6.2.2 Fault Test Setup Description

Eagle 21™ system performance, while subjected to the fault tests described in section 5.2, was monitored in the following manner:

- Channels adjacent (left, right, top, bottom) to the channel under test were chosen for monitoring.

- Minimum physical separation between the channel under test and adjacent channels was provided. Cabinet configuration was altered to provide minimum physical separation for the digital contact output board tests.

- The channel under test was continuously monitored immediately prior to the fault application, disconnected from the data acquisition system (DAS) during fault application, and reconnected to the DAS upon removal of the fault.

Following the test, all necessary repairs were recorded noting all component failures and channel operability was verified.

Figure 6-11 is the fault test data sheet.

6.2.3 Surge Withstand Capability (SWC) Test Setup Description

Eagle 21™ system input/output performance, while subjected to the SWC tests described in section 5.3, was monitored in the following manner:

- Analog outputs -- Four analog output channels were monitored continuously during the surge tests. The channels monitored replicated signals processed by current loop, wide range RTD, and narrow range RTD input signal conditioning boards. Thus, system analog input/output processing performance was measured.

I/O Module ______________ Procedure Rev. ____
Date ____________
Test # __________

TYPE

SHORT CIRCUIT ______________, AC ______________, DC ______________

COMMON MODE ________ GROUND CONNECTED TO VOLTS PLUS _____ MINUS _____ GROUND

LINE TO LINE ______________ VOLTS (+) TO (+) ________ (+) TO (-) ________
VOLTS (-) TO (+) ________ (-) TO (-) ________

TEST INJECTION POINT ____________ TEST CONDITION ____________

I/O CARD TYPE ____________ POINT # ____________

PRE-TEST

DATA LOGGER VERIFICATION* PRINT OUTPUT # ____________

SYSTEM STATUS ______________________________

REMARKS AND TEST OBSERVATION ______________________________

____

DISCONNECT DATA LOGGER ______________

TEST

TAPE RECORDER FOOTAGE BEGIN ____________ END ____________ SET # ______
SPEED ____________ TIME: (START): _____(STOP): _____

SYSTEM STATUS: ______________________________

REMARKS AND TEST OBSERVATION ______________________________

____

POST-TEST

DATA LOGGER DATA VERIFICATION* PRINT OUTPUT # ____________

SYSTEM STATUS: ______________________________

REMARKS AND TEST OBSERVATION ______________________________

____

PERFORMED _______ REVIEWED _______

Figure 6-11. Fault Test Data Sheet

- Digital outputs -- A single variable NR RTD (Thot3) was chosen to toggle all six Delta T/Tavg system trip outputs. All six trip output channels were toggled utilizing the variable RTD circuit shown in Figure 6-6. The control relay was cycled continuously during pre-test, test, and post-test runs [

  ].b,c The Delta T/Tavg system inputs were set just below and above the trip output toggle point (.2% or less). The Delta T/T_{avg} system utilizes current loop, NR RTD and 0-10 volt analog input signals to generate partial trip output signals (see section 3 for system block diagrams). Thus, any significant degradation in system input signal processing would result in a trip output status failure. The control relay was not cycled during the partial trip module tests to ensure that the channel in test remained in one state (energized/deenergized) during the application of the surge.

  Trip output status was monitored continuously during the noise tests using a strip chart recorder.

The following test methods were utilized to best measure system performance:

- Input/output channels adjacent to the output channel under test were monitored.

- During application of the surge test wave, the strip chart recorder chart speed was increased to improve resolution.

- Analog output channels replicating input channels under test were monitored.

Figure 6-12 is the Surge Test Data Sheet.

SURGE TEST DATA SHEET

Procedure Rev. ____
DATE ____
TEST # ____

TYPE

TRANSVERSE MODE ____

COMMON MODE ____

TEST INJECTION POINT ____ I/O CARD TYPE ____ POINT # ____

PRE-TEST

DATA LOGGER VERIFICATION PRINT OUTPUT # ____

SYSTEM STATUS: ____

REMARKS AND TEST OBSERVATION ____

____

____

DISCONNECT DATA LOGGER ____

TEST

TAPE RECORDER FOOTAGE BEGIN ____ END ____ SET # ____

SYSTEM STATUS: ____

REMARKS AND TEST OBSERVATIONS: ____

____

____

____

____

POST-TEST

DATA LOGGER DATA VERIFICATION* PRINT OUTPUT # ____

SYSTEM STATUS: ____

REMARKS AND TEST OBSERVATION: ____

____

____

PERFORMED ____ REVIEWED ____

Figure 6-12. Surge Test Data Sheet

6.2.4 Radio Frequency Interference Test Setup Description

Eagle 21™ system input/output performance, while subjected to RFI, was monitored in the following manner:

- o Analog outputs -- Four analog output channels were monitored continuously during the RFI test. The channels monitored replicated signals processed by current loop, wide-range RTD, and narrow-range RTD input signal conditioning boards. Thus, system analog input/output processing performance was measured.

- o Digital outputs -- A single variable NR RTD (Thot3) was chosen to toggle all six Delta T/Tavg System trip outputs. All six trip output channels were toggled utilizing the variable RTD circuit shown in Figure 6-6. The control relay was cycled at the start of each frequency run, measuring trip output performance during the RFI event. The Delta T/Tavg system inputs were set just below and above the trip output toggle point (.2% or less). The Delta T/T_{avg} system utilizes current loop, NR RTD and 0-10 volt analog inputs to generate partial trip output signals (see section 3 for system block diagrams). Thus, any significant degradation in system input signal processing would result in a trip output status failure. A normally open contact output channel was also monitored. The contact output was normally energized throughout the test.

