A Relay Fragility Test Experience of Nuclear Power Plant in Taiwan

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Content

- **Introduction of Test Facility**
- **Background and Test Specimens**
- **Test Configuration**
- **Test method and require response spectrum**
- **Test steps**
- **Functional test and chatter monitoring**
- **Test results**
- **Conclusion**

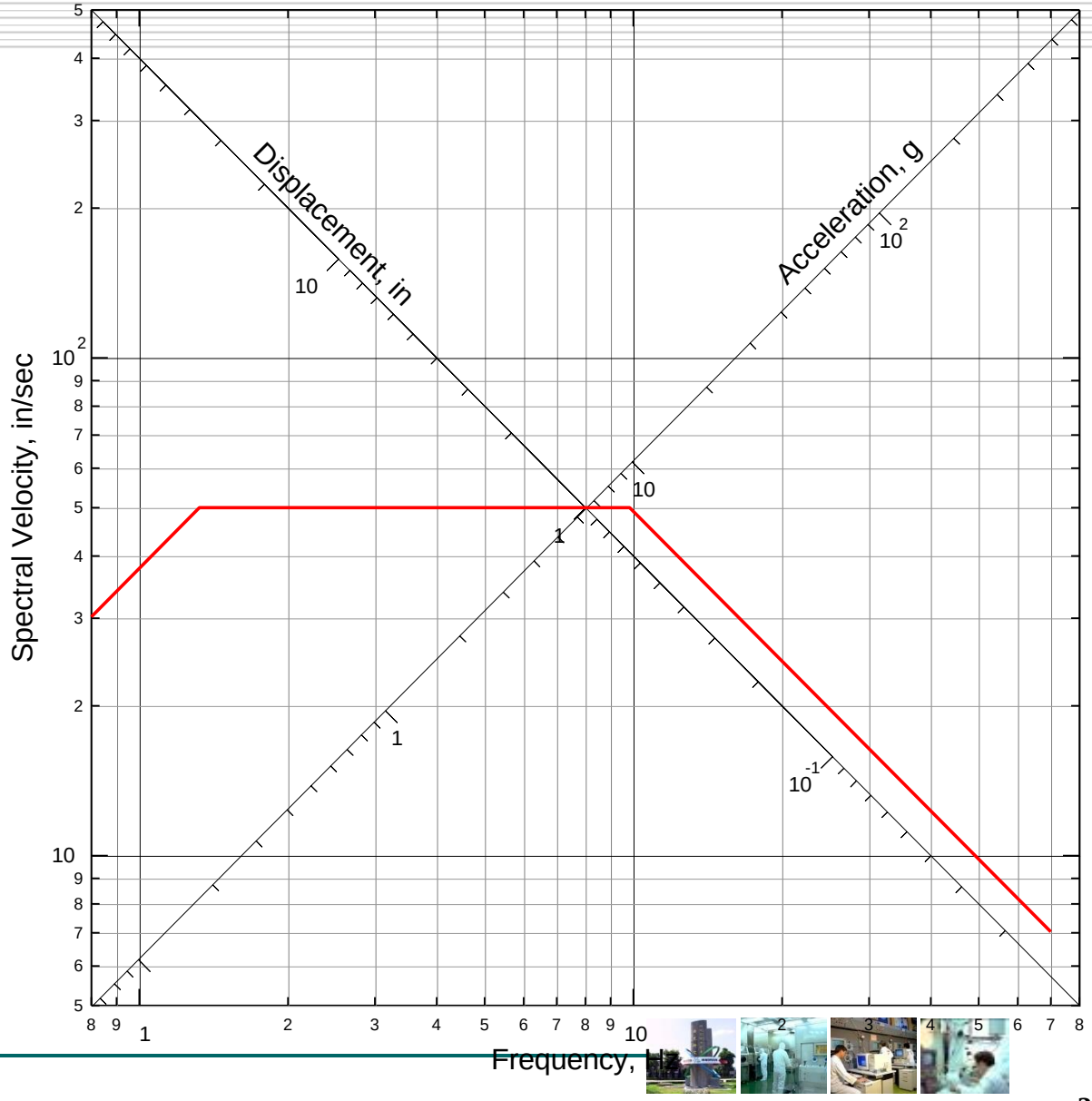
Test Facility

Shake Table of Seismic Test Laboratory

- Dependent Biaxial
- 45^0 inclination of actuator

Performance curve of INER's shake table

Freq. Hz	Velo, in/sec	Disp, in	Acc. g
0.8	30.15929	6	0.39233
1.322912	50	6	1.07558
9.839595	50	0.80875	8
70	7.028282	0.01598	8



Seismic Testing Laboratory of INER

- Under Mechanical and System Engineering Program of INER.
- Recognized testing laboratory of TAF(Taiwan Accreditation Foundation),and TAF has Mutual Recognition Arrangement with ILAC (International Laboratory Accreditation Cooperation)
- Certified by Taiwan AEC as a dedication laboratory for seismic qualification of commercial grade items for NPP since 1994.
- Quality Program comply with ISO 17025 and 10 CFR 50 App.B
- 9 staffs
- Task of function monitoring is supported by dedication group of MSEP

Background

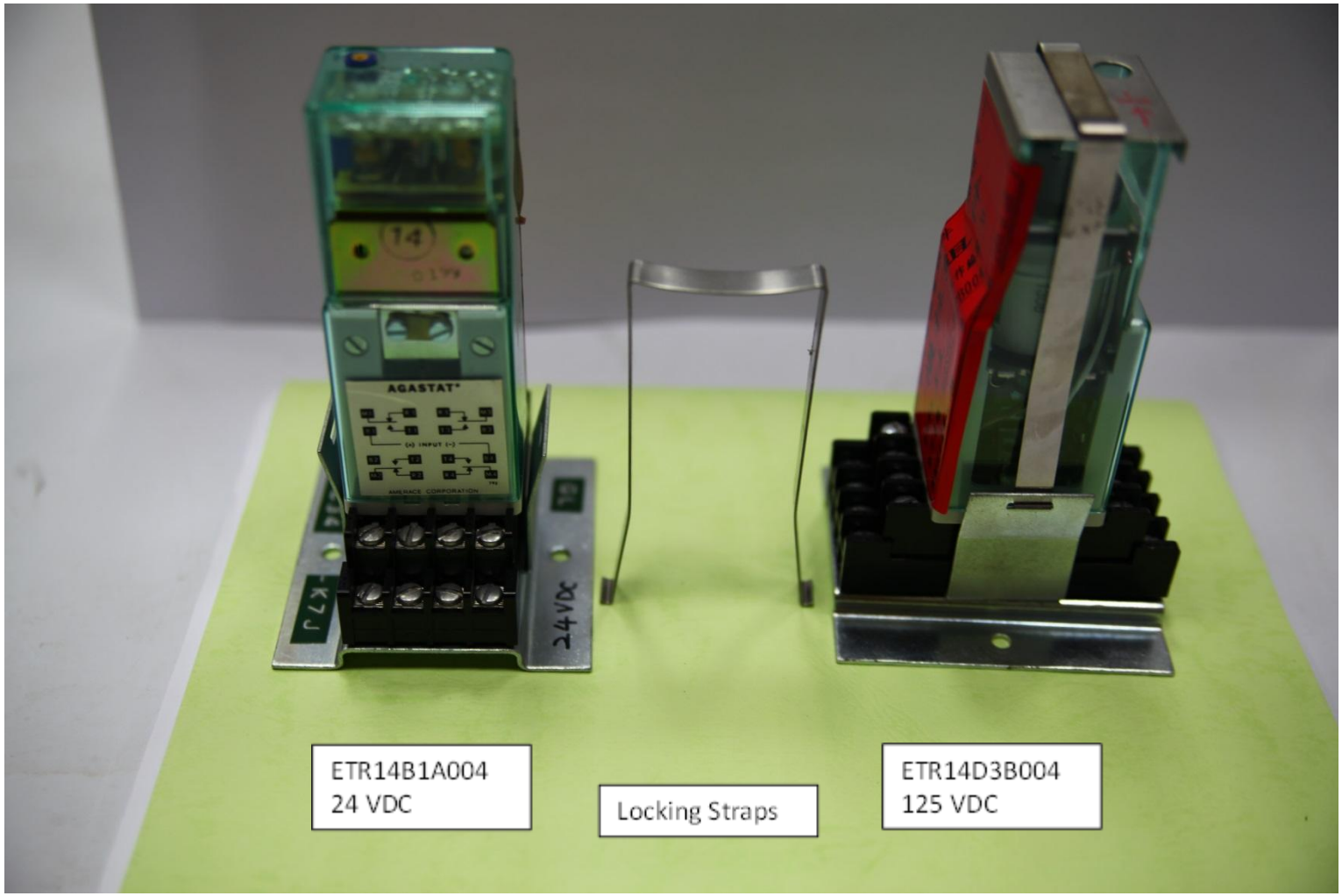
- Initiation ： Kuosheng NPS conducted SMA project in 2011,came out a relay chatter outlier list.(in early 2013)
- 2 Agastat's ETR series relays in the outlier list were determined to do fragility test to solve the problem on March 2014 finally.
- Chattering of these 2 relays will open minimum flow valve of RHR system and stay open.(relays are mounted in the control room panel)
- Fragility level of these 2 relays were assessed to be 3.3 g/1.32 g (peak G/ZPA) both, and RLE (Review Level Earthquake) demand capacity are 5.2 g/2.29 g the same.

