IAEA
SAFETY
STANDARDS
SERIES

Fire Safety in the Operation of Nuclear Power Plants

SAFETY GUIDE

No. NS-G-2.1

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

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Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

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FIRE SAFETY IN THE OPERATION OF NUCLEAR POWER PLANTS

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

Printed by the IAEA in Austria
July 2000
STI/PUB/1091

SAFETY STANDARDS SERIES No. NS-G-2.1

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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2000

VIC Library Cataloguing in Publication Data

Fire safety in the operation of nuclear power plants : safety guide. — Vienna : International Atomic Energy Agency, 2000.
p. ; 24 cm. — (Safety standards series, ISSN 1020–525X ; no. NS-G-2.1)
STI/PUB/1091
ISBN 92–0–100900–3
Includes bibliographical references.

1. Nuclear power plants—Fires and fire prevention. I. International Atomic Energy Agency. II. Series.

VICL 00–00243

FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of nuclear energy.

The following advisory bodies oversee the development of safety standards: the Advisory Commission for Safety Standards (ACSS); the Nuclear Safety Standards Advisory Committee (NUSSAC); the Radiation Safety Standards Advisory Committee (RASSAC); the Transport Safety Standards Advisory Committee (TRANSSAC); and the Waste Safety Standards Advisory Committee (WASSAC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed by experts on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA.

Non-radiological aspects of industrial safety and environmental protection are also not explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Operational experience gained from incidents in nuclear power plants around the world has continued to demonstrate the vulnerability of safety systems to fire and its effects. Considerable developments have taken place in recent years in the design of and regulatory requirements for fire safety in operating nuclear power plants, resulting in substantial improvements at many plants. If these improvements are to be maintained, a systematic approach to fire safety is necessary for both plants built to modern standards and those built to earlier standards.

1.2. Some IAEA safety standards have addressed fire safety as a design issue. Paragraphs 5.10–5.13 of the relevant Safety Requirements publication [1] give requirements for fire safety in the design of nuclear power plants and a related Safety Guide [2] provides guidance on meeting those requirements.

1.3. Fire safety is important throughout the lifetime of a plant, from design to construction and commissioning, throughout plant operation and in decommissioning. Requirements for fire safety in the operation of nuclear power plants are established in an IAEA Safety Requirements publication [3] (para. 2.30). The present Safety Guide provides guidance on how to meet these requirements by making recommendations on the elements of plant management and operation that are necessary to achieve and maintain satisfactory fire safety.

OBJECTIVE

1.4. This Safety Guide provides guidance for plant managers, operators, safety assessors and regulators on suitable measures for ensuring that an adequate level of fire safety is maintained throughout the lifetime of a nuclear power plant.

SCOPE

1.5. This Safety Guide applies to new and existing nuclear power plants with thermal neutron reactors of types in general use, such as light water reactors, heavy water reactors and gas cooled reactors. The general guidance may also be applicable to a broad range of other types of nuclear installation, but its detailed application will depend on the particular technology and the related fire risks.

1.6. For the purposes of this publication, it is assumed that the design of the nuclear power plant incorporates fire protection measures that conform to the recommendations given in Ref. [2]. If this is not the case, a comprehensive assessment should be made on the basis of those recommendations, and the implications of any deviations should be fully considered (see para. 2.7.).

1.7. This Safety Guide covers a number of distinct elements which should be considered in the fire safety arrangements for the plant. These are: an application of the principle of defence in depth; a fire protection organization with clearly defined individual responsibilities; a fire prevention and protection programme including administrative procedures for the control of combustible materials and ignition sources; updating of the fire hazard analysis; control of plant modifications; periodic inspection, maintenance and testing (where applicable) of all installed fire protection measures (both passive and active); a quality assurance programme; training of plant personnel; and manual fire fighting capability.

1.8. Throughout this publication, the term 'safety' without qualification is used in relation to the nuclear safety of a plant (see also the Glossary) as distinct from 'fire safety'.

STRUCTURE

1.9. Section 2 discusses the general concept of defence in depth as it applies to fire prevention, detection and extinction. Section 3 makes recommendations on the organization and responsibilities of personnel involved in plant fire safety activities. Sections 4–7 provide guidance on: how the fire hazard analysis should be kept up to date; the need to control plant modifications which could affect fire safety; procedures for the control of combustible materials and ignition sources; and meeting inspection, maintenance and testing requirements for fire protection. Sections 8 and 9 cover manual fire fighting capability and training of plant personnel. Within the context of this Safety Guide, manual fire fighting capability includes consideration of both on-site and off-site resources and covers organization, staffing, equipment, training and planning of fire fighting strategies. Training of plant personnel includes the permanent plant staff as well as contractor personnel who may be temporarily assigned to the plant. Finally, Section 10 addresses the quality assurance programme as it relates to specific fire safety issues, and the need to maintain adequate records and documentation. The Annex provides additional information on inspection, maintenance and testing in the form of a sample list of features, systems, equipment and components to be considered in relation to fire safety.

2. APPLICATION OF DEFENCE IN DEPTH

DEFENCE IN DEPTH

2.1. Principle 11 of the IAEA Safety Fundamentals publication on The Safety of Nuclear Installations [4] is that the design of nuclear installations includes the appropriate application of the defence in depth principle. The concept of defence in depth incorporates multiple levels of protection which are subject to layers of overlapping provisions and should be extended to all safety activities, whether organizational, behavioural or equipment related. These levels of protection are intended to compensate for human errors or plant failures, and should encompass radiation protection and the prevention and mitigation of accidents. Fire is a hazard which has the potential to create a common cause failure mode for which prevention and mitigation measures should be provided.

