10/30/79

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
OFFSHORE POWER SYSTEMS	)	Docket No. STN 50-437
	)	
(Floating Nuclear Power Plants)	)	

SUPPLEMENT TO NRC STAFF RESPONSE TO QUESTION 4
POSED BY THE LICENSING BOARD IN ITS MARCH 29, 1979 LETTER

Q. "What reasons were there for not considering interactions with sediment in offshore cases (LPGS, p. 4-14)? Since we believe consideration should have been given, what are the effects of such interactions?"

SUMMARY

In testimony dated July 13, 1979 the Staff partially addressed the issue of the effects of sediments on radionuclides released from the floating nuclear plant (FNP) in the offshore case. Consideration has already been given in the FES Part III (NUREG-0502) to the biological effects of naturally occurring sediments contaminated by dissolved radioactivity released from the FNP both in the offshore and estuarine siting cases. The Staff deferred final response to the problem of radioactive sediment pending further study of the complicated issues involved in the assessment of impacts due to core debris particles transported outside of the offshore breakwater. The Staff requested that the Applicant, Offshore Power Systems (OPS), address the factors related to the effect of transport of core debris particles outside of the breakwater.

The Staff has concluded that the consequences to marine biota from the low probability release of particles from the breakwater would not be demonstrably

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greater than those consequences presented in the FES Part III for dissolved releases alone. Furthermore, with effective source and usage interdiction of bivalve mollusks, the doses to man would not be demonstrably greater than those presented in the FES Part III.

BACKGROUND

The Staff previously estimated that the quantity of radioactivity in core debris particles which could escape the breakwater in the event of a core meltdown accident was insignificant compared to the quantity of radioactivity in dissolved form (some of which could later become associated with naturally occurring sediments). The Staff analyses did not, however, consider in detail all potential mechanisms for suspension and transport of fine particles of core debris.

In order to assure that the consequences of the transport of core debris particles was not underestimated, the Staff requested the Applicant to estimate the quantity and size distribution of particles transported out of the breakwater of the offshore FNP into the ocean. The mechanisms capable of this transport included steam explosions, wave circulation, thermal convection, operation of the second FNP unit, ocean cross current, tide and floatation due to insoluble gases.

The Staff reached the following conclusions about the transport of particulate core debris after reviewing the Applicant's report[1/] and performing independent appraisals:

[1/] Enclosure to letter dated July 13, 1979 to R. Ballard of NRC from P. B. Haga of OPS.

1. The presence of significant quantities of fine core debris particles depends on a steam explosion, which is an unlikely event even if the core does melt through the barge (LPGS, NUREG-0440, Appendix A);

2. Particles of core debris would be largely confined to the basin by the presence of the sills. Mechanisms inside the breakwater could mobilize and lift a fraction of the finest core debris over a period of time. The Staff concurs in the Applicant's upper limit estimate of 10 percent of the core debris leaving the breakwater as fine particles;

3. Particles fine enough to leave the breakwater could be held in suspension once outside the breakwater by turbulence during high seas, and transported by ambient currents. During calmer periods most of the particles would settle, although the very finest might remain indefinitely suspended.

In addition to estimating the transport of particles, the Applicant was requested to assess the radiological effects of the particles on ocean biota as well as man and to explore methods of interdiction necessitated by particulate contamination. The Staff reviewed the Applicant's responses and performed independent analyses. The Staff's appraisal of the consequences is presented below.

DOSES TO BIOTA

Suspended Sediment Effects

External radiation to an immersed organism depends on the concentration of the radionuclide in curies/liter, and should be no different whether it eminates from dissolved radionuclides or suspended radioactive particles. Therefore, the Staff concludes that the present analyses of the doses from external radiation for dissolved radionuclides on biota presented in the FES Part III Section 3 encompass those effects from waterborne particulate core debris.

