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Addendum 2
Project 2925-02
Final Report
April 1995

Seismic Ruggedness of Relays

Prepared by
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REPORT SUMMARY

EPRI *Leadership in Science and technology*

Seismic Ruggedness of Relays
Volume 2: Addendum 2

Relay GERS (Generic Equipment Ruggedness Spectra) provide utilities with generic seismic capability for more than 100 electrical relays most commonly used in nuclear power plants. The data can be used directly for the assessment of relays in the resolution of Unresolved Safety Issue A-46, "Seismic Qualification of Equipment in Operating Nuclear Plants," and for the Individual Plant Evaluation for External Events (IPEEE) for resolution of USNRC severe accident policy issues. This addendum is the second in a series that will broaden the base of data available for these reviews.

INTEREST CATEGORIES

Nuclear Seismic Risk, Design, and Qualification
Nuclear component Reliability

KEYWORDS

Earthquakes
Seismic effects
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Equipment anchorage

BACKGROUND The GERS for an equipment class constitutes a suitable bound on all known successful (no damage) seismic shake-table tests available for equipment in that class. EPRI report NP-5223, revision 1, gives GERS for several classes of equipment needed for safe shutdown following an earthquake. Problems arise in the development of GERS for electrical relays in that a great variety of relay types are used in nuclear plants and their seismic capacities depend on details, such as contact spring tension, that vary with vintage and model number. Consequently, in addition to the collection of existing relay tests, new testing of specific relays must be conducted to cover these parameter variations. The result is a larger number of GERS than for other classes of equipment, with each GERS being applicable to a specific subclass of relays.

OBJECTIVES To establish the seismic ruggedness of nuclear power plant relays using existing generic and new test data.

APPROACH For the original report, researchers collected data on shake-table seismic qualification tests from utilities, manufacturers, and test laboratories. They then conducted additional shake-table tests to obtain data for 70 models of new and used relays with varying dates of manufacture. The research team categorized the relays into 11 subclasses and constructed a ruggedness spectrum for each relay model identified in each subclass. A ruggedness spectrum represents the maximum input motion for which the relay remained functional during and after the motion. The team also developed checklists identifying various caveats associated with specific relay models.

RESULTS The original report presents GERS for more than 100 relay models and discusses the applicability of seismic ruggedness ratings to relays of older vintage. Results also include important identifying nomenclature for each relay type and an examination of relay adjustment effects on seismic ruggedness.

Report NP-7147-M provides an overview and summary of the test procedures and a basic approach to establishing the relay seismic ruggedness spectra. Report NP-7147-SL presents the test results in detail, provides discussion of issues and their resolutions, and includes all relay ruggedness spectra. Addendum 1 covers the performance of an additional set of six seismic tests with a total of 23 relays. This addendum adds eight tests with a total of 59 relays to the database. This test series adds to the database of relay GERS available to utility engineers.

EPRI PERSPECTIVE The development of relay GERS is part of an overall effort to reduce the seismic assessment of a potentially large number of relays to a small, manageable task. Unlike other classes of equipment, electrical relays cannot be screened based on experience data because their mode of seismic failure is contact chatter or change of state. These failures are not readily apparent to investigators after the occurrence of an earthquake. EPRI report NP-7148 gives the overall methodology for determining relay seismic functionality and covers system screening as well as the use of relay GERS. Report NP-7146 gives generic amplification factors to be applied to floor response spectra to obtain in-cabinet spectra for comparison with the relay GERS. When this multimethod approach was used in several trial plants, the number of relays for which seismic capacity was of concern was very small.

PROJECT

RP 2925-02
EPRI Project Manager: R. P. Kassawara
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EPRI Technical Information Specialists (415) 855-2411.

Seismic Ruggedness of Relays

NP-7147-SL, Volume 2
Addendum 2
Research Project 2925-02

Final Report, April 1995

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ABSTRACT

This addendum to EPRI report NP-7147-SL summarizes the results of eight additional seismic tests with a total of 59 relays by EPRI and the Seismic Qualifications Utility Group (SQUG) that are not documented in the original report. It adds to the data that can be used for the assessment of relays in the resolution of Unresolved Safety Issue A-46, "Seismic Qualification of Equipment in Operating Nuclear Plants," and for the Individual Plant Examination for External Events for resolution of USNRC severe accident policy issues. This addendum will broaden the base of data available for these reviews.

ACKNOWLEDGMENTS

This report was prepared by Paul Ibanez, Thomas J. Solimeo, Robert S. Keowen, John F. Gray, Phil Martinez and John Stoessel of ANCO Engineers, Inc., under the direction of Robert P. Kassawara of the Electric Power Research Institute (EPRI). This addendum report benefitted by the review of several individuals. Especially useful were technical inputs of Bruce Fong of EPRI and Jess Betlack of MPR Associates.

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SUMMARY

This addendum report summarizes the results of the Electric Power Research Institute (EPRI) and the Seismic Qualification Utility Group (SQUG) testing of additional relays not documented in NP-7147 and Addendum 1 to NP-7147. The results of eight additional test group series are reported herein.

In NP-7147, the groups were designated Test Groups 1 through 6. In Addendum 1 to NP-7147, the groups were designated Test Groups 7 through 12. The test groups discussed herein are designated Test Groups 13 through 20.

The general objective of this third series of relay tests was to supplement the test results reported in NP-7147 and Addendum 1 to NP-7147.

All testing was conducted as described in NP-7147. The general approach to testing, test procedure, test setup, data acquisition, and relay performance monitoring is discussed in detail in NP-7147. Any deviations to these procedures are identified in the test results discussed herein.

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TEST SPECIMENS

For Test Groups 13 through 20, the majority of the relays were provided by various Seismic Qualification Utility Group (SQUG) member utilities. The relays were either new or used. A few of the test specimens were purchased as new devices by a SQUG contractor (MPR) and submitted for testing on behalf of SQUG.

As noted in NP-7147, the test settings for relays are specified in ANSI C-37.98. These settings were adhered to for all tests.

