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IAEA SAFETY STANDARDS

for protecting people and the environment

Step 7
First review of the draft safety standard by the SSC(s)

Human induced External Hazards in Site Evaluation for Nuclear Installations

DRAFT SAFETY GUIDE NUMBER DS520

Revision of Safety Guide NS-G-3.1

FOREWORD

Later

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide supplements and provides recommendations on how to meet the requirements for nuclear installations established in the IAEA Safety Standards Series No. SSR-1, Site Evaluation for Nuclear Installations [1] with regard to the evaluation of hazards associated with human induced external events[1] (HIEEs). It thus complements other Safety Guides that deal with the evaluation of nuclear installation site [2-6]~~, [3], [4], [5], [6]~~ and the design of nuclear installations against external events excluding earthquakes [7].

1.2. The present Safety Guide supersedes and replaces earlier Safety Guide: External Human Induced Events in Site Evaluation for Nuclear Power Plants (NS-G-3.1, 2002).

1.3. Over the past two decades, significant new knowledge and experience has been gained of hazards associated with human induced external events. This Safety Guide incorporates:

(a) Recent developments and regulatory requirements on risk informed and performance-based approaches for assessing the safety of nuclear installations, including reference to IAEA's Safety Fundamentals and Safety Requirements relevant to hazards associated with human induced external events;
(b) Progress in regulatory practice in Member States relevant to human induced external events;
(c) A systematic approach to the identification, screening and subsequent hazard analysis for all human induced external events;
(d) Reference to good practice methodologies for analyzing the hazards arising from the most significant human induced external events.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide recommendations on evaluation of hazards associated with human induced external events that could affect the safety of nuclear installations. These hazards need to be considered in the selection and evaluation of nuclear installation sites, in the design of new installations, and in the operation stages of existing installations.

[1] An external event is an event that originates outside the site, and for which the operator has a very limited or no control over its occurrence, and whose effects on the nuclear installation should be considered. Such events could be of natural or human induced origin and are identified and selected for design purposes during the site evaluation process. Events originating on the site but outside the ~~safety related~~ buildings important to safety should be treated the same as off-site external events, but taking into account the higher level of control over these events (this includes any coupled facilities on the site, e.g. to produce hydrogen). A slightly ~~different~~ modified definition of the term 'external event' is used in this publication.

1.5. This safety guide is intended for use by regulatory bodies, which are responsible for establishing regulatory requirements, for designers of nuclear installations and for operating organizations, which are directly responsible for safety of nuclear installations and for the protection of people and the environment from harmful effects of ionizing radiation.

SCOPE

1.6. The recommendations in this safety guide are intended to be used for the evaluation of hazards associated with HIEEs for nuclear installations. The approach for evaluation of these hazards and utilizing these evaluations in the design and operation of nuclear installations need to be planned and implemented in a systematic way. This process can be phased as follows:

- Phase 1: Identification and screening of hazard sources;
- Phase 2: Evaluation of hazards and characterization of loading conditions;
- Phase 3: Design and evaluation of structures, systems and components;
- Phase 4: Performance, assessment and acceptance criteria of the nuclear installations on the site;
- Phase 5: Operator response to potential HIEEs.

1.7. This Safety Guide considers Phases 1 and 2. Phases 3 and 4 are covered in the IAEA Safety Guide on design of nuclear installations against external events excluding earthquakes [7]. Phase 5 is covered in the IAEA Safety Guide on the protection against internal and external hazards in the operation of nuclear power plants [8]. These phases are closely linked, and the work undertaken for each one is to be recognised the needs of the others, especially at the interfaces between them where the outputs from earlier phases inform and provide input data to later phases.

1.8. Phase 1 includes source identification and screening of potential sources in the region around the nuclear installation site. Phase 2 builds on Phase 1 and considers only the HIEEs screened-in by the screening exercise. Phase 2 includes detailed evaluation of hazards for characterization of loading conditions for screened-in hazards.

1.9. In this Safety Guide, the HIEEs are grouped into following Event Categories:

- External rRelease of hazardous substances;
- External eExplosions;
- External fire;
- Aircraft crash;
- External tTransport events excluding aircraft crash;
- Other human induced external events.

1.10. This guide includes some discussion of consequential hazards arising from HIEEs, e.g. aircraft fuel fires following an aircraft impact. However, it does not address hazard combinations. Hazard combinations are covered in IAEA Safety Guide on design of nuclear installations against external events excluding earthquakes [7].

1.11. This Safety Guide addresses a range of types of nuclear installation[2]. The methodologies recommended for nuclear power plants need to be applied to other nuclear installations through a graded approach. The recommendations need to be tailored to meet requirements for different types of nuclear installation in accordance with the potential radiological consequences of accidents. The recommended direction of grading is to start with attributes relating to nuclear power plants and, if appropriate, to grade down to installations with which lesser radiological consequences are associated. If no grading is performed, the recommendations relating to nuclear power plants are applicable to other types of nuclear installation.

1.12. The evaluation of hazards associated with HIEEs needs to be performed or reviewed at all stages of the lifecycle of a nuclear installation from site selection to permanent shutdown~~end of operational stage~~.

1.13. This Safety Guide is mainly focused on the evaluation of ~~a~~ the site of a new nuclear installation~~ site~~. However, the recommendations are also applicable in the re-evaluation of existing nuclear installation site, and in the periodic safety reviews.

1.14. For the purpose of this Safety Guide, existing nuclear installations are those installations that are either: (a) at the operational stage (including long term operation and extended temporary shutdown periods); (b) at a pre-operational stage for which the construction of structures, the manufacturing, installation and/or assembly of components and systems, and commissioning activities are significantly advanced or fully completed; or (c) at temporary or permanent shutdown stage while nuclear fuel is still within the facility (in the core, spent fuel pool, on site waste storage, etc.).

1.15. This Safety Guides also addresses the site evaluation for multiple nuclear installations and eventual coupled facilities (if any) on the same site or on adjacent sites.

1.16. The external human induced events considered in this Safety Guide are all of accidental origin but will be questioned when response and mitigation are discussed which is out of scope of this Safety Guide. Considerations relating to the ~~physical protection~~ nuclear security of nuclear installations against malicious activities, i.e. deliberate acts of sabotage, damage etc., by third parties are outside its scope. However, the methods described herein for the development of protection/mitigation measures against HIEE of accidental origin may also have application to the development of measures against malicious activities. Guidance on security considerations can be found in the IAEA Nuclear Security Series Documents Refs. [9-14]~~, [10], [11], [12], [13] and [14]~~. Due consideration should be given to the fact that the information on externals hazards can be highly sensitive from a security point of view. For example, information on human induced external hazards that can be beyond the safety design basis is highly sensitive because terrorists could use it as a potential way for an attack. Therefore, such information should be handled carefully in cooperation with nuclear security specialists.

[2] The term ‘nuclear installation’ includes: nuclear power plants; research reactors (including subcritical and critical assemblies) and any adjoining radioisotope production facilities; spent fuel storage facilities; facilities for the enrichment of uranium; nuclear fuel fabrication facilities; conversion facilities; facilities for the reprocessing of spent fuel; facilities for the predisposal management of radioactive waste arising from nuclear fuel cycle facilities; and nuclear fuel cycle related research and development facilities.

STRUCTURE

1.17. Section 2 provides general recommendations on the evaluation of hazard associated with HIEEs for nuclear installations. Section 3 describes the identification and screening of sources and evaluation of hazards for HIEEs. Section 4 describes the data collection and investigations. Sections 5 to 10 provide detailed guidance on hazard evaluations for event categories. Section 11 provides recommendations on applying a graded approach to the evaluation of nuclear installations other than nuclear power plants. Section 12 provides recommendations on management systems to be put in place for the performance of all activities. For definitions and explanations of the technical terms used, see the IAEA Safety Glossary [15]. Explanations of technical terms specific to this Safety Guide are provided in footnotes.

2. GENERAL RECOMMENDATIONS

APPLICABLE SAFETY REQUIREMENTS

2.1. SSR-1 [1] establishes Requirement 6 for identification of site-specific hazards, Requirement 7 for evaluation of natural and human induced external hazards, Requirement 8 for measures for site protection, Requirement 9 for site evaluation for multiple nuclear installations on the same site and on adjacent sites, Requirement 14 for Data Collection in site evaluation for nuclear installations and Requirement 24 for evaluation of hazards associated with human induced events. These requirements are of particular interest to the evaluation of nuclear installation site for hazards associated with HIEEs. Requirements 6, 7, 8, 9, 14 and 24 are reproduced here for convenience:

“Requirement 6: Identification of site-specific hazards

“Potential external hazards associated with natural phenomena, human induced events and human activities that could affect the region shall be identified through a screening process.

……

“Requirement 7: Evaluation of natural and human induced external hazards

“The impact of natural and human induced external hazards on the safety of the nuclear installation shall be evaluated over the lifetime of the nuclear installation.

…….

“Requirement 8: Measures for site protection

“If the projected design of the nuclear installation is not able to safely withstand the impact of natural and human induced external hazards, the need for site protection measures shall be evaluated.

………

“Requirement 9: Site evaluation for multiple nuclear installations on the same site and on adjacent sites

“The site evaluation shall consider the potential for natural and human induced external hazards to affect multiple nuclear installations on the same site as well

as on adjacent sites.

…….

"Requirement 14: Data Collection in site evaluation for nuclear installations

"The data necessary to perform an assessment of natural and human induced external hazards and to assess both the impact of the environment on the safety of the nuclear installation and the impact of the nuclear installation on the people and environment shall be collected

…….

"Requirement 24: Evaluation of hazards associated with human induced events

"The hazards associated with human induced events on the site or in the region shall be evaluated.

"5.33. Human induced events to be addressed shall include, but shall not be limited to:

(a) Events associated with nearby land, river, sea or air transport (e.g. collisions and explosions);

(b) Fire, explosions, missile generation and releases of hazardous gases from industrial facilities near the site;

(c) Electromagnetic interference.

"5.34. Human activities that might influence the type or severity of natural hazards, such as resource extraction or other significant re-contouring of land or water or reservoir-induced seismicity, shall be considered.

"Aircraft crashes

"5.35. The potential for accidental aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of potential changes in future air traffic and aircraft characteristics.

"Chemical hazards

"5.36. Current or foreseeable activities in the region surrounding the site that involve the handling, processing, transport and/or storage of chemicals having a potential for explosions or for producing gas clouds capable of deflagration or detonation shall be addressed.

"5.37. Hazards associated with chemical explosions or other releases shall be expressed in terms of heat, overpressure and toxicity (if applicable), with account taken of the effect of distance, and non-favorable combinations of atmospheric conditions at the site. In addition, the potential effects of such events on site workers shall be evaluated.

2.2. The requirements for research reactors and nuclear fuel cycle facilities are provided in Ref [16] and [17], respectively.

GENERAL CONSIDERATIONS

2.3. HIEEs are caused by people and the way people act creates the environment in which hazardous events can occur and propagate. The important consideration is to recognise the possibility of an event and seek experience data to support judgements on what events are likely to be significant and how frequently they occur. Human factors relevant to the identification and analysis of HIEE hazards include direct human action (e.g. exceeding a safe speed limit or energising an incorrect item of equipment), indirect human action (e.g. sub-standard design of equipment, poor maintenance practice), errors of commission and omission ~~and data uncertainty~~ etc.

2.4. Potential *sources* of HIEEs are classified as either stationary, or mobile sources and both should be considered:

1. *Stationary sources*, are those that handle, process or store potentially hazardous substances such as explosive, flammable, corrosive, toxic or radioactive materials, and for which the location of the initiating mechanism (explosion centre, point of release of flammable~~explosive~~ or toxic gases) is fixed, such as chemical plants, oil refineries, storage depots, pipelines, and other nuclear facilities at the same or a nearby site. Facilities such as dams that control large volumes of water are stationary sources of HIEEs but are covered in a different Safety Guide [3].

2. *Mobile sources* are those for which the location of the initiating mechanism is not totally constrained, such as any means of transport for hazardous materials or potential projectiles (by road, rail, waterways, air, pipelines). In such cases, an accidental explosion or a release of hazardous material may occur anywhere along a road, route, or pipeline.

2.5. The region of nuclear installation site should be examined for facilities and human activities that have the potential to endanger the nuclear installation over its entire lifetime. Each relevant potential source should be identified and assessed to determine the potential interactions with nuclear installation items important to safety.

2.6. The region to be investigated depends on the type of HIEE sources, from few kilometres for fire to tens of kilometres for aircraft crashes and bombing ranges. All HIEEs should be investigated in the site evaluation. It should not be overlooked that, in specific situations, a minor event may lead to severe effects[3].

2.7. Some of HIEE effects are of considerably more widespread than others. They could affect both the ~~plant's~~ nuclear installation's associated offsite facilities and items essential for safety, such as by affecting the availability of evacuation routes (the site might lose links to safe areas in the region), the possibility of implementing emergency procedures (access by the operator could be impaired), and the availability of the external grid and the ultimate heat sink. Special care should be given to understand the various levels of defence in depth that may be challenged for such events.

2.8. ~~As different~~Unlike ~~from~~ most natural external hazards, new sources of HIEEs can evolve rapidly. Therefore, a prognosis should be made for possible regional development over the anticipated lifetime of the nuclear installations~~plant~~, with account taken of the degree of administrative control that could realistically~~is possible to~~ be exercised over activities in the region. In this respect, allowance should be made for the fact that technologies in the chemical and petrochemical industries, as well as traffic densities, may evolve rapidly.

2.9. HIEEs initiated at a source may eventually result in different hazards at a nuclear installation site after going through an interacting mechanism. ~~To clarify the process of HIEEs~~

[3] ~~For example, in the safety review of the plant, the potential for a fire of small extent and with no direct effect on the plant was found. Examination of the power supply to the offsite emergency system showed that the power lines should be put underground to protect them against fire in order to prevent any impairment of safety related systems.~~

and their possible effects on nuclear installations, this guide introduces a number of inter-related terms to describe the morphology of such events, the most important being source, event and hazard. A number of potential HIEE sources are presumed to exist around a nuclear installation (e.g. a chemical process site); each source is capable of one orf more events (e.g. plant failure causing explosion and releasing stored process gas); and each event may create one or more hazardous conditions (e.g. explosion pressure wave, release of toxic gas) at the site with the potential to challenge nuclear safety at a nearby nuclear installation. In principle, HIEE hazard analysis of each scenario is required but only a small subset of these sequences is likely to represent a credible risk to nuclear safety. In order to make the overall HIEE analysis traceable, the procedure described in this Safety Guide includes identification and screening to ensure that only those sequences that are significant to nuclear installation safety are retained through the entire process. To clarify the process of HIEEs and their possible effects on nuclear installations, this guide introduces a number of inter-related terms to describe the morphology of such events, the most important being source, event and hazard.

2.10. To further illustrate the notion of 'interacting mechanism', as to how hazardous events originating at a source can lead to sequences of further events, creating a hazardous situation at a site, examples of HIEE event categories, generic screening distance values, identification of sources along with required information, potential HIEEs at sources, possible hazards at site, load characterisation parameters and possible consequences at a nuclear installation site are provided in Tables I-V, Appendix.