  In addition to continuous monitoring via the strip chart recorder, trip output status was also sampled by the control computer before, during, and after energization of the control relay. Any discrepancies between actual and expected trip output status were flagged by an error message. See figures 6-13 and 6-14 for RFI modulation and keying test data sheets. Figure 6-15 is the Tape Recorder Log Sheet.

RADIO FREQUENCY INTERFERENCE TEST DATA

TARGET: (CABINET POSITION)
CALIBRATION FILE:
FIELD STRENGTH LEVEL: (V/m)
TYPE OF ANTENNA: (LOG PERIODIC OR BICONICAL)
ANTENNA POLARIZATION: (HORIZONTAL OR VERTICAL)

DATE: ____________________

TEST PERFORMED BY: ______________________________

REVIEWED BY: ______________________________

TAPE NAME:
TAPE SET:

TAPE RECORDER START AT: (FOOT)

FREQUENCY: (MHZ)

(DATE)
(TIME)

EVENT	DIG/INPUT	
1	00 0011	(EXPECTED TRIP OUTPUT PATTERN)
2	11 1100	
3	00 0011	

REMARKS:

FREQUENCY: (MHZ)

(DATE)
(TIME)

EVENT	DIG/INPUT
1	00 0011
2	11 1100
3	00 0011

REMARKS:

FREQUENCY: (MHZ)

(DATE)
(TIME)

ERROR IN THE CHANGING CONDITION OF BISTABLE STATUS (TRIP OUTPUT ERROR MESSAGE)

EVENT	DIG/INPUT
1	00 0011
2	11 1101
3	00 0011

REMARKS:

ENDING TAPE RECORDER FOOTAGE FOR THIS SET OF DATA: (FOOT)

Figure 6-13. RFI Modulation Test Data Sheet

RADIO FREQUENCY INTERFERENCE TEST DATA

TARGET: (CABINET POSITION)
FIELD STRENGTH LEVEL: (V/M)
TYPE OF ANTENNA: (LOG PERIODIC OR BICONICAL)
ANTENNA POLARIZATION: (HORIZONTAL OR VERTICAL)

DATE: ____________________

TEST PERFORMED BY: ______________________________

REVIEWED BY: ______________________________

TAPE NAME:
TAPE SET:

TAPE RECORDER START AT: (FOOT)

FREQUENCY: (MHZ)

(DATE)
(TIME)

	EVENT	(FIRST KEY CYCLE) DIG [K-OFF] INPUT	(SECOND KEY CYCLE) DIG [K-ON] INPUT
(EXPECTED TRIP	1	00 0011	00 0011
OUTPUT PATTERN)	2	11 1100	11 1100

REMARKS:

FREQUENCY: (MHZ)

(DATE)
(TIME)

EVENT	DIG [K-OFF] INPUT	DIG [K-ON] INPUT
1	00 0011	00 0011
2	11 1100	11 1100

REMARKS:

FREQUENCY: (MHZ)

(DATE)
(TIME)

EVENT	DIG [K-OFF] INPUT	DIG [K-ON] INPUT
1	00 0011	00 0011
2	11 1100	11 1100

REMARKS:

ENDING TAPE RECORDER FOOTAGE FOR THIS SET OF DATA: (FOOT)

Figure 6-14. RFI Keying Test Data Sheet

006-A-19866-29

TAPE RECORDER: ____

TAPE RECORDER LOG SHEET

			LOOP CONDITIONS						RECORDING																				
SET	DATE	TIME	PUMPS				TEMP.	PRESS	TAPE NO.	START	STOP	IPS	MIN.	GROUP	CHANNELS														REMARKS
			1	2	3	4									1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 6-15. Tape Recorder Log Sheet

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SECTION 7
ACCEPTANCE CRITERIA

7.1 DESCRIPTION

The general acceptance criterion for the 1E safety-related system is that the system shall remain operational before, during, and after any one of the abnormal events described in Section 5 and listed below. Specific acceptance criteria for the noise, fault, surge withstand capability, and radio frequency interference tests are defined in the following paragraphs.

7.1.1 Noise Test Acceptance Criteria

The Eagle 21™ system shall remain operational and maintain protective action before, during, and after any credible noise event described in section 5.1.

7.1.2 Fault Test Acceptance Criteria

The Eagle 21™ system shall remain operational and maintain protective action before, during, and after the application of any credible faults as described in section 5.2. Faults shall not propagate across the class non-1E to class 1E isolation barrier or from channel to channel.

7.1.3 Surge Withstand Capability Test Acceptance Criteria

The Eagle 21™ system shall remain operational and maintain protective action before, during, and after application of the surge withstand test wave to the designated class non-1E to class 1-E isolators as described in section 5.3. In addition, no component damage or shift in calibration exceeding the specified accuracy of the board under test shall occur due to the application of the surge withstand test wave to any cabinet input/output excluding the test panel and MMI communications connections.

7.1.4 Radio Frequency Interference Test Acceptance Criteria

The Eagle 21™ system shall remain operational (i.e., continuous microprocessor operation) while exposed to the radio frequency interference tests described in section 5.4.

SECTION 8
TEST RESULTS

The results of the system noise, fault, surge, and RFI tests are based on the acceptance criteria defined in Section 7. System performance during these abnormal events is described in the ensuing sections. The results are reported in tabular format at the end of this section.

8.1 NOISE TEST RESULTS

Tables 8-1a through 8-1g report the results of the noise tests. Analog output noise in all cases was coupled wire-to-wire from the non-1E cabling to the 1E cabling or directly into the analog output channel. The noise did not affect analog input or digital output signal processing. Thus, protective action was maintained before, during, and after all credible noise events. In all cases the analog output signals returned to normal upon removal of the noise signal.

The test effects column of tables 8-1a through 8-1g reports the worst-case analog output signal shift for each test run.

