Title: **Expert System GIP-WWER for Verification of Seismic Adequacy of WWER Equipment**

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EXPERT SYSTEM GIP-VVER FOR VERIFICATION OF SEISMIC ADEQUACY OF VVER EQUIPMENT

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1. Introduction

Earthquake experience data was recognized in the U.S. as an efficient basis for a simplified and indirect seismic verification procedure of mechanical and electrical NPP's equipment components by the Seismic Qualification Utility Group (SQUG) about 15 years ago. SQUG collected data available from past earthquakes and seismic tests and reviewed them in detail. This review was then used to develop and establish the formal procedure titled as the Generic Implementation Procedure (GIP) [1,2] which is now widely used for verifying of safe shutdown equipment on western NPPs.

The purpose of this report is to describe the modified GIP titled as GIP-VVER which can be used to verify seismic adequacy of the safe shutdown mechanical and electrical equipment and also distribution systems of operating or constructed VVER-type NPPs, namely VVER-440/213 type NPPs.

The procedure GIP-VVER has been prepared using public available information contained in GIP [3,4] and also experience taken from various seismic inspections and evaluations of VVER-type NPPs performed in the last five years.

The scope of equipment covered by the procedure GIP-VVER includes, similarly as the original GIP, the following classes of mechanical and electrical equipment:

- motor control centers,
- low and medium switchgears,
- transformers,
- horizontal and vertical pumps,
- fluid, motor, and solenoid-operated valves,
- ventilators,
- air handlers and chillers,
- air compressors,
- motor and engine generators,
- distribution panels,
- batteries on racks and battery chargers and invertors,
- instruments on racks,
- temperature sensors,
- I&C panels and cabinets.

European and particularly VVER-type relays, switches, transmitters and electric penetrations are different from those included into the original American SQUG databases. Therefore, these classes of equipment have been excluded from GIP-VVER.

In addition this procedure also includes guidelines for simplified seismic evaluation of the following classes of equipment:

- vertical and horizontal tanks,
- vertical and horizontal heat exchangers,
- cable and conduit raceway systems,
- small bore and cold large bore pipes,
- HVAC ducts,
- anchorage of equipment.

A summary of GIP-VVER equipment classes is given in Table 1.

2. General Description of GIP-VVER

As shown in Figure 1, this procedure is primarily a screening procedure. However, if safe shutdown equipment is classified as an outlier, more detail methods to verify its seismic adequacy may be used. Generally, four major steps of this procedure are as follows:

- selection of Seismic Review Team (SRT),
- identification of safe shutdown equipment,
- screening verification and walkdowns,
- outlier identification and resolution.

An engineering judgment is the major tool used by SRT during the screening verification and walkdowns to evaluate seismic adequacy of the equipment. The SRT should include system engineers, plant operation personnel, experienced and professionally trained seismic capacity engineers, and also personnel to identify and evaluate essential relays (if necessary).

The basic criteria to verify seismic adequacy of an equipment item during the screening walkdown are (see also Figure 1):

- seismic capacity greater than seismic demand (by comparison of the corresponding $ISRS_{SSE}$ or GRS_{SSE} to the Bounding Spectrum (Figure 2, Table 2),
- similarity to the equipment in the seismic experience data bases (checking of caveats, based on walkdowns and information available from documentation),
- adequate anchorage of equipment (calculations or engineering judgment, based on walkdowns and information available from documentation),
- potential seismic interactions evaluated (based on walkdowns).

The Expert System called GIP-VVER [5] has been developed by Stevenson and Associates on the basis of corporation experience [6,7,8] and it can be efficiently used for practical applications directly on the plant. Two basic documents are available as results of seismic screening verification and walkdowns:

- Screening Verification Data Sheet (SVDS) in which an each equipment component or distribution line to be evaluated is identified simply by a single live item (used by the most experienced experts when all important factors relating to seismic adequacy are evidently obvious)
- Seismic Evaluation Work Sheet (SEWS) as shown in Appendix A for more detail seismic evaluation of individual equipment components or distribution lines.