2.2. To ensure adequate fire safety in a nuclear power plant in operation, an appropriate level of defence in depth should be maintained throughout the lifetime of the plant, through the fulfilment of the three principal objectives identified in Ref. [2]:

(1) Preventing fires from starting;
(2) Detecting and extinguishing quickly those fires which do start, thus limiting the damage; and
(3) Preventing the spread of those fires which have not been extinguished, thus minimizing their effects on essential plant functions.

2.3. It should be ensured by means of the above approach that:

— the probability of a fire occurring is reduced to as low as reasonably practicable;
— safety systems are adequately protected to ensure that the consequences of a single fire will not prevent those systems from performing their required function, account being taken of the effects of a single failure as required by Ref. [1].

2.4. The three objectives of defence in depth listed in para. 2.2. should be achieved through a combination of: design, installation and operation of fire prevention and protection systems; management of fire safety; fire prevention and fire protection measures; quality assurance; and emergency arrangements. These aspects are addressed in the following paragraphs and are considered in more detail in Sections 3–10.

2.5. Finally, an important aspect of defence in depth is the capability to extinguish fires manually. Fires should be fought manually, for example:

— if one or more of the existing active and passive systems fails either to extinguish the fire or to contain it; or
— if a fire occurs in an accessible area not containing fixed fire fighting systems.

In addition, manual fire fighting should be considered a complementary means of fire fighting in support of the main lines of defence against fire provided by the automatic extinguishing systems. The use of or reliance on manual fire fighting should be identified and justified in the fire hazard analysis.

DESIGN

2.6. In any nuclear power plant, every effort should be made to minimize fire risk by design. In general, the fire containment approach is preferred, since it emphasizes passive protection and thus the protection of safety systems does not depend on the operation of a fixed fire extinguishing system.

2.7. For new plants and wherever possible for existing plants, the design for fire protection should satisfy the recommendations specified in Ref. [2]. For existing plants that were not designed in accordance with these recommendations, a comprehensive assessment should be made of the existing fire safety measures on the basis of the recommendations and the implications of any deviations should be fully considered. Where deviations from the recommendations are identified, fire safety should be enhanced or technical justifications should be prepared for not modifying the existing conditions[1]. Where design improvements to the fire protection features are identified as necessary, the improvements should, to the extent practicable, follow the recommendations in Ref. [2].

FIRE SAFETY MANAGEMENT

2.8. The operating organization should clearly define in writing the responsibilities of all staff involved in the fire prevention and protection programme and in the fire fighting activities and mitigatory measures (see Section 3).

[1] In some Member States it may be necessary for such technical justifications to be approved by the regulatory body.

2.9. Plant personnel engaging in activities relating to fire safety should be appropriately qualified and trained so as to have a clear understanding of their specific areas of responsibility and how these may interface with the responsibilities of other individuals, and an appreciation of the potential consequences of errors.

2.10. Staff should be encouraged to adopt a rigorous approach to their fire fighting activities and responsibilities and a questioning attitude in the performance of their tasks, to foster continual improvement.

2.11. The cause(s) of any fire or of the failure or spurious operation of fire protection equipment that has the potential to affect safety should be established and corrective actions should be taken to prevent a recurrence. The potential implications for fire prevention and protection of operational experience from fires at other plants should be considered. Communication should be maintained and information exchanged between plants (and with the regulatory body) on safety related aspects of fire safety.

FIRE PREVENTION AND FIRE PROTECTION

2.12. Procedures should be established for the purpose of ensuring that amounts of combustible materials (the fire load) and the numbers of ignition sources be minimized in areas containing items important to safety and in adjacent areas that may present a risk of exposure to fire for items important to safety.

2.13. Effective procedures for inspection, maintenance and testing should be prepared and implemented throughout the lifetime of the plant with the objective of ensuring the continued minimization of fire load, and the reliability of the installed features for detecting, extinguishing and mitigating the effects of fires, including established fire barriers (see Ref. [5], para. 403).

2.14. A comprehensive fire hazard analysis should be performed for the plant in order to do the following:

- demonstrate the adequacy of existing fire protection measures (both passive and active) to protect areas identified as important to safety for all operational states and design basis accidents;
- identify any specific areas where levels of fire protection are inadequate and where corrective measures are necessary;
- provide a technical justification for any deviations from the recommended practices (see Ref.[2]) for which no corrective measures are taken.

The fire hazard analysis should be updated regularly over the lifetime of the plant (see Section 4).

2.15. Any modification that may affect, directly or indirectly, the installed fire safety measures, including the manual fire fighting capability, should be subject to a procedure for controlling modifications. Such a procedure for modifications should provide assurance that there will be no detrimental effects on the installed fire safety measures or on the ability to provide an effective manual fire fighting capability in those areas for which fire safety measures are identified as necessary to maintain safety.

QUALITY ASSURANCE

2.16. A quality assurance programme specifically addressing fire protection measures should be in place for the lifetime of the plant (see Section 10). Requirements and recommendations for quality assurance provisions are established in Ref. [6].

EMERGENCY ARRANGEMENTS

2.17. Written emergency procedures that clearly define the responsibility and actions of staff in responding to any fire in the plant should be established and kept up to date.

2.18. The emergency procedures should give clear instructions for operating personnel on immediate actions in the event of a fire alarm. These actions should be primarily directed to ensuring the safety of the power plant, including shutdown of the plant if necessary. The procedures should set out the role of operating personnel in relation to the role of the fire fighting team taking immediate action, the plant fire brigade and outside emergency services such as local authority fire brigades.

2.19. Special attention should be paid to cases for which there is a risk of release of radioactive material in a fire. It should be ensured that such cases are covered in the emergency arrangements for the plant. Appropriate measures should be taken for radiation protection for fire fighting personnel.

