MEETING HANDOUT MATERIALS

FOR DECEMBER 4, 2002, NRC-SEQUAL MEETING

ON EXPERIENCE-BASED SEISMIC EQUIPMENT QUALIFICATION METHODOLOGY

Attachment 2: NRC Staff Assessment of SEQUAL's Response to RAIs and Other Issues Relating to The EBSEQ Topical Report Experience-Based Seismic Qualification Methodology

Attachment 3: Earthquake Experience Data for Fluid Operated Valves

Attachment 4: Operability Assessment of FOVs Based on Analysis

STAFF ASSESSMENT OF SEQUAL's RESPONSE TO RAIs

AND OTHER ISSUES RELATING TO THE EBSEQ TOPICAL REPORT

EXPERIENCE-BASED SEISMIC QUALIFICATION METHODOLOGY

FOR NON-A46 PLANTS

ATTACHMENT 2

Issue 1: Treatment of Concurrent Loads

- Response acceptable for pressure boundary components qualified to ASME III
- Response does not fully address non pressure boundary components (i.e.;mechanical component internals, electrical equipment anchorage) when both seismic and LOCA loads are required to be combined
- Use of the EBSEQ method would be acceptable only when non-seismic loads represent very small fraction of the seismic loads in non- pressure boundary parts of components and equipment
- EBSEQ should be revised to clarify resolution of this issue

Issue 2: Number of Response Spectra Used to Create Reference Spectrum

- This issue is generally resolved
- A supplemental concern regarding use of one reference spectrum to represent all equipment classes is addressed under Issue 5

Issue 3: Use of GIP-2 Method A

- Use of GIP-2 Method 'A' is unacceptable
- Method 'A' ignores properly calculated in-structure seismic demand, which already exists and is consistent with the licensing basis
- Method 'A' intended for use in older USI A-46 plants that didn't have in-structure floor spectra developed within their design bases
- Method A was derived based on median-centered in-structure response spectrum approach which is not consistent with the licensing basis for the affected facilities
- Use of method 'A' relies on use of the bounding spectrum as a capacity spectrum established for the evaluation of USI A-46 plants. The bounding spectrum may not be consistent with the Earthquake Experience-Based Capacity Spectrum (EES) as defined in section QR-A7412 of ASME, QME
- Use of Method 'B' is acceptable, if (1) reference seismic capacity spectrum meets provisions of Section QR-A7412 of ASME, QME, for the EES, and (2) the seismic demand is set about the 84thpercentile level, which would be consistent with the licencing basis of affected facilities

Issue 4: Equipment Class Definitions

- Number of equipment classes is immaterial provided the requirements of Part 100 are met
- All equipment (including subassemblies) within the same reference class should possess similar physical and dynamic characteristics that establish an acceptable set of inclusion rules to ensure seismic ruggedness and equipment function during and after an earthquake
- Documentation of the population of equipment relied upon in establishing and defining each class should be available for verification
- SEQUAL should specify that outlier equipment must be qualified by either (a) direct one-to-one similarity or (b) analysis, testing, or combination of analysis and testing
- Reliance on undocumented judgements made by SSRAP in conjunction with GIP-2 is insufficient and unacceptable to demonstrate reliability of the data base

Issue 5: Use of Reference Spectrum for all Equipment Classes

- Use of a single spectrum to represent capacity for all equipment classes is acceptable provided that the single spectrum is enveloped by the EES for each equipment class

- For each equipment class, the capacity spectrum should satisfy provisions of QME for each equipment class such that: (1)EES represents weighted average of the spectrum at each reference site, (2) the weight factor be the ratio of the number of independent items at each reference site to the total number of independent items at all reference sites, and (3) the reference equipment class includes a minimum of 30 independent items that performed satisfactorily during a reference seismic event

- Absent such demonstration, the capacity spectrum would have to be scaled down for some equipment classes until sufficient data exists to support higher equipment capacity

Issue #6: Evaluation of Subassemblies

- Approach presented in EBSEQ for evaluation of subassemblies would be acceptable if the reference to the acceptability of using the GERS is omitted

- Assumptions inherent in the justification to use the "Rule of the Box" are too broad and the methodology permits qualification of sub-components without any verification of the load path to the host equipment

- Use of Rule of the Box ignores the demonstration of specific function of each sub-component in the host equipment

- Use of Rule of the Box for seismic qualification of sub-components is unacceptable in its current form

Issue #7: Experience-Based Method

- EBSEQ procedure should contain a stand alone documentation of equipment classes, their definitions, descriptions of inclusion and exclusion rules, and clear identification of the caveats in each class

Issue #8: Fatigue-Sensitive Items

- SEQUAL should identify all fatigue-sensitive equipment or subassemblies from the earthquake experience database, or well documented test-experience database

- Necessary to demonstrate that equipment in the data base, and represented by the EES, have been successfully subjected to equivalent number of stress cycles of OBEs and SSE as required by 10CFR100

- Equipment that are known to be highly sensitive to fatigue based on existing testing data, should be removed from EBSEQ and qualified by testing or analysis if the use of analysis is appropriate

Issue #9: Equipment Functionality During Earthquake

- Equipment performance during and after an earthquake must be established to satisfy the requirements of 10CFR, Part 100
- Lack of structural damage to equipment examined during walk-downs following recorded earthquake events in database sites is not a sufficient demonstration of mechanical functionality during cited earthquakes
- To demonstrate equipment functionality during an earthquake, SEQUAL should identify relevant equipment in the earthquake experience database that have actually performed their required function during the earthquake
- For some equipment, demonstration of equipment functionality during earthquake to establish seismic qualification, may not be necessary if this equipment can be grouped into a class that has exhibited considerable ruggedness to dynamic excitation through documented testing
- For some electrical equipment, EBSEQ is not acceptable to demonstrate the functionality during earthquake (e.g., under, over voltage or current protection electrical equipment)

