April 11, 2014

Mr. Allen Hsu
HF Controls Corporation
1624 West Crosby Road
Suite 124
Carrollton, TX 75006

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION FOR TOPICAL REPORT PP901-000-01, REVISION C, "HFC-6000 SAFETY SYSTEM" (TAC NO. ME7577)

By letter dated June 29, 2011 (Agencywide Documents Access and Management System Accession No. ML11199A098), HF Controls Corporation (HFC) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review "Request for Amendment to HFC-6000 Safety Evaluation Report." Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review.

In an email dated March 25, 2014, Mr. Ivan Chow, representing HFC, and I agreed that the NRC staff will receive your response to the enclosed Request for Additional Information (RAI) questions by April 30, 2014.

If you have any questions regarding the enclosed RAI, please contact me at 301-415-7297.

Sincerely,

/RA/

Joseph J. Holonich, Sr. Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 731

Enclosure:
RAI questions

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HF Controls Corporation
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REQUEST FOR ADDITIONAL INFORMATION
FOR SIX OPEN ITEMS OF HF CONTROL CORPORATION
TOPICAL REPORT PP901-000-01, REVISION C, "HFC-6000 SAFETY SYSTEM"
(TAC NO. ME7577)

RAI-1

HF Control Corporation (HFC) uses Electric Power Research Institute Topical Report 107330 Figure 4-4 to demonstrate compliance with environment stress requirements as described on page 6 of "Qualification Retest Summary Report," RR901-001-04, ERD111, Rev. A. The figure shows the tests include maintaining 40 ºF and 5 percent relative humidity conditions for at least 8 hours. The U.S. Nuclear Regulatory Commission (NRC) staff noted that the test conducted by the Environmental Testing Laboratory (page 5 of Attachment 7.1 of RR901-001-04) only maintained conditions of 4 ºC (40 ºF) for 4 hours.

Please provide additional testing results or justification for qualification of the HFC-6000 platform under different environmental stress conditions than those conditions defined in EPRI TR-107330.

RAI-2

HFC uses NRC Regulatory Guide 1.180, Rev. 1, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference [(EMI/RFI)] in Safety-Related Instrumentation and Control Systems" to comply with EMI/RFI tests as stated in page 6 of "Qualification Retest Summary Report", RR901-001-04, ERD111, Rev. A. However, the NRC staff noted the following discrepancies between RG 1.180 and Nemko tests:

Emissions:

Name of Test	Standard	Limits	Discrepancies	Nemko Test Report Page Number
CE101 Low Frequency Conducted Emissions	MIL-STD-461E as modified by RG 1.180, Rev. 1	60 Hz – 10 kHz For AC Power ≤ 1kVA	Missing test for 60Hz – 120 Hz	Pages 14 –16
RE102 High Frequency Radiated Emissions	MIL-STD-461E as modified by RG 1.180, Rev. 1	2M Hz – 10 GHz	Missing test for Horizontal 2 – 3 MHz	Pages 26 – 32

ENCLOSURE

Immunities:

Name of Test	Standard	Limits	Discrepancies	
CS114 Conducted Susceptibility, Power & Signal Leads	MIL-STD-461E as modified by RG 1.180, Rev. 1	10kHz – 30 MHz 10 kHz – 0.2 MHz, 100 dBμA; 0.2 Mz – 30MHz, 97 dBμA	dBμA values are lower than the required values. (No operating envelopes Figure provided)	Pages 36 - 39
RS101 Radiated Susceptibility, Magnetic Field	MIL-STD-461E as modified by RG 1.180, Rev. 1	30 Hz – 100 kHz	Missing 10 kHz – 100 kHz (No operating envelopes Figure provided)	Pages 67 – 70 (See Page 69)

Please provide additional testing results, or justification for qualification of the HFC-6000 platform under different EMI/RFI conditions than those conditions defined in NRC RG 1.180.

ABSTRACT

This report describes the hardware and software technical features and provides qualification information for the HF Controls Corp. (HFC) HFC-6000 nuclear safety related instrumentation and control platform. The purpose of this report is to seek review and gain approval from the US Nuclear Regulatory Commission for the use of the HFC-6000 controller, I/O modules, communication modules and power supplies for safety related applications in US nuclear power plants. The review and approval is requested for a specified set of HFC hardware and software.

The HFC-6000 has been designed and qualified to meet the applicable safety related I&C requirements for nuclear power plants. Typical applications include:

- Reactor Protection Systems (RPS).
- Engineered Safety Features Actuation System (ESFAS) functions.
- Post Accident Monitoring Systems and Safety Parameter Display Systems.
- NSSS and Balance of Plant (BOP) safety control systems and related functions.

The HFC-6000 scalability makes it an effective approach for all nuclear power plant safety applications including small single loop controllers to complete plant control. The 19" rack mounted platform represents a modular structure whose components can be utilized for all plant safety applications. A HFC-6000 platform solution suitable for all safety applications can reduce the overall instrumentation and control complexity by minimizing operation and maintenance requirements.

The scope of this report addresses both the hardware and software associated with the HFC-6000 platform and the HFC commercial dedication process which prescribes the design and qualification techniques used to assess its reliability. Qualification of the HFC-6000 system is assessed in accordance with the guidance presented by RG 1.180 Rev 1, RG 1.209 and EPRI TR-107330. The report includes hardware and software design descriptions as well as processes by which they were designed. Hardware qualification, in addition to the verification, and validation of software quality are also included. Pre-Development Software quality was verified and validated through methods outlined in EPRI TR-106439 and IEEE Std 7-4.3.2. New software is qualified in accordant with BTP-14. Hardware was qualified through type testing in accordance with applicable regulatory guidance and the requirements of IEEE Std 323.

Regulatory concerns regarding control system defense-in-depth and diversity are summarily discussed in association with their potential respective resolutions. A detailed defense-in-depth and diversity analysis will be addressed during the plant specific licensing process. The detailed HFC 6000 system configuration, applications, and HMI will also be addressed as part of a plant specific licensing process.

The main body of this report describes the HFC-6000 controller, input/output modules, communication modules, and power suppliers with detailed discussions of the key issues cited in numerous reports and in the Standard Review Plan (NUREG-0800).

A summary of the current FMEA findings is provided in section 8. This section lists HFC-6000 potential failure modes and provides an evaluation of their probable effects.

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1 Introduction

1.1 Introduction to HFC

HF Controls (HFC), located in Carrollton, Texas, was established in 1961 as Forney Engineering Company and commissioned by Foster Wheeler to develop fossil plant control systems. In 1979 HFC entered the nuclear plant safety systems supply industry with the award of contracts for the Duke Power Cherokee 1&2 and Perkins 1&2 nuclear power plants. These contracts included the safety related control systems. The Duke Power control systems were 90% complete prior to cancellation of plant construction. Subsequently HFC was contracted by KEPCO in Korea to provide both safety related and non-safety digital control systems for the Yongwang 3 & 4 plants. These control systems, delivered in 1994, have experienced very reliable plant operation. In the years following Yongwang, HFC was contracted by KEPCO to supply the Ulchin 5 & 6 non-safety and safety related control systems. These systems were delivered in 2002 and 2003, and have also experienced very reliable plant operation. Although it was never constructed, KEPCO selected HFC to provide the KEDO plant safety related control systems. In addition to supplying a number of upgrades to nuclear and fossil operating plants in Korea, HFC provides I&C equipment support to over 450 power and industrial plants throughout the world.

HF Controls currently specializes in the design and construction of high reliability control systems for a variety of industrial, fossil power and nuclear power applications. Based on field-proven technology, HFC supplies its customers with a broad array of advanced control hardware that offer distributed intelligence and information management. HFC provides process control systems, technology, engineering, project management, and services.

The HFC control systems provided for the Yongwang 3 & 4 and the Ulchin 5 & 6 nuclear plants in Korea include non-safety and safety controls, I/O modules, data communication modules, power supplies, and control room HMI devices for the NSSS and BOP field components. To date HFC has provided the Korean nuclear power generation industry with over 4,000 individual controllers, with between 10,000 and 17,000 I/O points per plant in a highly functionally segregated and partitioned design. All systems were delivered on schedule, subsequently boasting exceptionally high reliability.

1.2 Introduction to HFC-6000

HFC currently supports two predecessor product lines: the AFS-1000 (Boiler Safety and Nuclear Safety I&C Systems) and the ECS-1200 (Plant Control System) on which the HFC-6000 (Nuclear Safety I&C System) design is based. HFC is requesting the NRC's review of the HFC-6000 product line for suitability in domestic safety related nuclear applications. The earlier ECS-1200 and AFS-1000 product lines have extensive fossil and nuclear power plant operating bases. Both HFC-6000 and ECS-1200 systems use basically identical software. The changes to develop the HFC-6000 hardware from the ECS-1200 hardware are associated with changes to the ECS-1200 form factor.

It is HFC's intent to employ this report as the vehicle by which HFC will receive the NRC's positive review of its control technologies which will enable domestic nuclear power plant licensees to reference the use of basic (i.e., as defined here) HFC-6000 hardware, software operating system, communication software, and I/O software in license applications for their safety system installation upgrades and future new nuclear plants. Review and approvals for specific plant applications will be addressed in plant-by-plant license applications.

In summary the base system described herein includes the redundant HFC-SBC06 controller and a specific set of HFC-6000 series input and output (I/O) modules. The HFC-SBC06 controller provides the process execution from the pre-defined control programs and updates the input and output signals respectively. The multiple channel I/O modules handle both digital and analog signals based upon the types of I/O devices. The HFC-6000 controller and associated I/O modules are microprocessor based printed circuit boards loaded with firmware. The communication between controller and I/O modules is via RS485 I/O communication Link (ICL). The connection medium can be either Fiber Optic media or twisted pair metal wires. The field proven HFC-6000 control software and I/O firmware referenced here is a qualified subset of the of Pre-Developed Software (PDS) software and firmware library that has been previously implemented on numerous nuclear safety applications. The C-Link communication provides a means for a controller to broadcast and receive information with other controllers in the same division and also to broadcast, but not receive, information with non-safety related equipment.

Table 1-1 provides a comprehensive list and description of the HFC-6000 base system.

Table 1-1 - The Base HFC-6000 System

Category	Module Type	Description	Processor
Hardware		HFC-6000 Controller Rack	N/A
Hardware	HFC-BPC19	HFC-6000 Controller Backplane	N/A
Hardware	HFC-BPE19	HFC-6000 Expander Backplane	N/A
Hardware and Software	HFC-SBC06	Redundant Controller Card Set	Control Input/Output Communication
Hardware	HFC-DPM06	Dual-Ported Memory for Redundant Controller	N/A
Hardware and Firmware	HFC-DI16I	16-Channel (Port) Digital Input Card	Input Processor
Hardware and Firmware	HFC-DO8J	8-Channel (Port) High Current Relay Output Card	Output Processor
Hardware and Firmware	HFC-DC33	Nuclear Power Plant Special Function Card with 2 channel 120-vac digital output and 12 channel digital input	Input/Output Processor
Hardware and Firmware	HFC-DC34	Nuclear Power Plant Special Function Card with 2 channel 125-vdc digital output and 12 channel digital input	Input/Output Processor

Hardware and Firmware	HFC-AI4K	4-Channel (Port) Pulse Input Card, High Resolution	Input Processor
Hardware and Firmware	HFC-AI16F	16-Channel (Port) Analog Input Card,	Input Processor
Hardware and Firmware	HFC-AO8F	8-Channel (Port) Analog Output Card	Output Processor
Hardware and Firmware	HFC-AI8M	8-Channel (Port) 100 Ohm RTD Input Card	Input Processor
Hardware	HFC-ILR06	I/O Link Fiber Optics Repeater/Terminator	N/A
Hardware	ECS-B232	Fiber Optic Transmitter	N/A

2 Documents and Definitions

The document structure used in the development and qualification of the HFC-6000 safety system include the following categories of interest:

- Topical Report and Related Documents submitted to the NRC
- HFC-6000 Qualification Project Documents
- QA Procedures and Related Documents
- HFC-6000 Product Line Documents

This structure constitutes a hierarchical document mapping system to guide the report's reviewers seeking data referenced throughout this report.

2.1 Definitions

Abnormal Conditions and Events (ACE). Postulated internal or external abnormalities that may affect performance of a system.

Acceptance Testing. Formal testing conducted to determine if a system satisfies its acceptance criteria and to enable a customer to assess the acceptability of the system.

Application Software. (1) Software designed to fulfill the specific needs of a user. (2) Software that performs a task related to the process being controlled rather than to an internal operation of the component itself.

Component Testing. Testing of hardware or software components or groups of related components conducted to verify the implementation of the design.

Computer. A programmable functional unit that consists of one or more associated processing units and peripheral equipment, that is controlled by internally stored programs, and that can perform substantial computation without human intervention during its processing sequence.

Computer Program. A combination of computer instructions and data definitions that enable computer hardware to perform computational or control functions.

Critical Component. Hardware or software integrated into control systems and instrumentation for a safety system. In this document, a *critical component* is synonymous with a *safety-related component.*

Design Basis Event. Postulated events used in the design to establish the acceptable performance required for structures, systems, and components.

Design Phase. The period in a project life cycle during which the designs for architecture, hardware or software components, interfaces, and data are created, documented, and verified to satisfy project requirements.

Design Inputs. The specific combination of functional and performance characteristics that a new design is required to fulfill. Design Inputs are also called Design Requirements.

Failure Modes and Affects Analysis (FMEA). A systematic evaluation of component responses to a postulated failure condition.

Form Factor. The hardware platform and backplane design for a computer system.

Implementation Phase. The period of a project life cycle during which hardware and software components are created from design documentation.

Integration Phase. The period of a project life cycle during which hardware and software components are progressively combined into their operating environment and tested in this environment to verify functional performance.

Life-Cycle Phase. Any period during a project that may be characterized by a primary type of activity being conducted. Different phases may overlap; for V&V purposes, no phase is complete until its development products are verified fully.

Regression Test. Selective retesting of a component following modification to correct an error or design problem. The purpose of such testing is to verify that the modification resolved the problem that had been identified without introducing any new problems.

Requirements Phase. The period of a project life cycle during which functional and nonfunctional requirements (design inputs) are defined and documented.

Software. Programs, procedures, rules, data, and any associated documentation pertaining to the operation of a computer system.

System Software. A computer program that performs tasks related to internal operation of the computer itself.

Traceability Analysis. A systematic method for tracing each requirement for a project to its final implementation in a project. The scope of such an evaluation may be restricted to a single life time phase, or it may encompass an entire project.

Validation. The process of evaluating an integrated computer system (hardware and software) or individual component during or at the end of its development process to determine if it satisfies specified requirements.

Verification. The process of evaluating a system or component to determine whether or not the products of a given development phase satisfies the conditions imposed at the start of that phase.

3 Acronyms

A	Ampere
AC	Alternating Current
ACE	Abnormal Conditions and Effects
ACK	Acknowledge
ADC	Analog/Digital Converter
AI	Analog Input
AMSAC	ATWS Mitigation System Actuation Circuitry
AO	Analog Output
AOT	Application Object Test
ASO	Application Software Objects
ATWS	Anticipated Transient Without Scram
BLRQ	Block Request
BOE	Burst of Events
BOP	Balance of Plant
C	Celsius; also Centigrade
CD	Compact Disk
CFR	Code of Federal Regulations
C-Link	Communication Link
CMS	Code Management System
CO	Category Owner
COMM	Communication Module
CPU	Central Processing Unit
CPUM	CPU Module
CQ4	HFC Analog Algorithm
CR	Condition Report
CRC	Cyclic Redundancy Check
CRG	Condition Review Group
CRT	Cathode Ray Tube
DAC	Digital/Analog Converter
dB	Decibel
dc	Direct Current
PCS	Plant Control System
PLC	Programmable Logic Controller
DDB	Dynamic Data Base
DF	Digital Flags
DI	Digital Inputs
DO	Digital Outputs
DPM	Dual Ported Memory
EMI/RFI	Electro-Magnetic Interference/Radio Frequency Interference
EOB	Electrically Operated Breaker
EPROM	Erasable Programmable Read Only Memory

ESD	Electrostatic Discharge
ESFAS	Engineered Safety Features Actuation System
EWS	Engineering Workstation
F	Fahrenheit
FL	Flags
FMEA	Failure Modes and Effects Analysis
FO	Fiber Optic
FOT	Fiber Optic Transmitter
GDC	General Design Criteria
H	Hertz
HAS	Historical Archiving System
HFC	HF Controls
HMI	Human Machine Interface
HPAT	HFC Plant Automated Tester
H/W	Hardware
Hz	Hertz
I&C	Instrumentation and Control
ICL	Intercommunication Link
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
IOM	Input/Output Module
ISG	Interim Staff Guidance
KEDO	Korean Peninsula Energy Development Organization
KEPCO	Korean Electric Power Company
KHz	Kilo Hertz
LED	Light Emitting Diode
LLC	Link Logic Control
mA	milli Ampere
MAC	Medium Access Control
MCL	Master Configuration List
MFM	Master for a Moment
MHz	Mega Hertz
μ	Micron
μV	Micro Volt
MMI	Man Machine Interface
MMS	Module Management System
MS	Microsoft
MSS	Maintenance Subsystem
MTBF	Mean Time Between Failures
MUX	Multiplex
NACK	Negative Acknowledge
NIC	Network Interface Chip
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam System Supplier

OBE	Operating Basis Earthquake
OEM	Original Equipment Manufacturer
OIS	Operator Interface System
OS	Operating System
PC	Personal Computer
PCB	Printed Circuit Board
PCS	Plant Control System
PDS	Previously Developed Software
PLC	Programmable Logic Controller
PMS	Plant Monitoring System
PO	Purchase Order
PROM	Programmable Read-Only Memory
PSM	Power Supply Module
QA	Quality Assurance
QAPM	Quality Assurance Program Manual
QC	Quality Control
RAD	Unit of Radiation
RAM	Random Access Memory
RELEX	Reliability Program
RF	Radio Frequency
RG	Regulatory Guide
RH	Relative Humidity
RMS	Root Mean Square
ROM	Read-Only Memory
RPS	Reactor Protection System
RRS	Required Response Spectrum
RTD	Resistance Thermal Detector
RTS	Reactor Trip System
SAR	Safety Analysis Report
SBC	Single Board Computer
SC	System Controller
SCM	Software Configuration Management
SCR	Software Change Request
SDD	System Design Description
SDP	Software Development Plan
SLC	Single Loop Controller
SMT	Software Management Team
SIP	System Integration Plan
SOE	Sequence of Events
SQAP	System Quality Assurance Plan
SQL	Microsoft Server Utility
SRS	System Requirements Specification
SSE	Safe Shutdown Earthquake
SSP	System Safety Plan
Std	Standard

STP	System Test Plan
SVVP	System Verification and Validation Plan
SVVR	System Verification and Validation Report
S/W	Software
SYS	System CPU
TCB	Task Control Block
TRS	Test Response Spectrum
TSAP	Test System Application Program
TCP/IP	Transmission Control Protocol/Internet Protocol
UCN	Ulchin Nuclear Power Plant
UCP	Universal Communication Packet
UDP	Universal Data Packet
UFSAR	Updated Final Safety Analysis Report
UPS	Uninterruptable Power Source
v	Volts
vac	Volts Alternating Current
VAX	Digital Computer
vdc	Volts Direct Current
YGN	Yongwang

4 Overview of HFC-6000 Qualification Project

The HFC-6000 system design requirements were established using the earlier AFS and ECS product lines design requirements with minor modifications where needed. Functional, environmental, module interface and performance requirements were established for the HFC-6000 system to be compatible with the USA nuclear installations and the associated plant digital control systems upgrade requirements. These requirements form the bases for the design of the system and with their specification defines the key areas for design reviews including audits and verification and validation processes. The Qualification Project was performed using the regulations, codes, standards and, guidance as discussed in Section 8.5 that are applicable to the design and qualification of digital safety systems and the scope of this Topical Report.

The technical scope and content of EPRI TR-107330 are focused on defining a series of steps needed to complete a generic qualification program. Accomplishing the qualification requires creation of a synthetic application, so the steps are similar to those in qualifying a device for safety-related service. For the HFC-6000, these steps and associated HFC qualification tasks were performed as defined in this document. The specific steps included;

A. Define an architecture overview of the HFC-6000 system and evaluate the suitability for the intended application, Input/Output modules, communication, and controller modules were defined so as to encompass a broad range of nuclear applications. This review also included the performance of a single failure analysis considering redundancy that would be incorporated in the plant design. Using this architecture, a Failure Modes and Effects Analysis (FMEA) for the HFC-6000 system was performed. This is to be used in the future as an input to the more detailed plant specific application and overall FEMA. This overview included an analysis of the deterministic features of the system.

B. Evaluate the HFC-6000 system's hardware and software QA programs that are applied to determine if they are adequate to support nuclear safety-related applications with a reasonable set of supplementary activities. The evaluation includes factors relating both to generic qualification and future potential applications of the qualified products.

C. Select a set of modules, supporting devices and software from the HFC-6000 system to be used as the qualification test specimen and included in qualification project.

D. Define and produce a Test System Application Program (TSAP). The TSAP serves as a synthetic application that is designed to aid in the qualification tests and demonstrate the acceptability of the system being qualified.

E. Combine modules of the Test Specimen and the TSAP into a suitable test configuration and perform a set of acceptance tests. This activity constitutes the system integration testing for the Test Specimen.

F. Specify the set of hardware qualification tests to be performed on the Test Specimen, including a defined set of tests to be conducted at suitable times in the qualification process.

G. Perform the hardware qualification tests, perform the data analyses, and document the results. Results documentation includes definition of the qualification envelope, identification of the specific products that were qualified, and guidance for using the qualified system in a specific application.

H. Perform a suitability analysis for HFC-6000 requirements including such features as accuracy, response times and physical characteristics. Identify all I/O points, scan rates and software features.

I. [

J.

]

K. Develop the test application software using the HFC quality standards. The HFC development process is mature and stable and provides safety related application software that meets all guidelines and regulations applicable to the scope of this report.

L. Ensure that the configuration identification and management program for the HFC-6000 hardware and software is maintained using the guidelines contained in the applicable standards and regulations.

M. Ensure that all specifications of the HFC-6000 system are consistent with the requirements of 10 CFR 50 Appendix B, IEEE Std 603-1991 and the applicable GDCs. Ensure that all applicable RGs and industry standards have been followed or adequate justification provided.

[

]

HFC requests that the NRC review the HFC –6000 platform as described in this Topical Report. This includes the hardware and software defined in this report. The following sections of this report will provide both design and qualification details that will demonstrate compliance with all applicable regulations for a programmable safety related instrumentation and control system.

5 HFC-6000 System Overview

HF Controls provides a programmable logic controller to support nuclear power plant safety, control, and information functions. The HFC-6000 digital safety system was designed to meet regulatory requirements for safety system applications. These include component quality, hardware and software qualification, redundancy, fault tolerance, deterministic performance, isolation and independence. The overall architecture of HFC-6000 control and information systems form the bases to meet the requirements for nuclear power plant applications.

The primary CPU Module (CPUM) in a HFC-6000 controller unit is the system controller (HFC-SBC06), which supports the execution of control logic programs, and I/Os scan and C-Link communication. **[**

]

The Power Supply Module (PSM) represents the redundant rack mounted power supply set. This hot swappable redundant power supply provides 24 vdc for both controller and I/O modules. **[**

] ***Figure 5-1 - HFC-6000 System Arrangement Diagram***

6 HFC Safety I&C Platform Hardware Description

This section provides an overview of the hardware components that make up the HFC-6000 nuclear safety I&C platform. They include various I/O, communication, power supply and controller modules and chassis. The software for the various modules is discussed in Section 7. This product line has been developed as a generic I&C application having a medium density I/O (up to 1000 points per controller). The scope of potential applications includes safety-related control functions for nuclear power plants.

6.1 System Controller Module

The HFC-6000 safety system provides plant monitoring and control functions, with monitoring and control capabilities. The HFC-SBC06 System Controller is the primary module used for implementing plant safety functions. The HFC-SBC06 System Controller module is positioned in the HFC-6000 safety system between the human machine interfaces through the I/O modules, which provide the signal-level interface to the equipment and devices under monitoring or control. Figure 6-1 shows the interface function for a single safety division of the HFC-SBC06 controller between its onboard system processor and its communications processors.**[**

]

Descriptions of the functional requirements of the HFC-SBC06 System Controller module and HFC-DPM06 Dual Ported Memory module, from an external perspective, are provided in the HFC-6000 Product Line Requirements Specification, RS901-000-01. Detail level descriptions of the HFC-SBC06 and HFC-DPM06 are contained in the HFC-SBC06-DPM06 System Controller Module Detailed Design Specification, DS901-000-01. Additional C-Link design discussions are in Sections 6 and the compliance with interim staff guidance on communication issues is contained in Section 8.

[

]

6.2 *Input /Output Modules*

The HFC-6000 I/O modules provide signal-level interface to the equipment and devices which are being monitored or controlled. The major functions performed by the HFC-6000 I/O modules are:

- Measuring input signals or setting output signals
- Communication with HFC-SBC06 system controller through the ICL
- Self-diagnostic functions

[

]

Table 6-1 provides a list of the current HFC-6000 I/O module types and a description of the I/O channels for each module type. Some module types have a combination of input and output points.

Table 6-1 - List of HFC-6000 I/O Modules

Name	I/O Channels (Ports)
DO8J	8 channel digital relay output
DI16I	16 channel digital input
DC33	2 channel 120-vac digital output and 12 channel digital input
DC34	2 channel 125-vdc digital output and 12 channel digital input
AI16F	16 channel analog input
AO8F	8 channel analog output
AI8M	8 channel 100Ω RTD input
AI4K	4 channel pulse input

The overall architectural design of standard HFC-6000 I/O modules and its standard functions are provided by document MS901-000-02, "HFC-6000 I/O Module Design Specification." The design descriptions of the common software modules of I/O modules are described in document DS901-000-02, "HFC-6000 I/O Module Detailed Design Specification."

6.2.1 Relay Output Module

The HFC-DO8J assembly is an eight-channel relay digital output module. **[**

]

6.2.2 Digital Input Module

The HFC-DI16I assembly is a 16-channel digital input module. **[**

]

6.2.3 Digital Controller Module

The HFC-DC33 is a special purpose, multi-channel I/O buffer module designed for nuclear power plant applications. It is used by the HFC-6000 for control, interrogation, and monitoring of field devices. This buffer is specifically designed to meet the unique control requirements of a dual-coil Motor Operated Valve (MOV) starter. Typical applications include controlling dual coil motor starters while monitoring coil continuity, overloads and valve position.

[

]

6.2.4 Digital Control of Breakers Module

The HFC-DC34 is a multi-channel Input/Output (I/O) buffer printed circuit module (PCB). It is used for control, interrogation, and monitoring of field devices in a HFC-6000 control system. Typical applications include monitoring Electrically Operated Breakers (EOB) for overloads. This module is designed to provide the specific combination of digital I/O channels needed to control motor starters or switchgear field equipment.

[

]

6.2.5 Analog Input Module

The HFC-AI16F module operates as a standard AI module in a HFC-6000 control system. **[**

]

6.2.6 Analog Output Module

The HFC-AO8F module operates as the standard AO module in a HFC-6000 control system **[**

]

6.2.7 RTD Input Module

The HFC-AI8M Resistance Temperature Detector (RTD) printed circuit module (PCB) is an input-conditioning device for a HFC-6000 control system.**[**

]

6.2.8 Pulse Input Module

The HFC-AI4K module provides four input channels for processing pulse signals from field equipment**.[**

]

6.3 Communication Modules

In an HFC-6000 System, C-Link communication and ICL communication support are integrated in the system controller modules and I/O modules. Figure 6-5 depicts the configuration.**[**

]

The purpose of the C-link is to provide operational information/data from a controller in a division to other controllers in the same division on the C-Link and to also provide operational information/data to non-safety related equipment through one-way communication devices attached to the C-link.

The ICL links handle communication between the HFC-SBC06 system controller module and its I/O modules.

[

]

6.4 Power Supplies and Chassis

The HFC-6000 product line provides a rack-mounted power supply module with slots for separate power supplies. The rack-mounted power supply module can accommodate up to eight separate (four redundant) power supply assemblies, and each set of power supplies can be connected to a different power source. The power capacity of this arrangement is adequate to supply operating power for eight, or more, fully loaded HFC-6000 controller chassis.

Each HFC-6000 cabinet includes power supply modules in a separate power rack that provides redundant 24-vdc and 48-vdc power via separate backplane traces. Since the power supply modules are redundant, the loss of one module will not degrade functional operation of the I&C system as a whole.

There are two types of backplanes in the HFC-6000 product line: the HFC-BPC01-19 and the HFC-BPE01-19.

HFC-BPC01-19 is a controller chassis backplane for a 19-inch equipment cabinet. It offers two slots for HFC-SBC06 system controllers, one slot for an HFC-DPM06, and capacity for a maximum of 11 HFC-6000 I/O modules. The backplane can receive operating power from redundant power cables that attach to a connector on the back of the chassis. The system controller(s) plugged into this backplane communicates with I/O modules via redundant serial Intercommunication Link (ICL) traces on the backplane. Redundant ICL connectors on the rear of the backplane card enable connection of the ICL with an expansion card chassis.

HFC-BPE01-19 is an I/O expansion chassis backplane for a standard 19-inch equipment cabinet assembly. It provides slots for a maximum of 14 HFC-6000 I/O modules. The backplane can receive operating power from redundant power cables that attach to a connector on the back of the chassis. The ICL cables from a controller chassis mate with connectors on the back of the card, and ICL traces are routed to the connector for each card slot.

The structures of all HFC-6000 card chassis are designed to meet category 1 seismic requirements.

7 HFC Safety Platform Software Description

The software that will be utilized for safety related applications of the HFC-6000 is broken down into the following categories:

- Operating Software
- Application Software (Plant Specific)

Operating software consists of firmware programs that provide the generic operating capability of the HFC-6000 product line. This generic firmware is written in Assembly language stored in non-volatile memory and is not alterable by the end user. The Operating Software has been in use for a number of years and is commercially dedicated as discussed in Chapter 10 of this report. The operating software for the HFC-6000 is discussed in detail below.

Application software consists of plant specific programs that provide the unique functionality required for a safety related application. Application software is stored in non-volatile memory and cannot be altered while the controller is operating in the on-line mode. The Applications software is written in accordance with BTP 7-14 and this process is discussed in Chapter 10 of this report.

Application software is created or modified with the use of an off-line Engineering Workstation (EWS) in accordance with a pre-established software development processes. The new or modified software can only be installed in one controller of a redundant set at one time. This new or modified Application software meets the guidance provided in BTP 7-14. The controller has to be in the off-line mode for installation.

This section consists of the following platform Operating Software topics:

- Controller Software
- Inter-Communication (ICL) Software
- The Development and Maintenance tools
- Communication Link (C-Link) Software

7.1 Controller Software

7.1.1 HFC-SBC06 Controller

The HFC-SBC06 controller module has a Pentium system (SYS) processor and two 32-bit subordinate microprocessors, each of which has a separate independent firmware programs installed in its private memory array. **[**

]

7.1.1.1 The System (SYS) Processor

The SYS processor has access to the flash memory that consists of installed application programs. The application program consists of a sequential set of instructions that are executed by the Equation Interpreter software task. [

]

7.1.1.2 SYS Processor Software Architecture

The SYS Processor software design is composed of a generic real-time Operating System (OS) and a set of configurable tasks that will be run by that operating system. The OS is mainly a deterministic task scheduler; that executes the configured tasks one after another according to a task control block (TCB) list. **[**

]

7.2 Communication Software

[

]

7.2.1 Communication Link (C-Link) Software

The C-Link processor of the controller is responsible for regulating messages sent over the C-Link.[

]

7.2.1.1 Message Types

[

]

7.2.1.2 Token Passing Scheme

[

]

7.2.1.3 Synchronization on Dual-Channels

[

]

7.2.1.4 Deterministic Nature of the C-Link

[

]

7.2.2 ICL Communication Software

The ICL protocol is an HFC proprietary design used for general communications between a controller module and its configured I/O modules.

7.2.2.1 I/O module communication

[

]

7.2.2.1.1 Redundant Serial Link

Each HFC-6000 controller includes a hardware interface for one or more ICL channels to provide the hardware link with configured I/O modules. All I/O modules include a redundant ICL interface to permit communication with the redundant controllers. During initialization, one controller becomes Primary, and the other becomes Secondary.[

]

7.2.2.1.2 Polling Operation

The ICL employs a poll-response communication protocol to control message exchanges between the controller and its configured I/O modules.[

]

7.2.2.1.3 Secondary Loopback Test

The ICL protocol supports secondary loopback tests for HFC-6000 controllers operating in a redundant configuration. The purpose of these tests is to verify the functional operation of the secondary link with each station. [

] ***Figure 7-1 - Secondary Loop Back Test***

7.2.2.1.4 Secondary Polling Function

If an I/O module does not respond to a regular poll message, the Primary controller will request the Secondary controller to poll the same I/O module.[

]

7.2.2.1.5 ICL Software Architecture

The ICL Processor software is designed based on the operating system component common to the SYS processor on the HFC-SBC06 module and a set of configurable tasks that will be run by the operating system.
[

]

7.2.3 Input/Output Module Firmware

[

] The firmware code controls initialization, diagnostics, ICL communication, I/O scan, and data processing functions. The initialization, diagnostics and ICL communication functions are identical for all I/O module types. The characteristics of the I/O scan and data processing functions are uniquely configured for each module type, and the hardware initialization code is designed to operate with the specific hardware components that make up that module.

The program algorithm for each I/O module automatically accesses the initialization routine immediately following power-up. This routine performs hardware and firmware validation checks and then transfers control to the initialization routine. **[**

] Between successive I/O scan cycles, the main program runs diagnostic checks as a background operation.

All I/O modules are configured as slave stations on the ICL.**[**

] If the data is valid, the routine returns the message in the current response buffer, transfers any message data received from the controller to memory, and then returns control to the main program.

[

]

Hardware timer is used to control I/O scan intervals, communication response time out, etc. When a timer interrupt occurs, the configured Timer Interrupt Service Routine handles the interrupt.

7.3 The Development and Maintenance Tools

The firmware for the controllers and I/Os of HFC-6000 safety platform software is written in Intel Assembly language. It was developed under Intel x86 Cross Assembler, Linker and Locater on a Digital VAX computer. [

]

Table 7-1 illustrates the HFC-6000 software development and maintenance tools. The code management was implemented through Digital Code Management System (CMS) for original source codes and Microsoft SourceSafe and utility software is the current configuration management tool. All listed development tools from Intel x86 Assembler, Linker and Locator are Intel products and used by HFC over the past twenty plus years. [

]

Table 7-1 - HFC-6000 Safety software development and maintenance tools **[**

]
The "Generation" and "Class" are CMS and MMS library utilities to manage the version and change process of software files and configuration. HFC uses "Class" to define the product line or project and uses "Generation" to dedicate a version of software files for a particular "Class".

The detail description on Software Operation and Maintenance is specified in the Section 10.1.5.

These software development and maintenance tools are managed under the HFC Configuration Management Procedure, and any error produced would be discovered under the HFC Software V & V program. Furthermore, the accuracy of these tools is validated through the historical use by HFC and other industries and also by the HFC tool validation program.

8 Safety System Design Topics

8.1 Deterministic and Time Response

A nuclear power plant safety system that utilizes the HFC-6000 product line must provide deterministic performance with predictable operation and defined maximum response time characteristics. This means that the calculated cycle time will be repeatable each and every cycle. This section will address the internal operation of a single channel or division, and will describe aspects of deterministic performance as it relates to the external interfaces with other redundant elements. Each independent channel and division of an HFC safety system will include an independent external hardware watchdog timer to monitor the deterministic performance and initiate the appropriate fail-safe action if it is not reset within a predetermined interval.

This description will define all aspects of deterministic performance including:

- System Controller
- System Processor Characteristics
- ICL Processor Characteristics
- I/O Module Characteristics
- C-Link Processor

8.1.1 System Controller

An HFC safety system is configured with redundant System Controllers. With a redundant System Controller configuration, a second System Controller and a Dual Ported Memory Board are required. One controller is in the primary control mode and the other is in the secondary mode. The secondary mode controller monitors the primary System Controller and updates its database through the DPM. If the primary controller fails, the secondary controller takes over the operation.
[

]

8.1.2 SYS Processor Characteristics

The real-time operation of the SYS processor is controlled by a task scheduler.**[**

]

8.1.2.1 Applications Tasks

The SYS processor performs the safety-related applications processing as scheduled by the real time tasks.[

]

8.1.2.2 Supervisory Tasks

The SYS processor performs self-diagnostics as a lower priority task than the safety-related applications. Error conditions are logged for system status determination. [

]

8.1.3 ICL Processor Characteristics

The ICL processor operation differs depending on whether it is operating in the primary controller mode or in the secondary controller mode.

