

Chapter 11

Safety and Security

Chapter abstract

Summary: ESS will be designed to a high level of safety in order to meet the expectations of the users, the personnel and the regulatory requirements. This applies to aspects of safety such as radiation, fire, cryogenics, chemicals, heavy loads and other hazardous items or situations. The security of the facility will be designed to meet the basic in-house security rules and regulatory requirements, as well as the need from the users and personnel to work in an open and friendly atmosphere.

Licensing of ESS is focused on the regulatory radiation safety requirements from the Swedish Radiation Safety Authority (SSM). Thus, the chapter mainly deals with the radiation safety principles for ESS design. The fundamental safety functions, the safety barriers and the safety systems are generally described.

Passive safety is the fundamental safety principle. The accelerator proton beam hits the target material and neutrons are produced in the spallation process. When the proton beam stops, the production of neutrons stops. Residual heat is removed from the tungsten target by passive conduction, convection and radiative cooling, even without any active systems.

Three confinement barriers contain the substantial nuclide inventory in the target, caused by proton bombardment. All possible other nuclide inventories at ESS will have at least two safety barriers.

11.1 Safety principles

ESS will be a complex facility with the potential to pose a variety of hazards to human beings and the environment. ESS prioritises prevention of harm to employees, the public, and the environment from both radiation and conventional safety threats. In 2011, ESS formally adopted the following project-wide set of *general safety objectives* (GSO) [1]:

- “To protect individuals, society and the environment from harm arising from the construction, operation and decommissioning of the ESS facility.
- To ensure that in normal operation, exposure of personnel to hazards within the facility is controlled, kept within prescribed limits, and minimised.
- To prevent accidents with high confidence.
- To ensure that any abnormal operational event has minimal consequences for ESS personnel and for the public.
- To minimise the hazardous waste arising from the operation and decommissioning of ESS, both in its quantity and level of hazard potential.”

These overarching goals will guide ESS through all phases of its multi-decade life-cycle, through all stages of conceptual and detailed design, fabrication of components and construction, commissioning, operation, planned and unplanned maintenance, and eventual dismantling and decommissioning. The GSO govern the design and implementation of the specific safety systems and programmes.

In accordance with well-established international best practice, a few basic principles constitute the framework for the ESS safety programme: exposure to hazards will be *as low as reasonably achievable* (ALARA); multiple and redundant levels of safety barriers and protective systems will provide *defence-in-depth*; ESS design will incorporate both *passive* and *active* safety measures; and an ongoing process of *review and assessment* of safety systems will shape the entire engineering design process. These principles will enforce the *safety culture* within the ESS organisation. Maintaining that safety culture will be a top priority for ESS management.

As low as reasonably achievable

ESS will keep exposures to hazardous materials as low as reasonably achievable. The ALARA principle means that ESS will make every reasonable effort to minimise exposure to radiation, even when exposure falls far below dose limits prescribed by Swedish law (as will usually be the case). ESS will operate on the principle of achieving the lowest level of exposure that is consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the financial cost of achieving further reductions in exposure, and the impact of further reductions on the project’s scientific objectives. Application of the ALARA principle implies that predicted doses (during the design phase) and actual doses (during operational phases) should generally decrease as the project proceeds and new data become available, permitting more precise and more realistic estimations of dose levels. ESS will maintain documentary records of the predicted and measured personnel and environmental exposures, in accordance with Swedish law and International Committee for Radiation Protection guidelines and as a necessary step for implementation of ALARA best practice.

Review and assessment

Throughout the engineering design process, ESS personnel will conduct safety reviews and assessments to ensure that the design satisfies the top-level safety objectives and is in compliance with SSMFS 2008:27 [2]. These assessments will include analyses of: normal operation; maintenance; incidents and accident scenarios; waste handling and waste storage; commissioning and test operation; and decommissioning. The results of these analyses will be available to assist the preparation of documentation for regulatory applications.

Safety culture

No set of protocols, rules or laws by itself can guarantee the safe operation of a complex facility. Organisations have cultures, and those cultures affect the safety of their operations. INSAG [3] described a “safety culture” as:

“... that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, ... safety issues receive the attention warranted by their significance.”

Indicating the importance of this issue, a subsequent INSAG report [4], offers recommendations to tackle the practical and managerial challenges to building and maintaining such a safety culture. The management of ESS embraces the INSAG recommendations, and is committed to fostering a safety culture that nourishes an open and constructive attitude towards safety concerns and an organisation-wide commitment to a continuous process of safety improvement.