Issue #10: Risk Significance of EBSEQ Approach

- SEQUAL provided a risk assessment to support its argument in favor of the EBSEQ method
- Staff identified technical concerns with the fragility assumptions used in the risk assessment
- EBSEQ method is an experience-based approach, is not intended to be a risk-informed approach and was not submitted in support of risk-informed license amendments
- The use of risk-based argument is not appropriate for the approval process being requested

Issue #11: New and Replacement Equipment

- More detailed descriptions of equipment in each equipment class (physical and dynamic characteristics) in the data base would enable more accurate comparisons between New And Replacement Equipment (NARE) and actual equipment identified in the earthquake experience database

Issue #12: IEEE 323 Test Sequence Requirements

- SEQUAL needs to identify equipment that are likely to experience a harsh environment and specify that the use of the EBSEQ methodology is not appropriate for equipment in harsh environments

SEQUAL

Earthquake Experience Data for Fluid Operated Valves

SEQUAL Meeting with USNRC
Rockville, MD
December 4, 2002

Issues

- GIP Equipment Class Definition
- GIP Capacity Spectrum
- Operation During Earthquake
- OBE

ATTACHMENT 3

FOV General Characteristics

- Operation is by pressure of a fluid (air, oil, etc.) against a surface (diaphragm, piston, poppet) to move a shaft (up or down) and change position of valve (open or close)
- Movement of surface is opposed by a spring
- Operator is attached to valve body by a yoke

FOV Failure Modes

- Structural failure of yoke
- Binding of stem
- Loss of fluid pressure

Basic Earthquake Data

- Facilities that have experienced large earthquake have hundreds of fluid operated valves
- Pre-1985 earthquake facilities were surveyed by SQUG and SSRAP
- SSRAP developed equipment class definitions from these surveys
- Information on a sampling of equipment was documented and stored in the SQUG library

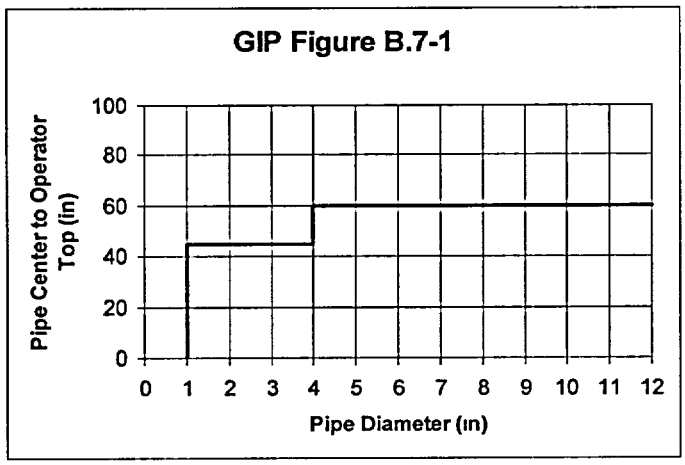
Basic Earthquake Data

- SQUG continued surveys of earthquakes and facilities from 1985 to the present
- Information on a sampling of equipment was documented and stored in the SQUG library
- Some of the library information was put into the electronic database

GIP FOV Class Definition

- Air-operated valves only
- Diaphragm, piston and spring-opposed relief valves
- Straight and angled operators
- Horizontal and vertical orientation
- All valve types (gate, globe, butterfly), sizes and orientations
- Limits on operator length versus pipe size

Operator Length Limits



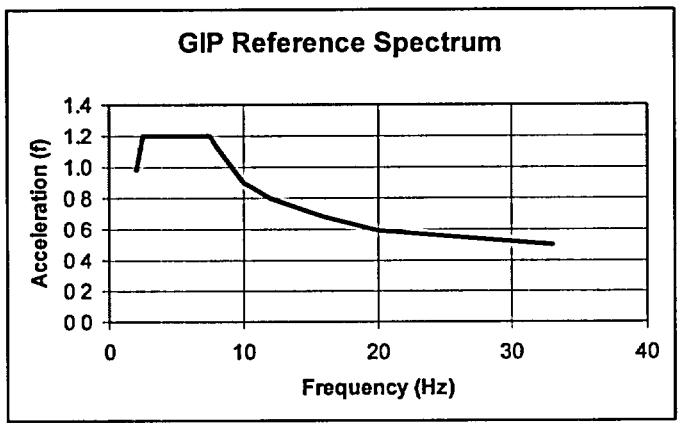
Prohibited Features (Caveats)

- Valve body not cast iron
- Valve yoke not cast iron for piston and relief valves
- Pipe diameter 1-inch or greater
- Cannot exceed operator length limit, or do 3g load check
- For heavy piston valves, compare weight and length to Figure B.7-2, or do 3g load check

Prohibited Features (Caveats)

- Actuator and yoke not independently braced
- Sufficient slack and flexibility in attached lines to accommodate differential displacement

GIP Capacity Spectrum



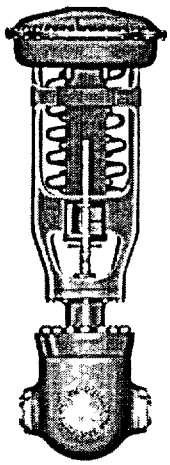
FOV Earthquake Data

- For this meeting, information on FOVs was retrieved from the SQUG library
- Data were assembled by independent item (per QME) and put into a separate database
- Data "counts" are very conservative; for example, Manzanillo Power Plant has 4 units, each with over 200 FOVs. Data count for Manzanillo is only 9

Summary of FOV Data

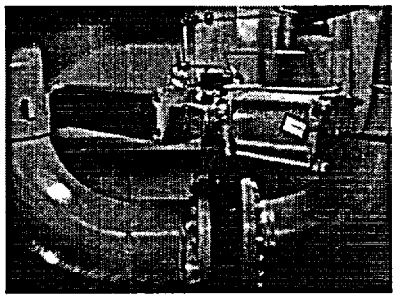
- 31 Facilities
- 180 FOVs
- 3 Types of Actuators
  - Diaphragm-Operated Valves (146)
  - Piston-Operated Valves (28)
  - Spring-Opposed Relief Valves (6)
- Only Air-Operated Valves considered
- Many manufacturers represented