There is also another sheet titled as Outlier Seismic Verification Sheet (OSVS) in which outlier issues and proposed methods of outlier resolution are described. The form of this sheet is more or less free.

Seismic interactions are physical interactions of any structures, distribution systems or mechanical or electrical components with nearby items of safety-related structural systems or equipment components caused by an earthquake. An inspection should be performed in the area adjacent to and surrounding safety-related structures, distribution systems and equipment components to identify any seismic interactions which could adversely affect their capability to withstand earthquake effects.

The four seismic interaction effects which are considered are:

- proximity (impacts of adjacent equipment or structures on safety-related equipment due to their relative motion during an earthquake),
- structural failure and falling of overhead or adjacent structures, systems, or equipment components),
- flexibility of attached lines and cables,
- flooding due to earthquake induced failures of tanks or vessels.

3. Similarity of VVER-440/213 Type Equipment to Equipment Included in the SQUG Databases, Additional Background

Similarity of VVER-440/213 type equipment to equipment included in the original SQUG databases which is the keystone of practical application of this procedure can be estimated on the basis of already performed seismic walkdowns on the VVER-440/213 type NPPs as follows:

- pumps, valves — up to 100 %,
- motor control centers, switchgears — about 50 %,
- HVAC equipment — about 90 %,
- transformers — about 80 %,
- generators — up to 100 %,
- distribution panels, cabinets — about 80 %,
- batteries — about 80 %,
- relays, switchers, transmitters — low,
- cable supporting structures — about 80 %,
- tanks, heat exchangers, HVAC ducts, pipes — up to 100 %,
- anchorage details are similar with several specific exclusions.

Additional Background:

- systematic review of experience data from application of GIP to seismic evaluation and reevaluation of different NPPs [9 to 17],
- original Soviet seismic procedures and engineering documentation (f.e. OTT-82, OTT-87 [18]),
- seismic walkdowns and evaluations performed on the VVER-type NPPs in relation to the IAEA guide [19],
- IAEA sponsored Benchmark Study for the seismic analysis and testing of VVER-type NPPs [20],
- experience database of Romanian facilities subjected to the last three Vrancea earthquakes [21].

4. Practical Aspects of GIP-VVER Applications and Conclusion

Based on experience from several seismic walkdows performed during the last five years on the VVER-type NPPs, it may be concluded that the main problems related to seismic adequacy of their mechanical equipment components which may occur in some cases are:

- missing or non-proper anchorage of components, missing anchor bolts, non-proper tightening of anchor bolts,
- large seismic nozzle loads due to long unsupported attached pipes,
- large valve operator cantilever length,
- motor operated valves with remoted drivers (cardan-type connection must be evaluated),
- missing or non-properly performed pipe and duct supports,
- additional pipe restraints (f.e. application of viscous dampers for large hot pipe systems),
- replacement of brittle elements (f.e. glass level indicators etc.),
- inadequate base isolation,
- potential seismic interactions.

For electrical and I&C equipment components the main problems related to their seismic adequacy are:

- missing or non-proper anchorage of components, missing bolts, nuts and screws, non-proper tightening of anchor bolts,
- seismic functionality of relays, switches and similar items must be verified by seismic tests, performed as usually separately from the supporting cabinets or panel,
- determination of in-cabinet seismic response spectra necessary for separate verification of internal items,
- fixation of internal drawers, relays, switches, sensors and similar items to the cabinet or panel structure is often weak,
- original accumulator batteries must be replaced,
- potential seismic interaction.

The GIP screening criteria should be used with caution. Some equipment in VVER-type NPPs is not adequately represented in the SQUG experience database to confidently apply the GIP screening criteria without some modifications. While the most equipment components are seismically rugged, there are some unique items that have been observed during seismic walkdowns for which the screening criteria clearly are not applicable without additional engineering justification. The modified GIP-VVER procedure contains several such modifications of screening criteria.