8.1.3.1 Operation in the Primary Controller

The ICL processor controls two serial interface channels for communication with I/O modules connected on the serial I/O link.[

]
Similar to the SYS processor, the ICL processor performs periodic diagnostics and passes the diagnostic status to the SYS processor.

8.1.3.2 Operation in the Secondary Controller

In the standard redundant configuration, the ICL processor on the primary controller performs the periodic I/O polling. The ICL processor on the secondary controller only performs I/O operations at the request of the primary ICL processor. There are two operations that the ICL processor on the secondary controller is permitted to perform:
[

] This capability provides a level of fault tolerance to the I/O process, while maintaining deterministic performance of I/O operations.

8.1.4 I/O Module Characteristics

An I/O module is an independent card in the chassis. Each I/O module has a microprocessor. All I/O modules use a common protocol for communication with the ICL processor of the controller.
[

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8.1.5 C-Link Processor Characteristics

The redundant C-Link communication design utilizes a token passing protocol for deterministic communication with other safety systems within its own division.
[

]

8.1.6 Deterministic Performance Conclusion

The HFC-6000 system is designed to have deterministic performance with a predetermined maximum response time to changing input signals and messages communicated locally and remotely. It is accomplished from the deterministic data scan scheme and fixed communication structure. The input signals are scanned by input modules in a fixed scan rate.[

]As noted above, the C-Link architecture is designed to be deterministic without handshaking or interrupts. The HFC-6000 communication scheme provides the deterministic characteristic to process the control signal from input device to output device.

8.2 Failure Mode Effects Analysis (FMEA)

The HFC-6000 System FMEA covers the existing system design for the HFC-6000 product line as described earlier in this report. The FMEA as presented in Tables A-1 through A-17 of the FMEA report, RR901-000-01-Rev C, was performed in accordance with EPRI TR-107330, Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants, Section 6.4.1, and the more detailed qualitative guidance in IEEE Std 352-1987, IEEE Guidance for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems. In general, the guidance and descriptions provided have been used in this analysis. These techniques included definition of system functional areas for the HFC-6000 operation, as listed in the FMEA Appendix. The postulated failure effect on each functional area was then analyzed, as summarized in Section 4.0 of the FMEA report.[

]
A summary of the impact on system performance is presented in Section 4.2 of the FMEA report. The HFC FMEA evaluated the effects of failures within HFC-6000 system components and the ensuing effect on system safety functional performance. The existing HFC-6000 System design provides confidence that all failure conditions are detectable or that, for certain failures, the HFC06000 System redundant components permit continued operation of critical system functions in the presence of automatic switchover.

The FMEA analysis was performed on the HFC-6000 system components and configuration as proposed in the system hardware descriptions in this qualification report. This includes the controller, the I/O modules, the C-Link communication network and the ICL communication network. The analyzed configuration simulates a single channel of a typical nuclear system installation for a safety channel implementation.

The objective of the FMEA report is to document the methodology and results of the failure modes analysis for the HFC-6000 platform. Attachment A of FMEA provides tables showing the postulated failure mode, the possible causes, the symptomatic effects, method of detection, the effect of the failure on the system and the method of remediation.

[

]

The HFC-6000 FMEA was used to identify postulated failure states for the HFC-6000 system. This analysis does not address failure modes associated with application of multiple PLC systems in redundant safety divisions. A typical plant design, since safety systems are always single-failure proof, provides for redundancy by implementing a three or four channels configuration. Although plant-specific mitigating design features are described for certain of the postulated failures, theses features would have to be verified during a plant-specific application and its resulting FMEA.

[

]

The results of the FMEA should be applied to each plant-specific safety system design to disclose any potential hazard that will require additional mitigation for that application.

8.3 Reliability and Availability

A reliability and availability analysis was performed on the HFC-6000 product line for use in nuclear safety-related applications. For purposes of the analysis the Test Specimen configured for qualification testing was used. This configuration includes all the typical modules of the HFC-6000 control system.**[**

]
The basic set of HFC-6000 I&C is composed of system controller modules, I/O modules, ICL link, C-Link and power supply modules. The system configuration required by Article 4.2.3.2, EPRI TR-107330 is used to perform the availability analysis.

Both EPRI TR-107330 and IEEE Std 352-1975 have been extensively used as guidelines in performing this reliability analysis. MIL-HDBK-217F was used for reliability prediction of individual parts that have been used to build HFC-6000 products. A software tool, RELEX software was used to perform the MIL-HDBK-217 Analysis on parts and assemblies of the HFC-6000 product line. RELEX software is one of the leading software tools for reliability and maintainability analysis. It provides software solutions for reliability predictions and MTBF calculations, which provide the basis for reliability evaluation and prediction.
[

]
Mean Time to Repair has a strong influence on the availability that the equipment can achieve, but it is only partially under the control of the manufacturer. The best the manufacturer can do is to make the equipment easy to diagnose and repair. The owner has the responsibility to aggressively monitor the equipment for failure and expeditiously replace any part that fails. The owner also has the responsibility to maintain the system according to HFC's maintenance manual and replace modules according to the recommended replacement schedule.

Each system can have a different configuration and architecture. The reliability of the overall system is highly influenced by the choice of configuration and architecture design. From the system design side, there are two ways to improve availability of overall system: one is to select high reliability parts and products for the product line design, and the other is to utilize

redundancy in system design and configuration. Availability is improved significantly when redundancy is applied. HFC-6000 products provide redundancy support at different levels of the system. They can be used to build safety related control system with different configurations. The owner's decision on selecting the system configuration will decide the final availability of the overall system.

8.4 Quality Assurance Programs

The HFC Quality Program provides the administrative measures and procedures necessary to assure that all HFC hardware and software products as well as its support services meet or exceed all applicable guidance and regulatory guidelines. This Quality Program complies with
:

- ANSI/ASME NQA-1&1a-1994; "Quality Assurance Requirements for Nuclear Facilities"
- ANSI/ASME NQA-1a-1995 Addenda
- 10 CFR 50 Appendix B; "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"
- ANSI/ISO/ASQ Q9001-2000, "Quality Management Systems - Requirements".

Software quality was verified per the guidance of ANS/IEEE Std 7-4.3.2-2003, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations which incorporates guidance from ASME NQA-2a-1990 Part 2.7.

The HFC software quality assurance plans follow the guidance of IEEE Std 730-1984, "IEEE Standard for Software Quality Assurance Plans" and IEEE Std 983-1986, "IEEE Guide for Software Quality Assurance Planning".

Measures to assure the quality management of the software life-cycle were patterned after those described in HICB BTP-14, "Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems". HFC-6000 Verification and Validation efforts follow those described by IEEE Std 1012, "IEEE Standard for Software and Verification and Validation Plans".

Pre-Developed Software quality was verified using the commercial software guidance of IEEE Std 7-4.3.2, EPRI TR-106439, "Guideline on Evaluation and Acceptance of Commercial Grade Equipment for Nuclear Safety Applications" and TR-107330, "Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety Related Applications in Nuclear Power Plants."

The HFC QA program assures that the HFC-6000 design meets the requirements of

- Criterion 1, "Quality Standards and Records",
- Criterion 21 "Protection System Reliability and Testability" of Appendix A and
- Appendix B of 10 CFR 50.

Furthermore, IEEE Std 603, which requires that the quality of components be achieved through the specification of requirements known to promote high quality, was adopted as the basis from which HFC developed its requirements for design, inspection and testing. HFC has assumed the responsibility, as an Appendix B vendor, to comply with the regulations of 10 CFR 21. All applicable defects of HFC-6000 components are part of the HFC Part 21 notification process.

The HFC QA Program covers the design, implementation and commissioning of the HFC-6000 system. Requirements of this program apply to all activities (systematic and planned actions) affecting the quality of products and services provided and performed by HFC. The essential prerequisites for an effective quality assurance program were all incorporated into the QA program.[

]

To assure that the QA Program was being rigorously adhered to the Programs mandated; an independent verification effort to assess compliance with the QA Program and to provide on-going assessment of the adequacy of the measures was undertaken to ensure technical correctness of the QA processes.

The HFC Quality Assurance Manager has the responsibility for establishing the Quality Assurance Program and verifying that activities affecting the quality of deliverables are performed in accordance with this program. The performance of the group, that the manager represents, is assessed independent from the costs and schedule impacts of the group's mandated quality assurance measures. By reporting directly to the President of HFC, the Quality Assurance Manager is afforded sufficient authority and organizational freedom, to identify quality problems; to initiate, recommend, or provide solutions to quality problems; and to verify implementation of solutions to quality problems. Per the HFC QA Program, all employees share the same responsibility and authority as the QA Manager to identify quality problems; to initiate

and provide solutions to quality problems; to verify implementation; and to resolve deficiencies that affect quality.

As a minimum, formal management review of the quality system is performed annually to ensure its continuing appropriateness and effectiveness in satisfying HFC's business policies and objectives. Records of the management review meeting and associated completed action items are maintained in accordance with documented procedures.

HFC has established and maintains documented procedures to ensure that applicable regulations, codes, standards, and customer requirements are translated into design documents, procedures, and/or instructions. These documents include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from defined requirements are controlled.

As noted earlier, organizational and technical interfaces between different design group disciplines are defined by the Project Quality Plan. All design information communicated between the respective disciplines necessary to ensure satisfaction of these interface requirements is documented and regularly reviewed.

The design control program is established and implemented to assure that the activities associated with the design of systems, components, structures, and equipment and modifications thereto, are executed in a planned, controlled, and orderly manner. The program includes provisions to control design inputs, processes, outputs, changes, interfaces, records, and organizational interfaces. Major elements of this program include the following measures:

- Design input requirements, relating to the HFC products, are established, documented and their selection reviewed and approved for adequacy.
- Design outputs are documented and expressed in terms that can be verified against design input requirements and validated.
- Individuals or groups other than those that performed the original design review output documents.
- Independent design reviews occur at prescribed stages within the design process. Participants at each design review include, when necessary, representatives of all functions concerned with the design stage being reviewed.
- Records of design reviews are maintained.

Design verification includes design reviews, alternate calculations, qualification tests or a combination of methods executed in accordance with approved procedures. Design verifications are performed in accordance with approved procedures, performed prior to release for procurement, manufacturing, or to another organization for use to ensure that the design output meets the design input requirements. Independent design validations ensure that developed products conform to the specified requirements.

Design Analyses are performed in a planned, controlled and documented manner. They are sufficiently detailed as to purpose, method, assumptions, design input, references and units.

Methods such as computer programs and calculations are described and controlled. Qualification testing demonstrates adequacy of performance under conditions that simulate the most adverse design conditions.

Design changes are subject to design control measures identical to those applied to the original design. Design documents, including revisions, are reviewed, approved, released, distributed, and controlled in accordance with prescribed procedures and/or instructions. The HFC Software Configuration Management Program provides a method to track all past, current and future software configurations. This is discussed in more detail in HFC SCM documents.

8.5 Regulations, Codes, Standards and Guidance for Digital System Implementation

8.5.1 General

Listed below are those regulatory documents, codes, standards, and regulatory commitments that are applicable to the design, documentation, review, procurement, manufacture, installation, testing, operation, modification and maintenance of digital systems and their components and constituent parts for implementation in operating nuclear power plants.

8.5.2 Compliance with Nuclear Regulatory Commission (NRC) Documents

RG 1.22 1972 "Periodic Testing System Actuation Functions"

The HFC-6000 platform conforms to this Regulatory Guide (RG). Design principles have been employed that facilitate periodic testing of the HFC system to verify its ability to perform protective initiation functions. The HFC system allows complete testing of its actuated devices in accordance with the RG. This testing can be done with the plant at power or shutdown. An additional level of HFC-6000 testing is provided by diagnostic testing. A plant specific implementation will provide further details regarding periodic testing.

RG 1.29 "Seismic Design Classification"

The HFC-6000 system is qualified as a safety related system. As such, it is designated as a Seismic Category I system. The system is qualified by type testing to the required OBE and SSE levels. This is discussed in detail in the seismic qualification report (Section 9).

RG 1.47 1973 "Bypassed and Inoperable Status Indications for Nuclear Power Plant Systems"

Bypass and inoperable status information will be provided on a plant-specific basis.

RG 1.53 2003 "Application of the Single Failure Criterion to Nuclear Power Plant Systems"

Single failures of the HFC-6000 system have been evaluated in the earlier discussed FMEA summary. That assessment led to the conclusion that the system will meet the single failure criterion of IEEE-603 upon a plant specific implementation in a redundant safety system. Due to plant specific system redundancies, a plant specific implementation will provide the required information.

RG 1.62 1973 "Manual Initiation of Protective Actions"

All HFC-6000 actuation functions can be initiated manually. Provisions for this are maintained at the system level. However, provision for component level manual actuations will also be retained through past control system designs. The manual initiation path remains a relatively simple design. Details regarding manual initiation designs should be reviewed during the plant specific design reviews.

RG 1.75 2005 "Physical Independence of Electrical Systems"

The design of the HFC-6000 system conforms to this RG. The field-implementation of the HFC-6000 (e.g., the connecting wires, cables, switches and relays) will also conform to the physical, mechanical and electrical separation standards provided by the guide. A plant specific implementation will provide further details regarding physical independence.

RG 1.89 1984 "Qualification for Class 1E Equipment for Nuclear Power Plants"

The HFC-6000 system has been tested to verify its conformance with this RG, RG 1.209 and IEEE Std 323. The environmental qualification tests employed both type-testing and analysis which were followed per the provisions of EPRI TR-107330. This is described in more detail in Section 9 of this report.

RG 1.97 Rev 4 2006 "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants"

The HFC-6000 controller and its I/O modules provide the flexibility and processing capability to accommodate a wide range of both analog and digital user instrumentation. The particular combination of instrumentation and controls that will be needed to detect and respond effectively to an accident condition will depend on the specific safety system being implemented. Consequently, this will be addressed on a project-by project basis.

RG 1.118 1995 "Periodic Testing of Electric Power and Protection Systems"

The HFC-6000 platform includes the following features built into the system hardware and software for direct verification of field equipment: **[**

]
Additional utilities for periodic testing of safety systems will be implemented as part of a specific application on a project-by-project basis. All such testing utilities will be designed in conformity with this RG, IEEE Std 338 and HICB-17 as discussed in the RG 1.22 discussion below.

RG 1.152 Rev 2 2006 "Criteria for Use of Computers in Safety Systems of Nuclear Power Plants"

The HFC-6000 system design follows the guidance of this RG by meeting the applicable provisions of IEEE-ANS-Std 7-4.3.2. The software for the HFC-6000 is segregated into both pre-developed and new (application) software. For the new safety related software, HFC has implemented acceptable methods employed for designing, verifying, validating and implementing software to be used in safety related systems. The HFC software quality plan is consistent with this RG, the IEEE Std and ASME NQA-2a; this plan addresses all of the runtime resident computer software. The verification and validation processes are in accordance with applicable guidance. Those processes provide adequate confidence that the safety requirements and the requirements defined at each phase of the development process are implemented. The Pre-Developed Software is qualified based on the provisions of Section 5.3.2 and Appendix D of the IEEE Std. This qualification was also developed per the guidance of EPRI TR-106439 and TR-107330. Section 10 of this report provides detailed information on the qualification of the pre-developed software and the newly developed software.

RG 1.153 1996 "Criteria for Safety Systems"

This RG endorses IEEE Std 603-1991. It establishes functional and design requirements for all aspects of safety related I&C systems. HFC has applied these requirements in the development of the HFC-6000 system. NUREG-0800, references this RG as necessary acceptance criteria. Details regarding compliance with IEEE Std 603 are discussed below.

RG 1.168 Revised 2004 "Verification, Validation, Reviews, and Audits for Digital Computer Software Used In Safety Systems of Nuclear Power Plants"

The HFC V&V process addresses phases of the software life cycle as provided in BTP 7-14 up through the testing and installation of plant specific applications. The life cycle phases for plant operation will be provided during actual plant specific implementation. HFC has documented an acceptable software development methodology and follows this methodology consistently in developing any safety related new software.
[

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RG 1.169	1997	“Configuration Management Plans for Digital Computer Software Used In Safety Systems of Nuclear Power Plants”

The HFC’s Software Configuration Management, SCM, Plan documents the requirements, methods and procedures it will use to assure the continued quality of the HFC-6000 platform’s software including both the pre-developed and new software. This plan was formulated based upon the guidance provided by IEEE Std 828 and 1042. The intent of the latter document is to describe an acceptable SCM plan and its implementation. The HFC SCM is applied to all HFC-6000 software and associated documentation including the tools that are used during the design and implementation process.

Guidance and regulations require that the HF-6000 SCM activity be extended to encompass plant specific applications. In order to control and facilitate development of plant specific application efforts, as the HFC platform is fitted to the needs of a specific plant, the SCM will be extended to plant specific configuration activities as described in the HFC’s platform’s life cycle process. The plant specific effort will document the configuration baselines. Any changes to the HFC-6000 digital platform caused by the specific application will be subject to HFC’s SCM stringent change control process.

RG 1.170	1997	“Software Test Documentation for Digital Computer Software Used In Safety Systems of Nuclear Power Plants”

The HFC-6000 test plan includes the following items: [

]
Additional details are provided in Section 10 of this TR.

RG 1.171 1997 "Software Unit Testing for Digital Computer Software Used In Safety Systems of Nuclear Power Plants"

HFC's software test methods and procedures, tests conform to the guidance contained in this RG. The tests were performed and the results met all test objectives within the pre-established criteria for the new software. The software performed as specified by the design documents, the interfaces executed as anticipated.

Additional details are provided in Section 10 of this TR.

RG 1.172 1997 "Software Requirements Specifications for Digital Computer Software Used In Safety Systems of Nuclear Power Plants"

The SRS has been written to follow both the guidance contained in this RG and in the endorsed IEEE Std 830. HFC has developed its SRS to address the criteria and guidance of Section 2 of the RG.[

]An SRS change control program has been implemented by HFC as part of the overall HFC-6000 configuration management program.

The overall SRS conforms to guidance and criteria of the Regulatory Guide and IEEE Std 830. The HFC-6000 SRS are consistent with GDC 1 and the Appendix B criteria for quality assurance programs as they apply to the development of software requirements specifications.

RG 1.173 1997 "Development Software Life Cycle Processes for Digital Computer Software Used In Safety Systems of Nuclear Power Plants"

The RG, BTP 7-14 and the IEEE Std 1074 provide a structured approach for the development of a software life cycle program consistent with regulatory guidance. HFC recognizes that, for development and maintenance of high functional reliability and high quality safety software, there has to be an orderly structure to the entire software design and implementation process. HFC's Software Life Cycle addresses the issues and concerns of the standard although its

organization differs. The Software Life Cycle process that HFC used successfully provided the necessary framework for the HFC-6000 software project so that activities could be mapped. With this mapping, a concurrent execution of related activities can occur and staged checkpoints are available at which characteristics of certain activities can be verified.

HFC's life cycle plan insures that all necessary development and V&V activities are performed and that the required inputs, outputs, activities, pre-conditions and post-conditions are either described or have been accounted for in the HFC-6000 platform life cycle model. While the RG and IEEE Std do not specify the completion of specific documents, SRP BTP 7-14 places a great degree of emphasis on the output documents as a manner to judge successful completion of a life cycle process. HFC has completed the non-plant specific output documents and provided these to the NRC

RG 1.180 Rev 1 2003 "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems"

The HFC-6000 platform has been tested and evaluated for EMI/RFI based on guidance in this RG and in the EPRI TR on EMC. Details regarding this qualification are discussed in Section 9 of this report.

RG 1.204 2008 Lightning Protection

Plant specific applications should follow the guidance presented in RG 1.204.

RG 1.206 2007 Combined License Applications-summary of guides etc.

HFC has reviewed this RG and noted the guidance and requirements standards that are applicable for the qualification of a safety related digital platform. This report reflects this array of standards and how they relate to the HFC-6000 overall qualification effort.

RG 1.209 2007 Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants

The environmental qualification phase for the HFC-6000 is discussed in more detail in Section 9 of this report and the supplement documents.

NUREG-CR-6303 "Method for Performing Diversity and Defense-in-Depth Analyses of Reactor Protection Systems"

HFC has provided a discussion of its generic concept for meeting Diversity and Defense-in-Depth guidelines as provided in BTP 7-19. This generic discussion is in Section 8-6 of this report. Details regarding this concept will be provided during plant specific implementations.

NUREG-0737 "Requirements for Emergency Response Capability"

The HFC-6000 system will follow the guidance provided by this NUREG. Plant specific implementation descriptions will provide these details.

NUREG-0800 "Standard Review Plan (SRP Chapter 7)"Revised some areas

The design of the HFC-6000 system follows the guidance presented in Chapter 7 of this NUREG that involve I&C digital safety system design. The design and qualification information for both hardware and software is presented in Sections 6 through 10 of this report. Additional details can be found in supporting documentation provided to the NRC and within the HFC library.

NUREG-0800 BTP 7-11 "Guidance for Application and Qualification of Isolation Devices"

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NUREG-0800 BTP 7-14 "Branch Technical Position: Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems"

The HFC software development life cycle considers the guidance provided with this BTP. The HFC new safety related software is developed using software development plans that provide for varied life cycle phases. Management, implementation and resource planning procedures were established for new software. The functional characteristics and software development characteristics noted in the BTP were established and met by the HFC process.

Additional details are provided in Section 10 of this TR.

NUREG-0800 BTP 7-17 "Guidance on Self-Test and Surveillance Test Provisions"

The HFC-6000 is designed for in-service testability of hardware and software components. A balance has been made between providing the self-test capabilities and the added complexity that they introduce. Per the previously described FMEA, HFC surveillance testing and automatic self-testing measures provide adequate mechanisms to detect certain failures.

NUREG-0800 BTP 7-19 "Guidance for Evaluation of Defense-in-Depth and Diversity in Digital-Based I&C Systems"

HFC has provided a generic discussion for meeting Diversity and Defense-in-Depth guidelines in Section 8-6. Detail configurations regarding this concept will be provided during a plant specific implementation.

NUREG-0800 BTP 7-21 "Guidance on Digital Computer Real-Time Performance"

HFC-6000 system timing requirements are such that their allocation to events within a plant's safety analyses should support the timing requirements for each event. This is evident with the use of either small scale or large scale digital system modifications using the HFC-6000. A time analysis for each event will be part of the plant specific implementation process and during the plant specific implementation phase, an acceptable real-time performance will be demonstrated.

8.5.3 Institute of Electrical and Electronic Engineers (IEEE) Standards

IEEE Std 7-4.3.2-2003 "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations"

IEEE 7-4.3.2-2003 provides high-level design criteria for digital computers that includes discussions on qualification of digital systems related to software. The HFC-6000 system design follows the guidance of this RG by meeting the provisions of IEEE-ANS-Std 7-4.3.2. The software for the HFC-6000 is segregated into both pre-developed and new software. For the new safety related software, HFC has described methods employed for designing, verifying, validating and implementing software to be used in safety related systems. The HFC software quality plan is consistent with ASME NQA-2a; this plan addresses all of the runtime resident computer software. The verification and validation processes are in accordance with all applicable guidance. Those processes provide adequate confidence that the safety requirements and the requirements defined at each phase of the development process are implemented. The pre-developed software is qualified based on the provisions of Section 5.3.2 and Appendix D of the IEEE Std standard. Qualification factors were developed per the guidance of EPRI's TR-106439 and TR-107330. The discussion in Section 10 of this report provides the qualification criteria taken from both of these reports and provides a high-level discussion comparing the specific design criteria to the HFC-6000 System design. There is also a reference to other Sections of this report where additional discussion can be found. Other guides and standards are referenced for applicability.

Additional design and licensing criteria discussed in NUREG-0800, "Standard Review Plan (SRP Chapter 7), was also used in the digital platform design. The design of the HFC-6000 system followed guidance presented in Chapter 7 of this NUREG that involve I&C digital safety system design. The design and qualification information for both hardware and software is presented in Sections 6 through 10 of this report. Additional details can be found in supporting documentation within the HFC library of documents. Industry guidance contained in EPRI TR-107330, "Generic Requirements Specifications for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants", December 1996 was used for setting the qualification criteria for the HFC-6000. Per this standard, a matrix was developed that demonstrates that the HFC-6000 system design process complies with the individual specifications of this guidance document.
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If the plant-specific system requirements identify a system preferred failure mode, failures of the HFC-6000 platform would not preclude the safety system from being placed in that mode.
HFC has provided a design assuring that test and calibration functions will not adversely affect the ability of the controller to perform its safety function.

The HFC-6000 platform incorporates self-diagnostics functions scheduled for every scan cycle to detect and report system faults and failures in a timely manner. These self-diagnostic functions do not adversely affect the ability of the HFC-6000 platform to perform its designated safety function, or cause any spurious actuations of the safety function.

IEEE Std 323-2003 Revised "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

The HFC-6000 was environmentally qualified using the guidance contained in EPRI TR-107330, RG 1.209 and this IEEE Std. This qualification effort is discussed in more detail within Section 9 of this report and supplemental documentation.

IEEE Std 344-1987 Revised "IEEE Standard for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations"

The HFC-6000 system meets the seismic qualification criteria for safety related equipment. This is discussed in more detail in Section 9 of this report. The seismic test criteria represented the OBEs and SSEs discussed in EPRI TR-107330.

IEEE Std 352-1987 "IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems

The reliability and FMEA of the HFC-6000 system has been analyzed and the results are presented in Section 8 of this report. These results show that this system is highly reliable and acceptable for use in safety related systems. The results of the FMEA show that the HFC-6000

meets acceptance criteria. A plant specific application will provide system reliability and additional FMEA details.

IEEE Std 379-2000 "IEEE Standard Application of Single Failure Criterion to Nuclear Power Generating Station Class 1E Systems"

The HFC-6000 system meets the single failure requirements of IEEE Std 603 in addition to the guidance contained in this IEEE. However, this is only when the system is installed in a redundant design. When this occurs, considering the single failure criterion in association with all potential HFC-6000 applications, all requisite safety functions can be maintained without impeding the execution of other safety functions. This is valid for all functions where redundancy is maintained. The actual design and review of the HFC-6000 system in meeting the single failure criterion should occur during the plant-specific implementation review.

IEEE Std 384-1977 "Criteria for Independence of Class 1E Equipment and Circuits"

The review to meet the guidance of the IEEE Std should occur during the plant-specific implementation phase.**[**

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IEEE Std 472-1974 "Guide for Surge Withstand Capability Tests"

Surge withstand testing was performed on the HFC-6000 system in accordance with the guidance presented in EPRI TR-107330. Details regarding the test results are presented in Section 9 of this report.

IEEE Std 577-1976 "IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations

See the response to IEEE Std 352-1987.

IEEE Std 603-1991 "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations"

This IEEE Std establishes functional and design requirements for all aspects of safety related I&C systems. HFC has applied these requirements in the development and qualification of the HFC-6000 system. NUREG-0800 references this IEEE Std as necessary acceptance criteria. RG 1.152, "Criteria for Programmable Digital Computer System Software in Safety-Related Systems of Nuclear Power Plants" provides software guidance that supplements this IEEE Std. RG 1.153"Criteria for Safety Systems" endorses IEEE Std 603.

Additional design and licensing criteria discussed in NUREG-0800, "Standard Review Plan (SRP Chapter 7), were also used in the digital platform design. The design of the HFC-6000

system followed guidance presented in Chapter 7 of this NUREG involving I&C digital safety system design. The design and qualification information for both hardware and software is presented in Sections 6 through 10 of this report. Additional details can be found in supporting documentation within the HFC library. Industry guidance contained in EPRI TR-107330, "Generic Requirements Specifications for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants, December 1996" was used for setting up the qualification criteria for the HFC-6000 digital platform. Per this standard, a matrix was developed that demonstrates that the HFC-6000 system design complies with the individual specifications of this guidance document. Individual IEEE Std 603 safety system criteria are discussed below.

Single-Failure Criterion:

The results of the FMEA report show that there are no undetectable failures that affect any HFC-6000 safety function. While the HFC-6000 has significant redundancy there are certain single failures that will defeat the operational capability of the digital platform. However, plant specific applications will implement the HFC-6000 in redundant systems such that the Single Failure Criterion will be met.

Completion of Protective Action**:**
The completion of the protective action review should be carried out during the plant specific implementation phase when the channel outputs are distributed to the corresponding logic.

Quality:
The HFC-6000 hardware conforms to the quality assurance provisions of 10 CFR Part 50 Appendix B as well as NQA1-1989. The software quality requirements of IEEE Std 7-4.3.2 are met by the HFC software quality program which is implemented in two separate sections. The first section is the pre-developed software whose quality is assured through the HFC pre-developed software program. This program is discussed in Section 10 of this report. This program consists of a large operational data base accrued since 1990; a reverse-engineered review process to determine software quality; and an application of current quality guidance. The second section is the new software (application specific software) which is developed under a program that meets current requirements and guidance.

Equipment Qualification:
The HFC-6000 equipment has been qualified in accordance with the guidance contained in EPRI TR-107330, IEEE Std 323-1987/2003, IEEE 344-1987, RG 1.180 Rev 1 and EPRI TR-102323-R1. RG 1.180 Rev 1 and EPRI TR-102323-R1 were used as guidance for EMC qualification. This is discussed in detail in Section 9 of this report.

System Integrity:
The HFC-6000 system design includes the qualification of equipment for the condition that should be specified in a plant-specific design basis. This is assured by the conservative design of the HFC-6000 as verified during the equipment qualification testing as discussed in Section 9 of this TR. However, the plant-specific boundaries would need to be affirmed before actual

implementation could proceed. Another integrity concern is the timing for signal processing. The HFC individual controller timing has been verified but would need to be bounded by plant specific analyses for each postulated event.

Independence:
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Capability for Test and Calibration:
The HFC-6000 system is designed to meet the guidance of RG 1.22, RG 1.118, and IEEE Std 338-1987. The extent of the inherent test and calibration features including the on-line testing capability provide assurance that the single failure criterion is met and automatic operability is confirmed. Data errors and computer lockup are detected by plant specific and diagnostic test provisions. Disconnecting wires, installing jumpers or other similar modifications are not necessary to perform the requisite testing.

Information Displays:
There are only operability lights associated with the HFC-6000 system. There is no data information displays associated with the HFC-6000 system.

Control of Access:
The HFC-6000 has several design features to provide means to control the physical assess including access to test points for verifying and changing. Plant specific implementation will provide additional details for safety system doors and control of access to rooms and equipment.

Repair:
The HFC-6000 has on-line diagnostics to aid in troubleshooting as well as periodic on-line/off-line surveillance procedures such as calibrations and functional testing. With modular components, repairs are done in a rapid fashion.

Identification:
The identification of hardware components is controlled by HFC with its numbering system and record keeping capabilities. This is part of the HFC Configuration Management Plan. Coding of cabinets and cabling is a plant-specific item.

Auxiliary Features:
Not applicable for this Topical Report.

Multi-unit Stations:
Not applicable for this Topical Report.

Human Factor Considerations:
Equipment performance indicators and calibration processes are designed to conform to current human factor criteria. Additional human factor considerations will be coordinated and consistent with a licensee's commitments as documented in Chapter 18 of the UFSAR. This will be affirmed during the plant specific implementation.

Reliability:
Reliability and Quality of the HFC-6000 system is discussed in several sections of the TR. Redundancy, diversity and testability which adds to reliability will be addressed during the plant specific implementation phase.

Automatic Control:
The HFC-6000 design meets this requirement by providing the capability to automatically actuate and control protective actions. The actual implementation will occur during the plant specific implementation phase.

Manual Control:
The HFC-6000 design meets this requirement by providing the capability to manually actuate and control protective actions. The actual manual implementation design will occur during the plant specific implementation phase.

Interaction Between the Sense and Command Features and Other Systems:
[

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Deviation of System Inputs:
The deviation of system inputs is part of the plant specific design.

Operating and Maintenance Bypass:
Operating and Maintenance Bypass is part of the plant specific design.

Setpoints:
The HFC-6000 system is designed such that the setpoints for nuclear plants can be maintained considering anticipated operating transient and postulated accident conditions. Measurement uncertainties will be considered and factored into a plant's setpoint methodology. The actual plant setpoint methodology will be provided during the plant specific implementation phase.

IEEE Std 730-1989 "Software Quality Assurance Plans"

The HFC-6000 system quality assurance plans conform to the guidance of this Std. A discussion of the QA process is presented in Section 8 of this report. Supporting information is provided in HFC Quality Process Procedures and HFC Quality Plans. HFC's software quality assurance plan is compliant with this standard as well as 10 CFR Part 50 Appendix B.

IEEE Std 828-1990 "IEEE Standard for Software Configuration Management Plans (ANSI)

The software configuration management plans for HFC-6000 are discussed in the response to RG 1.169 above.

IEEE Std 829-1983 "IEEE Standard for Software Test Documentation"

See the RG 1.170 discussion above.

IEEE Std 830-1984 "IEEE Standard Guide for Software Requirements Specification"

See the RG 1.172 discussion above.

IEEE Std 1008-1987 "IEEE Standard for Software Unit Testing"

See the RG 1.171 discussion above.

IEEE Std 1012-1998 "IEEE Standard for Software Verification and Validation Plans"

The HFC-6000 system verification and validation plans conform to this standard as described in the HFC software design descriptions and as noted in the RG 1.168 discussion above. This is applicable for all new software including all application software.

IEEE Std 1016-1987 "Recommended Practice for Software Design Description"

The HFC software design (both new and pre-developed software) offers the necessary information content and organization for a software design description that follows the guidance of both IEEE Stds 1016 and 1016.1. HFC recognized early on that a software design that was easily reviewed and understood by all interested parties would facilitate the acceptance of the system by designers, regulators and end-users alike. The resulting HFC-6000 Software Design Description is extremely "viewable" with descriptions of all categories of component software including clear descriptions of its purpose and discussions of its other salient attributes.

IEEE Std 1028-1988 "Standard for Software Reviews and Audits"

HFC complies with this Std. The HFC-6000 Quality Assurance Program assures that the requisite software reviews and audits are performed.

IEEE Std 1042 "IEEE Guide to Software Configuration Management"

The Software Configuration Management program for the HFC-6000 is discussed later in this report (Section 10) and also addressed in the RG 1.169 discussion above.

IEEE Std 1074-1995 "IEEE Standard for Developing Software Life Cycle Processes"

A life cycle is established for the design of any new software for the HFC-6000 system. This includes all application software. See the RG 1.173 discussion above and also the discussion on this topic in Section 10 of this TR.

IEEE Std 1228-1994 "IEEE Standard for Software Safety Plans"

The HFC-6000 system design includes the aspects of software safety management, software safety analyses, and post development which include training, installation, startup and transition, operations support, monitoring maintenance, and retirement. The HFC organization, schedule, resources, responsibilities, tools, techniques and methodologies used in the development of the safety related software were included in these aspects. As part of the software development process, an analysis was continually performed on the requirements, preparation, designing, coding and testing. Training, monitoring, maintenance, event analyses and retirement are necessary issues that will be addressed during plant specific implementation.

IEEE Std C37.90.1-1989 "IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI)"

Surge withstand capability was part of the electrical qualification tests for the HFC-6000 system. This is discussed in detail in the test reports and also in Section 9 of this report as well as supplemental documentation.

8.5.4 Other Documents

ISA S67-06-1984 "Response Time Testing on Nuclear Safety-Related Instrumentation Channels"

The response time of the HFC-6000 system has been verified to be within acceptable limits for a generic set of safety-related plant specific applications. Of course, for each plant specific application this response time will be re-verified during both factory and site acceptance testing.

ISA S67-04 Part I-1994 "Setpoints for the Nuclear Safety-Related Instrumentation"

The HFC-6000 system is designed such that the setpoints for nuclear plants can be maintained considering anticipated operating transient and postulated accident conditions. Measurement uncertainties will be considered and easily factored into a plant's setpoint methodology. The actual setpoint methodology will be provided during a plant specific implementation.

MIL-STD-461C "Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility"

The HFC-6000 system was tested for EMI/RFI in accordance with RG 1.180 Rev. 1 and EPRI-TR102323-R1. This testing and the test results demonstrated that per this standard, the HFC-

6000 is qualified for safety related applications. Testing details and results are provided in Section 9 of this report.

MIL-STD-462D-461E "Measurement of Electromagnetic Interference Characteristics"

The HFC-6000 system was tested for EMI/RFI in accordance with RG 1.180 Rev. 1 and EPRI-TR102323-R1. This testing and the test results show that it is qualified for safety related applications. Test procedures were established that follow the guidance of this MIL-STD. Testing details are provided in Section 9 of this report.