The following relays comprised Test Group 13:

Model	Power	Type[1]	Manufacturer[2]	Condition
4U6 (Type PM)	DC	Auxiliary Relay (6 NO)	SYL/CLK	Unused
ETR14D (# 89060284)	DC	Time Delay Relay (4PDT) (with restraining clip - time delay 0.5 seconds)	Agastat	Unused
ETR14D (# 89060294)	DC	Time Delay Relay (4PDT) (without restraining clip - time delay 34 seconds)	Agastat	Unused
EMD8370794 (Type 36530082-01)	DC	Auxiliary Relay (3PDT)	Singer	Used
EGPIN003 (# 92090086)	AC	Auxiliary Relay (4PDT) (with restraining clip)	Agastat	Unused
EGPIN003 (# 92090090)	AC	Auxiliary Relay (4PDT) (without restraining clip)	Agastat	Unused
GP1R21D3000	DC	Auxiliary Relay (4PDT)	Clare	Unused
12HGA14AF65	DC	Auxiliary Relay (2 NO, 2 NC) (Hinged Arm)	GE	Unused
2180DFE44PA	DC	Auxiliary Relay (4 NO, 4 NC)	Rowan/ITE	Unused

The following relays comprised Test Group 14:

Model	Power	Type(1)	Manufacturer(2)	Condition
BFD22S (Model E)	DC	Auxiliary Relay (2 NO, 2 NC) (with Latch Module BFMLS)	W	Unused
BFD66S (Model E)	DC	Auxiliary Relay (6 NO, 6 NC) (with Latch Module BFMLS)	W	Unused
12HFA151A1H	DC	Auxiliary Relay (6 NO) (Hinged arm, 250 VDC)	GE	Unused
5U4 (Type PM)	AC	Auxiliary Relay (2 NO, 2 NC)	Smith/CLK	Used
PRD11AYO120	AC	Auxiliary Relay (DPDT) (Hinged Arm)	PB	Used
12HGA14BE98	AC	Auxiliary Relay (DPDT) (Hinged Arm)	GE	Used
KUP11A15-120	AC	Auxiliary Relay (DPDT)	PB	Unused
KHU17D12-24	DC	Auxiliary Relay (4PDT)	PB	Unused

The following relays comprised Test Group 15:

Model	Power	Type(1)	Manufacturer(2)	Condition
5UF (Type PMF)	AC	Auxiliary Relay (6 NO) (with PML Latch Unit)	Smith/CLK	Unused
713UP	AC	Pneumatic Time Delay Relay (Contacts: 1 NO, 1 NC timed and 1 NO, 1 NC instantaneous)	SYL/CLK	Used
J20A40	AC	Auxiliary Relay (2 NO, 2 NC)	ITE	Unused
12HMA111B9	AC	Auxiliary Relay (DPDT) (Hinged Arm)	GE	Used
214B111	AC	Single-Phase Undervoltage Monitor (uses ASCO #115277) (DPDT)	ASCO	Unused
5U6 (Type PM)	AC	Auxiliary Relay (5 NO, 1 NC)	Smith/CLK	Unused
5UH (Type PML)	AC	Auxiliary Relay (5 NO, 3 NC) (with PML Latch Unit)	Smith/CLK	Unused

Test Group 15 (continued):

Model	Power	Type[1]	Manufacturer[2]	Condition
4U2 (Type PM)	DC	Auxiliary Relay (1 NO, 1 NC)	SYL/CLK	Unused

The following relays comprised Test Group 16:

Model	Power	Type[1]	Manufacturer[2]	Condition
12IAC66K8A	AC	Time Overcurrent Relay - Long Time (Inst. Unit 20-80 amp; High Drop-out Inst. Unit 4-12 amp; Long Time 2.5/5 amp 60 Hz; Dial Setting 0.2)	GE	Unused
214A262	AC	Under Frequency Monitor (uses ASCO 255-102 DPDT)	ASCO	Unused
CR120C20241	DC	Auxiliary Relay (3 NO, 3 NC) (Horizontal Latch Relay)	GE	Unused
JR-1050	DC	Auxiliary Relay (SPDT) (PC board mounted)	PB	Unused
12HGA14BE98[3]	AC	Auxiliary Relay (DPDT) (Hinged Arm)	GE	Used
12HFA151A1H[3]	AC	Auxiliary Relay (6 NO) (Hinged arm)	GE	Used
12IJCV51A1A	AC	Overcurrent Relay w/Voltage Restraint (Pick-up Range: 1-4A @ 0 Volts; 4-16A @ 115 Volts: Dial setting 2)	GE	Used

The following relays comprised Test Group 17:

Model	Power	Type[1]	Manufacturer[2]	Condition
RYCA40 (MDL E)	AC	Auxiliary Relay (4 NO)	Micro	Unused
4471-40011 (Type HR)	AC	Auxiliary Relay (4 NO)	WL	Used
D40RB (Type R)	AC	Reed Relay (3 NO, 4 NC)	CH	Unused

Test Group 17 (continued):

Model	Power	Type[1]	Manufacturer[2]	Condition
CV-2 (#1875508A)	AC	Undervoltage Relay (Indicator 0.2-2A: Dial setting 1)	W	Unused
CV-5 (#1875512A)	AC	Overvoltage Relay (Indicator 0.2-2A: Dial setting 1)	W	Unused
156-14T300	AC	Auxiliary Relay (4PDT)	AEMCO	Unused

The following relays comprised Test Group 18:

Model	Power	Type[1]	Manufacturer[2]	Condition
12IAV53L1A	AC	Over/Undervoltage Relay	GE	Unused
CRN-1 (#290B038A09)	AC	Reverse Power Relay (Dial setting 1)	W	Unused
9050-BO2E (Series E)	AC	Pneumatic Time Delayed Contacts (2 NO, 2 NC)	SQD	Unused
2506 (#909905)	DC	DC Contactor - 30A 2 pole NO	ASCO	Unused
CSJ-38-70010	AC	Adjustable AC Voltage Sensor (DPDT)	PB	Unused
849A-ZOD24 (Series B)	AC	Pneumatic Time Delayed Contacts (1 NO/1 NC)	AB	Unused

The following relays comprised Test Group 19:

Model	Power	Type[1]	Manufacturer[2]	Condition
12HFA151A2F	DC	Auxiliary Relay Hinged Armature (6 NC)	GE	New
RXKE1	DC	Auxiliary Relay (2 NO/2 NC)	ABB	Unused
CO-6L110N	AC	Protective Relay, Inverse Time Delay, Overcurrent, Tap Setting = .2 amp: (Dial setting 1)	W	Unused
CF-1 (#2918995A10)	AC	Protective Relay Over/Under Frequency	ABB	Unused

Test Group 19 (continued):

Model	Power	Type(1)	Manufacturer(2)	Condition
RXMA1	AC	Auxiliary Relay (2 NO/2 NC)	ABB	Unused
12HFA51A49	AC	Auxiliary Relay Hinged Armature (3 NO/3 NC)	GE	Unused
50NC-120A	AC	Auxiliary Relay (1 NO/1 NC)	Pan	Unused

The following relays comprised Test Group 20:

Model	Power	Type(1)	Manufacturer(2)	Condition
GRM-FC	AC	Protective Relay, Ground Fault	ASEA	Unused
10337H192B	AC	Auxiliary Relay, Pneumatic Timing (1 NO/1 NC)	CH	Unused
AV(32A1528G01)	AC	Auxiliary Relay, Field Voltage (1 NO/1 NC)	W	Unused
EQ1933G2	DC	Auxiliary Relay, Time Delay (3 NO/3 NC)	SQD	Unused
12NGA15AG3	AC	Auxiliary Relay (2 NO/2 NC)	GE	Unused
7032PBB	AC	Auxiliary Relay, Timing (2 NO/2 NC)	Agastat	Unused
KLF	AC	Protective Relay Loss of Field	W	Unused
700-P400A1	AC	Auxiliary Relay Pneumatic Timing (4 NO)	AB	Unused

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(1) NC - normally closed; NO - normally open; PDT - e.g., 4PDT refers to four pole double throw; DPDT refers to double pole double throw; and SPDT refers to single pole double throw.

(2) AB - Allen Bradley; ABB - Asea Brown Boveri; AEMCO - Midtex/AEMCO; ASCO - Automatic Switch Company; CH - Cutler Hammer; GE - General Electric Company; ITE - I-T-E Imperial Corporation; Micro - MICRO SWITCH (Honeywell); Pan-Panalarm; PB - Potter Brumfield; Rowan/ITE - I-T-E Imperial Corporation (Rowan); Smith/CLK - A.O. Smith (Clark Controls Division); SQD - Square D; SYL/CLK - Sylvania (Clark Control); W - Westinghouse; WL - Ward Leonard Electric Co.

(3) Retest of relays from Test Group 14.

2

TEST RESULTS

A summary of fragility levels (in terms of the ANSI/IEEE C37.98 Broad-Band Spectral Shape except the ZPA is 60% of the peak spectral value) for the relays tested in Groups 13 through 20 is presented in Table 2-1. The values provided in Table 2-1 are Peak Spectral Values of the normalized standard GERS spectrum of Figure 2-1. Typical test response spectra are shown in Figure 2-2.

As with previous GERS testing, both normally open (NO) and normally closed (NC) relay contacts were monitored for chatter with the device in the de-energized, transition (de-energized to energized), and energized states.

For all fragility tests, the relays were mounted on a rigid vertical panel attached to the ANCO R-5 triaxial shake table and then subjected to a series of 20-second input motions to determine their ruggedness under simulated seismic conditions. Tests were performed in accordance to methods discussed in EPRI NP-7147.

In the energized and de-energized tests, contacts were deemed to have chattered if they opened (or closed) for a period of 2 milliseconds or greater. For transition tests, after the device had changed state, similar time criteria were used to determine contact chatter.

When multiple relays are listed, the lowest test values should be used.

Test Results: Group 13

This group was comprised of a total of nine relays. Four of the relays (two pairs of two) were of Agastat manufacture. The Agastat Models ETR and EPGIN are time delay and instantaneous relays, respectively. Both models are socket type devices and two of each type were tested, one with and one without a retaining clip. It was found that all these relays remained securely in their sockets regardless of whether a retaining clip was used. It should be noted that both the relays and the sockets were new; and consequently, the pin engagement was tight. It is possible that after repeated matings and de-matings, the clips could play a more significant role in the fragility of these relays. However, SQUG/EPRI tests have not shown this to be a concern.

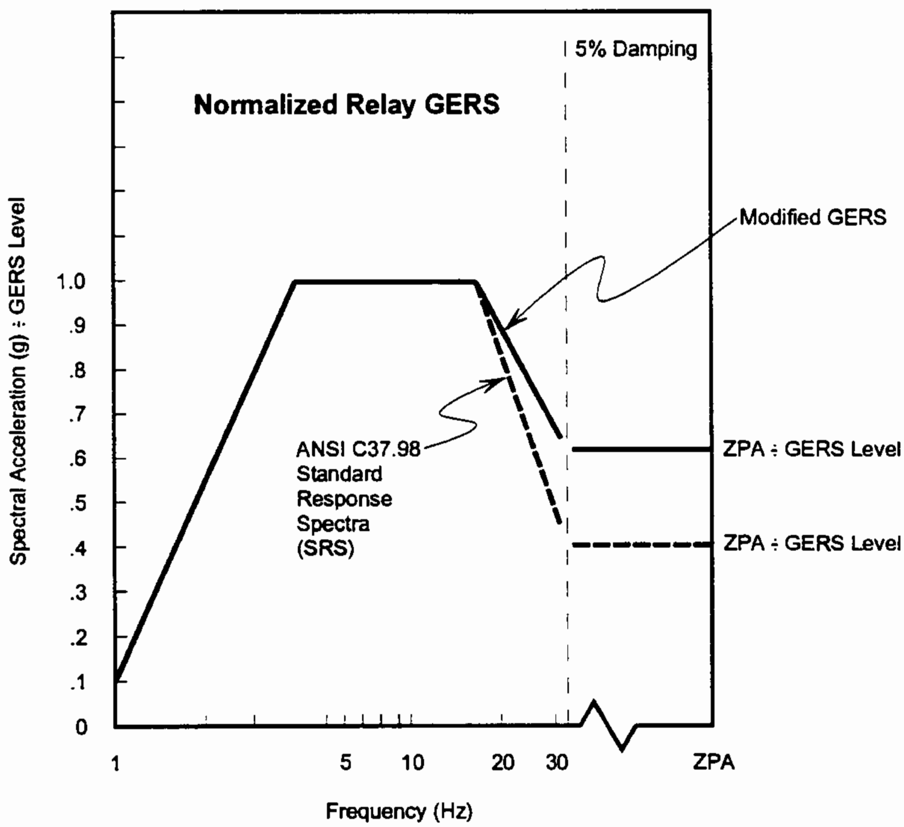
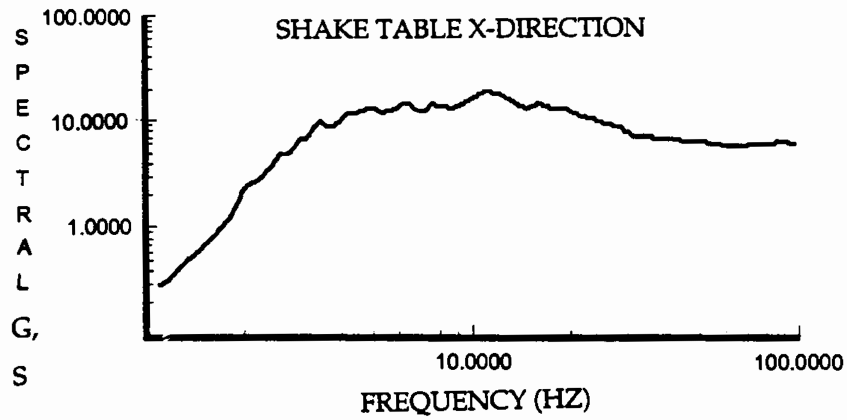
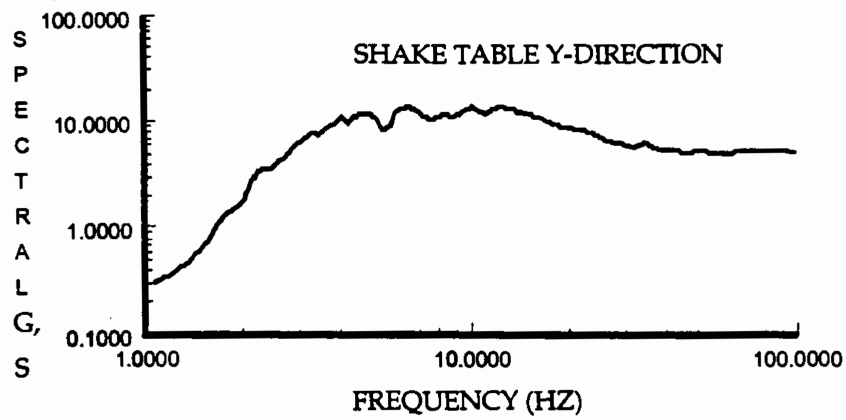