It is anticipated that the GIP-VVER procedure will become a more or less standard procedure for verification of seismic adequacy of equipment installed on existing VVER-type NPPs.

Used Abbreviations

BS	Bounding Spectrum
GIP	Generic Implementation Procedure
HVAC	Heating, Ventilating and Air Conditioning
ISRS	In-Structure Response Spectrum
NPP	Nuclear Power Plant
OSVS	Outlier Seismic Verification Sheet
SEWS	Seismic Evaluation Work Sheet
SQUG	Seismic Qualification Utility Group
SSE	Safe Shutdown Earthquake
SSRAP	Senior Seismic Review and Advisory Panel
SVDS	Screening Verification Data Sheet

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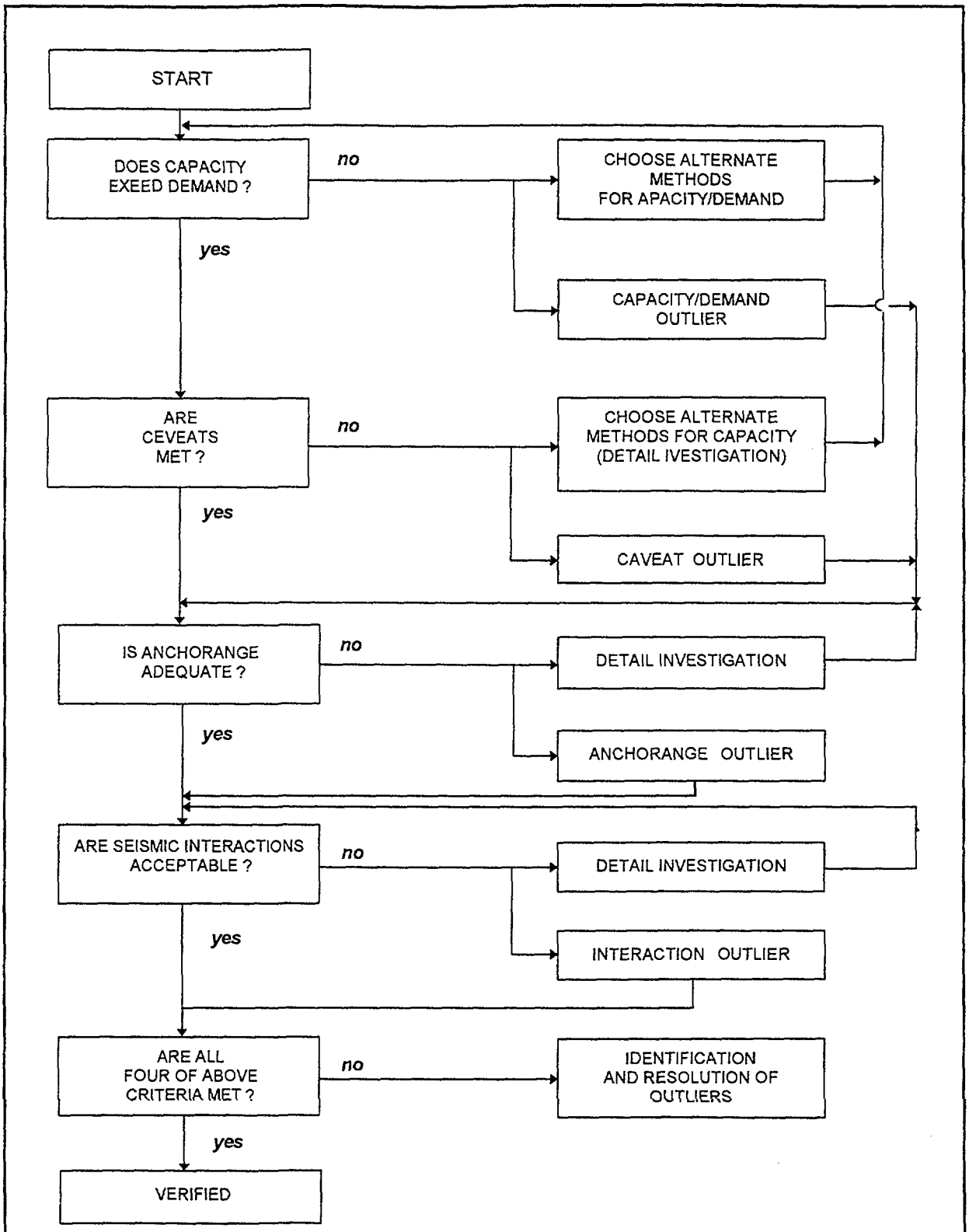
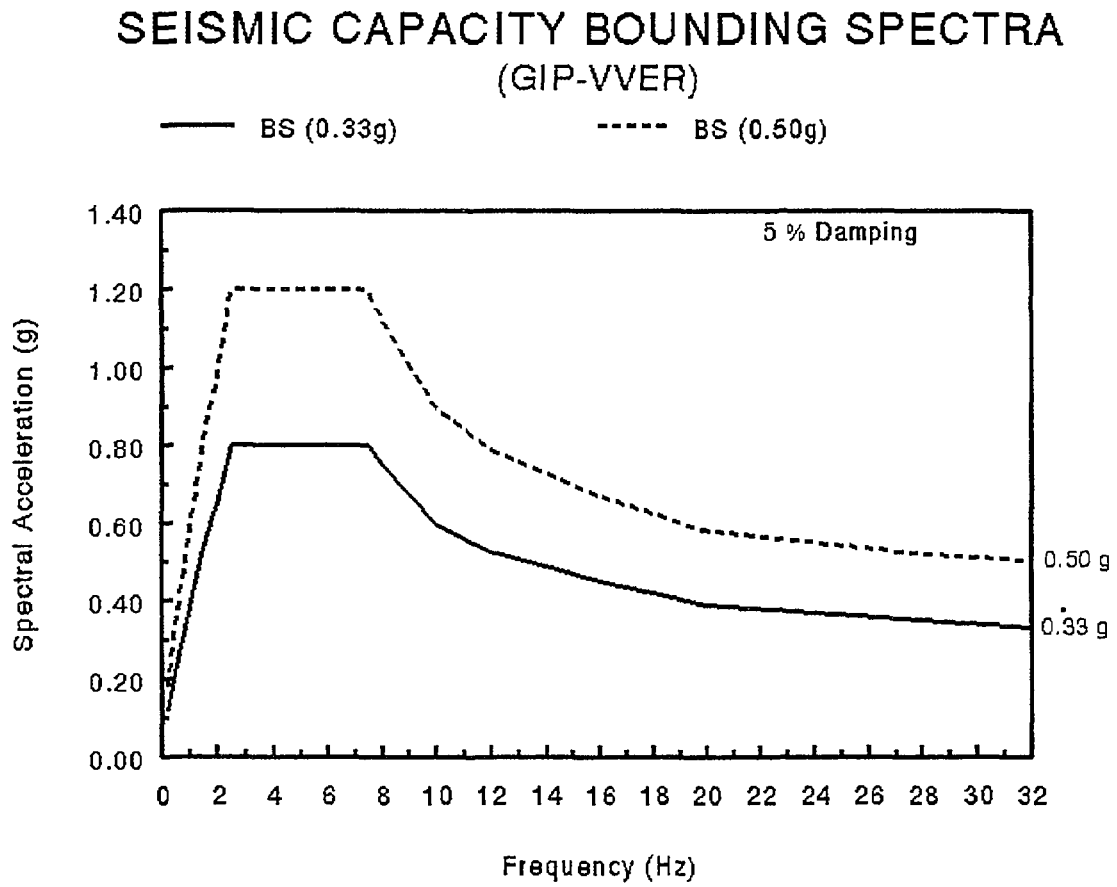
Table 1 Summary of GIP-VVER Equipment Classes