A system performance summary is given below for each type of noise test:

Noise Test	Worst Case Shift in Analog Output Signals	Results in Table
Random	[	]
Ac Chattering Relay		
Dc Chattering Relay		
Mil-Spec Noise #1		
Mil-Spec Noise #2		
High Voltage Transient		
Static		] b,c

The ac noise sources (ac chattering relay and Mil-spec noise #2) produced spiking on the analog output signal and an increase in the background noise level. There was no recorded shift in the nominal dc value. The random high-voltage transient and dc chattering relay noise sources produced a shift in nominal dc value and an increase in background noise level.

8.2 FAULT TEST RESULTS

Tables 8-2a and 8-2b report the results of the line-to-ground and the line-to-line fault tests. Class-1E isolation was maintained in all cases. Damage was limited to components located on the non-1E side of the isolator or the non-1E side of the isolation device. Analog output noise recorded was coupled wire-to-wire and was limited to a spike upon fault application in isolated instances. No effects were observed on the system input processing or trip/contact output processing subsystems. Thus, protective action was maintained before, during, and after fault application. Sections 8.2.1 and 8.2.2 summarize the test results of the final board designs (see section 3 for drawing references). Section 8.2.3 describes the board modifications required and tables 8-2a and 8-2b report the test results of the original board designs.

8.2.1 Line-to-Ground Fault

System Performance Summary:

Board Type	Fault Voltage	Effects on Adjacent Channels	Damage
Current Loop Output 10-50 mA	125 Vac		
	125 Vdc		
	250 Vdc		
	580 Vac		
Digital Contact Output	125 Vac		
	125 Vdc		
	250 Vdc		
	580 Vac		

b,c

Board Type	Fault Voltage	Effects on Adjacent Channels	Damage
Partial Trip Output	125 Vac	[	]
	125 Vdc		
	250 Vdc		
	580 Vac		] b,c

8.2.2 Line-to-Line Fault

System Performance Summary:

Board Type	Fault Voltage	Effects on Adjacent Channels	Damage
Current Loop Output 10-50 mA	125 Vac	[	]
	125 Vdc		
	250 Vdc		
	580 Vac		
Digital Contact Output	125 Vac		
	125 Vdc		
	250 Vdc		
	580 Vac		] b,c

Board Type	Fault Voltage	Effects on Adjacent Channels	Damage
Partial Trip Output	125 Vac		
	125 Vdc		
	250 Vdc		
	580 Vac		

b,c

MOV = Metal Oxide Varistor
SSR = Solid State Relay

8.2.3 Board Modifications Required

During fault testing of the original contact output and partial trip output board designs, failures in transient suppression devices (metal oxide varistors, MOV) caused component rupture and damage to adjacent channel circuitry. Since the fault test acceptance criteria (section 7) state that adjacent channels shall not be affected by faults applied to a non-1E channel, modifications were required. Applicable fault retests were performed following the board modifications. The modifications by board type are summarized below.

8.2.3.1 Partial Trip Output (EPT) Board

The original EPT board design utilized line-to-ground and line-to-line MOVs [ ]. $_{b,c}$ These MOVs failed and ruptured causing adjacent channel damage upon application of 250 Vdc and 580 Vac line- to-line and line-to-ground faults.

Design changes implemented to prevent MOV rupture are as follows. [ ] $_{b,c}$

For more information concerning the EPT modifications see Appendix A.

8.2.3.2 Digital Contact Output (ECO) Board

The original ECO board design utilized line-to-line MOVs [ ]. $_{b,c}$ These MOVs failed and ruptured upon application of a 580 Vac line-to-line fault. Although there was no recorded degradation in adjacent channel performance, MOV material was sprayed on adjacent channel circuitry. Since the EPT board experienced adjacent channel failure due to MOV rupture, a design change was implemented to prevent MOV rupture. [ ] $_{b,c}$

8.3 SURGE WITHSTAND CAPABILITY (SWC) TEST RESULTS

Table 8-3 reports the results of the SWC tests. No component failures occurred and there was no recorded changes in channel calibrations due to application of the SWC test wave. Protective action was maintained before, during, and after application of the SWC test wave to the designated class non-1E to class 1E isolators. Analog output noise recorded was coupled through the associated input signal conditioning channel while the surge was applied. Noise was radiatively, and conductively, coupled into the input channel. This conclusion is substantiated by the fact that noise was recorded on the channel under test as well as on adjacent channels. Trip output status failures were caused by noise coupled through the NR RTD input channels. Since the trip outputs are a function of the NR RTD inputs, erroneous trip outputs did occur. In no case was a false triggering of a partial trip or contact output hardware module recorded. In all cases these modules provided the appropriate outputs per loop calculation processor request. Thus, adverse system performance was limited to the analog I/O processing subsystem. In all cases, the analog I/O processing subsystem returned to normal operation upon removal of the SWC test wave. The loop processor subsystem maintained continuous operation before, during, and after all SWC test cases.

The test effect column of Table 8-3 reports the maximum recorded shift from nominal of an analog output signal for a specified test.

8.3.1 Common Mode Tests

System Performance Summary:

Type of I/O Board	Worst-Case Shift in Analog Output Signals	Component Damage, Calibration Snift
Wide-Range RTD Input	[	
Narrow-Range RTD Input		
WR RTD 0-10V Input		
Current Loop Input 10-50 mA, Active		
Current Loop Input 10-50 mA, Passive		
Current Loop Input 4-20 mA, Active		
Current Loop Output 10-50 mA		]b,c

[ ]b,c

Type of I/O Board (cont)	Worst Case Shift in Analog Output Signals	Component Damage, Calibration Shift
AC Input, Cabinet Power	[	
Partial Trip Output		
Digital Contact Output		]b,c

8.3.2 Transverse Mode Tests

System Performance Summary:

Type of I/O Board	Worst Case Shift in Analog Output Signals	Component Damage, Calibration Shift
Wide-Range RTD Input	[	
Narrow-Range RTD Input		
WR RTD 0-10V Input		
Current Loop Input 10-50 mA, Active		
Current Loop Input 10-50 mA, Passive		
Current Loop Input 4-20 mA, Active		
Current Loop Output, 10-50 mA		
Ac Input, Cabinet Power		
Partial Trip Output		
Digital Contact Output		]b,c

8.3.3 Board Modifications/Retests

The digital contact output and partial trip output boards experienced failures during the fault tests. See section 8.2 for a report on the required board modifications. These modifications were made to the transient voltage suppression circuitry on these boards.

