SCSIN-REP-2.2.2-A-85 (Rev.1)
SIN-5037.85
FR 8800624

FRENCH REPUBLIC

MINISTRY OF INDUSTRY

GENERAL DIRECTORATE FOR INDUSTRY

Paris, December 31, 1985

CENTRAL DEPARTMENT FOR THE SAFETY
OF NUCLEAR INSTALLATIONS
(SCSIN)

SIN Paris n°5037/85

BASIC SAFETY RULES

RULE N° II.2.2.a

(Revision 1)

PART II : Basic Structures and Systems Design

CHAPTER 2 : Engineered Safety Features

RULE IDENTIFICATION WITHIN REFERENCED CHAPTER : 2.a (Rev.1)

SUBJECT : Design of the Containment Spray System

SCOPE : Nuclear power plant units equipped with a pressurized water reactor

0 - INTRODUCTION

RFS or "Règles Fondamentales de Sûreté" (Basic Safety Rules) applicable to certain types of nuclear facilities lay down requirements with which compliance, for the type of facilities and within the scope of application covered by the RFS, is considered to be equivalent to compliance with technical French regulatory practice. The object of the RFS is to take advantage of standardization in the field of safety, while allowing for technical progress in that field.

These rules should make safety analysis easier and lead to better understanding between experts and individuals concerned with the problems of nuclear safety.

They do not dilute the responsibility of the operating utility and do not constitute an obstacle to the regulatory measures in force.

In principle, an RFS applies to any nuclear installation granted a construction permit more than one year after publication of the rule. Unless explicitly excluded, this time period is extended by two years in the interests of standardization, in the case of a facility regarded as identical to a facility that has already been granted a construction permit.

For any installation to which an RFS applies, in accordance with the above, the operating utility that does not wish to apply this RFS must demonstrate that the safety objectives of the RFS are met by such alternative means as it shall propose, within the context of the regulatory procedures in force.

The Basic Safety Rules being established in a spirit of openness to technical progress RFS does not, by itself, entail a requirement to modify other nuclear facilities or provide additional justification unless explicitly required by a decision applied retroactively.

Moreover, the SCSIN reserves the right to modify, when considered necessary, any RFS and specify, if need be, the terms under which a modification is deemed retroactive ; for other cases, the above-mentioned rules relating to the dates of applicability are to be applied under the same conditions as an original RFS when an RFS is revised.

In practice, therefore, the structure of RFS, with respect to nuclear power plant units equipped with a pressurized water reactor, corresponds to the table of contents appended to this RFS in Appendix 1.

1 - SCOPE OF THE RULE

1.1. The Containment Spray System reduces containment pressure and temperature, removes heat from the containment after a pipe break accident, reduces the quantity of airborne radioactive iodine and controls the chemical composition of the recirculation water.
The present Basic Safety Rule defines the functional requirements of this system and proposes certain complementary criteria or methods to be used in its equipment design. Provisions relating to manufacturing, qualification, or inservice inspection of system components and general precautions against the risks of operator or maintenance error, common mode failures, interaction between systems or externally generated hazards are given, as necessary, by particular Basic Safety Rules and are not given in detail in the present rule.

1.2. The Permanent Working Group responsible for nuclear reactors was consulted in the writing of the present rule.

2 - TEXT OF THE RULE

The Containment Spray System of a unit may be designed on the basis of the following rules :

2.1. Functional Requirements

a) General rules

The system and its auxiliaries are designed as Engineered Safety Features and respect the requirements relating to the classification of the components as well as the single failure criterion as defined in Basic Safety Rule I.3.a.

The design will take into account the conditions associated with accidents during which or as a result of which the system may be required to operate (in particular, the radioactivity and nature of the carried fluid and the ambient conditions created by the accident). The system shall, in particular, remain operational after a Safe Shutdown Earthquake. In addition, the components of redundant trains must be separated to prevent from the risk of total loss of the function, due in particular do common mode hazards (fire, flooding, missiles), except as provided in 2.2.a.

The main system performances are determined on the basis of the following rules :

b) Heat removal and pressure reduction function :

- The Containment Spray System is designed to operate over an extended period of time, possibly lasting several months.

- The Containment Spray System is the only means for long-term cooling of the core and the containment. Its heat exchange capability is sufficient to remove residual heat and to prevent exceeding the containment design limits.

- The heat exchange capability of the system is calculated by evaluating the thermal balance of the heat exchangers under the most adverse conditions, notably :

  . heat sink temperature equal to the highest value ever known
  . only one train is in operation
  . sump filter half clogged
  . reduced exchange capability to take account of possible exchanger fouling.

The design must also put in evidence sufficient margin to compensate for the imprecision of the characteristic parameters and modelings adopted.

- The evaluation of system performances concerning the function of pressure reduction following a loss of coolant accident (LOCA) is made by considering the overall thermal balance, notably the heat exchanges via the spray droplets.

- Dispositions permitting direct recirculation from the containment sumps are included, for use when the operation of spray nozzles is no longer necessary.

c) Chemical function

The pH value of the spray solution is chosen to make negligible the effects of steel corrosion and to make acceptable the consequences -hydrogen release, degradations of safety-related equipment necessary to attain the safety goal- of chemical attack on other metals, in particular aluminum, whose use is limited to that strictly necessary. These requirements lead to the use of a basic spray solution which favors the retention of iodine.