Diaphragm-Operated Valve



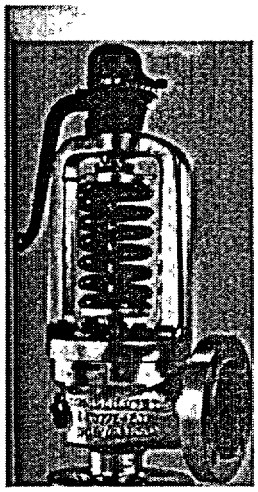
- Pressure on diaphragm in bell housing moves diaphragm to drive shaft
- Typically has short stroke
- Orientation can be in line with pipe or transverse

Piston-Operated Valve



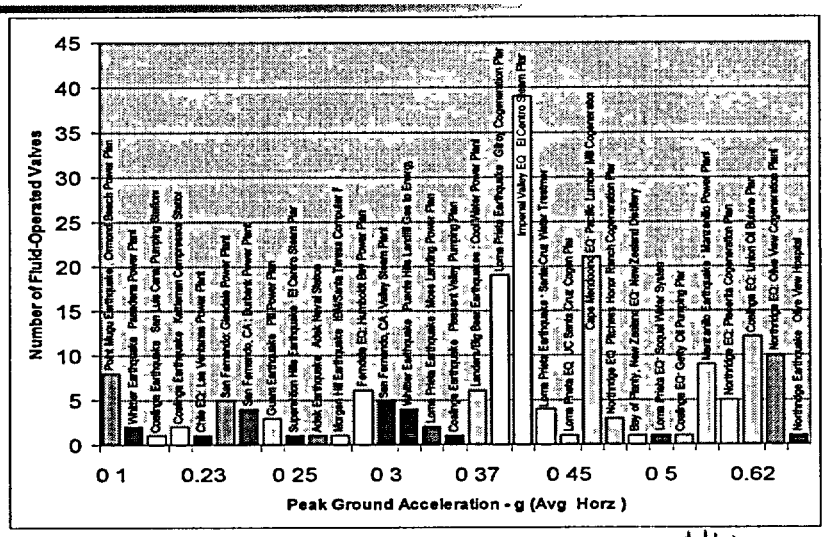
- Pressure moves piston to drive shaft
- Orientation can be in line with pipe or transverse
- Usually has heavier operator than diaphragm valve

Spring-Opposed Relief Valve



- Fluid pressure in pipe or vessel lifts poppet against spring
- No appreciable operator length or mass
- Seismic force is usually small compared to fluid discharge force

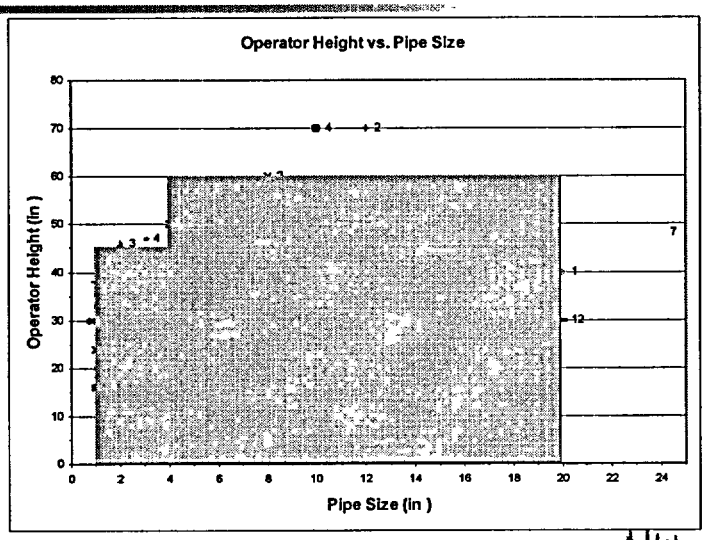
Summary by EQ-Facility Pair



Diversity of Data

- All operator types (air operated) are represented
- Wide range of manufacturers
- Both straight and angle operators
- Both horizontal and vertical operators
- Wide range of sizes

Comparison to GIP Figure B.7-1



Comparison to GIP Figure B.7-1

- Data goes up to the limits of the figure
- Figure bounds the earthquake data as intended
- SSRAP conclusion is valid for post-1985 data as well as pre-1985 data

Incidents of Damage

- Valley Steam
  - Control valve malfunction due to mercury switch vibration
  - Mercury switches prohibited by GIP (in relay review)
- El Centro
  - Valve yoke fractured due to impact against column
  - GIP requires adequate clearance to avoid seismic interactions

Incidents of Damage

- Getty Oil
  - Loss of offsite power disabled air compressor supplying air to valve and valve lost ability to function
  - GIP requires support systems (air supply to valve) to be capable of functioning
- Las Ventanas
  - Yoke fractured due to impact against handrail
  - GIP requires adequate clearance to avoid seismic interactions

Incidents of Damage

- Olive View Hospital
  - Cast iron valve body cracked due to concentration of forces at necked down region of piping or impact of operator against adjacent steelwork
  - GIP prohibits cast iron valve body and requires clearance to avoid seismic interaction