The contact output board was retested to verify compliance with IEEE-472-1974. Only transverse mode transient suppression across open contacts was affected by the the modifications. Retests S57 and S58 were performed following the modifications to verify board performance.

The partial trip output board common and transverse mode transient suppression circuitry was modified. An analysis was performed (appendix A) in lieu of retesting and supports the original SWC tests, S13-S16.

8.4 RADIO FREQUENCY (RF) INTERFERENCE TEST RESULTS

Tables 8-4a and 8-4b report the results of the RF modulation and keying tests. In general, analog output noise recorded was coupled through the associated input signal conditioning channel. At isolated low frequencies (100 MHz or less) some noise was coupled directly into the analog output channel. Trip output status failures were caused by noise coupled through the NR RTD input channels. Since the trip outputs are a function of the NR RTD inputs, erroneous trip outputs did occur. In no case was a false triggering of a partial trip or contact output hardware module recorded. In all cases, these modules provided the appropriate outputs per loop calculation processor request. Thus, adverse system performance was limited to the analog I/O processing subsystem. In all cases the analog I/O processing subsystem returned to normal operation upon removal of the RF field. The loop processor subsystem maintained continuous operation before, during, and after all modulation and keying test cases.

The two noise coupling paths (input and output) produced different recorded noise characteristics. The noise coupled through the inputs was most severe at the start and end of each frequency test run. The noise consisted of a spike upon application of the RF field, followed by a period of reduced noise, and ending with a spike upon removal of the RF field. The keying test results summary reports the worst-case transient analog output signal shifts. Noise coupled directly into the analog output channel produced a shift in the nominal dc value and an increase in the background noise level throughout the affected frequency test run.

An additional test was performed to confirm that the noise coupled through the input channel was radiatively coupled and not conductively coupled. The RF signal generator was used to inject an ac coupled RF signal directly into the NR RTD input board with a nominal dc voltage applied to the input. The man-machine interface terminal was monitored during the noise injection and no effect on the input signal was observed. [

]b,c

The test effect column of Tables 8-4a and 8-4b reports the maximum recorded shift from nominal of an analog output signal over the frequency range specified and reports the frequencies at which trip output status failures occurred.

8.4.1 Modulation Tests

System Performance Summary:

Frequency Band	Worst-Case Shift in Analog Output Signals
20 - 160 MHz	[
160 - 500 MHz	
500 - 1000 MHz	]b,c

[

]b,c

8.4.2 Keying Tests

System Performance Summary:

Frequency Band	Worst-Case Shift in Analog Output Signals
20 - 160 MHz	[
160 - 500 MHz	
500 - 1000 MHz	]b,c

[ ]b,c

8.4.3 Cabinet Modifications Required

Modifications were made to the Eagle 21™ cabinet to improve system immunity to RFI. [

]b,c There modifications were made prior to the recording of final data shown in tables 8-4a and 8-4b.

TABLE 8-1a
RANDOM NOISE TESTS
(ANTENNA COUPLED)

Test Number	Type of I/O Board	Test Effect
N1	Partial Trip Output	[ ]b,c
N2	10-50 mA Current Loop Output	
N3	Digital Contact Output NO, OC	
N4	Digital Contact Output NO, SC	
N5	Digital Contact Output NC, OC	
N6	Digital Contact Output NC, SC	

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures

OC = Open Circuit
SC = Short Circuit

NO = Normally Open
NC = Normally Closed

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TABLE 8-1b
AC CROSSTALK NOISE TESTS - CHATTERING RELAYS

Test Number	Type of I/O Board	Test Effect
N7	Partial Trip Output, Ant Co.	
N8	Partial Trip Output, Dir Co.	
N9	10-50 mA Current Loop Output, Ant Co.	
N10	10-50 mA Current Loop Output, Dir Co.	
N11	Digital Contact Output, NO, OC, Ant Co.	
N12	Digital Contact Output, NO, SC, Ant Co.	
N13	Digital Contact Output, NO, Dir Co.	
N14	Digital Contact Output, NC, OC, Ant Co.	
N15	Digital Contact Output, NC, SC, Ant Co.	

b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures
OC = Open Circuit
SC = Short Circuit
NO = Normally Open
NC = Normally Closed
Ant Co. = Antenna Coupled
Dir Co. = Direct Coupled

TABLE 8-1c
DC CROSSTALK NOISE TESTS - CHATTERING RELAYS

Test Number	Type of I/O Board	Test Effect
N16	Partial Trip Output, Ant Co.	
N17	Partial Trip Output, Dir Co.	
N18	10-50 mA Current Loop Output, Ant Co	
N19	10-50 mA Current Loop Output, Dir Co.	
N20	Digital Contact Output, NO, OC, Ant Co.	
N21	Digital Contact Output, NO, SC, Ant Co.	
N22	Digital Contact Output, NO, Dir Co.	
N23	Digital Contact Output, NC, OC, Ant Co.	
N24	Digital Contact Output, NC, SC, Ant Co.	b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures
OC = Open Circuit
SC = Short Circuit
NO = Normally Open
NC = Normally Closed
Ant Co. = Antenna Coupled
Dir Co. = Direct Coupled