Quality assurance management

High quality of design, materials, structures, components and systems, operation and maintenance is vital for the overall safety of ESS. Quality assurance programs will ensure the development of a safe design (including design of process and safety systems, design of safety barriers, design of modifications and safety analysis). Appropriate conservative assumptions and safety margins will be used for design and construction.

11.1.1 Confinement barriers and defence-in-depth

Safety engineers at nuclear facilities such as power plants have refined and developed the concept of “defence-in-depth” through years of practical experience. The approach allows facilities to compensate for potential human and technical failures by building several levels of redundant protection into the facility design, including sequential safety barriers to prevent the release of radioactive material to the environment. A failure at one level of a system is compensated by the barriers in place at the next level. While nuclear facilities pioneered the defence-in-depth approach, it can be and has been fruitfully applied to other types of facilities. ESS will use a set of physical confinement barriers that operate independently of one another to prevent and mitigate potential releases of radioactive isotopes. Demonstration of the adequacy of this set of barriers is an important part of the safety analysis. ESS will apply the defence-in-depth concept in order to minimise deviations from normal operation, to prevent accidents, and to mitigate the consequences of abnormal events.

In accordance with the principles laid down by the International Atomic Energy Agency working group INSAG (International Nuclear Safety Advisory Group), ESS will implement the defence-in-depth approach via four safety levels with procedures and systems: to minimise deviations from normal operation; to monitor and document deviations from normal operation and to intervene *before* such deviations progress to accidents; to control accidents if they do happen; and to mitigate the adverse effects of accidents. Table 11.1 provides more detail about this multi-level approach to safety. ESS has chosen to apply the defence-in-depth strategy, which implies that there will be confinement barriers in different parts of the facility. The confinement barriers are shown in Table 11.2.

Passive safety systems

Passive safety systems rely on facility features whose very nature acts to prevent accidents or to limit the adverse consequences of accidents. Passive safety systems rely predominantly on natural laws and material properties, and provide protection independently of human intervention. The ESS design constitute of two such fundamental characteristics of passive safety systems. The first crucially important feature of ESS’s design from the safety perspective involves the linear accelerator. The linac will depend on the continuous input of power from the electrical grid to produce beam. This is a powerful safety feature, because if the external power supply is interrupted for any reason, the accelerator will automatically shut itself down. Unlike nuclear reactors, there is no danger of ESS “going critical” once it has been accidentally or deliberately cut off from the power grid. The second important feature of the ESS design from the

Level	Objective	Tool
1	Prevention of abnormal operation and failures.	Conservative design and high quality in construction and operation. Qualification of materials in the target environment. Continuous survey and documentation during manufacturing and testing. Simple operation to reduce probability of human error. Redundancy, diversity and separation principles in active safety systems. Qualification of personal in all life-cycle phases. Quality assurance system covering the safety related activities by ESS and the subcontractors and partners.
2	Detection of deviations from normal operation and provision of means to prevent development of sequences leading to accident conditions.	Independent or redundant control, limiting and protection systems as well as other surveillance features including environmental radiation monitoring.
3	Control of accidents.	Engineered safety features and protection systems to prevent accident progression. Radioactive materials confined within a containment system.
4	Control of severe accident conditions and prevention of accident progression.	Procedures for mitigation of accidents in order to ensure that radioactive releases are kept as low as reasonably achievable.

Table 11.1: Levels of defence-in-depth to compensate for potential human and technical failures..

System	Number of barriers	Confinement barriers
Target	3	Target wheel envelope Monolith confinement Target building
Target systems	2	Monolith confinement Target building
Hot cell	2	Hot cell confinement Target building
Proton accelerator	2	Accelerator beampipe Accelerator tunnel
Neutron scattering instruments	3	Neutron guide shielding Neutron guide tunnel and bunker Instrument component confinement
Waste disposal building	2	Cask/package Building

Table 11.2: Confinement barriers for radiological protection.

safety perspective involves the cooling function of the ESS target station. The most likely reason for a loss of cooling system function is an electric power interruption. Although this guarantees an instantaneous shut-down of the accelerator, heat production in the target will continue for some time. ESS's adoption of a rotating, helium-gas-cooled tungsten target of 2.5 m diameter, which offers a large enough surface area for passive radiative cooling to avoid dangerous temperatures with a significant safety margin, passively eliminates this risk, even in the absence of an active cooling system.