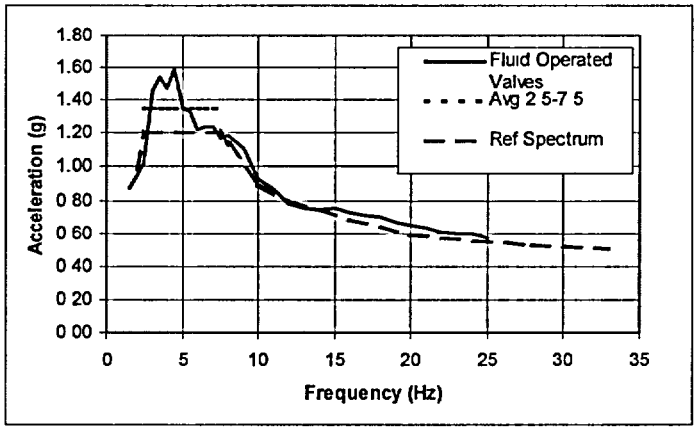
Conclusion

- FOV data supports GIP Equipment Class Definition
- All incidents of damage are addressed by the caveats (prohibited features)

QME Capacity Spectrum Calculation

- Weighted average spectrum based on:
  - Getty Oil: 1 independent item
  - Union Oil: 12 independent items
  - Placerita Cogen: 5 independent items
  - UC Santa Cruz: 1 independent item
  - Santa Cruz Water Treatment: 4 independent items
  - Manzanillo: 9 independent items
- Total: 32 independent items, 4 earthquakes, 6 sites

Capacity Spectrum Comparison



Capacity Spectrum Comparison

- QME capacity spectrum calculation (weighted average) agrees with GIP Reference Spectrum

Operability Assessment of FOVs Based on Analysis

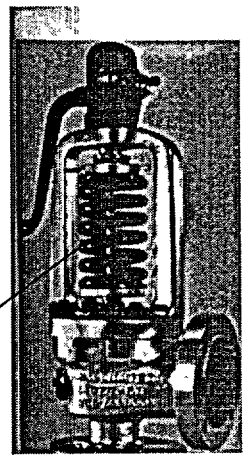
Purpose

- Review typical FOVs from an actual plant and apply bounding seismic demand
- Perform evaluation to demonstrate valve operability during seismic event

ATTACHMENT 4

Evaluation

- 10 FOVs were selected which represent typical valves – valves were from PWR plant and represent both safety and non-safety related applications.
- 8 are diaphragm valves, 2 are piston valves.
- Spring return relief valves were not evaluated due to small offset mass distance

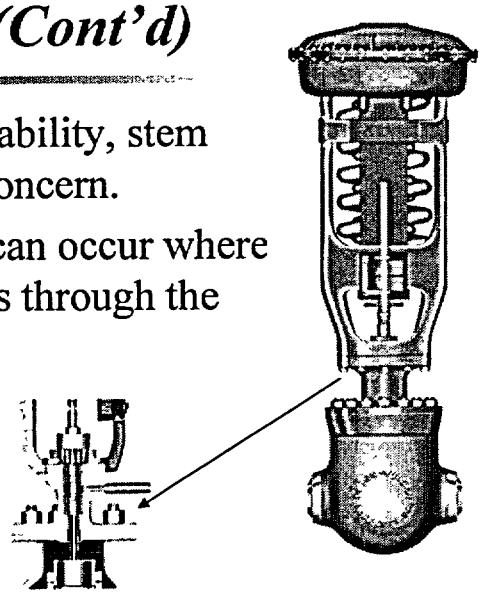


Evaluation

- Valves were first evaluated based on actual configuration (offset length)
- If offset length was less than limit of GIP Fig B.7-1, the length was then scaled up to GIP limit (6 additional analyses.)
- Offset mass based on drawing data. If offset mass not available, best estimate was used.

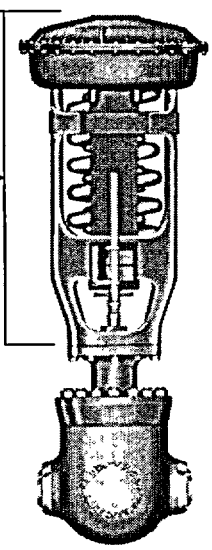
Evaluation (Cont'd)

- For valve operability, stem binding is of concern.
- Stem binding can occur where the stem passes through the bonnet.



Evaluation (Cont'd)

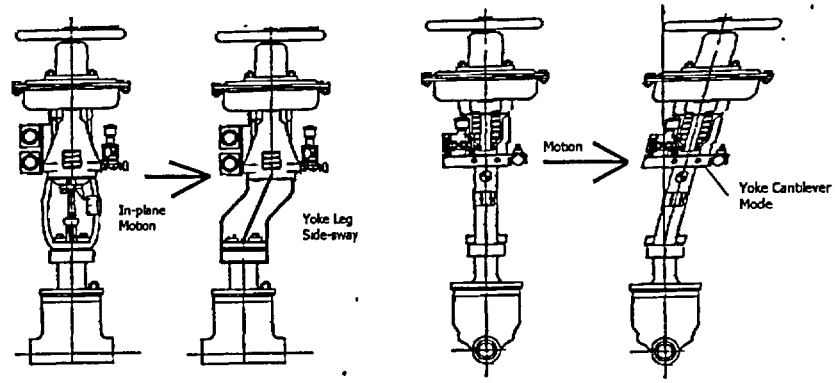
- Stem binding occurs as a result of top-works displacement from seismic motion of offset mass.
- The valve top-works displaces the top of the stem at the stem to spring or stem to diaphragm connection



Evaluation (Cont'd)

- Top-works displacement occurs primarily as a result of yoke flexibility.
  - in-plane motion (across yoke) results in yoke side-sway
  - out-of-plane motion results in yoke cantilever mode.

