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(Section 3)

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3. SITE AND SITE CRITERIA

3.1 Site Description

The specific site for the reactor described in this report is the NS Savannah. Since the NS Savannah is mobile, the off-ship characteristics of the site vary with the location of the vessel. In general, the NS Savannah may visit any commercial port facility adequate to handle a ship of similar length and displacement. In ports where high population densities occur near the wharf, special power history controls are sometimes necessary.

The specific site characteristics of ports that the NS Savannah will enter are evaluated prior to the visit of the ship and must conform to requirements set forth in the Port Operating Criteria.[2]

3.2 Port Operating Plans

The port operating criteria for NS Savannah port entries are summarized below:

1. A detailed port operating plan of the port to be visited must be prepared and must be approved by regulatory authorities prior to the ship's visit. This port operating plan specifies controlled zones and maximum fission product inventory limitations (normally based on noble gas fission products) at the time of port entry. The ship may not be moored at any location unless calculations, using well defined and conservative assumptions, show that the available evacuation capabilities can assure that no person would receive a dose in excess of 25 rem to the whole body and 300 rem to the thyroid should the maximum credible accident occur while the ship is moored there.

2. A port emergency plan to be followed in the event of a nuclear accident must be prepared in advance and must specify a remote anchorage.

3. Within one week before port entry, tests of the reactor compartment ventilation system filter units must demonstrate a removal efficiency of 99.9% for dioctyl phthalate (DOP) aerosol.

4. Within 4 hours before port entry, the alternate steering gear must be tested satisfactorily, and at least one bow anchor must be ready for use.

5. Within 3 months prior to port entry, tests of the iodine removal efficiency of the reactor compartment ventilation system filters must have demonstrated a removal efficiency of at least 99.9%.

6. Weekly tests of nuclear instrumentation and the standby filters must be satisfactorily performed.

7. The auxiliary propulsion system must be tested in the ahead and astern directions within 24 hours before port entry.

8. The ship shall berth where control zones have been established which conform to a pre-established maximum permissible fission product inventory. These control zones are analogous to those established for stationary reactors by Reactor Site Criteria (10 CFR 100.)3

9. Mobility assurance shall be provided while the ship is at berth by maintaining adequate tugs in attendance at the ship until such time as there is a calculated interval of 1 hour between an accidental loss of coolant and the first fuel clad melting. After that time the tugs shall be on call so that, in the event of an accident, the tugs can arrive at the ship at least 1/2 hour before the calculated time when such melting is predicted to start. These tug arrangements shall not be required whenever the reactor is shut down and the primary system is cooled down and depressurized to less than 300 F and 200 psig. These arrangements shall also not be required whenever the site meets the guidelines of 10 CFR 100 as modified by permissible credit for the engineered safeguards and by the recent reactor operational history.

10. Containment integrity shall have been tested, within the preceding 12 months, and shown to have a leakage of less than 1.2% of the contained volume in 24 hours at a 60 psig pressure in the containment vessel.

11. The reactor shall be shut down in the event of pier blockage or other loss of mobility.

12. Adequate tugs shall accompany the ship on entering and leaving port.

13. Visitors to the ship shall be limited to a maximum of 150 at any time.

14. A ship evacuation drill shall be performed within 24 hours of berthing and once in each 7-day period thereafter and shall show that unessential personnel can be off the ship within 30 minutes.

3.3. Control Zones

Population control zones are established at each berth prior to port entry. These zones are (1) the controlled zone, a zone that can be evacuated within two hours; (2) the low-population zone, a zone that can be evacuated within 24 hours and may include some residences; and (3) the dense-population zone, a zone that cannot be evacuated. A remote anchorage is also selected.

The ship shall not be moved to any location unless calculations based upon the actual fission product inventory show that:

1. The 2-hour zone, described below, lies completely within the controlled zone.
2. The 24-hour zone, described below, lies completely within the low-population zone.
3. The total population exposure as a consequence of an MCA while the ship is at the location will not exceed 2,000,000 man-rem.

3.3.1. Controlled Zone

A controlled zone is that area defined by fences, ocean-front, bays, or other barriers either natural or manmade in which all persons are under the direct control of the ship's personnel and local authorities so that in the event of an occurrence of the MCA to the NS Savannah evacuation could be effected in a graded fashion within 2 hours so that no member of the public inside the zone would receive an exposure exceeding a 25-rem-whole-body dose or a 300-rem-thyroid dose.

3.3.2. Low-Population Zone

A low-population zone is defined as that area in which it is reasonable to expect that in the event of an occurrence of the MCA total evacuation or protective measures could be carried out in a graded fashion within 24 hours so that no person in the zone would receive more than a 25-rem-whole-body dose or a 300-rem-thyroid dose.