- Objective：

  Prove these 2 relays have fragility level excess 5.2 g,

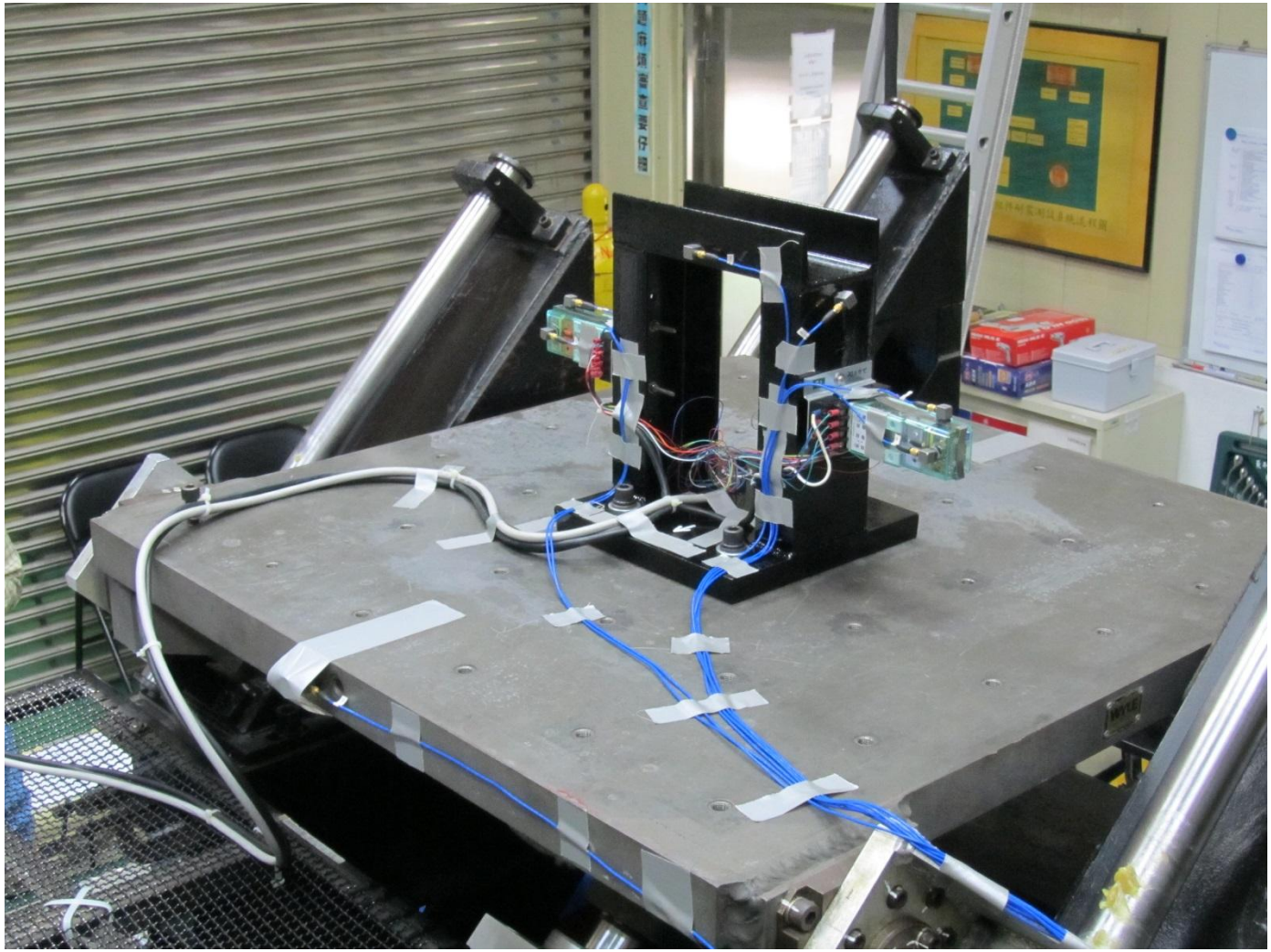
  under deenergized mode with NO contacts no chattering.