2.20. Regular fire exercises should be held to ensure that staff have a proper understanding of their responsibilities in the event of a fire. Records should be maintained of all exercises and of the lessons to be learned from them. Full consultation and liaison should be maintained with any off-site organizations that have responsibilities in relation to fire fighting.

3. ORGANIZATION AND RESPONSIBILITIES

3.1. The operating organization should establish a comprehensive programme for fire prevention and protection to ensure that measures for all aspects of fire safety are identified, implemented, surveyed and documented throughout the entire lifetime of the plant.

3.2. Responsibilities of site staff involved in the establishment, implementation and management of the programme for fire prevention and protection, including arrangements for any delegation of responsibilities, should be identified and documented. The documentation should identify the posts, specific responsibilities, authorities and chain of command for personnel involved in fire safety activities, including their relation with the plant organization. The areas of responsibility identified should include:

— control procedures for combustible materials and ignition sources;
— inspection, maintenance and testing of fire protection measures;
— manual fire fighting capability;
— emergency plans, including liaison with any off-site organizations that have responsibilities in relation to fire fighting;
— integration of plant fire safety arrangements and liaison between parties involved;
— review of plant modifications to evaluate effects on fire safety;
— training in fire safety and emergency drills;
— quality assurance in relation to fire safety issues;
— a records management system, including means for documentation and analysis of records of fire incidents;
— review and updating of the fire hazard analysis;
— follow-up of recommendations resulting from investigations of fire incidents.

3.3. The plant management should establish an on-site group with the specific responsibility for ensuring the continued effectiveness of the fire safety arrangements. Responsibility for co-ordinating fire safety activities should be assigned to an individual staff position, referred to in this Safety Guide as the fire safety co-ordinator.

3.4. The organizational structure for fire safety depends on the extent to which fire safety activities are implemented by dedicated fire safety staff, are delegated to other groups in the plant (such as engineering, maintenance, quality assurance, training and records management), or are contracted to outside agencies or contractors. These various fire safety resources can be successfully used in combination. However, the fire safety co-ordinator should retain the responsibility for ensuring that all fire safety

activities and functions necessary for safety are effectively co-ordinated to achieve the objectives of the fire prevention and protection programme.

3.5. Individuals who are assigned specific responsibility for fire safety activities should have sufficient authority and resources to allow them to take prompt and effective actions to ensure safety. This should include the authority to issue 'stop work' orders when safety may be affected.

3.6. Possible scenarios for fires that could affect safety should be considered in the emergency plan for the plant, which should include a description of the organization, responsibilities, authorities, chains of command, communications and means of co-ordination between the different groups concerned with fire. This should include consideration of both on-site and off-site resources, as appropriate.

4. PERIODIC UPDATING OF THE FIRE HAZARD ANALYSIS

4.1. Changes to the nuclear power plant over its lifetime should be reflected in the fire hazard analysis. The fire hazard analysis should be reviewed and updated following any plant modification that could affect fire safety, periodically[2] and at times as may be specified by the regulatory body. The review should cover any changes to the plant that may affect fire safety. These include changes to the fire protection systems, modifications to any other items of the plant or its buildings or structures that are important to safety, and changes to procedures or processes that could affect fire safety, whether the changes and/or modifications are temporary or permanent. The fire hazard analysis should also be reviewed as part of the periodic safety review process and updated as necessary.

4.2. The technical justification for any deviation from recommended practice (see Ref. [2]) that is identified when the fire hazard analysis is updated should include a discussion of the plant modifications that would be necessary to follow accepted practice and the reasons why it is not reasonably practicable to implement such modifications. The technical justification should also describe compensatory features provided to maintain an acceptable level of safety, where applicable.

[2] Some Member States consider it appropriate for this review and update to be performed every five to ten years and following major plant modifications.

4.3. If specific recommendations for modifications to the plant or operational improvements have been identified on the basis of the initial fire hazard analysis, the analysis for fire hazards should be repeated for the areas of the plant concerned to confirm the adequacy of the modifications or improvements recommended.

5. IMPACTS OF PLANT MODIFICATIONS ON FIRE SAFETY

5.1. Operating licences issued to nuclear power plants usually include a requirement for approved, written procedures for controlling modifications to structures, systems and components important to safety. All proposed plant modifications should be scrutinized for their potential effect on area fire loading and fire protection features, since a modification involving non-safety-related components could conceivably change an area fire loading or could degrade a fire protection feature whose primary purpose is to protect a safety system[3].

5.2. A review of implications for fire safety should be carried out for the following modifications to the plant, including design changes:

— modifications to the fire protection features;
— modifications to the protected safety systems or items important to safety or systems that could adversely affect the performance of the fire protection features;
— any other modification that could adversely affect the performance of the fire protection features, including modifications affecting area fire loading.

5.3. A formal review system to evaluate the impacts of modifications on fire safety should be incorporated into the overall modification procedure. Alternatively, a separate procedure should be established and implemented specifically for reviews for fire protection. Modifications should not be commenced until the review has been completed.

5.4. The staff assigned the responsibility for carrying out such reviews for issues of fire safety should be suitably qualified to evaluate the potential effect of any modification on fire safety and should have sufficient authority to prevent or suspend modification work, if necessary, until any issues identified have been satisfactorily resolved.

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[3] For example, if a cable tray carrying non-safety-related cables were to be installed directly below sprinkler heads protecting safety related cabling, the effectiveness of the sprinkler system could be reduced.

5.5. Modifications should only be carried out on the authority of a work permit issued by a person who is competent in and knowledgeable of the implications for fire safety.

