Off-Site Dose Consequences Resulting from a Pipe Break Between the Drywell and Isolation Condensers at the Oyster Creek Nuclear Generating Station

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November 1989

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Introduction

The Nuclear Engineering Section (NES), based on the leak before break application, performed an engineering evaluation of the isolation condensers at Oyster Creek Nuclear Generating Station (OCNGS) and identified that a pipe break between outside of primary containment and the isolation valves could result in a Loss of Coolant Accident (LOCA). The purpose of this study is to determine first order estimates for off-site radiological doses as a result of such a pipe break for three accident scenarios which result in a release to the environment.

Accident Scenarios and Assumptions

The leakage of coolant from a pipe break between the drywell and the isolation valves for the isolation condenser was evaluated by NES as a potential application of leak before break for boiling water reactors. Two groups of accident scenarios were evaluated for OCNGS; one based on the single failure and the other based on a single seismic event. Some of the information required for these analyses were not readily available in OCNGS Final Safety Analysis Report (FSAR). As a result, additional information was provided by the Licensee's (GPU Nuclear) technical staff. When neither of these sources provided the needed information, conservative assumptions were made to complete this evaluation.

Three scenarios were considered: (1) LOCA with all engineering safety features in operation (design basis accident-LOCA) for which the reactor site criteria (Title 10 Part 100 guidelines of the Code of Federal Regulations [CFR]) applies and (2) accidents that are more catastrophic in nature (i.e., class 9 accidents-low probability events) involving multiple failures resulting in cladding damage or fuel melt which do not come under 10 CFR 100 guidelines. In this study, two low probability accidents were evaluated (fuel cladding damage and fuel melt).

a. The source term and the fraction available for release to the environment from a line break scenario were taken from information provided by the Licensee. This accident could lead to a larger pipe line break resulting in a postulated LOCA. When considering a line break, the coolant activity is the controlling factor for the offsite doses. Duration of the release for a line break is assumed to be 2 hours during which the plant personnel will take some effective measure to terminate the release. It is assumed that all engineering safety systems in the plant are operational.

The LOCA addressed in the OCNGS FSAR is a credible case with all engineering safety system in operation to mitigate the accident. The offsite doses resulting from such a postulated LOCA can be compared to 10 CFR 100 guidelines.

b. The low probability accident scenario is based on a single seismic event (such as an earthquake) which not only causes a pipe break between the drywell and isolation valves for the isolation condenser, but causes damage to weak points in engineering safety systems such that primary coolant that leaks into secondary containment is released directly to the atmosphere as a ground level release without being filtered. Due to the seismic event, engineered safety systems fail resulting in cladding failure and fuel melt as the containment integrity is lost. For such a scenario, release durations of 8 hours for cladding damage and 10 hours for the fuel melt cases are assumed.

The following set of information are used to estimate offsite doses:

1. The core inventories for OCNGS is 1930 Mwt

2. During a fuel melt scenario, based on WASH-1400, 100% of noble gases and iodines are assumed to be released with an iodine partition factor of 1000. Ground level release is assumed.

3. The release fraction to the environment from fuel cladding damage and fuel melt case accidents are taken from the information provided in a memo from GPU Nuclear.

4. The fractional release remaining in the plume during the plume traversal is based on the Regulatory Guide 1.111 although this Regulatory Guide is applicable for normal operations.

c. Although there is significant contribution from other short and long-lived radionuclides, the following radionuclides are assumed to be of dosimetric significance during the plume exposure phase.

Whole Body:	Xe-133 ($T_{1/2}$ = 5.3 days)
	Kr-88 ($T_{1/2}$ = 2.8 hours)
Thyroid:	I-131 ($T_{1/2}$ = 8.04 days)

d. The most critical age group (i.e. child) has been selected for estimating the thyroid dose.

e. The duration of the exposure to the release was assumed to be the following. These exposure periods used in this study are based on Title 10 of CFR.

site boundary (0.25 miles): 0 to 2 hours
2 miles: 0 to 8 hours
5 miles: 0 to 30 days
10 miles: 0 to 30 days

f. Dose conversion factors are based on Regulatory Guide 1.109.

g. The release rate at a given distance was assumed to be constant.

h. Although there are various removal modes for radionuclides in the atmosphere, the only removal mode considered was radioactive decay.