Test Specimens

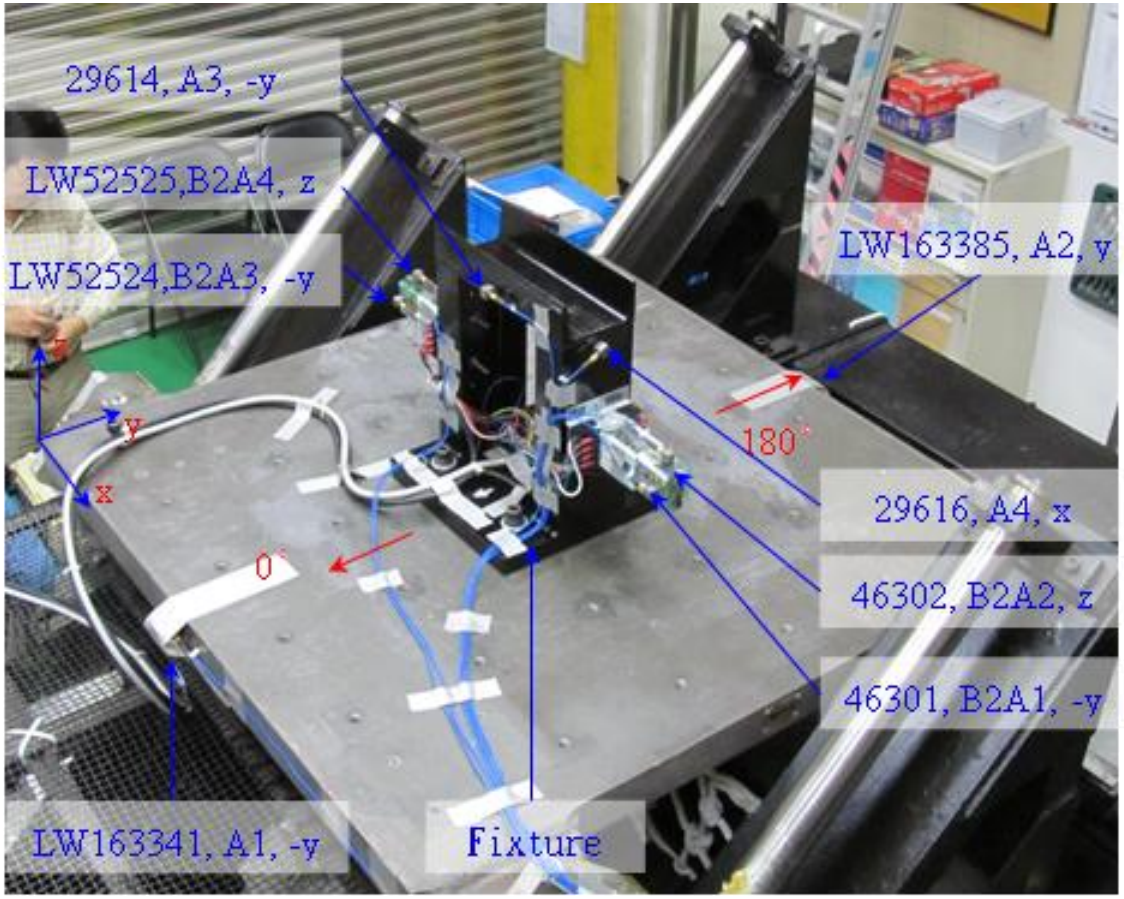


In Service Mounting(control room)

Fixture and mounting of specimens



Test Configuration & Accelarometers Deployment



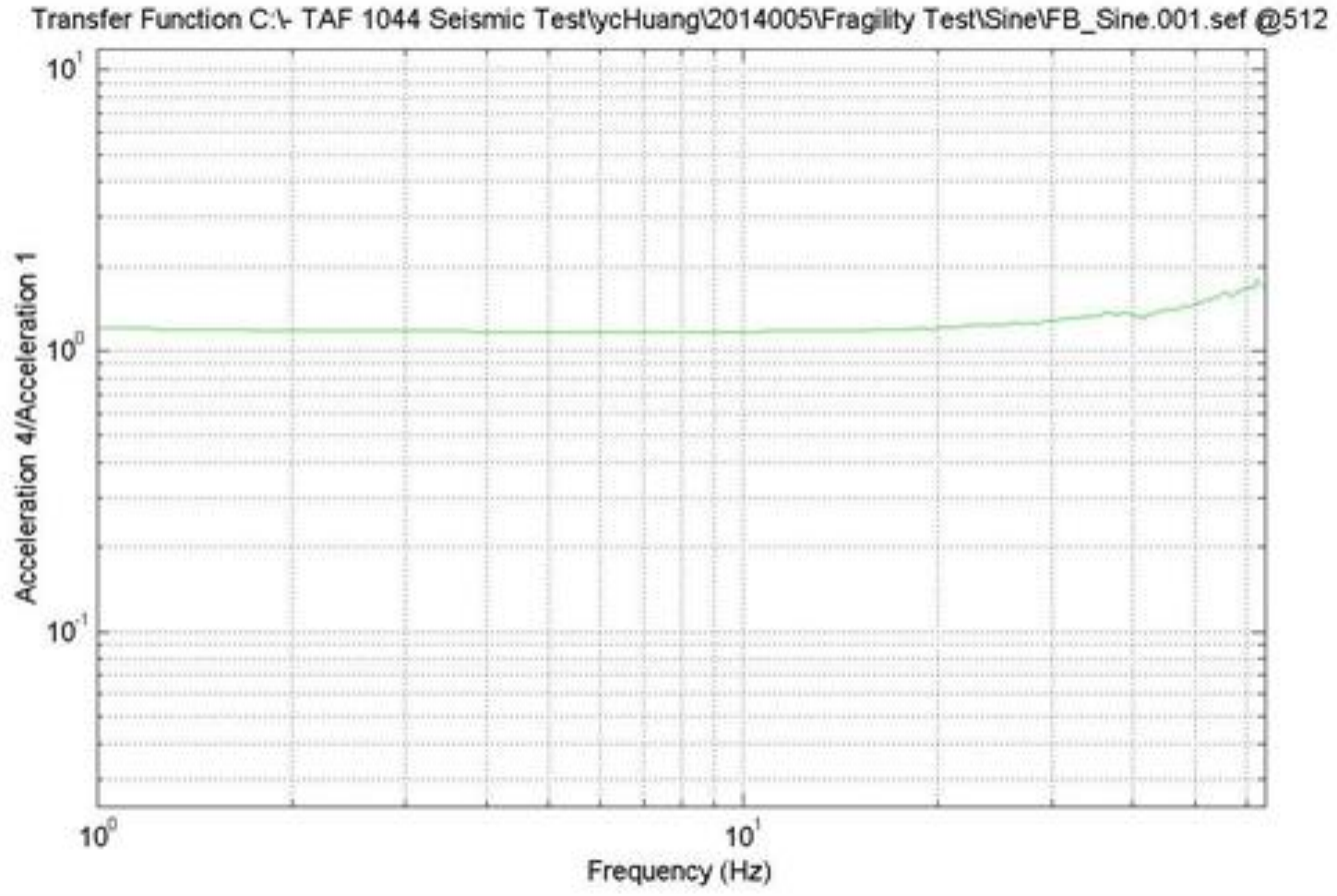
Note：(29614, A3, -y) (Accelarometer Series No., Channel No., Coordinate)

Resonance Search

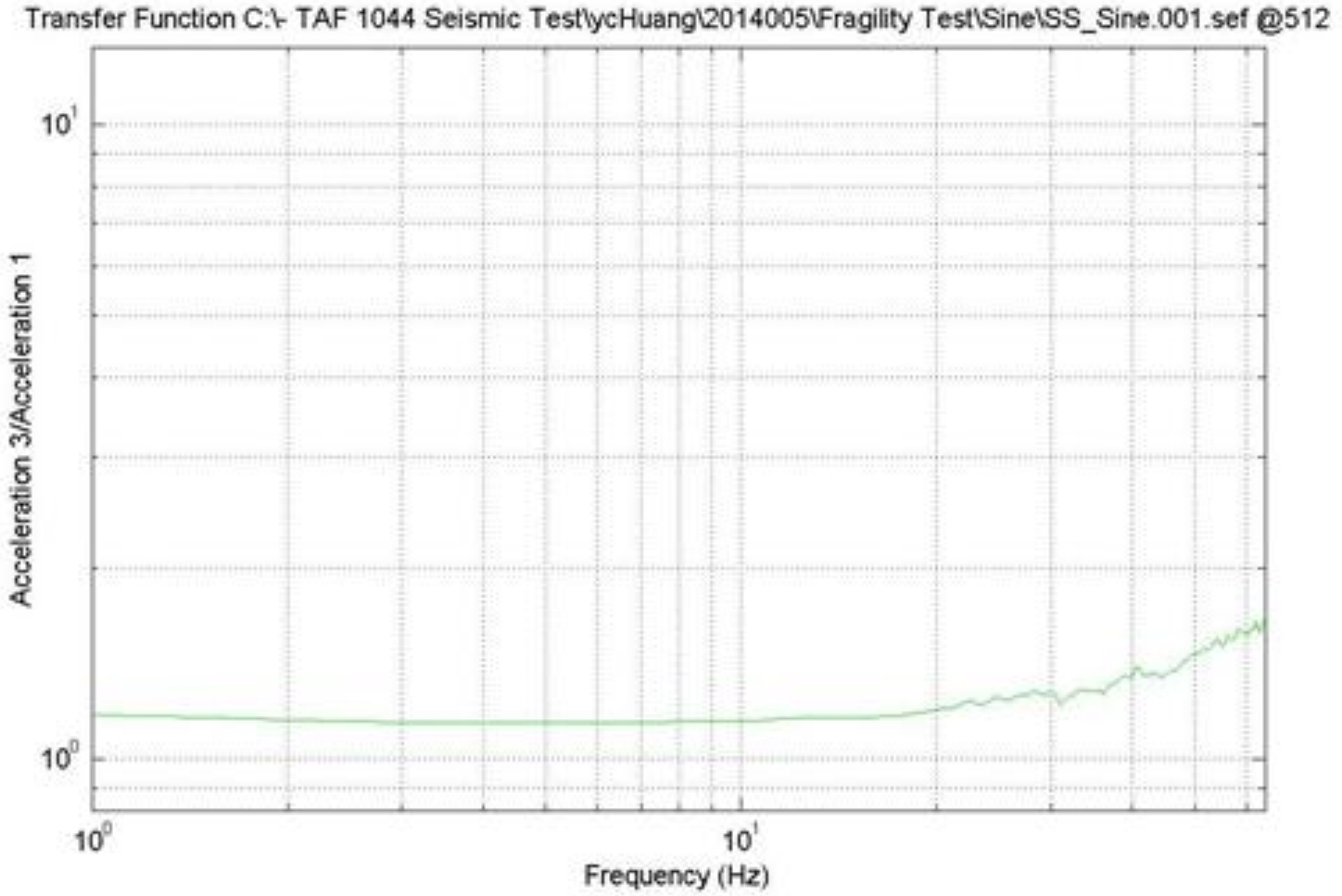
- A sinesweep test was conducted by 1 octave/min sweep rate, o.2 g amplitude, from 1 Hz to 64 Hz to find out the natural frequency of fixture and relay before fragilty testing.