Equipment Class	Data Available for Seismic Verification
Original 20 Classes	
1. Motor Control Centers	SSRAP BS (0.33 g), GIP-VVER
2. Low Voltage Switchgears	SSRAP BS (0.33 g), GIP-VVER
3. Medium Voltage Switchgears	SSRAP BS (0.33 g), GIP-VVER
4. Transformers	SSRAP BS (0.33 g), GIP-VVER
5. Horizontal Pumps	SSRAP BS (0.50 g), GIP-VVER
6. Vertical Pumps	SSRAP BS (0.33 g), GIP-VVER
7. Fluid-Operated Valves	SSRAP BS (0.50 g), GIP-VVER
8. Motor-Operated Valves	SSRAP BS (0.50 g), GIP-VVER
9. Fans	SSRAP BS (0.33 g), GIP-VVER
10. Air Handlers	SSRAP BS (0.33 g), GIP-VVER
11. Chillers	SSRAP BS (0.50 g), GIP-VVER
12. Air Compressors	SSRAP BS (0.50 g), GIP-VVER
13. Motor Generators	SSRAP BS (0.50 g), GIP-VVER
14. Distribution Panels	SSRAP BS (0.33 g), GIP-VVER
15. Batteries on Racks	SSRAP BS (0.33 g), GIP-VVER
16. Battery Chargers and Invertors	SSRAP BS (0.33 g), GIP-VVER
17. Engine Generators	SSRAP BS (0.50 g), GIP-VVER
18. Instrument Racks	SSRAP BS (0.33 g), GIP-VVER
19. Sensor Racks (Temperature Sensors)	SSRAP BS (0.33 g), GIP-VVER
20. I&C Panels and Cabinets	SSRAP BS (0.33 g), GIP-VVER
B. Additional Classes	
21. Relays, Switches, Transmitters, Solenoids, Sensors	not applicable for VVER-type equipment
22. Electrical Penetration Assemblies	not applicable for VVER-type equipment
C. Special Approaches	
22. Cable Supporting Structures	see [4,7]
23. Tanks and Heat Exchangers	see [4,22,23]
24. Filters	only supports, anchorage and interactions
25. Pipes and HVAC Ducts	see [24,25]

Note: 1) SSRAP = Senior Seismic Review Panel [3].
2) The document [28] gives examples of the most important seismic interactions which may occur on facilities as NPPs.
3) The document [29] is prepared for verification of anchorage of typical VVER-type NPP equipment components.



S&A-E **Stevenson and Associates - Europe** **S&A-CZ** **Stevenson and Associates - Czech Republic**	**SCREENING VERIFICATION AND WALKDOWN PROCEDURE (GIP-VVER)** **Figure 1**



S&A-E Stevenson and Associates - Europe **S&A-CZ** Stevenson and Associates - Czech Republic	**SEISMIC CAPACITY BOUNDING SPECTRA** **Figure 2**

Table 2 Criteria of Comparison Seismic Capacity to Seismic Demand [1)]

A. Comparison with SL2 (SSE) Ground Response Spectra (GRS)
This can be used is mounted below about 12 m above the effective grade and when the natural frequency of equipment is greater than 8 Hz [2)] $BS \geq GRS_{SL2,SSE}$ (5% damping) [3)]
B. Comparison with SL2 (SSE) In-Structure Response Spectra (ISRS)
$1.5 \times BS \geq$ realistic (median, mean, best estimated) $ISRS_{SL2,SSE}$ (5% damping) [3)]

Notes: 1) Apply at least one of these two rules, which applicable.
2) Do not apply the 8Hz limit for equipment mounted on piping systems (valves, valve operators etc.).
3) These criteria shall be met for all three orthogonal spatial directions.