5.6. If a modification necessitates the removal from service of any of the fire protection features, careful consideration should be given to the consequent reduced level of protection of the safety system(s), and appropriate temporary arrangements should be made to maintain adequate protection against fires. On completion of the modification, the plant as modified should be inspected to confirm its compliance with the modified design. In the case of an active system, the plant as modified should be commissioned and placed into or returned to normal service, as applicable.

5.7. The fire hazard analysis should be reviewed and updated to reflect the modification, as appropriate (see also Section 4).

6. CONTROL OF COMBUSTIBLE MATERIALS AND IGNITION SOURCES

CONTROL OF COMBUSTIBLE MATERIALS

6.1. Administrative procedures should be established and implemented for effective control of combustible materials throughout the plant. The written procedures should establish controls for delivery, storage, handling, transport and use of combustible solids, liquids and gases. Consideration should be given to the prevention of fire related explosions within or adjacent to areas identified as important to safety. For areas identified as important to safety, the procedures should establish controls for combustible materials associated with normal plant operations and those which may be introduced in activities related to maintenance or modifications.

6.2. Written procedures should be established and enforced to minimize the amount of transient (i.e. non-permanent) combustible materials, particularly packaging materials, in areas identified as important to safety. Such materials should be removed as soon as the activity is completed (or at regular intervals) or should be temporarily stored in approved containers or storage areas.

6.3. The total fire load due to combustible materials in each area identified as important to safety should be maintained as low as reasonably practicable, with account

taken of the fire resistance rating of the compartment boundaries. Records should be maintained that document the estimated or calculated existing fire load as well as the maximum permissible fire load in each area.

6.4. The use of combustible materials in the furnishings of the power plant should be minimized. Combustible materials should not be used for decorative or other non-essential effect in areas identified as important to safety.

6.5. Administrative controls should be established and implemented to ensure that areas important to safety are inspected periodically in order to evaluate the general fire loading and plant housekeeping conditions, and to ensure that means of exit and access routes for manual fire fighting are not blocked. Administrative controls should also be effected to ensure that the actual fire load is kept within permissible limits.

6.6. Administrative procedures should be established and implemented to provide effective control of temporary fire loads in areas identified as important to safety during maintenance and modification activities. These procedures should cover combustible solids, liquids and gases, their containment and their storage locations in relation to other hazardous material such as oxidizing agents. They should include a procedure for issuing work permits that requires in-plant review and approval of proposed work activities prior to the start of work to determine the potential effect on fire safety. The on-site staff member responsible for reviewing work activities for potential temporary fire loads should determine whether the proposed work activity is permissible and should specify any additional fire protection measures that are needed (such as the provision of portable fire extinguishers or the use of a fire watch officer, as appropriate).

6.7. Administrative procedures should be established and implemented to control the storage, handling, transport and use of flammable and combustible solids and liquids in areas identified as important to safety. The procedures should be established in accordance with national practice and should provide controls for solids and liquids. For solids:

(a) The use of combustible materials (such as wooden scaffolding) should be restricted. Where wooden materials are permitted, they should be chemically treated or coated so as to be fire retardant.
(b) The storage of combustible materials such as charcoal filters and dry unused ion exchange resins should be restricted; large stocks of such materials should be placed in a designated storage area with appropriate fire rated compartmentation and fire measures provided.

(c) The storage of combustible materials such as papers and protective clothing should be restricted; large stocks of such materials should be placed in designated storage areas with appropriate fire rated compartmentation and fire protection measures provided.
(d) The storage of all other combustible materials should be prohibited.

For liquids:

(i) The amounts of flammable or combustible liquids introduced into fire areas during maintenance or modification activities should be limited to the amount needed for daily use. Suitable fire protection measures such as the provision of hand held fire extinguishers should be taken, as appropriate.
(ii) Approved containers or dispensers should be used whenever possible for the transport and use of flammable or combustible liquids. Openings in containers should be fitted with spring loaded closures. Transport of flammable or combustible liquids in open containers should be avoided.
(iii) If it is necessary to store small amounts of flammable or combustible liquids within a working area, cabinets of an approved design for flammable liquids should be used.
(iv) All containers of flammable or combustible liquids should be clearly and prominently labelled to indicate their contents.
(v) Stores of large quantities of flammable or combustible liquids should be located and protected such that they will not compromise safety. Such bulk storage areas should be separated from other plant areas by fire rated compartmentation or by spatial separation with suitable fire protection measures taken as appropriate.
(vi) Warning signs should be placed at storage areas for flammable or combustible liquids.

6.8. Administrative procedures should be established and implemented to control the delivery, storage, handling, transport and use of flammable gases throughout the plant. The procedures should be established in accordance with national practice and should be implemented to ensure that:

(a) Cylinders of compressed gases that sustain fires, such as oxygen, are properly secured and are stored separately from flammable gases and away from combustible materials and ignition sources;
(b) Where a supply of flammable gas is needed inside a building for permanent use, it is supplied from cylinders or a bulk storage area safely located outside the building in a dedicated storage area such that a fire affecting the storage area would not compromise safety.

CONTROL OF IGNITION SOURCES

6.9. Administrative procedures should be established and implemented to control potential ignition sources throughout the plant. The procedures should include controls to:

- restrict personnel smoking to designated safe areas and to prohibit personnel from smoking in all other areas;
- prohibit the use of open flames for testing heat or smoke sensing devices (such as fire detectors) or for leak testing purposes;
- prohibit the use of portable heaters, cooking appliances and other such devices in areas identified as important to safety;
- limit the use of temporary wiring.

