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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

MAINE YANKEE ATOMIC POWER COMPANY
MAINE YANKEE ATOMIC POWER STATION
DOCKET NO. 50-309

Introduction

On March 13, 1979 the Commission issued an Order to Show Cause to Maine Yankee Atomic Power Company (licensee) requiring that Maine Yankee (facility) be placed in cold shutdown and the licensee show cause:

(1) Why the licensee should not reanalyze the facility piping systems for seismic loads on all potentially affected safety systems using an appropriate piping analysis computer code which does not combine loads algebraically;

(2) Why the licensee should not make any modifications to the facility piping systems indicated by such reanalysis to be necessary; and

(3) Why facility operation should not be suspended pending such reanalysis and completion of any required modifications.

The licensee's response to the Order, dated April 2, 1979, stated that all affected safety systems have been reanalyzed using an appropriate piping analysis method, and that no modifications are necessary as a result of these reanalyses. Therefore, the licensee requested that the Order be modified or rescinded such that the facility could be restarted. In support of this request the licensee provided information by letters dated April 2, 3, 12, 13, 19, 27 and May 2, 4, 5, 15 and 18, 1979. In the letter of April 13, the licensee indicated that two piping restraints needed to be modified as a result of the reanalyses to account for base plate flexibility. On April 19, the licensee reported that these modifications had been completed.

Discussion

The Stone and Webster (S&W) PSTRESS/SHOCK 2 computer code for pipe stress analyses sums earthquake loadings algebraically and is unacceptable for reasons set forth in the March 13, 1979 Order to Show Cause. This code was used in the seismic analyses of certain safety and nonsafety related systems at the facility. The licensee has identified the seismically analyzed (Seismic Category I) systems at the facility including those analyzed with SHOCK 2. It has also identified the other methods of seismic analysis used for other Seismic Category I systems. Furthermore, the licensee has summarized the results of the reanalyses of SHOCK 2 safety systems and has provided support for the acceptability of the analysis methods used on the remaining Seismic Category I systems.

We have evaluated the facility's safety related systems, the results of seismic reanalysis, and the methods of pipe stress analysis currently in effect for the facility.

Evaluation

1. Systems

The licensee has stated that the response to Question 1.3 of the Maine Yankee Final Safety Analysis Report (FSAR), submitted February 9, 1971, is the complete list of structures, systems and components that were designed to the Seismic Category I requirements.

Verification has also been provided by the licensee that the Seismic Category I piping systems identified in response to Question 1.3 of the Maine Yankee FSAR include all of the piping systems required to assure:

(a) The integrity of the reactor coolant pressure boundary;

(b) The capability to shutdown the reactor and maintain it in a safe shutdown condition; and

(c) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposure of 10 CFR Part 100.

Portions of the following systems were identified by the licensee as having been either analyzed with SHOCK 2 or analyzed by static seismic methods which were verified by SHOCK 2.

High Pressure Safety Injection
Residual Heat Removal
Containment Spray
Low Pressure Safety Injection
Primary Component Cooling Water
Steam Generator Feedwater
Chemical and Volume Control
Primary Vents and Drains
Waste Gas Disposal
Boron Recovery
Fuel Pool Cooling
Fire Protection
Auxiliary Steam
Auxiliary Condensate Return
High Pressure Drains (Secondary)

A total of 39 SHOCK 2 analyses (Computer runs) were performed. Piping associated with these analyses and the methods of reanalysis are identified in Enclosure 1 to this Safety Evaluation (SE).

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Nineteen of these 39 analyses have been identified by the licensee as pertaining to safety related piping. We have reviewed the information submitted and agree with the licensee's identification of piping which is safety related. The licensee has completed the reanalysis of all 39 SHOCK 2 analyses.

2. Verification of Analysis Methods

We have reviewed the acceptability of the analytic methods which are currently a basis for the facility piping design. The licensee has identified the following computer codes/analysis methods as applicable:

PSTRESS/SHOCK 1 (4 Versions - Initial 3 Versions sometimes referred to as SHOCK 0)

STRUDL - SHAKE (Combustion Engineering)

Static Analysis Methods

PSTRESS/SHOCK 3

NUPIPE - SW

PSTRESS/SHOCK 1

The licensee has identified four (4) versions of the PSTRESS/SHOCK 1 computer code. Documentation on only the last version of this code was available for our review.