Active safety systems

ESS's active safety systems will include mechanical, electrical and instrumentation and control components. They will ensure that the facility operates safely, and that safety is maintained in the event of an incident. For example, active safety systems will provide for cooling of the target material during normal beam operation. Other active safety systems will make sure that the beam is shut down and that components such as the target material are cooled in the event of an incident. Note that cooling of the target material will be done actively by gas cooling although from a defence-in-depth perspective, this function is not formally required since the cooling can be done passively. Active safety systems also encompass ESS protocols governing installations and training programs to ensure that all employees act in accordance with prevailing instructions and in compliance with Swedish regulation SSMFS 2008:27 [2]. ESS protocols will lay out a fixed schedule for maintenance, testing and adjustment of many mechanical and electrical safety devices, and for radiation monitoring of the experimental instruments.

11.2 The licensing application and regulatory processes

While ESS is a non-nuclear facility, it will produce activated materials. In developing its safety programmes, ESS has profited from decades of collaboration and exchange among regulators and facility operators within the nuclear community about how to handle such materials. The International Atomic Energy Agency (IAEA) is an important actor in this exchange, publishing reports and guidelines that analyse crucial safety issues, summarise the lessons learnt from industry experience, and establish best practices. This accumulated collective knowledge base informs ESS's own safety objectives and programme.

The licensing process of ESS is given by three different legal acts in Sweden, as shown in Figure 11.1; the Radiation Protection Act, the Environmental Code and the Planning and Building Act. In March 2012, ESS sent in the formal application to the Swedish Radiation Safety Authority (SSM) asking for a permit to construct. The Preliminary Safety Analysis Report (PSAR) [5] constitutes the basis of the application. The PSAR describe the overall technical concept, potential risks and the mitigation of those risks and the waste management of the radioactive material. In March 2012, ESS also sent in an application to the Swedish Environmental Court asking for permissibility to construct and operate ESS outside Lund. An Environmental Impact Assessment (EIA) forms the basis for the application. 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 Max-lab and the Lund municipality regarding the planning of the whole area northeast of Lund.

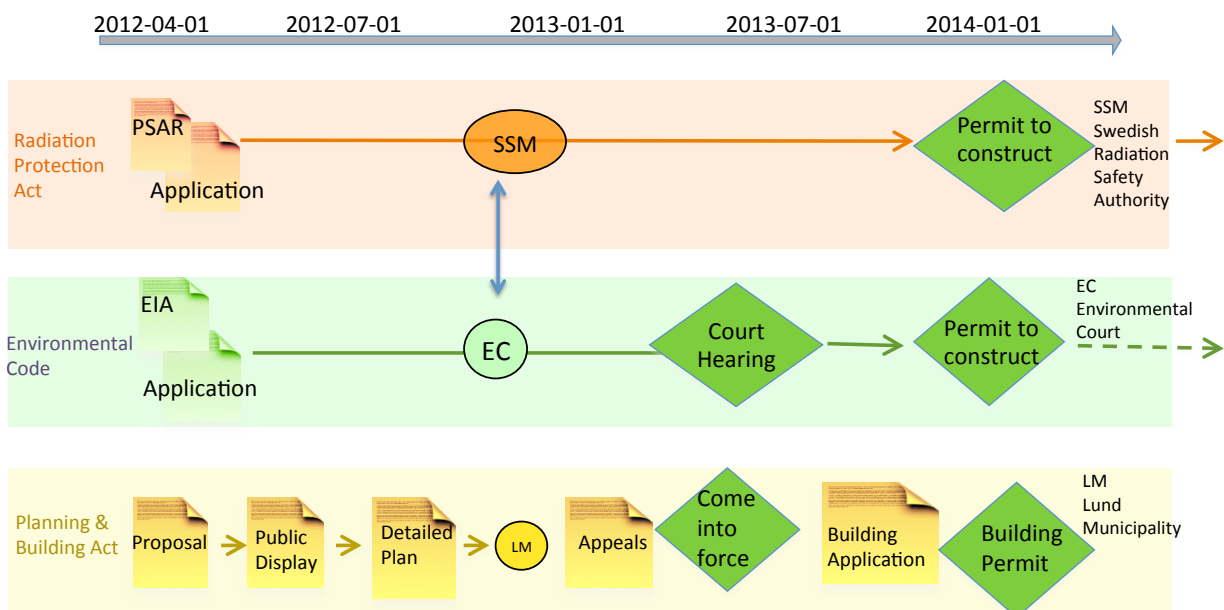


Figure 11.1: Licensing process for construction permits.

