

Analysis and Modification of Pipe Mounted Valves

R.P. Kassawara, E. Fishman

Impell Corporation, 225 Broad Hollow Road, Melville, New York 11747, U.S.A.

W.F. Hahn

Impell Corporation, 350 Lennon Lane, Walnut Creek, California 94598, U.S.A.

ABSTRACT

As a result of extensive tests, more accurate load definitions have been developed for postulated loss of coolant accident (LOCA) events in Boiling Water Reactors (BWRs). These developments resulted in loads of not only increased magnitude but also of higher frequency for the pressure suppression systems. Piping and equipment attached to the wetwell were in turn subjected to the more severe loads. This resulted in the need to reanalyze and qualify all equipment and piping for which the design LOCA loads had increased. Herein, design modifications and their rationale for pipe mounted valves are described for two types of General Electric BWRs, a Mark I plant and a Mark III plant.

1.0 INTRODUCTION

This paper presents innovative and cost effective methods for analysis and modification of pipe mounted, motor operated valves subjected to the effects of seismic and hydrodynamic excitations.

Reanalysis of pipe mounted valves in Boiling Water Reactors (BWRs) was required because of a significant change in the design basis loss of coolant accident (LOCA) loads. These revised loads are higher than those previously considered and contain significantly more energy in the high frequency range. Figure 1 shows the frequency content of the new loads. As a result, wetwell response to LOCA loads is significantly different than the response based on the original load definition. This higher response is transferred as a higher input load to piping attached to the wetwell and correspondingly, to valves mounted on the wetwell attached piping. In this paper, the basis for the analysis and design modifications for pipe mounted valves are described for two types of General Electric BWRs, a Mark I plant and a Mark III plant.

The following section describes a cost effective means for analysis of the Mark I and Mark III wetwell systems to obtain new valve loads with minimum conservatism. This is followed by a description of the modifications made to those valves which were found to be overstressed by the new loads.

2.0 ANALYSIS

2.1 Mark I Plants

The General Electric Mark I plants have a toroidal wetwell pressure suppression chamber (torus) which is partially filled with water and has a variety of piping systems attached to it. The torus is a relatively flexible structure with respect to the frequencies of the new hydrodynamic loads. Consequently, its response and the resulting response of the attached piping and valves is significant.

Because of their relative stiffness and mass, the response of the torus and attached piping are dynamically coupled. Separate decoupled analyses of the torus and then the piping would yield unreliable and often overly conservative results (see Figure 1) while a coupled model would be prohibitively costly. In place of either of these unattractive options, an accurate interaction analysis of the separate torus and piping models was performed using the CMDOF program [1]. This approach considered full dynamic coupling between the piping and the torus. CMDOF computes the coupled response of structures from the uncoupled torus and piping response in the time domain. The resulting time history response was transformed into a response spectrum which was then used in the SUPERPIPE program (an Impell Corporation proprietary general purpose piping code) to obtain the piping response. SUPERPIPE considers multiple input spectra to account for the different spectra at various pipe elevations and the differences between the support input and torus penetration input spectra.

Upon completion of the piping analysis, a qualification analysis of the valves was performed using deadweight, operating and dynamic response loads. Because of the long lengths of the valve's extended structural members (i.e. the yoke legs) and the mass and offset position of the motor operator, the frequencies of the valve/piping system often fell in the range of maximum hydrodynamic amplification. For example, the first two frequencies of one valve were 22 Hz and 29 Hz. Because of the resulting high inertial loads, several valves were found to be overstressed in the region between the operator mounting flange and the bonnet. Modifications for these valves are described in Section 3.0.

2.2 Mark III Plants

The General Electric Mark III plants have a cylindrical wetwell suppression chamber which is partially filled with water and has a variety of piping systems attached to it. The method for analysis of the Mark III pipe mounted valves is different from that for the Mark I case. Being of a later vintage, the Mark III hydrodynamic loads, were available in the form of response spectra at the pipe/valve interface as well as at connection points to the primary structure. Consequently, a dynamic analysis of the piping system was not necessary. However, as shown in Figure 2, the Mark III piping response has a much higher frequency content due to the LOCA loads compared to the Mark I case. This causes a higher level of dynamic response of the valve in bending, shear and torsion. This response causes overstressing of the valve similar to that which occurred with the Mark I valves but it also causes an additional problem. Qualification of motor operators in the newer Mark III plants involves the definition of a Required Response Spectrum (RRS) at the operator mounting point.