3.3.3. Dense-Population Zone

A dense-population zone is defined as that area which is immediately adjacent to the outer boundary of the low-population zone and cannot be evacuated, controlled, or protected. In the event of occurrence of the MCA, the total integrated population exposure to all persons in this zone plus the controlled zone and the low-population zone will not exceed 2,000,000 man-rem.

3.3.4. Remote Anchorage

A remote anchorage is that area to which the ship can be removed after occurrence of the MCA. A remote anchorage shall be deemed acceptable only if the stricken vessel can be anchored there for 30 days and if the following zones can be readily established around the vessel:

1. An uninhabited controllable exclusion zone through which no ship or member of the general public can pass except under the strict control and monitoring of the emergency team. The radius of this zone must equal or exceed that of the 24-hour zone.

2. A zone encompassing an area that can be evacuated within 24 hours and having a radius so that no person on the perimeter for 30 days would receive an exposure exceeding 25-rem-whole-body or 300-rem-thyroid dose.

3. To ensure appropriate limitations to long-term effects on the population as a whole, there is a limit of 2,000,000 man-rem-whole-body dose to the population assuming the duration of the radioactive release for 30 days.

3.3.5. Two-Hour Zone

That area, being circular in shape and concentric with the nuclear reactor, which has a radius such that calculations made in accordance with "The Port Operating Criteria" show that after the occurrence of the MCA no person at its outside boundary would receive more than a 25-rem-whole-body dose or a 300-rem-thyroid dose in a period of 2 hours after the occurrence of the MCA. The radius of this zone varies with actual fission product inventory in the reactor.

3.3.6. Twenty-Four-Hour Zone

That area, being circular in shape and concentric with the nuclear reactor, which has a radius such that calculations made in accordance with "The Port Operating Criteria" show that after the occurrence of the MCA no person at its outside boundary would receive more than a 25-rem-whole-body dose or a 300-rem-thyroid dose in a period of 24 hours after the occurrence of the MCA. The radius of this zone varies with actual fission product inventory in the reactor.

3.3.7. One-Hour Zone

A 1-hour zone may also be established while the ship is underway or at dockside with two or more tugs under power and in attendance at the ship if no external conditions prevent movement of the ship. This zone differs from any described in 10 CFR 100 in that it hypothesizes removal of the ship within the 1-hour time period under the conditions described. The same 25-rem-total-body dose and 300-rem-to-thyroid dose levels determine the zone boundary.

3.4. Comparison With Central Station Site Criteria in the USA

The site criteria outlined above differ from those used for central station nuclear power plants in the USA in the following basic considerations:

1. When credit is taken for ship mobility, it is assumed that the ship can be moved within 24 hours after the occurrence of the MCA. A single exception to this occurs when the ship has two or more tugs under power and in attendance at the ship. At such times, it is assumed the ship can be moved within 1 hour.

2. Engineered safeguards testing, especially containment vessel and reactor compartment ventilation system filter testing, is required on a much more frequent schedule for the ship than for stationary plants.

3. When it is possible for fuel element cladding to melt within 1 hour after a complete loss of all water over the reactor core, tugs are kept in attendance at the ship. With this expedient, it is expected that the MCA could occur and the ship would be removed so quickly that no exposure of the local population to resultant radiation hazards would occur.

Table 3-1 is an item-by-item comparison of the major considerations in the site evaluation of the NS Savannah compared with stationary plants. As may be noted in this table, the major difference between the Savannah port operating criteria and the site criteria for central station plants is in the considerably greater detail and testing required of the mobile plant.

In addition to the conservatism inherent in operation utilizing the zone concept of safeguards, in-port ship operation now includes tugs in attendance alongside except when calculations show that meltdown of the core would be delayed at least 1 hour after an MCA. This extra precaution implies that the ship would be removed from the port prior to any fission product release and augments the safety provided by the conservative zoning and port operating criteria previously considered. In this respect, it is evident that the NS Savannah's port operating criteria are more conservative than site criteria for central station plants.

