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SEISMIC QUALIFICATION OF FLUID OPERATED VALVES AT WWER-1000MW TYPE NPP

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ABSTRACT

The objective of the study is to clarify the seismic adequacy of already installed fluid operated valves (FOV) in operating WWER-1000MW type NPP. The approach is a combination of the earthquake experience based SQUG GIP methodology and analysis applying ASME code. The plant specific floor response spectra and the as-built conditions are taken into account. As a result of the study 86% of the FOVs are qualified for Review Level Earthquake (RLE), for 2% of the FOVs is prescribed upgrading and for 12% of the FOVs is recommended changing with seismically qualified ones. Based on Safety Analysis Report additional conclusions are made for the FOV, recommended for changing.

Keywords: SQUG GIP methodology, fluid operated valves, seismic adequacy, WWER-1000MW type NPP

1. INTRODUCTION

The objective of the study is to clarify the seismic adequacy of a total of 370 fluid operated valves (FOV).

The equipment is installed outside the Containment in the Reactor building (RB) of WWER-1000MW type NPP. The valves are in an operating NPP. The equipment includes a total of 17 sizes and is manufactured by two producers. Equipment is safety class 2, quality class B [5], seismic category 1 [3], [4]. Review Level Earthquake (RLE) is Safe Shutdown Earthquake (SSE) anchored to peak ground acceleration 0.2g.

The following four general approaches are possible for solving this seismic qualification problem:

- analysis;
- test;

- engineering judgment based on seismic experience;
- combination of the above mentioned approaches.

Qualification of the studied valves by test is not efficient, because:

- there is diversity of sizes and producers of the valves;
- performing of tests for all valves would be expensive;
- performing of tests for all valves would be time consuming;
- difficulty in testing of already mounted equipment as it is, without dismounting – access to valves is restricted;
- difficulty in testing of the equipment on shaking table – it has to be dismounted, cleaned, transported to the testing facility;
- after testing the same equipment cannot be used.
- there is no spare equipment available for testing.

Qualification of the studied valves only by analysis is not efficient, because:

- developing detailed models of all sizes and support conditions is expensive;
- analytical qualification of all valves would be time consuming.

Our approach in this study is to perform the seismic qualification by combination of engineering judgment based on seismic experience with analysis. The results are considered more reliable than the ones obtained by a single specific test or analysis, because the database reflects the lessons from numerous strong earthquakes of active equipment.

A project-specific methodology is developed for solving the problem.

In this paper we present the results of the selected approach combined with conclusions based on Safety Analysis Report.

2. BACKGROUND OF THE STUDY

The study is based on a pre-defined methodology for evaluating existing equipment in operating NPPs.

The project methodology follows SQUG GIP [1] procedures, adapted to the task. Originally GIP is developed for verification of seismic adequacy of mechanical and electrical safe-shutdown equipment at US NPPs. This approach has been applied for seismic issues in WWER reactors in Bulgaria, Hungary, Slovakia, Czech Republic, Armenia since 1992 by different teams, including EQE International and EQE Bulgaria teams.

The engineering judgment is based on the experience from assessment of valves performance during past events. The “rule of the box” is followed in identifying equipment – i.e. all components mounted on the equipment are considered part of it and are evaluated with it. Acceptance criteria (caveats) for seismic adequacy are developed in GIP for fluid-operated valves after analysis and recapitulation of the experience.

FOVs are subjected to a screening process. During the screening the evaluation personnel checks if the intent of the caveats is met. Those FOVs, which are outliers, are analyzed for seismic adequacy with other methods.

In this project the engineering judgment implies checks and analysis of the following:

- Equipment class identification - Fluid-operated Valves.
- Weight and geometry characteristics of FOVs. Defining of groups for analysis out of total list of FOVs using:

d – pipe diameter
e – distance from the centerline of the pipe to the top of the operator or cylinder
M – operator weight
e*M product.

- Applicable GIP methods for assessing demand-to-capacity ratio

Method A- comparison with Safe Shutdown Earthquake (SSE) ground response spectra,
Method B – comparisons with in-structure response spectra, corresponding to SSE.

- Bounding spectrum – representing the seismic capacity of a FOV if it meets the intent of the specified caveats.
- 3D disposition and structural peculiarities of the system FOV-pipe (including supports) – simplified calculation model, support conditions, as-built condition at the time of walkdown. This data is necessary for as precise as possible definition of FOV dynamic parameters and application of the corresponding method for demand-to-capacity check.
- Seismic input parameters – floor response spectra for the FOV mounting location and free field spectra.
- Interaction with elements of other systems, found out during walkdown.