Figure 2-1
Standard normalized GERS Spectrum

IEEE RELAY TEST GROUP 16 ENERGIZED 10G'S
TEST: 16RE RUN: G10 DAMPING: .0500
CHANNEL: 1



IEEE RELAY TEST GROUP 16 ENERGIZED 10G'S
TEST: 16RE RUN: G10 DAMPING: .0500
CHANNEL: 2



IEEE RELAY TEST GROUP 16 ENERGIZED 10G'S
TEST: 16RE RUN: G10 DAMPING: .0500
CHANNEL: 3

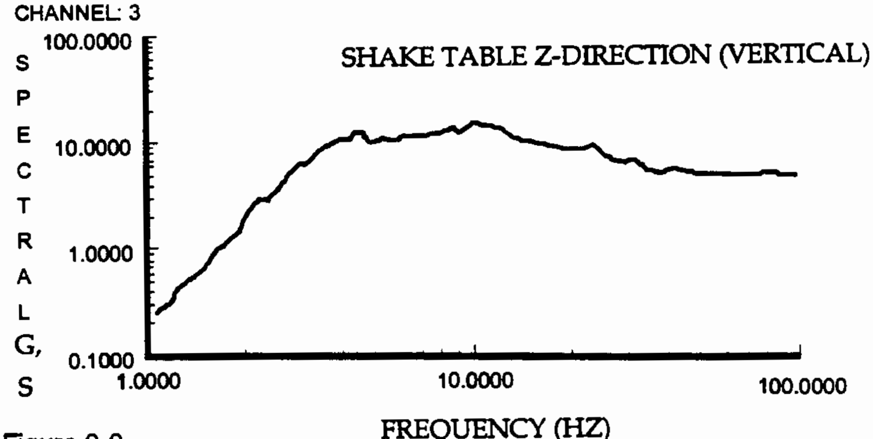


Figure 2-2
Typical Test Spectra

Table 2-1
Test Fragility Levels for Relay Groups 13 through 20

Test Group 13 - Model[2]		**Fragility**[1] **Level**			
		Non-Operate		**Operate**	
		NO	**NC**	**NO**	**NC**
SYL/CLK	4U6	5	NA	9	9
Agastat	TR (with clip)[6]	9	5	9	9
Agastat	TR (without clip)[6]	9	6	9	9
Singer	EMD8370794	9	9	9	9
Agastat	GP (without clip)[6]	9	5	9	9
Agastat	GP (with clip)[6]	9	6	9	9
Clare	GP1	9	9	9	9
GE	12HGA14A	4	NR	9	9
Rowan/ITE	2180[3]	NA	NA	9	9
Test Group 14 - Model[2]					
W	BFD/BFMLS	10	8	10	10
GE	12HFA151A (250 VDC)	Retested[4]			
Smith/CLK	5U4	7	6	10	10
PB	PRD11 (AC)[6]	10	3	10	10
GE	12HGA14B	Retested[4]			
PB	KUP11	10	10	10	10
PB	KHU17	10	10	10	10
Test Group 15 - Model[2]					
Smith/CLK	5UF	5	NA	9	NA
SYL/CLK	713UP	10	9	10	7
ITE	J20A40	10	5	9	10
GE	12HMA111 (AC)[6]	10	10	9	10
ASCO	214B	10	10	9	10
Smith/CLK	5U6	5	5	9	10
Smith/CLK	5UHD	5	5	9	10
SYL/CLK	4U2	5	5	9	10

Table 2-1
Test Fragility Levels for Relay Groups 13 through 20 (continued)

Test Group 16 - Model[2]		Fragility[1] Level			
		Non-Operate		Operate	
		NO	NC	NO	NC
GE	12IAC66K HDI	2	NA	10	NA
	STDI	7	NA	7	NA
	IN/TOC	5	NA	10	NA
ASCO	214A	10	10	10	10
GE	CR120C	10	10	10	10
PB	JR	10	10	10	10
GE	12HGA14B	6	NR	4	10
GE	12HFA151A (250 VDC)[7]	8	NA	NA	NA
GE	12IJCV51A	8	NA	10	NA
Test Group 17 - Model[2]					
Micro	RYCA40	5	NA	10	NA
WL	4471	4	NA	10	NA
CH	D40	10	10	10	10
W	CV-2	NA	8	NA	8
W	CV-5	8	NA	9	NA
AEMCO	156	10	10	10	10
Test Group 18 - Model[2]					
GE	12IAV53L[6]	10	7	2	10
W	CRN-1	7	NA	5	NA
SQD	9050-B	10	10	10	10
ASCO	2506	9	NA	10	NA
PB	CS	10	10	10	10
AB	849 A	10	10	10	10

Table 2-1
Test Fragility Levels for Relay Groups 13 through 20 (continued)

Test Group 19 - Model[(2)]		Fragility[(1)] Level			
		Non-Operate		Operate	
		NO	NC	NO	NC
GE	12HFA151A (DC)[(7)]	NA	3	NA	10
ASEA	RXKE1	10	10	10	10
W	CO - 6	8	NA	10	NA
ASEA	CF - 1	10	NA	7	NA
ASEA	RXMA1	10	2	10	10
GE	12HFA51A (AC)	10	5	10	10
PAN	50NC	10	10	10	10
Test Group 20 - Model[(2)]					
ASEA	GRM	10	10	10	10
CH	10337H192B	10	10	10	10
W	AV	10	2	5	10
SQD	EQ1933G2	10	10	10	10
GE	12NGA15A	10	9	10	10
AG	7032	10	10	10	10
W	KLF[(5)]	NA	NA	NA	NA
AB	700-P	9	NA	7	NA

(1) IEEE C37.98 spectral acceleration (g's), 4-16 Hz, 5% damping, □2 ms chatter criteria.

