PROBLEMS OCCURRING IN NUCLEAR PIPING SYSTEM ANALYSIS AND OPERATION

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SUMMARY

In the development of new criteria for the design of piping systems, many problems have arisen both in analysis and operation. This paper will deal with these problems and demonstrate that the majority of the operational incidents can be traced to design inadequacies of one form or another.

In the analysis area the new design criteria (i.e., ANSI-B31.7 and ASME BPVC SC III) have imposed heavy burdens on the standard piping design organizations. These can be divided into two distinct categories:

1. Lack of manpower;
2. Inadequacies in the area of stress analysis.

The first item will be discussed with respect to the relative differencies between staffing and cost requirements for an ANSI-B31.1 plant and an ASME BPVC SC III plant. The second item will discuss the new knowledge and expertise which must be brought to bear in performing piping analysis to the new criteria. Areas discussed will be calculation of temperature distribution, understanding stress indices and what they represent, seismic analysis, force-time history analysis, and fatigue evaluation. This discussion will not deal with the analytical derivations of the solutions to these problems but rather with the impact of these requirements on the piping industry and the necessity for the piping designer to be knowledgeable in these areas.

Some comparisons of ANSI-B31.1 solutions to ASME BPVC SC III solutions will be made specifically pointing out areas which can create problems. Specific examples of systems which were acceptable under one or the other criteria will be shown to be unacceptable when the requirements are reversed.

Throughout the discussion on analysis specific emphasis will be placed on the Design Specification and how weakness in that document can lead to increased costs and potential design problems.

Some examples of incidents which have occurred in piping in the operation of nuclear power plants will be discussed. The paper will demonstrate how all of the examples used could have been prevented if proper specification of conditions, adequate analysis, and engineering controls were used.

1. Introduction

The impact of new criteria ANSI B31.7 (1) and ASME BPVC Section III (2) for design of piping systems for nuclear power operation has been extremely severe. By comparison, the vessel industry, which certainly had its problems, was faced with a much easier task in adapting the design rules of Section III, 1965 due to their experience with similar criteria for U. S. Government projects. The piping designer was not as fortunate since U. S. Government regulations for piping did not embrace the design philosophy of Section III and hence no experience was gained.

In many cases, the knowledgeable piping designer was used to fill the gap, became overloaded, and was not available to consider the everyday problems associated with routing a pipe, supporting it, and insuring the system would survive imposed operating conditions.

Certainly, there will be exceptions to some of the procedures discussed in this paper; but, in the author's opinion, the discussion reflects the majority of the industry.

2. Manpower and Cost

2.1 Fossil-Fuel Power Plant

The manpower and cost requirements related to piping analysis of a fossil fuel plant were so small that their effect on the architect-engineer (AE) cost and man hours was insignificant. The piping layout man had at his disposal a number of nomographs and standards that assisted him in laying out a piping system which usually had considerable flexibility and easily met the requirements of ANSI B31.1 (3). In these cases the analysis effort was quite often only meaningful with respect to decreasing the amount of pipe (therefore reducing material costs) and to provide deflection information for the hanger supplier. The responsibility for support of the system was usually sub-contracted to a hanger manufacturer who, using the flexibility analysis supplied by the AE, located, selected, and detailed the support system. The submittal of a formal stress report is not required by B31.1 and therefore the only records of analysis were retained by the AE. A fair estimate of analysis work required for a fossil fuel plant is 2,500 man hours.

One can see, therefore, that the analyst was not in a dominant position with respect to production, control of design, and interface with fabricators. This situation changes dramatically when one discusses a nuclear plant.

2.2 Nuclear Power Plant

It is becoming increasingly obvious that the work of the piping analyst is having a significant effect on many areas of the plant design in Nuclear Power. The analyst is in a much more dominant position than for a Fossil Plant with respect to production, control of design, and interface with fabricators. The reasons for this will be discussed in detail in Section 3 of this paper. It then follows, that the manpower and cost for piping analysis in a Nuclear Power Plant are significant with respect to total engineering dollars.