Radiation regulations

The Swedish Radiation Protection Act (SFS 1988:220) governs activities and facilities emitting radiation in Sweden. The main purpose of the act is to protect humans and the environment from the harmful effects of radiation. Under power conferred by the act, the Swedish government has issued Radiation Protection Government Regulation (SFS 1988:293). In its turn, under power conferred by this regulation, the SSM has issued a large number of authority regulations supplementing the Radiation Protection Act and Government Regulation. For nuclear facilities, the Nuclear Activities Act (SFS 1984:3) applies. However, ESS does not qualify as a nuclear facility under the definition laid out by the Nuclear Activities Act. Under both the Radiation Protection Act and the Nuclear Activities Act, SSM is appointed as the regulatory authority.

A number of SSM regulations apply to ESS. These include SSMFS 2008:27, which regulates the operation of accelerators and sealed radiation sources; SSMFS 2008:51, which provides for the protection of workers and the public during activities involving ionisation radiation; SSMFS 2008:52, as amended by SSMFS 2010:1, which provides for the protection of outside workers who work with ionising radiation; and SSMFS 2010:2, which regulates the handling of radioactive waste and releases from activities with open radiation sources. In addition, the Swedish Civil Contingencies Agency (MSB) Regulation MSBFS 2011:1, on road and terrain transports of dangerous goods (ADR-S), will apply to the transport of radioactive substances to and from ESS. In the SSM regulations that apply to ESS, there are no specific regulations regarding accidental conditions, although both SSMFS 2008:27 and SSMFS 2008:28 require regulated facilities to develop an action plan for handling unexpected events from a radiation protection point of view.

SSM may, when granting a permit under the Radiation Protection Act, or at any point during the term in which the permit is valid, set permit conditions for ESS. While ESS is not a nuclear facility, it has taken into account those aspects of nuclear facility regulation that seem relevant to ESS activities in developing its own internal protocols and guidelines, which in many circumstances are more stringent than the national regulations [6]. ESS has declared that it will abide by the intention of this regulation. ESS has set 0.05 mSv as the upper annual dose limit for the general public, but aims at not exceeding 0.01 mSv per year for any of three exposure pathways: direct radiation, inhalation and ingestion.

11.3 Radiological safety

The radiological safety focuses upon limiting the doses for the ESS personnel as well as the environment. The limitation and estimation of radioactivity doses are based on regulations from SSM for facilities with major radioactive inventories. In particular, SSMFS 2008:17 requires that “events” be classified according to the probability of occurrence, and specifies that reference doses be established for each event class, which should not be exceeded. ESS has also taken into account experience from similar facilities around the world. The limiting doses are established for normal operation and for different hazardous events, which might occur during the lifetime of the spallation neutron source.

Classification of events

All possible incidents and accidents that might happen at the ESS facility, including normal operation, are categorised into four classes depending on the predicted annual frequency of such events. The classification of the events is presented in Table 11.3, using frequency values adopted from licensing practice in Western Europe [7]. The definitions of event classes are given below and the list of initiating events with their classification is provided in the document setting out ESS’s *General Safety Objectives* [1].

- **H1: Normal operation.** Normal operating regime includes different maintenance phases of the facility, including events and disturbances during the normal operation occurring more or less frequently but where a relevant safety system is available. The restart of the facility can be done after repairs that fall within the range of normal maintenance.
- **H2: Incidents.** Events which are unusual, but which are expected to happen at some point during the lifetime of the ESS facility are classified as incidents. The expected frequency of these events varies from 10^{-2} times up to less than once per year. The facility should be able to restart after several weeks of repair following an incident.

Event	Description	Frequency [1/y]	Unit	Rad. workers	Non- exposed workers	Public (effective dose)
H1	Normal operation	≥ 1	[mSv/y]	10	0.05	0.05
H2	Incidents	$10^{-2} - 1$	[mSv]	20	0.5	0.5
H3	Unexpected events	$10^{-4} - 10^{-2}$	[mSv]	50	5	5
H4	Design basis accident	$10^{-6} - 10^{-4}$	[mSv]	100	50	50
–	Beyond design basis accident	$\leq 10^{-6}$				

Table 11.3: Classification of radiation hazard events and summary of the General Safety Objective limits on radiological doses.