APPENDIX

SAMPLES OF SVDS & SEWS AS USED IN GIP-VVER

Equipment Class	Safety Class	Seismic Class	ID No.	Room	Elevation	Capacity vs Demand	Caveats	Anchorage	Interactions	Result

Note: Y ..... Yes or Satisfactory
N ..... No or Unsatisfactory
U ..... Unknown
N/A ..... Non Applicable

Component Class : **2. Low Voltage Switchgears**

Plant Name:		Unit:		Seismic Category:	

PART A: DESCRIPTION

I.D.Number:		Building:	
Model No.:		Room:	
Elevation:			

PART B: CAPACITY VS. DEMAND

1.	Capacity based on:	
2.	Demand based on:	

Does capacity exceed demand? ____

PART C: CAVEATS

1.	Earthquake experience equipment class	
2.	Rating of 600 V or less	
3.	Side-to-side restrain of breakers	
4.	Adjacent cabinets bolted together	
5.	Attached weight of 45 kg or less	
6.	Externally attached items rigidly connected	
7.	General configuration similar to national standards	
8.	Cutouts not large	
9.	Doors secured	
10.	Adequate anchorage	
11.	Potential chatter of essential relays evaluated	
12.	No other concerns	

Is the intent of all caveats met? ____

PART D: ANCHORAGE

Are all requirements of special guidelines for evaluation of equipment anchorage met?	

PART E: INTERACTION EFFECTS

1.	Soft targets are free from impact by nearby equipment or structures	
2.	If the equipment contains sensitive relays, it is free from all impact by nearby equipment or structures	
3.	Attached lines have adequate flexibility	
4.	Overhead or adjacent structures, equipment or distribution systems are not likely to collapse	
5.	No other adverse concerns were found	

Is equipment free of interaction effects? _____

IS EQUIPMENT SEISMICALLY ADEQUATE? _____

Note:
- Y ..... Yes or Satisfactory
- N ..... No or Unsatisfactory
- U ..... Unknown
- N/A ..... Non Applicable

Certification: All necessary evaluations of the equipment were made by the persons trained in accordance with GIP-VVER methodology and all information corresponds to the reality.

Responsible for Part A: Date:
Responsible for Parts B-E: Date:

Component Class : **5. Horizontal Pumps**

Plant Name:		Unit:		Seismic Category:	

PART A: DESCRIPTION

I.D.Number:		Building:	
Model No.:		Room:	
Elevation:			

PART B: CAPACITY VS. DEMAND

1.	Capacity based on:	
2.	Demand based on:	

Does capacity exceed demand? ____

PART C: CAVEATS

1.	Earthquake experience equipment class	
2.	Driver and driven component on rigid skid	
3.	Thrust bearings in both axial directions	
4.	Check of long unsupported piping	
5.	Base vibration isolation system checked	
6.	Sufficient slack and flexibility of attached lines	
7.	Adequate anchorage	
8.	Potential chatter of essential relays evaluated	
9.	No other concerns	

Is the intent of all caveats met? ____

PART D: ANCHORAGE

Are all requirements of special guidelines for evaluation of equipment anchorage met?

PART E: INTERACTION EFFECTS

1.	Soft targets are free from impact by nearby equipment or structures	
2.	If the equipment contains sensitive relays, it is free from all impact by nearby equipment or structures	
3.	Attached lines have adequate flexibility	
4.	Overhead or adjacent structures, equipment or distribution systems are not likely to collapse	
5.	No other adverse concerns were found	

Is equipment free of interaction effects? ____

IS EQUIPMENT SEISMICALLY ADEQUATE? ____

Note:
- Y ..... Yes or Satisfactory
- N ..... No or Unsatisfactory
- U ..... Unknown
- N/A ..... Non Applicable

Certification: All necessary evaluations of the equipment were made by the persons trained in accordance with GIP-VVER methodology and all information corresponds to the reality.