Just in the areas that are familiar to the B31.1 analyst (i.e. weight, flexibility, and earthquake), significant cost increases are apparent. The AE is significantly involved in hanger selection and design and is required to make appropriate analyses rather than relying on the hanger supplier. With respect to flexibility calculations, it is often necessary to run many more conditions than merely the worst stress conditions in order to obtain the necessary moments for stress evaluation. The earthquake loading (if it was considered in a fossil plant) is no longer treated as a static "G" analysis but rather as a modal analysis with applied spectra. These differences themselves result in sharply increased manpower.

and costs.

Added to this are the requirements of calculating temperature values for the purpose of fatigue evaluation, the fatigue evaluation itself, and the analysis for various dynamic loadings resulting from valve operations, pumping, postulated pipe break, etc.

The number of man hours required to fulfill all the pipe analysis obligations on a nuclear plant can run from 15,000 to 30,000. Added to this are computer costs in the range of $60,000 to $120,000. It is hoped that some reduction will come as the industry gains experience and can automate some of the analyses. However, experience tells us that new analysis requirements are continually generated and the dollars saved in efficiency are chewed up quickly. Some examples which come readily to mind are the postulated pipe break analysis requirements and the new analysis rules for component supports which will become a part of Section III. It would appear then that we can rely on manpower requirements of the order presented above for some time.

A comparison of analysis effort for a fossil versus nuclear plant is given in Table I. Table II provides ratios of estimated man hours between a fossil and nuclear plant for a complete analysis and some selected systems.

3. Stress Analysis Requirements

3.1 General

The imposition of new analytical requirements has been alluded to above. The following will discuss these in greater detail and point out the influence of the piping analyst in areas where one would not consider his input for a fossil plant.

3.2 Weight

The calculations of stresses resulting from weight loading have often been neglected in the past. The usual technique (as outlined in Table I) was to use the hanger spacing tables, which have been a part of Piping Codes for some time, or some simple beam analysis. With respect to the failure of a pipe due to dead loads, this was a reasonable approach. However, when one must combine the moments generated by the weight of the system with loads resulting from other sources, it becomes necessary to perform a detail analysis.

Since most flexibility programs in use today have the capability of calculating loads and stresses as a function of distributed and concentrated dead loads, this item does not appear, on the surface, to be a considerable increase in the analytical effort. Consider, however, the situation where an AE firm had been subcontracting hanger location and support to a hanger supplier. This now means the AE must begin locating and selecting supports as well as performing a weight analysis. There can be considerable man hours spent selecting locations for supports, particularly where there is not an abundance of structural steel (i.e. inside containment).

3.3 Flexibility

In the case of flexibility, the analyst is faced with considering more conditions than he would for a fossil plant. This also does not appear to be a significant manpower increase since one merely runs more computer cases. However, the real problem is associated with data extraction and manipulation. The more cases run, the more data to be reviewed and handled. This is the first area where a computer program can be cost effective. The use of the computer to store and manipulate the moments will substantially reduce manpower requirements and errors.

3.4 Seismic Analysis

This is the first area we have discussed which represents major problems and cost increases with respect to the analysis and design of nuclear piping. For the fossil plant piping, seismic analysis was usually not performed. When it was required, a static "G" analysis was normally used.

For nuclear piping, however, it is necessary to perform a dynamic analysis of all Seismic Category 1 piping. (This usually includes most Nuclear Class 1 and 2 systems.) The technique used by most people today is modal analysis with an applied spectra that has been developed for the building and/or equipment to which the piping is attached. In addition to the extensive manpower requirements to do this work, there are a number of procedural problems for which little if any guidance has been given to the individual analyst. A discussion of these seem in order.

3.4.1 Seismic Spectra

The spectra which the analyst receives usually is presented in the form of acceleration versus frequencies with acceleration peaks occurring at certain frequency values. This is represented as a solid line in Figure 1. The spectra is the result of a statistical approach, some modification of this curve should be made to cover minor differences between actual and calculated natural frequencies. A typical modification would be to provide plateaus at all peaks by applying the peak accelerations over a frequency range of + and - 10% of that specified. This type modification appears as a dash line in Figure 1. This situation may appear quite minor on the surface but when one investigates the approach used in the industry, one does not find complete consistency, for example, is 10% the value to use.