ASME NQA-1/NQA-2 "QA of Design Software"

The HFC quality assurance processes follow the guidance presented in these ASME standards and also meet the requirements of 10 CFR 50 Appendix B. Section 8 of this report provides a summary of the quality assurance process for the HFC-6000 system. Additional details are provided in HFC supporting documents.

EPRI TR-102323-R1 "Guidelines for Electromagnetic Interference Testing in Power Plants, April 30, 1996"

The HFC-6000 system was tested for EMI/RFI in accordance with EPRI-TR102323-R1. The results demonstrate that the HFC-6000 is qualified for safety related applications. EMI/RFI testing and test results can be found in Section 9 of this report.

EPRI TR-102348 "Guideline on Licensing Digital Upgrades, December 1993"

The applicable portions of this EPRI document were followed during the finalization of the design process of the HFC-6000 system. A significant portion of the document's guidance concerns plant specific concerns. Therefore, guidance in this area will be applied and conformed to during plant specific applications.

EPRI TR-103291 "Handbook of Verification and Validation for Digital Systems, Vol. 1: Summary, Vol. 2: Case Histories, Vol. 3: Topical Reviews, December 1994"

The verification and validation process used for the new software followed the guidance contained in IEEE Std 1012 and IEEE-ANS Std 7-4.3.2. This EPRI document was used to the extent necessary to reflect and apply the IEEE Std guidance and for additional knowledge and lessons learned.

EPRI-TR 106439 "Guidelines on evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications"

The HFC-6000 digital platform operational system uses commercial grade software that is designated in this report as pre-developed or legacy software. To ensure a level of adequacy for

this software commensurate with 10 CFR Part 50 Appendix B, the guidance provided in this TR was used extensively by HFC. The layered approach as illustrated in Figure 10-2 of the TR was used by HFC as the process for dedication of the HFC-6000 pre-developed software (PDS). Details regarding this process are discussed in Section 10 of this report, supporting documents provided to the NRC and in the library of HFC supporting documentation.

EPRI TR-107330	"Generic Requirements Specifications for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants, December 1996"

This EPRI TR provides generic specifications and requirements for qualifying commercially available PLCs for application in safety-related I&C systems at nuclear power plants. HFC used these generic specifications and requirements to qualify the HFC-6000 digital platform. These specifications are suitable for evaluating a digital platform like the HFC-6000, establishing a suitable qualification test program, and confirming that the quality assurance program is adequate for safety-related applications. The specifications include requirements for detailed design characteristics, quality assurance measures, documentation to support this qualification and the documentation to support plant specific implementation. Per this standard, a matrix was developed that demonstrates that the HFC-6000 system design complies with the individual specifications of this guidance document.

8.5.5 CFR and General Design Criteria (GDC)

a) GDC 1 - Quality Standards And Records (Category A)

The HFC-6000 QA procedures and record-keeping both conform to this requirement. Details are provided in Section 8 of this report and HFC supporting documentation.

b) GDC 2 - Design Bases For Protection Against Natural Phenomena (Category A)

The HFC-6000 system has been tested and found to conform to the requisite seismic design criteria. Details are provided in Section 9 of this report.

c) GDC 4 - Environmental And Missile Design Bases

The design basis for this requirement has been met and proven via qualification testing of the HFC- 6000 system. Details are provided in Section 9 of this report and HFC supporting documentation. Plant specific implementation will provide further information and should be reviewed at that time.

d) GDC 13 - Instrumentation And Control

The HFC-6000 is designed and tested to this requirement.

e) GDC 19 - Control Room

The control room requirements of this GDC are supported by the HFC-6000 design. Actual plant specific implementation will provide the control room design details. The requirements for an auxiliary shutdown location will be discussed during a plant specific implementation.

f) GDC 20 - Protection System Functions

The HFC-6000 has been designed for automatic initiation capabilities such that fuel design limits should not be exceeded for both transients and accidents. The requirements of this GDC are met by the margins included in the design and will be verified by proof testing. Actual plant specific implementation will provide the design details for this area.

g) GDC 21 - Protection System Reliability And Testability

The reliability and testability of the HFC-6000 digital platform meets the requirements of this GDC and is discussed in more detail in later sections of this TR.

h) GDC 22 - Protection System Independence

Protection system independence for the HFC-6000 based safety systems meets the requirements of this GDC.**[**

]This is discussed in more detail in Section 8.9 of this TR. Actual plant specific implementation will provide a plant-wide system level independence design that should be reviewed at that time.

i) GDC 23 - Protection System Failure Modes

HFC-6000 plant specific protection systems are designed (and verified) to fail to a fail-safe or acceptable state. For the Reactor Trip System for a plant-specific design, the loss of power will cause a reactor trip and for the Engineered Safety Features, the loss of power will cause the system to fail as is. A plant specific review is necessary to provide the determination of this feature at the system level.

j) GDC 24 - Separation of Protection And Control Systems

The HFC-6000 system design ensures that there is adequate separation of protection and control systems per this criterion. The HFC-6000 digital platform has connections to non-safety related equipment via the C-Link.**[**

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k) GDC 25 - Protection System Requirements for Reactivity Control Malfunctions

The HFC-6000 reactivity control systems will meet the requirements of this GDC. The review for this criterion is part of the plant specific implementation review.

l) GDC 29 - Protection Against Anticipated Operational Occurrences

HFC-6000 based protection and reactivity control systems will continue to meet the requirements of this GDC. Failure to accomplish the safety function has been determined to be unlikely. However, details are part of the plant specific implementation review.

m) GDC 37 - Testing of Emergency Core Cooling System

ESFAS HFC-6000 system applications will support this requirement with its configurations for periodic and functional testing. However, details are part of the plant specific implementation review.

n) GDC 40 - Testing of Containment Heat Removal System

o) GDC 43 - Testing of Containment Atmosphere Cleanup Systems

p) GDC 46 - Testing of Cooling Water System

q) GDC 54 - Systems Penetrating Containment

The above four GDC's are supported by the HFC-6000 system design when it is used in plant specific applications as called for by the individual criterion. However, details are part of the plant specific implementation review.

r) 10 CFR Part 50, Appendix B

All activities affecting the safety related functions of the HFC-6000 system meet the requirements of this Appendix and have been audited by a NUPIC member. The requirements of Appendix B are rigorously adhered to during the design control process, purchasing, fabricating, handling, shipping, storing, building, inspecting, testing, operating, maintaining, repairing and modifying of the HFC-6000 system. Quality assurance for the HFC-6000 system consists of the proper planned and systematic actions necessary to provide adequate confidence that that the HFC-6000 system will perform as required. Additional details regarding quality assurance activities for the HFC-6000 system are discussed in this section and are available for staff review and audit. Supplemental QA documentation contains further information.

s) 10 CFR Part 21

HFC, as the manufacturer for the HFC-6000 system, is responsible for adhering to requirements of Part 21.

t) 10 CFR Part 50.36

The HFC-6000 design will be able to maintain plant specific required limiting safety system settings. The HFC-6000 system setpoint methodology will readily replace existing analog system

setpoint methodologies with an accuracy and drift control rate superior to that previously reported with analog systems. This will be demonstrated during a plant specific implementation phase.

u) 10 CFR Part 50.49

The HFC-6000 is environmentally qualified for a mild environment in accordance with the guidance of IEEE Std 323 and RG 1.209. The qualification process is described in more detail in association with the discussion of the system's compliance with the qualification criteria presented in EPRI TR-107330. This discussion can be found in Section 9 of this report.

v) 10 CFR Part 50.62

This requirement is only relevant upon a plant specific implementation of the HFC-6000.

8.6 Defense-in-Depth and Diversity Evaluation Process

8.6.1 <u>NRC Position 1</u>

The applicant/licensee should assess the defense-in-depth and diversity of the proposed instrumentation and control system to demonstrate that vulnerabilities to common-mode failure have been adequately addressed.

8.6.1.1 Compliance to Position 1

A plant specific diversity and defense-in depth analysis will be performed utilizing the guidelines provided in NUREG/CR 6303, "Method for Performing Diversity and Defense-in-Depth Analyses of Reactor Protection Systems, "December 1994. In addition, newly available guidance in the Draft Interim Staff Position on D3 will be used during a plant specific implementation.

The analysis will demonstrate that diverse plant equipment and operator action can be utilized to cope with the plant's design basis anticipated operational occurrences concurrent with a common-mode failure in the HFC-6000 software-based equipment, such that the acceptance criteria stated in BTP 7-19 will be met. The defense-in-depth and diversity analysis will utilize best-estimate analytical methods and realistic assumptions, including crediting operator action where adequate displays and controls remain that are not affected by the common-mode failure and sufficient time exists to perform the operator action.

8.6.2 <u>NRC Position 2</u>

In performing the assessment, the vendor or applicant/licensee shall analyze each postulated common-mode failure for each event that is evaluated in the accident analysis section of the

safety analysis report (SAR) using best-estimate methods. The vendor or applicant/licensee shall demonstrate adequate diversity within the design for each of these events.

8.6.2.1 Compliance to Position 2

To simplify the defense-in-depth and diversity analysis, postulated common-mode failures of the software-based HFC-6000 equipment will be assumed to occur in such a manner that safety functions performed in this equipment will be disabled. The defense-in-depth and diversity analysis will then assume that the remaining plant instrumentation and control systems that do not utilize the HFC-6000 software-based equipment are available to be utilized to cope with the plant's design basis anticipated operational occurrences. This analysis will be performed on a plant specific base at a later date.

8.6.3 NRC Position 3

If a postulated common-mode failure could disable a safety function, then a diverse means, with a documented basis that the diverse means is unlikely to be subject to the same common-mode failure, should be required to perform either the same function or a different function. The diverse or different function may be performed by a non-safety system if the system is of sufficient quality to perform the necessary function under the associated event conditions.

8.6.3.1 Compliance to Position 3

The defense in depth and diversity analysis will consider each plant specific design basis anticipated operational occurrence that is evaluated in the plant's UFSAR. For each anticipated operational occurrence, a postulated common-mode failure in the software-based HFC equipment will be assumed in such a manner that the safety functions performed by the equipment are disabled. The analysis will then utilize the remaining diverse plant instrumentation and control systems and credit operator actions that are based on displays, indication, and alarms that are not affected by the common mode failure. The credit for operator action will utilize realistic assumptions for the time required to diagnose the plant transient and perform the required actions. The HFC-6000 safety system will be configured to enhance the plant's defense- in depth and diversity. Specific design techniques that will be utilized are described below.

8.6.4 Critical Analog Signals

Critical analog signals are defined as those signals that are utilized as input signals to the HFC-6000 safety system and that are also required to be utilized for indicator and/or control functions that support the defense-in depth and diversity analysis. For these signals, a separate analog signal(s) will be developed prior to the utilization of the signal in the HFC-6000 safety system as shown in the example in Figure 8-1 below. The separate analog signal will be isolated with a class 1E qualified isolator and sent to indicators and/or control system outside the safety channel.

In the event that only an indication is required to support an operator action, the diverse control system or operator action based on the control device could be credited in the defense-in-depth and diversity analysis to assist in coping with the anticipated operation occurrence.
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Figure 8-1 - Configuration for Critical Analog Signals

8.6.5 Critical Manual Signals

Critical manual signals are defined as manual control signals that are utilized to initiate a safety system function or to control a safety system component in the diversity and defense-in-depth analysis. These manual control inputs are typically system-level manual actuations of reactor trip or manual actuation of a specific engineered safety feature. These critical manual signals will be implemented in a manner that assures that they are independent of the HFC-6000 software-based safety functions.

8.6.6 Implementation of Critical Manual Signals

For reactor trip, the manual actuation signal will be implemented downstream of the HFC-6000 software-based automatic reactor trip functions. For engineered safety features actuation, the manual actuation will be implemented downstream of the automatic software-based engineered safety features action output.

8.6.7 Conclusion

The HFC concept for safety is based upon a simple system approach. Quality is designed and built into the HFC-6000 system such that any type of failure both hardware and software is highly unlikely. The design, qualification, and in-service testing afforded by the HFC-6000 system are implemented to minimize the probability of failures of all types. However, additional

safety is achieved by employing the concepts of defense-in-depth and diversity. HFC's strategy for Diversity and Defense-In-Depth techniques has been devised to satisfy NRC acceptance criteria contained in BTP 7-19. The HFC goal is to meet the requirements with the following implementation goals:

- New diverse instrumentation and manual controls should be limited because of the manner in which the HFC-6000 is designed and implemented at plant sites. The existing information available will be retained such that the plant can be placed in a hot-shutdown condition concurrent with a postulated SWCMF to the HFC-6000.
- Engineering assessments will be acceptable for most of FSAR Chapter 15 accident analysis. A detailed quantitative assessment will not be necessary. Where possible, risk-based assessments will be used to determine the significance of the event concurrent with the postulated SWCMF. This risk-based effort will follow the guidance offered by EPRI and the NRC.

The HFC-6000 architecture has been carefully designed and analyzed using the concepts and guidance of NUREG/CR-6303 and BTP 7-19 to assure that the plant control systems, AMSAC, and indications necessary for operator action remain available and are not subject to the postulated SWCMF. As stated above, the HFC design which includes measures for error avoidance and fault tolerance are extremely effective at both preventing and minimizing the consequences of postulated software failures.

HFC has demonstrated and will be able to demonstrate for future plant specific applications that the HFC-6000 design addresses Diversity and Defense-in-Depth consistent with NRC requirements and satisfy NRC acceptance criteria for this topic. Furthermore, HFC and future plant specific customers are expected to follow the risk-based Defense-in-Depth and Diversity assessment guidance and will use it when NRC approval is granted. Implementation of plant-specific HFC-6000 Instrumentation and Control system upgrades in accordance with guidance offered in NUREG/CR-6303 and BTP 7-19 assures that adequate diversity and defense-in-depth is provided with HFC's design approach.

8.7 Cyber Security

To adequately protect the HFC-6000 safety system from cyber security based intrusions and faults, a secure design including administrative requirements has been implemented by HFC.
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8.8 Isolation and Independence

The HFC-6000 platform is qualified as a safety related device without any non-safety related components. However, the C-Link does provide for the capability of communication to other controllers within one division (intra division) and for one-way communication to non-safety related components[

]However, these connections could be provided during a plant specific implementation phase. The actual details for acceptable isolation and independence for these areas will be provided during this plant specific implementation phase.

8.9 Digital Instrumentation and Controls (DI&C) Interim Staff Guidance (ISG)-04, Communications Issues

The C-Link provides intra-divisional communication capability that includes the transmission of data and information within an electrical safety division and communications between safety related controllers and non-safety related equipment. The C-Link intra-divisional communication capabilities are bi-directional within the same division and unidirectional to non-safety related equipment.

The NRC has stated that bi-directional communications within a safety division and one way communication between safety and non-safety related equipment is acceptable provided certain restrictions are enforced to ensure that there will be no adverse impact on safety systems. Design guidance for acceptance is provided in ISG-04 on communications issues. The C-Link of the HFC-6000 adheres to this ISG on communication as discussed below. The ISG-04 guidance is discussed (Italics) in the initial paragraph of each item.

1. A safety channel should not be dependent upon any information or resource originating or residing outside its own safety division to accomplish its safety function. This is a fundamental consequence of the independence requirements of IEEE603. It is recognized that division-voting logic must receive inputs from multiple safety divisions.

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2. The safety function of each safety channel should be protected from adverse influence from outside the division of which that channel is a member. Information and signals originating outside the division must not be able to inhibit or delay the safety function. This protection must be implemented within the affected division (rather than in the sources outside the division), and must not itself be affected by any condition or information from outside the affected division. This protection must be sustained despite any operation, malfunction, design error, communication error, or software error or corruption existing or originating outside the division.

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3. A safety channel should not receive any communication from outside its own safety division unless that communication supports or enhances the performance of the safety function.

Receipt of information that does not support or enhance the safety function would involve the performance of functions that are not directly related to the safety function. Safety systems should be as simple as possible. Functions those are not necessary for safety, even if they enhance reliability, should be executed outside the safety system. A safety system designed to perform functions not directly related to the safety function would be more complex than a system that performs the same safety function, but is not designed to perform other functions. The more complex system would increase the likelihood of failures and software errors. Such a complex design, therefore, should be avoided within the safety system. For example, comparison of readings from sensors in different divisions may provide useful information concerning the behavior of the sensors (for example, On-Line Monitoring). Such a function executed within a safety system, however, could also result in unacceptable influence of one division over another, or could involve functions not directly related to the safety functions, and should not be executed within the safety system. Receipt of information from outside the division, and the performance of functions not directly related to the safety function, if used, should be justified. It should be demonstrated that the added system/software complexity associated with the performance of functions not directly related to the safety function and with the receipt of information in support of those functions does not significantly increase the likelihood of software specification or coding errors, including errors that would affect more than one division. The applicant should justify the definition of "significantly" used in the demonstration.

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4. The communication process itself should be carried out by a communications processor separate from the processor that executes the safety function, so that communications errors and malfunctions will not interfere with the execution of the safety function. The communication and function processors should operate asynchronously, sharing information only by means of dual-ported memory or some other shared memory resource that is dedicated exclusively to this exchange of information. The function processor, the communications processor, and the shared memory, along with all supporting circuits and software, are all considered to be safety-related, and must be designed, qualified, fabricated, etc., in accordance with 10 C.F.R. Part 50, Appendix A and B. Access to the shared memory should be controlled in such a manner that the function processor has priority access to the shared memory to complete the safety function in a deterministic manner. For example, if the communication processor is accessing the shared memory at a time when the function processor needs to access it, the function processor should gain access within a timeframe that does not impact the loop cycle time assumed in the plant safety analyses. If the shared memory cannot support unrestricted simultaneous access by both processors, then the access controls should be configured such that the function processor always has precedence. The safety function circuits and program logic should ensure that the safety function will be performed within

the timeframe established in the safety analysis, and will be completed successfully without data from the shared memory in the event that the function processor is unable to gain access to the shared memory.

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Figure 8-2 – Public Memory shared between C-Link and SYS processors

5. The cycle time for the safety function processor should be determined in consideration of the longest possible completion time for each access to the shared memory. This longest-possible completion time should include the response time of the memory itself and of the circuits associated with it, and should also include the longest possible delay in access to

the memory by the function processor assuming worst-case conditions for the transfer of access from the communications processor to the function processor. Failure of the system to meet the limiting cycle time should be detected and alarmed.

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6. The safety function processor should perform no communication handshaking and should not accept interrupts from outside its own safety division.

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7. Only predefined data sets should be used by the receiving system. Unrecognized messages and data should be identified and dispositional by the receiving system in accordance with the pre-specified design requirements. Data from unrecognized messages must not be used within the safety logic executed by the safety function processor. Message format and protocol should be pre-determined. Every message should have the same message field structure and sequence, including message identification, status information, data bits, etc. in the same locations in every message. Every datum should be included in every transmit cycle, whether it has changed since the previous transmission or not, to ensure deterministic system behavior.

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8. Data exchanged between redundant safety divisions or between safety and no safety divisions should be processed in a manner that does not adversely affect the safety function of the sending divisions, the receiving divisions, or any other independent divisions.

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9. Incoming message data should be stored in fixed predetermined locations in the shared memory and in the memory associated with the function processor. These memory locations should not be used for any other purpose. The memory locations should be allocated such that input data and output data are segregated from each other in separate memory devices or in separate pre-specified physical areas within a memory device.

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Table 8-1 - Software Layers of C-Link processor

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10. *Safety division software should be protected from alteration while the safety division is in operation. On-line changes to safety system software should be prevented by hardwired interlocks or by physical disconnection of maintenance and monitoring equipment. A workstation (e.g. engineer or programmer station) may alter addressable constants, setpoints, parameters, and other settings associated with a safety function only by way of the dual-processor / shared-memory scheme described in this guidance, or when the associated channel is inoperable. Such a workstation should be physically restricted from making changes in more than one division at a time. The restriction should be by means of physical cable disconnect, or by means of key-lock switch that either physically opens the data transmission circuit or interrupts the connection by means of hardwired logic. "Hardwired logic" as used here refers to circuitry that physically interrupts the flow of information, such as an electronic AND gate circuit (that does not use software or firmware) with one input controlled by the hardware switch and the other connected to the information source: the information appears at the output of the gate only when the switch is in a position that applies a "TRUE" or "1" at the input to which it is connected. Provisions that rely on software to effect the disconnection are not acceptable. It is noted that software may be used in the safety system or in the workstation to accommodate the effects of the open circuit or for status logging or other purposes.*

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11. *Provisions for interdivisional communication should explicitly preclude the ability to send software instructions to a safety function processor unless all safety functions associated with that processor are either bypassed or otherwise not in service. The progress of a safety function processor through its instruction sequence should not be affected by any message from outside its division. For example, a received message should not be able to direct the processor to execute a subroutine or branch to a new instruction sequence.*

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12. *Communication faults should not adversely affect the performance of required safety functions in any way. Faults, including communication faults, originating in non-safety*

equipment, do not constitute "single failures" as described in the single failure criterion of 10 C.F.R. Part 50, Appendix A. Examples of credible communication faults include, but are not limited to, the following:

- *Messages may be corrupted due to errors in communications processors, errors introduced in buffer interfaces, errors introduced in the transmission media, or from interference or electrical noise.*
- *Messages may be repeated at an incorrect point in time.*
- *Messages may be sent in the incorrect sequence.*
- *Messages may be lost, which includes both failures to receive an uncorrupted message or to acknowledge receipt of a message.*
- *Messages may be delayed beyond their permitted arrival time window for several reasons, including errors in the transmission medium, congested transmission lines, interference, or by delay in sending buffered messages.*
- *Messages may be inserted into the communication medium from unexpected or unknown sources.*
- *Messages may be sent to the wrong destination, which could treat the message as a valid message.*
- *Messages may be longer than the receiving buffer, resulting in buffer overflow and memory corruption.*
- *Messages may contain data that is outside the expected range. Messages may appear valid, but data may be placed in incorrect locations within the message.*
- *Messages may occur at a high rate that degrades or causes the system to fail (i.e., broadcast storm).*
- *Message headers or addresses may be corrupted.*

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13. Vital communications, such as the sharing of channel trip decisions for the purpose of voting, should include provisions for ensuring that received messages are correct and are correctly understood. Such communications should employ error-detecting or error-correcting coding along with means for dealing with corrupt, invalid, untimely or otherwise questionable data. The effectiveness of error detection/correction should be demonstrated in the design and proof testing of the associated codes, but once demonstrated is not subject to periodic testing. Error-correcting methods, if used, should be shown to always reconstruct the original message exactly or to designate the message as unrecoverable. None of this activity should affect the operation of the safety-function processor.

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14. Vital communications should be point-to-point by means of a dedicated medium (copper or optical cable). In this context, "point-to-point" means that the message is passed directly from the sending node to the receiving node without the involvement of equipment outside the division of the sending or receiving node. Implementation of other communication strategies should provide the same reliability and should be justified.

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15. Communication for safety functions should communicate a fixed set of data (called the "state") at regular intervals, whether data in the set has changed or not.

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16. Network connectivity, liveness, and real-time properties essential to the safety application should be verified in the protocol. Liveness, in particular, is taken to mean that no connection to any network outside the division can cause an RPS/ESFAS communication protocol to stall, either deadlock or livelock. (Note: This is also required by the independence

criteria of: (1) 10 C.F.R. Part 50, Appendix A, General Design Criteria ("GDC") 24, which states, "interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired."; and (2) IEEE 603-1991 IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.) (Source: NUREG/CR-6082, 3.4.3).

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17. Pursuant to 10 C.F.R. § 50.49, the medium used in a vital communications channel should be qualified for the anticipated normal and post-accident environments. For example, some optical fibers and components may be subject to gradual degradation as a result of prolonged exposure to radiation or to heat. In addition, new digital systems may need susceptibility testing for EMI/RFI and power surges, if the environments are significant to the equipment being qualified.

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18. Provisions for communications should be analyzed for hazards and performance deficits posed by unneeded functionality and complication.

The C-Link has been analyzed for hazards and performance deficits as part of the digital platform FMEA. The results of this analysis are provided in the HFC-6000 FMEA.

19. If data rates exceed the capacity of a communications link or the ability of nodes to handle traffic, the system will suffer congestion. All links and nodes should have sufficient capacity to support all functions. The applicant should identify the true data rate, including overhead, to ensure that communication bandwidth is sufficient to ensure proper performance of all safety functions. Communications throughput thresholds and safety system sensitivity to communications throughput issues should be confirmed by testing.

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20. The safety system response time calculations should assume a data error rate that is greater than or equal to the design basis error rate and is supported by the error rate observed in design and qualification testing.

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9 Equipment Qualification

9.1 Introduction

HFC has completed the equipment qualification of the HFC-6000 system for safety-related applications in U. S. nuclear power plants. This section identifies the specific combination of tests that were performed, summarizes the results, and presents the conclusions of the testing program. The equipment qualification testing program was developed in accordance with EPRI TR-107330. The testing was performed at Wyle Laboratories in Huntsville, Alabama. Software qualification is discussed in Section 10.

9.2 System Qualification Test Plan

9.2.1 Scope

The technical scope, focus, and content of EPRI TR-107330 define the basis for the steps involved in completing a generic qualification program. Accomplishing the qualification requires creation of a Test synthetic application program (TSAP). The qualification steps are:

A. The HFC-6000 product line was selected by HFC for qualification for nuclear safety applications.

B. An evaluation of the HFC-6000 was performed. It was concluded that the HFC-6000 system, when fully and successfully tested in accordance with the EPRI TR-107330 and Regulatory Guide 1.180 Rev 01, was suitable to support nuclear safety-related applications.

C. A set of hardware test modules with supporting software was defined and used as the HFC-6000 qualification Test Specimen. The specific set of hardware modules and supporting software are defined in the Section 1 Table 1-1.

D. A Test System Application Program (TSAP) was defined and the software developed. The TSAP serves as a synthetic application that is designed to aid in the qualification and operability tests.

E. The Test Specimen and the TSAP were combined into a test configuration and a set of acceptance tests was performed. This activity constitutes the system integration testing for the Test Specimen.

F. A set of qualification tests to be performed on the Test Specimen was specified, including a defined set of Operability and Prudency tests to be conducted at suitable times in the qualification process.

G. The qualification tests were performed and the results documented. Documentation of results includes definition of the qualification envelope and identification of the specific products that were qualified.

This Section 9 addresses items A through G.

9.2.2 Equipment Tested

A qualification Test Specimen was designed to serve as a representative sample of the HFC-6000 system architecture. The Test Specimen was configured to be consistent with the requirements of EPRI TR-107330, Section 4. The HFC-6000 system incorporates a combination of architectural features from pre-existing HFC product lines, and the overall Test Specimen included sufficient functional capabilities to encompass a significant range of applications.

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System layout drawings, wiring and power distribution diagrams, and assembly diagrams defined specific details of the hardware design for the Test Specimen. Test plans and procedures provided detailed requirements and instructions for equipment mounting and interfaces to be used for equipment testing. Qualification Test Reports define the tests results and related analyses. A TSAP was developed as new application code using the guidance in BTP-14 and installed in the master controller of the Test Specimen. Detailed requirements for the individual modules in the Test Specimen and the TSAP were defined in a TSAP Requirements Specification. Detailed configuration information, such as module serial numbers and software versions, were recorded in the Master Configuration List (MCL), which is included as part of the qualification documentation.

9.2.3 Safety Functions Tested

The Test Specimen defined by HFC covered a subset of functional capabilities presented in EPRI TR-107330, Section 4. The specific capabilities demonstrated by the HFC qualification testing were as follows:

1. The capability of the Test Specimen to perform defined design functions within specified tolerances under normal environmental and operating conditions.

2. The capability of the Test Specimen to perform design functions within specified tolerances under the stressed conditions defined in EPRI TR-107330, Sections 5 and 6. Specific stress conditions demonstrated the capability of the Test Specimen to:

    - Function during and after exposure to abnormal temperature and humidity
    - Function during and after operational basis and safety shutdown seismic events

- Function during and after application of EMI/RFI waveform exposures.
- Function during and after application of ESD test discharges
- Function during and after exposure to surge test waveforms
- Function under varying conditions of source power quality
- Demonstrate specified levels of Class 1E isolation and continue functioning after application of the test voltage levels.

9.2.4 Test Requirements

The qualification Test Specimen was subjected both to a set of prequalification tests, a set of qualification tests, and a set of post qualification tests as illustrated in Figure 9.2. These tests served two primary purposes:

- Tests conducted prior to the start of qualification testing confirmed that the synthetic TSAP created for qualification testing purposes and the integrated hardware operated as intended.

- Operability and Prudency tests established a performance baseline for the Test Specimen. These tests were repeated at various points before, during and after the qualification test to demonstrate that the system performance remained within acceptable limits.

The qualification tests exposed the Test Specimen to a specifically defined set of abnormal conditions as defined in EPRI TR-107330. The purpose of these tests was to demonstrate the capability of the system hardware and software to continue operating within specified tolerances under extreme conditions.

9.2.4.1 Test Plans and Procedures

The following test plans and test procedures were prepared as part of the Equipment Qualification Program:

TN0401 Master Test Plan
TP0401 System Setup and Checkout Procedure
TP0408 TSAP Validation Test Procedure
TP0402 Operability Test Procedure
TP0403 Prudency Test Procedure
TP0404 Environmental Stress Test Procedure
TP0407 EMI/RFI Test Procedure
TP0409 ESD Test Procedure
TP0406 Surge Withstand Test Procedure
TP0405 Seismic Test Procedure
TP0410 Burn-in Test
TP0411 Isolation Test Procedure

The master test plan provides a link between the guidance of the EPRI TR-107330 standard and the procedures that were used to conduct the tests. The test plan addresses the general approach for the test program, and it included a separate test plan for each qualification test to be performed. Individual test plans for each test are included as attachments to the Master Test Plan, and each one identifies requirements, testing criteria, acceptance criteria, and documentation for a particular test.

The test procedures provided step-by-step instructions for conducting the tests and recording the results. These instructions included setup of equipment, test equipment requirements, environmental requirements, and procedural steps for conducting the tests, acceptance criteria, and tolerances.
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Figure 9-1 - Test Data Flow Chart

9.2.4.2 Test Sequence

Figure 9.2 illustrates the overall sequence of the test program for this project. This figure shows the test program consists of separate prequalification and qualification test phases. The requirements, design, manufacture, and assembly phases of the life cycle were completed prior to the start of the qualification testing in accordance with HFC procedures. Actual testing of the Test Specimen commenced with system integration.

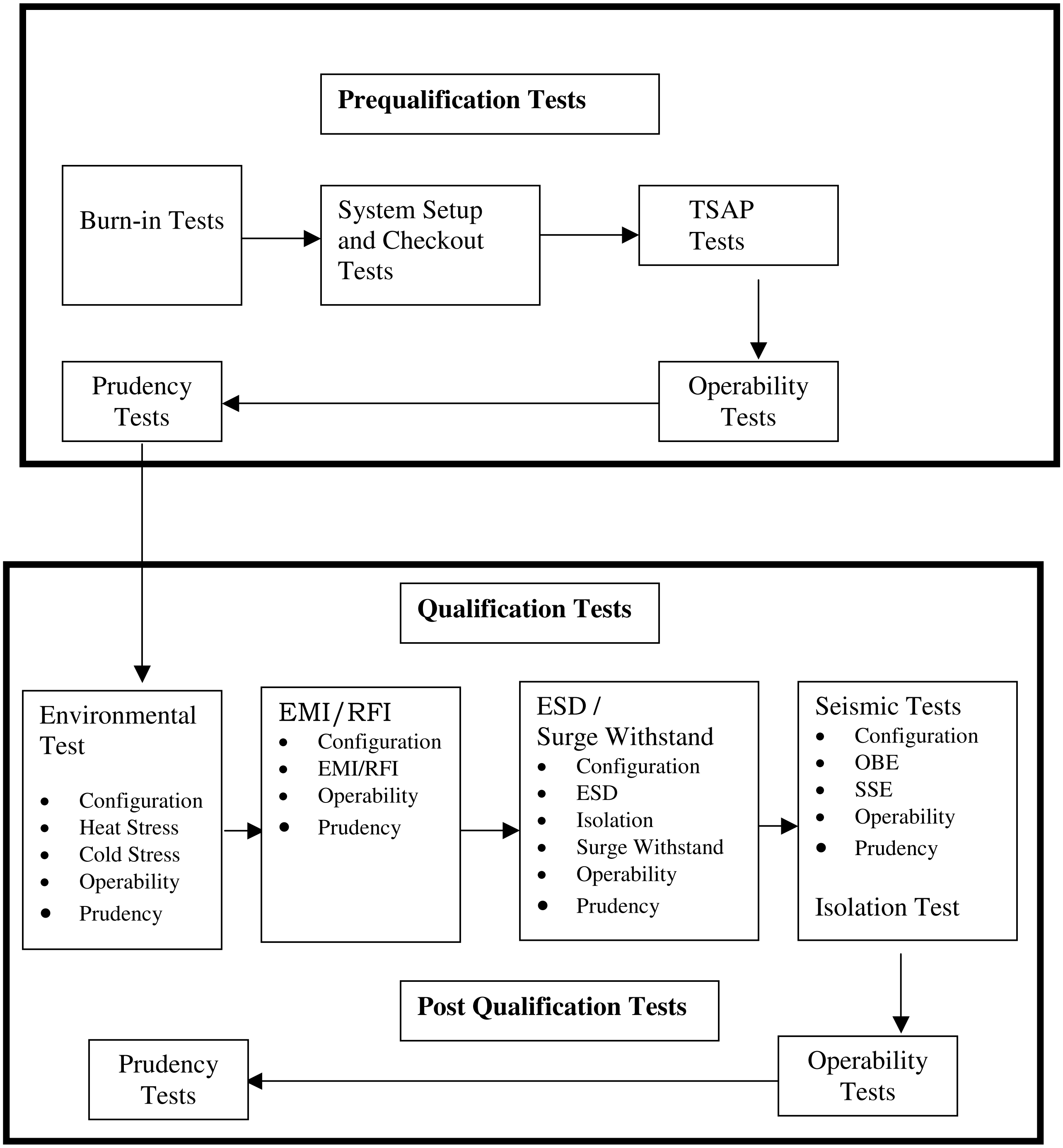

Figure 9-2 - Overall Test Sequence

NOTE

The EPRI standard required the environmental stress test to be performed first. No other specific sequence of execution was stipulated.

The prequalification phase was conducted by HFC test personnel at the HFC facility in Addison, Texas. The qualification tests were conducted at Wyle Laboratories. Wyle test personnel conducted the designated qualification tests based on requirements identified in the detailed test procedures. HFC test personnel were present to monitor and record performance of the Test Specimen. **[**

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Detailed requirements for each test were defined in the individual test plans included within the Master Test Plan. Detailed instructions for conducting the specific tests were contained in separate test procedures. Test results and the associated analyses are refined in the Qualification Reports.

9.2.4.3 Test Arrangement and Methodology

The test arrangement consisted of the Test Specimen connected to the HPAT controller and a PC workstation that are separate from the Test Specimen. The HPAT tester consisted of a separate HFC controller equipped with a test application program and a set of I/O modules configured to provide simulated inputs for the Test Specimen. The PC workstation was equipped with a standard set of HFC configuration, interactive graphics, and data logging software tools linked to both the HPAT and the Test Specimen. This arrangement permitted the test engineer to start/stop selected test routines and to record test results in the HAS and SOE data loggers.

During the prequalification testing phase, the Test Specimen was configured and subjected to a series of hardware, software, and functional tests. The TSAP was installed in the Test Specimen controllers, and its functional operation was verified. The TSAP included a set of simulated applications for safety system functions as well as algorithms specifically developed to support Operability and Prudency testing. The purposes for this phase of testing were as follows:

- Establish functionality of the software objects available to the TSAP.
- Verify functional operation of the TSAP.
- Validate operation of the automated test sequences.

- Establish an operational baseline for the Test Specimen.
- Document calibration and linearity of AI and AO modules included in the Test Specimen.

During the qualification tests, the Test Specimen was subjected to stress conditions to simulate various stress factors. While each test was in progress, the TSAP was processing test signal waveforms supplied by the HPAT. Responses of the Test Specimen during each qualification test were logged and compared to the performance baseline established during prequalification testing to detect any deviation in performance. After all of the qualification stress tests were completed, Operability and Prudency tests were repeated, and all responses were recorded and compared with the performance baseline to identify any degradation in performance. In each case, the logged responses of the Test Specimen provided the objective basis for evaluating the performance of the generic modular control system design.

9.2.4.4 Test Personnel

All prequalification test activities were conducted by one or more qualified HFC test engineers and test technicians. Qualification tests that required specialized test equipment (e.g., seismic, environmental, and EMI/RFI testing) were conducted for HFC by Wyle Laboratories personnel. HFC test personnel were present and conducted specified portions of the Operability and Prudency tests during these qualification tests.

9.2.4.5 System Operational Stress Conditions

EPRI TR-107330, Paragraph 6.3.1 identifies the major aging factors associated with a computer-based control system. The following sequence of tests exposed the qualification system to conditions that simulate the following stress factors:

- Environmental stress test. This test exposed the Test Specimen to abnormal combinations of high/low temperature and humidity.
- Pre-aging of relays and associated logic during prudency tests.
- Electrostatic Discharge test.
- Electromagnetic Interference/Radio Frequency Interference (EMI/RFI) test.
- Surge Withstand test.
- Seismic test.
- Isolation test. This test demonstrated Class 1E isolation of specified ports.

Each test exposed the Test Specimen to abnormal stress conditions while it was powered up and running the TSAP. The EPRI specification and Regulatory Guide provides detailed requirements for test parameters and the order in which particular tests are to be conducted. These requirements were incorporated into the individual test plans and illustrated in the test sequence diagram (Figure 9.2).
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9.3 *System Qualification Test Results*

9.3.1 Prequalification Tests

The Prequalification Tests consisted of the Burn-In Test, System Setup and Checkout Test, TSAP Validation Test, Operability Tests, and Prudency Tests as shown in Figure 9.2.

9.3.1.1 Burn-in Test (TP0410)

The circuit card assemblies for the HFC-6000 Test Specimen were run in a normal operating environment for a minimum period of 352 hours prior to system integration in accordance with the Burn-in Test Procedure. The purpose of this test was to detect any early-life failures of component circuit cards. The scope of this test included two and a half times the total number of cards required for the complete Test Specimen. Circuit card assemblies not included in the initial test configuration of the Test Specimen were reserved as spares to be used as replacements for any cards that failed during the subsequent qualification tests.

The test engineers maintained a separate test record for each card being tested. The test record included the following information:

- Card name, part number, serial number, and software ID.
- Card rack and slot designation (if applicable) for burn-in test.
- Date and time burn-in test started.
- Date and time when burn-in test ended successfully.
- Date and time when card was removed from the burn-in test.
- Description of equipment failure (if any).

9.3.1.1.1 Burn-in Test Results

All assemblies to be utilized in the qualification test program passed the burn-in test by successfully achieving the minimum cumulative 352 hours of burn-in operation.

9.3.1.2 System Setup and Checkout (TP0401)

The System Setup and Checkout Tests were performed to verify that the project specified hardware, wiring and communication cabling had been installed and that communication had been established over each communication link, prior to the TSAP Validation Test.

Included in the Scope of this testing were the following activities/results:
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9.3.1.2.1 System Setup and Checkout Test Results

All assemblies met the acceptance criteria for the setup and checkout tests.

9.3.1.3 TSAP Validation Test Procedure (TP0408)

The HFC-6000 system Test Specimen had a test synthetic application program (TSAP) installed that included sample control logic for power plant processes as well as logic to support automated qualification testing. The TSAP Validation Test Procedure validated the following activities:
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9.3.1.3.1 TSAP Test Results

All TSAP software met the acceptance criteria.

9.3.2 Pre-Qualification Tests

9.3.2.1 Operability Tests (TP0402)

The following set of Operability tests was performed following completion of the TSAP tests described above. The purpose of these operability tests was to establish the performance baseline for the system. This performance baseline was then used as the basis for evaluating system performance during and/or following each of the qualification tests required by the EPRI standard.

- **Accuracy Test** - This test developed a baseline to compare against the accuracy and linearity of the analog I/O modules observed during the qualification tests.
- **Discrete Input Operability Test** - This test verified the capability of discrete input channels to detect a transition in the input signal being monitored.
- **Discrete Output Operability Test** - This test verified the capability of discrete output channels to operate reliably within its specified loading conditions.
- **Communication Operability Test** – This test verified reliable data transfer over the ICL and the C-Link
- **Timer Test** – This test developed the baseline for the timer function accessible to the TSAP.
- **Failover Operability Test** – This test demonstrated correct operation of the failover function.
- **Loss of Power Test** – This test demonstrated correct response of all I/O channels to a loss of source power followed by reapplication of power to the system.
- **Power Interruption Test** – This test demonstrated the capability of the power modules to sustain system operation during a temporary (40-ms transient) power interruption.
- **Power Quality Tolerance Test** – This test was developed to demonstrate the capability of the Test Specimen to continue normal operation over a range of source power voltages and frequencies. The Power Quality Tolerance Test was not part of the Operability Tests; it was required during the high temperature phase of the environmental test and after the completion of the seismic test only.

All tests, with the exception of the Power Quality Tolerance Test, were performed at the HFC site prior to shipment of the equipment to Wyle labs. The Power Quality Tolerance Test was performed at Wyle as specified in the HFC Operability Test Procedure.

9.3.2.1.1 Operability Test Results

The acceptance criteria defined for the operability tests were met with the exception of the following findings

SOE Test Data

During the initial baseline tests, some of the SOE test data for the Operability Test and Prudency Test was overwritten during the test period due to a fault in the test data recording process. The digital input (DI) modules that provided the SOE function contained a circular buffer for logging SOE data as it was received. Due to the circular nature of the buffer, when its storage capacity is exceeded, the earliest recorded data is overwritten. This problem was detected and corrected prior to the final Operability Test and Prudency Test. Subsequent Operability and Prudency test results were used to supplement the lost data and verify the acceptability of the SOE test results.

The objective of the initial baseline test was to establish baseline performance characteristics for comparison with performance before, during, and after subsequent Test Specimen stress tests. While the loss of part of this initial baseline SOE data occurred, it did not present a problem during execution and analyses of the subsequent qualification test results.

After the SOE data recorder was returned to the HFC facility, the problems with the SOE data storage were resolved and the Operability and Prudency Tests were performed again during post qualification testing. Complete SOE test data was obtained for these retests. The prequalification test data was supplemented with post-qualification test data for the purpose of evaluating the test results and to determine if the acceptance criteria of the qualification tests were met.

Since the performance of the equipment after experiencing the environmental stress of the qualification program was acceptable, the performance of the equipment before the stress tests would also have been acceptable. The use of post stress test data to supplement pre stress test data was deemed to be acceptable.

HFC concluded that the loss of certain initial SOE test data for these tests, when supplemented by the additional test data from subsequent tests, had no adverse impact on the qualification test program.

Analog Input and RTD Input Modules Out of Calibration

The analog I/O modules have a specified design accuracy of 0.1% over their entire operating range. The Analog Input and RTD Input modules had individual channels whose performance was outside of this accuracy range during the initial performance of the Operability and Prudency tests. This was not detected prior to completion of the stress testing. Although out of calibration, the Analog Input and RTD Input modules tested during the subsequent stress tests operated consistently with the initial baseline test results. This allowed HFC to analyze the stress

test results and reach conclusions on acceptability. The stress conditions did not change the accuracy of these modules relative to the baseline accuracy for the modules.

After return of the Test Specimen to HFC, the post test was run with the cards as they were during the stress test. When the calibration problem was detected, a module was recalibrated to demonstrate that all channels could be restored to within the 0.1% accuracy range.

As defined in Section 9.2.4.2 item 17, the seismic test was preformed for the second time. When the decision was made to rerun the entire seismic test, all of the analog modules were recalibrated and retested before returning to Wyle. During this test, the calibrated analog I/O modules all performed within the specified 0.1% acceptance criteria.

HFC concluded that the out of calibration Analog Input and RTD Input cards had no impact on the performance of the qualification tests and had no impact on the ability to reach conclusions on the acceptance of the qualification test program.

9.3.2.1.2 Conclusion

HFC has concluded that these findings for the baseline Operability and Prudency tests had no adverse impact on the ability to evaluate the data and reach conclusions on the qualification test results.

9.3.2.2 Power Interruption Test

The HFC-6000 system operates with redundant 24 volt dc and redundant 48 volt dc power supplies. The power interruption test required a 40-ms interruption in the primary AC power line to the Test Specimen. When this disruption was imposed with all spare slots filled with operating modules, the internal power supplies for one or more of the modules went through the resetting cycle. After the AC power source was restored normal operation resumed.

Essentially all nuclear power plants have redundant sources of AC power for each safety channel. The HFC-6000 system was designed to operate with redundant AC power source connected to each safety channel to provide its redundant power to the redundant power supplies. Based on the single failure criterion, only one power source will experience a power interruption at any time, ensuring that the system will successfully maintain normal operation without resetting during that interruption.

9.3.2.2.1 Conclusion

HFC will define an interface requirement that all nuclear installations using HFC-6000 include two independent power sources with automatic switchover for each safety division to ensure that the system can sustain a 40-ms interruption in one power source without disruption to any control function.

9.3.2.3 Prudency Tests (TP0403)

The initial execution of the Prudency Tests was performed during the same time period as that of the Operability tests. These tests, as defined by the EPRI standard, do not address any specific requirement but exercise the Test Specimen in various ways to simulate potential stresses. Throughout the period that the Prudency tests were running the Test Specimen power source was set to 90 vac and 57 Hz to maximize operational stress. The following specific tests were defined:

- **Burst of Events Test** - This test was configured to impose a large number of operations on the HFC-6000 test specimen simultaneously in accordance with EPRI TR-107330, paragraph 5.4.A. This test was automated and was typically run as a continuous background operation for selected qualification tests.
- **Serial Port Failure Test** – The Test Specimen has two redundant serial communication links. For each link, this test imposed three simulated failures on a single channel of a redundant link; one failure condition at a time, transmit line open, transmit line shorted to ground, and transmit line shorted to receive line.
- **Serial Port Noise Test** - This test required introduction of a white noise signal on of the serial link one port at a time.
- **Fault Simulation Test** – This test required introduction of a simulated failure condition in the primary controller to trigger failover to the secondary controller. The intent of this test was covered by the Failover Operability test (TP0402) and so was not repeated as part of the Prudency tests.

The Prudency tests were executed during the prequalification phase of testing to establish a performance baseline for the Test Specimen. The BOE test was repeated at various points during the qualification stress tests to identify any performance degradation from the performance baseline, and the entire test was repeated following return of the equipment from Wyle Laboratory. The test data was captured and recorded by both the SOE and the HAS. The SOE system has a 1 ms response time for digital data only. The HAS can log both analog and digital data.

9.3.2.3.1 Prudency BOE Test Results

The acceptance criteria defined for the Prudency tests were met with the exception of minor deviations caused by problems with test setup or methodology. These include:

Loss of SOE Test Data

This matter was covered in the earlier Section on Operability Tests.

Automated Test Result Tolerance

This matter was covered in the earlier Section on Operability Tests

Conclusion

The deviations encountered were due to problems with test setup or methodology and not actual deviations in system performance. HFC has concluded that the deviations that occurred during the baseline testing had no adverse impact on the ability to evaluate those results and reach conclusions on the qualification test results.

9.3.2.3.2 Prudency Serial Port Failure Test Results

The Serial Port Failure test section of the Prudency test is configured to test the two redundant communication links in the Test Specimen. These are the (1) the C-Link between the controllers in the system, and (2) the ICL, which enables communication between the HFC-SBC06 and all input/output modules associated with a particular controller. The objective of the Serial Port Failure Test is to demonstrate that a hardware failure on a single serial link will have no adverse impact on the steady-state operation of the controller.

The Serial Port Failure test was run on the C-Link and the ICL during the prequalification phase of the program, and no transient disruption of the BOE waveform was detected at the moment the failure conditions were introduced or during subsequent steady-state operation. A full set of test data was available for the Post Qualification Testing and the only perturbation recorded was caused by the stopping the BOE test. The acceptance criteria were met.

Conclusion

No hardware failures (transmit line open, shorted to ground, or shorted to receive line) on a single serial communication channel produced either a transient or steady-state disruption in the performance of the controller.

9.3.2.3.3 Prudency Serial Port Noise Test Results

The Serial Port Noise test was designed to superimpose a white noise signal on either the transmit signal or the receive signal line of each serial link (one channel of the redundant pair) one at a time. This test was run after return of the equipment from Wyle.

The Serial Port Noise test procedure was written based on the use of a standard function signal generator. EPRI TR-107330 stipulates a 30 to 100 kHz white noise signal at 2.5 vrms. HFC substituted a 100 kHz saw tooth signal at 2.5 vrms with frequency modulation. This noise signal was used for testing the C-Link and the ICL.

The acceptance criterion for this test is that the BOE signal characteristics do not deviate by more than ±10% while the failure condition is being imposed.

Conclusion

The sweep modulated noise signal used for this test does not have the precise characteristics or frequency range of the white noise signal defined by the EPRI specification. HFC has concluded that the test using the substitute noise signal meets the intent of the original test requirements.
[

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9.3.3 Qualification Tests

The Qualification Tests consisted of the following tests: Environmental, EMI/RFI/ESD, Surge Withstand, Seismic, and Isolation as shown in Figure 9.2. Portions of the Operability Tests and Prudency Tests were repeated several times throughout these test sequences, as indicated in the detailed test procedure covering each test and as specified in the EPRI TR.

9.3.3.1 Environmental Stress Test (TP0404)

The environmental stress test is one of the tests described by EPRI TR-107330 to qualify a commercially available PLC for safety-related applications in a nuclear power plant. This test exposes a specially configured HFC-6000 Test Specimen to extremes of temperature and humidity in order to induce accelerated aging of functional components. This testing was accomplished by enclosing the Test Specimen in an environmental test chamber in accordance with Wyle Laboratories Test Procedure 50043-1. The Test Specimen was running a TSAP throughout the test period, and its operation was monitored by SOE and HAS data loggers located outside the test chamber. In addition, comprehensive functional tests were conducted before, after, and at specified points during the stress testing. The results of these tests were used to identify any deterioration in functional performance of the Test Specimen due to adverse environmental conditions.

The environmental stress test consisted of three major phases (Figure 9.3):

- A minimum 48-hour period with the ambient temperature at 140° ± 5° F and a relative humidity (RH) of 90% ± 5% (non-condensing).
- A transition period of 4 hours during which the ambient temperature was reduced to 40° ± 5° F with 0% to 10% RH (non-condensing).
- A minimum 8-hour period with the ambient temperature at 40° ± 5° F with 0% to 10% RH (non-condensing).
- A transition period of 4 hours during which the test chamber was brought back to ambient room temperature and humidity.

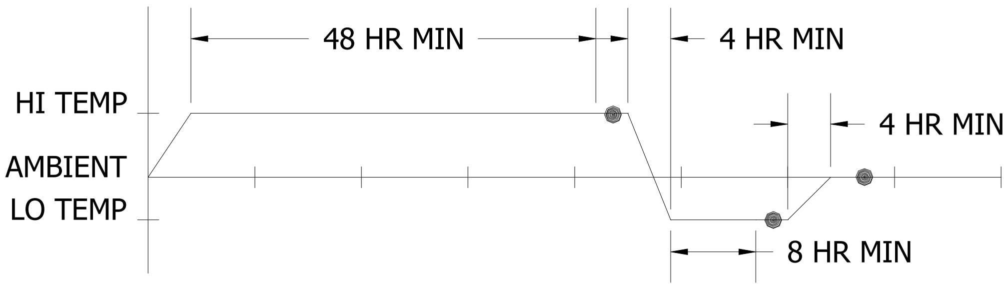

Figure 9-3 - Environmental Stress Temperature Profile

9.3.3.1.1 Environmental Test Results

The following evaluations and conclusions were reached regarding the environmental test results:

Power Drop to Test Specimen
[

]
HFC concluded that the intermittent shutdowns due to tripping of the power drop had no adverse impact on the test, nor did it affect the ability to reach conclusions on the test results.
[

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RTD Module

[

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AI Module

[

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Conclusions

The environmental test results show that the overall HFC6000 control system met all acceptance criteria [

]

9.3.3.2 EMI\RFI Test (TP0407)

The HFC-6000 Test Specimen is designed to operate in a wide variety of industrial applications. Both the HFC system hardware and the field equipment generate electromagnetic radiation (noise). The operation of the HFC system was tested to determine the susceptibility to EMI/RFI noise and the magnitude of EMI/RFI noise generated. This test sequence covered a series of four separate tests. During the first two tests, the Test Specimen was exposed to an external source of EMI/RFI, and the functional operation of the equipment was examined for signs of degraded operation. During the remaining two tests, the Test Specimen was configured for normal operation, and the magnitude of electromagnetic radiation generated by the equipment was measured.

The overall test requirements are defined by EPRI TR-107330-R1 and Regulatory Guide 1.180 Rev 1. The levels of EMI/RFI susceptibility and radiation limits are defined in Regulatory Guide 1.180 Rev 1. The test was conducted at Wyle Laboratories based on Wyle Test Procedure 50044-10. [

]
The susceptibility tests consisted of exposing the Test Specimen to a radiated or conducted electronic noise signal and monitoring functional operation of the control logic for abnormal operation. Wyle test personnel provided the EMI/RFI signal source and controlled injection of the test waveform to the Test Specimen. HFC test personnel controlled and monitored the functional operation of the Test Specimen. During each portion of the test, HFC test personnel ran specified portions of the Operability and Prudency tests and monitored operation of the Test Specimen for signs of susceptibility.

The radiated susceptibility test was divided into several frequency ranges with a different signal source and antenna for each frequency range. Each test was executed twice: once with the antenna positioned at front center of the Test Specimen and once with the antenna at rear center.

The low frequency conducted susceptibility test was run at 30 Hz and 50 kHz. These test signals were injected directly into power leads of the Test Specimen. The test was executed for power module A of the redundant power supply (Model Jasper HML 601-5).

The high frequency conducted susceptibility tests were run between 50 kHz and 400 MHz. These test signals were inductively coupled into the power leads of the Test Specimen.

Wyle test personnel performed radiated magnetic and electric field emissions tests in accordance with Wyle Test Procedure 50044-10 Appendices D and E. EPRI TR-102323-R1 Chapter 7 was used to define power plant emissions limits and acceptable methods to be used for measuring these emissions levels. In addition, MIL-STD-461D RE101 was used to define the test method to be employed for measuring magnetic field emissions between 30 Hz and 100 kHz, and MIL-STD-461D RE102 was used to define methods for measuring radiated electric field emissions between 10 kHz and 1 GHz. Specified portions of the Operability and Prudency tests were run during the test to ensure that a minimum level of controller activity was present while the measurements were being run. [

]

Wyle test personnel executed conducted emissions tests in accordance with Wyle Test Procedure 50044-10 Appendices B and C. The tests were performed in accordance with EPRI TR-102323-R1 Chapter 7, which covers power plant emissions limits and acceptable methods to be used for measuring these emissions levels.**[**

]

9.3.3.2.1 EMI/RFI Tests Results

During the test, the HFC-6000 Test Specimen was mounted in open instrument racks. No additional cabinet or cable shielding was installed, and no additional noise filters or suppression devices were used on the input/output interfaces. Therefore, the test specimen was fully exposed to radiation from an external source or open to emit radiation generated internally. In any power plant application, the HFC-6000 equipment will be installed in cabinets qualified for Class 1E applications. Such cabinets will provide shielding against external radiation, improving the overall radiation withstand capacity of the system. Furthermore, varied noise filters would be installed on certain power lines to lower emission levels at that source.

HFC has performed EMI/RFI tests for the Korea Ulchin 5&6 Nuclear Plant safety system project. The test specimen for this Korea system was composed of assemblies similar to the HFC-6000 Test Specimen,**[**
] The results for that test were satisfactory for all frequency ranges included in the test.

The results of each test are summarized below.
[

]
Low Frequency Radiated Emissions (RE101)

The HFC-6000 Control System was monitored in accordance with the RE101 Radiated Emissions Test procedure to measure the magnetic field emissions in the range from 30 HZ to 100 KHZ. All radiated emissions were within the specified limits over the entire frequency range.

High Frequency Radiated Emissions (RE102)

An evaluation was performed of the HFC-6000 radiated emissions from horizontal and vertical antennas positioned one meter from the front and one meter from the rear of the Test Specimen. The purpose of the test was to measure the electric field emissions from 10 KHZ to 1 GHZ relative to the criteria in EPRI TR-102323-R1. HFC later re-evaluated the emissions relative to the guidance in Regulatory Guide 1.180-Revison 1. The results below are based on this reevaluation:
[

] Substantially the same components have been qualified in such a cabinet during the development for the Ulchin nuclear power plant, and the HFC-6000 control system will be qualified in equivalent cabinet structures on a project by project basis. The Ulchin EMI/RFI test data is documented in the HFC documentation files.

Low Frequency Conducted Emissions (CE101)

The CE101 Conducted Emission Test was performed on the HFC6000 Test Specimen to measure emissions in the range of 30 Hz to 50 kHz range on all power leads. The conducted emissions on all power lines were within the specified limits.

High Frequency Conducted Emissions (CE102)

The CE-102 Conducted Emissions Test was performed on all power leads of the HFC-6000 Test Specimen to measure emissions in the range from 50 KHZ to 400 MHZ. Based on the acceptance criteria in USNRC Regulatory Guide 1.180 Rev 1, there are no anomalies in the frequency range covered by CS102.

Conclusions

[

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9.3.3.3 ESD Test (TP0409)

Components of a HFC-6000 control system may be installed in an electrical equipment room as well as at various locations near the field equipment under control. In either case, the potential exists for exposure of sensitive electronic components to high voltage electrostatic discharges (ESD). This test subjects each component of the HFC-6000 Test Specimen to simulated ESD pulses to establish its capability to withstand such discharges without disabling or disrupting normal operation.

Detailed requirements for ESD immunity are defined by EPRI TR-102323-R1; the specific level of ESD immunity required is defined in EPRI TR-102323-R1 Appendix B Paragraph 3.5. ESD testing was conducted by Wyle Laboratories based on Wyle Test Procedure 50044-10 Appendix I. The test methods used to apply the ESD pulses are defined by IEC 61000-4-2 (equivalent to IEC 801-2).

Overall acceptance criteria specified by the EPRI specification are as follows:

- Subjecting the system to the specified level of ESD shall not disrupt operation or cause damage.
- For redundant platforms, performance is satisfactory if the platform performs as intended after being subjected to the specified level of ESD.

9.3.3.3.1 ESD Test Results

[

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Conclusion ESD

The ESD test was successful.

9.3.3.4 Surge Withstand Test (TP0406)

Power, electrical I/O signal lines, and hardwired communication cables may be exposed to high amplitude transient signals in the locations where control system hardware may be installed. These locations include an electrical equipment room and various other locations near the equipment under control. The test covered by this document injected a large amplitude surge waveform at specified points of the Test Specimen. The purpose of this test was to demonstrate that Test Specimen performance characteristics remained within acceptable limits during and after exposure to such discharges. The Test Specimen was powered on and running the TSAP when the test pulses were being applied to specific circuits in accordance with EPRI TR-107330.

9.3.3.4.1 Surge Withstand Test

General acceptance criteria are that the Test Specimen shall continue operating satisfactorily during and after application of the test input waveforms without disruption of backplane signals or other data that could disable the capability of generating a trip. Specific acceptance criteria for each component subjected to the surge waveform shall be as follows:

- Application of surge waveform shall not damage any module, component, or channel other than those specific modules or circuits subjected to the test waveform.
- Channels or modules other that the one under test shall continue to operate within normal accuracy limits for those modules during and after application of the test waveform.
- Failure of a single controller of the redundant pair will not be considered a failure condition if the backup controller assumes normal operation for the Test Specimen.

- Failure of the particular channel or circuit under test will not be considered a failure of the Test Specimen if the circuit (e.g., power module) is redundant, if the failure does not disrupt overall operation of the Test Specimen, or the failure does not propagate to other channels or circuits.

9.3.3.4.2 Surge Withstand Test Results

The Test Specimen met all acceptance criteria. Some components were damaged as the result of the test pulses, but those damages were limited to the specific components under test and the remainder of the system continued operating normally before, during, and after application of the test waveform. No failures propagated to other modules.

[

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Conclusion Surge Withstand Test

The HFC-6000 Test Specimen satisfactorily met all of the acceptance criteria for surge testing.

9.3.3.5 Seismic Tests (TP0405)

Seismic testing exposed the HFC-6000 Test Specimen to a set of dynamic spectra designed to simulate an Operating Basis Earthquake (OBE) and a Safety Shutdown Earthquake (SSE). This test spectrum defined by EPRI TR-107330 is shown in Figure 9.4. The dynamic spectra

consisted of tri-axial, random, multi frequency waveforms that were transmitted to the Test Specimen by means of hydraulic actuators attached to a Seismic Simulator Table. The overall scope of testing consisted of the following phases:

- Initial setup and pretest for equipment verification
- Low amplitude resonance search to identify critical frequencies below 100 Hz
- Five OBE
- One SSE
- Post seismic test inspection and operability test.

Various Operability and Prudency tests were run throughout the test sequence. Performance during these tests was monitored by a combination of:

- 24 accelerometers,
- The SOE logger with a total capacity of 48 digital points, and
- The HAS that has the capacity to log any point available from the operational data base of the controller

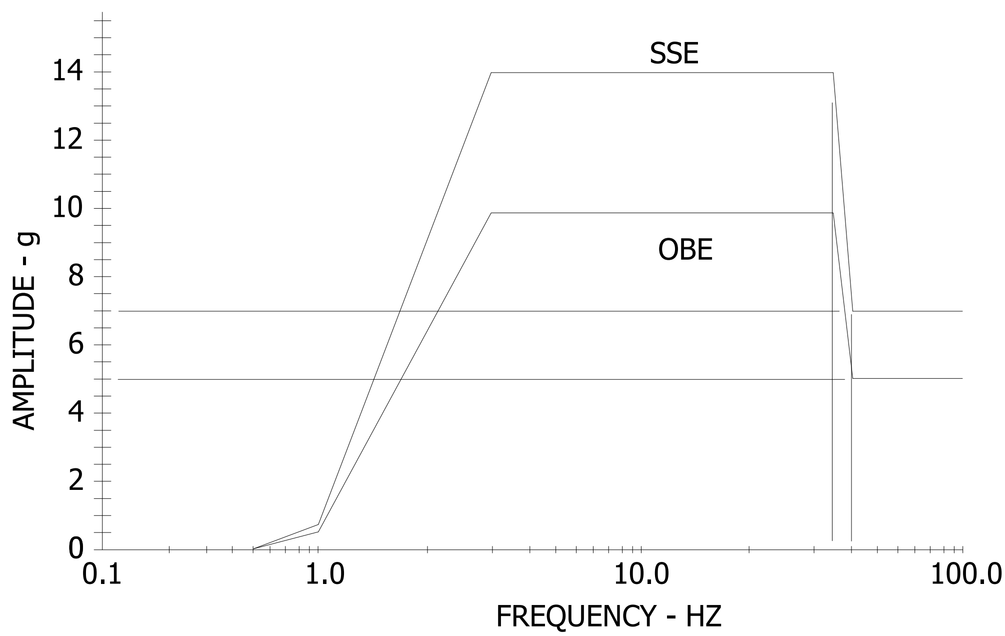

Figure 9-4 - Test Spectrum

A preliminary resonance test was conducted to determine if the Test Specimen components had any resonant frequencies within the RRS. The test was conducted by Wyle test personnel by imposing a low level sinusoidal sweep. If one or more resonant frequencies were detected, the Test Response Spectrum (TRS) was to be centered on the resonant frequency that produced the

maximum response in the Test Specimen. Overall requirements for the resonance search were governed by IEEE Std 344.

[

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9.3.3.5.1 Seismic Test Sequence

The initial seismic test was run after completion of the surge withstand test. According to the HFC qualification master test plan, the seismic test was scheduled to be conducted right after environmental test. The Seismic test was performed after the Surge Withstand test due to a Wyle scheduling conflict. This change of sequence did not result in any violation of the required standards.

HFC decided to repeat the entire seismic test because the Test Specimen experienced several anomalies and a fault in the data recorder resulted in incomplete data. The data recorder fault is test equipment and not part of the Test Specimen.

[

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Results of TSAP Validation Test (TP0408B)
[

]
All functional characteristics of the Test Specimen were found to be satisfactory.

Results of Operability Test (TP0402)

The Operability Test was repeated in its entirety after completion of the TSAP Validation Test. During execution of this test, every point configured for the HAS logger was verified, every manual test was run, and every automated test was run.

All analog points were verified to be within design tolerance. All automated tests were within the tolerance limits that had previously been identified. All functional tests were within the limits identified during the previous baseline test results.

Results of Prudency Tests (TP0403)

All of the Prudency tests were run at this time except for the Fault Tolerance test. The reconfigured Test Specimen successfully met all acceptance criteria.

Results of Seismic Test 2

The Test Specimen successfully withstood all seismic tests and continued to function normally. The overall system performance was within baseline tolerance limits with a limited number of minor anomalies. **[**

]

Conclusion

The Test Specimen was subjected to OBE and SSE test spectra up to the limit of the Wyle seismic simulator table (10 g maximum acceleration). [

]

9.3.3.6 Isolation Test

The scope of this Isolation Topical Report includes Class 1E isolation. Any module that meets Class 1E isolation requirements will also meet the less rigorous requirements for Non-Class 1E isolation.

The term "channel" and "channel to channel" in this section of the report means a "port" on an I/O module and "port to port" interactions on I/O modules. I/O modules will have multiple channels.

The HFC-6000 hardware may be installed both in an electrical equipment room and at various other locations near the equipment under control. When I/O chassis are physically located in a remote location with respect to the controller hardware, they will be connected to the controller by means of a dedicated Fiber Optic communication link. This link will provide the mechanism for ensuring physical and electrical isolation between the I/O modules and the controller.

Specific testing was performed to demonstrate two categories of Class 1E isolation:

- A fault on one channel of an I/O module will not effect the operation of other channels on the same module
- A fault on one channel of an I/O module will not effect the operation of other modules in the system

The tests addressed channel-to-channel isolation and channel to module isolation for each of the individual I/O module types. The primary purpose of these tests was to demonstrate immunity to faults on the inputs to the I/O modules. The test signals were applied to I/O channels both in the main chassis of Test Specimen and to remote I/O channels in the expansion rack. The general approach to testing consisted of two phases:

- First, selected channels were subjected to the maximum Class 1E isolation test signals. If the component under test exhibited acceptable isolation from other components within the system, application of additional test signals at lower fault levels was deemed unnecessary.

- If the component under test did not exhibit acceptable isolation in response to the initial maximum Class 1E test signal, additional testing at lower fault levels was conducted to determine the maximum test signal that could be applied to that type of channel without affecting performance of other portions of the Test Specimen.

The minimum acceptable level of channel-to-channel isolation for normal operation differs for each card type.[

]

9.3.3.6.1 Isolation Test Results

Acceptance criteria for Class 1E isolation is defined in EPRI-TR-107330 (4.6.4), IEEE Std 603, IEEE Std 384 and RG 1.75.

The isolation test results for the HFC-6000 I/O modules demonstrate that;

- No I/O channel other than the channel under test is affected by the test signal.
- No module other than the module under test is affected by the test signal.

The following I/O modules and qualification levels for channel to channel and module to module isolation resulted from the tests.

Isolation Test Results

Module	Type	Channel Isolation	Module Isolation
AI16F	4-20 mA AI	250 vdc, 40 vac	250 vdc, 283 vac

AI18M	RTD Input AI	250 vdc, 283 vac	250 vdc, 600 vac
DC34	48-vdc DI	250 vdc, 600 vac	250 vdc, 600 vac
DC33	48-vdc DI	250 vdc, 283 vac	250 vdc, 283 vac
DI16I	48-vdc	250 vdc, 600 vac	250 vdc, 600 vac
AI4K	Pulse Input	250 vdc, 600 vac	250 vdc, 600 vac
AO8F	Analog Output	250 vdc, 600 vac	250 vdc, 600 vac
DC33	AC Discrete Output	250 vdc, 283 vac	250 vdc, 283 vac
DC34	DC Discrete Output	250 vdc, 283 vac	250 vdc, 283 vac
DO8J	Relay Output	250 vdc, 600 vac	250 vdc, 600 vac

Conclusions

All HFC-6000 I/O modules tested met the acceptance criteria for isolation.

9.3.4 Post-Qualification Tests

The Post-Qualification Tests consisted of re-running the System Setup and Checkout, Operability, and Prudency Tests at HFC following the return of the equipment from Wyle labs after completion of the first round of qualification tests. The purpose of the Post-Qualification Tests is to prove that the HFC-6000 control system continued to operate properly after being subjected to the complete set of qualification tests.

All Operability tests, with the exception of the Power Quality Tolerance Test, were performed at the HFC site. All Prudency tests, with the exception of Serial Link Noise Test and Fault Simulation Test, were performed at the HFC site.

[

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9.3.4.1 Setup and Check-Out Test Results

All assemblies met the acceptance criteria for the set-up and check-out test.

9.3.4.1.1 Operability Test Results

The Test Specimen met defined acceptance criteria**[**

]

Analog I/O Modules Out of Calibration

This problem is discussed in subsection 9.3.2.1.1. All analog I/O channels were recalibrated and met the performance criteria prior to the seismic retest.

9.3.4.1.2 Prudency Test Results

The acceptance criteria defined for the Prudency tests were met**[**

]

Conclusions

HFC concludes that the Test Specimen continued to operate within acceptable criteria. The results of these tests replaced the data that had been lost during the prequalification test to provide the baseline for evaluation the qualification test results.

9.4 Conclusion

HFC has concluded that the HFC-6000 hardware as defined in the Test Specimen is suitable for use in nuclear safety-related applications. This hardware dedication is based upon the qualification test results and required functions of safety system.

10 Software Qualification

For more than 25 years HFC has provided safety critical digital control systems to industrial customers for critical applications where system quality, reliability and availability are key considerations. The digital software based platforms for these applications have a significant documented history of successful operation in these applications. HFC-6000 is the dedicated product line for safety related I&C platform applications for nuclear power plants. Software design and qualification are a critical aspect to the HFC dedication to high reliability and high availability systems. The basis for the qualification of safety related software for the HFC-6000 is taken from NUREG-0800, Chapter 7, Instrumentation and Controls. The HFC approach is also based on guidance provided in IEEE Std 7-4.3.2, BTP 7-14, EPRI TR-107330 and 106439. Compliance is demonstrated with 10 CFR Appendix B requirements with this approach.

The qualification process of HFC-6000 safety related software includes:

1. The dedication of Pre-Developed Software (PDS)
2. The development of any new controller software and I/O firmware
3. The development of application software

This report concentrates primarily on Type 1 software since all existing software in the scope of this report is PDS. However, the process for the development of any new software (Type 2 above) including application software (Type 3 above) is discussed later in this Section. The PDS encompasses all of the pre-developed Controller Software and the I/O firmware used by the HFC-6000. The PDS, including its documentation and development practices, were evaluated against regulatory criteria. The PDS operating history was evaluated and used as part of the COTS dedication process. This is discussed in more detail below.

Types 2 and 3 software or firmware has the same development process in accordance with the existing HFC quality procedures and work instructions. HFC accepts that the PDS may change in the future and that any changes made to PDS will need to follow current development requirements and guidance. The actual plant specific application software defined by future plant specified requirements and plant specific qualification will be performed at a later date. The process for development of Type 2 and Type 3 software is defined in this Section. The HFC process for this software is in accordance with the life cycle guidance presented in BTP 7-14, RG 1.152 which endorses IEEE Std 7-4.3.2 and Chapter 7 of the SRP.

The process for software design, testing and configuration management for all HFC-6000 safety related software, legacy and new safety related software, is defined in this Section.

10.1 The Dedication of Pre-Developed Software (PDS)

10.1.1 Software Commercial Grade Dedication Overview

The pre-developed software (PDS) implemented in the HFC-6000 digital platform is used in previous HFC product lines and is currently in operation at many sites both nuclear and non-nuclear. HFC-6000 controller software and PDS I/O firmware are based upon what HFC used in the ECS-1200 product lines (models -02, -03, -04 and -05). The ECS product line had its beginning in 1982 and was modernized and improved to its final stage in 1996. Each subsequent ECS software revision more closely replicates the HFC-6000 Software and Firmware. HFC has records for all of the changes and evaluations that have been performed to date. HFC maintains a library for this software/firmware including all revisions made to date.**[**

]

Figure 10-1 - Software Commercial Grade Dedication

The Sections below provide additional details on the PDS dedication process that creates the equivalent level of assurance required by NRC.

10.1.1.1 Verification of Software Documentation

The design evaluation reviewed the product's suitability for nuclear safety-grade applications, including the examination of failure modes, evaluation of the design process and review of the documentation. **[**

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10.1.1.2 Documentation Evaluation

[

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10.1.1.3 Software and Validation Testing Program

HFC determined that supplemental testing for the existing PDS needed to be performed to provide further evidence of product quality and suitability for dedication for safety-grade application. [

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Please refer to section 10.1.3 for a detailed description.

10.1.1.4 Operating History Evaluation

The software components to be utilized in the HFC-6000 safety applications were identified and the related operating history was evaluated. The evaluation of the operating history demonstrated that the software has significant experience in critical application, including Korean nuclear power plants. The software has been reliable for a long period of time with very few defects, supporting the conclusion that the inherent quality makes the software suitable for dedication for use in nuclear safety applications. The defects are discussed in the Table of operating history. Furthermore, it was concluded that the operating conditions in Korean plants were either similar to or even identical to the operating conditions that will be seen in US nuclear plants. The HFC-6000 software is an evolutionary product and, as a result, there have been

varied changes over the 20 plus years of history to this PDS. Each of these changes has been evaluated and the determination made that they did not alter the functional requirements or the basic architecture of the OS. All changes were minimal with impacts determined to be negligible. The HFC development and change process is strictly controlled and its integration into hardware is thoroughly tested. This is discussed further in section 10.1.4. The defects noted above are also discussed in the Operating History Section 10.1.4

10.1.2 Verification of Software and Documentation

HFC-6000 PDS is a field-proven commercial grade software product. The software is defined as "software components" and is used by related "hardware components". Table 1.1 of this report provides a listing of the HFC-6000 hardware within the scope of this report. The software components reside on the hardware modules within this list.

10.1.2.1 Software Requirements

The requirements of the PDS software modules were documented in the Requirement Specification for HFC-6000 modules during the software dedication process.**[**

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10.1.2.2 Software Design Specification

The HFC-6000 documentation scheme has a four layer arrangement; they are 1) Top Level, 2) Module Level, 3) Module Detail Level, and 4) Component Level. All dedicated software components require a complete design specification to illustrate the detail design of the software. The hardware specific software is defined in the higher level hardware module or module detail design specification. Software design specifications are provided in the HFC-6000 Product Line Documents set.

10.1.2.3 Software Dedication Process

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10.1.2.4 Source Code Inspection

To support the software dedication process, HFC performed a complete source code inspection of the PDS. The goal of this inspection was to detect specific types of faults, violations with coding standards, and to verify the correctness of the code. This effort was a complement to the dynamic testing that was performed later. This code inspection effort is performed to complement the initial software design process and provides a different reviewer's perspective who can detect fault information overlooked by initial software design; and not detected in the initial dynamic testing. The code inspection is also used to develop additional test cases for future dynamic testing.[

]
In summary, the code inspection examined the program designs and its interactions to determine consistency with the functional requirements. This analysis also targeted the design structure, logic and the data structures. The translation of the design into software code and standard compliance were part of the static analysis. Discrepancies were identified and corrections were made to the source code. The detailed code inspection process and the results are discussed in the HFC Code Inspection Report.

10.1.3 Software Validation and Testing Program

Software Testing was performed in the following series of tests.

10.1.3.1 Application Software Object Tests

In this section the term "application software" means operating software objects associated with the systems level functions of the controller. Plant specific application code is not included in this report and review.

A comprehensive Application Object Test (AOT) was conducted on the HFC-6000 product line. This included all software components that have a direct impact on the application code or that can be accessed by application code while it is running on the system processor of the HFC-SBC06 controller module. Such software components are designated as Application Software Objects (ASO). The scope of this testing included both normal operations and exceptional conditions for the following ASOs:
[

]
During compilation of the application object, the offline compiler generates error reports if any errors occur. Any compiling errors will be identified before the object code to be executed in the controller is generated. Only the successful compiled application object is used to test with the controller module.

All tests required by the test procedure have been completed and all acceptance criteria have been met. The ASO test reports were reviewed and documented with no error reports.

10.1.3.2 Software Component Tests

A software component can be a software routine, function, task, operating system or sets of software files. All identified software components are PDS software that are classified as such and placed into the HFC software library. These software components are used in various hardware modules across the HFC product lines.

Software component tests were conducted on the software components that are used in the HFC-6000 product line. Software component testing activities included determining the features to be tested, designing test cases, designing the test set up and the test environment, identifying acceptance and rejection criteria, executing the tasks, analyzing test results and reporting. A test design is based on the software functions described in the PDS documentation or the HFC-6000 product requirement specification. Test inputs were defined during design of the test cases and the expected outputs were determined. Since most of the software components are part of the printed circuit board firmware, software component testing is mostly low level code testing using an emulator to create a simulation testing environment. Test software including one or more software components were run on a representative hardware platform.
[

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All major software components were tested and test reports were reviewed and documented. No critical defects were detected during these tests.

10.1.3.3 Functional Tests

The purpose of functional testing is to test the functionality of hardware modules and associated software components. The function test procedures and acceptance criteria were based on the requirement specifications. Functional testing was performed with the final release version of software. Any calibration sequences needed were included in the functional testing as a pre-set up.

All HFC-6000 hardware modules have gone through functional tests after production.[

]

All functional tests for the qualification software were completed and all acceptance criteria have been met. Test reports were reviewed and documented.

10.1.4 HFC-6000 Operating History

10.1.4.1 Operating History Background and Evaluation Approach

The HFC systems and the associated hardware and software have extensive operating history. HFC has concluded that high reliability hardware components and software modules are demonstrated in the historic operation of the HFC systems in the installed base.
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The operating history evaluation is directed primarily at the controller software and I/O firmware. Critical defects are also evaluated for the software design.

The Operating History evaluation process included:

- Calculate the total hours of operation per software component type
- Define the critical software defects that occurred during the stated time period
- Calculate the critical software defects per hour of operation
- Evaluate the critical defects to show whether or not they would have an impact on the safety functions of the software module

10.1.4.2 HFC Product Lines

HFC has three product lines which are applicable to the operating history evaluation. They are:

AFS-1000	Boiler Safety and Nuclear Safety I &C system
ECS-1200	Plant Control System
HFC-6000	Nuclear Safety I &C system

The HFC-6000 product line incorporates many of the hardware and software features of the AFS-1000 and ECS-1200 product lines.[

]

10.1.4.3 Product line History

The AFS-1000 architecture is employed primarily for applications that employ single loop control of field equipment with its local I/O modules library. The product has been used for boiler safety applications. The ECS-1200 architecture is employed primarily for multi-loop Plant Control System (PCS) applications. The I/O modules can be connected either locally or remotely through RS-485 serial communication. Both product lines have extensive operating histories.

10.1.4.3.1 AFS-1000 Product line History

The following table illustrates the HFC AFS-1000 product line history.

Table 10-1 – AFS-1000 Product line history

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10.1.4.3.2 ECS-1200 Product line History

The following table illustrates the HFC ECS-1200 product line history.

Table 10-2 – ECS-1200 Product line history

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10.1.4.4 Relationship of HFC-6000 product line to the AFS-1000 product line

Table 10-1 shows the relationship of the HFC-6000 to the AFS-1000 product line. The software of the two product lines is essentially the same design with the exceptions of different coding for the earlier versions of the microprocessors**.** However, the HFC-6000 inherited not only the special I/O circuitry for nuclear safety I &C system but also the control system logics were merged into HFC control algorithms as the base of critical mission control algorithms.**[**

]Any changes made to HFC-6000 software will be made under the new process conforming to full safety quality requirements.

10.1.4.5 Relationship of HFC-6000 product line to the ECS-1200 product line

Table 10-2 shows that the HFC-6000 hardware and software are essentially identical to the existing ECS-1200 product line with the exception of changes in the form factor.[

]

Table 10-2 also shows that the basic system software modules used in the HFC-6000 are the subset of basic system software modules that have been used in the ECS-1200. This includes the operating system, controller, communications and I/O software.

10.1.4.6 ECS-1200 Operating History

As discussed above, the HFC-6000 is a technology extension of the ECS-1200 using the same basic hardware components with form factor changes and with no changes in the basic system software modules.[

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Table 10-3 - Key ECS-1200 Installations

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10.1.4.7 Module Operating Years (TMOY) calculation

The total module operating years (TMOY) for each module type has been calculated. This TMOY calculation applies to hardware modules and the associated software modules. An associated software module is the software contained in, and required to support a given hardware module.

For each module, the total module operating years (TMOY) is calculated by summing the plant module operating years (PMOY) and then summing these to reach the TMOY.

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10.1.4.7.1 Assumptions for TMOY Calculation

The following Assumptions were used in the calculations. The assumptions assure that only models with software identical to the HFC-6000 are considered in the evaluation.

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Table 10-4 - TMOY Calculation

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10.1.4.8 Determination on Critical/Non-critical Software Defects

Critical software defects are defined as “defects in the basic system software that prevent the associated hardware module from processing inputs and obtaining correct actuation outputs.”
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Table 10-5 - Operating history and defect hours

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10.1.4.9 Conclusions of defect analysis

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As a result, the summary of operating history for HFC-6000 application shows that, there have been no relevant critical software defects on any operating site for the ECS-1200 system since 1995.

10.1.4.10 Summary of Operating History

The evaluation of the operating history for HFC-6000 software components are based upon the real plant operating hours of existing ECS-1200 and applicable AFS-1000 control systems.

- AFS-1000 pre AFS-SBC-05 control systems (before 1995)

  The excellent operating history of AFS-1000 systems provides the qualitative proof of the HFC design and application engineering process.**[**

  ]
- AFS-1000 SBC-05 control systems

  The AFS-1000 SBC-05 had been used as the upgrade path for older AFS-1000 product line.**[**

  ]

- ECS-1200 Control System

  The HFC-6000 software components are a subset of the ECS-1200 product line software. The operating history of the ECS-1200 control system has been used in the calculation of the TMOY. Based upon the above evaluation process and calculation, it proves the excellent reliability of these software components (The defect per hour data is from 2.44 E-08 to 3.9 E-08 and all were non-critical defects).

10.1.5 Software Operation and Maintenance

The HFC Software Operation and Maintenance program is applicable for both PDS and the application software for the HFC-6000 control system.

Figure 10-2 illustrates the quality control process of the HFC-6000 software.
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Figure 10-2 - Software Operation and Maintenance

The operation and maintenance of HFC-6000 software is regulated by HF Controls Software Configuration Management (SCM) procedures and work instructions. The SCM identifies and dedicates the software components for the HF Controls product line. The identified SCM software components include source codes and executable codes.**[**

]The HFC SCM phases follow the applicable guidance in RG 1.169, IEEE Std 829 and IEEE Std 1042. The HFC SCM is applied to both PDS and new software.

10.1.5.1 Error Detection

HF Controls Corrective Action Program provides the governing procedure for HFC-6000 software error resolution tracking. Once the HF Controls software had been released, a Conditional Report (CR) is required when problems, non-conformances or conditions adverse to quality are discovered. This error detection and corrective process are implemented at the HF Control facility during factory testing and continuously at customer sites.

The Condition Review Group (CRG) is a management group consisting of as a minimum, Project Managers, QA Manager, Director of Operations and applicable Engineering Managers. This group meets on a regular basis. They are responsible for determining the category of Condition Reports, assignment of an appropriate manager responsible for the correction, and establishing the estimated completion date.

The responsible manager responds to the assigned CR with a problem investigation, and solution evaluation. The process of the error detection, dispositions and corrective actions are tracked by the Corrective Action Program. For critical errors, such as a software malfunction, impact to the

operation of customers, in addition to error solution tracking and a root cause analysis is required to prevent the similar issue happen in the future.

10.1.5.2 Error Correction Change Control

The change control process of software is managed through the HFC SCM procedures and the Change Control Tracker tools. This mechanism assures that the change process of the software component is accurately tracked at any given time. This change control software process provides the capability for using the HF Controls corporate network to "submit" change requests to the Software Management Team (SMT) and to record impacted component, implementation approval and implementation sign off process. It also provides connections between the change process and Version Manager utility software for component version control.

10.1.5.2.1 Change Management Levels of Authority

The manager of Development Engineering is the Category Owner (CO) and has the responsibility to handle the SCM activities of HFC-6000 software components regarding change request and impact analysis.

Once a change has been approved, the CO assigns one or more technically qualified individuals to implement the change. The implementation of the Software Change Request (SCR) shall be reviewed and approved by the CO and members of the Software Management Team (SMT). The members of the SMT include the senior management of engineering, the manager of QA and the V & V team leader.

10.1.5.2.2 Software Change Request (SCR)

The following table illustrates the complete cycle of the software change process.

Table 10-6 - Software Change Process

Step	Responsible Person	Actions
1	SCR Originator	1. Open, Edit & Submit SCR with ID 2. Notify Category Owner
2	Category Owner	1. Complete the impact analysis 2. Notify the Software Management Team for implementation approval
3	Software Management Team	1. Approve the change request 2. Notify Category Owner
4	Category Owner	1. Assign implementation engineer 2. Change Implementation Process, validation and review 3. Notify for implementation sign off
5	Software Management	1. Signoff implemented change

	Team	2. Notify Category Owner
6	Category Owner	1. Sign off SCR 2. Submit documents

10.1.5.2.3 Audits and Reviews

Both internal and external audits of the SCM process are performed. The QA Representative and V&V team perform the Internal Audits.

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]

Reviews shall be conducted throughout the project life cycle phases. Various reviews are defined in the HF Controls ISO Design Review procedure.

10.1.5.3 Training

The HFC Department of Customer Care is the organization that oversees training including schedules and resources. The training facility includes the HFC-6000 safety platform qualification test bed and simulation equipment. HFC performs training courses includes system hardware, software, application programming, tools and system maintenance and trouble shooting. The simulation equipment with pre-fabricated programs can be used as either close loop or open loop tests. The service engineers of the Customer Care Department can also perform on-site training courses. A Software Training manual has been written that discusses HFC training processes.

10.1.5.4 Customer Reporting

HFC has QA procedures in place to provide HFC personnel with instructions relative to documenting, evaluating and reporting problems associated with the design, fabrication, assembly, testing and installation of nuclear related plant equipment in compliance with the reporting requirements of the Nuclear Regulatory Commission (NRC) Code of Federal Regulations (CFR) Title 10, Part 21, “Reporting of Defects and Noncompliance.”

10.1.5.5 QA & CR Process

The HFC Quality Assurance Program Manual (QAPM) describes the Quality Assurance Program at HFC. The program is designed to provide administrative measures and procedures necessary for assuring that all HFC hardware and software products as well as any services meet or exceed customer requirements and applicable industry codes and standards. This Quality Program is designed to comply with ANSI/ASME NQA-1&1a-1994; *Quality Assurance Requirements for Nuclear Facilities*, (Basic Requirements) ANSI/ASME NQA-1a-1995

Addenda, 10 CFR 50 Appendix B; "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants", ISO 9001:2000, and 10CFR Part 21.

HFC's specific goals and objectives are to provide to our customers: 1) Quality products with no defects or failures, 2) Products delivered on or prior to the promised date 3) Continuous improvement of products and processes and 4) Services that exceed customer expectations. HFC also commits to continually broaden the knowledge base of our employees and services within a safe work environment.

The requirements of this manual apply to all activities affecting the quality of products and services provided and performed by HFC. HFC personnel at every level of the organization are required to fully support the HFC QA Program, achieve a high level of excellence through the application of proven technology in their respective areas of responsibility, and promote an atmosphere of continuous improvement.

Contractual arrangements between the customer and HFC, which specify requirements in addition to those specified by this Quality Program, are applied at the project level providing such requirements do not compromise the quality of our service or this Quality Program.

All non-conformance issues are handled through the Condition Report (CR) system as the control and tracking tool. The implementation of software changes as the solution for CR is handled in accordance with HFC software configuration management procedure and work instructions.

10.2 Safety Related Software Development

Any new software development process for the HFC-6000 is in accordance with the current HFC quality procedures and work instructions and follows the life-cycle guidance contained in BTP 7-14. All new software including the application software is controlled by this process once it is designated as safety related.

10.2.1 Software Development Life Cycle

Newly developed software will require V&V during each phase of development. Criteria for qualification of critical components are governed by the following standards:

- IEEE Std 1012-1998 provides the documentation requirements for V&V of both critical and non-critical components of software systems.
- IEEE Std 7-4.3.2-2003 provides additional guidance and standards for qualifying digital computer systems for use in safety systems of nuclear power plants.
- IEEE Std 603-1991 provides requirements for general qualification standards for digital systems to be used as part of a nuclear safety system.

- Regulatory Guide 1.168 augments guidance of IEEE Std 1012 for V&V of digital computer software used in safety systems of nuclear power systems.
- BTP 7-14 Provide Software Life Cycle guidance

RG 1.173 and IEEE Std 1074 provide a structured approach for the development of the HFC-6000 software life cycle program. HFC requires an orderly structure to the entire software design and implementation life cycle process. HFC's software life cycle addresses the issues and concerns of the requisite standards. The Software Life Cycle process that HFC uses provides the necessary framework for the HFC-6000 software project so that activities can be mapped. With this mapping, a concurrent execution of related activities can occur and staged checkpoints are available at which characteristics of certain activities can be verified.

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Table 10-7 - Life-Cycle Phase Cross-Reference Chart

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HFC's software test methods and procedures, tests conform to the guidance contained in RG 1.171. The software tests are performed and the results are required to meet test objectives within the pre-established criteria for the new software. HFC's software unit test methods and procedures, tests conform to the guidance contained in RG 1.172. The unit tests are performed and the results should meet all test objectives within the pre-established criteria for new software.

10.2.2 Life-Cycle Verification and Validation

This section defines the processes for new software/firmware development which includes all application software and any new modifications to the controller software and I/O firmware in accordance with BTP 7-14, IEEE Std 7-4.3.2 and IEEE Std 1012. The SVVP provides a detailed plan for each of the HFC-6000 system life-cycle phases. The following major topics apply to each phase of the life cycle.

- **V&V Tasks**. The V&V tasks constitute the activities of the V&V function throughout the software development life cycle. Depending on the particular life-cycle phase, these tasks may consist of generating plans, test procedures, and test cases or of using the previously generated plans and tests to evaluate particular new software components. The definition of V & V tasks are based on the tasks defined by IEEE Std 1012-1998 and Regulatory Guide 1.168 for safety system software.
- **Methods and Criteria**. These topics relate to the means by which particular software components are evaluated and the basis for pass/fail judgments.**[**

  ]
- **Inputs/Outputs.[**

  ]

The HFC V&V activities continue throughout the duration of product development project and nuclear system application project. For product development projects, V&V activities essentially end when the product is released for production. The HFC Software V&V Plan defines all V & V activities to be conducted for both a product development project and an application project.

10.2.2.1 Project Planning Phase

The primary guiding document for product development projects is the Product Development Plan (WI-ENG-11). A Project Quality Plan (QPP 2.1) provides the corresponding function for application projects. However, both product development and application projects begin with the existing HFC product lines as the starting design basis. **[**

]

10.2.2.2 Requirement Phase

The requirements phase of the project life cycle is the period during which specific functional, performance, and other requirements are identified and allocated to specific components. Detailed coverage for activities during this phase is provided by the following:

- QPP 5.2, "Preparation of Procedures"
- WI-ENG-002, "Design Inputs"
- WI-ENG-100, "Engineering Processes"
- WI-ENG-104, "Development of Hardware Requirements Specifications"
- WI-ENG-202, "Development of Software/Firmware Requirements Specifications"

In addition to the above work instructions that apply to all projects, a nuclear safety-related project may also require development of an Abnormal Conditions and Effects (ACE) list and requirements for remediation. This activity will be accomplished in accordance with specific contract requirements for such projects.

Task Inputs	Task Outputs
• Project Development Plan or Project Quality Plan • HFC V&V Program • Customer Specification • HFC Work Instructions • Qualification requirements defined by regulatory or industry standards	Requirements Specifications Document Reviews Traceability Analysis ACE List

10.2.2.3 Design Phase

During the design phase, component requirements are converted into the detailed design for individual components, for a product line, or for a specific control system composed of standard components. **[**

]
There are separate procedures for product development and application development.

10.2.2.3.1 Product Development Project

During this phase of a product development project, the defined design inputs are used to create a new design for a new standard HFC hardware or software product. All product development projects will be accomplished in accordance with Appendix B and NQA1 requirements. Detailed guidance for activities during this phase is provided by the following:

- QPP 5.2, "Preparation of Procedures"
- WI-ENG-001, "Design Verification and Reviews"
- WI-ENG-106, "Development of Hardware Design Specifications"
- WI-ENG-203, "Development of Software/Firmware Design Specification"

In addition to the above work instructions that apply to all product development projects, initial planning for product qualification begins at this stage of the lifecycle. Traceability analysis and evaluation of ACE immunity is undertaken as part of the review process for the completed design.

Task Inputs	Task Outputs
• Project Development Plan • Requirements Specification • Customer Specification • HFC Work Instructions • ACE List	Requirements Specifications Hardware Schematic Diagrams Traceability Analysis Design Review FMEA (if required) Qualification Test Plan (if required) Qualification Test Procedures (if required)

10.2.2.3.2 Application Development Project

During this phase of an application development project, plant specific functional requirements are used to develop the application software.**[**

]

Task Inputs	Task Outputs
• Project Quality Plan • Requirements Specification • Customer Specification • HFC Work Instructions • ACE List (if required)	Design Arrangement Drawings Schematic Diagrams Component Design and Assembly Drawings Logic Diagrams User Interface Design Traceability Analysis Design Review FMEA (if required)

10.2.2.4 Implementation Phase

The implementation phase of the life cycle is that period during which hardware components are fabricated and software code is developed. As before, different sequences are followed for product development and application projects.

10.2.2.4.1 Product Development Project

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Task Inputs	Task Outputs
• Project Development Plan • Design Specification • HFC Work Instructions • Engineering Drawings • Prototype Validation Test • ACE List (if required)	Traceability Analysis Design Review Prototype Test Report CR for nonconformance Qualification Test Report(s) FMEA Report (if required)

10.2.2.4.2 Application Project

Implementation for an application project consists of building the hardware designs and coding the software/firmware for that design. **[**

]

10.2.2.5 Integration and Testing Phase

This is the phase of an application project during which a complete control system is integrated together and tested as a unit. QC inspection of shop floor activities continues throughout this period, and generic integration/acceptance testing verifies system functional characteristics. **[**

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Task Inputs	Task Outputs
• Project Quality Plan • HFC Work Instructions • Engineering Drawings • Process Control Sheets • System Acceptance Test Procedure • Test Procedures	Traceability Analysis Test Reports CR for nonconformance

10.2.2.6 Deployment

After completion of acceptance testing, the product (individual hardware or software components or a completely integrated control system) is shipped for onsite installation. **[**

]

Task Inputs	Task Outputs
• Project Quality Plan • Customer PO • Engineering Drawings • Project-Specific Test Procedure	System and Component Documentation Installation Test Report (if required)

10.2.2.7 Operation and Maintenance

Following delivery and onsite acceptance of a control system, the customer normally assumes responsibility for operation and the regular preventive maintenance of the system. HFC does provide field service and spare part support for all customers. HFC also supports 10 CFR Part 21 reporting and record keeping for nuclear projects. These activities are performed in accordance with;

- QPP 16.3, “10 CFR Part 21 Reporting”
- QPP 20.1, “Servicing and Customer-Supplied Products”
- WI-CUST-001, “After Market Service Activities”
- WI-CUST-002, “Return Material Authorization”

10.2.3 V&V REPORTING

V&V activities are conducted using the guidance provided in IEEE Std 1012 and RG 1.168 for the lifecycle phases for both product development and application projects. As each task is accomplished, the individual responsible for executing that task is responsible for producing a

written report that identifies what was done and describes any discrepancies that may have been detected. These reports constitute the objective evidence that the V&V task was completed and provide the mechanism for initiating remedial activities, if necessary.

10.2.3.1 V&V Task Report

V&V tasks include phased reviews of documents, tests, and analyses covering the software process. Each review and each formal test includes a report form that provides a mechanism for recording results and any observed discrepancies. Both review documents and test result forms are designated as Quality records and will be retained by Document Control. V&V task reports that are developed are supplied to the V&V Team Leader and will provide the basis for generating the System V&V Report. HFC policy is that the V&V Team Leader responsibility is independent of the design and development responsibly.. The person assigned to a specific V&V activity shall not have been involved in the associated design activity.

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10.2.3.2 V&V Analysis Report

A separate report is generated to cover each phase conducted during the course of the software process. **[**

]

Any abnormal conditions or findings that are adverse to quality or safety are reported in a Condition Report (CR).

10.2.3.3 Software V&V Report

The Software V&V Report (SVVR) is a formal summary document that describes V&V activities conducted throughout a particular project. When a project requires formal submittal of V&V reports, the content of the individual V&V task reports will be summarized on a phase-by-phase basis and supplied to the customer and maintained in the HFC library. This report is intended to provide objective evidence of the oversight and review/approval activities conducted throughout the project.

10.2.3.4 Condition Reports

A separate Condition Report (CR) shall be created for each distinct discrepancy or for a group of related discrepancies between observed task results and expected results. As a minimum, the person having primary responsibility for performing a particular task shall report all

discrepancies detected while performing that task. Other HFC personnel or customer personnel may report perceived deficiencies apart from any specific test, test procedure or test case. Any discrepancy (practice, condition, or malfunction) detrimental to quality shall be reported on a CR in accordance with HFC procedure QPP 16.1, "Corrective Action Program." All CRs shall be reviewed and tracked in accordance with QPP 16.1.

10.2.3.5 Final V&V Report

When a project requires formal V&V reporting as a deliverable item, the final V&V Report shall constitute the final submittal of the SVVR. **[**

]

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 13, 2015

Mr. Allen Hsu
HF Controls Corporation
1624 West Crosby Road
Suite 124
Carrollton, TX 75006

SUBJECT: SAFETY EVALUATION FOR THE CLOSEOUT OF OPEN ITEMS RELATED TO DOOSAN HF CONTROL CORPORATION TOPICAL REPORT PP901-000-01, REVISION C, "HFC-6000 SAFETY SYSTEM" (TAC NO. ME7577)

Dear Mr. Hsu:

On April 27, 2011, the U.S. Nuclear Regulatory Commission (NRC) staff issued a Safety Evaluation (SE) for the Doosan HF Controls Corporation (HFC), "HFC-6000 Safety System" Topical Report (TR) PP901-000-01, Rev. C (Agencywide Documents Access and Management System (ADAMS) Accession No. ML110831017), for the HFC-6000 platform for use in digital upgrades in nuclear power plants. The SE included the identification of six generic open items (GOIs) related to equipment qualification.

By letter dated February 18, 2015, a NRC draft SE regarding our approval of the HFC TR was provided for your review and comment (ADAMS Accession No. ML15005A379). HFC did not have any comments on the draft SE.

Based on its review of the information submitted by HFC, the NRC staff finds the TR acceptable for referencing subject to the limitations specified in the TR and in the NRC SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review ensures that the material presented applies to the specific plant involved. License amendment requests that deviate from the TR are subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that HFC publish accepted versions of each TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed final SEs after the title page. Also, the accepted version must contain historical review information, including NRC requests for additional information (RAI) and your responses after the title page. The accepted version shall include an "-A" (designating accepted) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, HFC and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

If you have any questions or need additional information, please feel free to contact the NRC project manager, Mr. Joseph Holonich, at 301-415-7297.

Sincerely,

Mirela Gavrilas, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 731

Enclosure:
Safety Evaluation

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE U.S. NUCLEAR REGULATORY COMMISSION STAFF RELATED TO THE CLOSEOUT OF GENERIC OPEN ITEMS FOR THE DOOSAN HF CONTROL CORP. TOPICAL REPORT PP901-000-01, REVISION C, "HFC-6000 SAFETY SYSTEM" (TAC NO. ME7577)

1.0 INTRODUCTION

On April 27, 2011, the U.S. Nuclear Regulatory Commission (NRC) staff issued a Safety Evaluation (SE) for the Doosan HF Controls Corporation (HFC) "HFC-6000 Safety System" Topical Report (TR) PP901-000-01, Rev. C (Agencywide Documents Access and Management System (ADAMS) Accession No. ML110831017), for the HFC-6000 Platform for use in digital upgrades in nuclear power plants. The SE included the identification of six generic open items (GOIs) related to equipment qualification.

The HFC-6000 test specimen was retested to resolve the GOIs. In its letter dated June 29, 2011, HFC submitted "Request for Amendment to HFC-6000 Safety Evaluation Report (TAC No. MD8462)" (ADAMS Accession No. ML11199A098), which contains summary test reports of the retested HFC-6000 test specimen and requested closure of the GOIs.

In a letter dated April 11, 2014 (ADAMS Accession No. ML14041A002), the NRC staff transmitted requests for additional information (RAIs) to HFC. By letters dated April 30 and December 4, 2014 (ADAMS Accession Nos. ML14134A069 and ML14349A403), HFC submitted responses to the RAIs.

2.0 REGULATORY EVALUATION

Section 3.3 of the April 27, 2011, SE (Reference 1) addresses the environmental qualification of the HFC-6000 platform.

Two objectives of environmental qualification testing for a safety system are: (1) to demonstrate the system will not experience failures due to abnormal service conditions of temperature, humidity, electrical power, radiation, electromagnetic interference (EMI), radio frequency interference (RFI), power surge, electrostatic discharge, or seismic vibration, and (2) to verify those tests meet the plant-specific requirements.

Criteria for environmental qualification of safety-related equipment are provided in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena," and GDC 4, "Environmental and Dynamic Effects Design Bases." Additionally, 10 CFR 50.55a(h), "Protection and Safety Systems," incorporates by reference the requirements of the Institute of Electrical & Electronics Engineers (IEEE) Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," which addresses both system-level design issues and quality criteria for

qualifying devices. Regulatory Guide (RG) 1.209, "Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants," endorses and provides guidance for compliance with IEEE Std 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," for qualification of safety-related computer-based instrumentation and control (I&C) systems installed in mild environment locations.

To comply with the requirements of GDC 4, 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," and IEEE Std. 603-1991, an applicant must demonstrate through environmental qualification that I&C systems meet design basis and performance requirements when the equipment is exposed to normal and adverse environments.

Electric Power Research Institute (EPRI) TR-107330, "Generic Requirements Specification for Qualifying a Commercially Available PLC [programmable logic controller] for Safety-Related Applications in Nuclear Power Plants," which was accepted by NRC SE dated July 30, 1998, presents a specification in the form of a set of requirements to be applied to the generic qualification of PLCs for application and modification to safety-related I&C systems in nuclear power plants. It is intended to provide a qualification envelope corresponding to a mild environment that should meet regulatory acceptance criteria for a wide range of plant-specific safety-related applications. The qualification envelope is established by compliance with the guidance of EPRI TR-107330 and consists of the maximum (i.e., extremes) environmental and service conditions for which qualification was validated, and the range of performance characteristics for the PLC platform that were demonstrated under exposure to stress conditions. Any plant-specific application is obligated to verify that the qualification envelope provided by qualification to the guidance of EPRI TR-107330 bounds the requirements of the application.

3.0 TECHNICAL EVALUATION

The qualification program developed for the HFC-6000 platform addressed environmental qualification for a mild, controlled environment. The basis for the testing program was conformance with the guidance contained in EPRI TR-107330. The results of the qualification program establish the qualification envelope of the HFC-6000 platform. The testing program was conducted on a type test specimen (ERD111 test specimen) composed of HFC-6000 modules configured into a representative system to execute a test system application program (TSAP). The testing program was designed to demonstrate the capability of the ERD111 test specimen to: (1) perform defined design functions within specified tolerances under normal environmental and operating conditions, and (2) perform design functions within specified tolerances under stress conditions, as specified in EPRI TR-107330, Section 6, "Qualification Testing and Analysis."

In the SE dated April 27, 2011 (Reference 1), the NRC staff determined that acceptable qualification of the HFC-6000 was demonstrated for radiation, power surge, electrostatic discharge, and seismic withstand capabilities. In addition, the NRC staff concluded that electromagnetic compatibility (EMC) qualification for radiated magnetic field, low frequency conducted interference, and high frequency conducted interference emissions had been

demonstrated. Finally, the NRC staff found that the HFC-6000 platform demonstrated acceptable isolation among signal channels and input/output (I/O) modules within a safety-related system.

In Section 5.1 of the April 27, 2011, SE (Reference 1), the NRC staff identified six GOIs which must be resolved to establish acceptability of the platform for general use in implementing safety-related applications at nuclear power plants. The principal GOI, GOI number 1, relates to adequately demonstrating environmental qualification of the HFC-6000 platform for environmental stress and EMC. The subsequent GOIs, GOI number 2 thru GOI number 6, constitute corresponding elements of the HFC qualification program that require further evidence to acceptably demonstrate qualification of the platform in terms of performance characteristics and the testing envelope. The six GOIs are:

1. *HFC has committed to conducting a retest of both environmental stress withstand and EMI/RFI immunity capabilities of the HFC-6000 platform to demonstrate generic environmental qualification for temperature and humidity exposure and EMC (Reference 106). Submission of additional testing results or other comparable evidence for review is necessary to demonstrate environmental qualification of the HFC-6000 platform under the generic environmental and EM service conditions defined in EPRI TR-107330. The NRC staff review of environmental qualification of the HFC-6000 platform is discussed in Section 3.3 of this SE.*

2. *The qualification testing conducted for the HFC-6000 platform does not establish qualification of the hardware watchdog timer for the HFC-SBC06 controller module under the service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component. The NRC staff review of the scope of the HFC qualification program is discussed in Section 3.3.1 of this SE.*

3. *The qualification testing for the HFC-6000 platform does not establish qualification of the HFC-AI16F module under the environmental stress or EMI/RFI conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component. The NRC staff review of the establishment of a baseline performance envelope under the HFC qualification program is discussed in Section 3.3.2 of this SE.*

4. *The qualification testing for the HFC-6000 platform does not establish qualification of analog response time performance when the platform is subjected to the environmental extremes of the generic service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of the analog response time for the HFC-6000 platform as part of a comprehensive, credible qualified performance envelope. The NRC staff review of the establishment of a baseline performance envelope under the HFC qualification program is discussed in Section 3.3.2 of this SE.*

5. *The qualification testing for the HFC-6000 platform does not demonstrate an environmental stress withstand capability for several key performance characteristics*

that are necessary to establish suitability of the platform for use in safety-related applications. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of the HFC-6000 platform under the environmental stress conditions defined in EPRI TR-107330. The NRC staff review of the environmental stress (i.e., temperature and humidity) withstand testing under the HFC qualification program is discussed in Section 3.3.3 of this SE.

6. *The qualification testing for the HFC-6000 platform does not demonstrate EMC qualification:*

   - *For radiated electric field emissions from 10 kHz to 10 GHz. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate acceptable control of high frequency radiated emissions and establish EMC qualification of the HFC-6000 platform for radiated electric field emissions. The NRC staff review of EM emissions testing under the HFC qualification program is discussed in Section 3.3.5.1 of this SE.*

   - *For radiated electric field (high frequency) interference, high frequency conducted interference, and low frequency conducted interference. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity to radiated electric fields, low frequency conducted interference, and high frequency conducted interference. The NRC staff review of EMI/RFI susceptibility testing under the HFC qualification program is discussed in Section 3.3.5.2 of this SE.*

   - *For radiated susceptibility over the frequency range from 1 GHz to 10 GHz and conducted susceptibility of signal leads. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity of signal lines to low frequency conducted interference and high frequency conducted interference and platform immunity to very high frequency radiated electric field interference. The NRC staff review of EMI/RFI susceptibility testing under the HFC qualification program is discussed in Section 3.3.5.2 of this SE.*

The NRC staff reviewed the ERD111 test specimen equipment qualification retest summary report (Reference 7), detailed test reports (References 8, 9, 10, 11, and 12), and RAI responses (References 4, 5, and 6) submitted by HFC. The staff reviewed test procedures and tests results contained in several tables and graphs, and evaluated them using the guidance in EPRI TR-107330 and RG 1.180. The staff evaluation of HFC's documentation that described the resolution of the six GOIs is given below.

3.1 Generic Open Item 1

In the SE dated April 27, 2011 (Reference 1), the NRC staff concluded that qualification had not been adequately demonstrated for an environmental stress withstand capability (i.e., qualification for temperature and humidity). Additionally, the NRC staff found that EMC qualification had not been adequately established for radiated and conducted susceptibility or for radiated electric field emissions. HFC decided to conduct a retest of both environmental stress withstand capability and EMI/RFI immunity of the HFC-6000 platform.

HFC performed an environmental stress retest of the HFC-6000 platform at the Environmental Testing Laboratory in Dallas, Texas in July 2010. An EMI/RFI retest was performed at Nemko USA in Lewisville, Texas and at the HFC facility in Carrollton, Texas in the third quarter of 2010.