6.10. Administrative procedures should be established and implemented to control maintenance and modification activities that necessitate the use of a potential ignition source or that may themselves create an ignition source. The performance of such work should be controlled by means of formal written procedures, i.e. by means of either the work permit system discussed earlier or a special system for hot work permits. In the permit system adopted, procedures should be established to cover management, supervision, authorization and performance of the work, inspection of the work area, assignment of fire watch (if stipulated) and access for fire fighting. All personnel concerned with the preparation, issuing and use of permits for hot work should be instructed in the proper use of the system and should have a clear understanding of its purpose and application. Whether or not a fire watch is provided, at least one person engaged in the work should be trained in the use of any fire safety features provided.

6.11. In areas containing items important to safety, work which involves the use of a potential ignition source or which may create ignition sources should be permitted only after consideration of the possible consequences for safety. For example, such work may be prohibited from occurring simultaneously on functionally redundant components important to safety or in the areas containing such components.

6.12. Procedures should be established to ensure that, before any hot work is attempted, the immediate work area and adjacent areas are inspected for the presence of combustible materials and that the operability of necessary fire protection measures is confirmed. If the configuration and design of the work area may permit the spread of sparks or slag beyond the initial work area, spaces both above and below the work area should be checked, and any combustible materials should be either removed to a safe area or suitably protected.

6.13. During hot work, regular inspections should be made to ensure that the conditions of the permit are observed, that there are no exposed combustible materials present, and that the fire watch is on duty (if a fire watch has been stipulated in the permit).

6.14. In cases where the hot work permit identifies the need for a fire watch, the following procedures should be followed:

(a) The fire watch should be on duty in the immediate vicinity before any hot work is attempted, the work should be stopped if the fire watch leaves the work area, and the fire watch should remain in the work area for an appropriate period after open flame work is completed.
(b) While the work is in progress the fire watch should perform no other duties.
(c) Suitable dedicated fire fighting equipment should be readily available and means should be provided by which additional assistance can be readily obtained, if necessary. Adequate access routes for fire fighters should be maintained.

6.15. Any equipment or vehicle in use in areas in which a flammable gas could be released should be appropriately qualified for use in explosive atmospheres.

6.16. The use of compressed gas cylinders for cutting or welding operations or other hot work should be controlled by a system of work permits as described in paras 6.6, 6.10 and 6.14.

6.17. Warning signs should be erected at the entrances to areas containing combustible materials to warn personnel of restrictions or access requirements and of the necessity to permanently control ignition sources.

7. INSPECTION, MAINTENANCE AND TESTING OF FIRE PROTECTION MEASURES

7.1. A comprehensive programme should be established and implemented to perform appropriate inspection, maintenance and testing of all fire protection measures (passive and active, including manual fire fighting equipment) specified as important to safety. The specific fire protection systems, equipment, components and emergency procedures included in the programme should be identified and documented. Where such documentation is not available (for example, if the fire hazard analysis has not yet

been performed and other documentation is incomplete), all fire protection measures should be assumed to be important to safety unless the contrary assumption can be justified.

7.2. The inspection, maintenance and testing programme should cover the following fire protection measures:

— passive fire rated compartment barriers and structural components of buildings, including the seals of barrier penetrations;
— fire barrier closures such as fire doors and fire dampers;
— locally applied separating elements such as fire retardant coatings and cable wraps;
— fire detection and alarm systems, including flammable gas detectors;
— emergency lighting systems;
— water based fire extinguishing systems;
— a water supply system including a water source, a supply and distribution pipe, sectional and isolation valves, and fire pump assemblies;
— gaseous and dry powder fire extinguishing systems;
— portable fire extinguishers;
— smoke and heat removal systems and air pressurization systems;
— communication systems for use in fire incidents;
— manual fire fighting equipment including emergency vehicles;
— respirators and protective clothing for radiological applications;
— access and escape routes for fire fighting personnel;
— emergency procedures.

Additional information on the fire protection measures which should be inspected, maintained and tested is provided in the Annex.

7.3. Minimum acceptable levels of availability should be established and documented for all fire protection features identified as important to safety. Interim compensatory measures should be defined for each fire protection feature identified in this way. These compensatory measures should be implemented on a temporary basis in the event that the minimum level of availability for a given fire protection feature is not maintained or the fire protection feature is determined to be inoperable. Both the compensatory measure to be implemented and the allowable time schedule for its implementation should be determined, documented and reviewed. If the minimum acceptable level of availability of a fire protection measure has not been specified, it should be assumed to be 100%.

8. MANUAL FIRE FIGHTING CAPABILITY

8.1. A fire fighting strategy should be developed for each area of the plant identified as important to safety (including those areas which present a fire exposure risk to areas important to safety). These strategies should provide information to supplement the information provided in the general plant emergency plan. The strategies should provide all appropriate information needed by fire fighters to use safe and effective fire fighting techniques in each fire area. The strategies should be kept up to date and should be used in routine classroom training and in actual fire drills at the plant. The fire fighting strategy developed for each fire area of the plant should cover the following:

— access and exit routes for fire fighters;
— locations of structures, systems or components identified as important to safety;
— fire loadings;
— particular fire hazards, including the possible reduced capability for fire fighting due to external events;
— special radiological, toxic, high voltage and high pressure hazards, including the potential for explosions;
— the fire protection features provided (both passive and active);
— restrictions on the use of specific fire extinguishing agents because of concerns about nuclear criticality or other particular concerns, and the alternative extinguishing media to be used;
— locations of heat and/or smoke sensitive components or equipment important to safety;
— location of fixed and portable extinguishing equipment;
— water supplies for manual fire fighting;
— communication systems (not affecting safety systems) for use by fire fighting personnel.