For a piping system which is connected to more than one piece of equipment or different elevations in the building, another problem arises. The analyst is faced with a number of different spectras for each piece of equipment and each building elevation. How does he combine these to arrive at a single spectra to apply to the system under investigation? A number of approaches can and have been used:

1. Use the spectra with the maximum peaks;
2. Add the spectra directly;
3. Envelope the spectra so that the applied spectra includes the peaks at all frequency levels for all applicable spectra.

Each of these approaches gives significantly different results with Approach 1 and Approach 2 the limiting cases and Approach 3 perhaps the most reasonable.

Consider the situation of split responsibility with respect to engineering. One firm is responsible for the main coolant piping and another for the piping that is attached. (The Safety Injection System, for example.) If the firm responsible for the main piping does not develop spectra for the locations of piping attachments (local spectra), a dilemma results. The analyst responsible for the connected piping does not have a local spectra to apply. The best he can do with the information available under this circumstance is use the spectra applied to the main coolant loop in his dynamic analysis and take the local deflections obtained from a spectral analysis of the main coolant pipe, run a static case, and add the moments to those obtained from the dynamic analysis. This may not be conservative due to the failure of the approach to truly represent amplification of the deflections. The ideal situation is to have the connecting pipe included in the dynamic model of the main coolant pipe. Failing this, the next best approach is to develop local spectra for all connecting piping not included in the main model.

The major problem encountered with application of the various approaches suggested above is that the results are significantly different. The same geometry, with identical spectra applied in various manners discussed above, would result in significant differences in the number of restraints and snubbers required to maintain stress levels at allowable values. This certainly doesn't make engineering or economic sense.

We have really addressed two problems here. The first being the dramatic increase in man hours and technology that is necessary to perform the required seismic analysis of nuclear plant piping. The second is, that having assembled the technology and manpower, one still finds a divergence of approaches available.

A major step under the sponsorship of ASME is underway to correct the lack of standardized techniques for dynamic analysis. A special Task Force working under the auspices of ASME BPVC, Section III, is presently preparing standard (but non-mandatory) techniques for performing seismic analysis.

3.4.2 Seismic Moments

The same problem of divergence of approaches exists when one considers seismic moments. There are two basic techniques used to combine the modal moments to arrive at a moment value in a given direction; the are:

1. Absolute sum
2. Root mean square

In the first case (absolute sum) the value of the moments in a given direction (for example M_x) in each mode shape are added absolutely. In the second case (root mean square) the square root sum of the squares of the moments in a given direction for all mode shapes is found. The difference here is obvious.

A second problem arises when one considers directions of spectral input. Since the analyst is supplied with a spectra for two horizontal directions and one vertical direction to represent a given earthquake, he must somehow combine the loadings from the cases analyzed to find the value for the specific earthquake. Again, two techniques have been prevalent in the industry to date:

1. Adding the worst horizontal (X or Z) to the vertical (Y), X + Y or Z + Y;
2. Finding the resultant horizontal value ($\sqrt{X^2 + Z^2}$) and adding it to the vertical (Y), $\sqrt{X^2 + Z^2} + Y$.

These two techniques can be expressed mathematically as follows, considering M_x value only and using the root mean square technique:

TECHNIQUE 1

X + Y Response

Z + Y Response

$$M_{x_i} = \sqrt{\Sigma_{j=1}^{N} (M_{x_{ij}})^2_X} + \sqrt{\Sigma_{j=1}^{N} (M_{x_{ij}})^2_Y}$$

$$M_{x_i} = \sqrt{\Sigma_{j=1}^{N} (M_{x_{ij}})^2_Z} + \sqrt{\Sigma_{j=1}^{N} (M_{x_{ij}})^2_Y} \qquad (1)$$