2.11. In general, there are three types of protection against HIEE for a nuclear installation: (i) protection through a robust design of the safety related structures, systems and components important to safety, (ii) protection through the provision of site protection measures such as sufficient distance and barriers, (iii) protection through administrative measures such as 'no-fly zones. It should be kept in mind that administrative measures are generally the least reliable means of protection and they should be considered as complementing the first two.

2.12. Unless a A satisfactory engineering solution can should be achieved for protection against those HIEE hazards which have not otherwise been excluded from further consideration through the screening process (e.g. through a probabilistic screening, as discussed in para. 3.12), either the site should be deemed unsuitable during the siting stage, or aAppropriate administrative actions should be taken in the case of an existing nuclear installationplant plant where satisfactory engineering solutions are not considered reasonably practicable keeping in mind the recommendation provided in Paragraph 2.11.

2.13. Lack of confidence in the quality of the data — that is its accuracy, applicability, completeness, or quantity — may preclude the use of complex analysis techniques to characterise some HIEE hazards, either at the screening stage or for subsequent hazard evaluation. In such cases, a pragmatic approach based on engineering judgement should be taken, ensuring always that such judgments are demonstrably conservative. Details of data collection are provided in Section 4.

3. SOURCE IDENTIFICATION, SCREENING AND EVALUATION

METHODS

GENERAL PROCEDURE

3.1. Evaluation of hazards associated with HIEEs is a multiple-stage approach. In the first stage, sources should be identified based on available data, followed by collection of data for the relevant regions and screening is conducted based on the established distance and probability criteria. In the next stage, detailed evaluation of screened-in hazards should be conducted. The identification of sources should be first performed using limited, easily accessible data initially, then be refined as more data, knowledge and information of how the HIEE hazards might affect the nuclear site/installation becomes available. The process of source identification, screening and detailed evaluation of each source type is described in the following paras. and shown in Figure 1.

SOURCE IDENTIFICATION AND SCREENING

3.2. Screening Distance Value (SDV) is the distance from a nuclear installation site beyond which a hazard from an HIEE is considered insignificant to safety of nuclear installation. SDV is as a simple and conservative tool that ignores any additional factors like involved mass or typical atmospheric conditions. For some sources, a simple deterministic study, based on information on the distance and characteristics of the source, may be enough to show that no significant event can occur.

3.3. To initiate the evaluation process, the source regions centered on nuclear installation site should be identified based on Generic Screening Distance Values (SDV^g) given in Table II, Appendix for different Event Categories (see box 1 in Fig. 1). SDV^g's are typical values used by some Member States for large nuclear power plants with standardized designs. Since large nuclear power plants are more robust, these values should be checked for other nuclear installations. They should also be checked if the nuclear power plant design and layout present any potential weakness to HIEE hazards.

3.4. Local topography, regional and local meteorological effects may significantly modify these SDV^g values. In case of any peculiar site condition or significant specific hazard, screening should be taken to the next stage even screened out with respect to distance.~~it should be considered that the site has not been screened out with respect to distance.~~ Safe distances from potential sources greatly vary, e.g. a chemical plant located close to a nuclear installation site which is well protected by hills as compared to a nuclear installation located far away on flat area with~~hich~~ predominant winds blowing towards the site.

3.5. All stationary and mobile sources of potential HIEEs in the source regions should be identified and data for these sources (source type, distance, potential events, etc.) should be collected (see box 2 in Fig. 1). Details for data collection and investigations are given in Section-4.

3.6. A Source Display Map (SDM) showing all potential sources (both present and foreseeable sources) should be prepared and sources should be listed along with the distances from the nuclear installation site. Uncertainties related to these should be estimated (see box 3 in Fig. 1).

3.6.3.7. For each type of effect that could arise from a HIEE, a maximum acceptable loading limit should be established, based on structures, systems and components vulnerabilities.

3.7.3.8.Specific Screening Distance Value (SDV^s) for each hazard of an HIEE (stationary and mobile) should be determined by simple calculations using source specific data, considering local site conditions. The determination of the SDV^s should consider the severity and extent of the event including relevant uncertainties, as well as the expected characteristics of the nuclear installation to be located at the site. These characteristics may be assumed for the early stages of siting process to be those corresponding to the standard nuclear installation design.

3.8.3.9.Attention should be paid that potential HIEEs may generate different types of hazards (e.g. an event at the chemical plant may produce toxic gas and pressure wave) at the nuclear installation site (see box 4 in Fig. 1), as explained in Section 2.10. The SDV^s of both hazards will be quite different as a gas vapor cloud maywill travel much longer distance than the pressure wave.

3.9.3.10. After considering potential future changes in source characteristics and associated uncertainties related to distances and intensities, if the nuclear installation site is outside of all SDV^s for the specific source, no further action analysis is necessary (see box 5 in Fig. 1).

3.10.3.11. For sources generating effects of the same nature, a further screening should be performed which would depend on an enveloping criterion and which should exclude those sources that generate events that are enveloped by those for other selected sources, even if the site is inside the SDV^s for these sources. Care is needed here to ensure that the enveloped sources are considered if/when the event frequency is estimated.

3.11.3.12. If the nuclear installation site is inside one or more SDV^s, relevant HIEE(s) should be identified and the probability of occurrence of these event(s) should be estimated (see box 6 in Fig. 1).

3.12.3.13. If the probability of occurrence of an event under consideration is less than the specified Screening Probability Level (SPL)[4], no further analysis is necessary (see box 7 in Fig. 1). The SPL should be chosen with due consideration, given to the factsuch that the radiological risk associated with hazards associated withdue to HIEEs should not exceed the range of radiological risksis acceptable low. associated that are used in when applying the principle of ‘practical elimination’ [18]. Uncertainties should be considered in calculating the probabilities of occurrence for the HIEEs in probabilistic screening.

[4] In some States, a value for the probability of 10^{-7} per reactor-year is used in the design of new facilities as one acceptable limit on the probability value for interacting events having serious radiological consequences, and this is considered a conservative value for the SPL if applied to all events of the same type (such as all aircraft crashes, all explosions). However such grouping of similar events may not be appropriate where a specific single event has very severe consequences and requires a very low SPL.”Some initial events may have very low limits on their acceptable probability and should be considered in isolation.

DETAILED EVALUATION INCLUDING HAZARD PARAMETERS AND LOAD CHARACTERIZATION

~~3.13.~~3.14. If the probability of occurrence of the HIEE(s) under consideration is greater than the specified SPL value, a detailed evaluation should be made. For this purpose, more detailed data should be collected to evaluate the event(s) and interaction of a hazard(s) with nuclear installation site (see box 8 in Fig. 1).

~~3.14.~~3.15. Hazard analysis should be performed to check whether hazard(s) will interact with the nuclear installation site. If the results of hazard(s) show that they will not affect the nuclear installation site, no further ~~action~~ analysis is necessary (see box 9 in Fig. 1).

~~3.15.~~3.16. If any of the hazards can affect the nuclear installation site, a detailed hazard analysis should be performed, and hazard parameters and load characterization should be established (see box 10 in Fig. 1). Tables IV and V, Appendix list the common hazards likely to be encountered and indicate the relevant type of hazard and characterization parameters in each case.

~~3.16.~~3.17. If applicable, a second level of screening can be implemented based on-site and nuclear installation specific characteristics. Typical screening parameters to be applied are probability, magnitude and distance of ~~event specifics~~the HIEE and on-site characteristics (e.g. design conditions and zones of influence). Details are provided in Ref. [~~19~~18]

~~3.17.~~3.18. This process should be repeated for each source. More guidance on application of the process for each event category is provided in Sections 5 – 10.

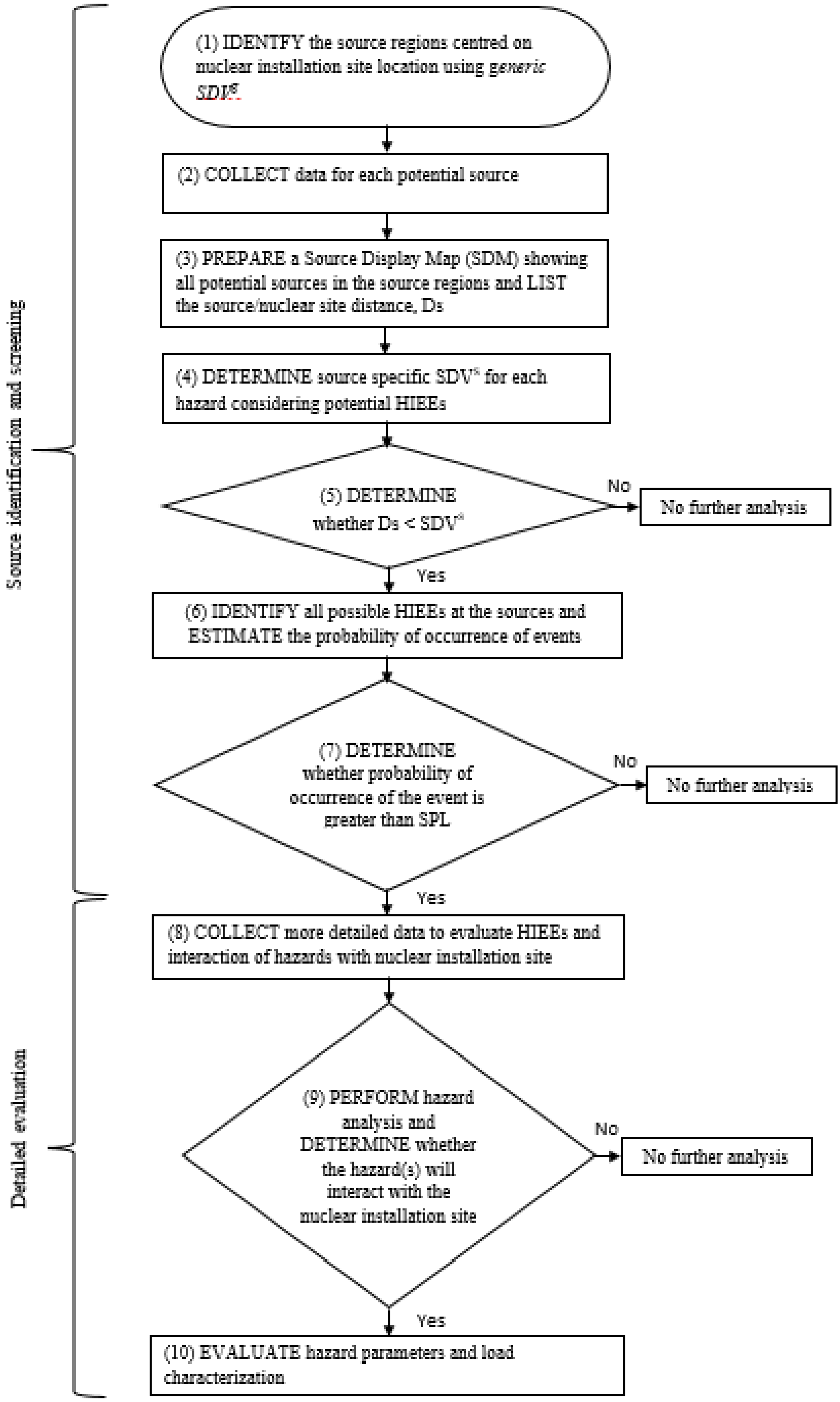

Fig. 1. Process for the source identification, screening, and detailed evaluation for each source type

4. DATA COLLECTION AND INVESTIGATIONS

GENERAL CONSIDERATIONS

4.1. The collection of data for potential source of HIEEs should involve the collection of site specific as well as generic data on events occurring in similar sources worldwide as such events may or may not have occurred in sources around the nuclear installation sites. It should be recognized that such data may not be readily available for reasons of confidentiality.

4.2. Member States have different ways of dealing with such issues. The guidance here provides a general approach to data and information collection that should be adapted to the specific legal environment of the Member State in which the nuclear installation site is situated.

DATA AND INFORMATION COLLECTION RESOURCES

4.3. The data and information collection process recommended in this guide is set out in Requirement 14 of Ref [1]. The following is a list of the most salient and important data and information collection resources:

– Source operators/owners;
– Local and national government organisations with an interest in controlling, licensing or authorising the activities of the source, including relevant health and safety regulatory agencies;
– Professional institutions and organizations;
– Generic data on HIEEs from literature, relevant documents, etc.;
– Experience of good practice in defining the nuclear significant hazards from similar sources elsewhere;
– Miscellaneous sources of data such as local maps, published reports and public records relevant to activities around the nuclear installation site likely to be relevant to HIEEs, public and private agencies and individuals (in additional to those identified above) likely to be knowledgeable about the characteristics of the local area.

Seeking advice from the source operator

4.4. The most important data and information resource regarding the hazards arising from a source is from the operator of the source itself. Contact with the source operator should be made at an early stage, with the objective of building a constructive relationship to facilitate information exchange. It is important to remember that while the source (industrial site etc.) presents a portfolio of hazards to the nuclear installation site, the nuclear installation also presents a portfolio of hazards to the source. The operator of the HIEE source is likely to:

— Understand the processes and hazards presented by its activities better than anyone else. The operator may already have well-developed data and safety analyses that could be made available, and almost certainly will be the best source of expert advice on its activities;

— Be subject to health & safety regulation. The appropriate regulator(s) should be consulted for advice, and in any case should be made aware of the development of the nuclear installation and the likely hazards it may pose to industrial sites in the region.

The information received from the source operators should be verified and validated and, wherever possible, ensuring that the information has been validated via an independent reviewer/organization.

Regional emergency plans:

4.5. Industrial sites that could impose hazards on a nearby nuclear installation will likely also impose those same hazards on the local population. In these cases, state and local government authorities (in addition to the site operator) should~~may~~ have a responsibility for population safety and such sites should~~may~~ be legally obliged to provide sufficient data to enable these authorities to construct regional emergency plans~~, for example~~. Such government authorities may have useful data on regional sources of HIEEs and should be collected.

Land-use planning

4.6. Many Member States have well developed land-use planning legislation that will apply to any new or proposed nuclear or conventional development; this same legislation will likely also have been applied to any existing HIEE sources in the region at the time of their planning and development. An objective of land-use planning requirements is usually to ensure that all national and local government agencies requiring knowledge of a planned hazardous site are able to obtain the information they need at an appropriate stage before and during the development process (including the data needed for the development of regional emergency plans), and have the opportunity to provide advice to the planning process on any public safety issues raised by the development. A further objective is to provide a platform for informing the general public (including other industrial site operators) that may be affected by the development and for facilitating public comment on it. The government planning authority for the region surrounding the nuclear installation may be able to provide useful information on sources of HIEE ~~and~~ that should be collected.

4.7. Consideration should be given to sources undergoing decommissioning, planned or under commercial developments, watercourse developments such as dams, and marine developments such as new or modifications to ports and harbours (and associated changes to sea lanes) and barrages etc. Such developments may lead to additional sources of hazards in the future and potentially to an increased risk of radiological consequences over the life of the nuclear installation[5]. Also important are developments that could change the population distribution in the region around the nuclear installation, since this may have implications for nuclear emergency planning. This aspect is covered elsewhere.