The licensee has stated that this version of SHOCK 1 combines the intermodal responses by the so-called "Navy Method". This consists in taking the largest absolute modal response and adding the root-mean-square value of all other modal responses. Intramodal responses due to multi-directional earthquake excitation were not calculated since the code only produced responses parallel to a given earthquake component excitation (i.e., the responses were considered uncoupled). A review of the code listing has confirmed these statements.

Some safety systems of the facility were analyzed with each of the four versions of the SHOCK 1 Code. Because this computer code only considers one direction earthquake excitation, it is not considered equivalent to current analysis techniques. A comparison of the results of each of the four (4) versions of PSTRESS/SHOCK 1 and the NUPIPE Code was conducted by the licensee using "typical" piping problems. The problems consist of different size piping, elbows, tees and reducers. The licensee reported that the general stress distribution of both codes was similar and PSTRESS/SHOCK 1 gave comparable results. The licensee concluded that although the PSTRESS/SHOCK 1 is not equivalent to current practice, it is suitably conservative to insure that the piping systems meet the allowable stress levels.

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By letter dated May 10, 1979, the licensee informed us that a listing of an early version of the Shock 1 program had been found. This listing indicated that the method of computing natural frequencies may be incorrect. Subsequently, it was determined that the listing found was a nonproduction developmental predecessor to Shock 1 which was not used at Maine Yankee. A review of the latest version of Shock 1, for which there is a listing, has shown that frequencies are computed correctly. Nevertheless, methods of computing natural frequencies in the first three Shock 1 versions (now known as Shock 0) used at Maine Yankee may have been similar to the methods in the developmental listing. (Shock 0 was used to analyze approximately 76 piping problems and Shock 1 was used to analyze approximately 10 piping problems.)

The licensee has reviewed the effects of the incorrect frequency methods. The licensee has determined that although random shifts in natural frequencies and mode shapes are noted, the previous comparative analyses, Shock 0 to Shock 1 and Shock 0 to NUPIPE-SW, include these effects and are the most valid indication of Shock 0 code acceptability. These comparative analyses show that Shock 0 produces stress results consistent with accepted programs and provides assurance that the FSAR criteria are met. Based on its review the licensee concludes that the studies and reanalyses performed to date demonstrate that the Seismic Category 1 piping is conservatively designed to withstand the effects of the design basis earthquake.

We have reviewed the piping configuration and results of the comparative analyses of NUPIPE and each version of the SHOCK 0 code and the SHOCK 1 code. We have determined that the problems analyzed produce representative comparisons. We have also determined that although SHOCK 1 and SHOCK 0 are not equivalent to current practice, the resulting stresses are at least consistent with the results as obtained from NUPIPE and in many cases are conservative. In addition the code comparison did not take credit for the alternative application of the "Robinson Fix" (i.e., adjusting the response spectra peak instead of increasing all analysis results) which would provide additional conservatism to the SHOCK 1 and SHOCK 0 stresses in this comparison (The "Robinson Fix" was described in Amendment 35 to the Maine Yankee FSAR). Therefore, we conclude adequate assurance has been provided that systems analyzed with SHOCK 1 and SHOCK 0 will withstand the design basis earthquake.

All Shock 0 analyses subjected to the comparison (10 Shock 0 problems compared to Shock 1 of which 3 were further compared with NUPIPE) show resultant seismic stresses within FSAR allowables. This provides assurance that the frequency computation method of Shock 0, although potentially incorrect, does not have a significant adverse affect on the Shock 0 stress results. As noted in the comparative analyses however, the natural frequency and mode shape changes between the versions of Shock 0 and codes known to compute natural frequencies correctly are random in nature. Therefore we conclude that additional comparisons, to verify that the remaining Shock 0 analyses stress results are within FSAR allowables when reanalyzed using an acceptable program, should be performed. By letter dated May 18, 1979 the licensee committed to reanalyze all remaining Shock 0 analyses with NUPIPE-SW and provide the results to the NRC staff within 60 days of facility restart. We find this further verification program and schedule acceptable.