(2) AB - Allen Bradley; AEMCO - Midtex/AEMCO; AG - Agastat; ASCO - Automatic Switch Company; CH- Cutler Hammer; GE- General Electric Company; ITE - I-T-E Imperial Corporation; Micro - MICRO SWITCH (Honeywell); PAN - Panalarm; PB - Potter Brumfield; Rowan/ITE - I-T-E Imperial Corporation (Rowan); Smith/CLK - A.O. Smith (Clark Controls Division); SQD - Square D; SYL/CLK - Sylvania (Clark Control); W –Westinghouse; WL - Ward Lenonard Electric Co.

(3) Tested for setup validation purposes. (Only the NO contacts, in the operate state, were monitored.)

(4) Results did not appear consistent for the relay type; relay was examined, functionally checked and retested in a later series.

(5) Erratic results; recommend retest

(6) Additional verification test level only; GERS level given in EPRI NP-7147, Volume 1.

(7) Additional test for unique configuration, GERS level given in EPRI NP- 7147, Volume 1.

NA - Not applicable.

NR - Not recommended due to low ruggedness.

The test indicated that the NC contacts in the non-operate condition had the lowest fragility for both the time delay and the instantaneous models.

Some manufacturers market a relay model under more than one brand name. For example, Clark Controls manufactures Clark, A.O. Smith and Sylvania, and Rowan manufactures Rowan and I-T-E.

The contact configuration of the Sylvania 4U6 relay tested in Group 13 is similar to the 4U8 and 4U3 devices which were tested in Test Group 5. It is also similar to various A.O. Smith, Clark Controls and other Sylvania relays tested in Test Groups 13 and 15. Specifically these relays are:

- Smith/CLK 5U4 Test Group 14
- Smith/CLK 5UF Test Group 15
- Sylvania/CLK 713UP Test Group 15
- Smith/CLK 5UH Test Group 15
- Sylvania/CLK 4U2 Test Group 15

Contact design is a major factor in relay fragility; and consequently, the GERS values measured for these relays should have similar magnitudes. Comparison of the test data from these devices does compare favorably with one exception, the Sylvania 713UP. This time delay relay has significantly higher fragility level for both NO and NC contacts in the non-operate mode than do the other similar relays. It is recommended that this device be retested with its time delay and instantaneous contacts monitored individually in an effort to determine the reason for this higher value.

The GE 12HGA14A relay is similar to the 12HGA14B tested in Test Group 14 (and again in Test Group 16). The difference between these models is that the 'A' suffix model is back connected and the 'B' suffix model is a front connected device.

Both the Singer and Clare relays exhibited high ruggedness values in both the non-operate and operate states.

The Rowan/ITE relay was only tested in the energized mode. This device was tested previously in Test Group 6. It was included in this test series to validate the revised shake table configuration that was in use for this series of tests (changed actuators). Its Test Group 6 fragility value was 9 g. In this series, a value of 9 g was also measured. These values indicate that fragility levels published in the Final Report, the First Addendum and this Addendum are comparable.

All relays in Test Group 13 passed the transition test.

Test Results: Group 14

This group was comprised of eight relays. The group included two mechanically latched relays (BFD22S and BFD66S) that were both manufactured by Westinghouse. They were identical devices with the exception of their contact arrangement. The BFD22S has 2 NO and 2 NC whereas the BFD66S had 6 NO and 6 NC contacts. Under normal operation, the latches engage automatically when the relay coil is energized and hold the contacts in the energized state when power is removed from the coil. A second coil is energized to release the mechanical latch. For GERS testing, the mechanical latch was released manually. Identical fragility levels were measured for both relays.

One of the relay types had been tested previously and its fragility had already been documented in NP-7147 in the Final Report. It was:

- PB PRD-11AYO Test Group 6

In Test 14, it was tested in a horizontal mounting; Test 6 used a vertical mounting. For comparison, the results obtained from the two tests are:

		Fragility Level			
		Non-Operate		Operate	
Model	**Test Group**	**NO**	**NC**	**NO**	**NC**
PRD-11AYO	6 (vertical mount)	10	3	10	10
	14 (horizontal mount)	10	3	10	10

The fragility values obtained for the NO contacts of the GE HFA151 (250 VDC) and GE HFA14B relays, in the non-operate condition, did not appear to be consistent with test data for similar relays; these relays were examined, functionally checked, and retested in Test Group 16 where fragility values more consistent with similar tests were obtained. Of the remaining four relays, two were manufactured by Potter & Brumfield. Both those relays had high ruggedness values.

All relays in Test Group 14 passed the transition test.

Test Results: Group 15

This group was comprised of eight relays. Five of the devices had been manufactured by Clark Controls under different brand names (A.O. Smith and Sylvania). These relays were all similar in basic configuration.

The 713UP Sylvania/CLK relay was a pneumatic timer relay with both instantaneous and timed contacts. It exhibited much higher fragility in the non-operate state for both

NO and NC contacts than any of the other four similar relays. For chatter monitoring, both timed and instantaneous NO contacts were connected in parallel and both timed and instantaneous NC contacts were connected in series. Consequently, it is not possible to determine the individual characteristics of the two types of contacts. It is recommended that this relay be retested with the timed and instantaneous contacts individually monitored in an effort to clarify the reason for the apparent higher ruggedness of this particular model.

The GE 12HMA111 exhibited similar high ruggedness to the HMA relay tested in Test Group 1. The ITE and ASCO relays both had high ruggedness with the exception of the NC contact on the ITE relay in the non-operate state.

All relays in Test Group 15 passed the transition test.

