The Viewpoint of the Safety Authorities about the Application to the Belgian Plants of the SQUG Methodology

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1. INTRODUCTION

Back in 1980, the U.S. Nuclear Regulatory Commission (NRC) initiated the Unresolved Safety Issue (USI) A-46 : "Seismic qualification of equipment in operating nuclear plants". The primary objective of USI A-46 is to verify the seismic adequacy of the equipment required to bring to a safe shutdown an operating plant which was not qualified to the more recent seismic criteria. Actually, use of these criteria is impracticable for equipment already in operation, because it would result in extensive analyses and testing of old vintage equipment, sometimes unique.

Therefore, in 1982, the Seismic Qualification Utility Group (SQUG) was formed to evaluate the feasibility of using an alternative method based on the performance of industrial equipment in actual earthquakes. This SQUG feasibility study demonstrated that not only standard equipment installed in industrial facilities is similar to equipment installed in nuclear plants, but also they are able to survive real strong earthquakes.
In the frame of USI A-46, the NRC approved the use of this method based on earthquake experience data as an alternative to rigorous seismic equipment qualification.

2. SEISMIC REEVALUATION IN BELGIUM.

In the frame of a general safety reassessment, after 10 years of operation, the Safety Authorities, with the help of seismic experts from the European Community Commission (ECC), requested that Tihange 1 unit be evaluated for a SSE of 0,17 g (with OBE left unchanged). Design seismic requirements were OBE = 0,05 g, SSE = 0,10 g with free field ground response spectra of Housner type.

Further, an SSE of 0,17 g was imposed on Tihange 2 and 3 units late in the design stage. As it was too late to incorporate this requirement in the design of the plants, the Safety Authorities gave their agreement to proceed with the original design basis (SSE of 0,10 g) and to perform a seismic verification later on with the upgraded seismic requirements.
Actually, experience data base methodology (or SQUG methodology) is being used for the reevaluation of the safe shutdown equipment (excluding the piping) of the 3 Tihange units to an SSE of 0,17 g.

3. APPLICATION OF THE SQUG METHODOLOGY.

The decision to use the SQUG methodology in Belgium was taken after a joint mission Utility-Safety Authority to the US in October 1985, which included a visit to the NRC. As a result of this mission, the Belgian Utility (now ELECTRABEL) became a SQUG member at the end of 1985, and followed the development and progress of the methodology since that time.

In the US, qualification methods and acceptance criteria have been developed in procedures, for instance the Generic Implementation Procedure (GIP), and submitted to the NRC for approval. At the present time, final approval from the NRC has not come yet, therefore implementation of the SQUG methodology has not commenced to date. However, the remaining problems in the US either are of no concern for Belgium (US legal aspects) or can be treated specifically (anchorages, training,...). Consequently, the Belgian Utilities decided not to wait for the finalisation of the SQUG procedures and to start the program earlier.

This program comprises the following steps :
- set-up of the list of equipment needed to bring and keep the plant in a safe shutdown condition
- assessment of the experience data base applicability to European equipment
- training programs and plant walkdowns aiming at inspecting each individual item of equipment,in order to verify if the criteria for qualification are met
- resolution of the outliers.

Specific requirements were imposed by the Belgian Safety Authorities at each of those steps.

4. SAFETY AUTHORITIES REQUIREMENTS.

4.1. List of systems needed to reach safe shutdown conditions

According to the GIP, it is not necessary to verify the seismic adequacy of all equipment defined as seismic category I (cfr. RG 1.29) : only the systems needed to accomplish four safe shutdown functions secured by two independent paths must be identified.
Detailed procedures have been developed to establish the list of equipment needed to assure the four functions : as an alternative to the primary safe shutdown path, the Safety Authorities agreed to consider either a redundant item of an active equipment, within that path, or a separate backup path.
It is important to mention that, if an SSE occurs, it is not necessary to use only the safe shutdown equipment identified hereabove, but the operating procedures for shutting down the plant should be reviewed to verify that they do not preclude the use of the safe shutdown equipment if some other method of shutting down is attempted first.

Safe shutdown is defined in the GIP as bringing the plant and maintaining it in a hot shutdown condition during the first 72 hours following an SSE. The Belgian Safety Authorities requested that safe shutdown be defined as any state between hot and cold shutdown, with RHR system operational.

According to the GIP, no concurrent or sequential potential events are postulated to occur other than an SSE and a loss of offsite power. This NRC-position has not been accepted by the Belgian Safety Authorities, who requested to consider the possible occurrence of an SSE in the post-LOCA or post-SLB phase :

a probabilistic assessment was performed to allow the identification of those systems to be added to the safe shutdown list (cf. par. 5 of this paper).
This assessment does not apply as such to Tihange 1, where there is only one main steam isolation valve, therefore requiring the High Head Safety Injection System to be included in the safe shutdown list.