- Result identify the natural frequency of fixture is at 64 Hz, proof the structure rigidity of fixture.

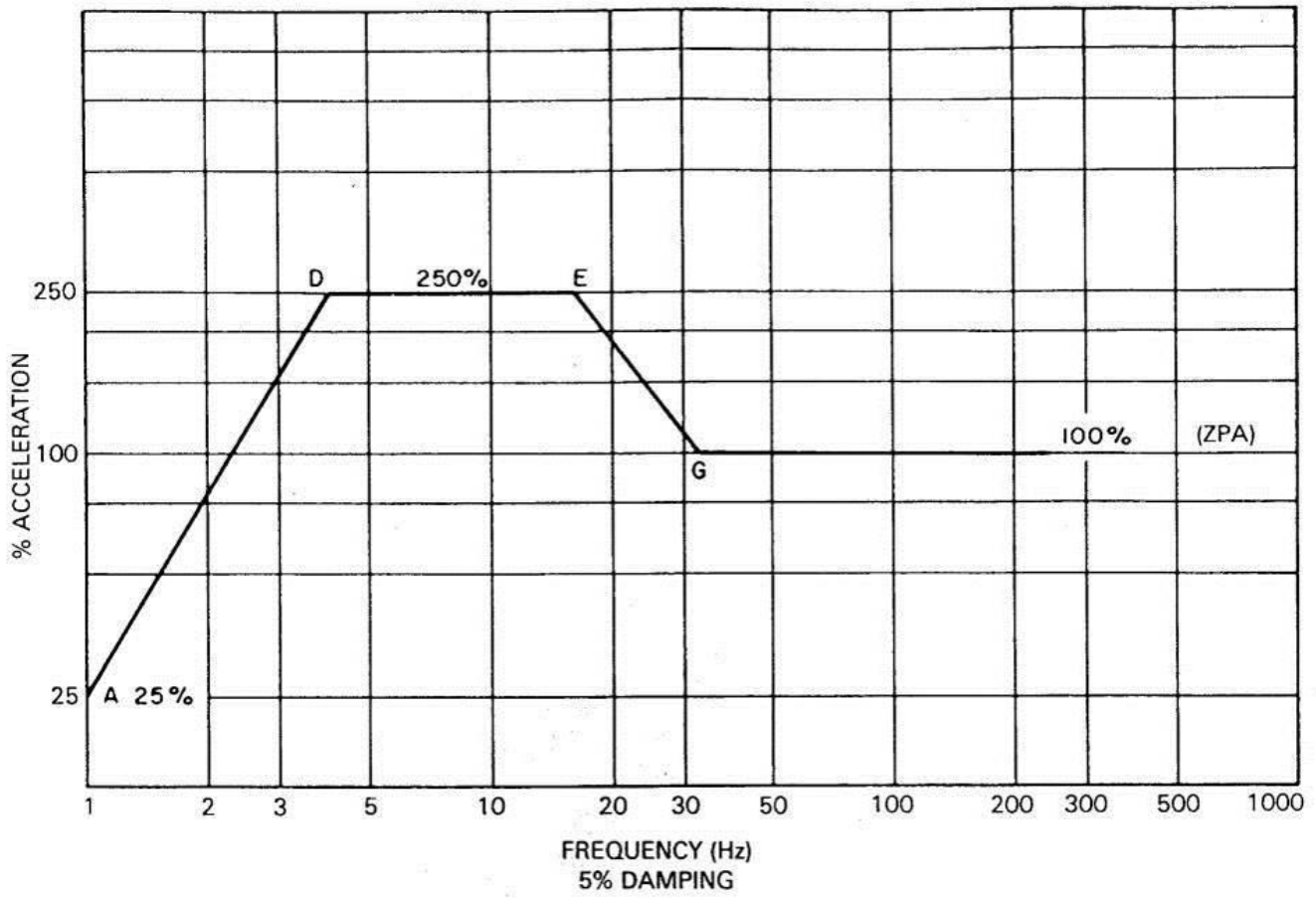
FRF of fixture in horizontal direction (front-to-back)



FRF of fixture in horizontal direction (side-to-side)



Multifrequency Broadband Standard Response Spectrum Shape



RRS of Tests

- Differ from SRS of C37.98 in G point, same as modified GERS of EPRI NP-7147-SL,V2 Fig. 2-1, modified GERS.
- Modified GERS level equal to 1.5 times the orignal ZPA

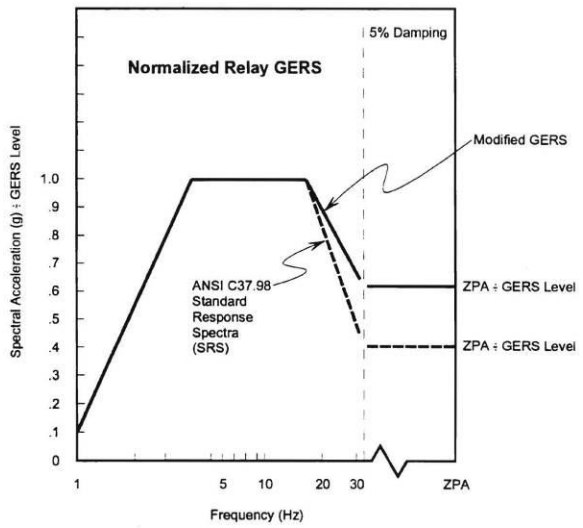
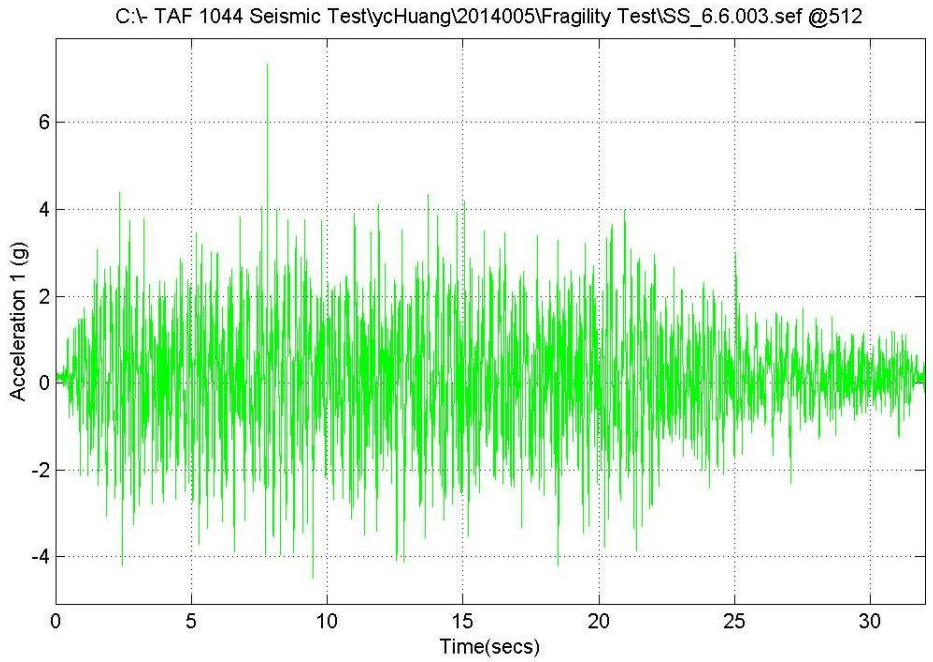