- **H3: Unexpected events.** Events that are not expected to occur during the lifetime of the ESS facility are classified as unexpected events. The predicted frequency of these events varies from 10^{-4} to 10^{-2} times per year. The facility should be able to restart after several months of repairs following an unexpected event.
- **H4: Design basis accidents (DBA).** Events which are very unlikely to occur within the lifetime of the facility are classified as DBA events. The predicted frequency of these events ranges from 10^{-6} to 10^{-4} times per year. The facility will be designed and constructed to withstand DBA events, within specific limits.
- **Beyond design basis accidents (BDBA).** Events which are not expected to happen within the lifetime of the facility are classified as BDBA events. The frequency of these events is less than 10^{-6} times per year. The facility probably would not be able to restart after a BDBA.

The commissioning process will include conservative and realistic assessments of the facility's capacity to cope with normal operation, incidents, unexpected events and DBA events. BDBA events have such a low probability that they will not be included in the commissioning safety assessments. Nevertheless, BDBA events will be analysed during the ESS design phase in order to evaluate alternative emergency response scenarios by the relevant authorities. As part of this analysis, ESS will estimate the potential radiological impact of BDBA events. Preliminary evaluations indicate that the radiological impact of BDBA events would not be dramatically larger than that of the DBA events that the facility will be designed to withstand.

General radiation safety requirements

Under Swedish law, the regulations regarding risk and exposure limits for ionising radiation are different for employees and the general public. The summary of the GSO for radiation hazards towards workers with risk for exposure to ionising radiation, non-exposed workers at ESS as well as general public together with the collective dose for ESS staff is presented in Table 11.3. The upper dose limits for H1-H4 events are also provided.

Staff

ESS employees are divided into two classes: those who might be exposed to ionising radiation during their duties and non-exposed employees. The latter group will not have access to areas where there is a risk for radiation exposure. In accordance with Swedish regulation SSMFS 2008:51, the maximum annual effective dose for workers shall not exceed 50 mSv, while the cumulative dose over five years is limited to 100 mSv. Swedish law requires that employee doses be individually monitored, and that doses be monitored online in real time during an employee's presence in radiation risk areas. The Swedish regulations [8] prescribe an annual effective dose limit of 1 mSv for employees who are not exposed to radiation.

In accordance with the ALARA principle, ESS guidelines call for more restrictive dose limits than does Swedish law [1]. For ESS employees whose duties might subject them to radiation exposure, dosage should not exceed 10 mSv per year. The ESS goal for non-exposed employees is 0.05 mSv per year. In addition to the individual dose limits for ESS workers, ESS has adopted a maximum collective annual effective dose,

which includes exposures for subcontractors, consultants, and other non-employees present at the facility. ESS has set this collective limit at 1 personSv per year. ESS will also comply with Swedish exposure limits for pregnant women, in accordance with SSMFS 2008:5 [8], which requires that once the employer becomes aware of the pregnancy, the maximum effective dose to a foetus may not exceed 1 mSv during the remainder of the pregnancy.

In case of incident conditions, the Swedish regulations for employees working with ionising radiation is taken as a reference. In accordance with SSMFS 2008:51 [8] the maximum annual effective dose must not exceed 50 mSv, while the total obtained dose during five years has to be lower than 100 mSv for employees. ESS guidelines again set a more restrictive limit of 20 mSv per year. Since there are no governmental requirements related to dose limits for non-exposed workers, ESS guidelines call for the same dose limit as for general public, namely 1 mSv per year [8]. ESS will also comply with the Swedish regulatory requirement that rescue efforts that could lead to an effective dose higher than 100 mSv, may only be performed by volunteers in possession of valid scientific information about the radiation danger.

The public and the environment

Under SSMFS 2008:51 [8], the effective annual dose limit for individuals from the general public who do not work with ionisation sources shall not be higher than 1 mSv. In specified exceptional circumstances, SSM allows for a higher effective dose for a single year provided that the average over five consecutive years does not exceed 1 mSv per year. Again, ESS guidelines call for more restrictive dose limits than does Swedish law, with 0.05 mSv as the upper annual dose limit for the general public. The doses to a representative individual must be estimated with appropriate documentation of methodology. In July, 2012, ESS submitted a dose assessment report to SSM describing likely exposure of the representative person including living conditions, food pathways and a statistical analysis of meteorological dispersion conditions. The analysis demonstrated adequate protection of the environment and biosphere [9]. The results from the activation calculation performed [10] show that ESS radiation emissions will not harm any species or the ecosystem as a whole.