TECHNIQUE 2

$X^2 + Z^2 + Y$ Response

$$M_{x_i} = \left(\left(\sqrt{\sum_{j=1}^{N} (M_{x_{ij}})^2_X}\right)^2 + \left(\sqrt{\sum_{j=1}^{N} (M_{x_{ij}})^2_Z}\right)^2 \right)^{\frac{1}{2}} + \sqrt{\sum_{j=1}^{N} (M_{x_{ij}})^2_Y} \qquad (2)$$

In the case of a piping run which does not lie along the axis of the applied spectra (X or Z), Technique 1 (X + Y or Z + Y) is unconservative when compared to Technique 2 -($\sqrt{X^2 + Z^2}$ + Y).

In all this discussion concerning seismic analysis, it should be obvious that a criteria is not all that is needed. Additionally, one needs a cadre of talented piping people in the planning, specification, and analysis areas. The input of the piping designer, who is knowledgeable enough to recognize the problems that will be faced, is of utmost importance at all levels and during all phases of a given project.

3.5 Temperature Distribution

3.5.1 General

This is the second area where major costs are incurred in satisfying the analysis requirements for nuclear piping. Section III, NB-3650 requires that specific values of temperature differences be generated for each condition to which the piping system is subjected. Without going into detail concerning the definitions, the specific values to be generated are ΔT_1, ΔT_2 and $T_a - T_b$.

A number of approaches may be used to generate these quantities and they shall be discussed below. First, the most important point is to understand the effect of these values on the pipe. How does the pipe wall respond to these temperature distributions and how can this response contribute to fatigue? Again the vessel industry or the professional stress analyst should have little trouble dealing with the generation of these values, understanding their effect and solving for the resulting stresses.

The average piping designer never heard the word "discontinuity" (either geometry or load) so how could he be expected to understand it? It is therefore extremely important to have a piping designer who understands these areas and can provide guidance. Most designers can, with a little experience, go through the mechanics of generating temperature values, plugging them into the equations and calculating the "stress." What happens if a component fails to meet the requirements? What load (pressure, moment, temperature) caused the problem? How can I modify my analysis to reduce the conservatism? What is the effect of the specified conditions on the problem? These are the areas where a knowledgeable analyst can provide the necessary direction and eliminate confusion. Following are brief discussions of three methods of determining ΔT values.

3.5.2 Method 1 - Fluid ΔT's

The first, and easiest method, is to take the fluid changes specified, and use those values as ΔT_1, ΔT_2, and $T_a - T_b$ for each condition. This is obviously conservative and is only applicable where system fluid changes are not severe.

3.5.3 Method 2 - Simplified Analysis

This method is defined as simplified because it does not involve the use of computers and are relatively easy to apply.

A number of curves have been prepared by D. R. McNeill and John E. Brock (4), which give the value of ΔT_1, ΔT_2, and average temperature in a pipe wall for both a ramp and jump (step) change in temperature as a function of the Fourier (N_{FO}) and the Biot (N_B) numbers. This approach is extremely efficient and can be used for most situations. It does neglect the effect of axial heat flow and is cumbersome to apply for complex transients in which increases in temperature are followed immediately by decreases and/or the slopes or flow rates change dramatically.

3.5.4 Method 3 - Detail Analysis

This approach uses one of the many digital computer programs for calculating temperature distribution in a structure that is available today. Due to the input requirements of most programs, this approach can be time-consuming and therefore expensive. There are some significant advantages, such as considering the effects of axial heat flow (particularly in branch connection problems), the ability to handle complex transients, and the elimination of conservatism. If pre-processors and post-processors for the main program are written properly, this approach can be as economically feasible as Method 2. There is the additional advantage of being able to store the ΔT values in the computer and manipulate them for processing.

3.6 Stress Indices

For many years, piping designers and analysts have been using the stress intensification factors which are presented in all the ANSI B31 Codes. As you know, these factors, when multiplied by the equivalent straight pipe stress, predict the fatigue stress in a standard piping component. This may have been all the knowledge of stress intensification needed to design and analyze a system in a fossil fuel plant. The similar factors in the nuclear code are called stress indices and predict the elastic stresses in a piping component. In most cases, the stress indices for moments are approximately two times the value of the stress intensification factor. This makes sense when one considers that the fatigue stress is one-half the elastic stress.