Figure 2-1
Standard normalized GERS Spectrum

Decision of g level for Test

- 3.63 g- verify assessed capacity of 3.3 g + 10% margin.
  for conservative, instead of peak g, the 3.63 g
  is designated as ZPA of modified GERS
- 4 & 5 g-the increment of test ZPA level is made by
  experience.
- 6 g- velocity of shake table needed to be about 48
  in/sec approaching limitation.

Seismic waves of input motions



Proceeding of Tests

TEST STEPS

By steps of increasing levels of seismic input until a failure (or malfunction) occurs or the shaking table reached its capacity limits. Four levels of seismic input in terms of Zero-Period Acceleration (ZPA) are chosen, i.e., 3.63 g, 4.4 g, 5.5 g and 6.6 g

The fragility test steps for each desired level as following:

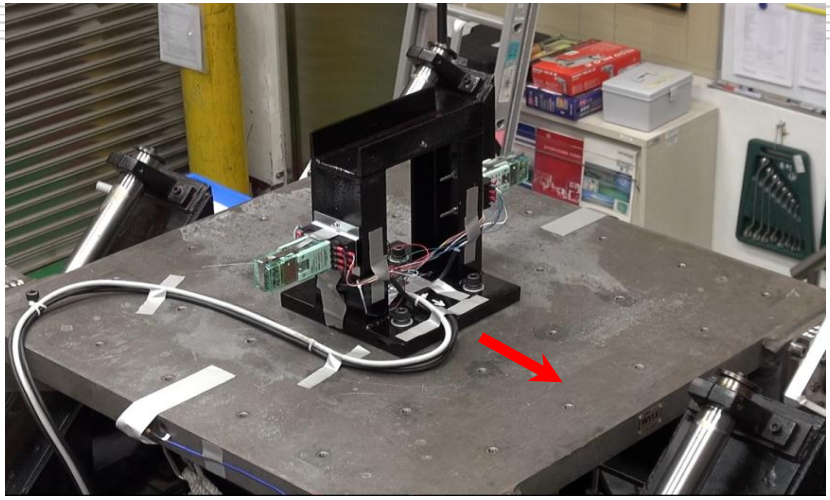
(1)With relays at 0^0 position(front-to back orientation)

(2)With relays rotated 180^0 about the vertical axis

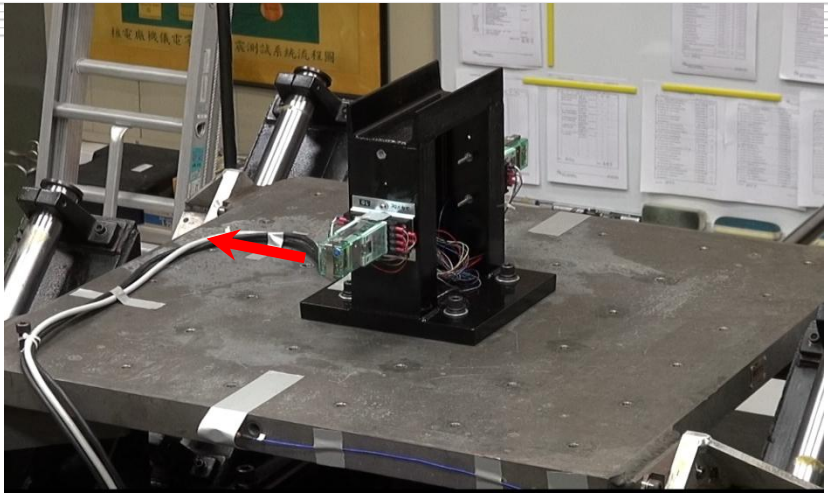
(3)With relays rotated 90^0 about the vertical axis (side-to-side orientation)

(4)With relays rotated 180^0 about the vertical axis again

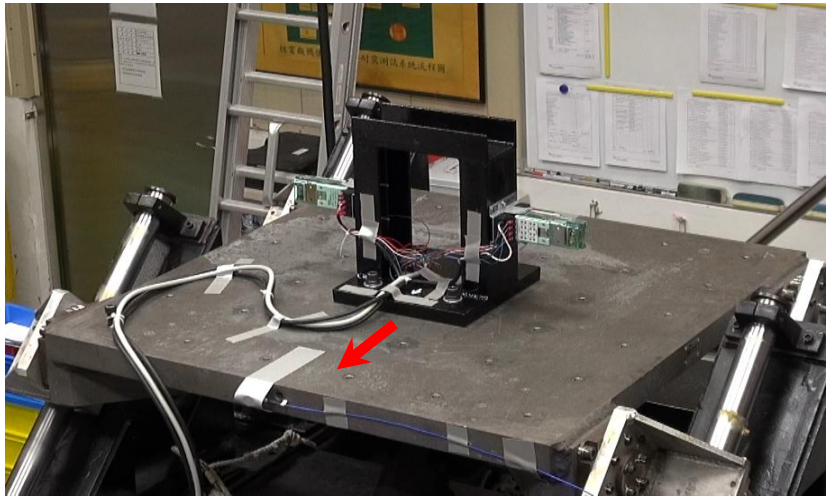
6.6 g test in front-to-back 180^0 orientation (record video shown)



