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Licensing Approach Applicable to Land Facilities Supporting Nuclear-Powered Submarines

Baroni[a] D. B., Borsoi[a] S. S., Mattar Neto[b] M., Oliveira[b] P. S. P., and Maturana[a] M. C.

[a] *Centro Tecnológico da Marinha em São Paulo - CTMSP, 05508-000, São Paulo, SP, Brazil*

[b] *Instituto de Pesquisas Energéticas e Nucleares - IPEN-CNEN, 05508-000, São Paulo, SP, Brazil*

e-mail address of the corresponding douglas.baroni@marinha.mil.br

ABSTRACT

The nuclear licensing process is a fundamental stage for the design and deployment of a nuclear facility. In Brazil, the licensing process of Central Nuclear Almirante Álvaro Alberto (CNAAA) nuclear power plants, in Angra dos Reis - RJ, was established mainly based on the U.S. Nuclear Regulatory Commission (U.S.NRC) guidelines. However, for each purpose specific requirements are established which promote a standardization appropriate to the type of installation in question. Thus, not every nuclear installation can be adequately framed in the standards and requirements established for the licensing of a nuclear power plant, especially when considering nuclear facilities for strategic and defense purposes. For instance, the Specialized Maintenance Complex (CME) project is being developed by the Brazilian Navy and aims to offer all the structures and systems for support on land to the first Brazilian nuclear-powered submarine. Therefore, when considering the interfaces between maritime/naval systems and operations, the purpose and specificity of installations such as CME extrapolate the commonly established nuclear normative framework. Due to the innovation of this type of installation in Brazil, there is no specific regulation for its licensing, constituting a unique situation for both the Brazilian Navy (applicant) and the National Nuclear Energy Commission - CNEN (Brazilian Nuclear Licensing Agency, which, soon, will have its function incorporated into the National Nuclear Safety Authority, ANSN). Even when researching standards and other guides in ostensible sources of nations that hold nuclear reactor technology for naval propulsion (and land support facilities), no normative guidance dealing specifically with the safety analysis and licensing of this type of installation has been identified. Thus, this paper proposes a first approach and analysis of the standards used by the U.S. Department of Defense (U.S.DOE) comparing them to the standards of the U.S. Nuclear Regulatory Commission (U.S.NRC) aiming to compose a specific normative proposition to carry out the safety analysis and licensing of a nuclear-powered submarines land support facility.

Keywords: **Nuclear-powered submarine, Nuclear propulsion, Land Support Facilities, Nuclear licensing.**

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1. INTRODUCTION

CNEN is the regulatory agency that, since its creation, has, among other attributions, the responsibility of licensing nuclear installations in Brazil. However, law nº 14.222 of October 15, 2021 [1], created the National Nuclear Safety Authority (ANSN) assuming licensing activities previously under CNEN responsibility (ANSN is not regulated and operational at the moment), and defines as private competence of the Brazilian Navy Command to regulate, license, inspect and control the nuclear-powered vessels. With such an assignment, the Brazilian Navy created the Naval Nuclear Safety and Quality Agency (AgNSNQ).

Nevertheless, it is not common sense that the interpretation of this Provisional Measure also assigns to the Brazilian Navy Command the competence to license the nuclear-powered submarine's land support facility. On the other hand, CNEN NE 1.04 [2] standard that regulates the process of licensing nuclear installations by CNEN, defines in its section 1.2.1.1 that:

> *"Activities related to nuclear reactors used a source of energy in means of transport, both for propulsion and for other purposes, are excluded".*

Summarizing, these initial circumstances are intended not only to illustrate the absence of specific framework regulation for the licensing of a nuclear-powered submarines land support facility, but also a possible uncertainty of the regulatory authority responsible for such licensing, when considering its assignments and competences. However, in terms of criteria and requirements to be met, the safety fundamentals and philosophy that guide the establishment of a normative basis should converge to a common understanding, independent of the regulatory authority, representing a commitment to protect public health and safety and the environment against the harmful effects of radiation.