In nuclear piping, indices are given for pressure, temperature, and bending moment stresses and it is really necessary for the analyst to understand what the indices represent. This is required when the analyst is faced with a component which does not meet the requirements of Section III. What load is causing the problem and what is the basis for the index used?

For example, the C_3 index for a girth fillet weld to socket weld fittings is 1.8. An analysis of a cylinder built into a wall with no local flexibility effects is the basis for that number. Therefore, the 1.8 value is a maximum that could ever be expected.

There is a large discrepancy between the K_1 values for branch connections and butt welding tees (1.7 versus 4.0). There are two reasons for this. The first is that considerable experimental work has been performed on nozzles which meet the branch connection requirements of Section III and significant data was available to generate reasonable and well-founded indices while little, if any, data was available for butt welded tees and conservative engineering judgment had to be used. The second reason is that complete geometry control of the branch connection is firmly established in Section III while tees have little control particularly with respect to corner radii (both internal and external). Since many of the indices are soundly based on existing empirical and analytical data, it is essential for the designer to review this information to understand the reaction of the piping to given loadings. This knowledge as to where in a given component the maximum stresses occur can lead to better component design. A typical example is the fact that the maximum bending stress in as elbow occurs on or near the center line arc (which is the neutral axis for in-plane bending) and, therefore, attachments at this point on the elbows should be forbidden.

3.7 Stress and Fatigue Evaluation

This is the point at which all of the work preceeding is used to solve the required equations of NB-3650 of Section III. Essentially, one has completed the design and support of the system and must now demonstrate its adequacy.

Since time does not allow for a detail discussion of the requirements of NB-3650, only a few major points will be discussed here. Section III, NB-3650 presents requirements which, if met, provide for protection against two types of failure: catastrophic, and fatigue or leak type. Catastrophic failure protection is provided by meeting the Pressure Design rules of NB-3640 and Equation (9) of NB-3650. The general requirements of NB-3640 are not too different from B31.1 so this should not present a real problem to the designer. Equation (9) is not too different from the "Additive Stress" paragraph of the B31 Codes. The major difference is that Equation (9) deals with stress intensities rather than maximum longitudinal stress as done in B31.1. For this reason, the pressure stress term of Equation (9) calculates the hoop (circumferential) stress rather than the axial (longitudinal) stress. Additionally, the loadings which are to be considered are very explicit for Equation (9).

Fatigue failure is provided by meeting Equations (10), (11), (12), (13), and (14) of NB-3650. These are comparable (with great differences) to meeting the S_A value in the B31 Codes. The five equations of NB-3650 which provide for fatigue protection can be separated into two basic categories: elastic fatigue and elastic-plastic fatigue. Meeting the requirements of Equation (10) demonstrates that the structure cycles elastically, peak stresses can be directly calculated using Equation (11), and a usage factor determined. Failure to meet the requirements of Equation (10) does not mean the system is inadequate; it only indicates that some plastic cycling will occur. If plastic cycling is indicated, it is necessary to demonstrate that a hinge moment is not developed (Equation (12)) and that the range of primary-plus-secondary membrane plus bending stress intensity is less than $3S_M$ (Equation (13)) before proceeding to do the fatigue analysis. Additionally, for those sets of conditions which produce plastic cycling, a correction to the Alternating Stress Intensity must be made to account for the decay of fatigue life in the plastic range.

The fatigue evaluation itself is not complex and is essentially a bookkeeping problem, if the loadings (pressure, moment, and thermal) have been generated properly. The major problems occur in calculating the loads, handling the data, and understanding the results.

3.8 System Operational Loading

This area of analysis is relatively new to the piping industry and to the author's knowledge has not been commercially used or required on non-nuclear plants. The term system operational loading refers to the dynamic loadings imposed on a piping system as a result of sudden opening or closing of valves, sudden changes in pump flow, and relief valve operation. The introduction of this type analysis occurred because of problems associated with system operation for which proper consideration was not given in the design stage. Further discussion of these operational problems will be given.