4.8. Particular consideration should be given to the possibility that such new sources may present hazards that are currently screened out as insignificant from existing sources, or where the potential exists for adverse interaction of any new hazards introduced with those from existing sources, e.g. the possibility of fire spreading from a new source to an existing one. In

~~[5] Also important are developments that could change the population distribution in the region around the nuclear installation, since this may have implications for nuclear emergency planning. This aspect is covered elsewhere.~~

both cases, it may be necessary to provide additional protection/mitigation measures either at the nuclear installation site, or as part of the new development. The progression of industrial development should be strictly followed by keeping a continuous liaison with the local authorities.

Military sites and civil sites undertaking national defence work

4.9. These sites will almost always be subject to extensive restrictions on the dissemination of information about the processes and activities that take place, which may make it impossible for nuclear installation operators to undertake a credible safety analysis of potential HIEEs arising from such sites. National regulators, as government agencies themselves, may have preferential access or even information exchange agreements with the defence agencies controlling these sites. Nuclear installation operators should seek advice from their regulator on the need for and the extent of HIEE safety analysis that is required in these cases. ~~Since~~ In case Military ~~may~~ do not give information, ~~use of~~ generic data can be used~~is recommended~~.

DATA AND INFORMATION

Data Source

4.10. Para 1.9 lists six major categories of HIEE that should be considered. The region surrounding the nuclear installation site should be investigated for the presence of any human activities that have the potential to cause events in these categories. The size of the region to be investigated will depend on the nature of the human-induced activities taking place. For example, the presence of a large petrochemical site storing very large quantities of hazardous materials may have the potential to affect a larger geographical area in the event of an accident than, say, a small quarrying site, storing and using only limited quantities of mining explosives. Table II provides generic screening distance values that are considered representative of common hazards belonging to each event category and their ability to affect a nuclear installation site.

Data uncertainty and the use of expert judgement

4.11. For many HIEE hazards there is often insufficient information available locally to permit a reliable evaluation of probability of occurrence and of the probable severity of the event. It may therefore be useful to obtain statistical data on a national, regional or global basis. Values thus obtained should be examined to determine whether they should to be adjusted to compensate for unusual characteristics of the source, or the nuclear installation site and its environs. Where there is no reliable basis for calculating the severity of the effects of an external human induced event using local data, all available information and assumptions about that event should be obtained on a global basis and the hazard analysis undertaken also using expert judgement.

STATIONARY SOURCES

4.12. The following information for stationery sources should be collected but the necessary level of detail could vary according to the specific site evaluation stage:

— The nature of hazardous material involved and the quantities in store, in process and in transit on the source site;
— The types of storage (physical conditions) and processes (flow sheets);
— The dimensions of major vessels, stores or other forms of containment;
— The locations of these forms of containment; their construction and their isolation systems;
— Their operating conditions (including the frequency of maintenance);
— Their active and passive safety features.

4.13. The severity of the hazard may not bear a direct relation to the size of the facilities on the source site, but the maximum amount of hazardous material present at any given time and the processes in which it is used should be taken into consideration in establishing the significance of the source to nuclear safety. Furthermore, the progression of an accident with time, such as fire spreading from one tank to another on the source site, should also be considered.

4.14. Pipelines carrying hazardous materials that leave or transit between different stationary source locations should be included as mobile sources.

4.15. Other sources to be considered are construction yards, mines and quarries that use and store explosives and may cause the temporary damming of water courses with the possibility of subsequent flooding, subsidence, or collapse of ground at the site should also be considered.

4.16. Mines and quarries are hazardous because the explosives used in their exploitation can generate pressure waves, projectiles and ground shock; moreover, mining and quarrying entail the possibility of ground collapse and landslides. Information should be obtained on the locations of all past, present and possible future mining and quarrying work and the maximum quantities of explosives that may be stored at each location. Information on geological and geophysical characteristics of the subsurface in the area should also be obtained to ensure that the nuclear installation is safe from ground collapse or landslide caused by such activities.

4.17. Fracking[6] activities should also be considered as they may be hazardous to nuclear installations and are similar to mining activities in that they can cause ground vibrations, subsidence and even ground failure.

4.18. At military installations, hazardous materials are handled, stored and used, and may be associated with hazardous activities such as firing range practice and handling of munitions. In particular, military airports and their associated air traffic systems, including training areas, should be considered potential sources.

MOBILE SOURCES

4.19. Mobile sources are typically aircraft (and other aerial vehicles), road and rail vehicles, sea and river transport vessels.

Transport by air

[6] Fracking is a proven drilling technology used for extracting oil, natural gas, geothermal energy, or water from deep underground.

4.20. Regarding aircraft crash, a study should be made of:

— Local airports, their layout, take off, landing and holding patterns and procedures, types of aircraft and movement frequencies;

— Air traffic corridors (airways) and other designated restrictions to flight transit (e.g. restricted and prohibited zones) should also be considered;

— Information on aircraft accidents for the region and for similar types of airport and air traffic should be collected. Information should be collected for bothgeneral aviation, civil and military air traffic. Of particular interest are military aircraft training areas (especially low flying areas) within the region, since these may indicate areas of relatively high crash probability.

— Information on crash rates of each aircraft type flying near the nuclear installation in the respective flight mode (enroute, landing, and taking off including normal or special flight mode for military aircraft).

4.21. The size of the geographical region considered for aircraft crash hazard should, in general, be larger than that for other sources because of the high speeds associated with air transport.

Transport by sea and river

4.22. The conveyance of hazardous materials by sea or inland waterways may present significant hazard. Besides the accidental release of flammable or toxic gases / vapours, Vvessels, together with their loads and the possibility of water borne debris, could have the potential for mechanically blocking or damaging cooling water intakes and outfalls associated with ultimate heat sinks. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals could also jeopardize cooling water intakes and outfalls associated with ultimate heat sinks.

4.23. Experience indicates that the bulk of sea traffic accidents occur in coastal waters or harbours, so it is important that shipping lanes near the site should be identified. Information should be collected on the characteristics of traffic flows in the region, such as:

— Location of shipping lanes local to the nuclear site;
— The nature, type and quantities of material conveyed along a route in a single transport movement;
— The sizes, numbers and types of vessels;
— The point of closest approach to the nuclear site;
— Accident statistics including consequences.

Harbours should be also studied due to the presence of dangerous cargo.

Transport by road and rail

4.24. Railway rolling stock and road traffic, together with their loads, are potential sources that should be given careful attention, particularly for busy routes, junctions, marshalling yards and loading areas. Information should be collected on the characteristics of traffic flows in the region, such as:

— Location of road and rail routes local to the nuclear site;

- The nature, type and quantities of material conveyed along a route in a single transport movement;
- The sizes, numbers and types of vehicles;
- The point of closest approach to the nuclear site;
- Speeds, control systems and safety devices;
- Accident statistics including consequences.

Marshalling yards should be also studied due to the presence of dangerous cargo.

Transport by pipelines

4.25. The following is a typical set of data and information that should be collected for pipelines:

- Location of pipe routes local to the nuclear installation site;
- Whether the pipeline is on the surface or buried near the nuclear installation site and the diameter of the pipe;
- The nature of the substance transported, flow capacity, internal pressure;
- The distances between valves or pumping stations;
- The point of closest approach to the nuclear site;
- Safety features, and relevant accident records including consequences.

4.26. The hazards to a nuclear installation arising from surface transport (by road, rail, sea, inland waterways and pipelines) are similar to those from industrial plants. On-site transport of hazardous material relevant to collocated nuclear installations should also be considered as potential sources of HIEE hazards. Air traffic presents a different type of mobile hazard because of the possibility of an aircraft crash directly on to the nuclear installation and this should be taken into consideration.

SOURCE DISPLAY MAP

4.27. Source display maps should be prepared, preferably using a Geographical Information System ~~Graphical Interface System~~ (GIS) platform, showing the locations and distances from the nuclear installation of all sources identified in the data collection stage along with the size of the regions considered for each hazard type. Stationary and mobile sources should be indicated, noting transport routes close to the site, the regions considered and identifying the most hazardous point (normally the point of closest approach) for each route. Any unusual features should be shown, such as sources whose hazards interact to provide an increased challenge to nuclear safety.

4.28. These maps should also reflect any foreseeable developments in human activity that may affect safety over the projected lifetime of the nuclear installation.

5. RELEASE OF HAZARDOUS SUBSTANCES

GENERAL CONSIDERATIONS

5.1. Hazardous substances (flammable, corrosive and toxic, including liquefied gases) are normally kept in closed containers but upon release could cause a hazard to items important to safety and to human life at a nuclear installation site. The following substances should be considered:

- Flammable gases, liquids and vapours that can form explosive clouds and can enter ventilation system intakes and burn or explode,
- Toxic and Aasphyxiant ~~and toxic~~ gases and liquids which can threaten human life and impair safety functions,
- Corrosive and radioactive gases and liquids which can threaten human life and impair safety functions associated with structures, systems and components directly.

5.2. HIEEs and dispersion mechanisms are discussed in this section; explosive effects are discussed in Section 6. The ways in which these different substances affect structures, systems and components and personnel at a nuclear installation vary substantially and are covered in detail in other Safety Guides (e.g. IAEA safety standard on design of nuclear installations against external events excluding earthquakes [7]), but the propagation phenomena from source to nuclear site are discussed in this section.

5.3. This section considers each of the major groups of hazardous substance in turn[7]:

- Hazardous liquids
- Hazardous gases

HAZARDOUS LIQUIDS

5.4. A significant factor affecting the dispersion mechanisms of liquids is the local topography between source and nuclear site. Liquids disperse across land primarily under gravity by flowing downhill; their dispersion is therefore heavily dependent on regional and sources-to-site topographical features and is very likely to be directional and this should be considered.

5.5. Care should be taken to consider the secondary factors especially the local meteorological conditions in the region. Ambient temperature, for example, will govern the rate of evaporation of a discharged liquid and will certainly control the rate of release of volatile vapors from a pooled liquid.

5.6. If the hazardous liquid is volatile, such as a petroleum spill, it can give rise to hazardous vapour clouds, whose dispersion as a plume will be consistent with the characteristics of gas cloud dispersion and should be considered.

5.7. The extent of dispersion of liquids, i.e. the extent of pooling given a rate of release, typically would require ~~very~~ large quantities to be released for the liquid to affect directly an

[7] Substances considered here are fluids since these can flow and therefore spread from source to nuclear installation. Hazardous solids of concern in this guide are explosives, which are considered in Section 6.

adjacent nuclear installation some kilometers away. A more likely safety concern is that Tthe liquid substance will pool and give off toxic or flammable or explosive vapors, and it is these secondary hazards that are likely to pose the most significant hazard to nuclear safety and should be considered.

5.8. Liquids dispersing underground are typically under high pressure and seek fissures and lines of weakness through which to disperse. As above, these may be strongly directional, and this aspect should be considered.

5.9. Chemicals including hazardous liquids stored at the nuclear installation site may vary from case to case. The safe distances for explosivity, toxicity and heat flux of these hazards should be determined and considered in the layout and appropriate measures should be taken.

5.10. On multi-unit sites, a possible source of HIEE hazardous liquids is likely to be adjacent units, since these will be relatively nearby and may be sited at the same level or higher than `the host installation and should be considered.

5.10.5.11. The dispersion of liquids on bodies of water depends on the characteristics of the liquids (e.g., density compared to the density of water) and the characteristics of the body of water (e.g., sea, river or lake). Whereas on standing water bodies, dispersion is slow, hazardous liquids on bodies of flowing water may be transported over large distances quickly. The concentration of hazardous liquids in a given distance from the source will depend on the specific situation. Besides the toxic, corrosive or explosive properties of the liquid also its potential to clog the cooling water intake should be considered.

HAZARDOUS GASES

5.11.5.12. Gases, vapours and aerosols from volatile liquids or liquefied gases may, upon release, form a cloud and drift. The drifting cloud may adversely affect the safe operation of the nuclear installation. For example, if it permeates installation buildings, it may pose a hazard to personnel and items important to safety. It can also affect the habitability of the control room and other important plant areas and should be considered.

5.12.5.13. The most practical method of defence against a hazard of this type is to ensure protection from the potential source by means of distance. Otherwise, the hazard should be evaluated in order to design engineered protection by means of protective barriers and/or ventilation systems.

5.14. Clouds of toxic or asphyxiant gases can have severe effects on the personnel of a nuclear installation with special attention to be devoted to control room –and emergency centers habitability. Corrosive gases can damage safety systems and may, for example, cause loss of insulation in electrical systems. These matters should be given careful consideration in the evaluation of the hazards.

5.13.5.15. Drifting clouds of explosive or flammable gases or vapors can also adversely affect the nuclear installation without entering buildings, protection measures should be taken. More details on the protection against explosions and fires can be found in Sections 6 and 7 of this Safety Guide.

5.14.5.16. Meteorological information should be considered in estimating the danger due to a drifting cloud as local meteorological conditions will affect dispersion. In particular, dispersion studies based on probability distributions of wind direction, wind speed and atmospheric stability class should be made. A secondary consideration is local topography between source and nuclear installation site, especially for dense (heavier than air) gases that will tend to form gravity flows downhill in a similar way to liquids.

~~5.15.~~5.17. For the postulated event of an underground release of hazardous gases or vapours, consideration should be given to escape routes and to seepage effects which may result in high concentrations of hazardous gases in buildings or the formation of hazardous gas clouds within the SDV.

~~5.16.~~5.18. On multi-unit sites, a source of hazardous gases can likely to be the adjacent units, since these will be relatively nearby and the opportunity for dispersion of the gas plume will be limited and should be considered.

HAZARD ASSESSMENT

Source identification

~~5.17.~~5.19. Sources of hazardous liquids and gases are included in Table III (stationary and mobile). Guidance on data collection is provided in Section 4. First the regions should be located based on SDV^g values (Table II). Sources within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources should also be identified just beyond these regions if these are large or especially hazardous sources. Data in this region of potential sources should be collected and source/nuclear installation site distance values, D_S, should be calculated.

Screening by distance

~~5.18.~~5.20. Based on collected source data, simple and conservative calculations can be made and SDV^s values for the hazardous fluids~~gases~~ can be estimated as these can travel long distances originating from both liquid and gas sources. Those sources that lie further away from the nuclear installation site ($D_S > SDV^s$) can be screened out. Meteorological and topographical considerations are important in this evaluation.

Screening using probability

~~5.19.~~5.21. If a hazard cannot be screened out by distance, generic events data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of potential event(s) that can release hazardous fluid~~gas~~. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out. The screening exercise of each event that could lead to the generation of a hazardous fluid~~gas~~ at the nuclear installation site should be completed, and the screened-in sources should be listed.

