COMPUTER METHODS USED IN THE COMPLEX STRUCTURAL ANALYSIS OF A DRYWELL STRUCTURE

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SUMMARY

This paper describes finite element models and computer analyses used for the design of the drywell structure of a boiling water reactor. Descriptions of the geometry and the loading conditions are included. Two- and three-dimensional idealization of the structure for static, dynamic, linear and non-linear analyses are illustrated.

The drywell structure of the General Electric MARK III containment system serves as primary enclosure and housing for the reactor pressure vessel. It also supports the loads of the upper fuel pools. The drywell includes the following integrated reinforced concrete structural parts:
— Cylindrical drywell wall with its perforated bottom portion,
— Drywell roof, which also serves as bottom slab for the fuel pools,
— Walls of the fuel pools and stiffening system for the drywell roof,
— Structures of the main steam tunnel, other rooms, refueling floor.

Loading conditions include: dead load, operating and refueling live loads, operating dynamic pool pressure loads, internal and external pressure loads, pool swell load, seismic loads and thermal effects.

The major portion of the analysis was conducted using a large three-dimensional model. The structure was modeled with plate bending and beam elements. The foundation was modeled using springs. The combinations of several basic load cases served to determine critically stressed places, where the local forces and moments were used for the reinforcing design. Three-dimensional partial models, occasionally with refined meshes were prepared for the detailed analysis of the equipment hatch, the penetration of main steam pipes, the drywell roof and the steam tunnel. The boundary forces for the partial models were taken from the large model. Some of these models were also used in dynamic analyses to determine structural responses to various dynamic loading conditions such as seismic, operating, and accident loads.

An axisymmetrical non-linear analysis, which considers concrete cracking and material yielding, was conducted to determine thermal effects. The structure was modeled with layers of concrete, reinforcing steel, structural steel and steel liner plates. Three different thermal conditions were analyzed in combination with the various pressure and other loads. The analysis resulted in displacements, element stresses, section resultant forces and moments and the limits of propagation of the concrete cracking. The same program, with a two-dimensional horizontal sectional model, was used to determine the thermal response of the cylindrical wall in areas where it is restrained by outside walls and slabs.

Dynamic loads from main steam relief valve discharges into the lower suppression pool were analyzed with a simplified three-dimensional model. Various loading distributions were investigated using this model.

Several postprocessing and design programs were used to determine local stresses and reinforcing required at critical locations.

The design of the internal structures of the reactor containment provides a complex analytical task for the structural engineer. The capabilities of the available structural programs provide appropriate means for complex analysis of complicated structures for various load conditions.