RIL FILE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 18 1981

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 114
"PIPING BENCHMARK PROBLEMS"

114

INTRODUCTION AND SUMMARY

Dynamic analyses of piping systems are normally performed using computer programs to handle the complex geometries and various static or dynamic loading conditions. Applicants for nuclear power plant licenses are required to provide confirmation of the adequacy of their programs. The requirement to provide this confirmation is given in the Standard Review Plan, Section 3.9.1 and Appendix B, Section III of 10CFR50. The Office of Nuclear Reactor Regulation has indicated a need for verification of these programs.

This Research Information Letter (RIL) transmits the results of efforts at Brookhaven National Laboratory (BNL) to develop benchmark problems and solutions, of sufficient complexity to check the adequacy of the applicant's computer programs. This work represents one task of the program, "Mechanical Piping Benchmark Problems."

Seven piping problems and solutions were selected as a benchmark for the verification of computer programs using uniform support motion and the response spectrum method of analysis. The benchmark problems and solutions are presented in the report, NUREG/CR-1677, "Piping Benchmark Problems, Volume 1." All the benchmark problems were used in some form to evaluate the seismic method of analysis of the five plants which were shut down in 1979 in response to IE Bulletin 79-07. The computer programs, EPIPE, which were used for generating solutions to the benchmark problems, and PSAFE2, are suitable for the analysis of linear elastic structures subjected to static or dynamic loads. These were developed and are available on the BNL computer system.

APPROACH

Owing to the lack of problems suitable for benchmarks in the open literature, specific problems were developed. To accomplish this, an available general purpose finite element code (EPIPE) was modified and optimized to perform piping analysis of elastic structures in accordance with current NRC practice (response spectrum method, Regulatory Guide 1.92). The updated code (EPIPE) was then verified against available closed form solutions, limited experimental results, and solutions developed from existing domestic (ANSYS) and European (SPANDLE) computer programs. These verification studies are described, in part, in the report BNL-NUREG-21241, dated January 1976, by M. Reich, T. Y. Chang and S. Prachuktam. The benchmark problems and solutions were next developed and transmitted to various nuclear power plant licensees for preliminary evaluation. The subsequent matching of results (between the benchmark problem solutions and those submitted by the licensees) corroborated the correctness of the solutions, and further verified the EPIPE Code.

The computer program, EPIPE, is a completely verified, full feature, finite element piping code. It permits the static analysis of piping systems subjected to gravity, concentrated loads, thermal expansion, pressure and anchor/supports moment loads. EPIPE incorporates additional options to allow dynamic analysis via the response spectrum method, time history method using modal superposition, and the time-history method using direct integration. For all analysis options, it performs stress evaluation in accordance with accepted engineering formulae.

EPIPE is serving as the backbone for a more sophisticated and useful program called PSAFE2. Eventually, PSAFE2 will incorporate the features of EPIPE and serve as the primary computer code for static and dynamic analysis. PSAFE2 was developed to verify applicant compliance with ASME Code Criteria, a feature not available in EPIPE. In addition, PSAFE2 allows for analysis of piping systems on a production basis. PSAFE2 performs stress evaluations of ASME class 2 and class 3 piping in accordance with the appropriate ASME criteria, and allows the evaluation of systems subjected to multiple support excitation. The code is continually modified to expand its capabilities and to comply with the benchmark problem development needs as defined by NRR. Continuing verification of the codes is accomplished through their use in developing confirmatory problem solutions to assess the acceptability of applicant solutions and analysis methods.

RECOMMENDATIONS

The benchmark problems should be incorporated into the licensing procedure. Each applicant for a nuclear power plant license should be required to solve the benchmark problem set using its computer programs. NRC evaluation of these results will verify the applicant's methods.

The elastic analysis code, EPIPE, should be used to perform independent evaluations and confirmatory analyses of selected applicant problems. These evaluations will further verify the applicant's computer programs while also serving as a check on applicant implementation.

CONCLUSIONS

The benchmark problems developed to date have a restricted range of application. They can only verify the accuracy of the analytical solution of computer programs used for the seismic analysis of linear elastic piping structures subjected to uniform support motion and evaluated using the response spectrum method of analysis. A future set of benchmark problems will be developed to extend the range to evaluation of linear elastic piping structures using time-history methods, and also, independent multiple support excitation reponse spectrum methods. In addition, major efforts are underway to extend the benchmarks to assess the degree of applicant compliance with ASME criteria for both class 1 piping in accordance with ASME-Boiler and Pressure Vessels Code, Section III, Subarticle NB-3600, and class 2/3 piping in accordance with ASME, Section III, NC/ND-3600. The information, results, and recommendations reported in this RIL were reviewed for appropriateness and application to the licensing process by the cognizant NRR techincal monitor for this program.

Robert B. Minogue

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cc: T. E. Murley, DST
G. Knighton, RSCB

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Record Note: This RIL was fully coordinated with Dr. M. Hartzman the NRR Technical Monitor for the Piping Benchmark Program. Revisions reflecting Dr. Hartzman's comments were incorporated.
**See attached yellows for concurrences.

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SUMMARY

A set of benchmark problems and solutions has been developed for verifying the adequacy of computer programs used for dynamic analysis and design of nuclear piping systems by the Response Spectrum Method. The benchmark problems cover a wide range of configurations and are assumed to experience linear elastic behavior. The dynamic loading is represented by uniform support motion assumed to be induced by seismic excitation in three spatial directions. The solutions provide frequencies, participation factors, nodal displacement components and internal force and moment components.

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