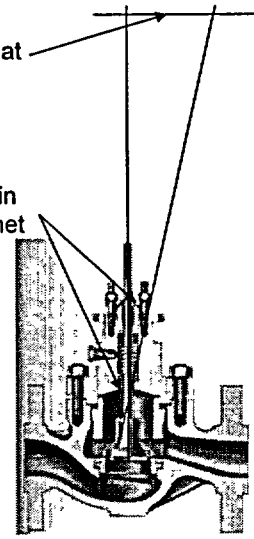
Evaluation (Cont'd)



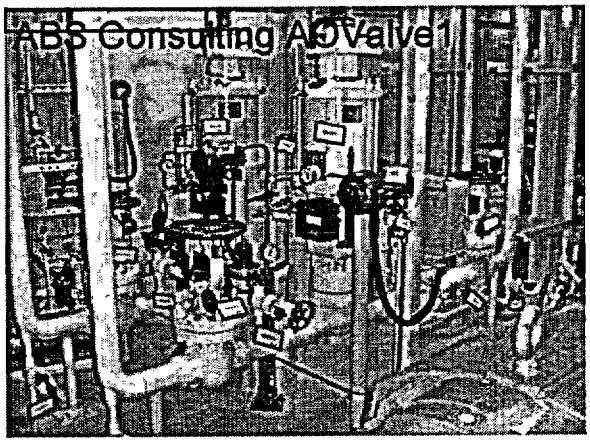
In-plane Motion -> Side-sway

Out-of-plane Motion -> Cantilever Mode

Evaluation (Cont'd)

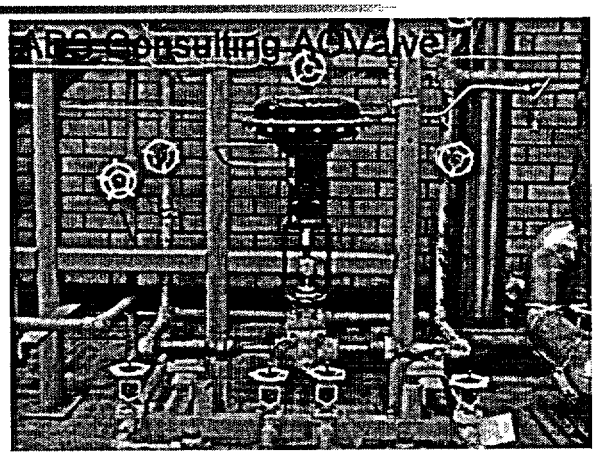


Evaluation Samples – FOV 1



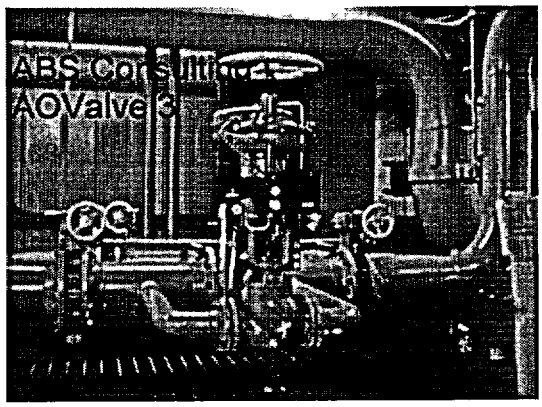
(2" pipe, 45.3" total height, 490 lb offset mass – piston actuator)

Evaluation Samples – FOV 2



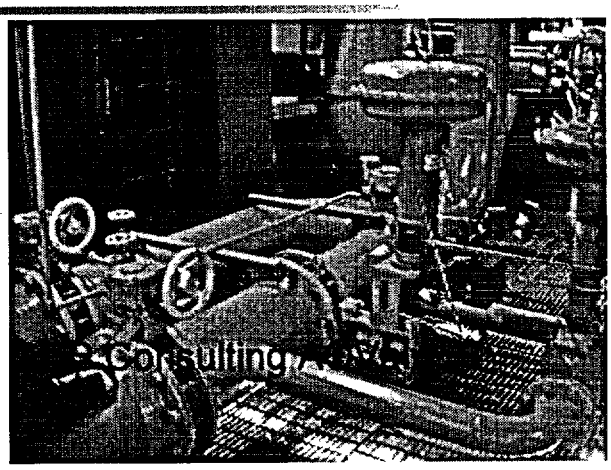
(1" pipe, 28.5" total height, 60 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 3



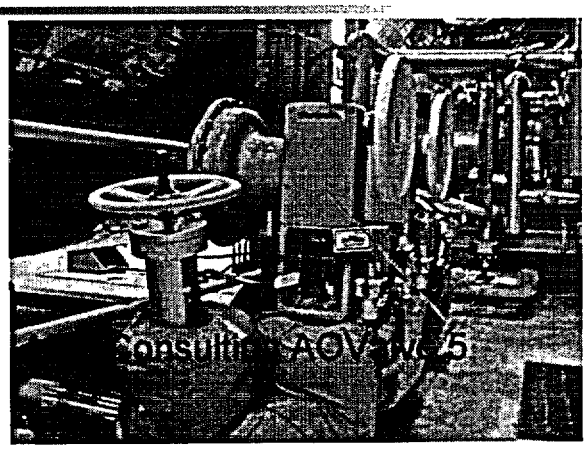
(4" pipe, 40.6" total height, 100 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 4



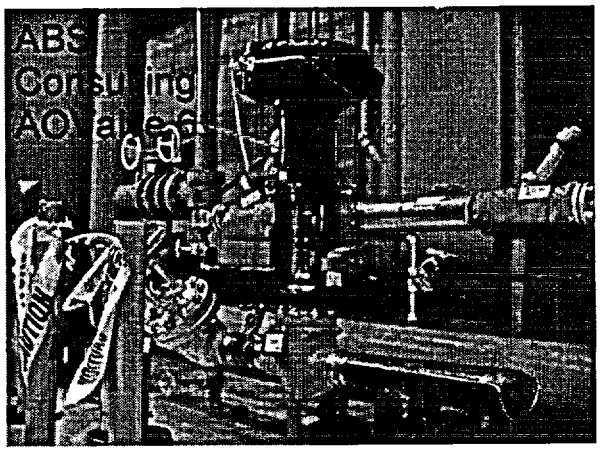
(12" pipe, 54.7" total height, 160 lb offset mass – diaphragm actuator)