Detailed evaluation

~~5.20.~~5.22. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

~~5.21.~~5.23. In broad terms the evaluation process should consider leak of hazardous liquid at a specified location in terms of leak rate and possibly other factors if storage was not at ambient atmospheric conditions. The evolution of the release is driven by local topography for overland spills and the local marine or watercourse conditions for spills into the hydrosphere. These aspects should be modelled explicitly or ~~sweeping~~ extremely conservative assumptions should be made. ~~As explained at 5.11, these liquids are not likely to reach a nuclear installationNI,~~ At least liquids released in the hydrosphere and gases emanating from ~~these~~ liquids are extremely important and should be considered.

~~5.22.~~5.24. The vapour clouds released after an incident/accident can travel to the nuclear installation~~NI~~ site with different damaging potential to a safety-related structure or may impact control room habitability. Different chemicals have different hazardous effects relating to explosion, thermal radiation and toxicity. In the evaluation, the worst case meteorological conditions should be assumed~~incrementally changed~~ as inputs to the model within bounding conditions of temperature, atmospheric stability class, and wind speed for each chemical modelled and each hazard condition until the bounding (maximum potential effect) is confirmed. The toxic vapour cloud may travel large distances and should be carefully studied.

~~5.23.~~5.25. The nearest point to the nuclear installation where hazardous liquids may collect in pools should be determined, with account taken of the topography of the land and the layout of the installation. Similarly, the gas release should be modelled by assuming maximum credible inventory and assuming that it occurs at the point of closest approach to the nuclear site, or the most unfavourable release point if this is different. Mobile sources, such as barges and ships carrying large amounts of hazardous liquids or gases within the SDV^{s}, should be assumed to become stranded at the point of approach to the nuclear installation for which the most unfavourable effects would result.

~~5.24.~~5.26. For evaluating the generation of hazardous gases, vapours, or aerosols and interaction with items important to safety, distinction should be made between:

- subcooled liquefied gases; and
- gases liquefied by pressure and non-condensable compressed gases.

~~5.25.~~5.27. Usually the release of a subcooled liquefied gas will occur as a steady leak over a considerable period (at a given leak rate), but the possibility of an effectively instantaneous release (a total sudden release) should also be considered, depending on the following conditions associated with the release:

- the type of storage container and its associated piping;
- the maximum size of the opening from which the material may leak;
- the maximum amount of material that may be involved;
- the relevant circumstances and mode of failure of the container.

~~5.26.~~5.28. The starting point for the detailed hazard analysis is the evaluation of a range of leak rates and related failure probabilities, or the total amount of gas released (equivalent to the maximum credible release) and related failure probability. If a large amount of subcooled liquefied gas is released, much of it may remain in the liquid phase for a long time. It should be treated as a liquid throughout this period, although a fraction will vaporize almost instantaneously.

5.27.5.29. The characteristics of the pool formed by the liquid, such as its location, surface area and evaporation rate, should be evaluated, with account taken of the wind speed and the permeability and thermal conductivity of the soil (if the spillage occurs on soil). If the source site has arrangements for containing any spills or releases, these should be accounted for in the hazard modelling. However, giving credit to such arrangements should be well justified.

5.28.5.30. To evaluate the maximum concentration at the site, the models presented in [5] may be used. They should be used with caution, since often the gases released are at a very low temperature and the models may not be strictly applicable to a gas–air mixture of negative or positive buoyancy.

5.31. The formation of a large cloud is more likely for gases liquefied by pressure and non-condensable compressed gases than it is for subcooled liquefied gases. The detailed analysis is easier because the source is more easily defined and in some cases dispersion of the plume is governed by simpler phenomena.

5.29.5.32. As with subcooled liquefied gases, the release gases liquefied by pressure and non-condensable compressed gases should be characterized by a leak rate or by a sudden total release, and a similar evaluation should be carried out. The assumptions to be used will depend on the type of storage tank, the process vessels, their associated piping, pipelines with associated flow rate and operating pressure, and the associated failure probability.

5.30.5.33. In making an appropriate assumption for the amount of material available to be released in the event of an accident, account should be taken of the time interval before action is taken to stop the leak. For example, pipeline valves may close automatically, thus isolating the ruptured section quickly.

5.31.5.34. With buried pipelines, the soil cover is usually insufficient to prevent the escape of gases released from the pipelines. Seepage may occur or gas may escape through fractures or discontinuities. In all cases, when the characteristics of the gaseous release to the atmosphere have been established, a model should be selected to determine the dispersion of the gas towards the nuclear installation site. As noted above, the dispersion of the plume is primarily governed by the prevailing meteorological conditions assumed at the time of release. Given the large degree of uncertainty with meteorological and other factors involved in plume modelling, consideration should be given, at least initially, to use a simplified dispersion model with assumptions made on a conservative basis.

Hazard parameters

5.32.5.35. The following are example of parameters that should be considered and are given in Table III:

— Nature of substance

- PhysicalMechanical properties:
  - density, temperature and pressure as contained,
  - density, temperature (including freezing/boiling temperatures), partial vapour pressures under ambient conditions,
  - flow characteristics under ambient conditions.
- Chemical properties

        - composition,
        - reactivity with environmental and atmospheric substances
    - radiochemistry,
    - flashpoint/ignition temperature
- Maximum credible release, or frequency versus quantity release curve
- Meteorological and topographical characteristics of the region
- Bathymetric and tidal characteristics of the coastal region
- Water course and flooding characteristics of the fluvial region
- For underground sources, geological seepage routes and opportunities for liquid concentration
- Existing protective/mitigative measures at the source location

Load characterisation parameters

~~5.33.~~5.36. The following are example of parameters that should be considered and are given in Table V (5) & (6):

- Asphyxiant/toxic effects
    - Concentration & quantity as a function of time
    - Volatility in ambient conditions
    - Toxicity and asphyxiant limits ~~– e.g. LD50 (Lethal Dose 50%)~~
- Corrosive/radioactive liquids
    - Concentration & quantity as a function of time
    - Corrosive & radioactive limits
- Provenance (origin over/in sea or over/under ground)

6. EXPLOSIONS

GENERAL CONSIDERATIONS

6.1. The word explosion is used in this Safety Guide broadly to mean any exothermic chemical reaction between solids, liquids, vapours or gases that may cause a substantial increase in pressure, possibly owing to impulse loads, drag loads, fire or heat, or a rapid release of liquid or gas from a pressurised container. The explosive potential of a given mass of chemical substance is often quoted in terms of an equivalent mass of trinitrotoluene (TNT). This facilitates comparison of the explosive potential of different substances and many empirical formulae for predicting the effects of explosives are derived on the basis of TNT equivalence Ref. [~~20~~19]. These should be used with care.

6.2. Explosions are highly energetic and often destructive events. Particular care should be taken that ~~They~~ they can occur for many reasons.~~,~~ ~~but~~ O~~o~~nce an explosion has occurred, its effects are propagated into the surrounding environment by means of an expanding pressure wave. There are two types to consider:

- Deflagrations, which generates moderate pressures, heat or fire,
- Detonations, which generates high near field pressures and associated drag loading but usually without significant thermal effects.

6.3. These pressure waves, also known as blast waves, propagate approximately as spherical waves expanding away from the source location and should be considered. However, they are influenced by the ground and other confining surfaces. The specific energy in a spherical wave front attenuates according to the inverse square law based on distance from the source if no further energy is being added to the wave, say by continued burning. However, constrained blast waves may attenuate much more slowly[8]. More details are provided in Ref. [~~20~~19].

~~6.4.~~ Explosions at an industrial site usually occur due to over-pressurization of contained liquids/gases, deflagration in case of liquid pool fires, leak or failure storage tanks, pipelines, accidents with explosives etc. Dust explosions can also occur where any dispersed powdered combustible material is present in high-enough concentrations in the atmosphere or other oxidizing gaseous medium gaseous medium. Explosions caused by any reason~~s~~ should be considered. ation ~~Explosions at industrial sites are usually the result of:~~

~~6.5. Over-pressurisation of contained liquids/gases,~~

~~Unintended exothermic chemical reactions,~~
~~Dust explosions.~~

~~6.6.~~6.4. ~~Leak or failure of storage tanks, pipelines etc.~~

~~6.7.~~6.5. Explosions normally arise from hazardous (often flammable) substances and the way they are contained or handled. The release of hazardous substances is covered in Section 5. The ways in which explosion hazards affect structures, systems and components and personnel at a nuclear installation are covered in detail in other Safety Guides (e.g. IAEA Safety Standard on design of nuclear installations against external events excluding earthquakes [7]), but the propagation phenomena from source to nuclear installation site are discussed in this section.

~~6.8.~~6.6. Over-pressurisation event is an event arising from an over-pressurised contained liquid or gas can cause an explosive release of stored liquid or gas if the container fails and should be considered. However, when such a release is also associated with heating, or the released substance ignites, the result can be an extremely energetic form of release known as a BLEVE (Boiling Liquid Expanding Vapour Explosion). BLEVEs can occur to all sorts of contained substances, but generally occur when pressurised Liquid Petroleum Gas (~~LNG~~LPG)/Liquid Nitrogen Gas (LNG) or propane tanks fail catastrophically. If such tanks are accidentally heated, as might be the case if they are immersed in an external fire, the pressure in the tank rises until eventually it bursts. The mechanical overpressure effects of the burst itself may be sufficient to cause a BLEVE, but if the LNG vapour ignites, this adds substantially to the energy of the explosion and can lead to an extremely destructive event, characterised by a detonation blast wave and should be considered.

~~6.9.~~6.7. ~~Unintended exothermic reactions are typically~~ In case of hydrocarbon liquid pool fires or similar, ~~where~~ the hydrocarbon has escaped containment and ignited. In flammable atmospheres, the explosion pressure wave is characterised by a flame front. The speed of

[8] The attenuation referred to here is geometric attenuation as this is normally the most significant effect. For comparison purposes, cylindrical waves geometrically attenuate as the inverse of distance from the source, and one-dimensional waves do not attenuate at all. Blast waves will also suffer viscous attenuation with time of travel, but this phenomenon is relatively slow acting. Note that attenuation refers to energy of the wave front. Since energy is related to the square of particle velocity and strain, these parameters attenuate as the square root of energy.

propagation of the flame front depends on the availability and rate of burning of the fuel source (e.g. petroleum vapour). These events generally produce deflagration pressure waves and should be considered.

~~6.10.~~6.8. Dust explosions are especially dangerous and can easily lead to detonations because of the rapid rate of combustion of fine particles – the rate of combustion is related to the surface area of fuel in contact with air, so a large number of fine particles (or vapour droplets) burns more effectively than a small number of larger ones. The presence of obstacles that are often found in powder stores (e.g. grain stores) can cause intense mixing as the blast wave propagates, leading to more rapid burning and hence a more intense blast wave, often with very dramatic effects and should be considered.

~~6.11.~~6.9. Blast waves cause a sudden increase in pressure on one side of a structure with insufficient time for pressure on the other side to equalise through the action of normal ventilation processes. This results in large pressure forces across the affected structure surface and hence large stresses that must be reacted by the structures load paths and should be considered.

~~6.12.~~6.10. An explosion can produce pressure waves (dominant hazard), projectiles, heat, smoke & dust and ground shaking. Moreover, vapour cloud explosion is also possible if relevant conditions are met and these should also be considered.

~~6.13.~~6.11. Explosions are very likely to create secondary hazards. For example, structural damage close to the event can generate projectiles~~missiles~~ and initiate fire. Secondary hazards associated with explosions should be considered~~.~~

~~6.14.~~6.12. A significant factor affecting the propagation of blast waves is the presence of obstacles between source and nuclear site and inside the vapor cloud; local topography may also play a role and both effects should be considered.

~~6.15.~~6.13. Interaction between units collocated at a multi-unit site should be considered carefully for its contribution to HIEE explosion hazards.

~~6.16.~~6.14. Particular attention should be paid to potential hazards associated with large explosive loads such as those transported on railway freight trains or in ships.

~~6.17.~~6.15. Unless there is adequate justification, a conservative assumption should be made that the maximum amount of explosive material usually stored at the source will explode, and an analysis should then be made of the effects of hazards (incidence of pressure waves, ground shock and projectiles) on items important to safety. Secondary effects of fires resulting from explosions should also be considered, as discussed in Section 7.

~~6.18.~~6.16. The probability with which explosions of the sort that characterises the source occur should be calculated based on experience data or derived from general national or world-wide data. More information on explosion hazards can be found in Ref. [~~20~~19].

HAZARD ASSESSMENT

Source identification

~~6.19.~~6.17. Sources of explosions are included in Table III. Guidance on data collection is provided in Section 4. First, the regions should be located based on SDV^g values (Table II). Sources existing within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources should also be identified just beyond these regions if these are large or especially hazardous sources.

~~6.20.~~6.18. Data of potential sources should be collected and source/nuclear site distance values, D_S, should be calculated.

Screening using probability

~~6.21.~~6.19. Using source data, SDV^s for overpressure (dominant hazard) should be estimated by means of a simplified conservative approach based on the engineering relationship between the TNT equivalent mass and the distance. Note that it is only applicable for high explosives with potential for mass casualties. Other methodologies appropriate for hydrocarbon-air vapor cloud explosions should be used. Sources of explosion can be screened out if lie further away from the nuclear site (D_S > SDV^s). Meteorology, topography, and existing protective measures at the source are important considerations.

~~6.22.~~6.20. If a hazard cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can create an explosion. if the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out. Appropriate methods for calculating the probability of an explosion should be used. If there are not enough statistical data available for the region to permit an adequate analysis, reference should be made to global statistics, to pertinent data from similar regions and/or to expert opinion. The screening exercise of each event that could create a pressure wave at the nuclear installation~~NI~~ site should be performed and the screened-in sources should be listed.

Detailed evaluation

~~6.23.~~6.21. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

~~6.24.~~6.22. In this phase, list of screened-in hazards should be refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear installation under design or assessment. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence.

~~6.25.~~6.23. The pressure waves drag level and local thermal effects at the nuclear installation~~plant~~ would differ according to the nature and amount of the explosive material, the configuration of the explosive, meteorological conditions, the nuclear installation~~plant~~ layout and the topography. Certain assumptions are usually made to develop the design basis for explosions, with data on the amounts and properties of the chemicals involved taken into account. TNT equivalents are commonly used as first approach to estimate safe distances for given amounts of explosive chemicals and for a given pressure resistance of the structures concerned. Note that it is only applicable for high explosives with potential for mass casualties. Other methodologies appropriate for hydrocarbon-air vapor cloud explosions should be used. For certain explosive chemicals, the pressure–distance relationship has been determined experimentally and should be used directly.

6.26.6.24. Projectiles that may be generated by an explosion should be identified by using experience data and engineering judgement by taking into account the source of these projectiles. In particular, the properties of the explosive material concerned and the characteristics of the facility in which the explosion is assumed to occur should be considered.

6.27.6.25. Consideration should also be given to possible ground motion and to other secondary effects such as the outbreak of fire, the release or production of toxic gases and the generation of dust.