Thus, even if CNEN NE 1.04 [2] is not used as a definitive reference, there are general concepts and propositions associated with the nuclear licensing process that can initially contribute to the establishment of a normative basis aiming at the licensing of a nuclear-powered submarines land support facility. For example, one can make use of the steps foreseen in the general process of licensing a nuclear installation according to its section 4.1.1: Site Approval, Construction Permit, Nuclear Material Use Authorization, Initial Operation Authorization and Permanent Operation

Authorization. The issuance of these permits and authorizations is subjected to the submission and review/approval of Safety Analysis Reports (PSAR or FSAR, depending on the step on question).

Thus, in its item 6.4, CNEN NE 1.04 standard [2] defines the minimum information that must be included in the PSAR, but still without establishing a standard format, acceptance criteria or other guidelines for its elaboration, leading to the application of the provisions in its item 6.5.2:

> "*In the absence of adequate Brazilian standardization, Codes, Guides and Recommendations of the International Atomic Energy Agency should preferably be used and, in their absence, international standards or standards from technically developed countries provided that these standards and regulations are accepted by CNEN*".

Thus, when assessing IAEA guides and recommendations, they present general and comprehensive fundamentals and concepts, possibly applicable to a wide variety of installations, in view of its most fundamental purpose regarding the protection of the public and the environment against the risks involving exposure to radiation.

Nonetheless, despite being useful and having significant importance in the establishment of nuclear normative bases, they do not have the applicability and the proposal of, for example, to define codes and standards that will establish criteria and normative requirements to be used in the design, licensing and construction of nuclear installations. Consequently, considering the history of nuclear licensing in Brazil, in which US standards and codes have been used, it is worth evaluating the relevance and adequacy of the U.S.NRC and U.S.DOE regulations to carry out the safety analysis and licensing of a nuclear-powered submarines land support facility.

2. MATERIALS AND METHODS

2.1. Main Features and Specificities of Nuclear-Powered Submarines Land Support Facilities

For the purposes of this work, the following definition of a land support facility for nuclear-powered submarines will be considered:

"*All infrastructure (structures, systems and components) located on land to provide support and necessary resources to nuclear-powered submarines during maintenance activities, repairs, nuclear refueling operations, storage for new and irradiated fuel elements and processing and storage of waste (solid, liquid and gaseous)*."

HMNB Devonport in Plymouth/England (Figure 1), and Specialized Maintenance Complex – CME (Figure 2) under construction by the Brazilian Navy in Itaguaí/RJ, are examples of land support facilities for nuclear-powered submarines

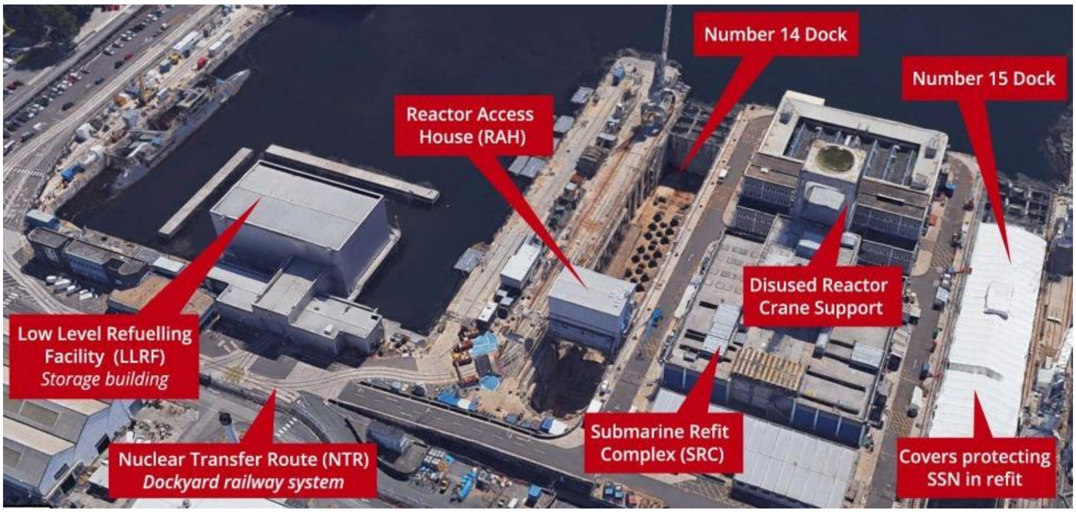

Figure 1: *HMNB Devonport (source: www.naval.com.br).*

Figure 2: *Artistic Conception of CME (source: www.naval.com.br).*

Initially, an analysis of the characteristics and specificities of the nuclear-powered submarines land support facility was performed, grouping their nuclear operations into conventional (commonly found in nuclear facilities) and non-conventional (specific to this type of installation and not commonly found in nuclear installations). Subsequently, the structures, systems, and components (SSC) necessary to perform these operations shall be analysed~~, also~~ as well. According to [3], [4] and [5], the conventional nuclear SSC and operations of these facilities are:

- Spent fuel pool;
- New fuel storage area;
- Nuclear waste processing system;
- Initial nuclear waste storage area; and
- Radiological protection monitoring systems.