Bottom Sediments

The presence of core debris particles would affect the analyses for biological effects to bottom dwelling organisms. The analysis in the FES Part III Section 3 considers that up to 0.5 percent of the dissolved radioactivity released from the breakwater could become associated with naturally occurring sediment. Settling of this sediment onto the seabed would cause a local area of radioactivity lethal to some highly susceptable organisms exposed during their most radiosensitive life stages. If 50 rads exposure is considered lethal to demersal fish eggs (assumed to be a typical example of the most sensitive organism and life stage), the area impacted would probably be less than 2 km^2. Furthermore, after the passage of the first storm capable of resuspending the particles, there would be no area of seabed with lethal concentrations.

If 10% of the core debris is assumed to escape the breakwater, then the amount of radioactivity initially deposited on the seabed is larger than shown in the FES Part III by a factor of 20. An area of up to 12 km^2 could receive greater than 50 rads. An area of up to 6 km^2 could receive an irradiation of greater than 1500 rads, an exposure conservatively considered lethal to adult and juvenile demersal fish. After the first resuspension due to a moderate storm, there would be no area which could irradiate an organism with greater than 50 rads; the area would be open to repopulation by even the most radiosensitive organisms after a time estimated on the basis of the frequency of ocean storms to be on the order of several weeks.

The maximum bottom area impacted due to particulate core debris would be 12 km^2 as compared to the maximum area of seawater with lethal concentrations of 40 km^2 estimated in the FES Part III. It must be recognized, however, that if the radioactivity is largely tied up with particulate core debris or sediment, there would be less available to the dissolved phase and vice versa.

The area of potential impacts to biota from either the dissolved or the particulate phases is roughly comparable, but the organisms affected might be different. Free floating eggs or larvae would tend to be more affected by the dissolved radioactivity, while bottom dwelling eggs and larvae would be more affected by sediment and particulate core debris. In either case, the lethal effects are of a relatively short duration (up to several weeks) and areas (up to 40 km^2), and repopulation of the region would be expected to be swift.

DOSES TO MAN

The two major pathways to man due to sediments or particulate core debris are irradiation from the shoreline (shine) and ingestion of marine organisms which contain sediment. The shine from the shoreline was already taken into account in the dose calculations by considering that beach sand irreversibly sorbs dissolved radioactivity from the plume in which it is immersed. This calculation is highly conservative because it does not consider depletion of the dissolved radioactivity, dilution by fresh sand, back-leaching or interdiction. The beach exposure is a factor of 3 to 10 smaller than the fish ingestion pathway; the largest contribution to dose.

The Staff estimates that within several kilometers of the site, radioactivity deposited from core debris particles would be about the same as that calculated to deposit as a result of sorption of dissolved radioactivity. The maximum individual and population doses to man would be about the same from either mechanism. Considering the extremely conservative nature of the beach dose calculations, the Staff concludes that there would be no significant additional radiological impact to man from beach shine due to deposited core debris particles.

Swimming Doses

External radiation to an immersed human depends only on the concentration of the radionuclide in curies/liter and should be no different whether it emanates from dissolved radioactivity or suspended radioactive particles. The Staff, therefore, concludes that there are no significant immersion (swimming) doses due to external radiation from suspended particulate core debris beyond those already calculated from dissolved radioactivity.

Seafood Ingestion

Relative to the soluble radioactivity in the dissolved phase, there would be little transfer of the insoluble radionuclides associated with particles across the gut of either marine fish or invertebrates. In addition, it is likely that those radionuclides easily transported across the gut are highly soluble and would at least be partially leached in the seawater before ingestion. Therefore, doses to man from ingestion of flesh should be relatively minor compared to those doses calculated for dissolved radioactivity.

Marine invertebrates such as clams and oysters (bivalves) are normally eaten whole. Therefore, there is an opportunity for man to directly ingest radioactive sediments contained in the gut of these animals. Close to the site and shortly after the release, such organisms could accumulate significant quantities of contaminated sediment, since most bivalves are highly tolerant of radioactivity. It is extremely improbable, however, that highly contaminated bivalves would be taken and eaten without close monitoring and interdiction, if necessary following an accident. Maximum dose would, therefore, be tied to the interdiction level.