STRUDL - SHAKE

The licensee has provided the following description of the analysis technique used by Combustion Engineering (STRUDL - SHAKE Code):

"The dynamic seismic analysis of the reactor coolant system main loop and pressurizer surge line piping was performed utilizing 3 dimensional mathematical models subjected to unidirectional support motion response spectra. The six components of force or moment at a particular piping location were determined separately for each significant mode of response for a single direction of excitation. The separate modal responses for each component of force or moment were then combined on a root-sum-square basis to define the total force or moment response to a single direction of excitation. The loads due to each horizontal earthquake were added, manually, to the loads due to the vertical earthquake by the absolute sum method. The larger of the two loads thus calculated was employed in the stress analysis of the piping system."

We have reviewed the analysis technique of Combustion Engineering. The procedures are in compliance with the plant FSAR and conservatively combine (absolute sum) both the spatial components from each of two independent earthquake directions and the contribution of each mode (SRSS). We find this technique acceptable.

Static Analysis

Some of the safety related systems at the facility were analyzed using static analyses techniques. The licensee submitted documentation (letter dated April 12, 1979) detailing the basis for static analysis technique use in the design. Generally piping 6 inches in diameter and smaller was designed using the static methods unless the criteria for support placement could not be met, then a more rigorous dynamic analysis was performed. Some piping larger than 6 inches in diameter was analyzed using the static methods if the geometry and support configurations were sufficiently simple to make the static analysis methods practical. The major constraint on applying static methods to larger piping was one of economics in that a dynamic analysis typically would result in fewer restraints at a more optimum spacing and supports for larger piping were sufficiently more costly to warrant less conservative but more expensive analysis techniques.

The analysis technique used at the facility is outlined in Amendment No. 35 to the FSAR and the procedure was submitted in detail in the report, "Non-dynamic Seismic Analysis of Piping and Supports by Stone & Webster at Maine Yankee" submitted April 12, 1979. The procedure states that the piping frequencies will be designed to be a minimum of 1.5 times the peak resonant frequency of the amplified response spectra by locating seismic supports at appropriate span lengths. Orthogonal responses will be decoupled by including supports at elbows, tees and concentrated masses. The piping systems were designed considering a horizontal static load of (1.3) X (22 X peak ground acceleration) acting concurrently with a vertical static load equal to two-thirds the horizontal value. The method of equivalent analysis outlined in this procedure has been reviewed against the NRC's Standard Review Plan 3.7.2 and is acceptable.

PSTRESS/SHOCK 3

The licensee has stated that in this code the intramodal responses are calculated by adding the absolute value of the responses due to the vertical earthquake component to the root-mean-square of the responses due to the two horizontal earthquake components. The intermodal components are calculated by the root-mean-square method. A review of the code listing has confirmed these statements. A confirmatory analysis was performed by an NRC consultant, Brookhaven National Laboratory (BNL), of a typical piping design problem in the Maine Yankee plant. A problem (no. 803) has been submitted by S&W together with the corresponding solution obtained by using PSTRESS/SHOCK 3. This problem has been analyzed by BNL using a different code (EPIPE), and the results have been submitted to the NRC staff.

A comparison of the solutions indicates that various quantities of interest such as frequencies, displacements, forces, and stresses, appear to differ by not more than 10%.which is within the accuracy of the analyses. In addition, hand calculations were performed with the PSTRESS/SHOCK 3 results as a check on the modal combination methods. We find that the S&W results have been adequately confirmed by BNL and are therefore acceptable.

NUPIPE - SW

The licensee has stated that this code calculates intramodal and intermodal responses according to the provisions in Regulatory Guide 1.92. A review of the code listing by the staff has confirmed this to be the case. Additional documentation has also been submitted by the originators of this code (Nuclear Services Corporation) providing detailed information on the methods of modal combinations. This information has been reviewed and also provides reasonable confirmation of the statements made by the licensee. A confirmatory analysis has also been performed by our consultants on the piping problem listed above. A comparison of the solutions again indicates that the various quantities of interest listed above again differ by not more than 10%. Therefore, the use of this code is acceptable.