This type of analysis requires the use of personnel who are extremely capable in the fluid dynamics and structural dynamics area. It is necessary to have complete knowledge of the system operation (flow rates, pressure, temperature, valve operating time, etc.) before one can properly solve the problem. Knowing this, the loads imposed on the system with respect to time can be generated. The piping system is then dynamically analyzed applying these force-time histories at appropriate locations and the resultant deflections, loads, and stresses versus time are found.

An example of where this analysis is appropriate is for a Main Steam line during Turbine trip valve operation. The sudden closing of the valve results in a pressure wave which travels down the pipe, away from the valves, generating loads at each change in direction of the piping system. Even though this pressure wave is traveling at sonic velocities down the pipe, the generated loads at changes in direction occur at different times thereby generating a dynamic response of the system. A typical system appears in Figure 3 with the associated force-time history values which occur at selected locations.

3.9 Computer Programs

3.9.1 General

A computer program to handle the volumes of loading data and solve the equations of NB-3650 is almost a necessity if one wants to do the work economically and with a minimum of errors. A program of this type is not a real technical problem and perhaps is best accomplished by using a programmer with some business background. The criteria of NB-3650 requires the manipulation, calculation, sorting, comparing, and eliminating of tremendous amounts of data which is similar to the things most business programs do.

Programs of these types have been written and are available. They range in sophistication from, on the one hand, a single program which starts with a flexibility analysis type input and ends up with the solutions to the equations of NB-3650, to a set of programs each of which solves for specific loads (moments and ΔT values) stores them and they are then called by a program which solves the NB-3650 equations.

Accepting the fact that one needs a computer program if he is going to do much of this analysis work, the only remaining questions is what type. Some advantages and disadvantages are given below.

3.9.2 Advantages and Disadvantages

a) Economics - It would appear on the surface that the single program is the most economical. This is certainly the case when the final results indicate compliance with the Code; however, if a component is inadequate it may require (depending on the program capabilities) a complete regeneration of the entire analysis to accommodate a revision either to geometry or loading conditions. Using sets of programs allows for changing only those loadings which need modification.

b) Understanding Results - When the single program prints out data at various stages in its formulation of the analysis (for example; moments due to weight, flexibility, and seismic, ΔT values for each component for each transient) then there should be little difference between the two approaches. The need to review this information is most important for situations which fail to meet requirements.

4. Comparison Analyses

Some problems can occur when the analyst uses a B31.1 analysis to assume satisfaction of

Section III. This may seem like a strange approach but is quite often used to locate hangers supports, and seismic restraint. The location, ordering, and design of these items usually cannot wait until the Section III solution is completed. For example, the analyst will perform weight, flexibility, and seismic analysis of the piping system using a criteria from B31.1 as follows:

a. Expansion stress $\leq S_A$

b. Longitudinal pressure, weight, and seismic stress $\leq 1.2\ S_h$

Having met this criteria, hanger and piping orders are usually placed and fabrication begun. This is a sensible approach as long as some thought is given to a revised criteria. This is necessary at least for particular components such as elbows. Take the particular example of a 12-inch, schedule 140, stainless steel, long radius elbow with a design pressure of 2485 psi and temperature of 650°F.

From B31.1, $1.2\ S_h = 22{,}500$ psi

From Section III, $S_M = 17{,}000$ psi

Taking values for stresses calculated in accordance with B31.1 as follows:

Loading	Longitudinal Stress (psi)
Pressure	5237
Weight	1219
Earthquake	6152
Total	$12608 < 1.2\ S_h$

Using the values of stress above, the corresponding stresses in Equation (9) of Section III would be:

Loading	Longitudinal Stress (psi)
Pressure	10474
Weight	2511
Earthquake	12673
Total	$25658 > 1.5\ S_M$

The reason for the increase in the individual stresses has been discussed in general in preceeding sections and will be detailed below.