Even in cases where stresses are adequate, unless the valve frequency is above 100 Hz, the valve amplifies the motion at its base. The operator RRS is, therefore, different than the known spectrum at the pipe/valve interface and needs to be calculated. However, the time history of the valve base is normally not available. Only the spectrum is provided. In order to develop the operator RRS in those cases where modification was not necessary, a direct generation technique was employed using the FLORA program.

FLORA, an Impell Corporation proprietary computer program, is used to generate secondary response spectra directly from given primary response spectra using random vibration techniques [2]. The dynamic characteristics of the intermediate structure (i.e. frequencies, mode shapes, mass participation factors and damping) are used to accurately calculate the spectra on the structure without the need for explicit time history analysis using synthetic time histories. The FLORA code takes into account the interaction effects between the primary and the secondary structures using separate modal damping values for each

structure. The structural frequencies, mode shapes and mass participation factors can be obtained from either test data or finite element models.

Those valves which were overstressed, however, were modified as described in the following section and did not require such analysis. Analysis was not required because, in addition to strengthening the valve, the modification also raised its frequency into the rigid range.

3.0 MODIFICATION

Several concepts can be applied to resolve the valve overstresses identified in the previous section. The pipe adjacent to the subject valve can be supported off of nearby primary structures. Alternatively, the valve operator mounting flange can be tied to a primary structure. However, in both of these concepts, costly iteration on the piping analysis needs to be performed. The addition of a support on a piping system can have far reaching effects. For instance, adjacent supports may have to be relocated, removed or at a minimum, requalified. Furthermore, supporting the valve operator from a primary structure can be counterproductive. Although this substantially reduces the acceleration seen by the operator, the valve in effect becomes a pipe support. Piping loads are transferred through the valve to the primary structure and thus the valve is still subject to high stresses.

A more cost effective approach was developed in this case by designing valve modifications which only affect the valve itself and local sections of pipe rather than the surrounding structures and the piping system as a whole. The objective of the modifications to the Mark I valve was to stiffen the extended structure locally to raise the valve frequency above the amplified region of the spectrum. The yoke portion of the valve was found to be the most flexible component of the load path from the motor operator to the valve body. Consequently, efforts to stiffen the valve concentrated on the area between the motor operator mounting flange and the bonnet mounting flange. In one case, raising the valve's natural frequency above the amplified region of the spectrum was accomplished by designing a simple removable auxiliary yoke support to stiffen the yoke in bending as shown in Figure 3. In other cases the valve was similarly stiffened and strengthened by adding material to the yoke cross section itself as shown in Figure 4. Torsional moment was found to be a significant load component. In at least one case, the design of a closed section in the yoke leg through the addition of a cut tube member was implemented to increase torsional stiffness and load carrying capability.

In the case of the Mark III motor operated valves, the frequency of the loadings is much higher than for the Mark I valves. Consequently, the addition of stiffeners to the yoke itself would not raise the frequency past 100 Hz. Here, a modification was designed wherein the valve was stiffened and operator inertial load transferred to the pipe by means of supporting struts attached from the valve bonnet (see Figures 5 & 6). In this manner the valve frequency can be raised to greater than 100 Hz to avoid peak loads induced by the hydrodynamic excitation. Also, the reduced operator inertial loading is shared by the valve yoke and the supporting strut. The amount of load in each element can be controlled by adjusting the stiffness of the struts. In certain cases, valves requiring strut type modifications were only slightly overstressed. It was determined that stiffening the valve in only one direction was sufficient in reducing load in the valve. In other instances, two systems of struts were needed to stiffen two perpendicular directions of acceleration. Upon investigation, it often became apparent that one acceleration direction was most critical, in that it induced the greatest stress in the valve assembly. Therefore, valve stiffening was considered in that direction first. Where possible, struts which primarily were intended to reduce shear forces and bending moment, were also designed to eliminate torsional moment in the valve structure by restricting motor operator rotation (see Figure 5). This was often difficult to accomplish.

However, reduction of other load components (shear forces) sufficiently lowered overall valve stress, in most cases, to acceptable levels. These modifications described above were all made to be removable for valve maintenance by the use of pipe clamps or bolted connections.