3. Reanalysis Methods and Results

The safety related piping systems at the Maine Yankee nuclear plant have been reviewed to determine the method of analyses. Nineteen (19) computer stress problems of safety related piping have been identified where the analysis used an algebraic intramodal summation of responses to earthquake loadings. The problems where an algebraic intramodal response combination technique was used in the design have been reevaluated using the criteria in the FSAR. The reevaluation included a static analysis technique, and a dynamic computer analysis using either the PSTRESS/SHOCK 3 or NUPIPE programs.

A static analysis technique was employed for reanalysis of some lines 6 inches in diameter and smaller. The static design procedure is outlined in a report titled "Non-dynamic Seismic Analysis of Piping and Supports by Stone & Webster at Maine Yankee" submitted April 12, 1979. The acceptability of this procedure has been discussed in Section 2 of this SE.

The dynamic analysis technique incorporated a lumped mass response spectra modal analysis using the PSTRESS/SHOCK 3 or NUPIPE programs. The floor response data used in the reanalysis included the "Robinson Fix" criteria.

The "Robinson Fix" criteria required the peak resonant frequency acceleration values to be a minimum of (22) x (peak ground acceleration) and the peaks to be broadened by $\pm$ 10% of resonant frequency. The piping systems were modeled as three dimensional lumped mass systems which included considerations of eccentric masses at valves and appropriate flexibility and stress intensification factors. The dynamic analysis procedures meet the criteria specified in the plant FSAR and are acceptable.

The piping support designs for affected system piping were inspected by the licensee to verify the "as built" configuration. As noted in NRC Inspection Report 79-05 issued April 12, 1979, differences were found to exist between the "as built" configuration and the support drawings. The differences noted resulted from the use of drawings which had not been updated to include installation changes. Subsequently the licensee has verified that updated drawings which do reflect the supports as installed, were used in the support design calculations.

The support designs were reevaluated in cases where the original support design loads were exceeded as a result of piping reanalysis. The support reevaluation included the consideration of local stresses at regions of discontinuity and base plate flexibility considerations. Modification

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of two supports was determined to be necessary to account for base plate flexibility. These modifications consist of adding a stiffener to the base plate of each hanger and have been completed.

Loads on attached equipment nozzels were also checked and verified to be either below the initial allowable values or verified by the equipment manufacturers to be acceptable.

The design and analysis of the supports and attached equipment are in accordance with the criteria specified in the plant FSAR.

The pipe break criteria for Maine Yankee were reviewed and determined not to be altered by this reanalysis. Pipe break considerations were required for High Energy Lines outside of the containment structure and break locations were determined by inspection and their proximity to safety related systems. The pipe break considerations are outlined in a report titled "Supplementary Report on Effects of a Postulated Break in a High Energy Piping System Outside the Containment" dated September 1973.

The piping systems and supports were designed to the allowable limits of ANSI B31.1 for the gross properties and to the limits of ANSI B31.7 Appendix F for local stress considerations per the FSAR criteria.

The safety related piping systems, supports and attached equipment, where the original analysis used an algebraic intramodal response summation technique, have been reanalyzed with acceptable methods which do not use an algebraic intramodal response technique. The procedures used in the reanalyses and their results have been reviewed against the criteria in the plant FSAR and found acceptable.

As a separate but related matter, the staff has also reviewed the inherent seismic conservatisms in the facility design. Methods of analysis, material properties, actual earthquake characteristics, construction practices and actual seismic experience were considered. The NRC staff has concluded that the facility could withstand earthquake ground motion in excess of that to which the facility was originally designed. The NRC will be further considering the issue of seismic design capability of all operating reactors within the next few months. That effort will further examine the seismic design capability of Maine Yankee. That effort will also assist the staff in determining whether additional seismic reevaluation is needed at any operating facility

Conclusion

The licensee has demonstrated that PSTRESS/SHOCK 2 is the only method of analysis used for the facility's safety related systems which combines seismic loads algebraically. Safety related systems analyzed with Shock 2 have been reanalyzed with an acceptable dynamic code or with static analysis techniques as permitted by the FSAR criteria. The results of these reanalyses have shown that the subject systems will withstand the design basis earthquake.

