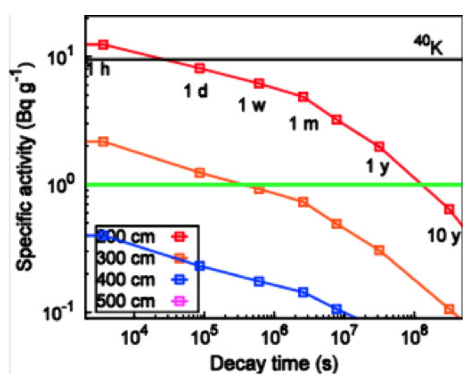

Figure 2: Study of residual activity contribution of ^{40}K and other radionuclides in the soil as a function of shielding thickness, after 40 years of operation. Green line stands for the exemption limit.

SHIELDING OPTIMAZATION

ESS does not foresee any construction problem regarding the shielding for the accelerator. The challenge is to fulfil the environmental requirements related to radiation and at the same time optimize the construction of the shielding in a cost-effective way. One of the contributors for the accelerator regarding the amount of radiation reaching the public is the specific pathway of activated soil being transported via the groundwater. This will occur as one contribution during normal operation. According to the GSO the total allowed dose rate to the public arising from the accelerator during normal operation is a maximum value of 0.03 mSv/y as design criteria. Including the pathway through the groundwater.

Another example is the expected event "Beam loss" which could result in a 5 MW beam pointing up through the ground, reaching a person on the surface. The GSO states that the received dose rate from this specific category of events is not allowed to exceed 0.05 mSv. Together with a safety system, cutting off the beam, this event will define the need of radiation shielding between the accelerator and people on the surface, which is a different criteria and thus give rise to another shielding thickness and other possible solutions compared to the groundwater issue.

ESS has discussed several possible alternatives for the shielding of the accelerator tunnel. Further discussions are needed as well as updated calculations. The final optimization is a balance between cost of material (soil, steel and concrete), water level of groundwater and shielding requirement.

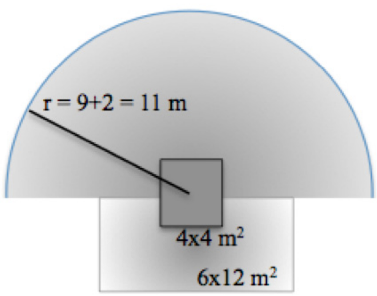

Figure 3: Possible shielding solution, which might consist of different material on top and bottom of the Accelerator.

LICENSING PROCESS

The licensing process of the ESS facility is given by three different legal acts in Sweden; the Radiation Protection Act, the Environmental Code and the Planning and Building Act. A formal notification was sent to the Swedish Radiation Safety Authority (SSM) in August 2010 saying that ESS intend to send an application for start of construction late 2011. An important statement is that SSM regards ESS as a non-nuclear facility. However, due to the uniqueness of ESS as a spallation source SSM also state that special requirements (e.g. the same as for nuclear facilities) might be applied for ESS. After the notification, meetings between SSM and ESS are and have been held on a regular basis. Our primary goal is to produce a PSAR (Preliminary Safety Analysis Report) in which we describe the technical concept, potential risks and the mitigation of those risks, waste management and decommissioning of the facility. The PSAR will form the basis for the application of construction.

Our Environmental Impact Assessment (EIA) is planned to be sent to the Environmental Court late 2011. Continuous work has been done for the facility planning layout process towards the Lund municipality in accordance with the Planning and Building Act. In these matters, ESS has a strong connection and cooperation with both Maxlab and Lund municipality regarding the planning of the whole area north east of Lund.

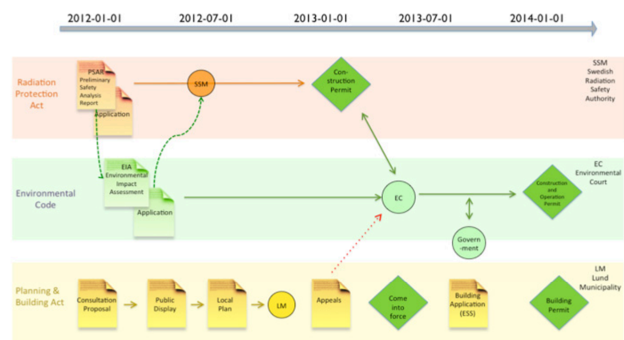

Figure 4: Timetable for the licensing process.

ESS is planning to set up a Safety Review Committee (SRC) as a support to the Director-General for review of all aspects to the safety of the ESS facility. The Safety Review Committee will, as TAC (Technical Advisory Committee) and SAC (Scientific Advisory Committee), consist of international experts in various fields of safety. ESS is planning to have the first meeting with SRC later on in 2011.

REFERENCES

[1] T. Hansson ESS, "Compilation of the Swedish Radiation Legislation", 2011-03-29

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[3] P. Jacobsson ESS, "General Safety Objectives for ESS", 2011-08-25

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