4.2. Applicability to European equipment of the experience database.

An important aspect of using experience data in Europe is that the most of the seismic experience database has been developed from the performance of US-manufactured equipment. A prerequisite for the use of experience data is to demonstrate applicability to the equipment being evaluated. To assess the similarity between Belgian and database equipment, a walkdown of a representative sample of the Tihange equipment was organized at the end of November 1989, with the help of a recognized expert : Dr. R.P. Kennedy, chairman of SSRAP (Senior Seismic Review Advisory Panel).

The conclusions of this walkdown, to which an engineer from the Safety Authorities participated as an observer, were that the Belgian electrical and mechanical equipment are essentially similar to or even more seismically rugged than the database equipment. Further, Belgian equipment are usually well supported, strongly anchored and seismically braced, except a few equipment of the oldest unit, for which additional caveats were defined.

To support the hereabove conclusion concerning the Belgian equipment, it is worthwhile to mention that a similar exercise took place in Switzerland, where the two units of Beznau are undertaking a seismic requalification, and that it came also to the conclusion that the Beznau components are well represented in the experience database.

4.3. Participation to training programs and plant walkdowns.

It must be recalled that a generic implementation procedure (GIP) has been developed by SQUG for application of seismic and testing experience data to resolve the USI A-46 issue.
This procedure has been implemented at Tihange in the following manner :

1. compare the site earthquake response spectrum to the database bounding spectrum.
   Actually, this bounding spectrum envelopes the site specific seismic spectrum for a 0,17 g maximum ground acceleration.
2. verify by plant walkdowns that each item of equipment to be qualified either is covered by an existing formal qualification, or is represented in the database, in which case caveats must be met.
   These walkdowns have been performed by a team of high-level seismic experts. A particular type of equipment to look at are the relays : those used in Tihange are not included in the types for which SQUG has qualified data, therefore their method of qualification is specific and based on the qualification of the electrical cabinets as a whole, as soon as a cabinet contains one needed relay (Lafaille, 1991).
3. Validate the anchorage.
   This has not been done according to the SQUG documents. Instead, a specific set of anchorage criteria and calculation methods has been defined, based on European bolt types, domestic test results and Tihange practice. (Lepièce, 1991).
4. Check for seismic interaction.
   This includes mainly proximity issues, as well as structural failure and falling of non-seismic items onto safety related items.

As the training program to be followed by the experts of the Seismic Review Team (SRT) was not finalized when the Tihange walkdowns were to start, a replacement program comprising the following activities was established by the architect-engineer (TRACTEBEL) :
- elementary course on seismic qualification
- participation to SQUG meetings in the US
- review of important US-documents on the subject, like the NUREG's-1030 and 1211, the GIP, the EQE/EPRI/SSRAP reports, the SER's from the NRC.
- assistance to seismic qualification tests on shake tables
- participation to trial walkdowns in Belgium, especially the one when Dr. Kennedy was present
- presentation of the methodology used to verify the anchorages.

One engineer from the Safety Authorities participated to this training program with a double objective :
1. to be aware of all aspects related to the SQUG methodology, in particular the discussions going on in the US with the NRC.
2. to get integrated in the Seismic Review Team, in such a way that compliance with the applicable implementation procedures could be directly evaluated.

Actually, this trained engineer participated to the walkdown of unit 1 on a quasi full-time basis. Further, for unit 1, which is the oldest among the 3 units to be reassessed, an audit by an independent expert was requested by the Safety Authorities. This audit took place at the end of the walkdown and was done again by Dr. R.P. Kennedy. His report stated his total concurrence with the work performed by the inspectors of the Seismic Review Team and with the conclusions they had reached.

4.4. Resolution of outliers.

An outlier is an item of equipment which either does not comply with all of the screening guidelines provided in the GIP or is not represented in the database.
The details for resolving outliers are beyond the scope of the GIP; it is the responsibility of the Utility to address these areas which do not meet the screening guidelines :
- by taking straightforward measures directly on site
- by applying engineering judgment
- by performing additional evaluations

In all cases, the Belgian Safety Authorities require the outliers to be clearly recorded on a seismic verification sheet, fulfilled during walkdowns, and any modifications on site to be performed in accordance with the QA manual of the Utility.

5. PROBABILISTIC ASSESSMENT AIMING AT THE IDENTIFICATION OF ADDITIONAL SAFE SHUTDOWN SYSTEMS.

As mentioned earlier in this paper, the Belgian Safety Authorities requested to take into account the sequential occurrence of a seismic event (SSE) and a Design Basis event (DBE, i.e. LOCA, SLB or small break LOCA).
A probabilistic assessment was launched with the goal to identify the systems which have a probability to experience an SSE in the post-DBE recovery phase (or a DBE in the post-SSE recovery phase) greater than 10-7 : those systems are then added to the list of systems, whose seismic adequacy shall be verified using the SQUG methodology.