It may be important to note that alternatives exist which in certain cases, could resolve an overstress concern without the use of structural modification. An acceleration direction was significant because of several factors. The obvious factor is a high acceleration valve. Perhaps less obvious factors are motor operator orientation and yoke leg orientation. The non-symmetrical offset of the motor operator center of gravity (c.g.) causes a greater induced moment in the valve for one direction of acceleration given equal acceleration valves in all three orthogonal axes. Thus, rotation of the motor operator can reduce certain stresses by reducing the moment arm of the eccentric mass. Similarly, rotation of the yoke legs could allow the stiffer yoke leg direction to resist the larger moment. One disadvantage of this course of action is that increased maintenance specifications may be required to insure proper valve assembly orientation.

4.0 SUMMARY

Qualification of motor operated valves attached to BWR pressure suppression chamber piping was required because of increases in hydrodynamic design loads. Cost effective analyses were performed for both Mark I and Mark III pipe mounted valves to obtain valve response to the increased high frequency excitations. Loads were developed considering coupling effects between the pressure suppression chamber and the attached piping, and valve flexibility where significant. Required response spectra were calculated for operator qualification where necessary using direct generation techniques.

For those valves found to be overstressed because of the new loads, simple, cost effective modifications were made to strengthen the valve and decrease loadings by altering the valve's dynamic response. These modifications were designed to be simple to install, removable, and require no iteration on the analysis of the associated piping. Licensing risk was avoided and a potentially large scope problem was resolved with a minimal effort.

5.0 REFERENCES

- / 1 / Kennedy, R.P., and Kincaid, R.H., "CMDOF - A Computer Program to Couple the Response of Structures and Supported Equipment for Multiple Degrees of Coupling Using the Results from Uncoupled Structure and Equipment Analysis," SMA 12101.03:R001, Structural Mechanics Associates.
- / 2 / Miller, G.V., Uyei, H., Hahn, W.F., Ratiu, M.D. 1983, "Comparison of Secondary Spectra Generation Techniques," presented at 4th National Congress on Pressure Vessel and Piping Technology, ASME PVP, Portland, Washington.

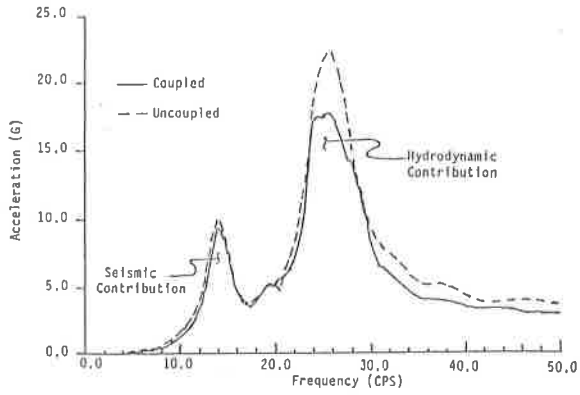


FIGURE 1 MARK I Seismic and Hydrodynamic Loading (2% Damping)

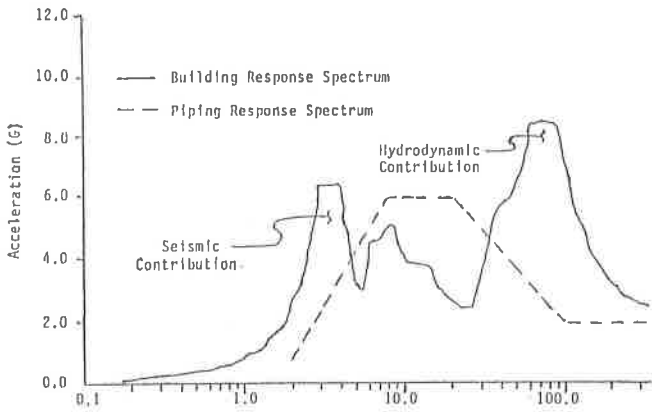


FIGURE 2 MARK III Seismic and Hydrodynamic Loading (4% Damping)