Front to Back, 0º



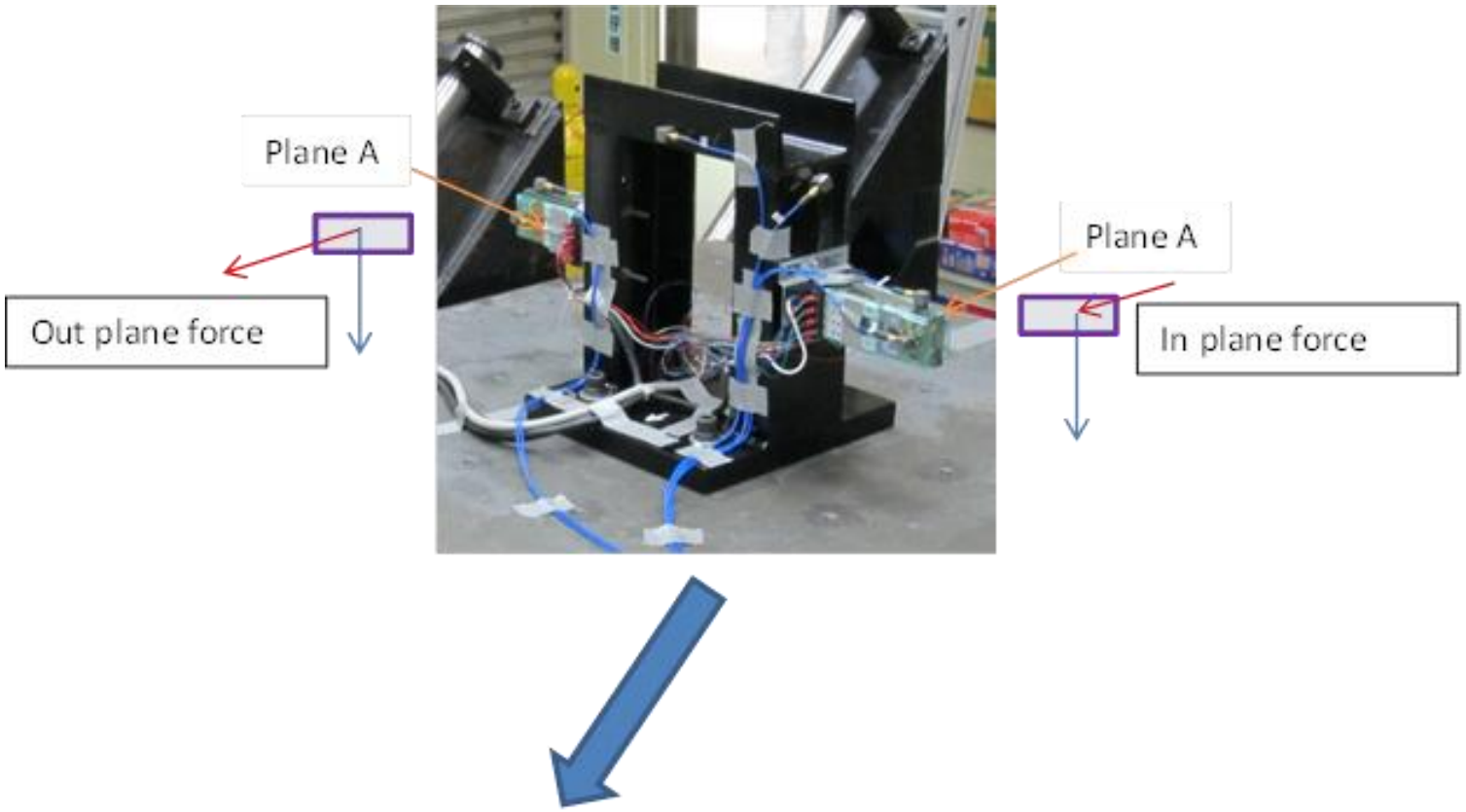
Front to Back, 180º



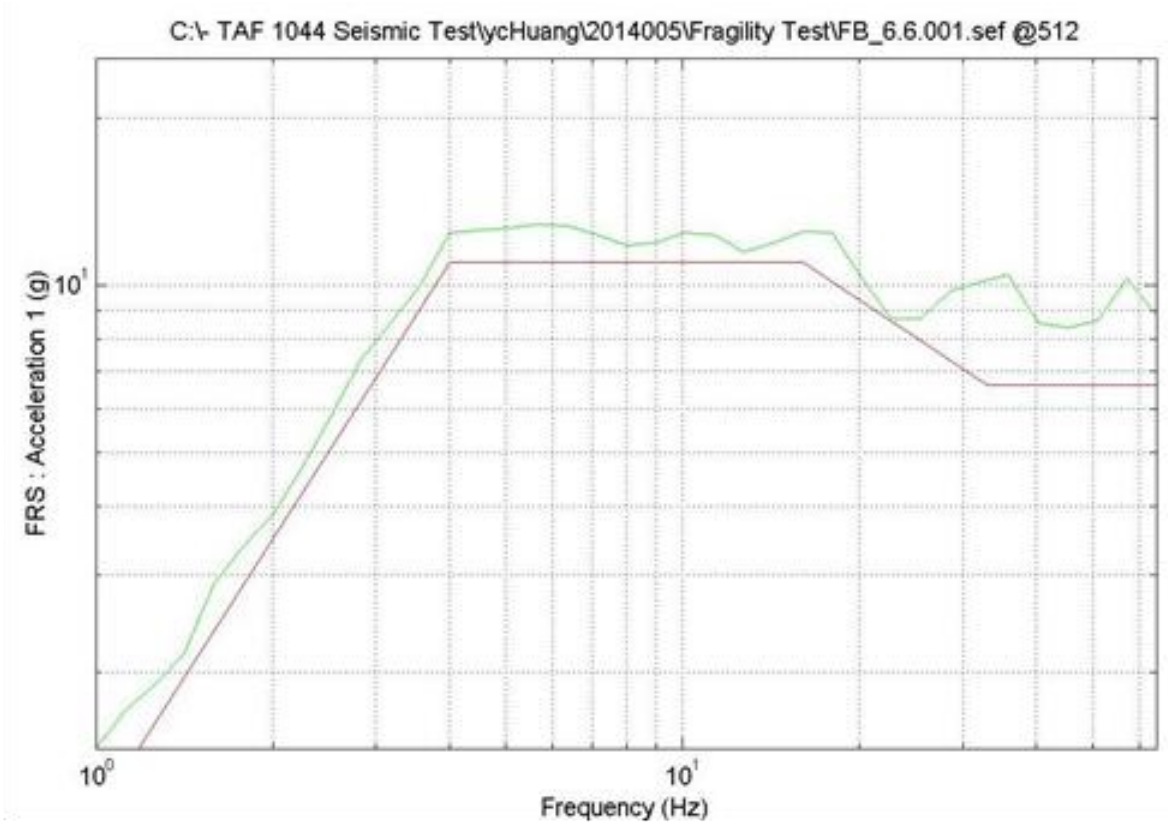
Side to Side, 0º

Side to Side, 180º

Phenomenon of input 180^0 out of phase



FRS of 6.6 g test in front-to-back 180^0 orientation



Run log of tests (1)

Date of test ：April 23th, 2014.				
Sine sweep				
File name	Time	Test direction		Result
FB_Sine.001.sef	10:38	Front to Back		Completed
SS_Sine.001.sef	10:21	Side to Side		Completed
Fragility test				
File name	Time	Test direction and orientation		Result
FB_3.63g.001.sef	10:45	Front to Back	0°	Valid
FB_3.63g.002.sef	10:53	Front to Back	180°	TRS<RRS
FB_3.63g.003.sef	10:54	Front to Back	180°	TRS<RRS
FB_3.63g.004.sef	10:57	Front to Back	180°	TRS<RRS
FB_3.63g.005.sef	10:59	Front to Back	180°	Valid
SS_3.63g.001.sef	11:05	Side to Side	0°	Valid
SS_3.63g.002.sef	11:10	Side to Side	180°	Valid
SS_4.4g.001.sef	11:12	Side to Side	180°	TRS<RRS

Run log of tests (2)