TABLE 8-1d
MILITARY SPECIFICATION
NOISE SOURCE #1 TESTS
(ANTENNA COUPLED)

Test Number	Type of I/O Board	Test Effect
N25	Partial Trip Output	
N26	10-50 mA Current Loop Output	
N27	Digital Contact Output, NO, OC	
N28	Digital Contact Output, NO, SC	
N29	Digital Contact Output, NC, OC	
N30	Digital Contact Output, NC, SC	

b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures

OC = Open Circuit
SC = Short Circuit

NO = Normally Open
NC = Normally Closed

TABLE 8-1e
MILITARY SPECIFICATION
NOISE SOURCE #2 TESTS
(ANTENNA COUPLED)

Test Number	Type of I/O Board	Test Effect
N31	Partial Trip Output	
N32	10-50 mA Current Loop Output	
N33	Digital Contact Output, NO, OC	
N34	Digital Contact Output, NO, SC	
N35	Digital Contact Output, NC, OC	
N36	Digital Contact Output, NC, SC	[ ]b,c

OC = Open Circuit
SC = Short Circuit

NO = Normally Open
NC = Normally Closed

TABLE 8-1f
HIGH VOLTAGE TRANSIENT NOISE TESTS
(ANTENNA COUPLED)

Test Number	Type of I/O Board	Test Effect
N37	Partial Trip Output	
N38	10-50 mA Current Loop Output	
N39	Digital Contact Output, NO, OC	
N40	Digital Contact Output, NO, SC	
N41	Digital Contact Output, NC, OC	
N42	Digital Contact Output, NC, SC	

b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures

OC = Open Circuit
SC = Short Circuit

NO = Normally Open
NC = Normally Closed

TABLE 8-1g
STATIC NOISE TESTS

Test Number	Type of I/O Board	Test Effect
N43	Partial Trip Output, Ant Co.	
N44	Partial Trip Output, Dir Co.	
N45	10-50 mA Current Loop Output, Ant Co.	
N46	10-50 mA Current Loop Output, Dir Co.	
N47	Digital Contact Output, NO, OC, Ant Co.	
N48	Digital Contact Output, NO, SC, Ant Co.	
N49	Digital Contact Output, NO, Dir Co.	
N50	Digital Contact Output, NC, OC, Ant Co.	
N51	Digital Contact Output, NC, SC, Ant Co.	b,c

OC = Open Circuit
SC = Short Circuit

NO = Normally Open
NC = Normally Closed

Ant Co. = Antenna Coupled
Dir Co. = Direct Coupled

TABLE 8-2a
LINE-GROUND FAULT TESTS

Test No.	Voltage Level	Type of I/O Board	Test Connections	Effects on Adjacent Channels	Damage
F1	125 VAC	Current Loop Output, 10-50 mA	H to +		
F2	125 VAC	Current Loop Output, 10-50 mA	H to -		
F3	125 VDC	Current Loop Output, 10-50 mA	+ to +		
F4	125 VDC	Current Loop Output, 10-50 mA	+ to -		
F5	125 VDC	Current Loop Output, 10-50 mA	- to +		
F6	125 VDC	Current Loop Output, 10-50 mA	- to -		
F7	250 VDC	Current Loop Output, 10-50 mA	+ to +		
F8	250 VDC	Current Loop Output, 10-50 mA	+ to -		
F9	250 VDC	Current Loop Output, 10-50 mA	- to +		
F10	250 VDC	Current Loop Output, 10-50 mA	- to -		
F11	580 VAC	Current Loop Output, 10-50 mA	H to +		
F12	580 VAC	Current Loop Output, 10-50 mA	H to -		
F13	250 VDC	Digital Contact Output, EN	+ to NO		
F14	250 VDC	Digital Contact Output, EN	+ to NC		
F15	250 VDC	Digital Contact Output, EN	- to NO		
F16	250 VDC	Digital Contact Output, EN	- to NC		
F17	580 VAC	Digital Contact Output, EN	H to NO		
F18	580 VAC	Digital Contact Output, EN	H to NC		
F19	125 VAC	Partial Trip Output, EN	H to LO		
F20	125 VAC	Partial Trip Output, EN	H to HI		
F21	125 VDC	Partial Trip Output, EN	+ to LO		
F22	125 VDC	Partial Trip Output, EN	- to LO		
F23	125 VDC	Partial Trip Output, EN	+ to HI		
F24	125 VDC	Partial Trip Output, EN	- to HI		
*F25	250 VDC	Partial Trip Output, EN	- to HI		
*F26	250 VDC	Partial Trip Output, EN	+ to HI		

b,c

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TABLE 8-2a (Continued)
LINE-GROUND FAULT TESTS

Test No.	Voltage Level	Type of I/O Board	Test Connections	Effects on Adjacent Channels	Damage
*F27	250 VDC	Partial Trip Output, EN	+ to LO		
*F28	250 VDC	Partial Trip Output, EN	- to LO		
F29	250 VDC	Partial Trip Output, DEN	+ to HI		
F30	250 VDC	Partial Trip Output, EN	+ to HI		
F31	250 VDC	Partial Trip Output, EN	- to HI		
F32	250 VDC	Partial Trip Output, DEN	- to HI		
F33	250 VDC	Partial Trip Output, EN	- to LO		
F34	250 VDC	Partial Trip Output, DEN	- to LO		
F35	250 VDC	Partial Trip Output, EN	+ to LO		
F36	250 VDC	Partial Trip Output, DEN	+ to LO		
F37	580 VAC	Partial Trip Output, EN	H to LO		
F38	580 VAC	Partial Trip Output, DEN	H to LO		
F39	580 VAC	Partial Trip Output, EN	H to HI		
F40	580 VAC	Partial Trip Output, DEN	H to HI		