The maximum effective dose for general public must not depend on incident or accident conditions. ESS will estimate release doses for H2 events, and will describe in detail the steps to be taken to mitigate the consequences of releases during such events. In general, SSMFS 2008:51 [8] stipulates that the annual effective dose from H2 events shall not exceed 1 mSv per person who does not work with ionisation sources. In exceptional circumstances, SSM allows for a higher effective dose for a single year provided that the average over five consecutive years does not exceed 1 mSv per year. The calculation results of the released doses under accident conditions will help to determine which measures ESS should apply to mitigate accident consequences and protect employees and the general public. In accordance with [1], ESS guidelines call for the following maximum effective doses to the public: 0.5 mSv/event for H2 events, 5 mSv/event for H3 and 50 mSv/event for H4 events.

11.3.1 Safety functions

The IAEA [11] has identified three fundamental safety functions that,

“...shall be performed in operational states, in and following a design basis accident and, to the extent practicable, on the occurrence of those selected accident conditions that are beyond the design basis accidents:

- control of the reactivity;
- removal of heat from the core; and
- confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases”

Because ESS is not a nuclear facility, these safety functions must be adapted to fit its circumstances. A spallation source neither creates the reactivity threat posed by a fission reactor nor has the same level of decay heat arising from a fission process. The fundamental safety functions in a spallation source are: stopping the spallation process (by stopping the proton beam); removal of afterheat from the target; and confinement of radioactive materials and control of operational discharges, as well as limitation of

accidental releases. There is no need for active cooling of the helium-cooled tungsten material of the target after shut down of the proton beam [12]. However, active cooling of the target is required during proton beam on the target. While the design of the complete ESS safety programme is an ongoing effort, progressing in an integrated way with the design of the entire facility, the outlines of its basic principles and functions have been established.

Stopping the proton beam

The proton beam will be stopped in the case of any of the following events:

- Loss of target wheel rotation (to avoid compromising the first target confinement barrier)
- Loss of active cooling of the target material on the target wheel (to avoid compromising the first target confinement barrier)
- Loss of cooling of the moderator hydrogen (to avoid an uncontrolled pressure rise that could harm the first and second target confinement barriers)
- Loss of cooling of the pre-moderator water (to avoid an uncontrolled pressure rise that could harm the first and second target confinement barriers)
- Loss of cooling of the reflector (to avoid compromising the first and second target confinement barriers as well as the first confinement barrier of the reflector)
- Loss of cooling of the proton beam window (to avoid compromising the first PBW confinement barrier)
- Loss of vacuum in the accelerator tub (to avoid compromising the accelerator confinement barrier as well as protection of the machine)

The beam will also be stopped (for personnel protection) in the case of: personnel entrance into the target rooms above the monolith; personnel entrance into the accelerator tunnel; or personnel presence in the neutron instruments if there is no appropriate shutter in the line of sight if the personnel, or if an installed shutter fails to close. Abnormal beam steering can also lead to the loss of vacuum in the accelerator, which also turns the beam off. Several levels of safeguards will protect against personnel exposure within the neutron instruments. The high-radiation environment of the instrument will be searched and closed off before the shutter is opened. However, if a person is accidentally locked inside one of the neutron instruments despite these precautions, he or she will be able to trip the proton beam. In addition, an emergency switch will shut down the beam in case equipment malfunction leads to an unsolicited shutter opening. The uncontrolled release of high beam power can lead to serious damage and/or long repair times of the accelerator, the target station and neutron instruments. It is therefore crucial to maximise the operational efficiency of the facility by avoiding accidents. But also any interruptions of operations due to repair and/or maintenance work should be limited to a shortest time possible.

Figure 5.4 shows the relation between the main safety and protection systems at the ESS facility: the target safety system (TSS), the personnel protection system (PPS) and the machine protection system (MPS). The TSS addresses the actions required to operate the target station in accordance with the Swedish nuclear regulatory guidelines, and must fulfil the highest reliability demands. It covers the target station systems, the A2T (Accelerator to Target Station) section, and the intersection between target and neutron instruments. The TSS interacts with the accelerator, mainly to request a machine shutdown (switch off of the proton beam). The PPS and MPS will be designed for the protection of personnel and machine equipment throughout the conventional facilities, the accelerator, the target station and the neutron instruments. The reliability demands for the PPS are higher than those for the MPS. Details on the MPS and PPS are described in Chapter 5. Both MPS and PPS are under the responsibility of ICS.

Cooling systems, removal of afterheat and confinement of the radioactive inventory

Cooling systems for the following components must be operational for a safe performance of the facility: the target material in the target wheel and its confinement; the hydrogen moderator; the water pre-moderator; the reflector; the proton beam window; and the monolith shielding. Controlled ventilation of the following

components is required for the mitigation and/or reduction of releases of radioactive substances to the environment: the target monolith; the target station connection cells; the target station building; the target station active cell; the accelerator tunnel; and the waste treatment building. Confinement of the radioactive inventory will be controlled via the leak tightness of the first barrier (the target wheel shroud), and the second barrier (the monolith lining). Controlled pressure relief will be operational for the following cooling systems: the target wheel; the moderator (safety valve outside the monolith); the pre-moderator (safety valve outside the monolith); and the proton beam window. Controlled pressure relief will also be provided for the monolith in case of a moderator fire, explosion, or similar event.

11.3.2 Safety systems

Redundancy and diversity in active safety systems provide multiple levels of protection for personnel, the general public, and the environment. The following safety systems have been identified:

- Target safety system
- Personnel protection system,
- Target wheel cooling system,
- Target moderator cooling system,
- Target pre-moderator cooling system,
- Target reflector cooling system
- Target proton beam window cooling system
- Target wheel confinement system
- Target monolith confinement ventilation system
- Target building confinement ventilation system
- Active cells ventilation system
- Accelerator tunnel ventilation system
- Target monolith pressure relief system
- Target moderator pressure relief system
- Target pre-moderator pressure relief system
- Target proton beam window pressure relief system
- Target component handling system

Safety classification of facility systems

There are standards that deal with safety classification of systems and components for nuclear power plants. Safety classification is based on event classes with adopted maximum environmental impact that govern reliability requirements for different systems. A similar approach can be applied for ESS but it is not relevant to talk about breakdowns in the same way as in a nuclear fission reactor. However, one can determine which systems and components that are most important to prevent the release to the environment of radioactive nuclides during an accident and those essential for fulfilment of a safe operation of ESS. For ESS one safety class is suggested with the criteria given below. The following systems, structures and components are defined as radiation safety classified:

- System that has a confinement barrier function.
- Control system that provides information on safety related process parameters and the ability to control safety features.

- System for mitigating release of radioactivity to the environment.
- Monitoring system for monitoring of radioactive emissions during normal operation and accidents.
- Systems for protection of confinement barriers.
- Systems for the supply of power and media to the system defined as safety related.
- Structures that prevent the spread of contamination within the facility.
- Structures that carry static loads and protects safety related systems.
- Fire mitigation systems for protection of safety related systems.

Some external systems that are not in this list – such as cranes – could compromise these classified safety systems. The risk could come from pressurised components, accumulated heat, potential chemical reactivity, or mass, (e.g. in case of an earthquake). Such components must be secured if they are in the vicinity of classified components, or they can simply be eliminated.

11.4 Conventional safety

The radiation safety question is important both for the public as well as for the ESS employees. The conventional safety is mainly an occupational safety issue for the ESS employees and the visiting scientists. For ESS construction the main focus will be on: fire safety; hydrogen; cryogenic safety; pressure vessels; electrical safety; chemical handling; and heights and heavy loads.

Fire safety

Prevention of fire is essential especially in high-energy physics facilities as ESS. A typical fire can arise from electrical cabinets, cables and high-voltage equipment. Other sources must also be considered in the analysis. The need for local fire fighting capabilities at ESS has to be analysed in more detail. At present no on-site local fire brigade is foreseen. A fire in the accelerator, target, instrument buildings and waste building may give rise to release of radioactive gases.

Hydrogen

Hydrogen will be used as ion source of the accelerator and as a moderator in the target monolith. The handling and use of hydrogen in the accelerator will be done according to existing regulations. The main hazard of handling and operating with hydrogen is the risk of explosion. Hence, the system will be designed to be intrinsically safe. Hydrogen has a low ignition point and therefore it is vital to remove or limit all possible ignition sources, e.g. electrical connections. The assessments of radionuclide inventory in the accelerator do not indicate that this will be of any major radiological risk. Within the target monolith there will be two circuits of hydrogen at 20 K and 1.5 MPa, which will be cooled by cryogenic helium. Empty rooms within the monolith will be filled with helium, which will reduce the risk of hydrogen explosion within the target. Further analyses of the potential risk have to be evaluated.