Evaluation Samples - FOV 5



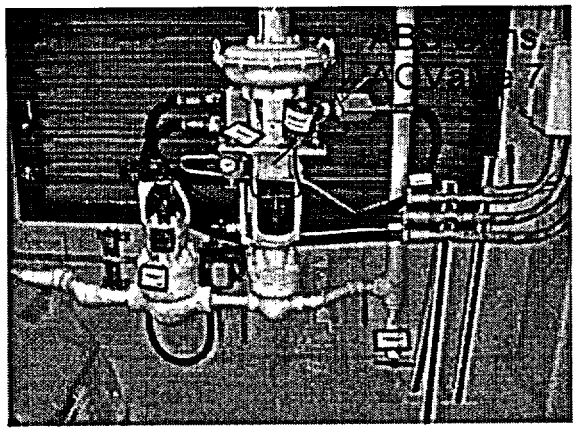
(3" pipe, 49" total height, 175 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 6



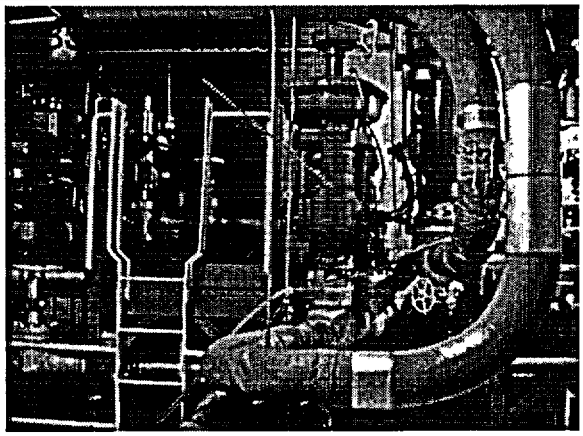
(4" pipe, 45.8" total height, 40 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 7



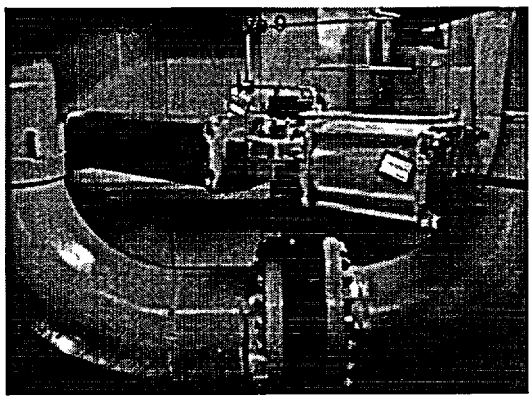
(1" pipe, 39.5" total height, 100 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 8



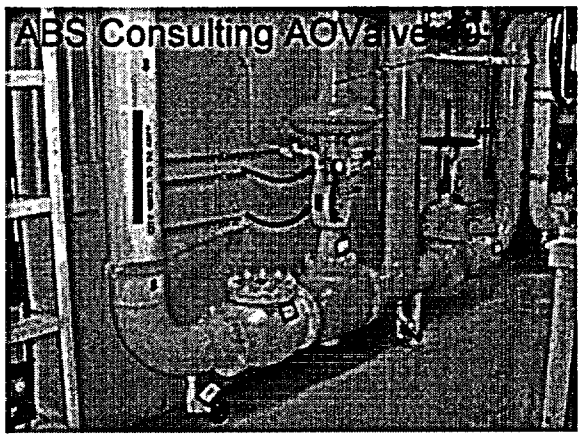
(6" pipe, 81.75" total height, 500 lb offset mass – diaphragm actuator)

Evaluation Samples – FOV 9



(20" pipe, 35" total height, 1100 lb offset mass – piston actuator)

Evaluation Samples – FOV 10



(8" pipe, 59.5" total height, 370 lb offset mass – diaphragm actuator)