8.2. Plant documentation should provide a clear description of the manual fire fighting capability provided for those areas of the plant identified as important to safety. The manual fire fighting capability may be provided by a suitably trained and equipped on-site fire brigade, by a qualified off-site service or by a co-ordinated combination of the two, as appropriate for the plant and in accordance with national practice.

8.3. If reliance is placed on off-site response, designated plant staff in each shift should be assigned the responsibility to co-ordinate and liaise with the off-site fire fighting service and to establish a clear line of authority at the fire scene. Appropriate plant staff should be designated even in situations in which the off-site response is supplementary to a primary response by a qualified on-site fire brigade.

8.4. Where full or partial reliance for manual fire fighting capability is placed on off-site resources, there should be proper co-ordination between the plant personnel and the off-site response group in order to ensure that the latter is familiar with the hazards of the plant. The responsibilities and lines of authority for manual fire fighting personnel should be documented in a fire fighting plan.

8.5. If an on-site fire brigade is established to provide a manual fire fighting capability, the fire brigade's organization, minimum staffing level, equipment (including self-contained breathing apparatus) and training should all be documented and their adequacy should be confirmed by a competent person.

8.6. Members of the on-site fire brigade should be physically capable of performing fire fighting duties and should attend a formal programme of fire fighting training prior to assignment to the plant fire brigade. Regular training (routine classroom training, fire fighting practice and fire drills) should be provided for all on-site fire brigade members. Special training should be provided for fire brigade leaders to ensure that they are competent to assess the potential safety consequences of a fire and advise control room personnel.

8.7. If manual fire fighting represents the primary means of fire protection, it should be ensured, as far as possible, that the necessary actions in the event of fire can be carried out safely in terms of radiological protection.

9. TRAINING OF PLANT PERSONNEL

9.1. All plant staff and contractors' personnel temporarily assigned to the plant should receive training in plant fire safety, including their responsibilities in fire incidents, before starting work at the plant. This training should include the following topics:

— fire safety policy at the plant;
— awareness of specific fire hazards, including limitations on area fire loading and, where necessary, associated radiological concerns;
— the significance of the control of combustible materials and ignition sources and its potential impact on the permissible fire loading in an area;
— means of reporting fires and actions to be taken;
— recognition of audible and visual fire alarm signals;
— means of exit and emergency evacuation routes in the event of fire;
— the different types of fire extinguishing equipment provided and their use in extinguishing fires in the initial stage.

9.2. Specialized fire safety training should be established for designated plant staff involved in operations, maintenance and fire fighting at the plant, including contractors' personnel temporarily assigned to the plant, where applicable. The training programme should provide training to ensure that the staff have adequate technical skills and familiarity with the detailed procedures to be followed. Training should be sufficient to ensure that individuals understand the significance of their duties and the consequences of errors arising from misconceptions or lack of diligence. The specialized training programme should cover the following:

(a) The importance of maintaining the integrity and operability of plant fire protection features (both passive and active) by performing regularly scheduled inspections, routine and unplanned maintenance of equipment, and periodic functional tests of equipment and systems;
(b) The design and operating details of the specific fire protection features installed in the plant to permit effective maintenance of equipment for operability;
(c) The significance of planned design changes and plant modifications with respect to fire safety, including both direct and indirect impacts on fire safety and any effects on the integrity or operability of the fire protection features (both passive and active) as a result of the planned modifications;
(d) The need to ensure that the individual who is responsible for the review of planned design changes and plant modifications is sufficiently knowledgeable to recognize issues that may have implications for fire protection features; this necessitates detailed knowledge of the design and testing requirements of hardware for fire protection and knowledge of specific design objectives for fire protection features in each fire area of the plant, as specified in the fire hazard analysis or similar documentation;
(e) Training for personnel who may initiate or authorize work activities involving hot work and staff who may be assigned the duties of a fire watch, to ensure that they are made aware of the hazards associated with activities such as cutting and welding which could produce a potential ignition source;
(f) The stipulations of the work permit system, specific situations in which a fire watch is necessary, and the significance of introducing potential ignition sources into fire areas containing components identified as important to safety;
(g) Training for personnel who may be involved in the work permit system or the system for hot work permits, who should receive instructions on work implementation and on general fire safety training so that they can readily recognize various fire hazards in the plant and can understand the implications of introducing combustible materials or ignition sources into safety related areas;
(h) Familiarization with the physical location of safety systems, preferably through a plant walkdown;
(i) Familiarization with the physical location of plant fire protection features.

9.3. Selection and appointment procedures for plant staff should establish minimum initial qualifications for all personnel involved in fire safety functions and activities which may affect safety. These minimum qualifications should be based on an evaluation of the necessary education, technical competence and practical experience for the job concerned.

9.4. The plant fire safety training programme should be documented and should include:

— identification of specific training needs for particular staff;
— development of training materials and instructors' notes;
— periodic evaluation.

9.5. Assessment of the technical competence of trainees should be considered an essential element of the training programme. The training programme should include both initial training and periodic retraining, as appropriate. Training programme activities should be conducted under the quality assurance programme and should be documented in the records management system.

9.6. The content, completeness, effectiveness and overall adequacy of the fire safety training programme should be periodically reviewed. Review should include consideration of whether to modify the training programme to take into account relevant operating experience and modifications.

10. QUALITY ASSURANCE FOR MATTERS RELATING TO FIRE SAFETY

10.1. Fire protection features are not generally classified as safety systems and thus they may not be subject to the rigorous qualification requirements and the associated quality assurance programme applied to safety systems. However, fire has the potential to give rise to common cause failure and thus to pose a threat to safety, and therefore the installed active and passive fire protection measures should be considered safety related. An appropriate level of quality assurance should therefore be applied to fire protection features.