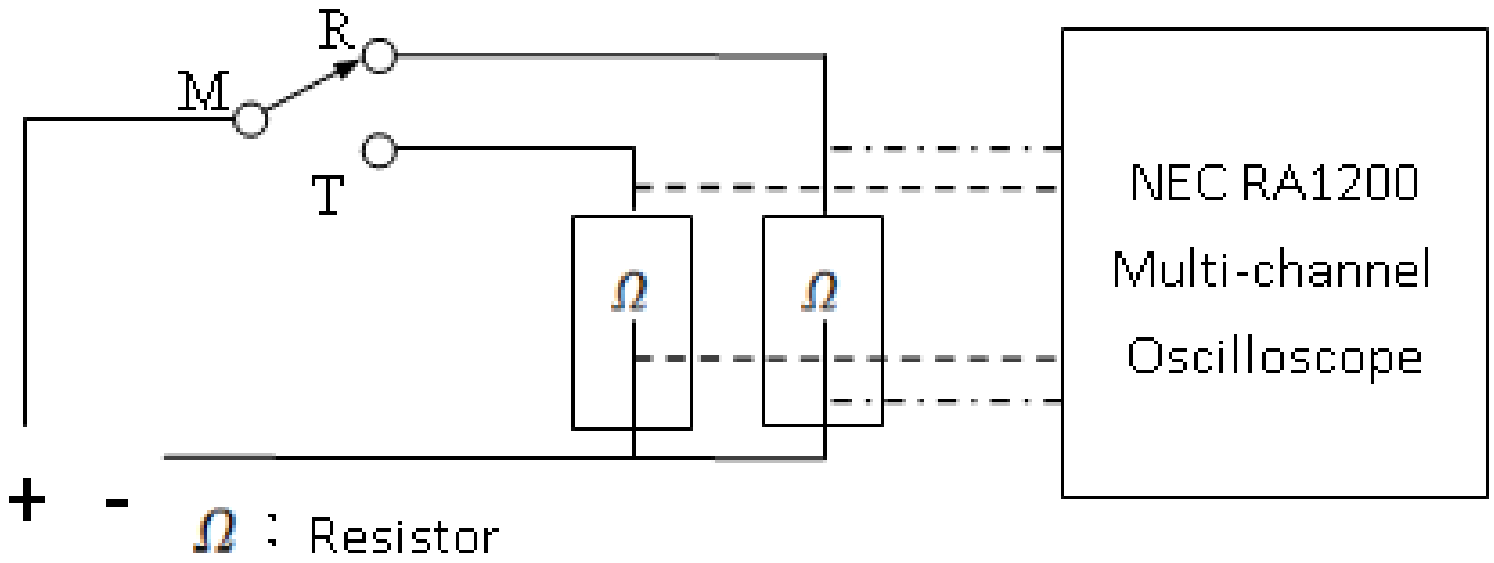
Fragility test				
File name	Time	Test direction and orientation		Result
SS_4.4g.002.sef	11:14	Side to Side	180°	Valid
SS_4.4g.003.sef	11:32	Side to Side	0°	Valid
FB_4.4g.001.sef	11:37	Front to Back	180°	Valid
FB_4.4g.002.sef	11:43	Front to Back	0°	Valid
FB_5.5g.001.sef	11:44	Front to Back	0°	Valid
FB_5.5g.002.sef	13:43	Front to Back	180°	Valid
SS_5.5g.001.sef	13:48	Side to Side	0°	Valid
SS_5.5g.002.sef	13:52	Side to Side	180°	Valid
SS_6.6g.001.sef	13:54	Side to Side	180°	Valid
SS_6.6g.002.sef	14:01	Side to Side	0°	Chatter monitoring failed
SS_6.6g.003.sef	14:04	Side to Side	0°	Valid
FB_6.6g.001.sef	14:09	Front to Back	180°	Valid
FB_6.6g.002.sef	14:14	Front to Back	0°	Hydraulic power trip
FB_6.6g.003.sef	14:17	Front to Back	0°	Valid

Functional Test and Chatter Monitoring

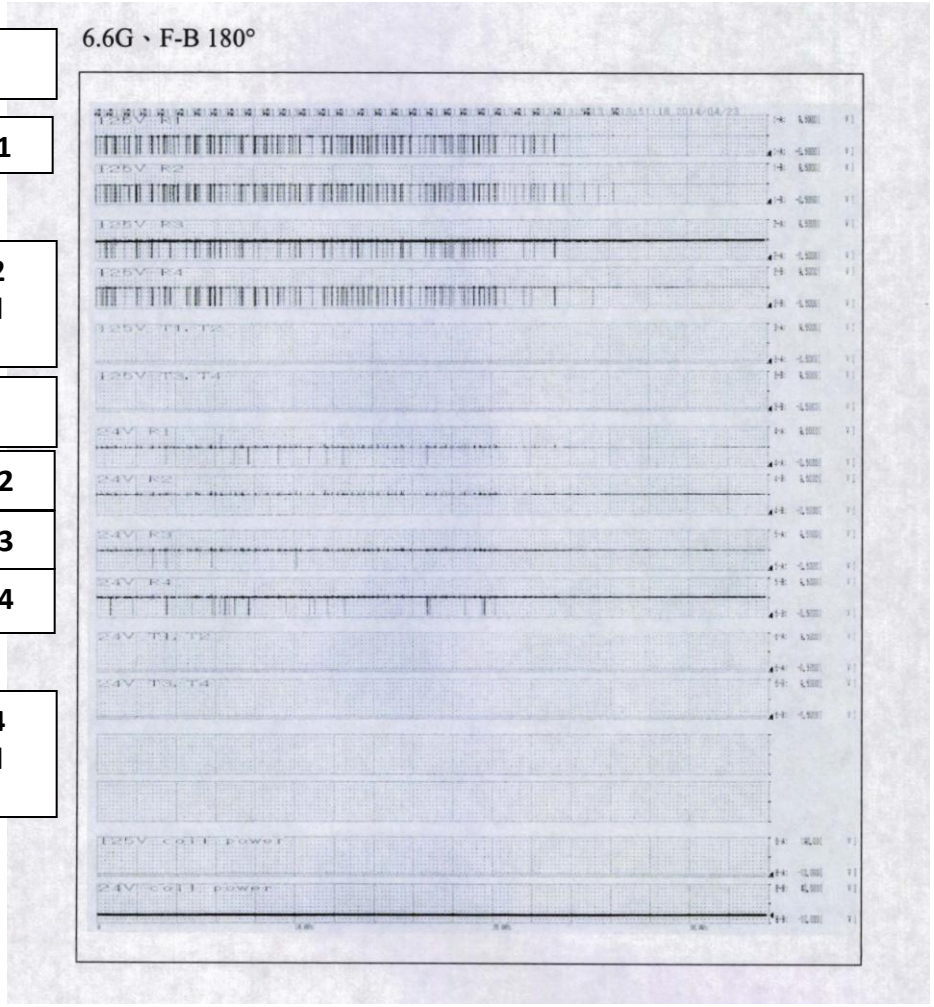
- Functional test had been performed before and after fragility testing by supplying rated DC power and functionality were verified.

- During fragility tests, relays in the nonoperating mode(deenergized) were monitored to check if chattering phonemenon of contacts occurred.