Engineering judgment is performed based on the GIP caveats, using the existing technical documentation, data collected during walkdown and preliminary static and dynamic calculations if necessary. Conclusion is made for the seismic adequacy of FOVs for the defined seismic input – SSE/RLE.

If a small modification of the FOV as-built condition could lead to meeting the caveats, a corresponding design solution is given.

Analytical solutions are developed for three types of FOVs. The analysis is according to ASME NC [2] for the corresponding equipment safety class 2, quality class B, seismic category 1.

When FOV is far beyond limits of specified caveats, specification for its replacement is developed. Additional analyses of SAR are provided for outliers and corresponding recommendations are given.

4. PROCEDURE DETAILS AND RESULTS

4.1 Seismic Capacity versus Seismic Demand

Seismic capacity for this task is represented by Bounding Spectrum (BS), respectively 1.5*BS, based on earthquake experience data [1], see Fig.1.

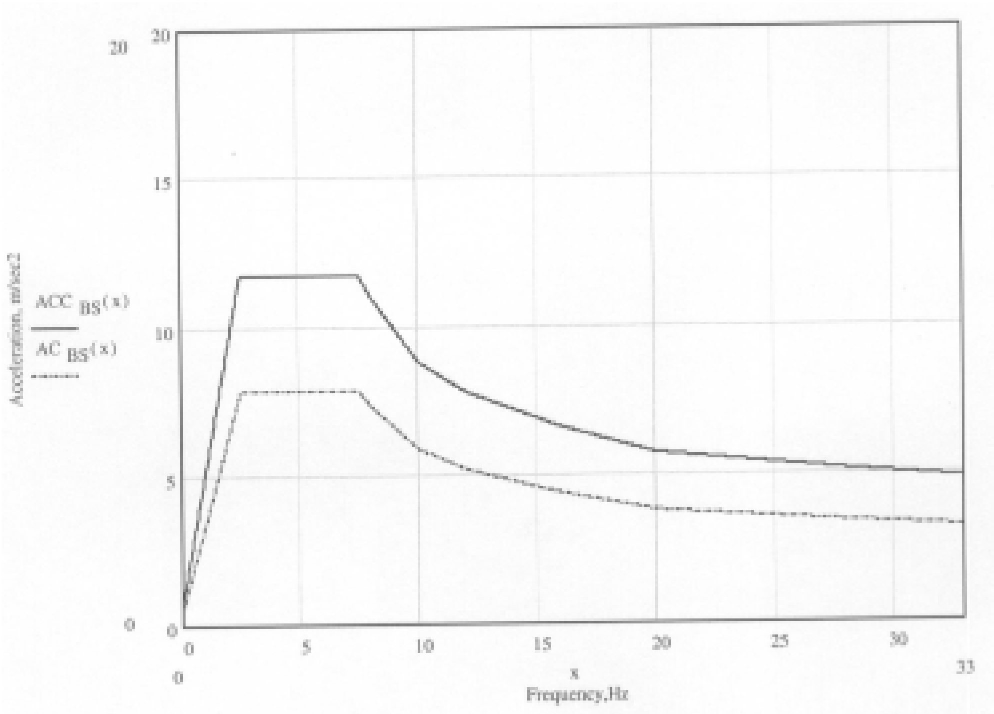

*Figure 1 Seismic capacity - Bounding Spectrum (BS) or 1.5*BS*

Seismic demand for this task is defined in terms of free field response spectrum (FFRS) or floor response spectra (FRS) for the corresponding FOV mounting location.

Two methods for assessing seismic capacity to seismic demand are applied in this study Method A.1 and Method B.1.

Method A.1 is applied when equipment is mounted below elevation 12m and FOV natural frequency if above 8Hz. Seismic capacity is defined by BS and seismic demand - by FFRS. Demand-to-capacity check is satisfied, if seismic capacity spectrum (BS) envelopes the seismic demand spectrum (FFRS) in the entire frequency range of interest. In this task the range of interest is at and above equipment lowest natural frequency, which should exceed 8 Hz.

Method B.1 is applied when equipment is mounted at any elevation and for FOV with any natural frequency. Seismic capacity is defined by 1.5*BS and seismic demand - by FRS. Demand-to-capacity check is satisfied, if seismic capacity spectrum (1.5BS) envelopes the seismic demand spectrum (FRS) in the entire frequency range of interest. In this task the range of interest is at and above equipment lowest natural frequency. Seismic capacity spectrum (1.5*BS) has been compared with seismic demand spectra (FRS) for various FOVs' mounting elevations. The frequency above which 1.5*BS envelopes each FRS was defined, see Table 1. The seismic experience database can be applied if the natural frequencies of FOVs at the corresponding elevation exceed the lowest natural frequency for that elevation (Table 1).