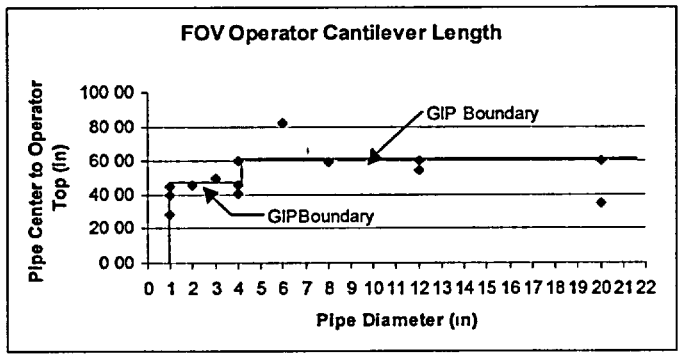
Data Input

Valve Identifier # -->		FOV 1	FOV 2	FOV 3	FOV 4	FOV 5	FOV 6	FOV 7	FOV 8	FOV 9	FOV 10
Item	Unit	photo 1	photo 2	photo 3	photo 4	photo 5	photo 6	photo 7	photo 8	photo 9	photo 10
Valve Manufacturer	-	CCI	Fisher	C-V	Fisher	Masoneilan	Fisher	C-V	C-V	Posi-Seal	Masoneilan
Actuator Manufacturer	-	CCI	Fisher	C-V	Fisher	Masoneilan	Fisher	C-V	C-V	Posi-Seal	Worthington
Valve Type	-	GLOBE	Plug	Globe	Bfly	Globe	Plug	Plug	Globe	Bfly	Globe
Pipe Size	-	2	1	4	12	3	4	1	6	20	8
ANSI Class	#	900	600	150	150	600	600	1500	900	300	150
Actuator Type	-	Piston	Diaphragm	Diaphragm	Diaphragm	Diaphragm	Diaphragm	Diaphragm	Diaphragm	Piston	Diaphragm
Actuator Model	-	1000	667-34	CV-600-10	656-60	Sigma F	667-20	D-100-100	D-100-140	Type1031	#18 R
Actuator Weight	lbs	490	60	100	160	175	40	100	500	1100	370
Body H-Body	in	7 50	3 00	7 00	9 50	7 50	6 00	5 00	10 00	12 00	8 50
Bonnet H-Neck	in	3 25	3 25	5 00	2 00	7 50	4 50	5 00	8 75	6 00	11 00
Yoke YL	in	7 63	7 63	11 00	7 25	9 25	12 56	8.00	10 00	5 00	11 00
Actuator H-Act-1	in	17 00	11 63	11 00	12.00	13 00	18 75	14 50	34 00	5 00	12 00
Actuator H-Act-2	in	10 00	3 00	8 60	24 00	12 00	4 00	7 00	19 00	5 00	17 00
Wt Offset Delta-Z	in	13 50	7 75	8 00	0 00	8 00	12 50	9 67	22 67	10 00	17 67
Wt Offset Delta-X	in	0 00	0 00	0 00	5 75	0 00	0 00	0 00	0 00	10 00	0 00
Wt Offset Delta-Y	in	0 00	0 00	0 00	28 00	12 00	0 00	0 00	0 00	10 00	0 00
Total Offset	in	45 38	28 50	40 60	54 75	49 25	45 81	39 50	81 75	35 00	59 50
GIP Fig B.7-1 Bound	in	45 00	45 00	60 00	60 00	45 00	60 00	45 00	60 00	60 00	60 00
GIP Rate (Offset/Bound)	-	0 99	1 58	1 48	1 10	0 91	1 31	1 14	0 73	1 71	1 01
Yoke Type	-	Channel	Flat	Flat	T-out	Flat	Flat	Curve	Curve	Flat	Flat
Yoke W YLW	in	8 00	2 50	2 75	3 38	5 25	3.31	NA	NA	6 75	5 00
Yoke t YLT	in	0 50	0 38	0 75	0 63	0 75	0 44	0 75	1 50	0 50	0 63
Yoke D YSL	in	3 50	2 00	2 56	2 56	3 25	4 06	2 50	4 00	7 00	2 81
Rib W YRW	in	1 00	0 00	0 00	0 63	0 00	0 00	0 00	0 00	0 00	0 00
Rib t YRT	in	1 00	0 00	0 00	0 63	0 00	0 00	0 00	0 00	0 00	0 00
Yoke Circ Alpha	deg	0 00	0 00	0 00	0 00	0 00	0 00	36 86	40 00	0 00	0 00
Yoke/Body Attach	-	Bolted	Bolted	Bolted	Bolted	Integral	Bolted	Bolted	Bolted	Bolted	Bolted
No of Bolts	-	6	1	1	4	NA	1	4	8	8	1
Bolt Circle Diameter	in	4	NA	NA	2x8 25	NA	NA	2 5x2 5	10	8 5	NA
Bolt Diameter	in	0 50	2 00	2 50	0 63	NA	3.63	0 75	0 75	0 75	4 00
Valve Stem Diameter	in	0 38	0 38	0 75	1 25	1 00	0 75	0 75	1 00	2 75	1 00
Act Stem Diameter	in	0 75	0 75	1 13	1 00	0 63	1 25	0 75	1 00	NA	1 00
Coupling Diameter	in	0 38	0 38	0 75	1 25	0 63	0 75	0 75	1 00	NA	0 75
Coupling Type	-	Thread	Thread	Thread	Link	Thread	Thread	Thread	Thread	Yoke	Thread
Stem Orientation	-	V	V	V	H	V	V	V	V	V	V
Stem Load	lbs	2000	3000	5000	5000	5000	0	5000	40000	0	12000
Stem Torque	in-lbs	0	0	0	0	0	25000	0	0	60000	0

Analysis Methodology

- Followed "weak link" analysis methodology
- Operation load based on typical operating pressure times diaphragm/piston area
- Seismic load was 3g static in each direction, combined by SRSS
- Seismic load is 2.5 to 6 times the capacity spectrum (3g is 2.5 times 1.2g peak value, and 6 times 0.5g ZPA)