HFC submitted both proprietary and non-proprietary versions of the following test documents:

- RR901-001-04 Rev. A, HFC-6000 Safety Platform, ERD111 Control System, Equipment Qualification Retest Summary Report (Reference 7),
- TR901-200-02 Rev. A, HFC-6000 Safety Platform, ERD111 Control System Test Specimen, Pre-Qualification before Retest Detail Report (Reference 8),
- TR901-200-03 Rev. A, HFC-6000 Qualifying System, ERD111, Environmental Stress Retest Detail Report (Reference 9),
- TR901-200-04 Rev. A, HFC-6000 Qualifying System, ERD111, EMI/RFI Retest Detail Report (Reference 10), and
- TR901-200-05 Rev. A, HFC-6000 Control System, ERD111- Control System Qualification Project, Post-Qualification after Retest Detail Report (Reference 11).

HFC states the ERD111 test specimen was running a TSAP throughout the test period, and its operation was monitored by sequence of events (SOEs) and Historical Archiving System (HAS) data loggers located outside the test chamber. Table 2 of RR901-001-04, Rev. A (Reference 7), lists the HFC-6000 modules installed in the ERD111 test specimen. Modules listed in bold fonts indicate that they are listed in the SE dated April 27, 2011 (Reference 1).

The NRC staff noticed in the figure on page 5 of 5 of Attachment 7.1 of RR901-001-04, Rev. A (Reference 7), that the environmental stress test conducted by Environmental Testing Laboratory only maintained conditions of 40 degrees Fahrenheit and 5 percent relative humidity for 4 hours, as opposed to at least 8 hours as specified in EPRI TR-107330. In a letter dated April 11, 2014 (Reference 3), the NRC staff requested additional information to clarify the qualification of the HFC-6000 platform under environmental stress conditions different than those conditions defined in EPRI TR-107330. By letter dated April 30, 2014 (Reference 5), the HFC response stated that the figure the NRC staff was referencing was for a different test required by IEC 61508 certification of a subsystem in the test set; HFC referred the NRC staff to Figure 5 of TR901-200-03, Rev. A (Reference 9), which shows that the 40 degrees Fahrenheit and 5 percent relative humidity conditions were maintained for at least 8 hours, as specified in EPRI TR-107330. The NRC staff finds that the low temperature/low humidity portion of the environmental stress test was performed appropriately.

The NRC staff has reviewed the test reports for the environmental-stress withstand and EMI/RFI immunity capabilities of the retested ERD111 test specimen, and finds HFC has submitted sufficient test documentation to demonstrate environmental qualification of the HFC-6000 platform under the generic environmental and EMC service conditions defined in EPRI TR-107330. This closes GOI 1.

3.2 Generic Open Item 2

To address GOI 2, HFC added a watchdog timer detection test, "Test of Failure to Complete Scan," to the operability test sets. The test was designed to failover from the primary controller to the secondary controller once the primary controller does not stroke the watchdog timer for one complete scan cycle, which is 100 milliseconds (ms). When the test is initiated, the algorithm forces the application program to enter an infinite loop. When the primary controller detects failure to complete scan status, it activates an alarm flag and forces failover to the secondary controller. Because it takes one complete scan cycle, 100 ms, for the watchdog timer to timeout, the failover to the secondary controller has to occur within the next scan cycle, or less than 200 ms from the time the infinite loop starts for the detection time to be valid.

This watchdog timer detection test was performed during pre-qualification (Reference 8), environmental stress (during the high temperature and high humidity phase) (Reference 9), and post-qualification (Reference 11) test phases. The environmental stress test results show that the detection time was less than 2 scan cycles, which is 200 ms. These results were consistent with the pre-qualification and post-qualification test results.

The NRC staff has reviewed the environmental stress test results for the HFC-6000 HFC-SBC06 controller module hardware watchdog timer, and finds that the watchdog timer has been qualified under the service conditions defined in EPRI TR-107330. This closes GOI 2.

3.3 Generic Open Item 3

3.3.1 Environmental Stress

Section 3.3.2 of RR901-001-04, Rev. A (Reference 7), contains the acceptance criteria for the environmental stress qualification tests. For the analog input (AI), the acceptance criteria is ±0.35 percent accuracy over the entire range per EPRI TR-107330. Table 3 of RR901-001-04, Rev. A (Reference 7), shows the accuracy of the HFC-AI16F module measured during the pre-qualification, environmental-stress, back-to-ambient, and post-qualification test phases.

Section 4.1.1.1 of TR901-200-03, Rev. A (Reference 9), provides the environmental stress retest results for the HFC-AI16F module. The AI channel for HFC-AI16F was monitored throughout the operability tests performed at the end of the high-temperature/high-humidity stress period, at the end of the low-temperature/low-humidity stress period, and after returning to ambient conditions.

The HFC-AI16F module exhibited some increase in error magnitude during the temperature stress conditions - the maximum error occurring during the low-temperature/low-humidity phase. However, the measured accuracy of the HFC-AI16F module was within the acceptance criteria

of ±0.35 percent of span over the entire range. Therefore, the NRC staff finds that the HFC-AI16F module meets the acceptance criteria of accuracy in an environmental stress profile in accordance with EPRI TR-107330.

3.3.2 EMI/RFI Conditions

Section 4.3.7 of EPRI TR-107330 identifies the EMI/RFI susceptibility and emissions withstand requirements. For analog I/O levels, the accuracy shall not vary more than ±3 percent. The HFC-AI16F analog input module underwent the following military standard (MIL-STD) radiated and conducted susceptibility tests, MIL-STD-461E: conducted susceptibility (CS) 101, CS114, CS115/Electrical Fast Transient (EFT), CS116, radiated susceptibility (RS) 101, and RS103.

The NRC staff noted on the RS101 test data sheet on RR901-001-04, Rev. A (Reference 7), that the test was not conducted for frequencies from 10 kHz to 100 kHz, as specified in RG 1.180. In letter dated April 11, 2014 (Reference 3), the NRC staff requested additional information to clarify the discrepancy in frequency limits. In letter dated April 30, 2014 (Reference 5) HFC responded that the data on RR901-001-04, Rev. A (Reference 7), had a recording error, and that the actual upper test limit was 100 kHz, not 10 kHz. HFC contacted Nemko USA to confirm the recording error and in a letter dated December 4, 2014 (Reference 6), provided a copy of the Nemko USA letter stating that instead of the actual 100 kHz frequency stop, 10 kHz was incorrectly written on the data sheet. The NRC finds that the RS101 test was performed appropriately.

The EMI/RFI test results for the HFC-AI16F module are contained in TR901-200-04, Rev. A (Reference 10). The maximum variation for each susceptibility test was recorded. For all conducted susceptibility tests and RS103 the maximum variation was well under ±3 percent. For the RS101 test, the maximum variation was -3.01 percent. This accuracy was for one of the eight locations where magnetic disturbances were generated (four on each side of the cabinet). For the RS101 test, the average accuracy for all eight locations is recorded as -0.03 percent. Additionally, HFC stated that all systems continued to execute with no anomalies. Although the maximum accuracy variation was at ±3 percent for the RS101 test, the system continued to function normally. The NRC staff finds that the HFC-AI16F module is not susceptible to radiated or conducted interference and meets the acceptance criteria in EPRI TR-107330.

The NRC staff has reviewed the environmental stress and EMI/RFI test results for the HFC-6000 HFC-AI16F module, and finds that the HFC-AI16F module has been qualified under the environmental stress and EMI/RFI conditions defined in EPRI TR-107330.
This closes GOI 3.

3.4 Generic Open Item 4

Section 3.3.2 of RR901-001-04, Rev. A (Reference 7), contains the acceptance criteria for the environmental-stress qualification tests. For analog response time the acceptance criteria is a response time of less than 300 ms from activation of a trip condition to output of a trip signal.

Table 4 of RR901-001-04, Rev. A (Reference 7), contains the average analog response time measured for the ERD111 test specimen during the pre-qualification, environmental (high-

temperature/high-humidity, low-temperature/low-humidity, and back-to-ambient conditions), and post-qualification test phases. The analog response time was less than 300 ms for all phases of the test.

The NRC staff reviewed the environmental-stress test results for the HFC-6000 platform analog response time, and finds that the qualification has been established for the analog response time performance when the platform is subjected to the environmental extremes of the generic service conditions defined in EPRI TR-107330. This closes GOI 4.

As noted in Section 3.3.2 of the SE dated April, 27, 2011 (Reference 1), the HFC-6000 platform still does not fully comply with the criterion of a 100 ms response time, as specified in Section 4.2.1, "General Functional Requirements," Item A, "Response Time," of EPRI TR-107330.

Additionally, Section 3.3.2 of the SE dated April, 27, 2011 (Reference 1), states, in part:

> *Nevertheless, the HFC-6000 platform has demonstrated a credible baseline capability for response time performance that can reasonably service safety functions (see Section 3.4 of this SE) pending analysis of the specific safety application ...*
>
> *The synthetic application program used for the qualification program is not intended to be an optimized code nor implement a simple safety function. It is noted that the actual response time for any particular system will depend upon the actual system configuration, and may vary significantly from simple to complex systems. Thus, the determination of the suitability of the HFC-6000 platform response time characteristics for a particular application is a plant-specific requirement and, therefore, is an ASAI that is subject to plant-specific review (see Section 5.2 of this SE). Thus, the capability of the HFC-6000 platform to satisfy application-specific requirements for system response time must be determined on a plant-specific basis in terms of the validated system design in relation to the accident analyses in Chapter 15 of the safety analysis report of the plant.*
>
> *The response time performance baseline is limited to the AI16F analog input module in combination with the DO8J digital output module and the DI16I digital input in combination with the DO8J digital output module. EPRI TR-107330 identifies performance criteria for a more expansive range of input-output module combinations. It is an ASAI to demonstrate acceptable response time for other input-output combinations as needed (see Section 5.2 of this SE).*

It is still an application-specific action item (ASAI) to determine the suitability of the HFC-6000 platform response time characteristics for a particular application, and to demonstrate acceptable response time for other input-output combinations as needed (see Section 5.2 of the SE dated April, 27, 2011(Reference 1)). This ASAI does not affect the closure of GOI 4.

3.5 Generic Open Item 5

Section 3.3.3 of the SE dated April, 27, 2011 (Reference 1), states that test results were not available to demonstrate that certain performance characteristics of the HFC-6000 platform

remained within the specified tolerances established in EPRI TR-107330. Specifically, the NRC staff review of the test summaries, addenda and corrections, and detailed records determined that qualification was not demonstrated for the following key performance characteristics:

- I/O accuracy (HFC-AI16F, HFC-AI8M, and HFC-AI4K modules)
- Analog response time
- Digital response time
- Communication operability (Communication-Link (C-Link), intercommunication link (ICL))
- Power interruption tolerance (power hold up capability)
- Power quality tolerance

Section 3.3.2 of RR901-001-04, Rev. A (Reference 7), contains the following acceptance criteria for the environmental stress qualification operability tests:

- Analog Input Accuracy (4 to 20 mA) - ±0.35 percent accuracy over the entire range
- Analog Response Time - Within the baseline acceptance range less than 300ms
- Digital Response Time - Within the baseline acceptance range less than 100ms
- Communication Operability - No communication errors which lead to loss of packets
- Power Interruption - All performance data shall not be impacted by the power interruption
- Power Quality - All performance data shall not be impacted before the drop of power lead to power outage

Environmental-stress qualification for these performance characteristics is discussed below.

3.5.1 I/O Accuracy (HFC-AI16F, HFC-AI8M, and HFC-AI4K modules)

3.5.1.1 HFC-AI16F module (Analog Input Card (4 to 20 mA))

The NRC staff reviewed HFC-AI16F accuracy under environmental stress conditions in GOI 3 (see section 3.3.1 of this SE), and finds that it meets the acceptance criteria of accuracy in an environmental stress profile in accordance with EPRI TR-107330.

3.5.1.2 HFC-AI8M module (Resistance Temperature Detector (RTD) Input Card, 100 ohm)

Section 4.3.2.1.3 of EPRI TR-107330 specifies that the RTD input accuracy shall be equal or less than ±2 degrees Celsius over the range of environmental operating conditions. Section 4.1.1.3 of TR901-200-03, Rev. A (Reference 9), contains the test results for the HFC-AI8M module. The accuracy of the RTD input card remained within ±2 degrees Celsius during high temperature/high humidity and low temperature/low humidity conditions, thus meeting the requirements of EPRI TR-107330.

3.5.1.3 HFC-AI4K module (Pulse Input Card)

Section 4.3.2.3.1 of EPRI TR-107330 specifies that the pulse input accuracy shall be equal to or less than 0.1 percent over the range of environmental operating conditions. Section 4.1.1.4 of

TR901-200-03, Rev. A (Reference 9), contains the test results for the HFC-AI4K module. The accuracy of the pulse input card remained within 0.1 percent during high-temperature/high-humidity and low-temperature/low-humidity conditions, thus meeting the requirements of EPRI TR-107330.

3.5.2 Analog Response Time

The NRC staff has reviewed the environmental-stress test results for the HFC-6000 platform analog response time in GOI 4 (see section 3.4 of this SE), and finds that the qualification has been established for the analog response time performance when the platform is subjected to the environmental extremes of the generic service conditions defined in EPRI TR-107330.

3.5.3 Digital Response Time

Table 5 of RR901-001-04, Rev. A (Reference 7), contains the average digital response time measured for the ERD111 test specimen during the pre-qualification, environmental-stress (high-temperature/high-humidity, low-temperature/low-humidity, and back-to-ambient conditions), and post-qualification test phases. The range of average response time is between 74 ms and 94 ms, which is within the acceptance criteria of less than 100ms, and meets the requirements of EPRI TR-107330.

3.5.4 Communication Operability (C-Link, ICL)

Section 4.1.4 of TR901-200-03, Rev. A (Reference 9), contains the test results for the ERD111 test specimen communication operability test. This test monitored the operation of the ICL and C-Link error counters during each phase of the environmental stress test. The acceptance criteria for this test are the system and both of its communication links continue operating without disruption before, during, and after application of the environmental stress conditions. The test method consisted of recording the count value of the error counters at the start and end of a test period and interpreting the total accumulated error count as the measure of communication reliability. The automatic tests were run to provide background activity for the communication test. HFC stated that error logs indicate that no C-Link and no ICL errors were logged during the test, and that nominal performance of the background tests indicate that the ERD111 test specimen continued operating reliably. The NRC staff finds that the system and both of its communication links meet the acceptance criteria for the communication operability test.

3.5.5 Power Interruption Tolerance (power hold up capability)

Section 4.1.9 of TR901-200-03, Rev. A (Reference 9), contains the results of the power interruption test performed on the ERD111 test specimen. This test subjects the system to a 40 ms interruption in source alternating current (AC) power to demonstrate the capability of the system to continue functional operation during switchover to a backup power source. The test was conducted during the high-temperature/high-humidity and low-temperature/low-humidity phases of the environmental test, as well as during pre-qualification and post-qualification test phases.

Section 4.6.1.1 of EPRI TR-107330 contains the PLC power sources and power supply requirements. It states that the holdup time for the power supplies shall be 40 ms on loss of AC power when the slots are loaded as above. During the 40 ms holdup time, the discrete I/O shall not change state, the analog I/O shall not change by more than 5 percent, and the processor shall not reset.

Consistent with the EPRI TR-107330 requirements, the following acceptance criteria were specified for the test:

- No controller resets
- No static digital output channel changes state
- No static analog output point changes its value by more than 5 percent
- Logged parameters for all of the automated tests remain within tolerance

The test results state that:

- No data disruption occurred during the high temperature/high humidity or the low temperature/low humidity execution of the test
- No changes in values of static points occurred
- The average analog output accuracy was within 5 percent
- Values for the automated digital and analog response time are comparable to those measured without the power interruption

The NRC staff finds that the ERD111 test specimen power interruption tolerance test meets the requirements of EPRI TR-107330.

3.5.6 Power Quality Tolerance

Section 4.1.10 of TR901-200-03, Rev. A (Reference 9), contains the results of the power quality tolerance test performed on the ERD111 test specimen. This test was executed at the end of the high-temperature/high-humidity period of the environmental-stress test, as specified in EPRI TR-107330. During this test, the voltage and frequency of the primary source power were varied over the limits of the ERD111 test system power supplies, and system performance was monitored. The test included three phases:

- Pretest - Source power was set to the normal level of 120 (volts of alternating current (vac) at 60 hertz (Hz). Automated accuracy, timer, and response time test were run, and selected static point values were monitored.
- Low voltage limit - Source power was set to 90 vac at 57 Hz and then to 90 vac and 63 Hz. Then the source voltage was reduced until the power supplies shut down. Automated accuracy and burst of events (BOE) tests were run and selected static points were monitored.
- High voltage - Source power was set to 150 vac at 57 Hz, to 150 vac and 63 Hz, and then back to 120 vac at 60 Hz. Automated accuracy and BOE tests were run and selected static points were monitored.

The automated accuracy tests of the analog cards were running during each phase of this test to measure system stability under varying states of supply power quality. The test results show that the analog input card (HFC-AI16F) had an accuracy within ±0.35 percent and the analog output card (HFC-AO8F) had an accuracy within ±0.32 percent, as required by EPRI TR-107330.

Based on the review of the HFC documentation of the temperature and humidity test results, the NRC staff determined that qualification of the HFC-6000 platform for environmental stress withstand has been acceptably demonstrated for the key performance characteristics identified above in GOI 5. This closes GOI 5.

3.6 Generic Open Item 6

The EMC qualification items of GOI 6 are discussed below.

3.6.1 Radiated electric field emissions from 10 kHz to 10 GHz (first bullet of GOI 6)

The objective of EMC emissions testing is to ensure that the new equipment will not interfere with the function or operation of existing power plant equipment. The guidance on emissions testing that the HFC-6000 platform is required to satisfy is given in Section 4.3.7, "EMI/RFI Withstand Requirements," of EPRI TR-107330, with reference to Section 7, "Plant and Equipment Emissions Limits," of EPRI TR-102323, Revision 1. EPRI TR-102323 identifies four MIL-STD tests to determine equipment emissions: Radiated Emissions (RE) 101, RE102, Conducted Emissions (CE) 101, and CE102.

The SE dated April, 27, 2011 (Reference 1), states that the HFC-6000 platform met the acceptance criteria for the RE101, CE101, and CE102 tests. However, in the same SE, the NRC staff determined that the HFC-6000 platform did not satisfy the acceptance criteria of the two guides (EPRI TR-107330 and EPRI TR-102323) for radiated electric field emissions due to excessive radiated emissions in the frequency range from 10 kHz to 1 GHz. Furthermore, no measurements were reported for radiated electric fields above 1 GHz, as specified in RG 1.180.

HFC stated in Section 4.1.4 of TR901-200-04, Rev. A (Reference 10) that radiated emission test RE102 was performed on the HFC-6000 platform in accordance with MIL-STD-461E and the required test spectrum in RG 1.180. The RE102 tests were completed on July 28, 2010.

Although the tests were conducted following the guidance of EPRI TR-102323, the analysis of the test results was based on the test limits from RG 1.180. The NRC staff finds this approach to be acceptable because the test methods from the two guides (EPRI TR-107330 and EPRI TR-102323) are equivalent (i.e., virtually identical versions of the same tests from different generations of the standard).

The NRC staff noted that the horizontal test was performed for frequencies of 30 MHz to 10 GHz, while the vertical test was performed for frequencies of 2 MHz to 10 GHz. In a letter dated April 11, 2014 (Reference 3), the NRC staff requested additional information to clarify the discrepancy in lower frequency limits between the vertical and horizontal tests. By letter dated April 30, 2014 (Reference 5), HFC responded that Section 3.4 of RG 1.180 specifies that at

frequencies above 30 MHz, the test method should be performed for both horizontally and vertically polarized fields. Since RG 1.180 does not specify that both horizontal and vertical polarized field tests are to be performed for frequencies below 30 MHz, HFC only performed the vertical polarized field test for 2 MHz to 30 MHz. The NRC staff finds this approach consistent with RG 1.180.

Section 4.1.4 of TR901-200-04, Rev. A (Reference 10) contains the RE102 test results for the ERD111 test specimen. The RE102 test results are within the RG 1.180 operating envelope.

Based on comparison of the test results against the limits from RG 1.180, the HFC-6000 platform met the acceptance criteria for the RE102 high frequency radiated emissions test.

3.6.2 Susceptibility to high frequency radiated electric field (second bullet of GOI 6), and Susceptibility to radiated electric field over the frequency range of 1 GHz to 10 GHz (third bullet of GOI 6)

The objective of EMC susceptibility testing is to ensure that equipment will function and operate as designed when installed in the EMC environment of a power plant. The guidance on susceptibility testing that the HFC-6000 platform is required to satisfy is given in Section 4.3.7 of EPRI TR-107330, with reference to Appendix B, "EMI Susceptibility Guide," of EPRI TR-102323, Revision 1.

EPRI TR-107330 identifies the following acceptance for EMI/RFI withstand testing:

- The main processor continues to function,
- I/O data transfer is not disrupted,
- Discrete I/O does not change state due to noise, and
- Analog I/O levels do not vary more than 3 percent.

RG 1.180 states that MIL-STD-461E RS103 test ensures that equipment and subsystems are not susceptible to radiated electric fields in the frequency range of 30 MHz to 1 GHz. This test is also applicable for frequencies above 1 GHz.

The information provided by HFC indicates test RS103 was performed on the ERD111 test specimen on August 2010. The electric fields of frequencies from 30 MHz to 10 GHz at 10 V/m were radiated in vertical and horizontal polarization from the rear side to the test specimen with the cabinet doors open. Sections 4.2.6 and 4.2.7 of TR901-200-04, Rev. A (Reference 10), contain the RS103 test results for the ERD111 test specimen. The analog I/O maximum variations were within ±3 percent accuracy, the analog and digital response times were under 300 ms and 100 ms, respectively, and no static I/O points were excited from their original states during testing.

Based on the NRC staff's review of the RS103 test results, the NRC staff finds that the HFC-6000 platform is not susceptible to radiated electric fields frequencies from 30 MHz to 10 GHz.

3.6.3 Susceptibility to high frequency conducted interference and low frequency conducted interference (second bullet of GOI 6)

RG 1.180 states that the baseline suite of tests for conducted EMI/RFI susceptibility along power leads consists of CS 101 and CS114. The low frequency conducted susceptibility test was performed between 30 Hz and 150 kHz. These test signals were injected directly into power leads of the ERD111 test specimen based on the CS101 test method. The high frequency conducted susceptibility tests were executed between 10 kHz and 30 MHz. These test signals were inductively coupled into the power leads of the ERD111 test specimen based on the CS114 test method.

As stated in RG 1.180, the CS101 test ensures that equipment and subsystems are not susceptible to EMI/RFI present on power leads in the frequency range 30 Hz to 150 kHz. The test is applicable to ac and dc input power leads, not including grounds and neutrals. The CS101 test results in Section 4.2.1 of TR901-200-04, Rev. A (Reference 10), show that the ERD111 test specimen met the test acceptance criteria: the analog I/O cards' accuracy was within ±3 percent, the average analog response time was under 300 ms, and the average digital response time was under 100 ms.

Based on the NRC staff's review of the test results provided, the NRC staff finds that the HFC-6000 platform is not susceptible to CS101 conductive interference and meets the test acceptance criteria.

As stated in RG 1.180, the CS114 test simulates currents that will be developed on leads as a result of EMI/RFI generated by antenna transmissions. The test covers the frequency range 10 kHz to 30 MHz and is applicable to all interconnecting leads, including the power leads of the equipment under test. The CS114 test can also be applied to assess signal line susceptibility.

Section 4.2.2 of TR901-200-04, Rev. A (Reference 10), contains the CS114 test results. The NRC staff noted that the CS114 test signal limit values were lower than the values in Figure 4.2 in RG 1.180. In letter dated April 11, 2014 (Reference 3), the NRC staff requested additional information to clarify the lower signal values used in the test. In a letter dated April 30, 2014 (Reference 5), HFC responded that due to the limitation of test equipment at the Nemko USA laboratory, the calibrated test signals could not reach the signals as depicted in Figure 4.2 in RG 1.180.

HFC contracted NTS Corporation at Plano, Texas to perform the CS114 tests again on the same set on April 25, 2014. The test signal limits shown in Figure 4.2 of RG 1.180 were used for this test. HFC submitted "NTS Report PR028559 - RG 1.180: Regulatory Guide 1.180 CS114 Susceptibility Tests on US NRC HFC-6000 Safety Qualification System Part Number: ERD111/ERD921," dated April 28, 2014 (Reference 12). The NTS CS114 test results show that the analog I/O cards' accuracy was within ±3 percent, the average analog response time was under 300 ms, and the average digital response time was under 100 ms. Thus, the ERD111 test specimen met the test acceptance criteria. Additionally, HFC stated that the ERD111 test specimen did not exhibit any malfunction or degradation of performance when subjected to the test signals.

Based on the NRC staff's review of the test results, the NRC staff finds the HFC-6000 platform not susceptible to CS114 conductive interference, and therefore meets the test acceptance criteria.

3.6.4 Susceptibility of signal leads to low frequency conducted interference and high frequency conducted interference (third bullet of GOI 6)

Regulatory Guide 1.180 states that MIL-STD-461E contains test methods that can be applied to address conducted susceptibility for interconnecting signal leads. The tests for conducted EMI/RFI susceptibility along signal leads are:

- CS114 - Conducted susceptibility, high-frequency, 10 kHz to 30 MHz
- CS115 - Conducted susceptibility, bulk cable injection, impulse excitation
- CS116 - Conducted susceptibility, damped sinusoidal transients, 10 kHz to 100 MHz

HFC states in Section 4.4.2 of RR901-001-04, Rev. A (Reference 7) that conducted susceptibility tests CS114, CS115/EFT were performed on the signal lines at the Nemko USA laboratory. Due to the time limit and schedule of using the Nemko USA laboratory, the CS116 tests were rescheduled and were executed at the HFC facility. When performing CS114 and CS116 tests, the signal lines were grouped into 3 bundles and each bundle was tested separately. All susceptibility tests performed with the required test signals operating at 100 percent signal strength.

As mentioned in Section 3.6.3 above, HFC contracted NTS Corporation to perform the CS114 tests again on April 25, 2014. The CS114 test is discussed in Section 3.6.3 above.

The CS115/EFT test verifies the compliance of the test specimen to repetitive EFTs/bursts, on supply, signal or control lines. Signal levels of 1kV and 2kV were used for this test. The CS115/EFT test results in Section 4.2.3 of TR901-200-04, Rev. A (Reference 10), show the ERD111 test specimen met the test acceptance criteria: the analog I/O cards' accuracy was within ±3 percent, the average analog response time was under 300 ms, and the average digital response time was under 100 ms.

Based on the NRC staff's review of the test results provided, the NRC staff finds the HFC-6000 platform is not susceptible to CS115/EFT conductive interference on the signal lines, and therefore meets the test acceptance criteria.

The CS116 test verifies the abilities of the test specimen to withstand damped sinusoidal transients coupled onto test specimen associated cables and power leads. The signal lines were grouped into 3 bundles. Each bundle was tested at 10kHz, 100kHz, 1MHz, 10MHz, 30MHz, and 100MHz damped sinusoidal transients.

The CS116 test results in Section 4.2.4 of TR901-200-04, Rev. A (Reference 10), show the ERD111 test specimen met the test acceptance criteria: the analog I/O cards' accuracy was within ±3 percent, the average analog response time was under 300 ms, and the average digital response time was under 100 ms.

Based on the NRC staff's review of the test results provided, the NRC staff finds the HFC-6000 platform is not susceptible to CS116 conductive interference on the signal lines and meets the test acceptance criteria.

In Section 5.0 of TR901-200-04, Rev. A (Reference 10), HFC summarizes the test results for the radiated and conducted susceptibility tests RS101, RS103, CS101, CS114, CS115/EFT, and CS116:

- All transitions of discrete I/O cards were detected and no anomalies occurred.
- Response time stayed within the acceptance limits as compared to the measurements without EMI/RFI disturbance.
- No outstanding errors in both C-Link and ICL communications.
- Time functions were within acceptance limits indicating the controllers were functioning correctly throughout the susceptibility tests.
- All BOE events were detected. Analog levels of I/O cards were within 3 percent accuracy. All transitions of discrete I/O driven by the BOE algorithm were detected.

The NRC staff has reviewed the EMI/RFI test results for the ERD111 test specimen, and finds the HFC-6000 platform has demonstrated EMC qualification in accordance with EPRI TR-107330 and RG 1.180. This closes GOI 6.

4.0 CONCLUSIONS

As described in the Section 3.0 of this SE, the NRC staff concludes that HFC has provided sufficient information to close GOIs 1 through 6. The NRC staff concludes that, when properly installed and used, the HFC-6000 platform is acceptable for safety-related use in nuclear power plants, subject to satisfactory licensee compliance with the Limitations and Conditions identified in Section 5.0 of the SE dated April, 27, 2011 (Reference 1).

5.0 REFERENCES

1. NRC letter to HF Controls Corp., "Final Safety Evaluation for the HFC-6000 Safety System Topical Report," April 27, 2011 (ADAMS Accession No. ML110831017)

2. HF Controls Corp. letter to NRC, "Request for Amendment to HFC-6000 Safety Evaluation Report (TAC No. MD8462)," June 29, 2011 (ADAMS Accession No. ML11199A098)

3. NRC letter to HF Controls Corp., "Request for Additional Information for Topical Report PP901-000-01, Revision C, "HFC-6000 Safety System" (TAC No. ME7577)," April 11, 2014 (ADAMS Accession No. ML14041A002)

4. HF Controls Corp. letter to NRC, "Responses to RAI (ML14041A002) in correspondence to HFC-6000 Amendment (ML11199A098) for Safety Evaluation (ML110831014) of Doosan HFC-6000 Safety System (TAC No. ME7577)," April 30, 2014 (ADAMS Accession No. ML14134A064)

5. Doosan HF Controls, "Responses to RAI (ML14041A002) from NRC in correspondence to HFC Amendment (ML11199A098) to Safety Evaluation (ML110831014)," RR901-001-05, Revision A, April 30, 2014 (ADAMS Accession No. ML14134A069)

6. HF Controls Corp. letter to NRC, "Response to RAI (ML 14041A002) in correspondence to HFC-6000 Amendment (ML11199A098) for Safety Evaluation (ML 110831014) of Doosan HFC-6000 Safety System (TAC No. ME7577)," December 4, 2014 (ADAMS Accession No. ML14349A403)

7. Doosan HF Controls, "HFC-6000 Safety Platform, ERD111 Control System, Equipment Qualification Retest Summary Report," RR901-001-04, Revision A, June 30, 2011 (ADAMS Accession No. ML11199A100)

8. Doosan HF Controls, "HFC-6000 Safety Platform, ERD111 Control System Test Specimen, Pre-Qualification before Retest Detail Report," TR901-200-02, Revision A, June 29, 2011 (ADAMS Accession No. ML11199A101)

9. Doosan HF Controls, "HFC-6000 Qualifying System, ERD111, Environmental Stress Retest Detail Report," TR901-200-03, Revision A, June 28, 2011 (ADAMS Accession No. ML11199A102)

10. Doosan HF Controls, "HFC-6000 Qualifying System, ERD111, EMI/RFI Retest Detail Report," TR901-200-04, Revision A, June 29, 2011 (ADAMS Accession No. ML11199A103)

11. Doosan HF Controls, "HFC-6000 Control System, ERD111- Control System Qualification Project, Post-Qualification after Retest Detail Report," TR901-200-05, Revision A, June 30, 2011 (ADAMS Accession No. ML11199A104)

12. NTS Report, "Regulatory Guide 1.180 CS114 Susceptibility Tests on US NRC HFC-6000 Safety Qualification System Part Number: ERD111/ERD921", PR028559 RG 1.180, April 28, 2014 (ADAMS Accession No. ML14134A065)

Principal Contributor: S. Darbali

Date: April 13, 2015

HF Controls

HFC-6000 Safety Platform
ERD111 Control System
Equipment Qualification Retest Summary Report

RR901-001-04 Rev. A

Effective Date: 6/30/2011

Prepared By: Ivan Chow

Reviewed By: Ed Herchenrader

Approved By: Allen Hsu

[ ]

Revision History

Date	Revision	Author	Changes
6/29/11	A	I. Chow	Initial Revision.

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1.0 Introduction

1.1 *Background*

Doosan HF Controls (HFC) HFC-6000 Safety Control System was approved by US Nuclear Regulatory Commission (NRC) in April 2011 as a qualified safety system to be used in US nuclear power plants. The HFC-6000 Safety Control System as described in HFC Topical Report PP901-000-01 was evaluated by the NRC in accordance with the provisions of Institute of Electrical and Electronics Engineers (IEEE) Standard (Std) 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," and IEEE Std 7-4.3.2-2003, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations," based on the guidance contained in NRC Standard Review Plan (SRP) Chapter 7, Appendix 7.1-C, "Guidance for Evaluation of Conformance to IEEE Std 603," and Appendix 7.1-D, "Guidance for Evaluation of the Application of IEEE Std 7-4.3.2," which provide acceptance criteria for these two standards. The NRC safety evaluation report (SER), ML110831017, concludes that HFC-6000 when properly installed and used, the HFC-6000 platform is acceptable for safety-related use in nuclear power plants with six open items listed. To resolve these open items, HFC retested the ERD111 test specimen as described in the SER. This document summarizes the retest results.

1.2 *Purpose and Scope*

In the HFC-6000 SER, there are 6 open items related to the equipment qualification tests. The followings are excerpts of the open items listed on page 186 to page 187 of the SER:

1. HFC has committed to conducting a retest of both environmental stress withstand and EMI/RFI immunity capabilities of the HFC-6000 platform to demonstrate generic environmental qualification for temperature and humidity exposure and EMC (Reference106). Submission of additional testing results or other comparable evidence for review is necessary to demonstrate environmental qualification of the HFC-6000 platform under the generic environmental and EM service conditions defined in EPRI TR-107330.

2. The qualification testing conducted for the HFC-6000 platform does not establish qualification of the hardware watchdog timer for the HFC-SBC06 controller module under the service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component.

3. The qualification testing for the HFC-6000 platform does not establish qualification of the HFC-AI16F module under the environmental stress or EMI/RFI conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component.

4. The qualification testing for the HFC-6000 platform does not establish qualification of analog response time performance when the platform is subjected to the environmental extremes of the generic service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence

for review is necessary to demonstrate qualification of the analog response time for the HFC-6000 platform as part of a comprehensive, credible qualified performance envelope.

5. The qualification testing for the HFC-6000 platform does not demonstrate an environmental stress withstand capability for several key performance characteristics that are necessary to establish suitability of the platform for use in safety-related applications. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of the HFC-6000 platform under the environmental stress conditions defined in EPRI TR-107330.

6. The qualification testing for the HFC-6000 platform does not demonstrate EMC qualification:

   - For radiated electric field emissions from 10 kHz to 10 GHz. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate acceptable control of high frequency radiated emissions and establish EMC qualification of the HFC-6000 platform for radiated electric field emissions.

   - For radiated electric field (high frequency) interference, high frequency conducted interference, and low frequency conducted interference. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity to radiated electric fields, low frequency conducted interference, and high frequency conducted interference.

   - For radiated susceptibility over the frequency range from 1 GHz to 10 GHz and conducted susceptibility of signal leads. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity of signal lines to low frequency conducted interference and high frequency conducted interference and platform immunity to very high frequency radiated electric field interference.

To address these open items, HFC performed a retest of the HFC-6000 platform with equipment listed in the SER for both environmental and EMI/RFI qualification tests. The tests were performed at Environmental Testing Laboratory and Nemko USA for environmental and EMI/RFI tests respectively. Although there were enhanced HFC-6000 PCBs installed in the cabinet which went through qualification tests, this document only focuses on the equipment listed in the SER to address the open items.

1.2.1 Environmental Stress Tests

For environmental stress tests, although there were other profiles applied on the ERD111 test specimen, this report focuses on the EPRI TR 107330 Figure 4-4 compliance test profile, see Figure 1.