Test Results: Group 16

This group was comprised of seven relays. Two of the devices (the 12IAC66K and 12IJCV51) relays were protective relays which have multiple relay modules necessitating multiple channels of chatter monitoring and/or variable voltage or power requirements. Of the other five relays, two were of the hinged arm variety, one was a PC board-mounted Reed relay, and one was a Under Frequency Monitor (which utilizes a ASCO 255-102 DPDT relay). The remaining device was a horizontal latch relay. This device does not utilize gravity in its operation. The contacts being actuated horizontally by the energization of two opposing coils.

The two hinged arm relays were the GE HFA and HGA relays tested in Test Group 14. These relays both exhibited lower than anticipated ruggedness when tested in Test Group 14. As the ruggedness value did not appear to be consistent for the relay type, they were examined, functionally checked, and retested as part of this group. They both exhibited ruggedness levels that were more consistent with tests of similar relay types; and consequently, the Test Group 16 results are being included in this report.

The 12IAC66K protective relay has contacts that perform three different control functions. They are the HDI (high drop out instantaneous overcurrent), STDI (standard drop out instantaneous overcurrent), and the IN/TOC (instantaneous time overcurrent). The NO HDI contact has the lowest fragility level.

All relays in Test Group 16 passed the transition test.

Test Results: Group 17

This group was comprised of six relays. Two of the relays were protective relays which required variable voltage sources during testing. One of the relays was a multi-pole

Reed relay and the remaining three relays were all auxiliary models. The CH Reed relay and the AEMCO Socket relay both exhibited high ruggedness values.

All relays in Test Group 17 passed the transition test.

Test Results: Group 18

This group was comprised of six relays. There were two protective, two pneumatic timing relays, a DC Contactor, and an Adjustable Voltage Sensing relay. With the exception of the protective relays, the relays all exhibited high ruggedness. The NO contact on the GE 121AV53L1A had a fragility level of two in the operate state and the Westinghouse CRN-1 failed during testing. Visual examination indicates that the failure was caused by an adjustment screw becoming loose and causing an internal short. The failure occurred during the latter stages of the energized test. It is suggested that this model of relay be subjected to additional testing to determine if this mechanically electrical failure is an isolated case.

All relays in Test Group 18 passed the transition test.

Test Results: Group 19

This group was comprised of seven relays. There were six auxiliary relays and one protective relay. High ruggedness was exhibited on all relays except the RYMA1 and the HFA151A2F. The RYMA1 showed low ruggedness only on the NC contact during non-operate tests. The HFA151A2F showed low ruggedness only on the NC contact during non-operate tests.

All relays in Test Group 19 passed the transition test.

Test Results: Group 20

This group was comprised of eight relays. There were six auxiliary relays and two protective relays. All of the relays except the KLF protective relay and the 32A1528G01 auxiliary relay exhibited high ruggedness. The KLF relay was not energized during testing and this may have caused the inconsistent results. It is recommended that this relay be retested in order to determine its fragility level. The auxiliary relay 32A1528G01 exhibited high ruggedness on the NO contact during nonoperate tests and on the NC contact during operate tests. The opposite contact configurations exhibited lower ruggedness.

All relays in Test Group 20, except the KLF which was never energized, passed the transition test.

3

CONCLUSIONS

The primary purpose of the EPRI/SQUG relay testing program documented in this second addendum to NP-7147 was to increase the amount of relay fragility data available by testing relays that are used in critical circuits in nuclear powered generating facilities.

With some exceptions, the tests documented herein were on different models of relays to those reported in NP-7147 and Addendum No. 1. The exceptions were the tests that were conducted to verify or correct previous GERS results that were considered to be questionable in light of factors such as experience, similarity, or other data that conflicted with the test results obtained.

As noted in Section 1, the hinged arm type of relay has been shown to have a 1-2 g variability in NC contact fragility between identical models with identical physical adjustments. For this reason, hinged arm relays (that were tested in this series of tests) are identified in Section 1.

Appendix A to this addendum is a schedule of all relays that have been tested in the EPRI/SQUG program. This schedule provides a synopsis of both model descriptive information and test data for each relay. In the relay description section of this schedule, the relay type is identified by various acronyms. These acronyms reflect the division of relays into two basic groups each with various types as detailed in Section 4 of NP-7147.

In Test Groups 1 through 20, eight types of auxiliary relays and three types of protective relays were tested. They are:

Auxiliary Type	Acronym
• Pneumatic timing	A-PT
• Hinged arm	A-HA
• Socket	A-S
• Industrial #1 (600V)	A-I1
• Industrial #2 (300V)	A-I2
• Rotary	A-R
• Lockout	A-L
• Miscellaneous	A-M
• Protective Relay	P-1
• Protective Relay	P-2

- Protective Relay P-M

This schedule can be used to identify hinged arm type relays that were tested in Test Groups 1 through 12.