Table 1 Condition for application of seismic experience database - Method B.1

FOV mounting elevations	FOV lowest natural frequency
6.60 m	2.0 Hz
19.20 m	2.22 Hz
24.60 m	2.27 Hz
28.80 m	2.34 Hz
33.60 m	2.45 Hz
36.90 m	2.5 Hz

FOVs' first eigen frequency is defined by simplified FEM models, using equipment specific material and geometry data, as well as support conditions.

4.2 Caveats

The intent of the FOV equipment class has to be met in order to apply demand-to-capacity check given in 4.1. The GIP equipment-specific caveats are adapted to the project, considering the available data for seismic input at the site and at mounting locations, as well as our experience in NPP seismic qualification. The caveats are applicable to the studied equipment – FOV, which can be with any orientation. Here are the caveats, applied for the task:

Caveat 1 – The valve should be similar to and bounded by the FOV class of equipment.

Caveat 2 –Valve body should not be made of cast iron. The intent is to avoid brittle failure.

Caveat 3 –The yoke of the valve should not be made of cast iron. The intent is to avoid brittle failure.

Caveat 4 –The valve should be mounted on a pipeline of at least 1" diameter. This is the lower bound pipe size supporting FOVs in the earthquake experience database for that equipment class. In this project, to satisfy the intent of the caveat, is performed analytical analysis by ASME code [2] criteria. The analysis shows that stresses in pipe and valve are within required limits. The analysis is performed for three sizes of FOVs.

Caveat 5 –The distance from centerline of pipe to the top of operator should non exceed limits given in Fig.2. for light weight valves. The intent is to avoid excessive valve yoke stress due to longer operator. The operator lengths in Fig. 2 can be exceeded by 30 %, provided caveat 3 applies.

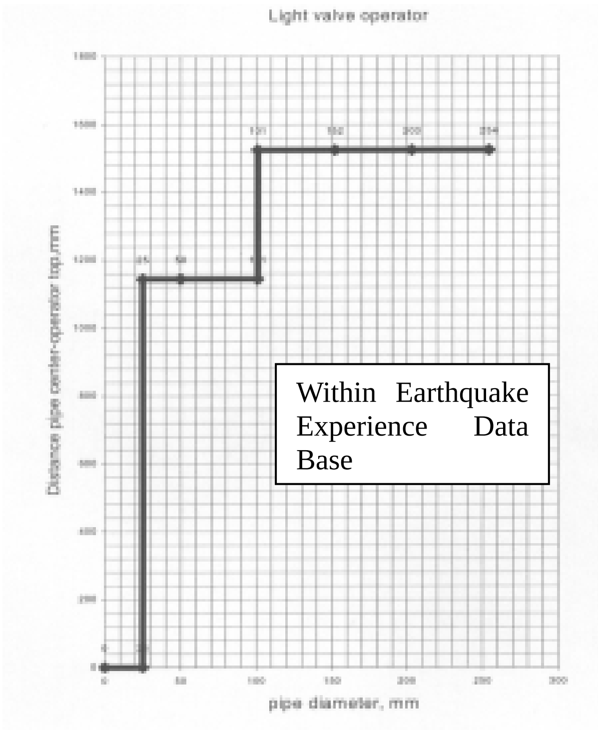

Figure 2 Light Valve Operator Cantilever Length Limits for Application of Experience Data Base

Caveat 6 – The distance from centerline of pipe to the top of operator should non exceed limits given in Fig.3. for heavy weight valves. The intent is to avoid excessive valve yoke stress due to longer operator. The operator lengths in Fig. 3 can be exceeded by 30 %, provided caveat 3 applies.