<u>Meteorological Parameters Considered</u>

A total of eight meteorological cases were developed for each scenario. Two sets of dilution factors or atmosphere dispersion factors (X/Q), three different stability classes and two different wind speeds were used for evaluating this accident. A set of 8 atmospheric dilution factors based on 8 different meteorological conditions provide a wider spectrum to estimate the offsite doses.

a. One set of site specific dilution factors was obtained from the Licensee's meteorologist. These factors are annual average values and sector weighted (i.e. dependant on the wind direction). The wind speed is assumed to be 10 mph and the stability class is assumed to be unstable (class C). In order to obtain a range of off-site doses, the dilution factors used in this study were the most dominant wind direction (i.e. lowest dilution factor) and the least dominant wind direction (i.e. highest dilution factor).

b. The second set of dilution factors were taken from the Licensee's Emergency Plan and Implementing Procedures (EPIP) and are direction independent (non-weighted). In addition to the Licensee's reference atmospheric condition of unstable and 10 mph wind speed, a wind speed of 2 mph and stability classes of D and F were used. The 2 mph wind speed is the average value from BNE's off-site radiation monitoring station equipped with meteorological instruments (located 0.6 miles southwest of OCNGS). The neutral stability class (class D) was the most frequent stability condition at OCNGS (based on data reported in the Licensee's effluent release reports from 1982 through 1988). Stable conditions (stability class F) were also considered because they provide worst case atmospheric conditions.

Table 1 summarizes the various cases considered for each scenario in this study. Cases 1 and 2 represent the range of meteorological conditions provided by the Licensee. Case 3 through 6 represents a mix of parameters used by the Licensee and the BNE. The last two cases assume stable atmospheric conditions. The parameters in case 6 would represent the most probable meteorological conditions in the vicinity of OCNGS. Case 8 would be the worst case meteorological conditions for off-site exposure because of the stable atmospheric condition and low wind speed.

Calculational Methodology

The off-site doses were calculated at the site boundary (0.25 miles from the plant), 2 miles, 5 miles and 10 miles. The outer edge of the Emergency Planning Zone (EPZ) is 10 miles. The beginning of Low Population Zone (LPZ) is at 0.25 miles. The definition of the LPZ in 10 CFR 100 is defined in a manner that its size can be interpreted anywhere from the site boundary out to 10 miles.

The doses from exposure to a plume of radioactive material released as a result of a line break were calculated using the following equations.

1. Whole Body Dose = (A) * (B) * (C)

where:
A = noble gas source term (curies)
B = dose conversion factor for Kr-88 or Xe-133 $((\text{rem} - m^3)/(\text{sec} - \text{Ci}))$
C = atmospheric dispersion factor (sec/m^3)

2. Thyroid dose = (E) * (F) * (G) * (H)

where:
E = iodine source term (curies)
F = dose conversion factor for I-131 (rem/curie)
G = breathing rate (m^3/sec)
H = atmospheric dispersion factor (sec/m^3)

The X/Q values are dependant on the distance from the plant, the wind velocity and stability class.

Results

The off-site doses for the small line break scenario are presented in Table 2. The doses in Tables 2 through 5 are in units of rems. Table 3 are the off-site doses for the fuel damage scenario and Table 4 presents the results to the fuel cladding damage scenario. Doses did not necessarily decrease with distance because exposure to the plume was longer (30 days) at distances of 5 and 10 miles.

Case 8 had the highest off-site doses (whole body and thyroid) for each scenario in which non-weighted dilution factors, stable atmospheric conditions and 2 mph wind velocity were used. Doses from the most frequent meteorological conditions (Case 6) were within a factor of 10 of the worst case meteorological conditions (Case 8). Cases 5 and 6, which utilized X/Q that are not sector-weighted, produced off-site doses that were greater that Cases 1 and 2, which used sector-weighted dilution factors. Case 3 had similar doses to the sector-weighted cases because the wind velocity and stability class were the same.

The doses in Table 2 were significantly lower than Table 3 and 4 because the engineering safety systems were assumed to be operational and the release was filtered. The highest doses were found in Case 8 at a distance of 5 miles from OCNGS with doses of 5 mrem for whole body and 13.8 rem for thyroid.