Hazard parameters

6.28.6.26. The following are example of parameters that should be considered and are given in Table III:

— Nature of explosive substance
  - Mechanical Physical properties:
  - chemical properties
  - radiochemistry
  - flashpoint/ignition temperature
— Maximum credible pressure & thermal release, or frequency of explosion v. severity relationship
— Meteorological and topographical characteristics of the region
— Existing protective/mitigative measures at the source location

Load characterisation parameters

6.29.6.27. The following are example of parameters that should be considered and are given in Table V (1), (2), (3), (4) & (7):

— Overpressure as function of time
— Hard and Soft Missiles
— Heat
  - maximum temperature flux and duration
— Smoke & dust
  - Composition
  - Concentration and quantity as a function of time
— Ground shaking
  - Frequency response spectrum for vibrational motion

7. EXTERNAL FIRE

GENERAL CONSIDERATIONS

7.1. There are several possible sources of external fire that could threaten a nuclear installation including fires starting in adjacent units/installations on the same nuclear site. Fires from aircraft crashes are discussed in detail in Ref. [2019].

7.2. A survey should be made at and around the site to identify potential sources of fire, such as forests, peat, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), wood or plastics, factories that produce or store such materials, their transport lines, vegetation, pipelines or chemical plants, accidents on major highways etc. Fires can be accompanied by other hazards such as explosion and release of hazardous substances because of their ability to fail (or cause the failure of) containment structures such as tanks. Fire is often also a secondary or consequential hazard following such events.

7.3. Fires arising from highly flammable materials such as petroleum products typically occur as fireballs, e.g. ignition of a flammable vapour cloud, or pool fires from ignition of a pool of liquid material. Flammable vapour clouds can ignite under certain conditions leading to explosive fireballs called Boiling Liquid Expanding Vapour Explosions (BLEVEs), which are especially violent events and should be covered.

7.4. Fire can spread horizontally in differenttwo ways: either by radiation heating from the thermal flux associated with the fire, or via flammable material situated between the fire source and the site/installation or by sparks. Significant passive protection can therefore be afforded by the presence of fire breaks or areas immediately external to the site/installation free from flammable material and should be considered. In the case of external fires, alternative fire spread paths should also be identified such as airborne dispersion of firebrands (embers) or transportation of liquid fuel in the sewer system.

7.5. Heat flux in quiescent conditions will obey the inverse square law of energy attenuation, however some fire related hazards such as smoke and dust may propagate directionally due to the prevailing wind direction and attenuate slowly in this direction. The fire itself will spread preferentially in the downwind direction, especially if there is a supply of flammable material along the route such as dry vegetation and should be considered.

7.6. Installations may have a substantial ability to withstand thermal heating before loss of safety function occurs, but smoke damage may quickly lead to loss of safety function if, for example, it impairs an operator from performing an important safety function or blocks an air filter. Multi-unit sites especially should be considered carefully for their contribution to HIEE fire hazards.

7.7. The protections taken at the nuclear installation against fires and provided against fire hazards at the source of the fire should also be considered in evaluating the effects of external fires on the nuclear installation. However, before giving credit to these in the hazard evaluation, sufficient justification should be provided.

HAZARD ASSESSMENT

Source identification

7.8. Sources of fire are included in Table III. Guidance on data collection is provided in Section 4. First the regions should be located based on SDV^g values (Table II). Sources existing within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources should also be identified just beyond these regions if these are large or especially hazardous sources.

7.9. Data of potential sources should be collected and source/nuclear site distance values, D_S should be calculated. Sources existing within this region should include forests, peat, vegetation, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), industrial facilities that process flammable materials and associated transport routes.

Screening by distance

7.10. Based on source data, SDV^s for heat flux (dominant hazard) can be estimated by means of a simplified conservative approach. Sources of fire can be screened out if lie further away from the nuclear site ($D_S > SDV^s$). Meteorology, topography, and existing protective measures at the source and nuclear installation are important considerations.

Screening using probability

7.11. If a fire hazard cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can initiate a fire. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screen-out.

7.12. If the potential hazard from screened-in sources is likely to be less than that due to similar materials stored on the nuclear site itself and against which protection has already been provided, then it can be screened out. If several sources are screened-out on the same basis, it may be necessary to reflect the frequency contribution arising from the sum of all such sources by nominating a bounding source and screening on this. The screening exercise of each event that could initiate a fire and affect the nuclear installationNI site should be performed. The screened-in sources should be listed.

Detailed evaluation

7.13. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

7.14. In this phase, list of screened-in hazards is refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear installation under design or assessment. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence.

7.15. A hazard evaluation considers the source location and assumes a type of fire and/or flammable substance and ignition mechanism. The probability with which fires that characterize the source occur can be found from experience data or derived from general national or world-wide data.

7.16. To avoid fire effects from forests/bushes, a zone around the nuclear installation site should be devoid of any vegetation and a fire safety program at the site should be implemented to avoid fires from other sources that could affect the safety of the nuclear installation.

7.17. The thermal exposure to external nuclear installation~~plant~~ ~~structures and~~ structures, systems and components ~~is~~ should be quantified in terms of radiative and convective heat flux incident on the target surface and the duration of the exposure. Methods to assess external fireballs and pool fires from a sudden release and ignition of combustible liquid or gas provided in Ref. [~~20~~19]. Smoke is another important hazard to be evaluated as it travels longer distances.

Hazard parameters

7.18. The following are example of parameters that should be considered and are given in Table III:

- Nature of flammable substance
  - Flashpoint, flammability concentrations in air, or other ignition criteria
  - Max. credible substance/thermal release, or fire frequency v. severity relationship
  - Thermal load vs time
- Meteorological and topographical characteristics of the region
- Existing protective measures at the source location, e.g. fire breaks

Load characterization parameters

7.19. The following are example of parameters that should be considered and are given in Table V (1), (2), (3), (4) & (5):

- Overpressure as function of time
- Projectiles
- Heat
  - Maximum temperature flux and duration
- Smoke & dust
  - Composition
  - Concentration and quantity as a function of time
- Asphyxiant and toxic substance
  - Concentration and quantity as a function of time

- Volatility in ambient conditions
- Toxicity and asphyxiant limits

8. AIRCRAFT CRASH

GENERAL CONSIDERATIONS

8.1. Methods currently in use for considering aircraft crash as a HIEE may contain differences of detail, however, they all contain the same basic elements which should be considered:

— Categorisation of aircraft by type, mass, velocity and size
— Categorisation of airspace by the type of flying rules or restrictions that apply, e.g. commercial airways, airspace around airports, restricted airspace etc.
— FrequencyProbability analysis to determine the aircraft crash at the location of the nuclear site in terms of crashes per year per km^2 for each aircraft category
— FrequencyProbability analysis to determine the aircraft crash onto nuclear installations that could lead to a consequential release of radioactivity. This includes calculating that area of the nuclear site, called variously the target area, zone of influence, damage footprints etc.

There are only few examples of nuclear installations other than NPP that have been designed against airplane crash. This is because in general they lack the inherent structural robustness of NPPs. In order to protect these installations against aircraft crash, every effort should be made to screen out the hazard through distance and/or probability.

8.2. Aircrafts should be considered to be a mixture of hard and soft missiles and impact onto reinforced concrete structures typically results in damage modes such as perforation, penetration, scabbing, local punching, bending failure and vibrations.

8.3. In some nuclear power plants, specific protection is provided against malicious aircraft crash; such protection measures are generally sufficient to envelope the risk from accidental aircraft crash hazard significantly, such that it can be screened out. Nevertheless, it should be carefully checked whether the assumed scenarios for malicious aircraft crashes fully cover potential accidental scenarios and also the protection means are suitable for accidental aircraft crashes. Malicious aircraft crash is not considered in this Safety Guide however some of the methods recommended herein, may also be applicable to malicious aircraft crash. Malicious aircraft crash is not considered in this Safety Guide however some of the methods recommended herein, may also be applicable to malicious aircraft crash.

8.4. Aircraft crash hazard is potentially one of the most significant of all HIEE hazards and a great deal of research work has been conducted, both into the methods for crash probability analysis and into the effects of impact events onto heavy concrete targets. This research and experience should be considered in the aircraft crash hazard evaluation.

8.5. it is important to consider all the potential effects of the aircraft crash event on the nuclear installation if any aircraft crash is not screen out:

— Direct effects

- Impact damage to structures including perforation, penetration, etc.
- Vibration effects
- Global stability

— Secondary effects

- Secondary missiles ejected from the impact site and scattering widely,
- Rapid spread of flammable liquid from the point of impact, including impulsive damage to structures from the released momentum of the liquid when ejected from the aircraft,
- Entry of combustion products into ventilation or air supply systems,
- Fire and explosion generating heat and blast effects and generating tertiary missiles,
- Release of hazardous substance carried as cargo.

8.6. The main component in the loading function resulting from a collision of the deformable fuselage can be predicted assuming a soft missile impact. Aircraft engines and landing gear can be classified as semi-hard or hard missiles and should be considered. Use of concrete constitutive models should be verified by numerical analysis.

8.7. Fire from fueloil spillage can result into fireball or pool fire pool or both and should be considered. Details are provided in Ref. [2019].

8.8. On multi-unit sites, there may be multiple safety related structures serving different units. Impact on structures associated with an adjacent unit may not directly impact the unit under consideration, but secondary hazards such as missiles, fire and explosion may do and should be considered.

HAZARD ASSESSMENT

8.9. The process includes three types of aircraft crashes. It is recognised that air traffic encounters several different operational environments that critically affect the probability of the crash events. The following types of aircraft operations should be considered:

— Type 1: Aircraft cCrash occurring from general aviation traffic, sometimes called the background crash rate.

— Type 2: All aircraft crash hazard arising from take-off and landing manoeuvres at a local airport.

— Type 3: Aircraft crash occurs at the site owing to air traffic in the main civil traffic corridors and military flight zones.

Type-1 events:

Source identification

8.10. Information of aircraft crashes in respective country should be collected from the civil and military aviation authorities of the country or other departments working in the aviation industry. Details should include aircraft crashes of all types of different aircrafts flying in the country. SDV[g] is not applicable for this type event.

Screening by distance (SDV[s])

8.11. Screening by distance is not applicable for this type event.

Screening using probability

8.12. Aircraft crash data covering a regional circular area of 100-200 km in radius for each type of both civil and military crashes should be determined. The probability of Type 1 events should be carefully evaluated, in particular in densely populated regions with several civil airports and thus more flights. Appropriate zoning of the area considered should be carried out to avoid nonconservative averaging.

8.13. The probability of occurrence of all types of aircraft crashes should be evaluated by considering the site as a tract or circular area of 0.1–1 km^2 by dividing site area by the regional area and multiplying by crashes/year for different types. Those classes of aircraft for which probability of occurrence, P_{PE} is less than SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Type-2 event:

Source identification

8.14. Sources are included in Table III and S~~V~~DV^{g} in Table-2. Guidance on data collection is provided in Section 4. The probability of aircraft crashes is usually higher in the vicinity of airports, both civil and military. A separate check should be carried out for both types. Most aircraft crashes tend to occur within approximately semi-circular areas of 8 km (SDV2) in radius centred at the ends of the runways.

Screening by distance (SDV^{s})

8.15. I~~i~~f regional or national specific values were developed or regulated, it can be used. Otherwise S~~V~~DV^{g} should be used.

Screening using probability

8.16. If a hazard cannot be screened out by distance, probability of occurrence of particular types of crashes should be determined and it should be compared with SPL. Those aircrafts for which probability of occurrence, P_{PE} is less than SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Type-3 event:

Source identification

8.17. Sources are included in Table III and S~~V~~DV^{g} in Table-2. Guidance on data collection is provided in Section 4. The potential hazards arising from aircraft crashes are considered owing to air traffic in the main civil traffic corridors and military flight zones if airways or airport approaches pass within 4 km (SDV3) of the site.

Screening by distance (SDV^{s})

8.18. I~~i~~f regional or national specific values were developed or regulated, it can be used. Otherwise S~~V~~DV^{g} should be used.

Screening using probability

8.19. If a hazard cannot be screened out by distance, probability of occurrence of particular types of crashes should be determined and compared with SPL. Those aircrafts for which probability of occurrence is less than SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Detailed evaluation for all type of event

8.20. Hazard analysis should be performed for the screened-in sources and hazards should be characterized.

8.21. In this phase, list of screened-in hazards should be refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear power plant (or other nuclear installations) under design or assessment.

8.22. This second level of screening is based on specific site and nuclear installation characteristics. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence. An additional consideration is the type and number of co-located installations on the site that can have positive or negative effects on prevention, detection, control of consequences (normal and severe conditions) and emergency response. Details provided in Ref. [1918].

8.23. Significant effort has been expended internationally to develop cost effective approaches to addressing the issues of extreme human induced external events by following a systematic approach. An approach similar to the zone of influence approach is recommended. The concept of defining areas of consequence for each of the hypothesized impact locations is employed. The areas of consequence are denoted damage footprints. Damage footprints are defined for impact, shock and fire loading conditions.

8.24. The systematic approach to the evaluation should consider the buildings containing nuclear fuel material and the buildings housing the SSC important for safety (e.g. equipment for heat removal):

— Impact locations to be considered are defined, which are identified based on the aircraft parameters (such as type of aircraft, nature of flight, angle of impact, etc. and manoeuvrability of aircraft), shielding by topography, nuclear installation buildings, transmission lines and other considerations.
— Conservative assumptions about the angle of aircraft impact, for example perpendicular to the centreline of the containment building and perpendicular to the spent fuel storage building are made.
— Local response, global response and vibration loading conditions are considered.

Damage footprints due to any consequences of the aircraft crash should be developed, including structure failure modes, fire and vibration effects. The end product is aircraft impact locations and damage footprints. Studying the effects of an aircraft crash requires evaluations of global structural response, local response, vibration effects and fire, as detailed in Ref. [2019].

8.25. In addition, all building housing the structure, system and componentsstructures containing equipment necessary to prevent damage of fuelan accident in the reactor or the spent fuel pool should be identified for screening or evaluation. For example, Ffront line and support systems needed for safe shutdown of the reactor or continued cooling of the spent fuel pool should be identified. Exterior faces of the buildings should be evaluated to screen out the need for further evaluation or to determine impact locations:

— The faces or partial faces of buildings could be screened out from further consideration due to shielding by adjacent structures, intervening structures, or other site features.
— Faces of buildings that are partially screened out are subdivided into portions for which aircraft impact is possible and not possible;
— The impact of multiple buildings during the event is considered, the result being the identification of multiple buildings vulnerable to a single aircraft crash;
— Candidates for aircraft impact assessment are the end products.

Damage footprints for each building and each impact location of the buildings should be developed for evaluation.

8.26. After evaluation, loading functions for the screened-in human induced external events should be defined for the engineering evaluation.

8.27. The load characterization is the link between the events and the definition of the loading environment for evaluation. The resulting matrix of loading conditions produced by the events is to be applied to the entire facility or to portions of it [Ref. 18, Table 4, Scenario-1].

8.28. Tables 5–7 [1~~9~~8] expand on Scenario 1 in Table 4 (aircraft impact event) to identify the following parameters for engineering evaluation: impact, heat/fire and vibration. Ref. [~~20~~19] describes the complete evaluation methodology for structural impact, induced vibrations, thermal effects from fire, local & global effects and acceptance criteria.