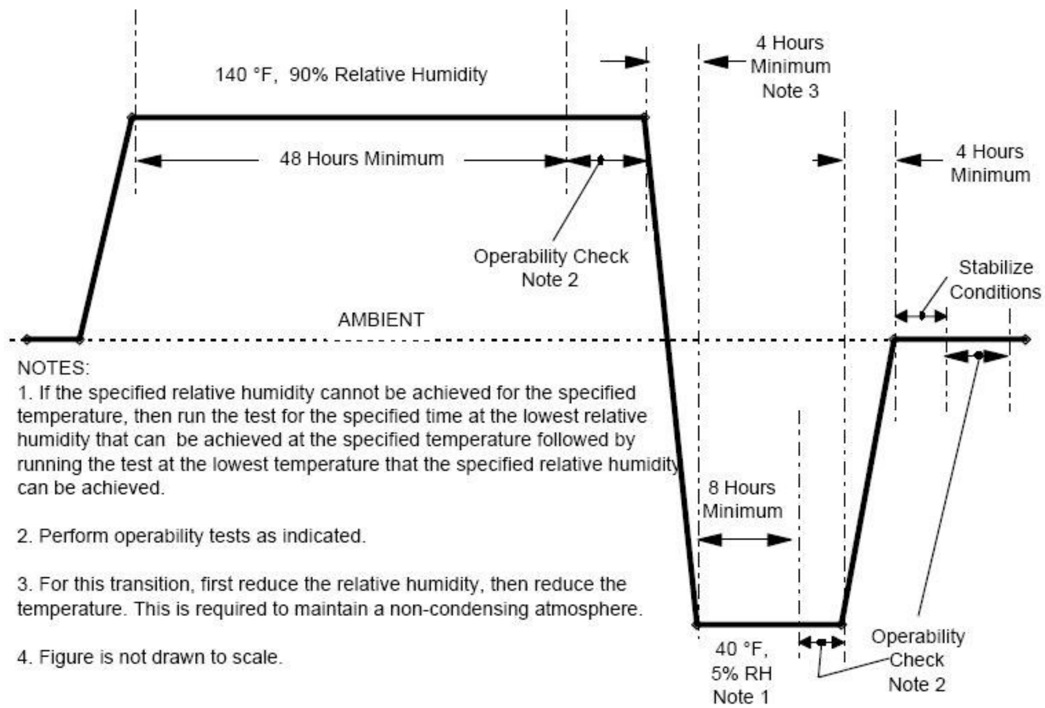

Figure 1 – EPRI TR 107330 Environment Stress Profile

Note: The black dots on the graph designate the operability check points required by the standard.

1.2.2 EMI/RFI Tests

On page 104 of the SER, it states that:

- "Based on the review of the of the test results and assessment of the testing approach, the NRC staff finds that the HFC-6000 platform meets the requirements for surge withstand capability specified in EPRI TR-107330 and is, therefore, acceptable for safety-related applications at nuclear power plants."
- "Based on view of the test procedure and results, the NRC staff concludes that the HFC-6000 platform met the ESD criteria of EPRI TR 107330."

Since the focus of this report is to address the open EMI/RFI items listed in the SER, although a complete set of EMI/RFI qualifications in accordance with NRC RG 1.180 was performed, the test results summarized in this document are limited to the related EMI/RFI tests performed on the ERD111 test specimen.

Table 1 – EMI/RFI Tests

Description	Testing Method (MIL-STD-461E)	Test Signal Range
Low Frequency Conducted Emission	CE101	60/120 Hz to 10 kHz
High Frequency Conducted Emission	CE102	10 kHz to 10 MHz
Low Frequency Radiated Emission	RE101	30 Hz to 100 kHz
High Frequency Radiated Emission	RE102	2 MHz to 10 GHz
Magnetic Field Radiated Susceptibility	RS101	30 Hz to 100 kHz
Electric Field Radiated Susceptibility	RS103	30 MHz to 10 GHz
Low Frequency Conducted Susceptibility (Power Lines)	CS101	30 Hz to 150 kHz
High Frequency Conducted Susceptibility (Power & Signal Lines)	CS114	10 kHz to 30 MHz
Conducted Susceptibility Bulk Injection (Signal Lines)	CS115	Electrical Fast Transfer
Conducted Susceptibility, Damped Sinusoidal Transient (Signal Lines)	CS116	10 kHz to 100 MHz

In addition, isolation tests in accordance with EPRI TR 107330 were performed to validate the Class 1E isolation of 250 vdc and 600 vac power limits are met for all modules.

2.0 References and Acronyms

2.1 *Industry References*

EPRI TR 107330	Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants, 1996
IEEE 603	IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations, 1991
IEEE 7-4.3.2	IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations, 2003
MIL-STD-461E	Department of Defense, Requirements for Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
NRC RG 1.180	Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems, 2003 R1

2.2 *References*

ML110831017	Safety Evaluation of HFC-6000 Safety Control System (NRC)
QPP 17.1	Quality Record
TP0402	ERD111 Operability Test, Rev. L
TP0403	ERD111 Prudency Tests, Rev. G
TR901-200-01	ERD111 Summary Report for Burn-In, Setup, TSAP for Environment & EMI/RFI Retest, Rev. A
TR901-200-02	ERD111 Pre-Qualification Before Retest Detail Report, Rev. A
TR901-200-03	ERD111 Environmental Stress Retest Detail Report, Rev. A
TR901-200-04	ERD111 EMI/RFI Retest Detail Report, Rev. A
TR901-200-05	ERD111 Post Qualification after Retest Detail Report, Rev. A
VV0414	ERD111 Master Configuration List, Rev. E
VV901-300-01	ERD111/ERD921 Qualification Master Test Plan, Rev B

2.3 *Acronyms*

EFT	Electrical Fast Transfer
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPRI	Electrical Power Research Institute
ERD111	Engineering Research and Development Project 111
ESD	Electrostatic Discharge
HAS	Historical Archiving System
HFC	Doosan HF Controls/HF Controls
NRC	Nuclear Regulatory Commission
PLC	Programmable Logic Controller
RFI	Radio Frequency Interference
RTD	Resistive Temperature Detector
SER	Safety Evaluation Report
SOE	Sequence of Events

3.0 Qualification Retest

3.1 *Test Sequences*

Although there are only a few environmental stress and EMI/RFI qualification tests related to the open items listed in the HFC-6000 SER, a complete qualification test sequence was performed. See Figure 2.

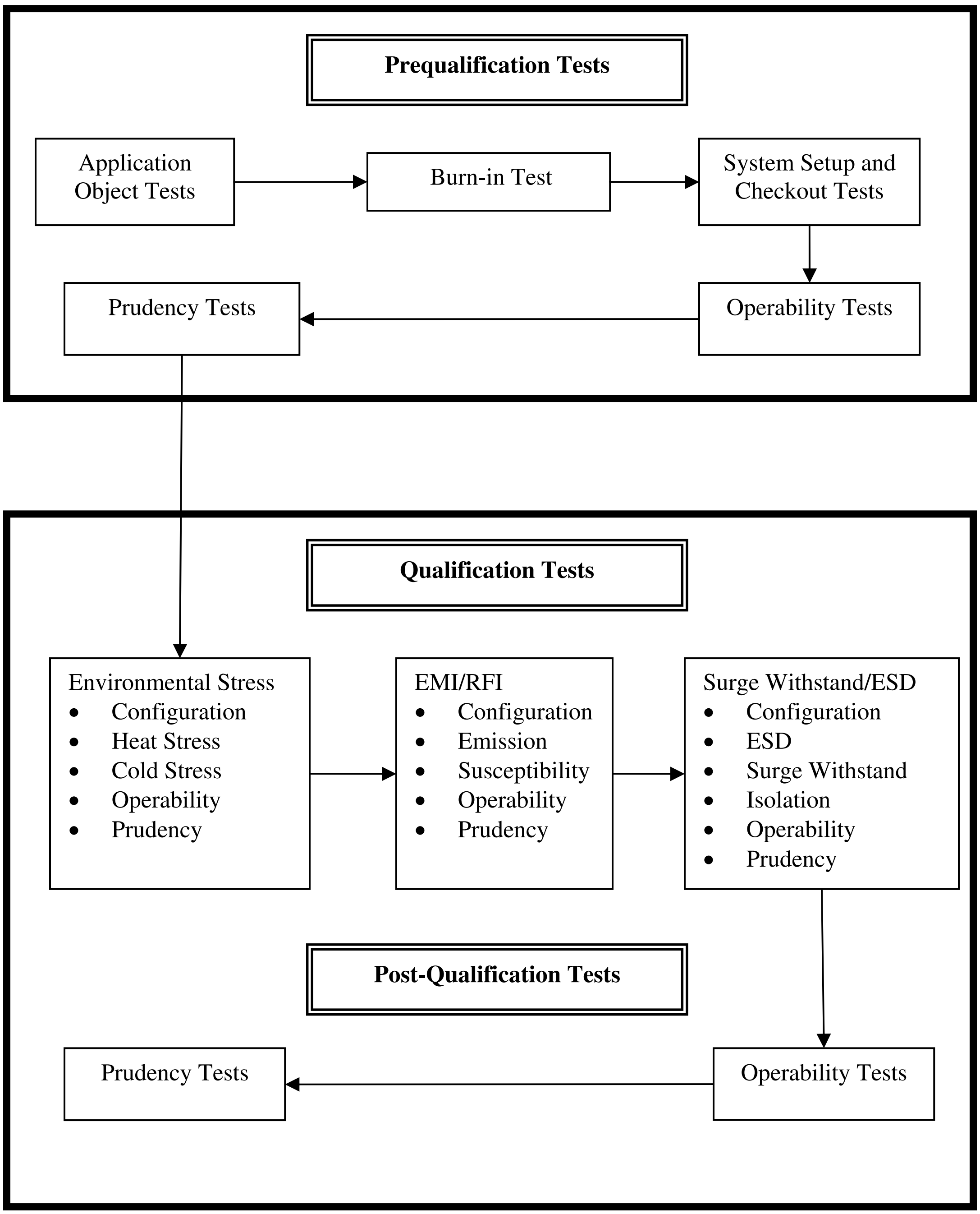

Figure 2 – Qualification Test Sequence

3.2 *Test Specimen Component List*

The HFC-6000 modules installed in the ERD111 test specimen are listed in Table 2. Modules listed in bold-faced fonts indicate that they are listed in HFC-6000 SER.

Table 2 – ERD111 Test Specimen HFC-6000 Modules

Quantity	Modular Type	Description
4	**PS, Jasper 24V**	**600W 24V Power Supply**
1	Rack, Jasper PS	8-slot Jasper PS Rack, 19"
2	HFC-FOT06	Fiber-Optic Transmitter
4	**HFC-ILR06**	**I/O Link Repeater/Terminator**
1	**HFC-BPC01-19**	**Controller Chassis backplane**
2	**HFC-BPE01-19**	**Expander Chassis backplane**
1	HFC-BPC03-08	3 Loop, 8 inch backplane
2	**HFC-SBC06**	**Main Controller**
1	**HFC-DPM06**	**Dual-Ported Memory**
2	HFC-SCG06	Communication Gateway
1	HFC-DPM06BP	Backplane Connected DPM06
1	HFC-DO16C	Solid State Output Card
2	**HFC-DC33**	**Special Function Card (120 vac output)**
4	**HFC-DC34**	**Special Function Card (125-vdc output)**
1	HFC-DC35	Special Function Card (120 vac output)
2	**HFC-AI4K**	**Pulse Input Card**
1	HFC-AI4K2	Pulse Input Card
1	**HFC-AI16F**	**Analog Input Card (4- to 20 mA)**
1	HFC-AI16FD	Analog Input Card (4- to 20 mA) (DSP)
2	**HFC-AO8F**	**Analog Output Card (4- to 20 mA)**
1	HFC-AI8LD	Thermocouple Input Card
1	**HFC-AI8M**	**RTD Input Card, 100 ohm**
4	HFC-AC36	Analog Input/Output Board
2	HFC-PCC06	Serial Channel Card
7	**HFC-DI16I**	**Digital Input Card with SOE**
1	**HFC-DO8J**	**Relay Output Card**
6	HFC-DO16J	Relay Output Card

Figure 3 shows the layout of the modules inside the qualification cabinet.

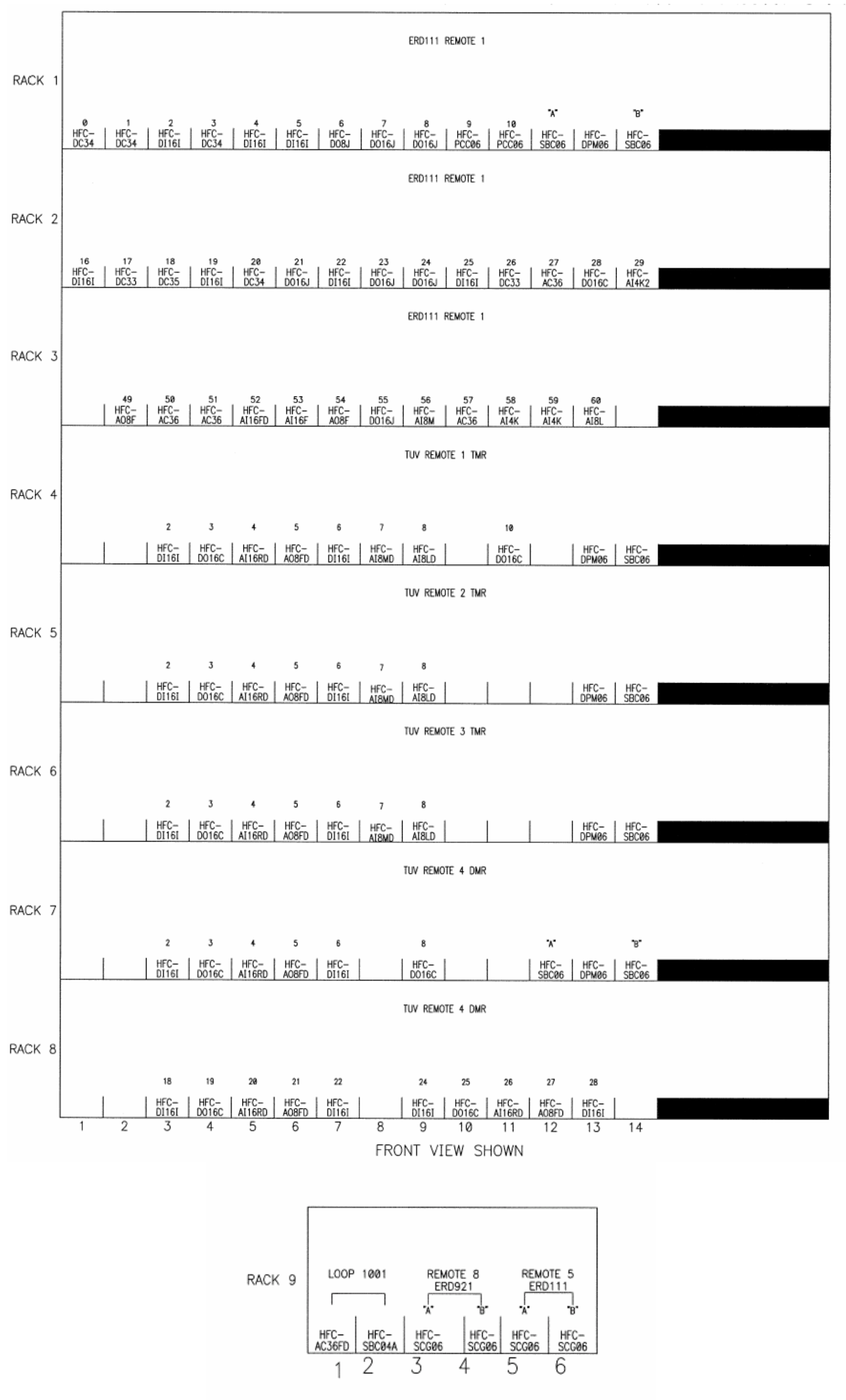

Figure 3 – Component Layout in the Cabinet

3.3 *Acceptance Criteria for Qualification Tests*

EPRI TR 107330 sections 5.3 and 5.4 provide the guideline for tests required for validating system functionality and performance. These tests are categorized into two groups: operability and prudencty tests. Refer to TP0402, ERD111 Operability Tests, and TP0403, ERD111 Prudency Tests for the details of these tests for the test specimen ERD111. The following section provides the summaries of the acceptance criteria for each qualification test phase.

3.3.1 Pre-Qualification Test

Before the test specimen is put into the qualification program, all components shall complete a consecutive 352 hours of burn-in tests. The application objects used in the system shall be validated. Checkout of the system shall be validated by integration test. The TSAP used for supporting the operability and prudency tests shall be validated. Performance data collected during the pre-qualification phase shall be used for establishing the baseline performance data for comparison in subsequent qualification tests.

3.3.2 Environmental Stress Qualification

For each operability check at the required checkpoints specified in Figure 1, test results shall demonstrate the following:

1. Operability tests performed shall meet their acceptance criteria for the modules/system.
   - 4- to 20 mA AI Channels – ±0.35% accuracy over the entire range
   - 4- to 20 mA AO Channels – ±0.32% accuracy over the entire range
   - Discrete input/output channels – All transitions shall be detected
   - Digital Response Time – Within the baseline acceptance range < 100ms
   - Analog Response Time – Within the baseline acceptance range < 300ms
   - Communication Operability – No communication errors which lead to loss of packets
   - Timer – Accuracy is within ±1%
   - Failure to complete scan detection – Continue to perform
   - Failover – Transfer of control to secondary controller shall not impact any performance data
   - Loss of Power – All AO channels and power outputs shall be open. All DO channels shall be de-energized
   - Power Interruption – All performance data shall not be impacted by the power interruption
   - Power Quality – All performance data shall not be impacted before the drop of power lead to power outage

2. Prudency tests performed at the end of the high temperature stress period shall meet their acceptance criteria for the modules/system.

3.3.3 EMI/RFI Qualification

According to EPRI TR 107330 Section 4.3.7 EMI/RFI Withstand Requirements, when the PLC modules subjected to EMI/RFI disturbances, the PLC modules shall perform as follows:

1. The main and any coprocessors shall continue to function
2. The transfer of I/O data shall not be disrupted
3. The emissions shall not cause the discrete I/O to change state
4. Analog I/O level shall not vary more then 3%

In addition, the system shall continue to provide the following performance:

A. Response Time

   The response time for Digital I/O and Analog I/O shall be within the manufacturer's acceptance limits. For the test specimen application program (TSAP) running on the system, the acceptance limits for analog response time is < 300ms and for digital response time is < 100ms.

   Note: This response limit is not the performance benchmark for the systems. The systems can be customized to have faster response time.

B. Discrete I/O Operability

   All states of the discrete input shall be detected and all changes of the discrete output shall occur.

C. Communication Operability

   Communication performance shall meet the manufacturer's acceptance limits. No errors shall be reported for the C-Link communication. The acceptable errors for the ICL communication are 0x01 "BUSY" and 0x03 "CRC Error".

D. Timer Test

   The accuracy of the timer functions shall meet the ±1%, ± 3 scan cycles.

E. Burst of Event (BOE) Operability

   All transitions of the states of all channels driven by the BOE shall be detected. Analog I/O levels shall not have variations greater than 3%.

For a specific EMI/RFI susceptibility test, when the results of these tests meet the acceptance criteria, it validates the test specimen has demonstrated no susceptibility to the test signals.

3.3.4 Post-Qualification Test

After the environmental stress and EMI/RFI tests, the test specimen shall show no degradation of performance below the requirements or manufacturer's specification in accordance with EPRI TR 107330.

4.0 Test Summary

4.1 *Venues*

The environmental stress tests were conducted at Environmental Testing Laboratory. The laboratory is located at 11034 Indian Trail, Dallas, TX 75229-3513. The testing period was from June 30th, 2010 until July 17th, 2010.

The EMI/RFI tests were conducted at Nemko USA. The laboratory is located at 802 North Kealy Street, Lewisville, TX 75057-3136. The testing period started from July 26th, 2010 until August 20th, 2010. CS116 was tested at HFC facility on 9/20/10.

Both laboratories are ISO/IEC 17025 certified.

In addition, the pre-qualification and post-qualification tests for the test specimen were performed at HFC Carrollton facility prior to the environmental tests and after the EMI/RFI tests respectively.

4.2 *Pre-Qualification Test Summary*

All components as listed in Table 2 completed a burn-in test of a minimum of consecutive 352 hours. The firmware on the components and the TSAP application were validated. All modules installed in the test specimen met their corresponding manufacturer's specification. In addition, for the AI and AO modules, namely AI16F, AO8F, AI8M, and AI4K, each demonstrated an average accuracy of < 0.1%. Characteristics of the discrete input/output, namely DI16I, DC33, DC34, and DO8J, all demonstrated the required performance in accordance with EPRI 107330 standard.

The redundant controller set, two HFC-SBC06's and one HFC-DMP06, were validated with the required operability and prudency tests. System response times were found to be within the acceptable range of 100ms for digital and 300ms for analog. The operability test data also validated the backplanes HFC-BPC01-19, HFC-BPE01-19 and HFC-ILR06 I/O Link Repeater/Terminator communication capability.

Operability tests related to power supply also validated the Japer 24V PS used in the test specimen.

A new test, "Failure to Complete Scan" test was added to the operability test set to address the open item in the SER about not establishing the watchdog timer timeout detection. The test design was to failover from the primary controller to the secondary controller when the primary controller did not stroke the watchdog timer for one complete scan cycle, 100ms. Results of this detection test showed that less than 2 scan cycles, 200ms, were needed for the system to failover to a redundant controller after application was notified not to stroke the watchdog timer. Such results validated that the detection was correct because it took one complete scan cycle, 100ms, for the watchdog timer to timeout. So as long as the failover occurred within the next scan cycle, the detection was valid.

Performance data during the pre-qualification tests were collected to establish the baseline data to be used in comparison during and after the qualification stress tests.

4.3 *Environmental Stress Retest Summary*

The environmental stress test exposed the HFC-6000 ERD111 test specimen to extremes of temperature and humidity in order to induce accelerated aging of functional components in accordance with the minimum requirements depicted in EPTRI TR 107330 figure 4-4.

The HFC-6000 ERD111 test specimen was running a TSAP throughout the test period, and its operation was monitored by SOE and HAS data loggers located outside the test chamber. In addition, comprehensive functional tests were conducted before, after, and at specified points during the stress testing. The results of these tests were used to identify any deterioration in functional performance of the Test Specimen due to adverse environmental conditions.

During the environment stress retest, the time of exposure of the ERD111 test specimen to the high temperature/high humidity (HT/HH) was longer than 48 hours. The first set of operability tests not related to power supplies were performed after the initial exposure of 48 hours. In order not to disrupt the operations, operability tests related to power supplies and power quality were performed at the end of HT/HH exposure before ramping down to low temperature/low humidity. A set of prudency tests were also performed during the first operability checkpoint at the end of the initial 48 hours exposure of HT/HH. No anomalies for the ERD111 test specimen were found at any operability checkpoints.

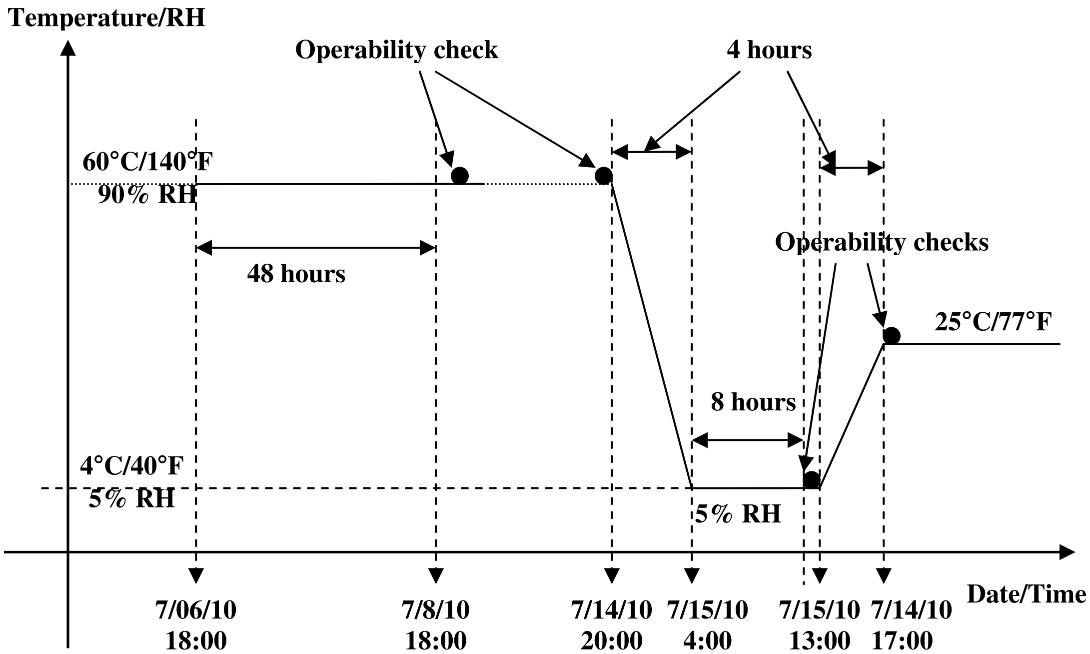

Figure 4 – Actual Environmental Test Sequences
(See ETL Lab Report for the detail profile)

The following evaluations and analyses were made related to the open items addressed in the SER:

4.3.1 Watchdog Timer Timeout Detection

During the environmental stress tests, the "Failure to Complete Scan" test was performed. The test results showed the raw detection time was from 244ms to 286ms. Since the digital transfer time (digital response time) had a range from 74 to 94ms, see section 4.3.3.2, the actual detection time was less than 200ms, 2 scan cycles. Based on the results, it can be concluded that the watchdog timer timeout detection was not impacted by environmental stressed conditions. Such a result is expected because the detection is a software implementation; environmental conditions will have no impact to software.

4.3.2 AI16F

The table below shows the accuracy of the AI16F measured during the qualification retest program. The data demonstrates that AI16F meets the acceptance criteria of 0.35% for analog input accuracy in test phases of the retest program.

Table 3 – AI16F Accuracy

Qualification Retest Test Phase	Average Accuracy
At the end of High Temperature/High Humidity	< 0.30%
At the end of Low Temperature/Low Humidity	< 0.31%
Back to Ambient	< 0.16%
Pre-Qualification/Post-Qualification	< 0.10%

4.3.3 Response Time

4.3.3.1 Analog Response Time

The table below shows the average analog response time measured for the test specimen ERD111 during the qualification retest program. The data demonstrates that there was no impact of the environmental stresses to the test specimen related to analog response time.

Table 4 – Analog Response Time

Qualification Retest Test Phase	Range of Average Response Time
At the end of High Temperature/High Humidity	Between 93ms to 147ms
At the end of Low Temperature/Low Humidity	Between 120ms to 148ms
Back to Ambient	Between 122ms to 148ms
Pre-Qualification/Post-Qualification	Between 117ms and 175ms

4.3.3.2 Digital Response Time

The table below shows the average digital response time measured for the test specimen ERD111 during the qualification retest program. The data demonstrates that there was no impact of the environmental stresses to the test specimen related to digital response time.

Table 5 – Digital Response Time

Qualification Retest Test Phase	Range of Average Response Time
At the end of High Temperature/High Humidity	Between 74ms to 94ms
At the end of Low Temperature/Low Humidity	Between 74ms to 84ms
Back to Ambient	Between 74ms to 78ms
Pre-Qualification/Post-Qualification	Between 77ms and 81ms

4.3.4 Conclusions

The environmental test results show that the HFC6000 control system ERD111 test specimen with component listed in Table 2 met all the acceptance criteria for safety control system operations under environmental stressed conditions in accordance with EPRI TR 107330-1996.

4.4 *EMI/RFI Test Summary*

The following evaluations and analyses were made related to the open items addressed in the SER:

4.4.1 Emission Tests

Emission tests in accordance with NRC RG 1.180, conducted emission tests, CE101 and CE102, and radiated emission tests, RE101 and RE102 were performed on the ERD111 test specimen. All four emission tests passed. See test results in the Nemko Report in the attachment.

4.4.2 Susceptibility Tests

Susceptibility tests in accordance with NRC RG 1.180 were performed on the test specimen. Conducted susceptibility tests CS101 and CS114 were performed on the power lines. Conducted susceptibility tests CS114, CS115/EFT were performed on the signal lines. Radiated susceptibility tests RS101 and RS103 were performed on the system. The data captured by alarm files, SOE logs and HAS files created by automated operability tests in accordance with EPRI TR 107330 shows the system is not susceptible to EMI/RFI spectrum provisioned in the tests.

Due to time limit and schedule of using the Nemko lab, CS116 tests were rescheduled and were executed on 9/20/2010 at HFC facility. Test results show that the system performed and was not susceptible to CS116 conductive interference on the signal lines.
(Note: When performing CS114 and CS116 tests, the signal lines were grouped into 3 bundles and each bundle was tested separately.)

4.4.3 Isolation Tests

Isolation tests were performed on ERD111 test specimen in accordance with EPRI TR 107330-1996. The test results show the system passed the class 1E isolation tests for both power signal limits at 250vdc and 600vac. See Nemko Report in the attachment.

4.5 *Post-Qualification Test Summary*

Post-qualification tests were performed after the test specimen completed the EMI/RFI and environmental stress tests. The purpose of the test is to validate the performances of the system are not degraded below the requirements by the aging process in environmental stress and EMI/RFI tests.

The post-qualification test data demonstrated that all components as listed in Table 2 did not show performance degradation after the environmental stress and EMI/RFI tests. The accuracies of the AI and AO modules, AI16F, AI8M and AI4K were within their acceptance criteria limits. Digital response time was found to be within 100ms and analog response time was found to be within 300ms.

5.0 Conclusions

HFC has completed a retest for the ERD111 test specimen for qualifying the platform in accordance with EPRI TR 107330-1996 and NRC RG 1.180. The test results show the ERD111 test specimen performances have met the acceptance criteria listed in EPRI TR 107330-1996 and NRC RG 1.180. No anomalies are found.

6.0 Amendment Request

Based on the information listed in section 4.0, HFC requests NRC to close the open items listed in the HFC-6000 SER. The following table summarizes the retest efforts:

Table 6 – Resolutions and Results to Open Items listed in SER

Open Item	HFC Resolution	Result
1. HFC has committed to conducting a retest of both environmental stress withstand and EMI/RFI immunity capabilities of the HFC-6000 platform to demonstrate generic environmental qualification for temperature and humidity exposure and EMC (Reference106). Submission of additional testing results or other comparable evidence for review is necessary to demonstrate environmental qualification of the HFC-6000 platform under the generic environmental and EM service conditions defined in EPRI TR-107330.	HFC performed environment stress retest at the Environmental Testing Laboratory, Dallas, Texas in July 2010. HFC performed EMI/RFI retest at Nemko USA in Lewisville, Texas and HFC facility in Carrollton in the third quarter 2010.	The ERD111 test specimen with the components listed in the SER met all acceptance criteria in accordance with EPRI TR 107330 and NRC RG 1.180.
2. The qualification testing conducted for the HFC-6000 platform does not establish qualification of the hardware watchdog timer for the HFC-SBC06 controller module under the service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component.	Added a watchdog timer detection test, "Test of Failure to complete scan detection", to the operability test sets. The test was performed during pre-qualification, at the end of high temperature exposure, and post-qualification test phases.	The detection test was validated as one of the operability tests used in the qualification retest program. Environmental and EMI/RFI stresses had no impact to the detection test.

3 The qualification testing for the HFC-6000 platform does not establish qualification of the HFC-AI16F module under the environmental stress or EMI/RFI conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of this hardware component.	An external device was installed in the HPAT….. ERD111 test specimen and went through the complete qualification retest program.	Results in the retests demonstrated that HFC-AI16F performed within the manufacturers' specifications during environmental and EMI/RFI stresses in accordance with EPRI TR 107330.
4. The qualification testing for the HFC-6000 platform does not establish qualification of analog response time performance when the platform is subjected to the environmental extremes of the generic service conditions defined in EPRI TR-107330. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of the analog response time for the HFC-6000 platform as part of a comprehensive, credible qualified performance envelope. 5. The qualification testing for the HFC-6000 platform does not demonstrate an environmental stress withstand capability for several key performance characteristics that are necessary to establish suitability of the platform for use in safety-related applications. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate qualification of the HFC-6000 platform under the environmental stress conditions defined in EPRI TR-107330.	Detail data was captured for the test specimen ERD111 including analog response time during the qualification retest program.	Results from the qualification retest program demonstrate that the ERD111 test specimen meets acceptance criteria for the environmental stress tests including analog response time.

6. The qualification testing for the HFC-6000 platform does not demonstrate EMC qualification: • For radiated electric field emissions from 10 kHz to 10 GHz. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate acceptable control of high frequency radiated emissions and establish EMC qualification of the HFC-6000 platform for radiated electric field emissions. • For radiated electric field (high frequency) interference, high frequency conducted interference, and low frequency conducted interference. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity to radiated electric fields, low frequency conducted interference, and high frequency conducted interference. • For radiated susceptibility over the frequency range from 1 GHz to 10 GHz and conducted susceptibility of signal leads. Submission of additional testing results or other comparable evidence for review is necessary to demonstrate EMC qualification for immunity of signal lines to low frequency conducted interference and high frequency conducted interference and platform immunity to very high frequency radiated electric field interference.	Complete EMI/RFI retest was performed on the test specimen ERD111 in accordance with EPRI TR 107330 and NRC RG 1.180.	Test specimen ERD111 met the acceptance criteria of EMI/RFI emission and susceptibility tests in accordance with EPRI TR 107330 and NRC RG 1.180.

7.0 Attachments

7.1 Environmental Testing Laboratory Test Report for Job # 11188
7.2 Nemko Test Report NO: 47110RG1180

Environmental Testing Laboratory, Inc.

11034 Indian Trail
Dallas, TX 75229-3513
(972) 247-9657
Fax (972) 247-9659
info@etldallas.com

CERTIFICATE OF TEST 11188

Customer: HF Controls Corporation 16650 Westgrove Drive, Suite 500 Addison, TX 75001	**Test:** Environmental Stress Test
	Test Completion Date: 09 July 2010
	Purchase Order Number: 012420-00

Test Unit Description

One (1) HFC-6000 Safety Control System, P/N 50040201, Dimensions: 48x36x96 Inches, Weight: 2000. (Qty = 1);

Specification

HF Controls Test Protocol for Environmental Stress Test.

Equipment

Equipment Name	Description	Model #	Calibration Due
ETL #071	Ransco Temperature Chamber	5349	CNR
ETL #1154	Eclipse Controls Circular Chart Recorder	9696	16 November 2010
ETL #1244	JC Systems Controller	510	22 February 2011
ETL #1359	Hewlett Packard Data Acquisition System	34970A	01 October 2010

Procedure

The test unit was placed in the test chamber. The test unit was subjected to environmental stress testing in accordance with the test specification (refer to test chart and profile).

Results

Test was performed in accordance with the above listed specification without requirement for certification. Test completed 09 July 2010.

Traceability

This Certificate of Test certifies that the above test was run in accordance with applicable specifications and that all instrumentation was in calibration and is traceable to the NATIONAL INSTITUTE OF STANDARDS and TECHNOLOGY or other recognized calibration sources when applicable.

Accreditation

This laboratory is accredited by Laboratory Accreditation Bureau. The test results relate only to the item/s tested when applicable.

LABORATORY ACCREDITATION BUREAU
ACCREDITED ISO/IEC 17025
Certificate # L2218 Testing

Respectfully,
ENVIRONMENTAL TESTING LABORATORY, INC.

Paul E. Little
Quality Manager

PEL/pel

ENVIRONMENTAL TESTING LABORATORY, INC.
TEST DATA SHEET

JOB #: 11188	**CUSTOMER:** HF Controls Corporation
TEST: Environmental Stress Test	
TEST UNIT: One (1) HFC-6000 Safety Control System, P/N 50040201, Dimensions: 48x36x96 Inches, Weight: 2000.	
SPECIFICATION: HF Controls Test Protocol for Environmental Stress Test.	

NOTES: Refer to Test Chart and Profile. Cost is for chamber time only. No Certificate of Test Required.

EQUIPMENT LIST		
1. ETL #071	6.	11.
2. ETL #1359	7.	12.
3.	8.	13.
4.	9.	14.
5.	10.	15.

DATE	TIME	LOG AND OBSERVATIONS
7/1/10		**Checked calibration dates Electronic Data Graphs**
		A visual examination of the test unit was performed before testing. No damage was
		observed.
		The test unit was operational and non-operational.
		Operational tests were performed by HF Controls Corporation
7/1/10	17:30	Start cycles as specified with unit non operational
7/5/10	17:30	Cycles complete. Hold at ambient until 7/6/10
7/6/10	09:10	Customer to perform post test and make unit operational for the next cycles.
	13:35	Start to 60°C (140°F) in 4 hours.
	17:40	Chamber at 60°C.
7/8/10	18:30	Test complete. UUT has problems
	22:10	Told to hold another 48hrs at 60°C
7/10/10	15:30	Told to continue holding at 60°C
7/11/10	16:10	Restart 48hr hold at 60°C, new parts installed.
7/15/10	20:00	Chamber at 60°C since 7/11/10, Set to -40°F (4.1°C) with a 8 hr ramp.
7/17/10	09:45	Testing complete
		A visual examination of the test unit was performed after testing.
		No damage was observed.
		The test unit returned to HF Controls Corporation.
Technician		Brady Richard

Environmental Testing Laboratory, Inc.

