

# ON THE CLASSIFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS OF NUCLEAR RESEARCH AND TEST REACTORS

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## ABSTRACT

The classification of structures, systems and components of nuclear reactors is a relevant issue related to their design because it is directly associated with their safety functions. There is an important statement regarding quality standards and records that says "Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed". The definition of the codes, standards and technical requirements applied to the nuclear reactor design, fabrication, inspection and tests may be seen as the main result from this statement. There are well established guides to classify structures, systems and components for nuclear power reactors such as the Pressurized Water Reactors but one can not say the same for nuclear research and test reactors. The nuclear reactors safety functions are those required to the safe reactor operation, the safe reactor shutdown and continued safe conditions, the response to anticipated transients, the response to potential accidents and the control of radioactive material. So, it is proposed in this paper an approach to develop the classification of structures, systems and components of these reactors based on their intended safety functions in order to define the applicable set of codes, standards and technical requirements.

## 1. INTRODUCTION

The design of structures, systems and components (SSCs) of nuclear research and test reactors as well other nuclear facilities must necessarily be based on codes and standards where the applicable acceptance criteria are well established for the applicable scope definitions, for the materials selection and certification, for the design itself, for the fabrication and erection, and for the inspections and tests.

In nuclear industry there is an important statement regarding quality standards and records which issues that "SSCs important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed". From this statement it clearly appears the concept of safety classes.

The main aspect considered in this classification according to the importance to the nuclear safety is to protect people, environment and workers from the effects of ionizing radiation because more stringent requirements on quality standards are applied to SSCs commensurate with their importance to safety. There is also an economical impact from the extratification of the SSCs in different safety classes and associated applicable commensurate quality standards.

Also, there is another statement regarding the design bases for protection against natural phenomena that issues that "SSCs important to safety shall be designed to withstand the

effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions”. Again, a classification indication appears to be assessed for the SSCs.

The safety classification reflects the significance for nuclear safety of the SSCs. Its purpose is to establish a gradation in the application of the requirements for design and the requirements for quality assurance. There are other possible classifications or categorizations of SSCs according to other aspects (e.g. the seismic categorization of SSCs).

In general, for a research and test reactor the following classifications should be defined:

- Classification based on the safety function.
- Classification for pressure components based on their safety functions, their mechanical complexities and their pressure levels.
- Classification for the resistance to earthquakes (or other natural phenomena) referenced to the need that the component continues to be undamaged or functional during and after an earthquake (or other natural phenomena) of a certain severity.
- Classification of the instrumentation and control systems based on their safety function, which may be different from that of other system types because of the existence of classification schemes specific to their field and commonly used.
- Classification related to Quality Assurance requirements.

It is important to notice that the first classification to be defined is that related the safety functions and classes.

Considering all aspects above indicated, this paper presents an approach to establish the safety classification for SSCs of research and test reactors. Furthermore, it is presented a guide to define the applicable codes and standards for SSCs regarding their design and construction, their material selection, their welding and fabrication and their inspections and testing.

## **2. SAFETY FUNCTIONS FOR RESEARCH AND TEST REACTORS**

To ensure attainment of the highest standards of safety that can reasonably be achieved, design measures have to be taken to:

- Control the radiation exposure of people and the release of radioactive material to the environment.
- Restrict the likelihood of events that might lead to loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.
- Mitigate the consequences of such events if they were to occur.

To ensure adequate safety, the following general safety requirements shall be met by the reactor design:

- Means shall be provided to control the reactivity of the reactor and, in particular, to safely shut down the reactor and maintain it in the safe shutdown condition during and after normal and abnormal operation and in accidents conditions.

- Means shall be provided to remove heat from the core and, in particular, to remove residual heat from the core after reactor shutdown following normal or abnormal operation and in accidents conditions.
- Means shall be provided to confine radioactive material and control operational discharges, and thereby reduce the potential for the uncontrolled release of radioactive materials and assure that any releases are within prescribed limits during and after operational states and within acceptable limits during and after accident conditions.

Safety functions are the essential characteristic functions associated with SSCs that ensure the safety of the reactor. Safety functions shall be appropriate for the particular reactor design. In normal operation, the equipment needed to perform safety functions will be the operating systems. In general, these systems will have to be supplemented by other engineered safety features to perform their functions for anticipated operational occurrences and in DBAs (Design Basis Accidents). In the design of the safety systems, including engineered safety features, that are used to achieve the three basic safety functions — shutting down the reactor, cooling, in particular the reactor core, and confining radioactive material — the single failure criterion shall be applied, high reliability shall be ensured and provisions shall be included to facilitate regular inspection, testing and maintenance.

According to [1] the main safety functions of a research and test reactor are:

- Safe reactor operation.
- Safe reactor shutdown and continued safe conditions.
- Response to anticipated transients.
- Response to potential accidents.
- Control of radioactive material.

All SSCs including software for instrumentation and control (I&C) that are items important to safety shall be first identified and then classified on the basis of their function and significance with regard to safety.

The method for classifying the safety significance of an SSC shall primarily be based on deterministic methods, complemented where appropriate by probabilistic methods and engineering judgment, with account taken of factors such as:

- The safety function to be performed by the SSC.
- The consequences of failure to perform its function.
- The probability that the SSC will be called upon to perform a safety function.
- The time following a postulated initiating event at which, or the period throughout which, it will be called upon to operate.

Appropriately designed interfaces shall be provided between SSCs of different classes to ensure that any failure in a system classified in a lower class will not propagate to a system classified in a higher class.