b,c

* = Tests of original partial trip output board design

EN = energized
DEN = Deenergized

NO = Normally Open
NC = Normally Closed

TABLE 8-2b
LINE-TO-LINE TESTS

Test No.	Voltage Level	Type of I/O Board	Test Connections	Effects on Adjacent Channels	Damage
F41	125 VAC	Current Loop Output, 10-50 mA	H to +, N to -		
F42	125 VDC	Current Loop Output, 10-50 mA	+ to +, - to -		
F43	125 VDC	Current Loop Output, 10-50 mA	- to +, + to -		
F44	250 VDC	Current Loop Output, 10-50 mA	+ to +, - to -		
F45	250 VDC	Current Loop Output, 10-50 mA	- to +, + to -		
F46	580 VAC	Current Loop Output, 10-50 mA	H to +, N to -		
F47	250 VDC	Digital Contact Output, EN	+ to NC, - to C		
F48	250 VDC	Digital Contact Output, EN	- to NC, + to C		
**F49	580 VAC	Digital Contact Output, EN	H to NC, N to C		
F50	125 VAC	Digital Contact Output, EN	H to NO, N to C		
F51	125 VDC	Digital Contact Output, EN	+ to NO, - to C		
F52	125 VDC	Digital Contact Output, EN	- to NO, + to C		
F53	250 VDC	Digital Contact Output, EN	+ to NO, - to C		
F54	250 VDC	Digital Contact Output, EN	- to NO, + to C		
F55	580 VAC	Digital Contact Output, EN	H to NO, N to C		
F56	250 VDC	Digital Contact Output, DEN	+ to NO, - to C		
F57	250 VDC	Digital Contact Output, DEN	- to NO, + to C		
**F58	580 VAC	Digital Contact Output, DEN	H to NO, N to C		
F59	125 VAC	Digital Contact Output, DEN	H to NC, N to C		
F60	125 VDC	Digital Contact Output, DEN	+ to NC, - to C		
F61	125 VDC	Digital Contact Output, DEN	- to NC, + to C		
F62	250 VDC	Digital Contact Output, DEN	+ to NC, - to C		
F63	250 VDC	Digital Contact Output, DEN	- to NC, + to C		
F64	580 VAC	Digital Contact Output, DEN	H to NC, N to C		
F65	580 VAC	Digital Contact Output, DEN	H to NO, N to C		

b,c

TABLE 8-2b (continued)
LINE-TO-LINE TESTS

Test No.	Voltage Level	Type of I/O Board	Test Connections	Effects on Adjacent Channels	Damage
F66	580 VAC	Digital Contact Output, EN	H to NC, N to C		
F67	125 VAC	Partial Trip Output, EN	H to HI, N to LO		
F68	125 VDC	Partial Trip Output, EN	+ to HI, - to LO		
F69	125 VDC	Partial Trip Output, EN	+ to LO, - to HI		
F70	250 VDC	Partial Trip Output, DEN	+ to LO, - to HI		
F71	250 VDC	Partial Trip Output, DEN	+ to HI, - to LO		
F72	250 VDC	Partial Trip Output, EN	+ to LO, - to HI		
F73	250 VDC	Partial Trip Output, EN	+ to HI, - to LO		
F74	580 VAC	Partial Trip Output, DEN	H to HI, N to LO		
F75	580 VAC	Partial Trip Output, EN	H to HI, N to LO		

circuited

b,c

** = Tests of original digital contact output Board Design

EN: energized
DEN: Deenergized

NO = Normally Open
NC = Normally Closed

TABLE 8-3
SURGE WITHSTAND CAPABILITY (SWC) TESTS

Test No.	Test Mode	Type of I/O Board	Test Connections	Test Effect
S 1	COM	Digital Contact Output, EN	NO/C	
S 2	TRANS	Digital Contact Output, EN	NO/C	
S 3	COM	Digital Contact Output, DEN	NO/C	
S 4	TRANS	Digital Contact Output, DEN	NO/C	
S 5	COM	Digital Contact Output, EN	NC/C	
S 6	TRANS	Digital Contact Output, EN	NC/C	
S 7	COM	Digital Contact Output, DEN	NC/C	
S 8	TRANS	Digital Contact Output, DEN	NC/C	
S 9	COM	Digital Contact Output, EN	NO/NC/C	
S10	COM	Digital Contact Output, DEN	NO/NC/C	
S11	TRANS	Digital Contact Output, EN	NO/NC	
S12	TRANS	Digital Contact Output, DEN	NO/NC	
S13	COM	Partial Trip Output, EN	H/N	
S14	TRANS	Partial Trip Output, EN	H/N	
S15	COM	Partial Trip Outout, DEN	H/N	
S16	TRANS	Partial Trip Output, DEN	H/N	
S17	COM	Current Loop Output, 10-50 mA	+/-	
S18	TRANS	Current Loop Output, 10-50 mA	+/-	
S19	COM	Current Loop Output, 10-50 mA	+/-	
S20	TRANS	Current Loop Output, 10-50 mA	+/-	
S21	COM	Wide Range RTD Input	V+, V-, I+, I-	
S22	TRANS	Wide Range RTD Input	V+, V-	
S23	TRANS	Wide Range RTD Input	I+, I-	
S24	TRANS	Wide Range RTD Input	V+, I-	
S25	TRANS	Wide Range RTD Input	V+, I+	
S26	TRANS	Wide Range RTD Input	V-, I-	
S27	TRANS	Wide Range RTD Input	V-, I+	
S28	COM	Wide Range RTD Input	V+, V-, I+, I-	
S29	TRANS	Wide Range RTD Input	V+, V-	
S30	TRANS	Wide Range RTD Input	I+, I-	
S31	COM	Narrow Range RTD Input	V+, V-, I+, I-	
S32	TRANS	Narrow Range RTD Input	V+, V-	
S33	TRANS	Narrow Range RTD Input	I+, I-	
*S34	COM	Narrow Range RTD Input	V+, V-, I+, I-	