We know that Section III uses hoop stresses for pressure while B31.1 uses axial stress; therefore, pressure stresses in Equation (9) are two times that of B31.1.

In the case of weight and seismic stress, it was pointed out above that the fatigue stress index (C_2) of Section III for moments are twice that of B31.1. The index for primary stress (B_2) in Equation (9) is .75 times the C_2 index. It follows that the B_2 index and therefore the weight and seismic stresses for Equation (9) will be at least .75(2) = 1.5 times that for B31.1. The stresses cited above are from an actual situation and required modification of the support system in order to meet the Equation (9) requirements.

Experience indicates that care should be taken in using an un-modified B31.1 approach for the following components:

a. Curved pipe or butt welding elbows, 3-inch or greater.

b. Butt welding tees, 3-inch or greater

Two more examples of problems which have occurred are described briefly.

	B31.1		Section III	
Component	Calculated Stress	Allowable Stress	Calculated Stress	Allowable Stress
3-inch, sch. 160 ell	S_E=26,000	S_A=27,900	Eq(12)=57,200	$3S_M$=52,000
21-inch, sch. 140 ell	add. stress=12,338	$1.25S_h$=22,000	Eq(9)=26,303	$1.5S_M$=25,500

5. Design Specifications

This is the one document that can relieve many of the problems discussed in this paper. Those areas for which significant options are available to the analyst should be covered in the Design Specification and the owner should select the option, or limit those available.

The Design Specification, or lack of it, was a leading contribution to many of the past problems in the vessel industry. At this date, the vessel industry is doing an outstanding job in preparing Design Specifications which close the loopholes, give guidance to the supplier, and supplement enforceable criteria. The same cannot be said for the piping industry.

The major problem in piping is that the designer is usually given a document which covers the reactor vessel and associated coolant or circulating piping. This may not be applicable to many of the other systems in the plant. The vessel specification will include operating information for each condition anticipated for the plant from things like power change to injection of core spray. The entire core spray system, however, is not subjected to all these conditions and the analyst should not be required to consider them. This same philosophy is applicable to most of the present safety-related systems in a nuclear plant. From the attachment to the reactor vessel or coolant piping to "some" point in the non-flowing safety system, it is reasonable to expect a response of the fluid to changes in the vessel or coolant pipe and this should be so stated in the specification.

The remainder of the system should be subjected to only the pressure and deflection variations of the source as well as its own operating conditions. The term "some" point can reasonably be taken as the first valve or, if that is a considerable distance from the source, a calculation can be made to determine at what point the fluid in the safety system is not responding to the source. This second approach is sometimes referred to as "thermal attenuation length."

A firm definition of the approach to be used for seismic analysis must be made to alleviate the problems discussed in section 3 of this paper.

For each system, it is necessary to provide a written description of the system function describing the following in detail.

a. When the system operates with respect to the operating history of the plant;
b. Why the system operates;
c. The effect on the plant of the operation of the system.

For each operating condition specified, it is necessary to provide a description of the variation of pressure, temperature, and flow rate versus time. This can best be done in the form of a figure which graphically shows these variations.

A minimum approach to preparing a Design Specification would be to take each paragraph in NB-3650 and decide whether information is required and/or guidance should be given. At each interface of responsibilities (contractual and/or philosophical), guidance must be given as to which party is responsible for supplying information or analysis to the other, and what should the scope of that effort be.

References

(1) American National Standard Code for Pressure Piping, ANSI-B31.7, "Nuclear Power Piping"

(2) American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components"

(3) American National Standard Code for Pressure Piping, ANSI-B31.1, "Power Piping"

(4) D. R. McNeill and John E. Brock, "Calculating Transient Temperature In Pipes"

TABLE I

COMPARISON OF ANALYSIS EFFORT

	Power Plant Type	
Type Analysis	Fossil	Nuclear
Flexibility	X	X
Hangers:		
Location	/	X
Selection	/	X
Weight	/[1]	X
Seismic		X
Force - Time History		X

X -- Analysis Performed

/ -- Usually Done By Hanger Supplier

/[1] -- Analysis Usually Based on Hanger Spacing Table of "Balance Beam" Technique