Precautions are taken to prevent any phenomena of precipitation by chemical reactions in the chemical additive storage equipment.

d) Confinement function

The system is designed by taking into account both the fact that it may have to operate for a long period of time under post-accidental conditions and that in this case it will be carrying fluids that may be highly radioactive. In particular, the parts of the system external to the reactor containment provide a confinement or containment function, notably during the recirculation phase. Consequently, the layout, design, performances (including leaktightness), qualification, and testing of system components enable ensuring that this system will not be at the origin of unacceptable radioactive releases. In addition, the components must remain accessible for maintenance or repair following failures.

2.2. Design criteria

The various parts of the installation must respect the following design criteria :

a) System (including the storage tank)

The Containment Spray System is specific to each nuclear plant unit. There is no direct connection to any other systems within the plant, except for the refueling water storage tank, which can be common to other systems, provided that the minimum capacity remaining available when this water may when this water may be necessary be justified. The evaluation of this available minimum capacity is made by taking into account the conditions of use of this tank.

The water storage tank can, in particular, be common to the Containment Spray System and to the Safety Injection System, as well as, possibly, to other systems, not in use when the above two systems are sollicited in the direct injection phase.

In the latter case, the efficiency of the devices provided or used to ensure that no flow is diverted to these other systems must be demonstrated.

Arrangements that allow possible interconnection between systems, in particular the possible interconnection of the Containment Spray System and the Safety Injection System, and do not modify the autonomy of these systems can be envisaged.

b) Spray nozzles

- The spray nozzles are located as high as possible in the containment dome, to maximize the volume effectively sprayed.

- The spacing of the spray nozzles on the spray rings, their location, and their orientation are such that the distribution of water spray inside the containment is as homogenous as possible, with sufficient overlapping. The spray nozzle system is designed to cover the entire cross-sectional horizontal surface of the containment.

c) Pumps

To ensure that the Containment Spray System performs its safety functions and that its heat exchange capability is sufficient, the recirculation pumps are designed and qualified to operate correctly under all conditions considered plausible, taking into account notably the nature of the fluid carried and the radiation environment.

The suction lines are designed so that the net positive suction head necessary for the pumps is less than the net positive suction head effectively available under the most unfavorable conditions.

This net positive suction head is defined by assuming that after a LOCA the pressure in the containment is equal to the saturated vapor pressure corresponding to the pump fluid in the containment sump, taken to be at least equal to the atmospheric pressure.

Furthermore, the net positive suction head is calculated assuming a zero head above the bottom of the sump filtering grilles. Any water head above this level constitutes an additional margin. In addition, the sump filters are also assumed to be half-clogged.

d) Sumps

In the design of the Containment Spray System, arrangements are made to allow the drainage of cooling water, including the spray water, to suction points. These suction points are the containment sumps.

The spray system sumps, when considered as the source of water for the cooling systems, are designed in accordance with the following criteria :

- Two physically separated and redundant sumps are associated each to a single train and provided each with a capacity sufficient to supply the Containment Spray System with water. They are protected against internally-generated hazards, in particular by an antiprojectile barrier and are designed to withstand the loads imposed by a Safe Shutdown Earthquake (SSE), respecting the requirements of RFS I.2.c.

- The sump intakes are protected by a suitable filter device. The filter flow section is designed to stop any particles liable to cause partial clogging of the nozzles or other system components and to allow normal recirculation pump operation.

- The useful surface area considered in determining coolant velocity is taken equal to one-half of the free surface area of the fine inner screen. Only the vertical parts above ground level are considered as filtering surfaces.

- The coolant velocity through the filters is limited to prevent the carryover of suspended matter, which could clog the filters.

- The parts making up the filtering device satisfy the selection criteria for materials used to withstand the corrosion induced by the cooling fluids.

Pump suction locations in the sump are carefully considered, to prevent any dynamic phenomenon that could cause damage, such as vortexes in particular. The sump water levels taken into consideration shall be evaluated in taking account of the possibilities of retention and run off in the containment, as well as possible losses due to a passive failure outside the containment on the system or on another system.

e) Penetrations

- The containment penetrations necessary for Containment Spray System operation are doubly isolated, one device being located inside the containment, the other outside it. If necessary, one of the isolation valves can be eliminated, this being compensated for by using a double envelope for the sump suction lines.

f) Instrumentation and controls .

- The instrumentation and control system and its equipment are designed to ensure automatic initiation (on "high-high pressure" signal) of the Containment Spray System in time short enough to permit correct performance of the spray function.

- Switchover from the direct spray phase (suction from the water storage tank) to the recirculation spray phase (suction from the reactor building sumps) is automatically achieved when the storage tank water level drops to its lower limit.

- The control channels for Containment Spray System actuation and switchover to the recirculation phase are part of the Protection System.

- Specific instrumentation enables indicating the operating status of the system and its components, independently of the control signals or the operating power supplies. The indications provided by the instrumentation enable ensuring that the performances or objectives defined in the design are attained.

- Interlocks and operating procedures are defined so that the status of the components, valves, and manual check valves is guaranteed whenever the condition of the plant is such that Containment Spray System availability is required.

2.3. Scope

The present revision applies to the units concerned by the original rule.

Christian de Torquat

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