Due to the facts that
1. as well the reactor coolant piping as the main steam piping are calculated to remain integer under a 0,17 g SSE,
2. some conservatisms taken at a design stage (like the combination of SSE and LOCA by the SRSS rule) may be released in case of a reevaluation of an existing plant,

a LOCA is not supposed to occur as a consequence of a SSE.

Therefore, the probability of sequential occurrence of an SSE and a DBE is simply : $P_{SSE} \times P_{DBE}$,

with P_{SSE} = probability of an initiator seismic event
P_{DBE} = probability of an initiator design basis event

Then, for a system which must be available X hours after a DBE, the probability to experience an SSE in the post-DBE recovery phase is :

$$\frac{X}{8700} \times P_{DBE} \times P_{SSE} \qquad (1)$$

Now, assuming that the duration of the post-SSE recovery phase is a few hours, let us say 8.7 hours, the probability for a system to experience a DBE in the post-SSE recovery phase is :

$$\frac{8,7}{8700} \times P_{SSE} \times P_{DBE} \qquad (2)$$

The desired probabilistic assessment was performed for the main systems needed after a DBE, based on the following values of probability for the initiating events : $P_{SSE} = 8.5 \times 10^{-3}$ $P_{LOCA} = 3 \times 10^{-4}$

$P_{SLB} = 1.3 \times 10^{-4}$ $P_{SBLOCA} = 3 \times 10^{-3}$

The results obtained lead to the conclusion that, among the systems needed after a DBE, only the Containment Spray System and the High Head Safety Injection System may be excluded from the SQUG Safe Shutdown list.
It is to be noted that such conclusion does not apply to Tihange 1 : indeed, the lack of redundancy of the main steam isolation valves, together with the application of the single failure criteria, has requested the qualification of the HHSI system.

6. SEISMIC VERIFICATION VERSUS SEISMIC QUALIFICATION.

In the terminology used currently by the NRC, the USI A-46 methodology is not a seismic "qualification" procedure. It is rather a "verification" of the seismic adequacy of equipment not qualified to more limiting criteria, specifically IEEE-344-1975 and later standards. This means that, in the US, application of the SQUG methodology is contemplated only for seismic reevaluation of existing plants against seismic criteria not in use when these plants were licensed.

Obviously only Tihange 1 looks like being a unit to which the SQUG methodology may be applied, because, for the two other units, conformity to IEEE-344-1975 is required by the safety analysis report to demonstrate the seismic qualification of all safety-related electrical and mechanical equipment to a 0,10 g SSE. As a matter of fact, only minor problems have been identified during the SQUG walkdowns performed at Tihange 2 and 3.

This is due to the following reasons :
1. Seismic margins at the design stage, using IEEE standards, are important
2. Conservatisms included in the GIP are less than the ones existing in the IEEE standard.
3. At the design stage (0,10 g), response spectra are generic RG 1.60 spectra, whereas, for the seismic reevaluation (0,17 g), response spectra are site specific spectra.

The Belgian Safety Authorities do not have objections to the use of the SQUG methodology to more recent plants : this leads to verify the seismic adequacy of a limited amount of safety-related equipment (those required to assure the four safe shutdown functions), whereas , for a small additional effort, it would have been possible to formally qualify to 0,17 g all safety-related equipment. However, SQUG walkdowns are useful to solve other problems, sometimes non-seismic dependent, which can not be underlined by a formal IEEE-qualification process, for instance :
- Seismic interactions
- inadequate anchorages
- prevention of flood (qualification of non-safety related liquid waste tanks)

7. CONCLUSION

The SQUG approach of using real earthquake experience and generic test data is a practical and economical alternative to conventional analytical and testing seismic qualification, mainly to verify seismic adequacy of operating plants, which were not formally qualified at the design stage. If such a qualification exists, it could be more cost-effective to go back to the existing qualification files, but walkdowns of the SQUG-type have proven their own interest, because of the nature of the problems identified, which are not always earthquake-related.

At the present time, besides some complementary walkdowns still to be carried out in 1991 an 1992, three important actions remain to be done by the Safety Authorities in order to complete their review of the work performed in the frame of the 0,17 g reevaluation of the Tihange units :
1. Check the content of the final version of all US-documents (GIP, SER,...) when they become available : if it turns out that important modifications are included, this could call into question some conclusions of the Tihange walkdowns, and lead to possible corrective actions
2. Review the operating procedures for shutting down the plants to verify that the chosen safe shutdown paths are taken into account and can be utilized, if needed.
3. Follow the resolution of all outliers, especially the way the calculations and modifications are documented.

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