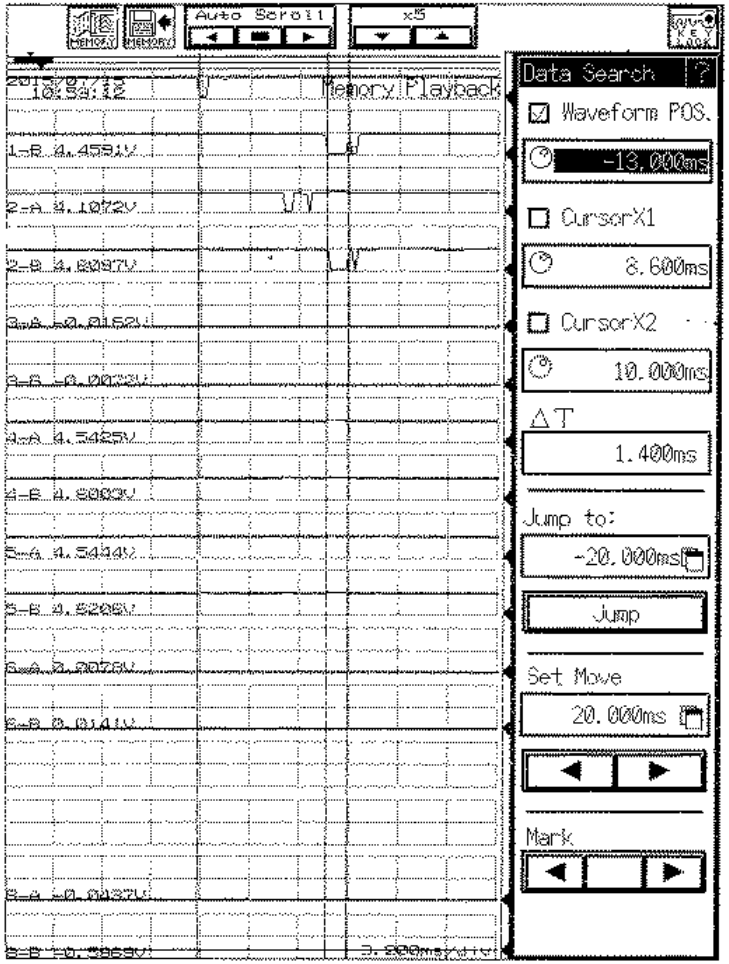
Sketch of chatter monitoring

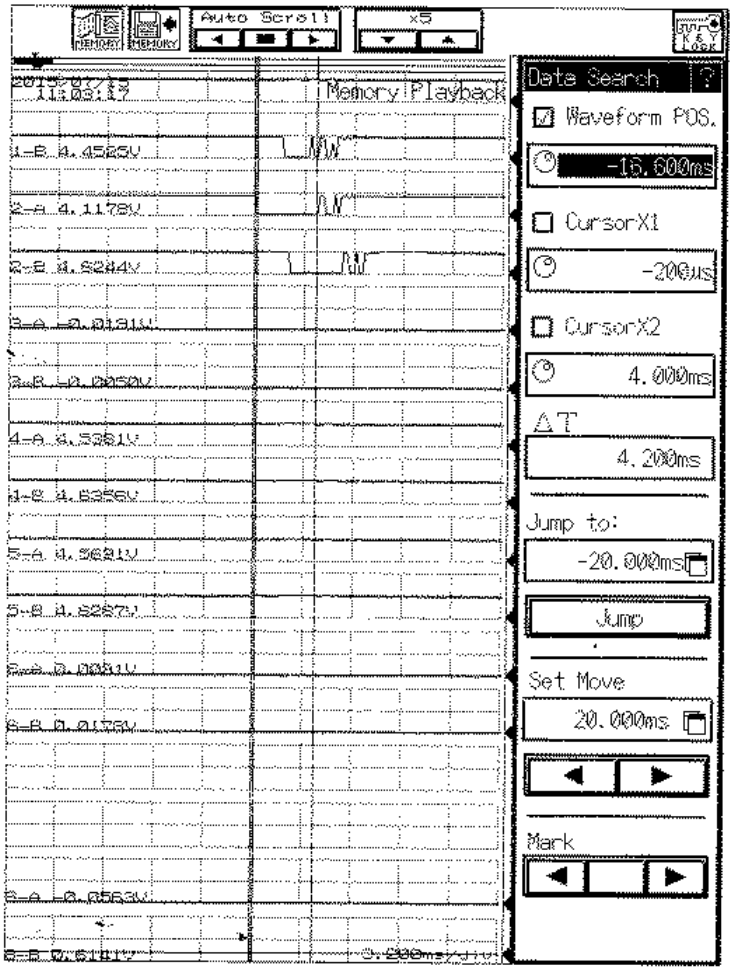


Chatter Monitoring



Chatter Judgement





Result of chatter monitoring

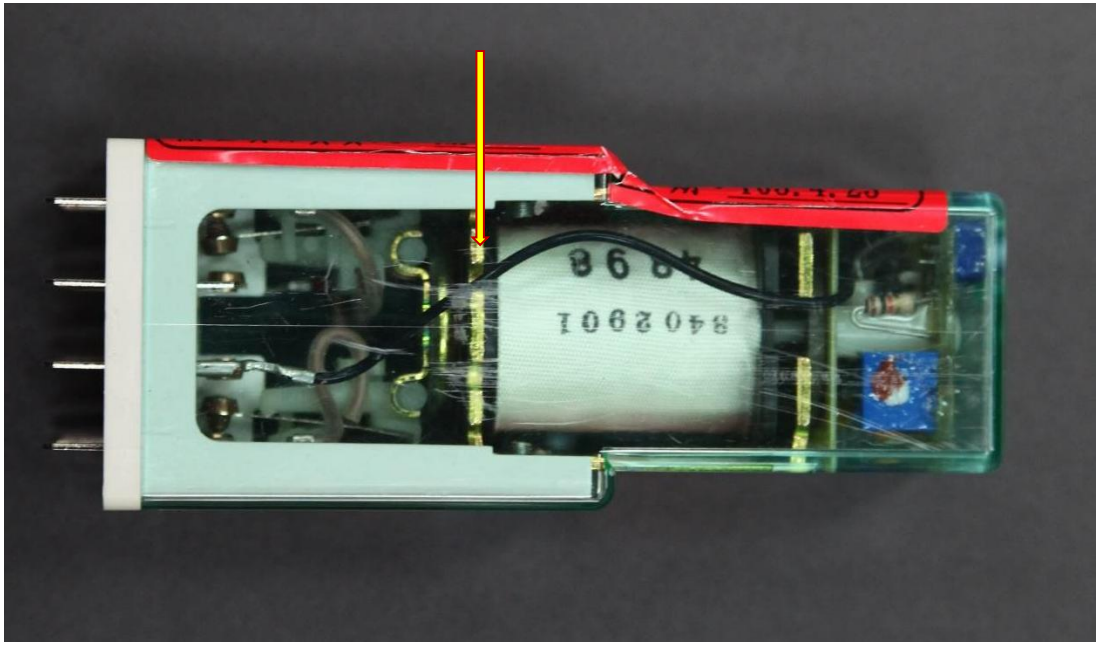
Test Condition		Normally Close	Normally Open	Test Condition		Normally Close	Normally Open
3.63G	F-B 0^0	chatter	OK	5.5G	F-B 0^0	chatter	OK
	F-B 180^0	chatter	OK		F-B 180^0	chatter	OK
	S-S 0^0	OK	OK		S-S 0^0	chatter	OK
	S-S 180^0	OK	OK		S-S 180^0	OK	OK
4.4G	F-B 0^0	chatter	OK	6.6G	F-B 0^0	chatter	OK
	F-B 180^0	chatter	OK		F-B 180^0	chatter	OK
	S-S 0^0	chatter	OK		S-S 0^0	chatter	OK
	S-S 180^0	OK	OK		S-S 180^0	chatter	OK

Test Results

- TRS enveloped RRS.
- Structural integrity maintained.
- No chattering observed on those normally open contacts of relays.
- These two relays are excluded from chattering outlier list.

Chatter Mechanism

- Movable in longitude direction (toward right when energized)
- Loose condition in deenergized mode easier to chatter



CONCLUSION

- Result showed that there were no structural or functional failure occurred during and after the tests. It demonstrates that two Agastat relays have a seismic capacity of at least 6 g by broad-band multi-frequency fragility testing according to ANSI/IEEE C37.98.
- The normally close contacts of tested relays has chattering phenomenon at a low rated ZPA of 3.63 g, when functionality using this contact formation should be carefully reviewed.
- Test orientation showed the front-to-back direction of relay is more vulnerable to chatter, the directional weakness is speculated has something to do with moveable mechanism of coil. While earthquake force is parallel to the relay's longitude axis, the tension/compression force will lift the moveable part up and cause contact chattering.

Thank you for your attention!