TABLE II

ESTIMATED MAN HOURS RATIOS

	Nuclear/Fossil
Main Feedwater System - Class 1	10
Core Spray - Class 1	8
Charging - Class 1	20
Total Plant	10 to 15

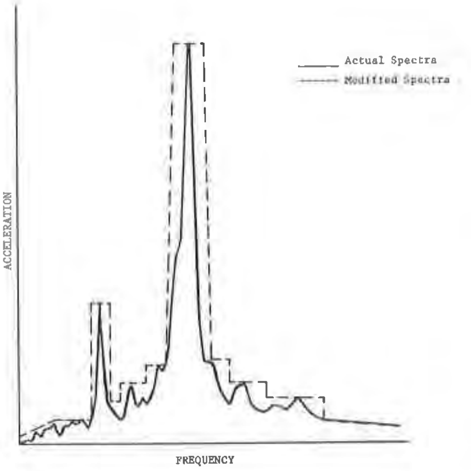
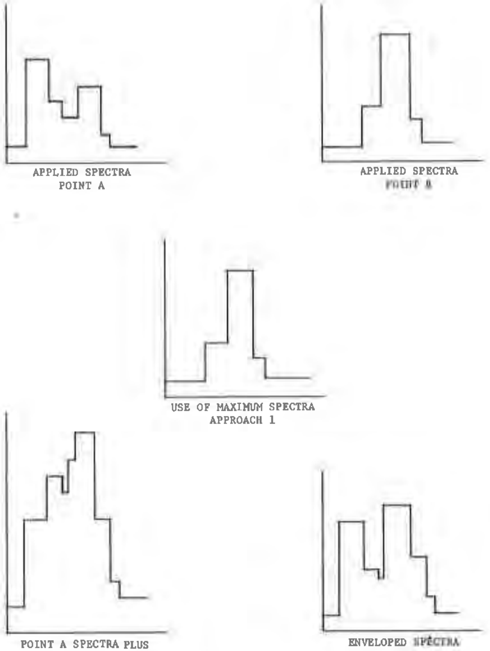


FIGURE 1


APPLIED SPECTRA POINT A

APPLIED SPECTRA POINT B

USE OF MAXIMUM SPECTRA APPROACH 1

POINT A SPECTRA PLUS POINT B SPECTRA APPROACH 2

ENVELOPED SPECTRA APPROACH 3

FIGURE 2

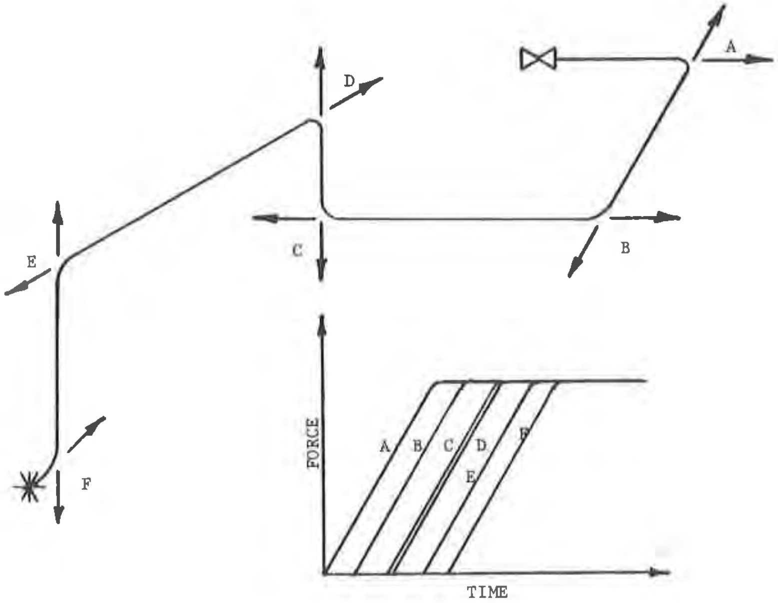


FIGURE 3