The reevaluation of supports performed by the licensee for the subject piping considered base plate flexibility. As a result stiffeners were added on two supports in the containment spray system.

We reviewed the acceptability of the analysis techniques which are currently a basis for the facility's piping design. We have determined that the application of these techniques, at Maine Yankee, assures that safety related systems can withstand the design basis earthquake and that there is reasonable assurance that the facility can operate without endangering the health and safety of the public.

Based on the above, we conclude that the requirements of the Order have been met for Maine Yankee and therefore the Order and its restriction on facility operation should be terminated.

Dated: May 24, 1979

MAINE YANKEE
SHOCK II REANALYSIS - MASTER LISTING

Enclosure

ITEM. #	ANAL #	CAS#. SA-	PRTY.	DESCRIPTION	LINE NUMBERS	NSK #	FM #	FP #	RESOLUTION
1	16A	10	1	CHARGING PUMP RCHST SUCTION	10"-CH-1	125A11.	31B	14	RERUN - SHOCK III
2	16B	10	1	CHARGING PUMP RCHST SUCTION	10"-CH-2	125A11.	31B	14	RERUN - SHOCK III
3	803	21	1	RESIDUAL HEAT REMOVAL SUCTION	12"-RC-29 / 14"-RH-1	107B	30A&32A	16	RERUN - SHOCK III
4	795-	24	1	CONTAINMENT SPRAY & LOW HEAD SAFETY INJECTION SUCTION	10"-CS-11&12 16"-CS-13&14&40 14"-CS-15&16&17 16"-RH-3&4	110G	32A	16&17	RERUN - SHOCK III (ORIGINAL HAS PART SHOCK I)
5	720	25	1	PRIMARY COMP COOLING SUCTION	20"-PCC-17 16"-PCC-18&19	117E	34A	20	RERUN - SHOCK III
6	70	17	1	RHR SUCTION SAFETY VALVE PPG	4"-RH-2&35 3"-DRL-199&200	146A	30A&32A	13&16	RERUN - SHOCK III
7	126	12	2	RCHST HEATER RETURN LINE	4"-PL-22	130A	32A	6	NEW HAND CALC
8	127	12	2	RCHST HEATER INLET LINE	2"-PL-21	130A	32A	6	NEW HAND CALC
9	134	12	2	DEMIN WTR STOR TK HTR RETURN	3"-HCPR-6	130A	12A	6	NEW HAND CALC
10	LN #	12	2	DEMIN WTR STOR TK HTR INLET	1.5"-HCPR-5		12A	3&6	NEW HAND CALC
11	11	15	2	NORMAL CHARGING LINE	3"-CH-61	132A	31A	9&14	RERUN - NUPIPE
12	142	19	2	SEAL WATER INJECTION HEADER	3"-CH-56	125A	31A	10&14	RERUN - NUPIPE
13	LN #	20	2	PCCW TO PRESSURIZER QUENCH TANK COOLER	1.5"-PCC-161		34A	20	NEW HAND CALC
14	77	31	2	PCCW HEADER TO COOLANT DEGAS-IFIER COOLER & CONDENSER	3"-PCC-34		34A	20	NEW HAND CALC
15	LN #	36	2	PCCW HEADER TO RAD WASTE HX	6"-PCC-47	117J	34A	20	RERUN - NUPIPE
16	LN #	36	2	PCCW TO WASTE EVAP CONDENSER	3"-PCC-56	117J	34A	20	RERUN - NUPIPE
17	LN #	36	2	PCCW FROM CHG PP SEAL LUG CLR	1"-PCC-307		34A	20	NEW HAND CALC
18	LN #	33	2	PCCW TO WASTE EVAP DISTIL CLR	1"-PCC-58		34A	20	NEW HAND CALC
19	LN #	36	2	PCCW FROM BORON RECOVERY EVAP	1.5"-PCC-117		34A	20	RERUN - NUPIPE