The doses from the fuel cladding damage scenario were generally one order of magnitude lower than the fuel damage scenario. The greatest whole body doses were seen in Case 8 at the site boundary. For the fuel cladding scenario, the whole body dose at this distance was 116 rem and for the fuel damage scenario, a maximum dose of 3130 rems was calculated. Regarding thyroid doses, a thyroid dose of 207 rem was determined for the fuel cladding accident in Case 3 at 2 miles and for the fuel melt accident, the highest dose was 7620 rems at the site boundary in Case 8.

Discussion

This study supports NES's engineering evaluation that a leak between the primary containment and the values leading to the isolation condensers at OCNGS could result in significant off-site doses. Although the off-site doses are first order estimates, it is important to note that the differences in doses between the scenario based on 10 CFR 100 criteria and the low probability accidents are several orders of magnitude. Increased sophistication for determining off-site doses (i.e. puff-trajectory or complex numerical models) will refine the dose estimates, not the orders of magnitude differences between the scenarios.

This study also revealed that the atmospheric dispersion factors used by the Licensee are sector-weighted, resulting in lower off-site doses compared to the most frequent atmospheric conditions. The most conservative X/Q value used by the Licensee is for winds towards the southeast, which would carry a plume over an area mainly covered by water (Barneget Bay). The use of sector-weighted dispersion factors would be appropriate for evaluating routine releases over a long period of time where equilibrium conditions are assumed. For evaluating accidents in which the release to the environment is of short duration and higher release rate, short term (daily) atmospheric conditions become more critical.

In addition to the X/Q values, the use of a 10 mph wind speed and an unstable stability class (class C) do not represent the most frequent for the OCNGS area. Based on the Licensee's meteorological data reported in their effluent release reports, the most frequent stability class was D (nearly 40% of the time and nearly 3 times the next most frequent class). The use of 10 mph wind velocity is much greater than observed by BNE at their meteorological station. The meteorological parameters used by the licensee are not representative of the conditions around OCNGS.

The off-site doses present in this report could be conservative (lower than expected) since only 3 radionuclides were considered in the study. For doses close to the plant (especially at a distance of 0 to 2 miles), short-lived radionuclides could contribute a significant portion of the total dose.

This evaluation concludes that there is the potential for significant off-site radiological consequences associated with a break in the piping leading to the isolation condensers. When potential radiological accident consequences are analyzed using Nuclear Regulatory Commission (NRC) guidelines for a single failure accident, the resulting off-site doses are well within 10 CFR 100 criteria. When an accident outside the application of 10 CFR 100 criteria is considered (low probability accident), the resulting off-site doses are significantly greater than the NRC reactor siting criteria, representing potentially severe radiological consequences to the public in the vicinity of OCNGS. In either case, the Department of Environmental Protection would be obligated to recommend protective actions for a significant population in Ocean County.

The significance of the off-site doses along with the weighted atmospheric dilution factor warrant that population doses be evaluated around OCNGS. The potential off-site doses also support the need for the installation of isolation valves inside the drywell for the isolation condensers. If valves were installed inside the drywell, then OCNGS would have increased its margin of safety by eliminating a direct pathway from the reactor into secondary containment.

Table 1: Summary of Meteorological Parameters Used

Case	Parameters
1.	Sector-weighted X/Q for dominant wind direction (to SE) Stability class = C; wind velocity = 10 mph
2.	Sector-weighted X/Q for least dominant wind direction Stability class = C; wind velocity = 10 mph
3.	Non-weighted X/Q Stability class = C; wind velocity = 10 mph
4.	Non-weighted X/Q Stability class = C; wind velocity = 2 mph
5.	Non-weighted X/Q Stability class = D; wind velocity = 10 mph
6.	Non-weighted X/Q Stability class = D; wind velocity = 2 mph
7.	Non-weighted X/Q Stability class = F; wind velocity = 10 mph
8.	Non-weighted X/Q Stability class = F; wind velocity = 2 mph