Hazard parameters

8.29. The following are example of parameters that should be considered and are given in Table III:

— Characteristics of aircraft by type, nature of flight, and crash rate
— Aircraft movements and flight frequencies from
  - Airfields
  - Airways
  - Controlled airspace around commercial and military airfields
  - Restricted and other forms of special airspace
  - Location of aircraft sources, runway directions and other related data, and direction of approach to nuclear site
  - Airfield plates[9] for take-off, landing and manoeuvring
— Parameters derived from regional or national aircraft crash data:
  - Probability distributions for direction of approach & angle of descent by aircraft type
  - Skid/footprint distances and rate of energy/momentum attenuation with distance by aircraft type.

Load characterization parameters

8.30. The following are example of parameters that should be considered and are given in

[9] Plates are (paper based and now digital) information providing all the navigational information needed by a pilot manoeuvring around a major airport. They are prepared by national authorities and specific to the airport, runway, runway direction and navigational procedure being used. They are publicly available for all international airports and many local ones.

Table V 1,2,3,4 & 6, also Ref. [2019]:

— Terminal Impact energy at nuclear installation:
  - Mass
  - Velocity
— Impact parameters
  - Components of aircraft classified as hard/soft missiles
  - Size and cross-section area in plane of impact or each component
— Derived from hazard analysis:
  - Probability distributions for direction of approach & angle of descent onto the nuclear site by aircraft type
  - Skid/footprint distances and rate of energy/momentum attenuation with distance by aircraft type.
  - Data needed for analysis of secondary hazards
  - Fuel load by aircraft type and stage of flight
  - Hazardous cargo: substances & volume

9. TRANSPORT EVENTS EXCLUDING AIRCRAFT CRASH

GENERAL CONSIDERATRIONS

9.1. This section deals with those Mobile sources excluding air traffic which may create HIEE hazards due to mobile sources excluding air traffic. The following sources are considered, (see Table III and (IV):

— Road transport,
  - Trucks carrying hazardous substances,
— Rail transport,
  - Trains carrying hazardous substances,
— Marine transport,
  - Ships carrying hazardous substances (cargoes),
  - Ships that possess significant kinetic energy,
— River transport,
  - Barges carrying hazardous substances (cargoes),
  - Barges that possess significant kinetic energy,
— Pipelines,
  - Pipelines conveying hazardous substances.

9.2. This section considers some general features of road, rail and water borne transport events before dealing collectively with all sources that present a direct impact hazard to nuclear structures, systems and components and those that can release hazardous substances.

9.3. Water borne vessels have the potential to interact with coastal and offshore structures belonging to a nuclear installation site. Nuclear reactor cooling water intakes and outfalls are a concern, as are docks and jetties that are used for loading/unloading nuclear materials onto vessels for transport. The potential for water borne vessels to interact with coastal and offshore structures of a nuclear installations should be considered.

9.4. Road, rail, marine and river vehicles and vessels routinely transport dangerous goods and the potential for release of hazardous substances is are always a potential risk to nearby nuclear installations and should be considered. All hazards should be dealt as per the guidance provided in the previous sections by taking minimum distance from the nuclear installations. Similarly, pipelines routinely convey hazardous liquids and gases and should also be considered.

MARINE AND RIVER VESSELS THAT POSSESS SIGNIFICANT KINETIC ENERGY

9.5. The effects for any given installation will depend on the nature of any shoreline/offshore nuclear structures, their layout and whether there is any natural or human-made protection. The significant hazard is collision between a massive vessel and a shoreline (dock or loading facility) or submerged (cooling water intakes) nuclear safety structure, where substantial structural damage is possible. Such events can be regarded as soft missile impacts, where significant deformation to both the vessel and the coastal structure is likely and should be considered.

9.6. The primary hazard is impact but secondary effects of oil spill, fire, explosion, release of gases etc are possible and should be considered as per the guidance provided in the previous sections. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals should also be considered to jeopardize the water intake.

9.7. Large commercial ships can also drift by tide and river currents. The local bathymetry around the nuclear installation should be considered, and tide/river flow conditions should be selected to identify the most onerous conditions of vessel reach and speed relative to the nuclear installation structures.

HAZARD ASSESSMENT FOR MARINE AND RIVER VESSELS THAT POSSESS SIGNIFICANT KINETIC ENERGY

Source identification

9.8. Sources of marine/river vessels include ships and barges (Table III). First the regions should be located based on SDV[g] values (Table II). Data of potential sources should be collected and source/nuclear site distance values, D_S, should be calculated. Data collection should comprise data of ships coming to the site area in the loading/un-loading area, commercial ships moving in the designated lanes and maintenance vessels for dredging. Publicly available information from local marine/river authorities on the location of shipping lanes, the local bathymetry and tide/river flows throughout the year, data on the frequency and nature of vessel movements should be collected.

Screening by distance

9.9. Based on collected data and site protections, whether a ship(s) can impact the intake structure should be checked. Local bathymetry and pre-dominant tide/wind direction are important considerations, but worst met conditions should be considered. If it does not impact, the hazard can be screen out.

Screening using probability

9.10. If it cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can initiate an impact. Iif the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out. The probability of an impact of a commercial ship with the intake structure could be very low as administrative measures are strictly in place and protective embankments are constructed with an opening for the cooling water. Ships entering the intake channel to meet the needs of the installation can impact the intake structure due to human error if necessary protective measures are not taken to limit their movement towards the intake structure. A maintenance vessel used for dredging in the intake bay could also impact the intake structure. The screening exercise of each event that could initiate an impact should be performed and the screened-in sources should be listed.

Detailed evaluation

9.11. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, load characterization should be performed by considering the data of ship/barge moving with a conservatively estimated velocity.

9.12. In broad terms the evaluation process considers a distressed or incorrectly navigated vessel impacting a submerged, offshore or coastal nuclear installation structure. Such impacts depend on the number of vessel movements per year by size and inventory, the location of shipping lanes in relation to the location of the nuclear structure, and the ability to model accurately how a distressed vessel might come to impact such a structure. These aspects should be considered in the screening process.

9.13. Once the potential for impact has been established, the energy of impact should be calculated, and other load characterisation parameters estimated. Note that although in principle there are similarities between vessel impacts onto nuclear marine structures and other types of projectile impacts discussed in this Safety Guide, the nature of vessels (high mass, low speed) and the type of structures being considered may be quite different and this should be taken into consideration.

Hazard parameters

9.14. The following are example of parameters that should be considered and are given in Table III:

— Passage routes and frequency of passage, e.g. road & rail routes, seaways,
— Location and routing of pipelines and associated pumping stations, etc.,
— Frequency, type and route of movements to/from the source,
— Existing protective measures on passagesvehicles or routes.

Load characterisation parameters:

9.15. The following are example of parameters that should be considered and are given in Table V (2):

— ~~Terminal I~~impact energy at nuclear installation shoreside/offshore facility location,
  - Mass,
  - Velocity,
  - Size, cross-section area in plane of impact, and penetrative capability,

— Type of missile – soft missile,

— Compass direction of approach.

CARGOES CONSISTING OF, AND PIPELINES CONVEYING, HAZARDOUS SUBSTANCES

9.16. Hazards under this topic include hazardous liquids and gases released on ground, covered in Section 5, explosions in Section 6 and fire in Section 7. The same methodology should be used for the mobile sources by taking the minimum distance from the nuclear installation~~NI~~ site. Hazardous liquids discharged in sea and river are also discussed in this section.

9.17. Major pipelines passing in the site area should be evaluated as they may carry hazardous fluids and gases. Such pipelines can leak from valves or during an accident and should therefore be treated in a similar manner.

9.18. An important route for hazardous interaction with the nuclear installation is provided by the water intake; danger may arise owing to spillage at an adjacent installation or tanker accidents, often after an uncontrolled drifting. Parameters for the dilution and dispersion of the liquid and its entry into the water intake should be evaluated and the nuclear installation should be adequately protected. Consideration should be given to the fact that spillage of explosive or highly flammable liquids on water may produce floating pools, which may approach a nuclear installation on the shore or along a riverbank. A conservative estimate should be made, and dispersion characteristics should be considered. Consideration should also be given to the possibility that liquids with low flash points may be extracted from contaminated sources of intake water. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals should also be considered to jeopardize the water intake.

9.19. Liquids discharged from sea and river going vessels disperse in response to local tide and/or river current conditions and can be carried several kilometres from the release point. For liquids released into a large body of water, dilution can be anticipated as distance from the release point and elapsed-time increase, but the rate of dilution can be very dependent on the local tide/current flow conditions at the time of release. Modelling of the way discharges are dispersed should be carried out. Alternatively, it can be assumed conservatively that no dilution occurs.

HAZARD ASSESSMENT FOR CARGOES CONSISTING OF, AND PIPELINES CONVEYING, HAZARDOUS SUBSTANCES

Source identification

9.20. Sources of hazardous liquids and gases are included in Table III. Guidance on data collection is provided in Section 4. First the regions should be located based on SDV^g values (Table II). Sources existing within this region should comprise of hazardous materials transported by the commercial shipping companies and should be available from relevant local or national government agencies with responsibility for controlling access to transport routes (types/quantities of hazards, frequency, routes etc). Data in this region of potential sources should be collected and source/nuclear site distance values, D_S, should be calculated.

Screening by distance

9.21. Based on collected source data, simple calculations can be made and SDV^g values can be estimated for the possible maximum spills as these can travel long distances, assuming conservative parameters for dispersion and local tide/current flow conditions at the time of release. Those sources that lie further away from the nuclear site ($D_S > SDV^s$) can be screened out.

Screening on probability

9.22. If a hazard cannot be screened out by distance, generic events data can be used, and pragmatic conservative judgment can be applied to establish the occurrence of potential event(s) for spillage. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out.

9.23. If the potential hazard from screened-in sources is likely to be less than that due to similar materials stored on the nuclear site itself and against which protection has already been provided, that is also effective against hazards from off-site sources, then it can be screened out. If several sources are screened-out on the same basis, it may be necessary to reflect the frequency contribution arising from the sum of all such sources by nominating a bounding source and screening on this. The screening exercise of each event that can affect the nuclear installationNI site from spillage in sea or river should be completed and the screened-in sources should be listed.

Detailed evaluation

9.24. Hazard analysis of screened-in sources should be performed for load characterization. Substances released into sea or river water could disperse and dilute in complex ways that require explicit modelling by subject matter experts to determine how the different types of hazardous fluids travel in sea/river and affect the nuclear safety structures or equipment, and to calculate the load characterisation parameters required.

Hazard parameters

9.25. The following are hazard parameters that should be considered for load characterization:

— Location of transport route around the closest approach to the nuclear site.
— Nature/quantities of transported substances and spillage.
— Meteorological and hydrological conditions.
—

Relevant bathymetric, tidal and river current conditions around this route that might influence the dispersion and hazardous characteristics of a release.

Load characterisation parameters

9.26. The following are load characterisation parameters that should be considered:

— Concentration of different hazardous substances in the cooling water at intake,
— Impact on once through cooling water system.

10. OTHER HUMAN INDUCED EXTERNAL EVENTS

GENERAL CONSIDERATIONS

10.1. This section deals with those HIEE hazards that are not captured by the hazard-specific Sections 5 – 9. The following hazards are listed in Table IV, but some regions surrounding a nuclear site may contain others, since it is not possible to comprehensively identify all possible hazards in this Safety Guide:

— Ground Subsidence,
— Electromagnetic interference (EMI),
— Eddy currents into the ground,
— Bombing and fire practice ranges.

GROUND SUBSIDENCE HAZARDS

10.2. Ground at a nuclear installationNI site can subside due to a local geotechnical issue under the site-specific location or from outside the site area due to human-made features such as mines, exploitation of natural gas fields, water wells and oil wells if such activities are foreseen in the site vicinity area.

10.3. All geotechnical and geological issues that can exclude a nuclear installationNI site should be taken up during the site selection stage. The local geotechnical issues are covered in IAEA Safety Standard Series NS-G-3.6, Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants [6] and geological issues are covered IAEA Safety Standard Series SSG-9, Seismic Hazards in Site Evaluation for Nuclear Installations [2].

10.4. For existing sites whenever new construction work is planned either on-site or nearby, subsidence issues should be studied as deep excavation work is required, especially for nuclear power plants. The issue is more complicated when nuclear power plants are founded on saturated soft soils with high water table and massive dewatering is required. In those cases, it should be well justified that dewatering does not lead to unacceptable (differential) settlement of the existing nuclear installation and this should be monitored. Reinjection of the extracted water may be necessary to keep pore pressures at the existing nuclear installation unaltered during dewatering and the restoring period thereafterwater should also be injected so that water table around the existing NPP does not go down.

10.5. Huge mining activities, exploitation of natural gas fields, extraction of oil and ground water in the site vicinity area can lead to subsidence. Specific assessment should be conducted in such cases and no SDV can be provided as it will depend on the volume of mining or oil or ground water extraction activities and distance from the nuclear installation NI site.

Detailed evaluation

10.6. Engineering solutions are available to handle the subsidence from local effects but depends on the quantum of works to be undertaken and may not be feasible. Engineering solutions to counter subsidence from human induced events can be established after detailed evaluation is made and may or may not be possible but administrative measures might beare available. As such, a decision to select a site should be taken after detailed evaluation.

Hazard parameters

10.7. The following are example of parameters that should be considered and are given in Table III:

— Location and nature of adjacent ground works,
— Location and nature of underground works,
— Relevant geological/geotechnical ground conditions,
— Details of planned activities in the site vicinity (mining, oil and water extraction).

Load characterisation parameters

10.8. The following are example of parameters that should be considered and are given in Table V (9) if a site can be selected:

— Settlement, differential settlement and settlement rate,
— Existing engineered mitigation measures (existing sites) or anticipated (new sites).

ELECTROMAGNETIC INTERFERENCE HAZARDS

10.9. Electromagnetic interference can affect the functionality of electronic devices. It can be initiated by both on-site (high voltage switchgear, portable telephones, portable electronic devices, computers etc) and off-site sources (radio interference, military radar stations, particle accelerators, high voltage transmission lines, telephone network etc). Particular attention should be provided to jamming facilities that may be used by the on-site security organization or by national security authorities' transmitters (airborne, seaborne or ground-located on- or off-site), as the actual power and antenna amplification of these transmissions might not be public, and the radiation power of the transmissions may be increased significantly with little or no warning. When information on these cannot obtained by the operator, the regulator should be asked to estimate the significance of these hazards.

10.10. The process of identification of potential sources of interference and quantification should be continued during the lifetime of the plant nuclear installation to ensure proper protection of plant components as the greater use of digital equipment in I&C systems is increasing the vulnerability to EMI.

10.11. Generic SDV have not been developed for EMI by member states and therefore, it should be managed by nuclear installationNI site specific situation.