Cryogenics

The use of cryogenics liquids and evacuated vessels constitute a potential explosion hazard and risk of suffocation. Oxygen deficiency hazards must be considered in every space where cryogenics are present. A complete risk analysis will qualify the zone of operation. Experience and construction guidelines and regulations from existing accelerator laboratories will be used. Adequate ventilation and expansion volumes will be considered. Cryogenic safety will also be important for the safety at the instruments where liquefied nitrogen and helium will be used for experiments.

Pressure vessels

Apart from the cryogenic safety, ordinary pressure vessels regulations apply as any normal industrial activity. Pressure vessels or pressurised systems containing water will or may occur in the heat recycling systems and the cooling systems.

Electrical safety

Electrical safety is of vital importance, especially in the klystron gallery where several high-voltage components will be installed. Swedish regulations specifically give the distance between high-voltage equipment if to perform maintenance during operation.

Chemical handling

At the laboratories and at the instruments, safe handling of chemicals will be important. All chemicals that are handled within ESS are under restriction of REACH [13], the European legislation for handling of chemicals. The chemicals, which are planned to be used at ESS must be registered in a database, updated by ESS and containing safety fact sheets for handling of the individual chemicals.

Height and heavy loads

An important part for the occupational safety will be preventive measures regarding heights and handling of heavy loads. Specific regulations apply for the construction of cranes and lifting devices but also the planning of how the heavy load will be internally transported (lifting zones) will be done from a safety point of view. Work places and/or work task involving high heights will be analysed, estimated from a point of risks and followed by mitigating actions or procedures.

11.5 Security

The security of ESS will be designed to meet the basic in-house security rules and fulfilment of regulatory requirements as well as the need from the users and personnel to work in an open and friendly atmosphere. Apart from the obvious in-house security rules in preventing stealth and protection of equipment, the security requirements will be treated and integrated together with the safety requirements. Especially the zoning of the facility will be integrated taking into account radiation safety, fire safety and security. Systems for entry and zoning permissions will be designed and maybe fully integrated with the personal protection system described in Section 5.2.3.

Bibliography

- [1] T. Hansson and P. Jacobsson. ‘General safety objectives for ESS.’ Technical Report EDMS 1148774, European Spallation Source, 2011.
- [2] ‘Regulation on operation of accelerators and sealed radiation sources.’ Swedish Radiation Safety Authority SSMFS 2008:27, 2008.
- [3] ‘Safety culture.’ Technical Report INSAG-4, International Nuclear Safety Advisory Group of the International Atomic Energy Agency, 1991.
- [4] ‘Key practical issues in strengthening safety culture.’ Technical Report INSAG-15, International Nuclear Safety Advisory Group of the International Atomic Energy Agency, 2002.
- [5] S. Nordlinder et al. ‘Preliminary safety analysis report for ESS.’ Technical Report ESS-0000002/1, European Spallation Source, 2012.
- [6] C. Carlile. ‘Application for permission under the Swedish Radiation Protection Act.’ ESS letter to regulatory authorities ESS-0000043, European Spallation Source, 2012.
- [7] R. Moormann. ‘Safety & licensing of the European Spallation Source (ESS).’ Report Jul 4136, Forschungszentrum Jülich, 2004.
- [8] ‘Regulation on basic regulations for protection of workers and public at activities with ionisation radiation.’ Swedish Radiation Safety Authority SSMFS 2008:51, 2008.
- [9] S. Nordlinder. ‘Dose assessment for severe accidents at ESS.’ Technical Report ESS-0000488/1, European Spallation Source, 2012.
- [10] D. Ene. ‘Radiation protection studies for the ESS superconducting linear accelerator.’ Technical Report EDMS 1093060, European Spallation Source, 2010.
- [11] ‘Safety of nuclear power plants: Design, requirements.’ IAEA Safety Standard Series NS-R-1, International Atomic Energy Agency, 2000.
- [12] C. Kharoua. ‘Design calculation report, estimation of the impact of the after heat – LOCA.’ Technical Report EDMS 1164510, European Spallation Source, 2011.
- [13] ‘Registration, evaluation, authorisation and restriction of chemical substances (REACH).’ European Community Regulation No. 1907/2006, http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm, last accessed 22 Feb 2013.