10.2. A formal, documented quality assurance system should be established and implemented for activities affecting, and information relating to, fire safety in areas identified as important to safety.

10.3. The quality assurance provisions should be applied to the following aspects of fire safety[4]:

— the fire hazard analysis;
— the engineering design basis, the design calculations, and the validation of computer software, instructions and drawings for any design changes and modifications;
— documentation relating to procurement, including certificates of compliance for new or modified installations, supplies and equipment;
— commissioning and installation records for new and modified work;
— engineering review of design changes and plant modifications;
— fire safety procedures and the emergency plan and procedures;
— the storage and use of replacement fire protection materials, systems and equipment;
— records of the combustible fire load in each fire area;
— control of combustible materials and ignition sources;
— documentation of completed inspection, maintenance and testing procedures and validation of emergency arrangements;
— audit, inspection and survey reports, including identified deficiencies and corrective actions;
— technical justifications for non-compliance with specified requirements for fire safety and temporary actions implemented to compensate for deficiencies, pending completion of final corrective actions;
— technical qualifications and training records of personnel;
— records of all fire events, large and small, including reports of investigations;
— actuation of fire detectors and/or extinguishing systems:
  • response to actual fire conditions;
  • false alarms and other non-fire responses;
— operational failures of fire safety measures, including failures of computer software;
— organization and responsibilities for fire safety.

10.4. Changes to any of these aspects of fire safety should be controlled to the same level of engineering review and approval as applied to the original documents in accordance with the applicable provisions of the quality assurance system.

[4] For some existing plants, the original documentation relating to the design, procurement and commissioning and other documentation might not be available. In such cases, the quality assurance programme should be applied to as many of the aspects listed as possible, and special importance should be placed on the periodic review of plant fire safety.

Annex

FIRE PROTECTION MEASURES FOR INCLUSION IN THE INSPECTION, MAINTENANCE AND TESTING PROGRAMME

This Annex provides a sample list of features, systems, equipment and components for inclusion in an inspection, maintenance and testing programme for fire safety. It gives information on the practical application of the recommendations made in this Safety Guide. The frequency of performance of recommended activities will be based on manufacturers' recommendations, national practice and specific operational experience.

TABLE A–1. INSPECTION, MAINTENANCE AND TESTING OF FIRE PROTECTION MEASURES

Fire protection measures	Inspection	Maintenance	Functional test
1. Passive fire protection features			
1.1. Fire rated compartment barriers and structural elements of buildings, including fire rated walls, floors and ceilings and fire rated barrier penetration seals, both mechanical and electrical:			
(a) general condition and indications of damage or deterioration, absence of unsealed openings	×		
1.2. Fire barrier closures such as fire doors and fire dampers:			
(a) general condition and indications of damage or deterioration, including obstructions which may prevent closure	×		
(b) component operability			×
(c) automatic closure and latching mechanisms		×	×
1.3. Locally applied separating elements, including fire retardant coatings, cable wraps and sleeves:			
(a) general condition and indications of damage or deterioration	×		
1.4. Combustible transient or stored material that could have an impact on the fire loading in an area:			
(a) general storage conditions, observance of the permissible fire load in the area	×		
2. Fire detection and alarm systems			
2.1. Fire detectors (including heat, smoke, flame, gas sampling and flammable gas detectors):			

Fire protection measures	Inspection	Maintenance	Functional test
(a) general condition and indications of damage or deterioration	×		
(b) sensitivity adjustments and periodic cleaning		×	
(c) equipment operability and automatic functioning			×
2.2. Manual fire alarm call points:			
(a) general condition, including accessibility, and indications of damage or deterioration	×		
(b) equipment operability and alarm function			×
2.3. Fire alarm and control panels:			
(a) general condition, including accessibility, and indications of damage or deterioration	×		
(b) equipment operability and audible and visual alarm functions, including automatic functioning			×
2.4. Electrical circuits:			
(a) general condition and indications of damage to or deterioration of cable insulation and junction boxes	×		
(b) circuit integrity			×
(c) normal and backup of power supplies	×	×	
3. Emergency lighting			
(a) general condition and indications of damage or deterioration	×		
(b) illumination level and distribution of light			×
(c) equipment operability			×
(d) batteries, as applicable	×	×	
4. Water based fire extinguishing systems			
4.1. Sprinkler systems, including wet pipe, dry pipe, deluge water spray and pre-action systems:			

Fire protection measures	Inspection	Maintenance	Functional test
(a) general condition and indications of damage or deterioration	×		
(b) integrity of piping and supports	×		
(c) valve position and accessibility	×		
(d) valve and system operability and alarm function		×	×
(e) obstruction of discharge flow	×		
(f) blockage of piping or nozzles (e.g. by air pressurization where possible)		×	×
4.2. Foam–water fire extinguishing systems			
(a) for mechanical components, refer to features in item 4.1, as applicable	×		
(b) quantity of foam concentrate	×		
(c) quality of foam concentrate			×
(d) for electrical components, refer to features in items 2.1–2.4, as applicable	×	×	×
(e) accessibility of manual actuation means	×		
(f) pattern of discharge flow	×		
(g) blockage of piping or nozzles (e.g. by air pressurization, where possible)			×
5. Gaseous fire extinguishing systems			
(a) general condition and indications of damage or deterioration	×		
(b) integrity of piping and supports	×		
(c) system operability and alarm functions			×
(d) operability of associated components (in particular discharge time delays), ventilation interlocks and passive barrier closures (doors and dampers)			×
(e) accessibility of manual actuation means	×		
(f) containment of gas within protected compartments (room pressurization test)	×		×