Detailed evaluation

10.12. Detailed evaluation should be conducted to establish the hazard parameters and load characterization.

10.13. The electromagnetic conditions at the point of installation for important to safety I&C systems should be assessed to identify any unique EMI/RFI sources that may generate local interference. The sources could include both portable and fixed equipment (e.g., portable transceivers, arc welders, power supplies, and generators). Steps should be taken during installation to ensure that systems are not exposed to EMI/RFI levels from the identified sources that are greater than the specified operating envelopes.

10.14. To ensure that the operating envelopes are being used properly, equipment should be tested in the same physical configuration as that specified for its actual installation in the nuclear installation. In addition, the equipment should be in its normal mode of operation (i.e., performing its intended function) during the testing. Following the tests, the physical configuration of the safety related I&C system should be maintained and all changes in the configuration controlled.

10.15. Exclusion zones should be established through administrative controls to prohibit the activation of portable EMI/RFI emitters (e.g., welders and transceivers) in areas where safety related I&C systems have been installed. The size of the exclusion zones should be site-specific and depend on the effective radiated power and antenna gain of the portable EMI/RFI emitters used within a particular nuclear installation.

Hazard parameters

10.16. Electromagnetic interference (EMI) in this Safety Guide includes Radio-Frequency Interference (RFI). The following are example of parameters that should be considered and are given in Table III:

— Frequency band and energy of EMI emissions of sources at/around the site,
— Existing protective measures at the source locations.

Load characterisation parameters

10.17. The following are example of parameters that should be considered and are given in Table V (10):

— Frequency band and energy rating of EMI emissions protection,
— Existing engineered mitigation measures (existing sites) or anticipated (new sites).

~~EDDY CURRENTS HAZARDS INTO THE GROUND~~

~~10.18. The eddy currents can lead to:~~

~~— Corrosion of underground metal components,~~
~~— Grounding problems,~~
~~— Incorrect/spurious electrical signals in safety related equipment leading to spurious operation or action.~~

~~10.19. There is a major heat loss cycling eddy currents cause loss of energy due to friction in the magnetic circuit, especially where the core is saturated. Thus, there is the loss of useful electrical energy in the form of heat and magnetic flux leakage.~~

~~10.20. Eddy currents should be minimized in these devices by selecting magnetic core materials that have low electrical conductivity (e.g., ferrites) or by using thin sheets of magnetic material, known as laminations. Electrons cannot cross the insulating gap between the laminations and so are unable to circulate on wide arcs.~~

10.21. If eddy current hazard is a credible risk to a nuclear site, engineered measures should be put in place to protect the safety critical nuclear equipment.

10.22. The subject of ground borne eddy currents and their ability to affect safety related electrical equipment is a specialized technical area and a specialist on electrical and I&C should be used to make a proper site-specific assessment.

Detailed evaluation

10.23. Detailed evaluation should be conducted to establish the hazard parameters and load characterization. Hazard evaluation for sources of Eddy currents and their effects on nuclear installations requires expertise in electrical engineering and I&C and should be acquired.

Hazard parameters

10.24. The following are example of parameters that should be considered and are given in Table III:

- Electrical characteristics, especially potential difference between source conductors and ground,
- Meteorological characteristics of the region, especially humidity.

Load characterisation parameters

10.25. The following are example of parameters that should be considered and are given in Table V (11):

- Intensity and duration,
- Existing engineered mitigation measures (existing sites) or anticipated (new sites).

BOMBING AND FIRING PRACTICE RANGES

10.18. 10.26 This hazard should be handled in a special way if the bombing and firing ranges are within the SVDVg of 30 km as such information is not easily available. For military institutions, eEfforts should be made through the Governmental channels to obtain the required information about the activities on the bombing and firing ranges[10]. from the military institutions. Moreover, the history of events/incidents happening outside their designated area relating to their activities should be collected and used in the assessment. Frequency of overhang ordnance, flight path(s) taken to a recovery site, and frequency of dropped ordnance should be collected. A confidentially agreement may be signed not to disclose any information and used without bringing it up into the project papers. Any screened-in hazards should be evaluated in a similar way. Alternatively, a site inside the SDV should be ruled out.

[10] if there exist undisclosed national security locations (e.g. permanent underwater minefields, electronic warfare installations or concealed munitions depots) near the site that might cause a hazard for the plant, the plant or the regulator should make their best efforts to contact the responsible authorities to determine and minimize the hazard caused to the plant

11.- EVALUATION OF EXTERNAL HUMAN INDUCED HAZARDS FOR NUCLEAR INSTALLATIONS OTHER THAN NUCLEAR POWER PLANTS

11.1. For the purpose of HIEE hazard assessment, nuclear installations should be graded on the basis of their complexity, potential radiological hazards and hazards due to other materials present. HIEE hazard assessment should be performed in accordance with this grading. This grading may be applied for each HIEE separately.

11.2. Prior to categorizing an installation for the purpose of adopting a graded approach, a conservative screening process should be applied in which it is assumed that the entire radioactive inventory of the installation is released by an accident initiated by a HIEE event. Provided that the potential result of such a radioactive release were that no unacceptable consequences would be likely for workers or for the public (i.e. provided that doses to workers or to the public due to the release of that radioactive inventory would be below the authorized dose limits established by the regulatory body), or for the environment, and provided that no other specific requirements are imposed by the regulatory body for such an installation, the installation may be screened out from further HIEE hazard assessment.

11.3. If the results of the conservative screening process show that the potential consequences of such releases would be 'significant', a HIEE hazard assessment and a safety evaluation of the nuclear installation should be carried out, in accordance with the procedure indicated in para.11.5-14.

11.4. The likelihood that a HIEE will give rise to radiological consequences will depend on the characteristics of the nuclear installation (e.g. its purpose, layout, design, construction and operation) and. Such characteristics should include the following factors:

(a) The amount, type and status of the radioactive inventory at the site (e.g. whether solid or fluid, processed or only stored);

(b) The intrinsic hazard associated with the physical processes (e.g. criticality) and the chemical processes that take place at the installation, if applicable;

(c) The thermal power of the nuclear installation, e.g. heat loading of high-level waste for example, if applicable;

(d) The configuration of the installation for activities of different kinds;

(e) The concentration of radioactive sources in the installation (e.g. for research reactors, most of the radioactive inventory will be in the reactor core and fuel storage pool, while in fuel processing and storage facilities it may be distributed throughout the installation);

(f) The changing nature of the configuration and layout of installations designed for experimental work (such activities have an associated intrinsic unpredictability);

(g) The need for active safety systems and/or operator actions for the prevention of accidents and for mitigation of the consequences of accidents;

(h) The characteristics of engineered safety features for the prevention of accidents and for mitigation of the consequences of accidents (e.g. the containment and containment systems);

(i) The characteristics of the processes or the engineering features that might show a cliff edge effect7 in the event of an accident;

(j) The characteristics of the site relevant to the consequences of the dispersion of radioactive material to the atmosphere and to the hydrosphere (e.g. size, demographics of the region);

(k) The potential for on-site and off-site contamination ~~resulting from the volcanic event~~.

11.5. HIEE hazards at the site should be evaluated in accordance with the procedures described in this Safety Guide.

11.6. Although most nuclear installations are located at surface sites, some smaller nuclear installations may be located below the surface. Most HIEE hazards are expected to have limited potential to affect the safety of a subsurface installation, although those that can induce ground failure clearly should be considered. However, any affects will depend on details of both the HIEE hazards to which the installation is subjected to and the nature of the installation.

11.7. Depending on the criteria used by the regulatory body, some or all of the factors mentioned should be considered. For example, fuel damage, radioactive release or dose may be the conditions or metrics of interest.

11.8. The grading process should be based on the following information:

(a) The current safety analysis report for the installation, which should be the primary source of information, if available;
(b) The results of a HIEE hazard assessment, if one has been performed;
(c) The characteristics of the installation specified in para. 11.5.

11.9. The grading of the installation leads to its categorization. This grading may have been performed at the design stage or later. If this grading has been performed, the assumptions on which it was based, and the resulting categorization should be reviewed and verified. In general, the criteria for categorization should be based on the radiological consequences of the release of the radioactive material contained in the installation, ranging from very low radiological consequences to potentially severe radiological consequences. As an alternative, the categorization may range from radiological consequences within the installation itself, to radiological consequences confined to the site boundary of the installation, to radiological consequences to the public and the environment outside the site.

11.10. As a result of this process for grading of the installation, three or more categories of installation may be defined on the basis of national practice and criteria, as indicated in para. 11.9. As an example, the following categories may be defined:

(a) The lowest hazard category includes those nuclear installations for which national building codes for conventional facilities (e.g. essential facilities, such as hospitals) or for hazardous facilities (e.g. petrochemical or chemical plants), as a minimum, should be applied.
(b) The highest hazard category contains installations for which standards and codes for nuclear power plants should be applied.
(c) There is often at least one intermediate category of hazardous installation, for which, as a minimum, codes dedicated to hazardous facilities should be used.

11.11. The number of categories within the scope of the intermediate (c) category will depend on the nature of the installation and also whether the nuclear site is a multi- or single installation site.

11.12. In the grading of nuclear installations, it should be borne in mind that most installations other than NPPs may not have sufficient inherent robustness against HIEEs. It may also be inappropriately costly to protect them against some HIEE through design, e.g. the crash of a large aircraft. Therefore, necessary precautions should be taken at an early stage to protect the nuclear installation through appropriate siting whereby ample SDVs are provided for major HIEEs.

11.13. The HIEE hazard evaluation should be performed using the following guidance:

(a) For installations in the lowest category, the HIEE hazard evaluation may be based on national building codes and standards, as established for important facilities within the State.
(b) For installations in the highest category, the HIEE hazard evaluation should be implemented in the same manner as for nuclear power plants.
(c) For installations categorized in the intermediate hazard category, the following cases may be applicable:
   (i) If the HIEE hazard assessment is performed using methods similar to those described in this Safety Guide, a lower HIEE Hazard level (than for NPPs) for designing these installations may be adopted at the design stage, in accordance with the safety requirements for the installation;
   (ii) If the database and the methods recommended in this Safety Guide are found to be disproportionately complex, time consuming and demanding for the nuclear installation in question, simplified methods for HIEE hazard assessment may be used. In such cases, the hazard parameter finally adopted for designing the installation should be commensurate with the reduced database and the simplification of the methods, with account being taken of the fact that both factors tend to increase uncertainties.

12. APPLICATION OF MANAGEMENT SYSTEM

12.1. A management system, to be established, applied and maintained as required by IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [~~21~~20], should be implemented for the activities that are performed for the hazards associated with HIEEs in site evaluation for the nuclear installations.

ASPECTS OF PROJECT MANAGEMENT

12.2. A project work plan should be established that, at a minimum, addresses the following topics:
(a) The objectives and scope of the project;
(b) Applicable regulations and standards;

(c) Organization of the roles and responsibilities for management of the project;
(d) Work breakdown, processes and tasks, schedule and milestones;
(e) Interfaces among the different types of tasks (e.g. data collection tasks, analysis tasks etc.) and disciplines involved, especially the various specialists required for the different types of HIEEs encountered with all necessary inputs and outputs;
(f) Project deliverables and reporting.

12.3. The project scope should prescribe to identify all the hazards generated by HIEEs from the various sources that are relevant for the safety of the nuclear installation and that will be investigated within the framework of the project. If some HIEE hazards are not included within scope, an explanation should be provided as to why this is the case, so it is clear that the project has not covered all aspects of the HIEE hazard analysis.

12.4. The project work plan should include a description of all requirements that are relevant for the project, including applicable regulatory requirements in relation to all the hazards considered to be within the project scope. The applicability of the set of regulatory requirements should be reviewed by the regulatory body prior to conducting the HIEE hazard analysis.

12.5. All approaches and methodologies that reference lower tier legislation (e.g. regulatory guidance documents, industry codes and standards) should be clearly identified and described. If procedures for experts' interaction are used to better capture epistemic uncertainties, the sophistication and complexity of these approaches should be chosen by the study sponsor based on the project requirements. The details of the approaches and methodologies to be used should be clearly stated in the project work plan.

12.6. At least the following generic management system process should be applied to ensure quality of the project: document control, control of products, controls for measuring and testing equipment, control of records, control of analyses, purchasing (procurement), validation and verification of software, audits (self-assessment, independent assessments and review), control of non-conformances, corrective actions and preventive actions [2~~1~~2]. Processes covering field investigations, laboratory testing, data collection, and analysis and evaluation of observed data should be applied. Communication processes for the interaction among the experts involved in the project should be also applied.

12.7. The project work plan should ensure that there is adequate provision, in the resources and in the schedule, for collecting new data and/or analysis that might be important for the conduct of the HIEE hazard assessment. This may arise where potential HIEEs have been identified at sources where the associated safety analysis is appropriate to the industry with which the source is associated, but level of detail is considered inadequate for inclusion in a nuclear safety analysis.

12.8. To make the hazard evaluation associated with HIEEs traceable and transparent to users (e.g. peer reviewers, the operating organization, the regulatory body, the designers, the vendors, the contractors and the subcontractors of the operating organization), the documentation for the analysis should provide a description of all elements of the analysis process and include the following information:

(a) Description of the study participants and their roles;
(b) Background material that comprises the data collection tasks, analysis documentation, including the source display map;
(c) A description of the computer software used, and input and output files;
(d) Reference documents;
(e) All documents supporting the treatment of uncertainties, opinion and related discussions;
(f) Results of intermediate calculations and sensitivity studies.

This documentation should be maintained in an accessible, usable and auditable form by the operating organization

12.9. The documentation and references should identify all sources of information used in the HIEE hazard analysis, including information on where to find important citations that might be difficult to obtain. Unpublished data that are used in the analysis should be included in the documentation in an appropriately accessible and usable form. Where data has been used that is restricted for security or commercial reasons (see para. 4.1), it may be necessary to prepare redacted versions of significant project documentation. However, where such documents are used by as part of the HIEE hazard analysis or passed to others, say by peer reviewers or nuclear ~~plant~~ installation designers, it will be the project organization's responsibility to ensure that sufficient information is provided so that such people are able to carry out their tasks effectively and in the best interests of nuclear safety.

ENGINEERING USES AND OUTPUT SPECIFICATION

12.10. An HIEE hazard assessment is usually conducted for the purposes of design and/or safety assessment of the nuclear installation. Therefore, from the beginning, the work plan for the HIEE hazard assessment should identify the intended engineering uses and objectives of the assessment and should incorporate an output specification that describes all the results necessary for the intended engineering uses and objectives of the study, see also para. 4.1. Given the large number of potential HIEEs that might be relevant to safety of a nuclear installation, it is not possible to define in a guide of this nature all the elements that are required, since these will vary from project to project and from one site/installation to another.

INDEPENDENT PEER REVIEW

12.11. An independent peer review should be conducted and implemented to provide assurance that: (i) a proper process has been duly followed in conducting the HIEE hazard analysis, (ii) the analysis has addressed and evaluated the involved uncertainties (both, epistemic and aleatory), and (iii) that the documentation is complete and traceable.

12.12. The independent peer review team members should include the multidisciplinary expertise to address all technical and process related aspects of the HIEE hazard analysis. The peer reviewer(s) should not have been involved in other aspects of the project and should not have a vested interest in the outcome. The level and type of peer review can vary, depending on the application of the HIEE hazard analysis.