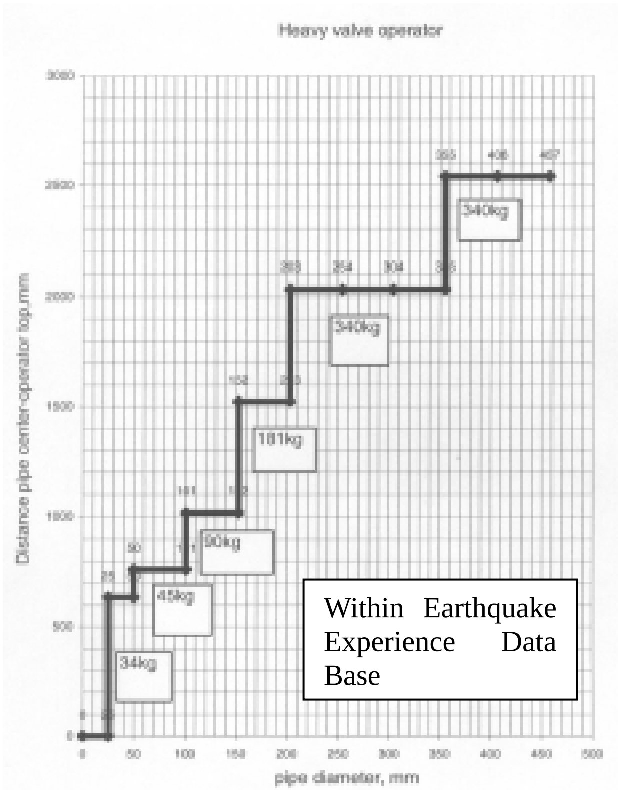

Figure 3 Heavy Valve Operator Cantilever Length Limits for Application of Experience Data Base

Caveat 7 –The valve and yoke should not be independently supported, unless the pipe is supported to the same structure immediately adjacent to the valve. The intent is to avoid differential motion of support points, and binding of the shaft.

Caveat 8 –Sufficient structural slack and flexibility of attached lines. The intent is to avoid line breach due to differential seismic displacement of equipment and line's nearest support.

Caveat 9 – Any details that could adversely affect the seismic capacity of the valves.

Screening Evaluation Datasheets (SEWs) are developed for the project. They reflect the caveats described above, as well as information for anchoring and interaction effects (Sections 4.3 and 4.4.). SEWs are filled in during walkdowns and are used for conclusion about FOVs seismic adequacy.

4.3 Equipment Anchorage

Screening for anchorage adequacy is important part of the evaluation procedure. The following peculiarities are considered in the task:

- Assessment of capacity of supports and anchoring of operators and valves is carried out.
- Assessment of capacity of supports and anchoring of pipelines, to which FOVs are attached, is not considered.
- Identification of cases of anchorage to the same structure of FOV, operator and pipeline are identified for pipelines with diameter less than 1". There are three such cases with pipeline diameters 15 mm and 10mm.

For each FOV during walkdown are performed the following checks:

- Anchorage of the FOV;
- Reliability of anchorage;
- Anchorage/support of pipeline near the FOV;
- Identification of nearest supports of pipelines.

The problems found during screening are written down in SEWs.

4.4 Interaction with other Equipment, Systems and Structures

Screening for seismic interaction with equipment, systems and structures is another important part of the evaluation procedure. The following peculiarities are considered in the task:

- Assessment if there is impact on FOV from nearby equipment, systems and structures;
- Assessment of flexibility of attached lines from other systems;
- Screening for danger of collapse of equipment, systems and structures above the FOVs;
- Identification of other adverse factors.

The problems found during screening are written down in SEWs.

4.5 Discussion of Results

As a result of the study each of the FOVs was given conclusion for its seismic adequacy.

Based on seismic adequacy evaluation procedure 86% of the FOVs are qualified for Review Level Earthquake (RLE). For FOVs of three sizes (40% of FOVs) the assessment is based on combination of engineering judgment with analytical calculations according to ASME code. The rest of the FOVs (46%, 11 sizes) are seismically qualified based on engineering judgment using experience database.

For 2% of the FOVs is developed detailed design for upgrading. The idea is to convert these FOVs from outliers to equipment, which covers the above compliance criteria. After implementation of the prescribed upgrading the FOVs will be considered qualified for the defined seismic input.

The results of the study show that for 12% of the FOVs the acceptance criteria, based on experience database, are violated considerably. We assume that there is low probability for proving their adequacy with more precise analyses. We recommend changing these FOVs with seismically qualified ones. For these FOVs is performed additional study based on Safety Analysis Report. The final conclusion is that they can remain unchanged, provided the corresponding FOVs within the Containment are seismically qualified.

5. CONCLUSIONS

Seismic qualification of active equipment (fluid operated valves) is presented.

An efficient and technically justifiable approach is utilized. It is based on engineering judgment combining seismic experience data and analysis. SQUG GIP criteria are adapted to the project. Analysis is performed applying ASME code. Seismic input is defined by floor response spectra. As-built conditions are considered.

Conclusion is made for the seismic adequacy of each of the valves. As a result of the study 86% of the FOVs are qualified for Review Level Earthquake (RLE), for 2% of the FOVs is proposed upgrading in order to receive seismic qualification and for 12% of the FOVs is recommended changing with seismically qualified ones.

The analysis of Safety Analysis Report for the FOV, recommended for changing, shows that they can remain as they are, if the corresponding FOV inside the Containment in the Reactor building have adequate seismic capacity.

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