APPENDIX A: SCHEDULE OF RELAY GERS TESTED UNDER THE NP-7147 PROGRAM

Item No.	Man	Part/Cat No.	Type/Model/Style	Pales	Type	Power	Cond.	Group	Page	Part-De-NO	Part-De-NC	Part-En-NO	Part-En-NC	Source	Ree'd	Notes
1	GE	12HFA11A42F	HFA	3NO/3NC	A-HA	125VDC	USED	01-01	2-31	8	2	10	10	AEP	8/23/87	RETESTED AS # 32
2	GE	12HGA11A700	HGA	DPDT	A-HA	115VAC	USED	01-02	2-31	10	3	10	10	AEP	8/23/87	
3	GE	12HMA11E6	HMA	DPDT	A-HA	125VDC	UNUSED	01-03	2-31	10	5	10	10	APL	10/30/87	PASSED FUNCTIONALS 11/5/87
4	GE	12IACS3A2A	IAC	NA	P-1	AC	USED	01-04	2-31	7	NA	10	NA	AEP	8/23/87	RETESTED AS - # 05
5	GE	12PJC11X1A	PJC	NA	P-M	25/60VDC	USED	01-05	2-31	5	NA	7.5	NA	AEP	8/23/87	INST# GE- 28803
6	GE	12IAVS4E1A	IAV	NA	P-1	115VAC	USED	01-06	2-31	NA	8	NA	10	AEP	8/23/87	RETESTED AS - # 86
7	W	SFD44	44E8814	4NO/4NC	A-13	125VDC	USED	01-07	2-31	10	8	10	10	RG&E	8/23/87	
8	W	300P472001	WL	6NO	A-L	125VDC	USED	01-08	2-31	10	NA	10	NA	YANKEE AT	8/23/87	COIL# 1611279
9	W	ARD0440SR	765A653G07	4NO	A-11	120VDC	UNUSED	01-09	2-31	10	6	10	10	PSEG	8/23/87	QTY 2 RECD, SEE # 188
10	PB	KRP11DN		DPDT	A-8	110VDC	UNUSED	01-10	2-31	10	8	10	10	WEPCO	8/23/87	QTY 2 RECD,SEE # 243
11	CH	D23MD	w/D26MPR CONTACTS	3NO/3NC	A-12	120VAC	USED	01-11	2-31	10	10	10	10	DUKE	10/30/87	MODULAR UNIT
12	CH	D26MS/D24MD/D26MF	SERIEB A2	2NO/6NC	A-11	64VDC	USED	01-12	2-31	10	10	10	10	DUKE	10/30/87	PARTS PUB # D32M-1
13	W	SFD66	44E3742	10NO/2NC	A-12	125VDC	UNUSED	02-01	2-31	10	10	10	10	RG&E	12/23/87	
14	SD	21SASA-P		SEE NOTES	A-8	115VDC	UNUSED	02-02	2-31	10	8	10	10	DUKE	10/30/87	POLES - 2POT PLUS 1NO & 1NC CONTACT
15	W	STC22R	765A342QQ1	2NO/2NC	A-P-T	120VAC	UNUSED	02-03	2-31	10	10	10	10	SCE	12/24/87	
16	SD	21S88X-P		SEE NOTES	A-8	120VAC	UNUSED	02-04	2-31	10	9	10	10	DUKE	10/30/87	POLES - 2POT PLUS 2 NO CONTACTS
17	SD	21S88X201		SEE NOTES	A-8	120VAC	UNUSED	02-05	2-31	10	9	10	10	SCE	12/23/87	POLES - 2POT PLUS 2 NO CONTACTS
18	GE	12HGA17A4G	HGA	DPDT	A-HA	125VDC	USED	02-06	2-31	6	2	10	4	AEP	8/23/87	INST # GE1 10190 - PT BUL. GEF 2823
19	GE	12HGA17H52G	HGA	DPDT	A-HA	125VDC	USED	02-07	2-31	5	2	5	5	AEP	8/23/87	INST # GE1 10190 - PT BUL. GEF 2823

Note: This Table provides test levels. Some of the levels indicated are not GERS.

Item No.	Man	Part/Cat No.	Type/Model/Style	Pales	Type	Power	Cond.	Group	Page	Part-De-NO	Part-De-NC	Part-En-NO	Part-En-NC	Source	Ree'd	Notes
20	PB	MDR131-1		4PDT	A-R	115VAC	USED	02-08	2-31	10	9	10	10	SCE	12/24/87	
21	AB	700-NT	SERIES C	SEE NOTES	A-PT	120VAC	UNUSED	02-09	2-31	10	10	10	10	FLORIDA	8/23/87	POLES - NO INSTANTANEOUIS PLUS 1NO & 1NC TIMED CONTACTS
22	SOD	S501-0000	SERIES D	8NO	A-12	120VAC	UNUSED	02-10	2-31	10	10	10	10	PSEG	8/23/87	
23	MWK	106A	6617	3PDT	A-8	110DC	UNUSED	02-11	2-31	10	10	10	10	PSEG	8/23/87	
24	CLR	HG-4B1014		4PDT	A-M	DC	USED	02-12	2-31	5	8	10	10	SCE	12/24/87	MERCURY WETTED RELAY
25	GE	CR2810A14AJ		1NO/1NC	A-12	115VAC	USED	03-01	2-32	6	4	10	10	GPU NUC	4/28/88	
26	GE	CR120A04002AA	SERIES A	2NO/2NC	A-12	115VAC	USED	03-02	2-32	10	9	10	10	NSP	4/13/88	
27	GE	CR120A04002AA	SERIES A	2NO/2NC	A-12	115VAC	USED	03-03	2-32	10	10	10	10	NSP	4/13/88	
28	W	2SSB363A11	MG-6 (LATCH TYPE)	3NO/3NC	A-HA	125VDC	UNUSED	03-04	2-32	10	5	10	10	RG&E	4/12/88	RETESTED AS - # 37
29	W	2SSB363A11	MG-6 (LATCH TYPE)	3NO/3NC	A-HA	125VDC	USED	03-05	2-32	10	3	10	10	RG&E	4/12/88	RETESTED AS - # 38 (ADJ 1)
30	W	1163001	MG-6	3NO/3NC	A-HA	125VDC	USED	03-06	2-32	10	4	10	10	RG&E	4/12/90	RETESTED AS - # 38(ADJ 1)
31	GE	12HFAS1A42H	HFA	3NO/3NC	A-HA	125VDC	USED	03-07	2-32	10	4	10	10	V. YANKEE	4/18/88	INST# GEM 2024 PUB# GEF - 2757
32	GE	12HFA11A42F	HFA	3NO/3NC	A-HA	125VDC	USED	03-08	2-32	10	8	10	10	AEP	8/23/87	RETEST - TEST GROUP 01-01(ADJ 2)
33	W	BFD44S	765A830G01	4NO/4NC	A-12	120VDC	UNUSED	03-09	2-32	10	9	10	10	SCE	12/24/87	SCE CODE # 027-22999
34	W	BFD64	44E3742	6NO/6NC	A-12	125VDC	USED	03-10	2-32	10	10	10	10	RG&E	4/12/88	
35	CH	D23MF/D23MD/D23MR		11NO/1NC	A-12	04VDC	USED	03-11	2-32	10	9	10	10	UNKNOWN	ND	
36	GE	12HEA61V18X2		7NO/8NC	A-L	250VDC	USED	03-12	2-32	10	10	10	10	AEP	4/12/88	INST # GEH 2068
37	W	28S8383A11	MG-6 (LATCH TYPE)	3NO/3NC	A-HA	125VDC	UNUSED	04-01	2-32	10	5	10	10	RG&E	4/12/88	RETEST OF # 28 - TEST GROUP 03-04
38	W	28S8383A11	MG-6 (LATCH TYPE)	3NO/3NC	A-HA	125VDC	USED	04-02	2-32	10	6	10	10	RG&E	4/12/88	RETEST OF # 29 - TEST GROUP 03-05 (ADJ,2)

Note: This Table provides test levels. Some of the levels indicated are not GERS.