12.13. One of the following ~~T~~two methods of peer review should be used: participatory peer review or, ~~and~~ late stage peer review. A participatory peer review is carried out during the assessment, allowing the reviewer(s) to resolve comments. A late stage (follow-up) peer review is carried out towards the end of the assessment. Participatory peer review will decrease the likelihood of the assessment being found unsuitable at a late stage.

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APPENDIX

TABLE I. HIEE EVENT CATEGORIES

	Event Category	Generic Screening ~~Source~~ Distance Value (SDV[g]) in Table II
(a)	*Release of hazardous substances*. These include chemically and radiologically toxic gases and liquids arising off-site, pressurized and liquefied gasses and flammable gases and liquids.	(1) (2) (3) (4)
(b)	*Explosions*. These can arise from operational plants and/or stores containing potentially explosive materials and/or undertaking processes with such materials that create situations where an enhanced potential for explosions exists.	(1) (2) (4)
(c)	*External fire*.	(1) (3)
(d)	*Aircraft crash*. This includes how to categorise different types of aircraft for hazard analysis purposes, how to characterize aircraft movements near to a site, and how to model an aircraft crash event so that the hazard can be parameterised and quantified. Air corridors should also be included when characterizing aircraft movements.	(5)
(e)	*Transport events excluding aircraft crash*. These can arise from road and rail vehicles, pipelines, river barges and sea vessels. Hazards from this category normally arise directly from crash events, which in turn can lead to consequential toxic gas release, fire and explosion events.	(1) (2) (3)~~–~~ (4)

(f)	*Other human induced external events*. These include hazards arising from stationary and mobile sources not included in (a) – (e). Four types of HIEEs are included: Subsidence, electromagnetic interference, ground borne eddy currents and bombing and firing ranges, all except the last one without generic SDV	NA and (6) for bombing and firing ranges

TABLE II. GENERIC ~~SOURCE~~ SCREENING DISTANCE VALUES (SDV[sg]) WHICH ARE USED BY SOME MEMBER STATES

	Sources	***Generic ~~Source~~ Screening Distance Value (SDV^g^)***[11]
1	Facilities for storing or handling flammable, corrosive or explosive material	5-10 km
2	Sources of hazardous clouds, vapours, gases, etc.	8-10 km
3	Source of Fire such as forests, peat, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), wood or plastics, factories that produce or store such materials, their transport lines, and vegetation	1–2 km
4	Military installations storing munitions, etc.	8.0 km
5	Aircraft crash events	
	i) A crash occurs at the site deriving from the general air traffic in the region. ~~(SDV1)~~	100–200 km
	ii) Airports with attributes of accidental aircraft crash at the site such as in a take-off or landing operation at a nearby airport. (SDV2)	8.0 km
	iii) Flight paths approaching an airport (SDV3)	4.0 km
6	Distance from military installations or air space usage such as practice, bombing and firing ranges	30.0 km

[11] SDV[g] values are intended to be conservative values. When using these values, analysts should ensure that they are appropriate to the HIEEs likely to occur at each source considered.

TABLE III. IDENTIFICATION OF SOURCES, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
STATIONARY SOURCES			
(1) Oil refinery, chemical plant, storage depot, broadcasting network, mining or quarrying operations, dams & dock facilities, forests, other nuclear facilities, high energy rotating equipment, underground gas storage, fracking, ground works adjacent to the nuclear installation site	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• Nature of substance – ~~mechanical~~physical properties, chemistry, radiochemistry, flashpoint, toxicity, or definition of other hazardous effects • Max. credible release, or frequency v. quantity release curve • Meteorological and topographical characteristics of the region • Below ground flows – geological seepage/flow routes and opportunities for substance concentration • Existing protective measures at the source location, e.g. bunds

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
	b) Explosion	• Deflagration wave (over pressurization) • Detonation waves • BLEVE • Exothermic chemical reaction • Dust explosion	• Nature of explosive substance • Max. credible pressure (over/under) & thermal release at source location, or explosion frequency versus severity relationship • Meteorological and topographical characteristics of the region • Existing protective measures at the source location, e.g. blast walls
	c) External fire	• Hydrocarbon fire • Chemical fires other than hydrocarbon	• Nature of flammable substance (soot, toxic products) / thermal release • Flashpoint, flammability concentrations in air, or other ignition criteria • Max. credible substance/thermal release, or fire frequency versus severity relationship • Meteorological and topographical characteristics of the region

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
			• Existing protective measures at the source location, e.g. fire breaks
	d) Aircraft crash	• See (3)	
	e) Transport events excluding aircraft crash	• See (4)	• See (4) (e) • Frequency, type and route of movements to/from the source
	f) Other HIEEs	• Projectiles & missiles • Subsidence • Electromagnetic interference • Eddy currents into the ground	• Nature of projectile/missile (Mass, initial velocity, trajectory) • Max. credible projectile/missile, or frequency of release • Location and nature of adjacent ground works • Location and nature of underground works • Meteorological and topographical characteristics of the region • Relevant geological/geotechnical ground conditions

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
			• Frequency band and energy of Electromagnetic emissions • Existing protective measures at the source location • Details of mining and fracking
(2) Military facilities (permanent and temporary)	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• See (1) (a)
	b) Explosion	• Deflagration • Detonation • Dust explosion	• See (1) (b)
	c) External fire	• Hydrocarbon fire • Chemical fire	• See (1) (c)
	d) Aircraft crash	• See (3)	• See (3) (d) • Frequency, type and route of movements to/from the source
	e) Transport events excluding aircraft crash	• See (4)	• See (4) (e) • Frequency, type and route of

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
			movements to/from the source
	f) Other HIEEs	• Projectiles & missiles • Electromagnetic interference • Eddy currents into the ground	• See (1) (f)
MOBILE SOURCES			
(3) Airport, air traffic,	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• See (1) (a)
	b) Explosion	• Deflagration • Detonation	• See (1) (b)
	c) External fire	• Hydrocarbon fire	• See (1) (c)
	d) Aircraft crash	• IEs not covered in (3) (a, b, c, f) • Crash related to take-off and landing • Other sources of aircraft	• Information not covered in (3) (a, b, c, f) • Types and characteristics of aircraft • Aircraft movements and flight frequencies from airfields

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
		crash: background, airways etc.	• Runway orientation, length & location • Airfield plates for take-off, landing and manoeuvring • Traffic type and frequencies in airways etc. • Location, elevations and cross-section characteristics of airways • Location and characteristics of restricted, controlled and other forms of airspace • Types and characteristics of aircraft, e.g. mass, fuel load, speeds for various stages of flight
	e) Transport events excluding aircraft crash	• See (4)	
	f) Other HIEEs	• Projectiles & missiles	• See (1) (f)
(4) Railway trains and wagons, road	a) Release of hazardous	• Release of flammable,	• See (1) (a)

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
vehicles, ships, barges, pipelines	substances	explosive, asphyxiant, corrosive, toxic or radioactive substances • Blockage, contamination (such as from an oil spill) or damage to cooling water intake structures	• Location of transport route around the closest approach to the nuclear site • Relevant topographic features in the region around this route that might influence the dispersion and hazardous characteristics of a release • Relevant bathymetric, tidal and river current conditions around this route that might influence the dispersion and hazardous characteristics of a release
	b) Explosion	• Deflagration • Detonation	• See (1) (b) • Tidal and bathymetric characteristics of the region
	c) External fire	• Hydrocarbon fire • Chemical fire	• See (1) (c) • Tidal and bathymetric characteristics of offshore & nearshore region
	d) Aircraft crash	• See (3)	
	e) Transport events	• IEs not covered in (4) (a, b,	• Information not covered in (3) (a, b,

Source Type	Event Category	HIEEs	Relevant source-related information to be collected[a]
	excluding aircraft crash	c, f) • Vehicle impact • Vehicle derailment, or misdirection	c, f) • Passage routes and frequency of passage, e.g. road & rail routes, seaways • Location and routing of pipelines and associated pumping stations etc. • Frequency, type and route of movements to/from the source • Existing protective measures on vehicles or routes
	f) Other HIEEs	• Projectiles & missiles • Electromagnetic interference	• See (1) (f)

[a] Examples of source-specific information listed here is assumed to be available to the nuclear site operator, but this may not be so in many cases, such as when national security or commercial confidentiality places restrictions on the type of information made available to operators. This is covered in more detail in Section 4 para. 4.9

TABLE IV. EVOLUTION OF SOURCE HIEEs AND POSSIBLE EFFECTS ON THE NUCLEAR INSTALLATION

Event Category	**HIEEs**	**Possible hazard at the NI site**[e]	**Possible hazard effects on the installation**[d, e]
a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Explosion o Hydrocarbon fire o Other types of chemical fire o Projectiles & missiles • Release of large volumes of water or change of watercourse	• Clouds or liquids can drift towards the installation and burn or explode before or after reaching it, outside or inside the installation • Clouds or liquids can also migrate into areas where operators or safety related equipment can be prevented from functioning • Flooding on to the nuclear site, or change of water table	(5) (6) (8)
b) Explosion	• Deflagration • Detonation • Dust explosion o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• Explosion pressure wave • Projectiles • Smoke, gas and dust produced in explosion can drift towards the installation	(1) (2) (3) (4) (7)

	o Hydrocarbon fire o Chemical fires other than hydrocarbon o Projectiles & missiles		
c) External fire	• Hydrocarbon fire • Chemical fires other than hydrocarbon o Explosion o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Projectiles & missiles	• Associated flames and fires Sparks can ignite other fires • Smoke and combustion gas of fire can drift towards the installation • Heat (thermal flux)	(1) (2) (3) (4) (5)
d) Aircraft crash	• Crash related to take-off and landing • Other sources of aircraft crash: background, airways etc. o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Explosion o Hydrocarbon fire o Projectiles & missiles	• Direct effects o Impact damage to structures including perforation, penetration, etc. o Vibration effects o Global stability • Secondary effects o Secondary missiles ejected from the impact site and scattering widely o Rapid spread of flammable liquid from	(1) (2) (3) (4) (6)

		the point of impact, including impulsive damage to structures from the released momentum of the liquid when ejected from the aircraft o Fire and explosion generating heat and blast effects and generating tertiary missiles o Release of hazardous substance carried as cargo` • Ground shaking	
e) Transport events excluding aircraft crash	• Vehicle impact • Vehicle derailment, or misdirection o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Blockage, contamination (such as from an oil spill) or damage to cooling water intake structures o Explosion o Hydrocarbon fire o Chemical fires other than	• Direct impact damage • Secondary projectiles • Fire • Explosion of fuel tanks/cargo	(2) (4) (7) (8)

	hydrocarbon o Projectiles & missiles		
f) Other HIEEs	• Projectiles & missiles • Subsidence of ground • Electromagnetic interference • Eddy currents into the ground	• Missile impact with Structure • Ground failure under structures • Direct damage to structures & equipment • Fire • Electromagnetic fields around electrical equipment leading to failure, malfunction, or spurious electrical signals • Electric potential into ground leading to failure, malfunction of equipment, or spurious electrical signals	(2) (9) (10) (11)

b IE bulleted with • are considered the primary fault IE for this category of HIEE. IEs bulleted with o are likely consequential events to the primary event, that can be classed as hazards in themselves.

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c E_N is the first event on the event sequence that is felt by and represents the hazard to the nuclear site.

d See Table VI for an explanation of the numerals.

e The possible effects on the installation are confined to direct effects of the primary IE only; consequential IE are not covered. But note that all consequential IE are covered as primary IE elsewhere in this table. For example, the direct effects of aircraft crash (d) are impact damage to structures and equipment, but the consequential events, including fire, are covered at (c) and apply where this is relevant.

Symbols used:

Primary HIEE •

Secondary HIEE ◦

Possible impact/hazard at the nuclear installation () - Table V

TABLE V. IMPACT ON THE NUCLEAR INSTALLATION AND CONSEQUENCES

Possible hazard effects on the installation	Load Characterisation parameters	Consequences of hazard effects
1) Pressure wave	Local overpressure at the installation as a function of time	Collapse of parts of structure or disruption of systems and components
2) Projectile	~~Terminal~~ Impact energy at nuclear installation location – mass, velocity Compass direction and angle of approach from horizontal Missile hardness/penetrative capability in safety related structures – shape, size, type of material Existing protective measures at the source location	Damage to structures – penetration, perforation, spalling, scabbing, collapse of structures Disruption/failure of structures, systems and components including buried systems and services Induced vibration Loss of access/egress for emergency and/or safety related operator actions Secondary hazards – fire, explosion, release of hazardous substances
3) Heat	Maximum temperature flux and duration	Impaired habitability of control room Disruption of systems or components Damage to structures Ignition of combustibles

Possible hazard effects on the installation	Load Characterisation parameters	Consequences of hazard effects
4) Smoke and dust	Composition Concentration and quantity as a function of time	Blockage of intake filters Impaired habitability of control room and other important installation rooms and affected areas
5) Asphyxiant and toxic substance	Concentration and quantity as a function of time Volatility in ambient conditions Toxicity and asphyxiant limits	Threat to human life and health and impaired habitability of safety related areas including MCR Incapacitation of operators or reduced ability to discharge safety related tasks
6) Corrosive and radioactive liquids, gases and aerosols	Concentration and quantity as a function of time Corrosive, radioactive limits Provenance (sea, land)	Threat to human life and health and impaired habitability of safety related areas Corrosion and disruption of systems or components, loss of strength Electrical short circuits Blockage of water intakes, site drains etc. Prevention of fulfilment of safety functions
7) Ground shaking	Frequency response spectrum for vibrational motion	Mechanical damage

Possible hazard effects on the installation		Load Characterisation parameters	Consequences of hazard effects
8)	Flooding (or drought)	Elevation of site above main water course/mean sea level Level of water with time Velocity of impacting water	Damage to structures, systems and components due to inundation Damage to structures, systems and components directly or functional failure due to water impact Damage to structures, systems and components or functional failure due to secondary effects such electrical short circuit
9)	Subsidence of the ground	Settlement, differential displacement, settlement rate Existing engineered mitigation measures (existing sites), or anticipated (new sites)	Collapse of structures, disruption/failure of structures, systems and components including buried systems and services Secondary hazards: Fire, explosion release of hazardous substances
10)	Electromagnetic interference	Frequency band and energy rating of EMI emissions protection Existing engineered mitigation measures (existing sites), or anticipated (new sites)	Incorrect/spurious electrical signals in safety related equipment leading to spurious operation or action
11)	~~Eddy currents into~~	~~Intensity and duration~~	~~Corrosion of underground metal components~~

Possible hazard effects on the installation		Load Characterisation parameters	Consequences of hazard effects
	~~ground~~	~~Existing engineered mitigation measures (existing sites), or anticipated (new sites)~~	~~Grounding problems~~ ~~Incorrect/spurious electrical signals in safety related equipment leading to spurious operation or action~~
12)	Damage to water intake	Mass of the ship, lost cargo, impact velocity and area, degree of blockage	Unavailability of cooling water

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