Responsible for Part A: Date:
Responsible for Parts B-E: Date:

Component Class : 8. Motor-Operated and Solenoid-Operated Valves

Plant Name:		Unit:		Seismic Category:	

PART A: DESCRIPTION

I.D.Number:		Building:	
Model No.:		Room:	
Elevation:			

PART B: CAPACITY VS. DEMAND

1.	Capacity based on:	
2.	Demand based on:	

Does capacity exceed demand? ____

PART C: CAVEATS

1.	Earthquake experience equipment class	
2.	Valve body not of cast iron	
3.	Valve yoke not of cast iron	
4.	Mounted on 25 mm diameter pipe line or greater	
5.	Valve operator cantilever length for motor-operated valves	
6.	Actuator and yoke not independently braced	
7.	Sufficient slack and flexibility of attached lines	
8.	No other concerns	

Is the intent of all caveats met? ____

PART D: ANCHORAGE

Are all requirements of special guidelines for evaluation of equipment anchorage met?	

PART E: INTERACTION EFFECTS

1.	Soft targets are free from impact by nearby equipment or structures	
2.	If the equipment contains sensitive relays, it is free from all impact by nearby equipment or structures	
3.	Attached lines have adequate flexibility	
4.	Overhead or adjacent structures, equipment or distribution systems are not likely to collapse	
5.	No other adverse concerns were found	

Is equipment free of interaction effects? ____

IS EQUIPMENT SEISMICALLY ADEQUATE?

Note:
- Y ..... Yes or Satisfactory
- N ..... No or Unsatisfactory
- U ..... Unknown
- N/A ..... Non Applicable

Certification: All necessary evaluations of the equipment were made by the persons trained in accordance with GIP-VVER methodology and all information corresponds to the reality.

Responsible for Part A: Date:
Responsible for Parts B-E: Date:

Component Class: **25. PIPING**

Plant Name:		Unit:		Seismic Category:	

PART A: DESCRIPTION

I.D.Number:		Building:	
Elevation:		Room:	

System Description:	

Piping System Topology:	

PART B: APPLICABILITY CRITERIA

Material:		Joint Type:	
Operating Temperature:		Operating Pressure:	
Pipe Contents:		Insulation:	
Cros Sectional Parameters:			

Are applicability criteria met? ____

PART C: CAPACITY VS. DEMAND

1.	Capacity Based on:	
2.	Demand Based on:	

Does capacity exceed demand? ____

PART C: PIPING CAVEATS

1.	Piping Meets Maximum Vertical Supports Span (incl. Cantilever Segments)	
2.	Piping Meets Maximum Lateral Supports Span	
3.	Long Straight Piping Segments Axially Restrained	
4.	Seismic Anchor Movement Evaluated	
5.	Construction Adequacy	
6.	Ductile Pipe Supports	
7.	Flexible Joints Adequately Restrained	
8.	No Corrosion or Erosion	
9.	No Hard Spots	
10.	In-Line Valves Acceptable	
11.	No Other Concerns	

Is the intent of all caveats met ? ____

PART E: SUPPORT CAVEATS

1.	Ductile Anchors	
2.	No Cracks in Concrete	
3.	No Gaps Under Base Plate	
4.	Support Connection Seismically Adequate	
5.	Unidirectional Supports are Acceptable	
6.	No Other Concerns	

Is the intent of all caveats met ? _____

PART F: EQUIPMENT (NOZZLE) CONSIDERATIONS

1.	Adequate Equipment Anchorage	
2.	Adequate Nozzle Loads Capacity	
3.	Adequate Piping Flexibility	
4.	No Other Concerns	

Are nozzles seismically adequate? _____

PART G: INTERACTION EFFECTS

1.	Soft Targets in Piping System Free From Impacts	
2.	Attached Lines Have Adequate Flexibility	
3.	Overhead Components or Distribution Systems Not Likely to Collapse	
4.	No Other Adverse Concerns	

Is piping free of interaction effects? _____

IS PIPING SEISMICALLY ADEQUATE? _____

Note:
- Y ..... Yes or Satisfactory
- N ..... No or Unsatisfactory
- U ..... Unknown
- N/A ..... Non Applicable

Certification: All necessary evaluations of the equipment were made by the persons trained in accordance with GIP-VVER methodology and all information corresponds to the reality.

Responsible for Part A: Date:
Responsible for Parts B-G: Date: