Enclosure 5

REVISED SOURCE TERM, SAFETY GOAL AND SEVERE ACCIDENT INSIGHTS FOR REACTOR SITING

The non-seismic, or demographic aspects of reactor siting involve primarily the determination of the size of the exclusion area and objectives regarding population density or distribution beyond the exclusion area. These are discussed below.

I. EXCLUSION AREA

The exclusion area, that area immediately surrounding the reactor where no residents are permitted and where the licensee has the authority to determine all activities, including the removal of persons in the event of an emergency, has been a requirement since promulgation of the rule in 1962. An earlier staff study by the Siting Policy Task Force (NUREG-0625) recommended continuation of this requirement. The staff continues to believe that an exclusion area should be required for the following reasons:

- to provide reasonable assurance that the radiological effluent design objectives associated with normal reactor operation, specified in 10 CFR Part 50, Appendix I, will be met;

- to provide reasonable assurance that the radiological consequences of a range of postulated accidents, up to and including the limiting design basis accident considered, will be acceptable for an individual located at the nearest boundary of the exclusion area for a specified time;

- to provide reasonable assurance that appropriate security plans can be made and measures established so that potential acts of sabotage pose no undue risk to the plant; and

- to provide reasonable assurance that adequate protective measures for members of the public can be taken in the event of an emergency.

Currently, the size of the exclusion area is based upon postulating a number of accidents (the so-called design basis accidents) and evaluating them to provide reasonable assurance that the radiological consequences of the limiting design basis accident are adequate to protect the public. The exclusion area serves to provide a limitation on individual accident risk. It should be noted that while the size of the exclusion area (together with plant design) assures acceptably low consequences for design basis accidents (up to and including degraded core accidents where the containment remains intact, but leaks at its maximum allowable leak rate), it is not intended to assure acceptable consequences in the unlikely event of severe accidents involving core-melt with containment failure.

Regulatory Guide 4.7 notes that the NRC staff has found that a minimum exclusion area distance of 0.4 miles (640 meters), even under adverse atmospheric relative dilution conditions, usually provides assurance that engineered safety features can be designed so that the calculated doses would be within the guideline values of 10 CFR Part 100. This finding is based, however, upon the source term into containment given in Regulatory Guides 1.3 and 1.4, which is taken from TID-14844. Further, this distance is also based upon a relatively conservative evaluation of the efficacy of fission product removal by engineered safety features.

Using a more realistic evaluation of engineered safety features together with the revised source term into containment given in draft NUREG-1465, the staff believes that significantly smaller exclusion area distances could provide reasonable assurance that the calculated doses would be within the guideline values of 10 CFR Part 100. While a minimum distance has not been determined, it appears that distances of 0.25 miles (400 meters), or less could provide reasonable assurance that engineered safety features can be designed so that the calculated doses would be within the guideline values of 10 CFR Part 100.

Since the quantitative health objectives (QHOs) of the Safety Goal provide guidance on the individual risk of early fatality and risk of latent cancer fatality, the size of a proposed exclusion area can be evaluated with regard to the QHOs. A range of exclusion area distances (from 0.25 to 0.5 miles) has been investigated for plants with a reactor power level of 3800 megawatts (thermal) and having the risk characteristics of those studied in NUREG-1150. All of these distances were found to easily meet the early and latent fatality QHOs of the Safety Goal. In view of the expected frequency of core damage and containment failure of less than 10^{-5} per reactor year, even for existing plants, such a plant would be able to satisfy the early fatality QHO with an exclusion area no larger than the minimum area required to site the major plant structures and buildings. Such an exclusion area is likely to be 0.1 miles or less in radius.

It is important to recognize that the QHOs of the Safety Goal provide guidance on individual risk only, not societal risk. For this reason, while the Safety Goal can be used to evaluate a proposed exclusion area distance, it provides no guidance with respect to population density or distribution beyond the exclusion area.

II. POPULATION DENSITY CRITERIA

Restrictions on population density beyond the exclusion area have also been required since issuance of the rule in 1962. The current Part 100 requires a "low population zone" (LPZ) beyond the immediate exclusion area. The LPZ radius must be of such a size that an individual located at its outer radius must not receive a dose in excess of the values given in Part 100 over the course of the accident (currently evaluated as 30 days). While numerical values of population or population density are not specified for this region, the regulation also requires that the nearest boundary of a densely populated center of about 25,000 or more persons be located no closer than one and one-third times the LPZ outer radius. Part 100 has no population criteria other than the size of the LPZ and the proximity of the nearest population center, but notes that "where very large cities are involved, a greater distance may be necessary."