The non-conventional nuclear aspects of these facilities and the submarines supported by them are [6], [7] and [8]:

- Reduced source term - of the submarine's reactor, if compared to a commercial nuclear power plant;
- Low permanence rate - the submarine (nuclear reactor) will be present only a fraction of the time at the installation, not permanently;
- Operation at low power - in general, the submarine reactor operates at 15% of total power;
- Reactor shutdown at quay;
- Intrinsic safety - after the reactor shutdown, the Thermal Rollover[1] is achieved in a few weeks;
- Reaction time - residual heat levels are low, allowing high reaction times;
- Additional systems - submarine systems and land support systems can operate in a coordinated mode;
- Interface naval structures - piers, pontoons and fenders, drydock, drydock gate, keel blocks, etc.

[1] *"The point at which the decay heat levels have fallen to a level where natural heat conduction through the submarine hull is sufficient to keep the fuel cool is called thermal rollover"* [9].

- Nuclear Refueling[2] - requires additional containment structures (as the Reactor Access House - RAH shown in Figure 3 and Figure 4, in HMNB Devonport);
- Mobility/buoyancy - additional margins against accidents, and for emergency actions and mitigation; and
- Extended levels of defense in depth – land support structures may serve as additional barriers against radiological releases.

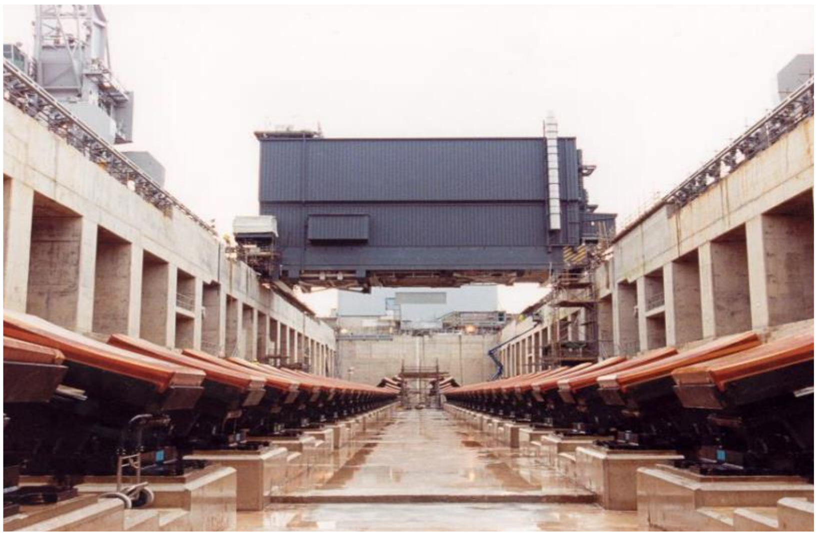

Figure 3: *Reactor Access House (RAH) - HMNB Devonport, Plymouth/England* [10].