Item No.	Man	Part/Cat No.	Type/Model/Style	Pales	Type	Power	Cond.	Group	Page	Part-De-NO	Part-De-NC	Part-En-NO	Part-En-NC	Source	Ree'd	Notes
39	W	1183801	MG-6	3NO/3NC	A-HA	125VDC	USED	04-03	2-32	10	5	10	10	RG&E	4/12/88	RETEST OF # 30 - TEST GROUP 03-06 (ADJ,2)
40	W	BFS0F	765A188G01	6N0/2NC	A-12	120VAC	UNUSED	04-04	2-32	10	NA	10	NA	WEPCO	6/13/88	
41	W	BFD538	764A544G01	5NO/3NC	A-12	120VDC	USED	04-05	2-32	10	10	10	10	NE UTIL	8/23/88	
42	ES	HA41A65211	384-006-128	3NO	A-M	120VAC	USED	04-06	2-32	10	NA	10	NA	NE UTIL	6/13/88	2 UNITS RECEIVED
43	W	SG	1878786A	DPDT	A-HA	125VDC	UNUSED	04-07	2-32	9	1	10	5	RG&E	8/23/88	MISSING FRONT COVER
44	GE	CR28200	11QAA2	1NO/1NC	A-PT	115VAC	UNUSED	04-08	2-32	10	10	10	10	NIAGARA M.	8/23/88	
45	GE	12HLA11S12A	HLA	3NO/3NC	A-HA	125VDC	UNUSED	04-09	2-32	9	4	10	10	NIAGARA M.	8/23/88	INST# GEK8863
46	PB	KRP14AG		2PDT	A-5	120VAC	UNUSED	04-10	2-32	10	10	10	10	WEPCO	8/23/88	
47	GE	CR1200 040	SERIES A	2NO/2NC	A-11	120VAC	UNUSED	04-11	2-32	10	8	10	10	NIAGARA M.	8/23/88	
48	W	AR440A	764A025G01	2NO/2NC	A-11	120VAC	UNUSED	04-12	2-32	10	10	10	10	NE UTIL	6/13/88	
49	PB	MDR137-8		4PDT	A-R	125VDC	UNUSED	04-13	2-32	10	10	10	10	GPU NUC	4/13/88	
50	AGA	7012PD	88170330	4PDT	A-PT	125VDC	UNUSED	05-01	2-33	10	10	10	10	DUKE	ND	
51	AGA	7012PD-LL		4PDT	A-PT	125VDC	UNUSED	05-02	2-33	10	10	9	7	DUKE	ND	
52	ITE	2180-E22PA		2NO/2NC	A-12	120VDC	UNUSED	05-03	2-33	9	10	10	10	SCS	ND	COIL 2090-4110
53	CLK	4U8-5	PM	3NO/4NC	A-11	120VDC	UNUSED	05-04	2-33	6	5	10	10	SCS	ND	
54	CLK	4U3-1		2NO/1NC	A-11	130VDC	UNUSED	05-05	2-33	8	6	10	10	SCS	ND	COIL TB-137-16, BUL#7304, NP AS 252110
55	GE	12SAM11A21A		NA	P-M	SEE NOTES	USED	05-06	2-33	10	7	10	10	DUKE	ND	48/125/250 VDC
56	W	CO-8H1101N	264C900A05	NA	P-2	AC	USED	05-07	2-33	7	NA	10	NA	BG&E	ND	RETESTED AS # 98
57	W	CO-8	1875282A	NA	P-2	AC	USED	05-08	2-33	10	NA	8	NA	SCS	ND	RETESTED AS # 66

Note: This Table provides test levels. Some of the levels indicated are not GERS.

Item No.	Man	Part/Cat No.	Type/Model/Style	Pales	Type	Power	Cond.	Group	Page	Part-De-NO	Part-De-NC	Part-En-NO	Part-En-NC	Source	Ree'd	Notes
58	GE	12IAC54A2A	IAC	NA	P-1	AC	USED	05-09	2-33	8	NA	8	NA	SCS	ND	RETESTED AS # 98
59	GE	12IAC7782A	IAC	NA	P-1	AC	USED	05-10	2-33	5	NA	-	-	SCS	ND	
60	W	CV-7	1875524A	NA	P-2	120VDC	USED	05-11	2-33	8	1	9	9	SCS	ND	
61	W	KF	6715287A00	NA	P-M	AC/DC	USED	05-12	2-33	8	10	10	4	SCS	ND	
62	W	HU	2900346A00	NA	P-M	AC	USED	05-13	2-33	2	NA	8	NA	SCS	ND	
63	SOD	S501-X060	FORM MT SERIES A	8NO	A-11	110VAC	UNUSED	06-01	2-33	8	6	10	10	MPR	10/2/89	
64	PB	KAP-14AG-120		3PDT	A-8	120VAC	UNUSED	06-02	2-33	10	4	10	10	MPR	8/2/89	
65	PB	KHS-17A 11-120		4PDT	A-8	120VAC	UNUSED	06-03	2-33	10	10	10	10	MPR	10/2/89	
66	PB	KHS-17D 11-110		4PDT	A-8	110VDC	UNUSED	06-04	2-33	10	10	10	10	MPR	10/2/89	
67	PB	PRD-11DYO-110		DPDT	A-HA	110VDC	UNUSED	06-05	2-33	10	4	9	9	MPR	10/2/89	
68	PB	PRD-11AYO-120		DPDT	A-HA	120VAC	UNUSED	06-06	2-33	10	3	10	10	MPR	10/2/89	
69	GE	3SAA1382A2		DPDT	A-8	DC	UNUSED	06-07	2-33	10	10	10	10	BG&E	10/2/89	
70	SD	218DXSP		4NO/2NC	A-8	120VAC	UNUSED	06-08	2-33	10	10	10	10	BG&E	10/2/89	
71	SOD	S601-00020		2NO	A-12	115VDC	UNUSED	06-09	2-33	10	10	10	10	SAVANNAH	10/2/89	
72	AGA	2112-A-H1		DPDT	A-PT	110VAC	USED	06-10	2-33	10	10	10	10	SAVANNAH	10/2/89	2 UNITS RECEIVED
73	ITE	2186-FE44AA	14-16-X3005	4NO/4NC	A-12	120VAC	USED	06-11	2-33	7	2	9	9	BG&E	10/2/89	
74	PB	MDR7032		SEE NOTES	A-R	25VDC	UNUSED	06-12	2-33	10	10	10	10	APL	ND	CONTACTS - 6 SETS OF 4PDT (3 SETS POWERE & 3SETS CONTROL)
75	W	CO-11N1111N	265C047A07	NA	P-2	AC	UNUSED	07-01	A1.2-2	6/9	NA	10	NA	TOLEDO	ND	(FRAGILITY - ICS = 6g, NT =9g) RETESTED AS # 100
76	W	CO-6H1101N	264C897A05	NA	P-2	AC	UNUSED	07-02	A1.2-2	X	X	X	X	TOLEDO	ND	REMOVED FROM TESTING

Note: This Table provides test levels. Some of the levels indicated are not GERS.