Whereas the exclusion area size is based upon limitation of individual risk, the imposition of population density requirements serves to set societal risk limitations. Further, since the radiological consequences of the limiting design basis accident are determined to be acceptable at the exclusion area boundary, limitation of population density beyond the exclusion area reflects consideration of societal risk as well. Accidents beyond the design basis were clearly a consideration in the original issuance of Part 100, since the Statement of Considerations notes as follows:

> "Further, since accidents of greater potential hazard than those commonly postulated as representing an upper limit are conceivable, although highly improbable, it was considered desirable to provide for protection against excessive exposure doses to people in large centers, where effective protective measures might not be feasible... Hence, the population center distance was added as a site requirement."

Limitation of population density beyond the exclusion area has the following benefits:

- it facilitates emergency preparedness and planning;
- it reduces potential doses to large numbers of people in the event of severe accidents; and
- it reduces potential property damage in the event of severe accidents.

As noted above, since the Safety Goal provides guidance on individual risk only, it cannot be applied to determine whether a particular population density would meet the QHOs of the Safety Goal.

However, results of severe accident risk studies, particularly those obtained from NUREG-1150, provide useful insights for considering potential criteria for population density. Severe accidents having the highest consequences are those where core-melt together with early bypass of or containment failure occurs. Such an event would likely lead to a "large release" (without defining this precisely). Based upon NUREG-1150, the probability of a core-melt accident together with early containment failure or bypass for the current generation of LWRs is estimated to be between 10^{-5} and 10^{-6} per reactor year. For future plants, this value is expected to be less than 10^{-6} per reactor year.

If a reactor were located within a large city, the likelihood of exposing a large number of people to significant releases of radioactivity would be the same as the probability of a core-melt and early containment failure, that is, less than 10^{-6} per reactor year for future reactor designs. This probability is sufficiently low that arguments could be made that siting a reactor within a large city would pose no undue risk from safety considerations. It is worth noting that the staff, in licensing actions, has regarded events of about 10^{-6} per reactor year or lower to be "incredible", and has not required them to be considered as part of the design basis of the plant.

If, however, the reactor were sited at some distance from the city, the likelihood of the city being affected is further reduced because of wind direction variability, the likelihood it would actually transport radioactive material towards the city is lower, and the inventory of the plume becomes depleted over time and distance. If the reactor were located at distances ranging from 10 to about 20-25 miles away from a city, depending upon its size, emergency planning is facilitated and the probability of exposure of large numbers of people within the city and possible contamination of major areas of the city would be reduced about one additional order of magnitude to less than 10^{-7} per reactor year. A population density guideline of 500 persons per square mile, as given in Regulatory Guide 4.7, provides an effective "standoff" distance of about 10 miles for cities having a population of about 100,000 or more persons, and a "standoff" distance of about 20 miles for cities of about 500,000 or more persons.

Siting reactors even more remotely than 10 to about 20 miles away from population centers would further reduce the potential risk for persons within the city, but at a lower rate. For example, to reduce the risk to a city to less than 10^{-8} per reactor year would require that reactors be sited at distances of about 50 or miles or more from cities. At these distances, site availability would be severely limited for many regions of the U.S.

In summary, next-generation reactors are expected to have risk characteristics sufficiently low that the safety of the public is reasonably assured by the reactor and plant design itself. Such a plant can satisfy the QHOs of the Safety Goal with a very small exclusion area distance (generally 0.1 miles or less). The consequences of design basis accidents, analyzed using revised source terms and with a realistic evaluation of engineered safety features, are likely to be found acceptable at distances of 0.25 miles or less. With regard to population density beyond the exclusion area, siting a reactor even within a densely populated city would pose a very low risk to the city from safety considerations. Hence, any population density restrictions on reactor siting should be viewed as a safety enhancement based upon defense-in-depth considerations, rather than as required to meet an adequate degree of safety. Locating reactors at distances ranging from 10 to about 20-25 miles away from population centers, where it is feasible to do so, can facilitate emergency planning and reduce the already low likelihood of exposure to large numbers of people by about an additional order of magnitude.

Since reactor sites must satisfy a number of criteria including water availability, environmental considerations and other land use restrictions, the staff believes that limitations on population density alone should not become so stringent as to preclude the use of otherwise suitable sites.