Table 3-1. Comparison of Environmental Safeguards Aspects of NS Savannah and Stationary Power Plants

Item	Stationary reactors	NS Savannah
Definition of MCA	There is only an exceedingly small probability of a serious accident in reactors approved or likely to be approved for construction. The loss-of-primary-coolant accident is normally the most severe.	Accident probability is exceedingly small. Most severe accident is loss of primary coolant.
Containment	Most stationary plants have a single containment vessel enclosing the reactor.	The double containment system of the NS Savannah includes the containment vessel, the reactor compartment, and the reactor compartment ventilation system, including particulate and iodine filters.
Fission product inventory	The saturation fission product inventory, as determined by the megawatt rating of the reactor at end-of-core-life conditions, is used as the reference point for the accident analysis.	The actual fission product inventory in the core at the time of port entry as determined by the power history is used as the reference point for the accident analysis.
Core and containment cooling systems	It is usually assumed that safeguard systems provided to flood or spray the core with water are either inoperative or insufficient to keep fuel elements from melting. Also, no credit is taken for washdown or filtering afforded by safeguards such as cooling sprays and internal air recirculating systems.	Same assumptions are applicable. Credit is not taken for the following NS Savannah safeguards systems or procedures: 1. Cooling water injection into the core through the buffer seal nozzles. 2. Filtering or washdown effects due to the containment vessel recirculating cooling system.

Table 3-1. (Cont'd)

Item	Stationary reactors	NS Savannah
Core and containment cooling systems (cont'd)		3. Cooling and pressure suppression due to the containment vessel recirculating cooling system except that it is assumed this and other systems prevent long term pressure increase after an MCA. 4. Containment pressure suppression due to flooding of the lower void. 5. Water spray into the lower void through the CO_2 nozzles. 6. Water spray into the containment through the CO_2 nozzles. 7. Procedures requiring immediate removal of the ship after the occurrence of any accident which endangers the health and safety of the public. Through the use of tugs and auxiliary propulsion the ship should be moved after an accident in less than 1 hour.
Fission product release	It is assumed that the reactor is a pressurized water type for which the MCA will release into the reactor building: Noble gases 100% Halogens 50% Solids 1%	Same assumption is applicable except that the release is into the inner containment.

Table 3-1. (Cont'd)

Item	Stationary reactors	NS Savannah
Iodine plateout in containment	Half of the iodines in the containment vessel are assumed to be available for release to the atmosphere.	Same assumption.
Containment leak rate	The release of available (airborne) radioactivity from the reactor building to the environment may be assumed to occur at a rate which is a function of the calculated postaccident pressure.	The release of available (airborne) radioactivity from the containment vessel to the reactor compartment is assumed to occur at a constant daily leakage rate of 1.5% of the radioactive material irrespective of actual pressure in the containment.
Filter efficiency	Credit may be taken for safety factors engineered into the facility to prevent or control the release of material to the environment.	Leakage from the containment to the environment is via the reactor space exhaust system with credit taken for efficiencies of 99.9% for particulates and 99% for iodines.
Wind direction	It is assumed that a shift in wind direction does not occur for the duration of the leakage of the fission products from the containment barrier.	Same as stationary plants.
Atmospheric dispersion	Atmospheric dispersion of material from the reactor building is assumed to occur according to the Sutton relationship involving meteorological factors of wind velocity, atmospheric stability, and diffusion parameters. Atmospheric dispersion is assumed to occur under inversion type weather	Same dispersion assumption.

Table 3-1. (Cont'd)

Item	Stationary reactors	NS Savannah
Atmospheric dispersion (Cont'd)	condition. For weather conditions existing for about 75% of the time at most sites, the atmospheric dispersion conditions could be more favorable by factors of 5 to 1000.	
Cloud depletion due to ground deposition	Cloud depletion as ground deposition (particulate fallout) is not assumed during cloud travel.	Same assumption.
Stack height	Atmospheric dispersion is assumed to occur at ground level since single containment is located at ground level.	No credit is taken for the fact that the material leaking from the containment vessel is pumped to the top of a 90-foot mast before it is released to the environment.
Fission product decay	Decay of fission products is assumed while they are confined to the containment building, but is not assumed during their transit to the receptor point.	Same assumption.
Population density	In determining the acceptability of a site for a stationary reactor, the population density and use characteristics of the site environs, including the exclusion area, low-population zone, and population center distance, are considered. There is no requirement to report changes in population distribution after plant startup.	Criteria are same as for stationary plant while ship is moored. Port plans represent current population distributions, however. Transits may be scheduled to coincide with day/night and week/weekend shifts in population to limit the potential population exposure during transit.

Table 3-1. (Cont'd)

Item	Stationary reactors	NS Savannah
Duration of accident	Overall population exposure is based upon a 30-day duration of the accident.	Overall population exposure at dock is limited to 24 hours because of ability to move ship. Exposure at remote anchorage is based upon entire 30-day period of accident.
Gross population exposure	No limitation.	No site is considered acceptable if an MCA occurring there would result in a gross population exposure in excess of 2,000,000 man-rem.