Table 2: Summary of Off-Site Dose From a Small Line Break Scenario at OCNGS

Case Number	Miles Distance	Doses in Rems Whole Body Dose	Thyroid Dose
1	0.25	<0.01	0.05
	2.0	<0.01	<0.01
	5.0	<0.01	0.08
	10.0	<0.01	0.03
2	0.25	<0.01	0.05
	2.0	<0.01	<0.01
	5.0	<0.01	0.08
	10.0	<0.01	0.03
3	0.25	<0.01	0.05
	2.0	<0.01	0.01
	5.0	<0.01	0.1
	10.0	<0.01	0.03
4	0.25	<0.01	0.24
	2.0	<0.01	0.02
	5.0	<0.01	0.4
	10.0	<0.01	0.13
5	0.25	<0.01	0.1
	2.0	<0.01	0.02
	5.0	<0.01	0.45
	10.0	<0.01	0.2
6	0 .25	<0.01	0.45
	2.0	<0.01	0.1
	5.0	<0.01	2.3
	10.0	<0.01	0.81
7	0.25	<0.01	0.24
	2.0	<0.01	0.1
	5.0	<0.01	2.8
	10.0	<0.01	1.1
8	0.25	<0.01	1.2
	2.0	<0.01	0.5
	5.0	<0.01	13.8
	10.0	<0.01	5.6

Table 3: Summary of Off-Site Doses from Fuel Damage Scenario at OCNGS

Case Number	Miles Distance	Doses in Rems Whole Body Dose	Thyroid Dose
1	0.25	132	320
	2.0	4.2	23.0
	5.0	0.9	189
	10.0	0.06	11.6
2	0.25	59.5	145
	2.0	1.1	10.5
	5.0	0.4	80.2
	10.0	0.2	5.0
3	0.25	34.5	83.8
	2.0	0.1	1.4
	5.0	0.1	12.7
	10.0	0.03	6.6
4	0.25	7.7	411
	2.0	0.1	7.2
	5.0	0.3	63.3
	10.0	0.2	32.5
5	0.25	221	549
	2.0	3.2	32.2
	5.0	1.0	205
	10.0	0.4	73.1
6	0.25	1130	2740
	2.0	16.3	165
	5.0	5.0	1026
	10.0	2.0	372
7	0.25	2790	6781
	2.0	14.3	145
	5.0	5.4	1231
	10.0	2.6	526
8	0.25	3130	7620
	2.0	78.2	790
	5.0	27.0	6150
	10.0	13.0	2630

Table 4: Summary of Off-Site Doses from Fuel Cladding Damage Scenario at OCNGS

Case Number	Miles Distance	Doses in Rems Whole Body Dose	Thyroid Dose
1	0.25	4.8	7.9
	2.0	0.1	6.0
	5.0	0.03	4.7
	10.0	0.002	0.07
2	0.25	2.2	3.6
	2.0	0.06	2.8
	5.0	0.02	2.0
	10.0	<0.001	0.1
3	0.25	1.7	2.1
	2.0	<0.001	0.4
	5.0	<0.001	0.3
	10.0	<0.001	0.2
4	0.25	6.2	10.2
	2.0	0.04	1.9
	5.0	0.01	1.7
	10.0	0.01	0.8
5	0.25	8.3	13.4
	2.0	0.1	8.4
	5.0	0.04	5.1
	10.0	0.01	1.8
6	0.25	45.3	68.0
	2.0	0.9	4.1
	5.0	0.2	25.4
	10.0	0.07	9.2
7	0.25	23.1	37.6
	2.0	0.9	42.4
	5.0	0.2	30.5
	10.0	0.1	12.9
8	0.25	116	189
	2.0	4.2	207
	5.0	1.0	153
	10.0	0.5	65.5

Table 5: Summary of Off-Site Doses
and
Relevant Federal and State Guidelines

	Doses in Rems	
Distance (miles)	Whole Body Dose	Thyroid Dose
0.25 (site boundary)	<0.1 - 3130	<0.1 - 7620
2.0	<0.1 - 78.2	<0.1 - 790
5.0	<0.1 - 27.0	<0.1 - 6150
10.0	<0.1 - 13.0	<0.1 - 2630
10 CFR 100 (reactor siting criteria)		
site boundary	25	300
in LPZ	25	300
New Jersey Radiological Emergency Response Plan's Off-Site Protective Action Recommendations Guidelines for the Public		
none	<0.5	<3
sheltering	0.5 - 1	3 - 5
evacuation	>1	>5