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MAINE YANKEE
SHOCK II REANALYSIS - MASTER LISTING

ITEM #	ANAL #	CASE SA-	PRTY.	DESCRIPTION	LINE NUMBERS	NSK #	FH #	FP #	RESOLUTION
20	73	29	3	FUEL POOL COOLING HEADER	6"-FP-6	137A	36A	19	NEW HAND CALC
21	12A	30	3	WASTE GAS COMP TO SEAL LIQ SEP.	1.5"-GR-17		39A	23	RERUN - NUPIPE
22	124	30	3	DEGAS FEED EFFL HX TO PREHEAT	2.5"-BRG-11	139A	39A	23	RERUN - NUPIPE
23	128	30	3	HYDR WASTE GAS HDR FROM PDT	3"-VRL-7		33A&B	24	RERUN - NUPIPE (W/ 2"-VRL-7)
24	129	30	3	VOL CONT TK SAFETY VALVE DISCH.	6"-VRL-4		33A&B	24	RERUN - NUPIPE
25	130	30	3	HYDR WASTE HDR TO PRIM DNS TK	3"-DRL-31		33A&B	24	RERUN - NUPIPE
26	336	30	3	SEAL LIQ SEP DRAIN LINE	3/4"-DRL-135		33A&B	24	NEW HAND CALC
27	140	30	3	DN HDR FROM WASTE GAS TANKS	1.5"-DRL-132		33A&B	24	RERUN - NUPIPE
28	400	12	4	AUX COND FROM SEAL WATER HTR	1"-HASD-44	136A	41A	4	RERUN - NUPIPE
29	402	12	4	AUX STEAM TO SEAL WATER HTR	2"-SA-72	136A	11A	4	RERUN - NUPIPE
30	135	12	4	NAOH FILL TO SPRAY CHEM ADD TK.	2"-CT-3	130A	32A	6	RERUN - NUPIPE
31	136	29	4	TO BORON WASTE STOR TK HEATER	2"-BR-10	120N	37A	16	RERUN - NUPIPE
32	137	29	4	BORON WASTE STORAGE TK (BWST) TO LIQUID WASTE PUMPS	3"-BR-2	120A	37A	16	RERUN - NUPIPE
33	139	29	4	WASTE DEMIN POST FLTR TO BWST	3"-BR-1	120A	37A	10	RERUN - NUPIPE
34	123	30	4	SEAL LIQ SEP TO DECAY DRUMS	1.5"-GR-8		39A	23	NEW HAND CALC
35	123	30	4	BORATED WASTE LIQUID	2.5"-BRG-12	139A	39A	23	RERUN - NUPIPE
36	125	30	4	BORIC ACID MIX TK DRN TO SUMP	2"-DRL-6	134A	33A&B	24	RERUN - NUPIPE
37	74	31	4	HIGH PRESS HTR DRN PUMP DISCH	16"-HHPD-112		26A	41	RERUN - NUPIPE
38	72	36	4	FIRE PPG RELIEF VALVE LINE	10" FIRE PPG, RV LINE.		N/A	FB-3A	RERUN - NUPIPE
39	LN #	36	4	BORON RECOVERY EVAPORATER DISTILLATE COOLER TO ACCUMULTR.	2"-BED-1	120A	37A	10	RERUN - NUPIPE

* - PRIORITIES: 1 - SAFETY RELATED PIPING FOR WHICH COMPUTER RUN SUMMARY NSK'S WERE ISSUED (GENERALLY, PIPING > 6")
2 - SAFETY RELATED PIPING <= 6"
3 - NON-SAFETY RELATED PIPING <= 6", IDENTIFIED BY YANKEE ATOMIC ELECTRIC CO. (3-31-79) AS NEXT GROUP TO BE REDONE
4 - NON-SAFETY RELATED PIPING, LAST GROUP TO BE REDONE

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