b,c

TABLE 8-3 (continued)
SURGE WITHSTAND CAPABILITY (SWC) TESTS

Test No.	Test Mode	Type of I/O Board	Test Connections	Test Effect
*S35	TRANS	Narrow Range RTD Input	V+, V-	
*S36	TRANS	Narrow Range RTD Input	I+, I-	
S37	COM	Narrow Range RTD Input	V+, V-, I+, I-	
S38	TRANS	Narrow Range RTD Input	V+, V-	
S39	TRANS	Narrow Range RTD Input	I+, I-	
*S40	COM	Narrow Range RTD Input	V+, V-, I+, I-	
*S41	TRANS	Narrow Range RTD Input	V+, V-	
*S42	TRANS	Narrow Range RTD Input	I+, I-	
**S43	COM	Narrow Range RTD Input	V+, V-, I+, I-	
S44	COM	WR RTD 0-10V Input	+/-	
S45	TRANS	WR RTD 0-10V Input	+/-	
S46	COM	Current Loop Input, 10-50 mA, act	LS+/LI+	
S47	COM	Current Loop Input, 10-50 mA, act	LS+, LI+, LS, LI-	
S48	TRANS	Current Loop Input, 10-50 mA, act	LS+, LS-	
S49	TRANS	Current Loop Input, 10-50 mA, act	LI+, LI-	
S50	TRANS	Current Loop Input, 10-50 mA, act	LS+, LI+	
S51	COM	Current Loop Input, 10-50 mA, pass	LI+, LI-	
S52	TRANS	Current Loop Input, 10-50 ma, pass	LI+, LI-	
S53	COM	Current Loop Input, 4-20 mA, act	LI+, LI-	
S54	TRANS	Current Loop Input, 4-20 mA, act	LI+, LI-	
S55	COM	AC Input, Cabinet Power	H/N	
S56	TRANS	AC Input, Cabinet Power	H/N	
+S57	TRANS	Digital Contact Output, EN	NC/C	
+S58	TRANS	Digital Contact Output, DEN	NO/C	b,c

* = Tests performed at 60 HZ repetition rate
** = Test performed at 50 HZ repetition rate
\+ = Retests required due to modifications made during fault testing

AOS: Analog Output Signal Shifts
TOF: Trip Output Failures

NO = Normally Open
NC = Normally Closed
LS = Loop Supply
LI = Loop Input

EN = Energized
DEN = Deenergized
act = Active
pass = Passive

TABLE 8-4a
RADIO FREQUENCY MODULATION TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 1	3 V/m	20 - 160	BICONICAL	VERT	FRONT	
RF 2	3 V/m	20 - 160	BICONICAL	HORZ	FRONT	
RF 3	3 V/m	160 - 500	LOG PERIODIC	HORZ	FRONT	
RF 4	3 V/m	500 - 1000	LOG PERIODIC	HORZ	FRONT	
RF 5	3 V/m	160 - 500	LOG PERIODIC	VERT	FRONT	
RF 6	3 V/m	500 - 1000	LOG PERIODIC	VERT	FRONT	
RF 7	3 V/m	20 - 160	BICONICAL	HORZ	RIGHT	
RF 8	3 V/m	160 - 500	LOG PERIODIC	VERT	RIGHT	

b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failures

TABLE 8-4a (Continued)
RADIO FREQUENCY MODULATION TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 9	3 V/m	500 - 1000	LOG PERIODIC	VERT	RIGHT	
RF 10	3 V/m	20 - 160	BICONICAL	VERT	LEFT	
RF 11	3 V/m	500 - 1000	LOG PERIODIC	HORZ	LEFT	
RF 12	3 V/m	160 - 500	LOG PERIODIC	HORZ	LEFT	
RF 13	3 V/m	500 - 1000	LOG PERIODIC	HORZ	REAR	
RF 14	3 V/m	160 - 500	LOG PERIODIC	VERT	REAR	
RF 15	3 V/m	500 - 1000	LOG PERIODIC	VERT	REAR	
RF 16	3 V/m	160 - 500	LOG PERIODIC	HORZ	REAR	
RF 17	3 V/m	20 - 160	BICONICAL	VERT	REAR	
RF 18	3 V/m	20 - 160	BICONICAL	HORZ	REAR	
RF 19	10 V/m	20 - 160	BICONICAL	HORZ	FRONT	
RF 20	10 V/m	500 - 1000	LOG PERIODIC	HORZ	FRONT	
RF 21	10 V/m	160 - 500	LOG PERIODIC	HORZ	FRONT	

b,c

TABLE 8-4a (Continued)
RADIO FREQUENCY MODULATION TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 22	10 V/m	500 - 1000	LOG PERIODIC	VERT	FRONT	
RF 23	10 V/m	160 - 500	LOG PERIODIC	VERT	FRONT	
RF 24	10 V/m	20 - 160	BICONICAL	VERT	FRONT	
RF 25	10 V/m	20 - 160	BICONICAL	HORZ	RIGHT	
RF 26	10 V/m	160 - 500	LOG PERIODIC	VERT	RIGHT	

b,c

TABLE 8-4a (Continued)
RADIO FREQUENCY MODULATION TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 27	10 V/m	500 - 1000	LOG PERIODIC	VERT	RIGHT	
RF 28	10 V/m	20 - 160	BICONICAL	VERT	LEFT	
RF 29	10 V/m	160 - 500	LOG PERIODIC	HORZ	LEFT	
RF 30	10 V/m	500 - 1000	LOG PERIODIC	HORZ	LEFT	
RF 31	10 V/m	20 - 160	BICONICAL	HORZ	REAR	
RF 32	10 V/m	20 - 160	BICONICAL	VERT	REAR	

b,c

TABLE 8-4a (Continued)
RADIO FREQUENCY MODULATION TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 33	10 V/m	500 - 1000	LOG PERIODIC	HORZ	REAR	
RF 34	10 V/m	500 - 1000	LOG PERIODIC	VERT	REAR	
RF 35	10 V/m	160 - 500	LOG PERIODIC	VERT	REAR	
RF 36	10 V/m	160 - 500	LOG PERIODIC	HORZ	REAR	

b,c

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TABLE 8-4b
RADIO FREQUENCY KEYING TEST RESULTS
(ALL RESULTS WITH CABINET DOORS CLOSED)