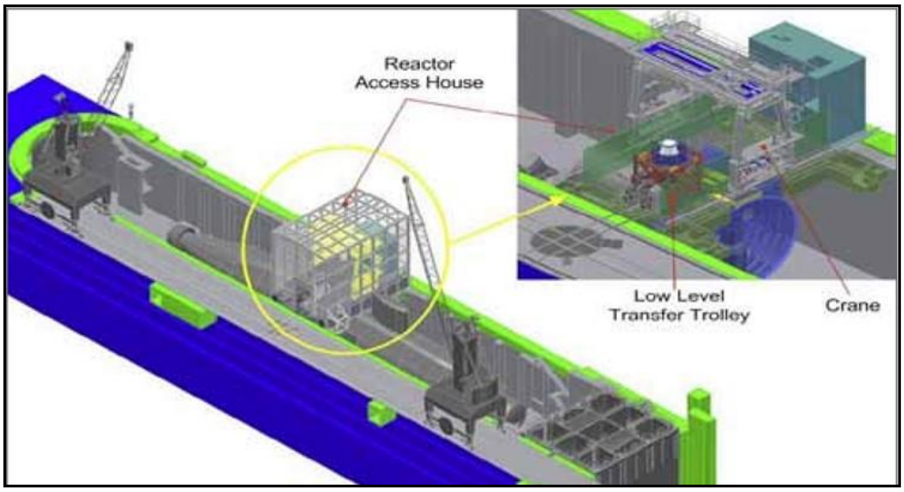

Figure 4: *"Reactor Access House"* [11]

[2] The nuclear refueling operation is the key point and the more complex activity (and SSC involved) realized.

2.2. Discussion on the Adequacy of U.S.DOE and U.S.NRC Regulatory Framework

Due to the nature of its application, the U.S.NRC normative basis (commercial nuclear power plants) does not allow an adequate and proportional consideration of the characteristics mentioned above. Hence, its exclusive use may not be sufficient and/or not take into account in a balanced way the intrinsic characteristics of a submarine land support facility, implying excessively conservative requirements in some cases, and may make its project/licensing inviable. In other cases, these standards may not be comprehensive enough to establish requirements for maritime installations, for example.

A non-prescriptive normative would be beneficial, as it would allow an adequate assessment and consideration of these characteristics and would allow the application of a "graded approach", by assigning criteria and dimensioning proportionate to the risks offered by these facilities. The safety analysis required for the licensing of these facilities should consider both conservative (deterministic) aspects, such as the concept of defense in depth and the single failure criterion, as well as concepts of "best estimate" in a more realistic (probabilistic) approach [8] and [12].

Thus, the use of the U.S.DOE normative set may be more appropriate, with a graded approach found in 10 CFR 830 [13], which should consider the following aspects:

- Relative importance to safety, safeguards, and security;
- Magnitude of any hazard involved;
- Life cycle stage of the facility;
- Programmatic mission of the facility;
- Particular characteristics of the facility;
- Relative importance of radiological and non-radiological hazards; and
- Any other relevant factor.

2.3. U.S.DOE Safety Requirements Adopted by the Naval Nuclear Propulsion Program

10 CFR 830 [13] regulates safety related activities of U.S.DOE nuclear facilities, except for facilities under the Director of Naval Nuclear Propulsion Program (NNPP), pursuant to Executive Order 12344 – Naval Nuclear Propulsion Program [14]. However, Executive Order 12344 [14] defines in Section 1:

"*Sec.1. The Naval Nuclear Propulsion Program is an integrated program carried out by two organizational units, one in the Department of Energy and the other in the Department of the Navy*."

Section 5 of this order defines U.S.DOE functions (related to NNPP):

"Sec. 5. Within the Department of Energy, the Secretary of Energy shall assign to the director the responsibility of performing the functions of the Division of Naval Reactors transferred to the Department of Energy by Section 309(a) of the Department of Energy Organization Act (42 U.S.C. 7158), including assigned civilian power reactor programs, and any naval nuclear propulsion functions of the Department of Energy, including:

- *(a) direct supervision over the Bettis and Knolls Atomic Power Laboratories, the Expended Core Facility and naval reactor prototype plants;*
- *(b) research, development, design, acquisition, specification, construction, inspection, installation, certification, testing, overhaul, refueling, operating practices and procedures, maintenance, supply support, and ultimate disposition, of naval nuclear propulsion plants, including components thereof, and any special maintenance and service facilities related thereto;*
- *(c) the safety of reactors and associated naval nuclear propulsion plants, and control of radiation and radioactivity associated with naval nuclear propulsion activities, including prescribing and enforcing standards and regulations for these areas as they affect the environment and the safety and health of workers, operators, and the general public;*
- *(d) training, including training conducted at the naval prototype reactors of the Department of Energy, and assistance and concurrence in the selection, training, qualification, and assignment of personnel reporting to the director and of personnel who supervise, operate, or maintain naval nuclear propulsion plants; and*
- *(e) administration of the Naval Nuclear Propulsion Program, including oversight of program support in areas such as security, nuclear safeguards and transportation, public information, procurement, logistics, and fiscal management."*