Based on the above considerations, the research and test reactors SSCs shall be classified, in general, in two classes:

- Important to safety (items that perform some safety function or have interfaces that require this classification).
- Non important to safety.

### **3. APPLICABLE CODES AND STANDARDS**

Codes and standards applicable to SSCs shall be identified and their use shall be in accordance with their classification. In particular, if different codes and standards are used for different types of items (e.g. for piping and for electrical systems).

In the case of SSCs for which there are no appropriate established codes or standards, an approach derived from existing codes or standards for similar equipment may be applied, or, in the absence of such codes and standards, the results of experience, tests, analysis or a combination of these may be applied, and this results based approach shall be justified.

Following the recommendations listed in [2], SSCs of research and test reactors should be designed and tested to requirements set forth in the codes and standards listed in Table 1.

Materials for pressure-retaining components, excluding HVAC (Heating, Ventilation and Air Conditioning) duct and fire protection piping, should conform to the requirements of the specifications for materials listed in Section II of the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code [3] except that malleable, wrought, or cast iron materials and plastic pipe should not be used. Materials should be compatible with the chemical, physical, and radioactive environment of specific applications during normal conditions and anticipated operational occurrences. Manufacturers' material certificates of compliance with material specifications such as those contained in the codes referenced in the materials column of Table 1 may be provided in lieu of certified material test reports.

Foundations and walls of structures that house the reactor systems should be designed to the natural phenomena and internal and external man-induced hazards criteria and have a height sufficient to contain the maximum liquid inventory expected to be in the building. The natural phenomena and internal and external man-induced hazards demand definitions are as given in Table 2.

The electric and electronic systems and components including software for instrumentation and control (I&C) important to safety shall satisfy the requirements of class 1E components according to IEEE (Institute of the Electric and Electronic Engineers) Standards.

### **4. CONCLUSIONS**

This paper addresses an approach to classify the SSCs of research and test reactor based on their safety functions, defined in [1], in two classes: important to safety and not important to safety.

Also, using an American codes and standards database some recommendations are issued related to the design, materials selection, construction, welding and fabrication, and inspection and testing of research and test reactors SSCs.

Closing the paper, the conditions related to natural phenomena and internal and external man-induced hazards to be considered in the structural design of the research and test reactors are indicated.

**Table 1. Codes and Standards Applicable to Research and Test Reactors**

Component	Design and Construction	Materials	Welding	Inspection and Testing
Structures - Concrete	ACI-318 or ACI 349	ACI-318 or ACI 349	ACI-318 or ACI 349	ACI-318 or ACI 349
Structures-Steel (Hot Rolled)	AISC-ASD or AISC LFRD or AISC N-690(S327)	ASTM-A36	AWS-D1.1	AISC Standards and AWS Standards
Structures-Steel (Cold Formed)	AISI SG-673	ASTM-A500	AWS-D1.3, D9.1	AISC Standards and AWS Standards
Piping and Valves	ANSI/ASME B31.3	ASME-Sec. II	ASME, Sec. IX	ANSI/ASME B31.3
Atmospheric Tanks	API-650	ASME Sec. II	ASME, Sec. IX	API-620
Tanks (0-15 psig)	API-620	ASME Sec. II	ASME, Sec. IX	API-650
Pressure Vessels and Tanks (>15 psig)	ASME BPVC Div. 1 or Div. 2	ASME Sec. II	ASME, Sec. IX	ASME Section VIII, Div. 1 or 2
Pumps	API-610; API-674; API-675; ASME BPVC Section VIII, Div. 1 or Div. 2	ASTM A571-84(1997) or ASME Sec. II	ASME, Sec. IX	ASME BPVC Code Section III, Class 3
Heat Exchangers	TEMA STD, 8th Edition; ASME BPVC Section VIII Div. 1 or Div. 2	ASTM B359-98 or ASME Sec. II	ASME, Sec. IX	ASME Section VIII, Div. 1 or 2
HVAC Systems	SMACNA Stds.	ASTM F856-97 ASTM C1290-00	AWS-D1.1, D1.3, D9.1	SMACNA Stds
Conduit and Cable Trays	NEMA TC2-1998 NEMA VE1-1998	ASTM B633-98, A123/A123M-01  NEMA TC2, VE1	AWS-D1.1, D1.3, D9.1	NEMA TC2-1998,  NEMA VE1-1998
Fire Protection Systems	NFPA-13; NFPA-14	ASTM-A795	AWS-D1.1, D1.3, D9.1, D10.9	NFPA-13
Flexible Hoses and Hose Connections	ANSI/ANS-40.37	ANSI/ANS-40.37	ANSI/ANS-40.37	ANSI/ANS-40.37

Codes and standards – References [3] to [45]

**Table 2. Natural Phenomena and Internal/External Man-Induced Hazard Design Criteria for Safety Classification**

Loading	Classification	
	Important to Safety	Not Important to Safety
Earthquake	OBE or 1/2 SSE	ASCE 7-95 [19] UBC-97 [39]
Wind	Reactor-specific definition	Reactor-specific definition
Tornado	Reactor-specific definition	Not Required
Tornado Missile	Reactor-specific definition	Not Required
Flood	Reactor-specific definition	Reactor-specific definition
Precipitation (Rain)	Reactor-specific definition	Reactor-specific definition
Accidental Explosion Fixed Facility	Reactor-specific definition	Not Required
Accidental Explosion Transportation Vehicle	Reactor-specific definition	Not Required
Malevolent Vehicle Assault	Reactor-specific definition	Not Required
Small Aircraft Crash	Reactor-specific definition	Not Required

OBE – Operational Basis Earthquake [2]

SSE – Safe Shutdown Earthquake [2]

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