Test No.	Field Strength	Frequency Band(MHZ)	Antenna Type	Polarization	(Cabinet Side) Target	Test Effect
RF 37	3 V/m	20 - 160	BICONICAL	HORZ	FRONT	
RF 38	3 V/m	160 - 500	LOG PERIODIC	HORZ	FRONT	
RF 39	10 V/m	160 - 500	LOG PERIODIC	HORZ	FRONT	
RF 40	10 V/m	20 - 160	BICONICAL	HORZ	FRONT	
RF 41	10 V/m	500 - 1000	LOG PERIODIC	HORZ	FRONT	
RF 42	3 V/m	20 - 160	BICONICAL	VERT	FRONT	
RF 43	3 V/m	160 - 500	LOG PERIODIC	VERT	FRONT	
RF 44	10 V/m	160 - 500	LOG PERIODIC	VERT	FRONT	
RF 45	10 V/m	20 - 160	BICONICAL	VERT	FRONT	
RF 46	10 V/m	500 - 1000	LOG PERIODIC	VERT	FRONT	b,c

AOS = Analog Output Signal Shifts
TOF = Trip Output Failure

SECTION 9
CONCLUSION

The Eagle 21™ system performance satisfied the acceptance criteria stated in section 7. The microprocessor subsystem maintained continuous operation while subjected to the abnormal events described in section 5.

Analog output signal noise coupled wire-to-wire or through the analog output channel has no effect on the protective action of the plant protection system since the Eagle 21™ does not use analog output signals for protection signal transmission. Analog output signals are used as interfaces to the plant control and monitoring equipment (e.g., computer, post-accident monitoring system (PAMS)).

9.1 NOISE TESTS

The protective action of the Eagle 21™ system was not affected by noise injected into or adjacent to class non-1E wiring. Analog output signal noise recorded was coupled wire-to-wire or through the analog output channel. Possible analog output noise effects on plant class non-1E systems and PAMS are summarized as follows:

- o The AC noise sources (AC chattering relay, Mil-Spec noise source #1) generated noise spikes on the analog output signal. No change in the nominal DC value of the analog output signal was recorded. These noise spikes will not affect slow responding monitoring equipment.

- o The DC and high voltage transient noise sources produced a shift in the nominal DC value of the analog output signal of 0.5% or less. Since the accuracy requirements of the plant monitoring systems are large compared to the observed effects, these effects are considered minimal.

9.2 FAULT TESTS

The protective action of the Eagle 21™ system was not affected by the injection of credible faults into the designated class non-1E to class 1E isolators. Analog output signal noise recorded was coupled wire to wire and consisted of a noise spike of 0.88% or less upon fault application. No change in the nominal DC value of the analog output signal was recorded. These noise spikes will not affect monitoring equipment.

9.3 SURGE WITHSTAND CAPABILITY (SWC) TESTS

The protective action of the Eagle 21™ system was not affected by the application of the surge withstand test wave to the designated class non-1E to class-1E isolators. In addition, no component damage occurred and no changes in channel calibrations were recorded due to the application of the surge withstand test wave to any cabinet input/output under test.

9.4 RADIO FREQUENCY INTERFERENCE TESTS

The Eagle 21™ system remained operational while exposed to radio frequency interference (RFI) . Analog input/output processing and protective action functions were affected but demonstrated full recovery upon removal of the RFI. To avoid protection system perturbations, Westinghouse recommends that the Eagle 21™ system equipment room(s) be "zoned" to prohibit the use of transceivers in the 20-700 MHz band.

APPENDIX A

PARTIAL TRIP OUTPUT BOARD SURGE WITHSTAND CAPABILITY ANALYSIS

Performed by: R. Nero, Westinghouse

During the fault testing portion of the qualification test for EAGLE-21™, it was necessary to modify the output circuitry of the EPT I/O board. Since the modification did not affect the portion of circuitry that was designed to handle high frequency oscillatory surges, the SWC tests (IEEE-472-1974) were not rerun on the EPT I/O board.

The modification involved suppresser devices on the output. [ ]$_c$

[ ]c

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[ ]c

To substantiate the decision not to rerun the SWC tests (IEEE-472-1974) on the EPT I/O board, analysis was performed with a circuit analysis program [ ]$_{b,c}$. The analysis confirms that the passive surge network attenuates the surge well below the requirements. The analysis was run worst case for both the common mode and differential mode surge conditions. Worst case for both modes is that no MOVs are installed, all outputs are deenergized, and the outputs are not loaded.

[ ]c

c

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c

Figure A-1. EQT Common Mode Equivalent Circuit

c

Figure A-2. EPT Common Mode SWC Test Response

c

Figure A-3. EPT Differential Mode Equivalent Circuit

c

Figure A-4. EPT Differential Mode SWC Test Response

APPENDIX B

EAGLE 21™ SIGNAL CONDITIONING AND MICROPROCESSOR PRINTED CIRCUIT BOARDS

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