Fire protection measures	Inspection	Maintenance	Functional test
(g) gas quantity and pressure	×		
(h) for electrical components, refer to features in items 2.1–2.4, as applicable	×	×	×
(i) blockage of piping or nozzles (by air or gas pressurization)		×	×
(j) obstruction of discharge flow and nozzle blockage	×		
6. Dry powder fire extinguishing systems			
(a) general condition and indications of damage or deterioration	×		
(b) quantity, quality, condition and pressure of dry powder	×	×	
(c) system operability and alarm function			×
(d) for mechanical components, refer to features in item 4.1, as applicable	×	×	×
(e) for electrical components, refer to features in items 2.1–2.4, as applicable	×	×	×
(f) accessibility of manual actuation means	×		
(g) piping or nozzle blockage (e.g. by air pressurization)			×
7. Wa ter supply			
7.1. Water sources			
(a) general condition and indications of damage or deterioration, as applicable	×	×	
(b) water volume and quality; valves	×		
(c) alarm function for low water level, as applicable			×
(d) measures to prevent freezing, as applicable	×		
7.2. Supply and distribution pipes and hydrants			
(a) general condition and indications of damage or deterioration, as applicable	×		

Fire protection measures	Inspection	Maintenance	Functional test
(b) available water pressure and flow rate			×
(c) accessibility and operability of hydrants and valves	×	×	
(d) valve position and alarm functioning, as applicable	×		×
(e) measures to prevent internal blockages of pipes	×		×
(f) elimination of marine or biological growth	×	×	
(g) measures to prevent freezing, as applicable	×		
7.3. Fire pump assemblies			
(a) general condition and indications of damage or deterioration	×		
(b) fire pump assemblies, including power supplies		×	
(c) operability of the fire pump assembly (manual and automatic), including power supplies and alarm functions		×	×
(d) performance characteristics of fire pumps, including flow and pressure			×
(e) fire pump batteries, as applicable	×	×	×
(f) fuel quantity and quality for non-electrically driven power supplies	×		×
(f) fuel quantity and quality for non-electrically driven power supplies	×		×
(g) alarm functions			×
(h) for electrical components, refer to features in items 2.2–2.4, as applicable	×	×	×
7.4. Rising main and hose reels/stations			
(a) general condition and indications of damage or deterioration	×		
(b) accessibility of equipment	×		
(c) integrity of pipes and supports	×		
(d) system pressure and flow rate			×
(e) operability and alarm function of valves and systems		×	×

Fire protection measures	Inspection	Maintenance	Functional test
(f) fire hose pressure testing			×
(g) gaskets and hose re-racking, as applicable	×	×	
(h) accessibility of hoses and nozzles	×		
(i) measures to prevent internal blockages	×		
(j) hose diameter and length	×		
8. Portable fire extinguishers			
(a) general condition and accessibility and indications of damage or deterioration	×		
(b) amounts and pressure of extinguishing media	×	×	
(c) suitability of extinguisher type for location	×		
(d) pressure integrity of extinguisher container			×
9. Smoke and heat removal systems and pressurization systems			
(a) general condition and indications of damage or deterioration, including ductwork	×		
(b) operability of fans and dampers and alarm functions		×	×
(c) power supplies, as applicable			×
(d) pressure and flow rate			×
(e) accessibility of manual means of actuation	×		
(f) for electrical components, refer to features in items 2.1–2.4	×	×	×
10. Communication system(s) used in fire incidents			
(a) general condition and indications of damage or deterioration	×		
(b) system operability			×
(c) for electrical components, refer to features in item 2.4, as applicable	×	×	×

Fire protection measures	Inspection	Maintenance	Functional test
(d) power supplies, as applicable			×
11. Emergency vehicles and equipment			
(a) general condition and indications of damage or deterioration	×		
(b) operability		×	×
(c) inventory of equipment	×		
12. Access and escape routes for fire fighting personnel			
(a) general condition and indications of damage or obstruction	×		
(b) operability of access doors		×	×
(c) marking of access and escape routes	×		
13. Validation of fire emergency procedures			
(a) documentation of current procedures	×	×	
(b) test of emergency procedures, by simulation			×

GLOSSARY

The following definitions apply for the purposes of the present publication.

combustible material. A material in solid, liquid or gaseous state capable of igniting, burning, supporting combustion or releasing flammable vapour when subject to specific conditions such as fire or heat.

fire barrier. Wall, floor, ceiling or device for closing a passage such as a door, a hatch, a penetration or a ventilation system to limit the consequences of a fire. A fire barrier is characterized by a fire resistance rating.

fire damper. A device designed to prevent by automatic operation the passage of fire through a duct under given conditions.

fire load. The sum of the calorific energies calculated to be released by the complete combustion of all the combustible materials in a space, including the facings of the walls, partitions, floors and ceiling.

fire resistance. The ability of an element of a building construction, component or structure to perform, for a stated period of time, the required load bearing function, integrity and/or thermal insulation, and/or other expected function specified in a standard fire resistance test.

fire retardant. The quality of a substance of suppressing, reducing or delaying markedly the combustion of certain materials.

fire watch. One or more persons responsible for providing additional (e.g. during hot work) or compensatory (e.g. for system impairments) coverage of plant activities or areas for the purpose of detecting fires or identifying activities and conditions that present a potential fire hazard. These people should be trained in identifying conditions or activities that present potential fire hazards, as well as in the use of fire fighting equipment and the proper fire notification procedures.

hot work. Work having the potential for causing fire, particularly work involving the use of open flames, soldering, welding, flame cutting, grinding or disk cutting.

ignition source. An applied (external) source of heat which is used to ignite combustible materials.

safety. The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the public and the environment from undue radiation hazards.

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