Sections 7 and 8 of this order define Department of the Navy (U.S.DON) functions (related to NNPP):

> *"Sec. 7. Within the Department of the Navy, the Secretary of the Navy shall assign to the director responsibility to supervise all technical aspects of the Navy's nuclear propulsion work, including:*
>
> *(a) research, development, design, procurement, specification, construction, inspection, installation, certification, testing, overhaul, refueling, operating practices and procedures, maintenance, supply support, and ultimate disposition, of naval nuclear propulsion plants, including components thereof, and any special maintenance and service facilities related thereto; and*
>
> *(b) training programs, including Nuclear Power Schools of the Navy, and assistance and concurrence in the selection, training, qualification, and assignment of personnel reporting to the director and of Government personnel who supervise, operate, or maintain naval nuclear propulsion plants.*
>
> *Sec. 8. Within the Department of the Navy, the Secretary of the Navy shall assign to the director responsibility within the Navy for:*
>
> *(a) the safety of reactors and associated naval nuclear propulsion plants, and control of radiation and radioactivity associated with naval nuclear propulsion activities, including prescribing and enforcing standards and regulations for these areas as they affect the environment and the safety and health of workers, operators, and the general public.*
>
> *(b) administration of the Naval Nuclear Propulsion Program, including oversight of program support in areas such as security, nuclear safeguards and transportation, public information, procurement, logistics, and fiscal management."*

Additionally, the objective of DOE O 420.1C – Facility Safety [15] is "*To establish facility and programmatic safety requirements for the Department of Energy (DOE), including the National Nuclear Security Administration (NNSA)*", and the equivalence to the U.S.DOE safety requirements in the NNPP is defined according to the "APPLICABILITY/Equivalencies and Exemptions" item:

"(3) Equivalency. In accordance with the responsibilities and authorities assigned by Executive Order (E.O.) 12344, Naval Nuclear Propulsion Program, codified in 50 United States Code (U.S.C.) sections 2406 and 2511, and to ensure consistency through the joint Navy/DOE Naval Nuclear Propulsion Program, the Deputy Administrator for Naval Reactors (Director) will implement and oversee requirements and DOE O 420.1C 3 12-4-2012 practices pertaining to this Directive for activities under the Director's cognizance, as deemed appropriate."

In fact, these agencies (NNSA and NNPP) have purposes that are more compatible with the design and licensing of a nuclear-powered submarines land support facility than the ones defined by the U.S.NRC. The U.S.DOE normative set is consistent and allows the association and the use of standards of the Department of Defense (U.S.DOD), subordinated to the Naval Facilities Engineering Systems Command – NAVFAC / Engineering Criteria and Programs Office – CIENG, with direct application to the type of installation under study.

3. RESULTS AND DISCUSSION

According to the characteristics and operations carried out in a nuclear-powered submarines land support facility, the use of the U.S.DOE regulations would make it possible to classify it as a non-reactor nuclear facility, as defined in 10 CFR 830 [13]:

"*Nonreactor nuclear facility means those facilities, activities or operations that involve, or will involve, radioactive and/or fissionable materials in such form and quantity that a nuclear or a nuclear explosive hazard potentially exists to workers, the public, or the environment, but does not include accelerators and their operations, and does not include activities involving only incidental use and generation of radioactive materials or radiation such as check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes and X-ray machines*."

This normative approach (Nonreactor nuclear facility) presupposes the use of Standard DOE-STD-3009-2014 – Preparation of Nonreactor Nuclear Facility Documented Safety Analysis [16] as a standard format for the preparation of its Safety Analysis Report - in this case entitled Documented Safety Analysis, and the DOE-STD-1104-2016 – Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents [17] as a reference for its review and approval by the nuclear regulatory authority.

4. CONCLUSION

This paper suggests the U.S.DOE normative set (and other related documents, including those of NNSA, NNPP and U.S.DOD) as the most appropriate to substantiate the licensing of a nuclear-powered submarines land support facility, equivalent to CME to be built by the Brazilian Navy. Consequently, the classification of the CME as a “Nonreactor nuclear facility” (as defined in 10 CFR 830) and the use DOE-STD-3009-2014 as a Standard Format and Content of Safety Analysis Reports for nuclear licensing is considered a reasonable proposal.

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