The Applicant has proposed a more detailed scenario to evaluate doses due to ingestion of particles contained in the gut of bivalves. The dose from ingesting a single bivalve containing all the radioactive particles in one square meter of ocean bottom would be about 14 millirem. This dose did not consider the self-cleaning of the organism, the ability of the organism to reject unnourishing particles, or deliberate "starving" of the organism before eating. In addition, it is likely that much of the soluble radionuclides in the small particles would have already been leached in the seawater prior to ingestion by the bivalves.

The Applicant's analysis did not take into consideration the probable quantity of consumption for these organisms; so population or individual doses are not directly comparable to those for ingestion of fish flesh. About 300 contaminated bivalves would have to be eaten, however, to achieve a dose comparable to the 5 rem interdiction level used in the FES Part III, Section 3.4.1.2. This number is about ten times greater than the estimated yearly per capita consumption of oysters and clams in the United States, based on U.S. landings and population in 1975.[2/] There are, of course, individuals whose consumption of clams and oysters is far greater than the average.

INTERDICTION

Source Interdiction

The above analysis of dose due to ingestion of bivalves assumes that source interdiction, such as sinking the barge and dredging several square kilometers around the FNP, has reduced the number of particles in the environment by a factor of 100, and that the remaining particles would be diluted with the alongshore transport of sediment by a factor of 10^5 after a period of initial dispersion. The Staff considers that source interdiction to the stated level is likely. The transport of up to ten percent of the core debris out of the breakwater as particulates would be slow relative to the transport of dissolved radioactivity. The slower transport would facilitate interdiction at the source. Once outside

[2/] U.S. Department of Commerce, "Fishery Statistics of the United States," 1975, Statistical Digest no. 69, Washington, D.C. December 1978.

of the breakwater, however, interdiction of the source would be more difficult. Dredging would have to start quickly before the particles dispersed over a wide area. The added lead time afforded by the core ladle would therefore be an important consideration in source interdictions.

The effectiveness and cost of interdiction measures are impossible to estimate without a detailed analysis on a case-by-case basis. By analogy with beach restoration projects, the Applicant has estimated that up to 25 square kilometers of contaminated sediment could be dredged for a cost of 13 million dollars. Spoils would presumably be placed back into the breakwater. The Staff estimates that the actual cost of such an operation would be much higher because of the peculiar problems of handling contaminated spoils and the need for quick deployment of the dredges and associated equipment.

Pathway Interdiction

The only potentially serious impact on dose to man from particulate core debris appears to be from ingestion of bivalves. Pathway interdiction would involve close monitoring of these organisms in the affected areas until safe levels of radioactivity are reached. This monitoring would be facilitated by the fact that bivalves tend to be immobile, and would not be expected to migrate from the area of contamination as swimming species do.

CONCLUSIONS

The Staff has evaluated the consequences of the transport of particulate core debris from the FNP breakwater in the event of a core meltdown accident and has reached the following conclusions:

- the creation of a large quantity of very fine core debris particles would depend on an energetic steam explosion, which is possible, but is a highly improbable event;

- most particles would remain within the breakwater because of the presence of sills on the sea entrances. A maximum of 10 percent of the core could leave as particles;

- particles once outside of the breakwater would be widely dispersed by the actions of waves, especially during storms;

- there would be little if any harm to biota beyond that already calculated from dissolved releases. Sensitive bottom dwelling organisms might be more affected by particles than by dissolved radioactivity. Lethal levels of radiation would last for no more than a period of several weeks. Repopulation would be rapid;

- doses to man from swimming, beach shine and ingestion of fish flesh should not increase significantly because of particulate core debris;

- with effective source and usage interdiction, doses from the ingestion of bivalves would be no greater than those doses calculated for ingestion of fish flesh.