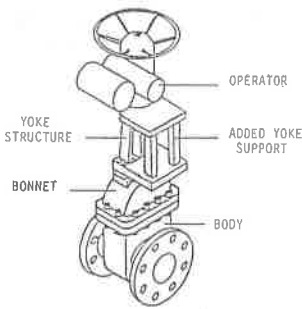


FIGURE 3 Yoke Support

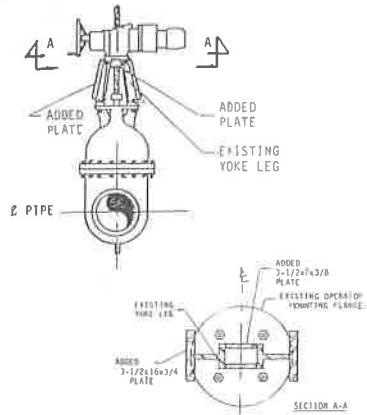


FIGURE 4 Yoke Modification

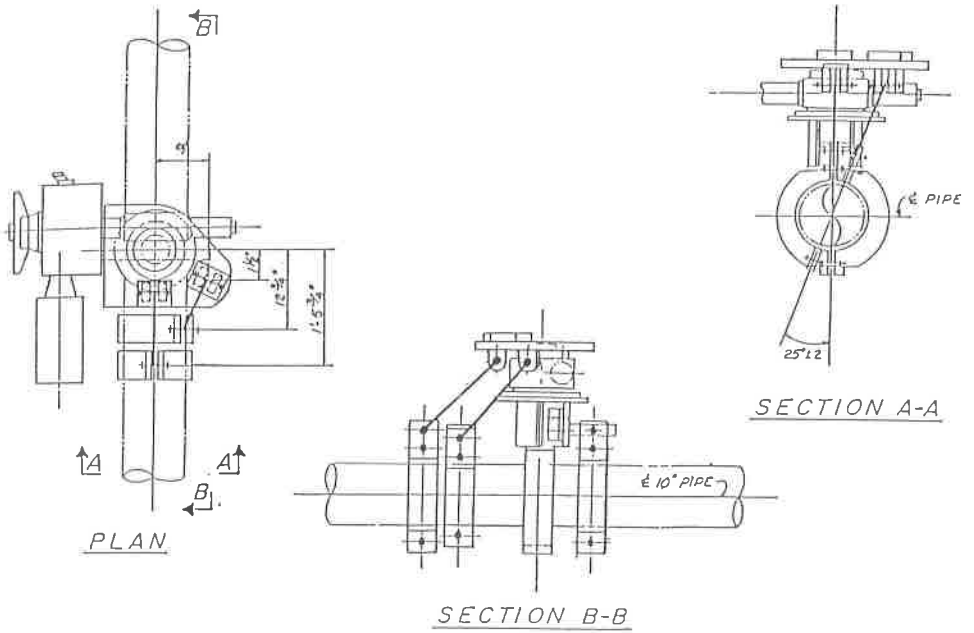


FIGURE 5 Strut Modification Type 1

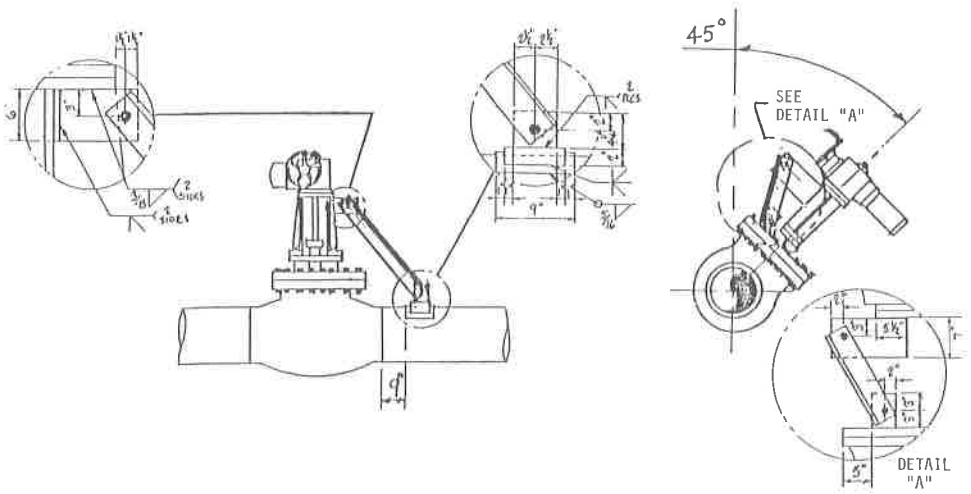


FIGURE 6 Strut Modification Type 2