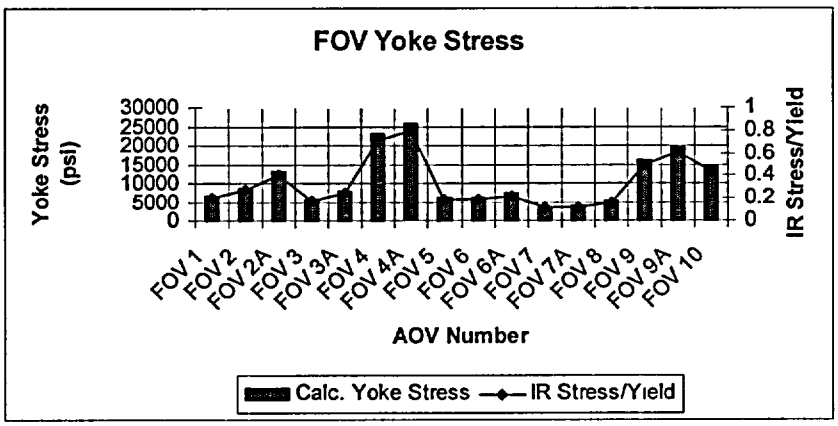
Comparison to GIP



Typical Medium Size FOV

Actual and factored valves are representative of GIP Fig B.7-1

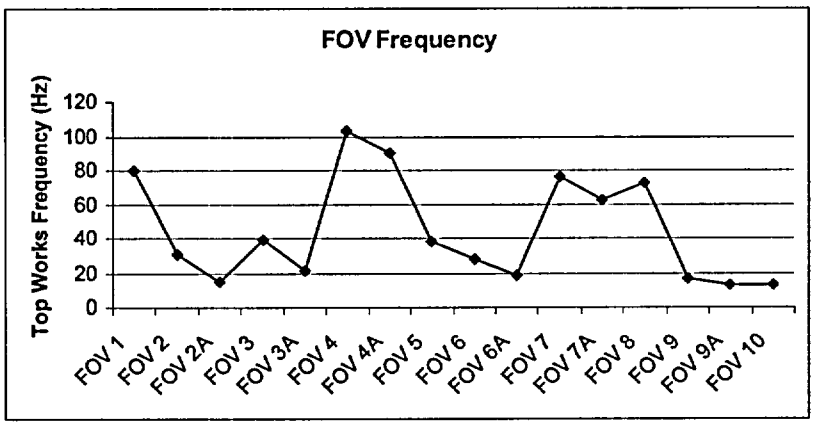
Results – Yoke Stress vs. Yield



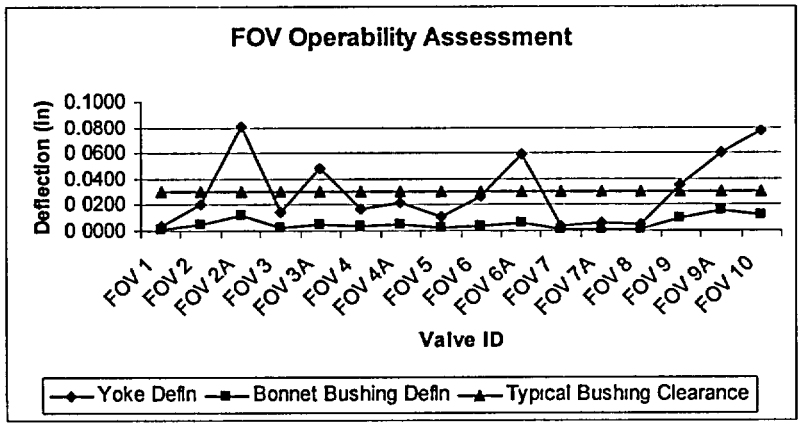
Yoke Stress arbitrary set at 32,400 psi

– typical for most steel & cast steel/iron yokes used in FOV manufacture

Results – Frequency



Results – Operability



OBE

- GIP Caveats: Preclude low cycle fatigue failure modes
- Analysis Results: Stresses are well within elastic limits for GIP capacity - stresses for 1/2 GIP capacity would be less than 1/2 elastic limits
- Multiple Earthquakes: Several sites experience multiple earthquakes – no affect on future operability of equipment

Multiple Earthquakes

Average Horizontal PGA in San Fernando (1971), Whittier Narrows (1987), Sierra Madre (1991) & Northridge (1994) Earthquakes			
Site	**Nearest Record**	**Earthquake Date**	**PGA (Av. Horiz.)**
Valley Steam Plant	Holiday Inn Orion Blvd	2/11/71	0 20g
Valley Steam Plant	LADWP Station E	1/17/94	0 50g
Burbank Power Plant	Glendale City Hall	2/11/71	0 25g
Burbank Power Plant	Base of Burbank High-rise	1/17/94	0 31g
Glendale Power Plant	Glendale City Hall	2/11/71	0 25g
Glendale Power Plant	Burbank Pacific Manor	10/1/87	0 24g
Glendale Power Plant	Base of Burbank High-rise	1/17/94	0 31g
Pasadena Power Plant	Cal Tech Millikan Library	2/11/71	0 20g
Pasadena Power Plant	San Marino SW Academy	10/1/87	0 17g
Pasadena Power Plant	San Marion SW Academy	6/28/91	0 16g
Pasadena Power Plant	San Marion SW Academy	1/17/94	0 14g

Multiple Earthquakes

Average Horizontal PGA in Imperial Valley (1979) & Superstition Hills (1987) Earthquakes			
Site	**Nearest Record**	**Earthquake Date**	**PGA (Av. Horiz.)**
El Centro Steam Plant	On-site free-field	10/15/79	0 44g
El Centro Steam Plant	On-site free-field	11/24/87	0 26g
Average Horizontal PGA in the Coalinga Earthquake Sequence of 1983			
Site	**Nearest Record**	**Earthquake Date**	**PGA (Av. Horiz.)**
Union Oil	Pleasant Valley Pump Station	5/2/83	0 55g
Union Oil	Palmer Avenue	5/9/83	0 24g
Union Oil	Palmer Avenue	5/12/83	0 12g
Union Oil	Palmer Avenue	5/24/83	0 11g
Union Oil	Palmer Avenue	7/9/83	0 16g
Union Oil	Palmer Avenue	7/22/83	0 29g
Union Oil	Palmer Avenue	7/25/83	0 16g

Multiple Earthquakes

Average Horizontal PGA in the Ferndale (1975), Humboldt County (1980) & Cape Mendocino Earthquake Sequence of 1992			
Site	**Nearest Record**	**Earthquake Date**	**PGA (Av. Horiz.)**
Humboldt Bay Plant	On-site free-field	6/7/75	0 31g
Humboldt Bay Plant	Unit 3 Control Room	11/8/80	0 26g
Humboldt Bay Plant	On-site free-field	4/25/92 11 06	0 22g
Humboldt Bay Plant	On-site free-field	4/26/92 00 41	0 24g
Humboldt Bay Plant	On-site free-field	4/26/92. 04 18	0 11g
PALCO Cogen	Rio Dell Overpass	4/25/92 11.06	0 47g
PALCO Cogen	Rio Dell Overpass	4/26/92 00 41	0 52g
PALCO Cogen	Rio Dell Overpass	4/26/92 04 18	0 45g

Conclusions

- The FOV data assembled and the analyses done show
  - GIP Equipment Class Definition is valid
  - GIP Capacity Spectrum is valid
  - GIP Criteria assure ability to operate during the earthquake up to seismic level of capacity spectrum
  - GIP Criteria addresses OBE concern up to level of capacity spectrum