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ENGINEERING TEST REPORT

NUMBER: 47110RG1.180

ON

Model Name:
HFC-6000 Qualifying Systems

IN ACCORDANCE WITH:
Test Plan
TP901-200-03 “ESD Test Procedures” Rev C
TP901-200-05 “EMI/RFI Test Procedures” Rev C
TP901-200-06 “Surge Withstand Test Procedures” Rev C
TP901-200-07 “Isolation Test Procedures” Rev C

TESTED FOR:
HF Controls Corporation
1624 West Crosby Suite 124
Carrolton, TX 75006

TESTED BY:
NEMKO USA, INC.
802 N. KEALY
LEWISVILLE, TX 75057-3136

TESTED BY:	Dwaine Hartman, EMC Engineer	**DATE:**	**09/20/10**
APPROVED BY:	Art Ruvalcaba, EMC Engineer	**DATE:**	**09/29/10**

Total number of pages: 117

Table of Contents

Section 1. Summary of Test Results

General:

All measurements are traceable to national standards.

These tests were conducted for the purpose of demonstrating compliance with Test Plan, TP901-200-03, -05, -06, -07 Rev C. These tests were conducted using measurement procedures per Regulatory Guide RG 1.180 Rev.1

Emissions:

Name of Test	Standard	Limits	Criteria	Results
CE101 Low Frequency Conducted Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 3.1 (AC Power ≤1kVA)	Pass/Fail	Pass
CE102 High Frequency Conducted Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 3.2 (115Vac Envelope)	Pass/Fail	Pass
RE101 Low Frequency Radiated Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 3.3	Pass/Fail	Pass
RE102 High Frequency Radiated Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 3.4	Pass/Fail	Pass

Immunities:

Name of Test	Standard	Limits	Criteria	Results
CS101 Conducted Susceptibility, Power Leads	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 4.1	Pass/Fail	Pass
CS114 Conducted Susceptibility, Power & Signal Leads	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 4.2	Pass/Fail	Pass
CS116 Conducted Susceptibility, Damped Sinusoidal Transients	MIL-STD-461E as modified by RG 1.180 Rev. 1	10KHz to 100MHz Imax = 5 Amperes	Pass/Fail	Pass
RS101 Radiated Susceptibility, Magnetic Field	MIL-STD-461E as modified by RG 1.180 Rev. 1	Figure 4.3	Pass/Fail	Pass
RS103 High Frequency Radiated Field Susceptibility	MIL-STD-461E as modified by RG 1.180 Rev. 1	RS103 30MHz to 10GHz 10V/M 1KHz AM Modulation	Pass/Fail	Pass
RF Conducted Immunity	IEC 61000-4-6 2006-05 (+A1 +A2) as modified by RG 1.180 Rev. 1	150 kHz to 80MHz 10Vrms 80% Mod.	A	Complies
Electrical Fast Transient / Burst	IEC EN 61000-4-4 as modified by RG 1.180 Rev. 1	Level 3, +/-2kVp-p coupling/decoupling network on AC Power +/-1kVp-p on Signal Cable Capacitive clamp	A	Complies
Surge	IEC EN 61000-4-5 as modified by RG 1.180 Rev. 1	Level 3, 1,2/50 (8/20) Tr/Thu uS +/-2 & 4kV peak on AC Power Line to Line & Line to ground	A	Complies
	IEC EN 61000-4-12 as modified by RG 1.180 Rev. 1	Level 3, 100KHz & 1MHz Ring Wave, 1,2/50 +/-2 & 4kV peak on AC Power Line to Line & Line to ground	A	Complies
ESD	IEC EN 61000-4-2 as modified by RG 1.180 Rev. 1	Level 4, 8kV Contact, 15kV Air	A	Complies
Isolation	EPRI TR-107330, 1996	Section 6.3.6	A	Complies

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This report applies only to the item/s tested and does not constitute endorsement by the United States of America.

THE FOLLOWING DEVIATIONS FROM, ADDITIONS TO, OR EXCLUSIONS FROM THE TEST SPECIFICATIONS HAVE BEEN MADE: **NONE**

Section 2. EUT (Equipment Under Test)

Assembly Manufacturer: HF Controls Corporation

Test Specimen: HFC-6000 Qualifying Systems

Systems Under Test: ERD111, ERD921 TMR & DMR, SLC System

Description of E.U.T:

For details see Test Plan:
TP901-200-03 “ESD Test Procedures” Rev C,
TP901-200-05 “EMI/RFI Test Procedures” Rev C,
TP901-200-06 “Surge Withstand Test Procedures” Rev C,
TP901-200-07 “Isolation Test Procedures” Rev C

Modifications Incorporated in E.U.T:

None.

Justification:

TP901-200-03 “ESD Test Procedures” Rev C,
TP901-200-05 “EMI/RFI Test Procedures” Rev C,
TP901-200-06 “Surge Withstand Test Procedures” Rev C,
TP901-200-07 “Isolation Test Procedures” Rev C

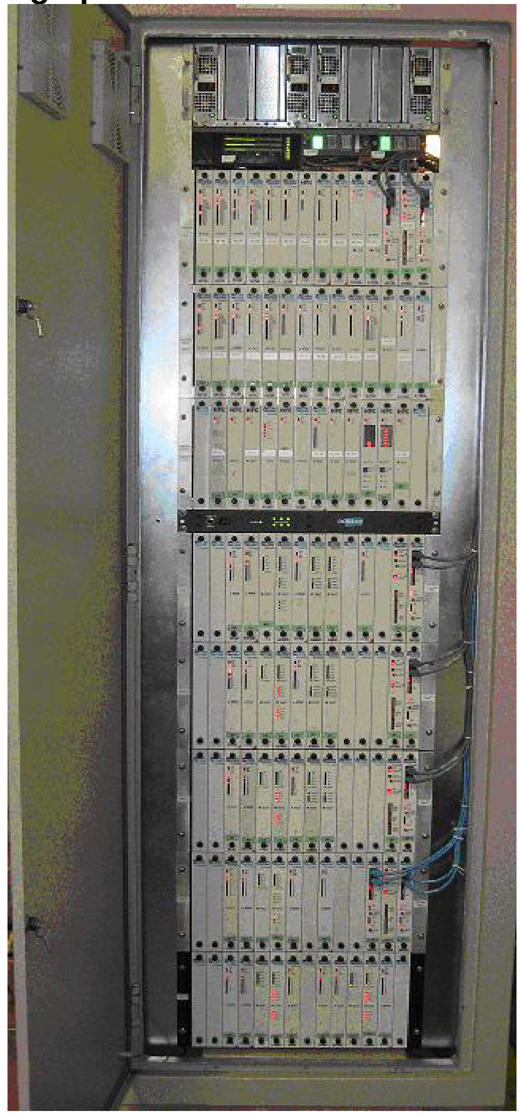
Exercise Program:

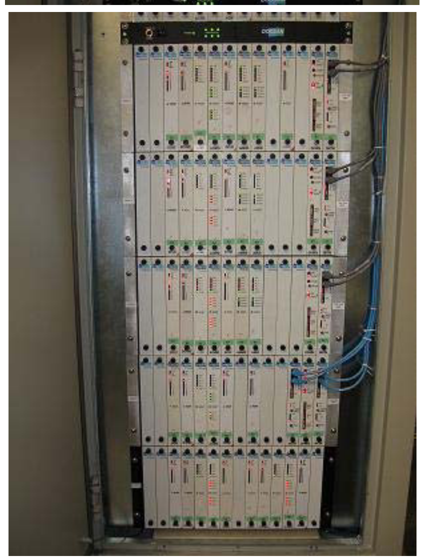
TP901-200-03 “ESD Test Procedures” Rev C,
TP901-200-05 “EMI/RFI Test Procedures” Rev C,
TP901-200-06 “Surge Withstand Test Procedures” Rev C,
TP901-200-07 “Isolation Test Procedures” Rev C

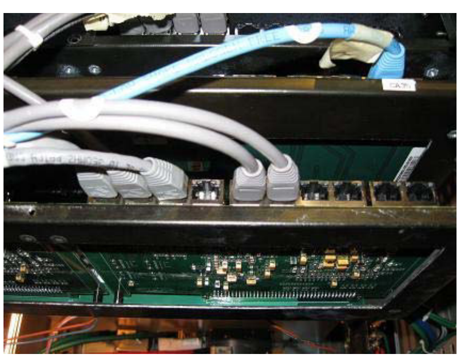
Exercise Mode:

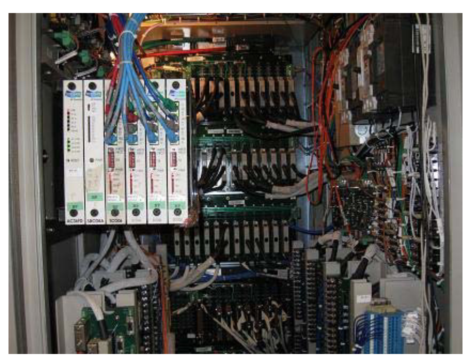
TP901-200-03 “ESD Test Procedures” Rev C,
TP901-200-05 “EMI/RFI Test Procedures” Rev C,
TP901-200-06 “Surge Withstand Test Procedures” Rev C,
TP901-200-07 “Isolation Test Procedures” Rev C

E.U.T. Photographs:

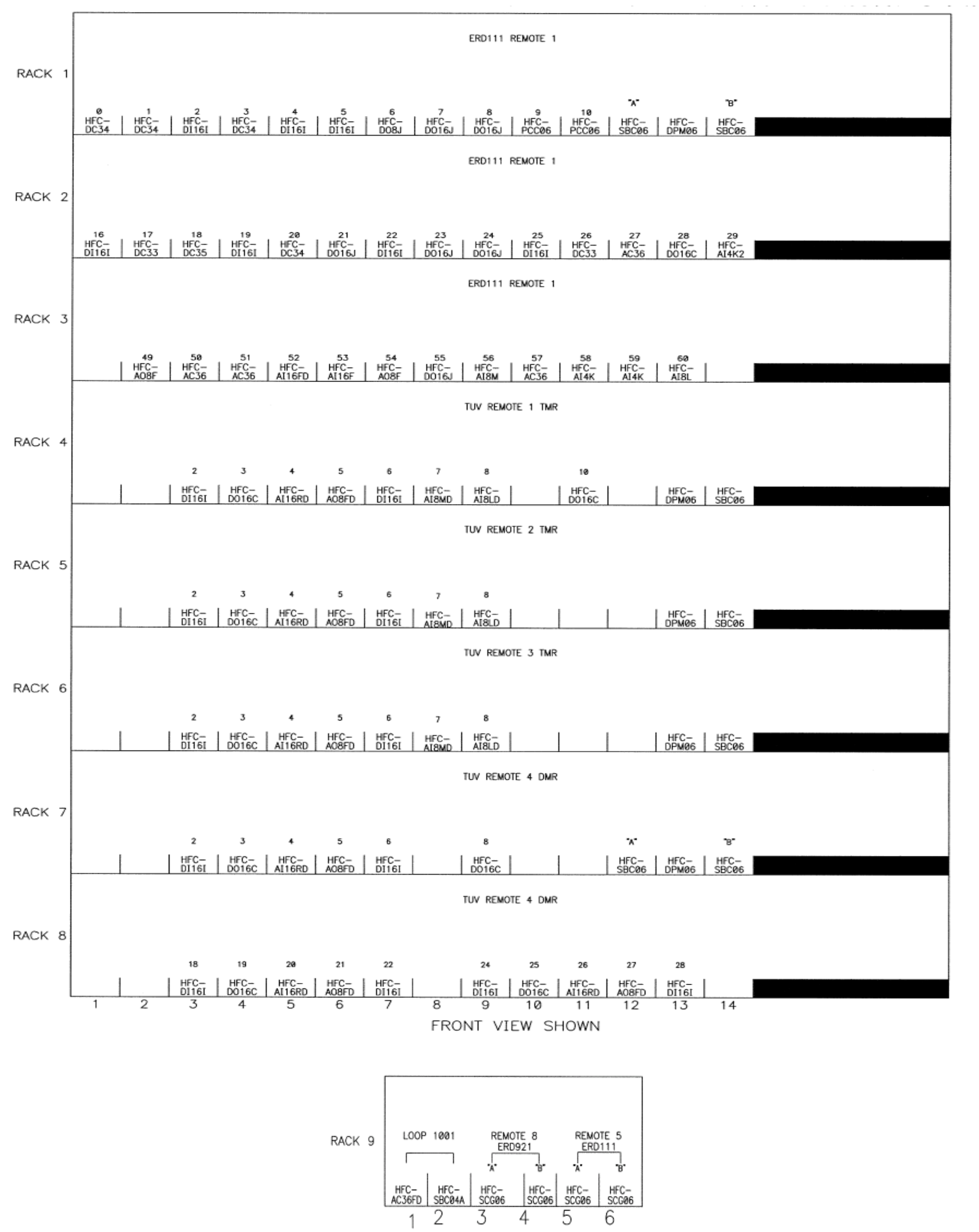








Equipment Layout:



Equipment List:

ERD111 Equipment List

Quantity	Modular Type	Description	Cabinet Location
4	PS, Jasper 24V	600W 24V Power Supply	Top of cabinet
1	Rack, Jasper PS	8-slot Jasper PS Rack, 19"	Top of cabinet
2	HFC-FOT06	Fiber-Optic Transmitter	Inside cabinet
4	HFC-ILR06	I/O Link Repeater/Terminator	Inside cabinet
1	HFC-BPC01-19	Controller Chassis backplane	Behind rack 1
2	HFC-BPE01-19	Expander Chassis backplane	Behind racks 2 & 3
1	HFC-BPC03-08	3 Loop, 8 inch backplane	Inside cabinet
2	HFC-SBC06	Main Controller	Rack 1, slots 12 & 14
1	HFC-DPM06	Dual-Ported Memory	Rack 1, slot 13
2	HFC-SCG06	Communication Gateway	Rack 9, slots 5 & 6
1	HFC-DPM06BP	Backplane Connected DPM06	Behind rack 9
1	AFS-CSM1-01	Control Switch Module	Inside cabinet
1	HFC-DO16C	Solid State Output Card	Rack 2, slot 13
2	HFC-DC33	Special Function Card (120 vac output)	Rack 2, slots 2 & 11
4	HFC-DC34	Special Function Card (125-vdc output)	Rack 1, slots 1, 2, 4 Rack 2, slot 5
1	HFC-DC35	Special Function Card (120 vac output)	Rack 1, slot 3
2	HFC-AI4K	Pulse Input Card	Rack 3, slot 11 & 12
1	HFC-AI4K2	Pulse Input Card	Rack 2, slot 14
1	HFC-AI16F	Analog Input Card (4- to 20 mA)	Rack 3, slot 6
1	HFC-AI16FD	Analog Input Card (4- to 20 mA)	Rack 3, slot 5
2	HFC-AO8F	Analog Output Card (4- to 20 mA)	Rack 3, slots 2 & 7
1	HFC-AI8LD	Thermocouple Input Card	Rack 3, slot 13
1	HFC-AI8M	RTD Input Card, 100 ohm	Rack 3, slot 9
4	HFC-AC36	Analog Input/Output Board	Rack 2, slot 12 Rack 3, slots 3, 4, 10
2	AFS-CSM	Control Switch Module Type1	Inside cabinet
1	AFS-CSM	Control Switch Module Type2	Inside cabinet
1	AFS-CSM	Control Switch Module (1-Button)	Inside cabinet
1	MA Station	M/A Station: 0-614-TIK-0007	Inside cabinet
1	MA Station	M/A Station with No Faceplate	Inside cabinet
1	MA Station	M/A Station: 531-LIK-0318A	Inside cabinet
2	HFC-PCC06	Serial Channel Card	Rack 1, slots 10 & 11
7	HFC-DI16I	Digital Input Card with SOE	R1, slots 3, 5, 6 R2 slots 1, 4, 7, 10
1	HFC-DO8J	Relay Output Card	Rack 1, slot 7
6	HFC-DO16J	Relay Output Card	Rack 1, slots 8 & 9 Rack 2, slots 6, 8, 9 Rack 3, slot 8

ERD921 TMR/DRM & SLC Equipment List

Quantity	Modular Type	Description	Cabinet Location
2	PS, Jasper 24V	600W 24V Power Supply	Top of cabinet (back)
1	Jasper PS Rack	19” 8-slot Jasper PS Rack	Top of cabinet (back)
1	HFC-HUB06-16-01	16 Port 10/100 Hub	Inside cabinet (back)
1	HFC-HUB06-16-02	16 Port 10/100 Hub	Inside cabinet (back)
1	HFC-HUB06-16-EXT	Hub Extender	Inside cabinet (back)
3	HFC-BPC01-19	Controller backplane	Behind racks 4, 5, 6
1	HFC-BPC03-08	3 Loop, 8 inch backplane	Behind rack 9 (same as ERD111)
2	HFC-SCG06	Communication Gateway	Rack 9, slots 3 & 4
1	HFC-DPM06BP	Backplane DPM06	Behind rack 9
3	HFC-SBC06 (TMR)	Main Controller	Slot 14 at racks 4, 5, 6
3	HFC-DPM06 (TMR)	Dual-Ported Memory	Slot 13 at racks 4, 5, 6
6	HFC-DI16I (TMR)	Digital Input Card	Slots 3 & 7 at racks 4, 5, 6
4	HFC-DO16C (TMR)	Solid State Digital Output	Slot 4 at racks 4, 5, 6 Slot 11 at rack 4
3	HFC-AI16RD (TMR)	Analog Input Card	Slot 5 at racks 4, 5, 6
3	HFC-AO8FD (TMR)	Analog Output Card	Slot 6 at racks 4, 5, 6
3	HFC-AI8LD (TMR)	Thermocouple Input Card	Slot 8 at racks 4, 5, 6
3	HFC-AI8MD (TMR)	RTD Input Card, 100 ohm	Slot 9 at racks 4, 5, 6
2	HFC-SBC06 (DMR)	Main Controller	Rack 7, slots 12 & 14
1	HFC-DPM06 (DMR)	Dual-Ported Memory	Rack 7, slot 13
6	HFC-DI16I (DMR)	Digital Input Card	R7, slots 3 & 7 R8, slots 3, 7, 9, 13
4	HFC-DO16C (DMR)	Solid State Output Card	R7-S4,-S9 R8 -S4, -S10
3	HFC-AI16RD (DMR)	Analog Input Card	R7-S5, R8-S5,-S11
3	HFC-AO8FD (DMR)	Analog Output Card	R7-S6, R8-S6, -S12
2	HFC-FOT06 (DMR)	Fiber-Optic Transmitter	Inside cabinet
4	HFC-ILR06 (DMR)	I/O Link Repeater	Inside cabinet
1	HFC-BPC01-19 (DMR)	Controller backplane	Behind rack 7
1	HFC-BPE01-19 (DMR)	Expander backplane	Behind rack 8
1	HFC-SBC04A (SLC)	Single Loop Controller	Rack 9, slot 2
1	HFC-AC36FD (SLC)	Analog I/O Module	Rack 9, slot 1

Section 3. Low Frequency Conducted Emissions (CE101)

Purpose:

The test is intended to demonstrate that electromagnetic emissions from the EUT (Equipment Under Test) does not exceed the specified requirements for power input leads including returns that obtain power from other sources not part of the EUT in Nuclear Power Plants.

Applicability:

Although both RG.1.180 & MIL-STD461E show the limit starting at 60Hz, this requirement is applicable starting at the second harmonic of the EUT power frequency per MIL-STD461E paragraph 5.4.1.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev C

Specification Limits:

Frequency range (Hz)	Limits (dbuA)
120 to 1150	120 to 90
1150 to 10000	90* to 85
Notes: *The limit decreases linearly with respect to the log of the frequency	

Test : CE101-4

Tested By: D. Hartman

Dates of Tests: 07/27/10, 08/10/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 22˚C

Humidity: 33%

Test Results:

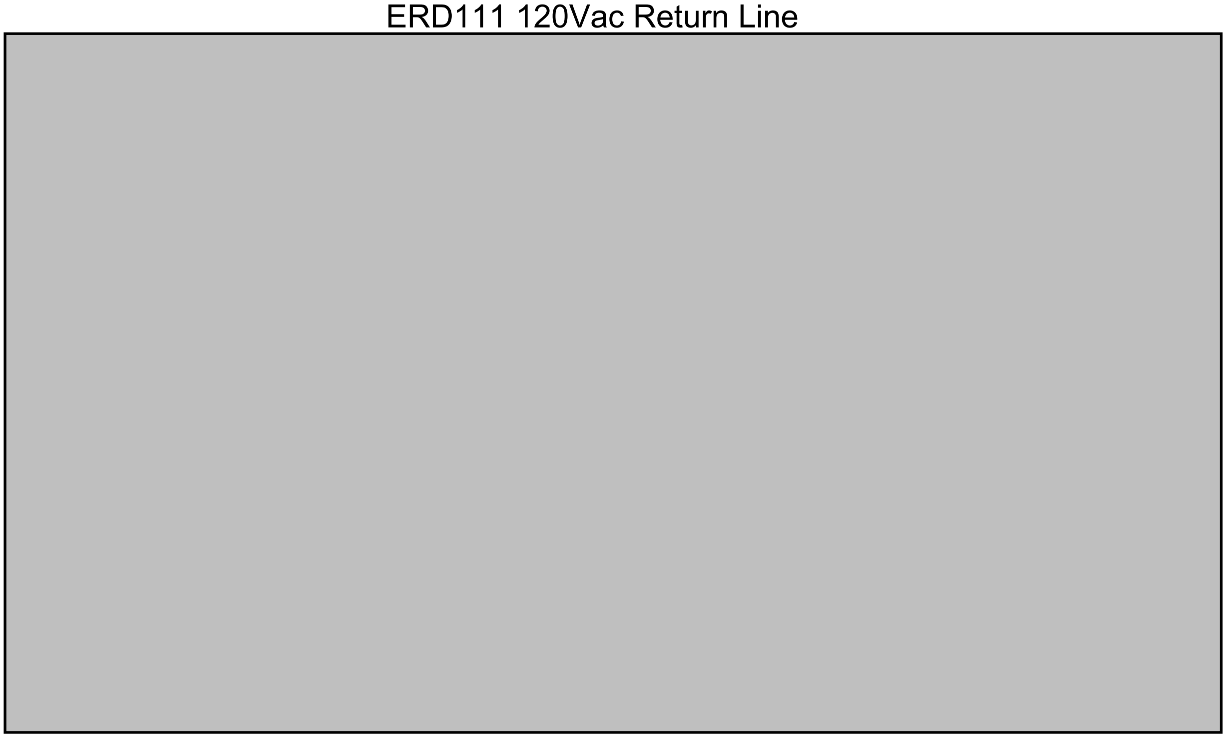
The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1152	Current Probe	Electro-Metrics	PCL-11	1148	02/08/10	02/08/11
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/10	02/27/11
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1852	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11
1811	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11

L.F. Conducted Emissions (CE101) Test Data

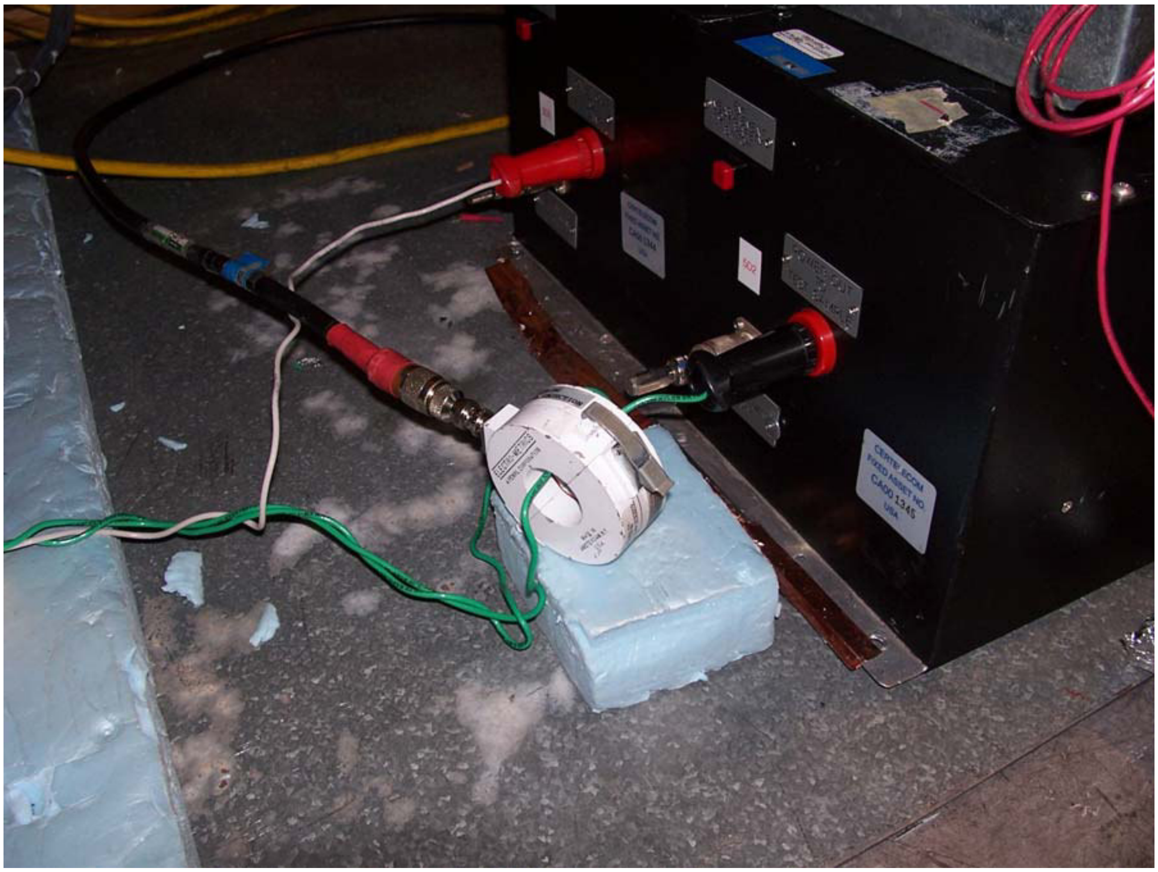
ERD111 120Vac Return Line



ERD921 120Vac High Line

ERD921 120Vac Neutral Line

L.F. Conducted Emissions (CE101-4) Test Photographs



Section 4. High Frequency Conducted Emissions (CE102)

Purpose:

The test is intended to demonstrate that electromagnetic emissions from the Equipment Under Test (E.U.T.) do not exceed the specified requirements for power input leads, including returns.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Specification Limits:

Frequency range (MHz)	Limits (dbuV)	Limits (dbuA)
0.010 to 0.112	100* to 79	66* to 32
0.112 to 0.500	79	32
0.500 to 0.500	79 to 73	
0.500 to 10	73	
Notes: *The limit decreases linearly with respect to the log of the frequency		

Test : CE102

Tested By: D. Hartman

Dates of Tests: 07/27/10, 07/29/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 22˚C

Humidity: 33%

Test Results:

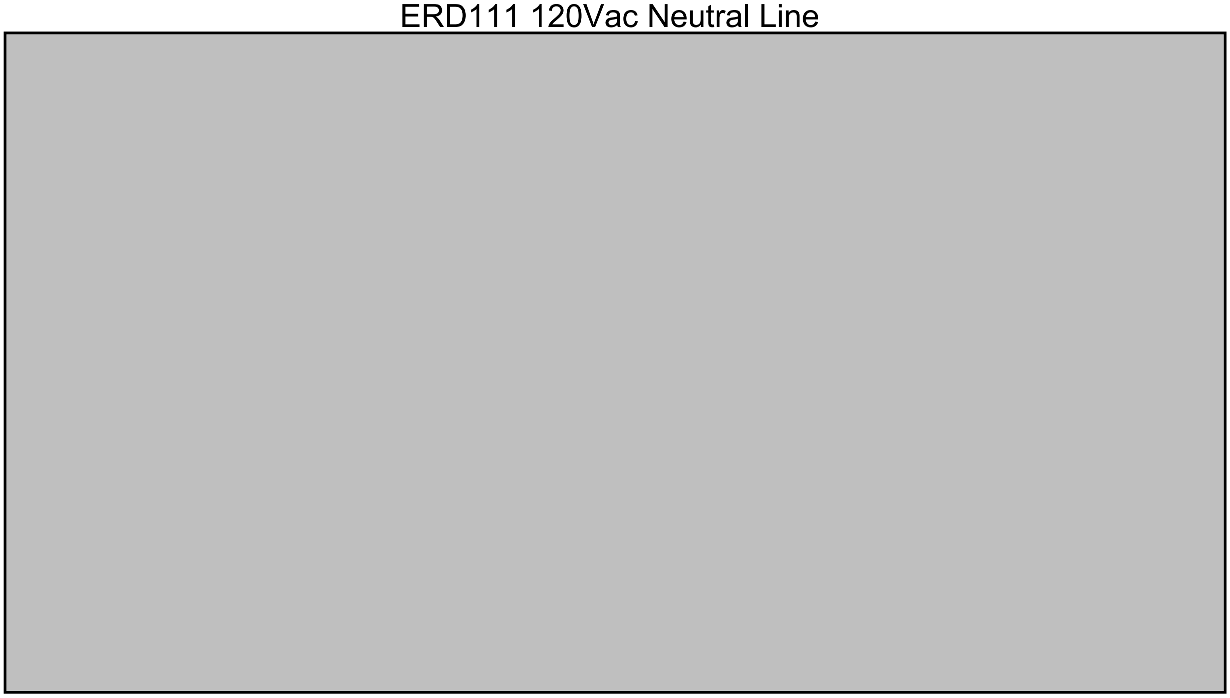
The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1560	Attenuator 10db	Midwest Microwave	392-11	N/A	01/18/10	01/18/11
1561	Attenuator 10db	Midwest Microwave	392-10	N/A	01/18/10	01/18/11
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/09	02/27/11
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1852	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11
1811	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11

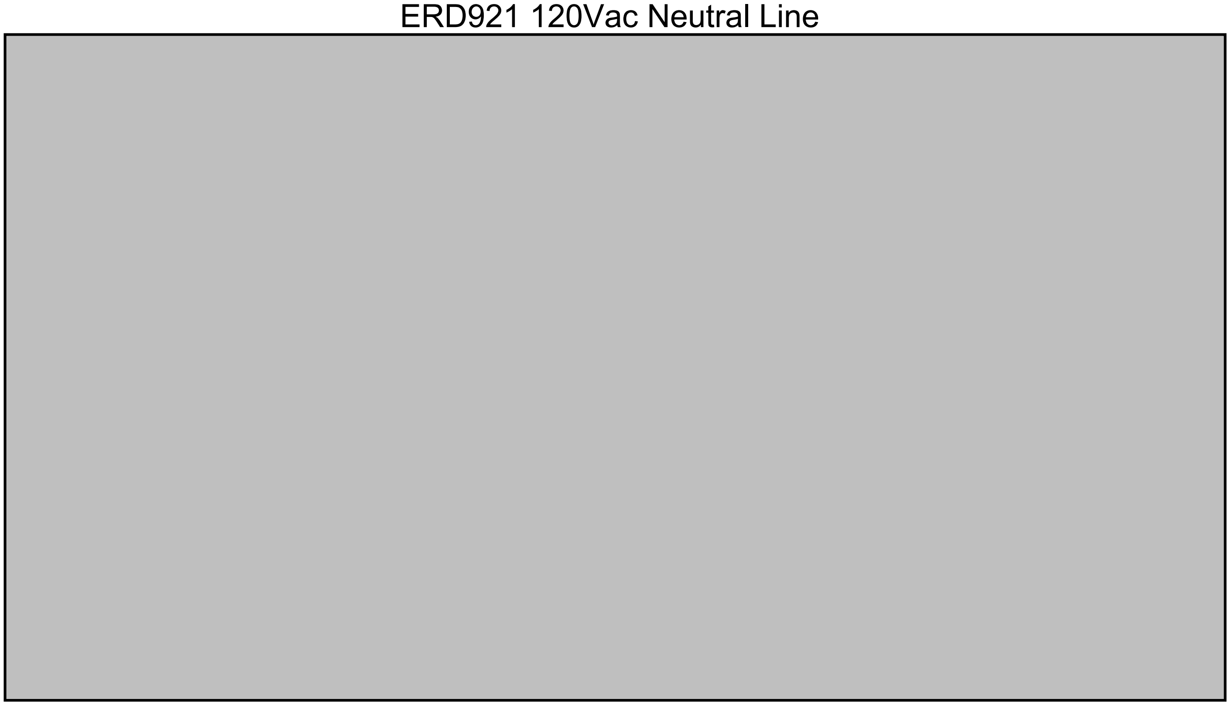
H. F. Conducted Emissions (CE102) Test Data

ERD111 120Vac Neutral Line



ERD921 120Vac High Line

ERD921 120Vac Neutral Line



H. F. Conducted Emissions (CE102) Test Photographs

Section 5. Radiated Emissions Magnetic Field, (RE101)

Purpose:

This test procedure is used to verify that the magnetic field emissions from the EUT and its associated electrical interfaces do not exceed specified requirements.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Specification Limits:

Frequency range (Hz)	Limits (dBpT)
30 -100000	160 to 90
Notes: *The limit decreases linearly with respect with the log of the frequency	

Test : RE101-1

Tested By: D. Hartman

Date of Tests: 07/28/10

Test Conditions:

Test Voltage: 28Vdc

Temperature: 22˚C

Humidity: 33%

Test Results:

The E.U.T. complies.

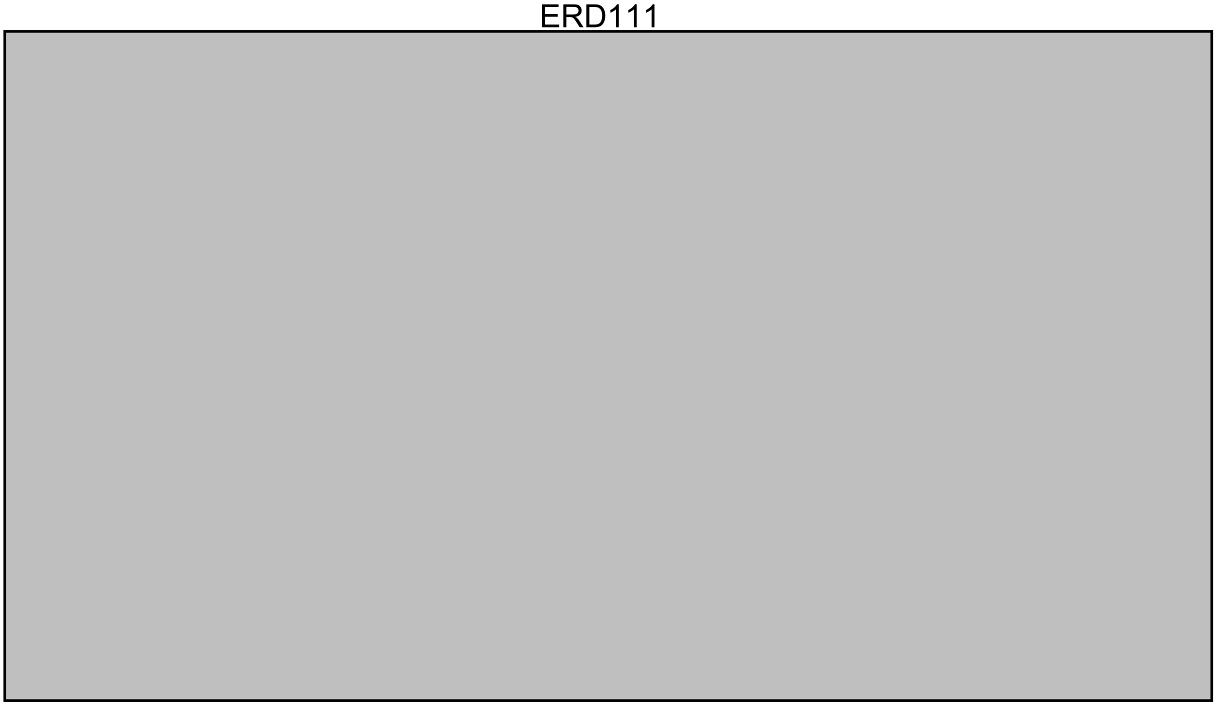
Test Equipment

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/09	02/27/11
1149	Loop Antenna	EMCO	7604	9104-2188	08/10/09	08/10/10
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1852	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11
1811	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	03/03/10	03/03/11

Radiated Emissions (RE101) Test Data

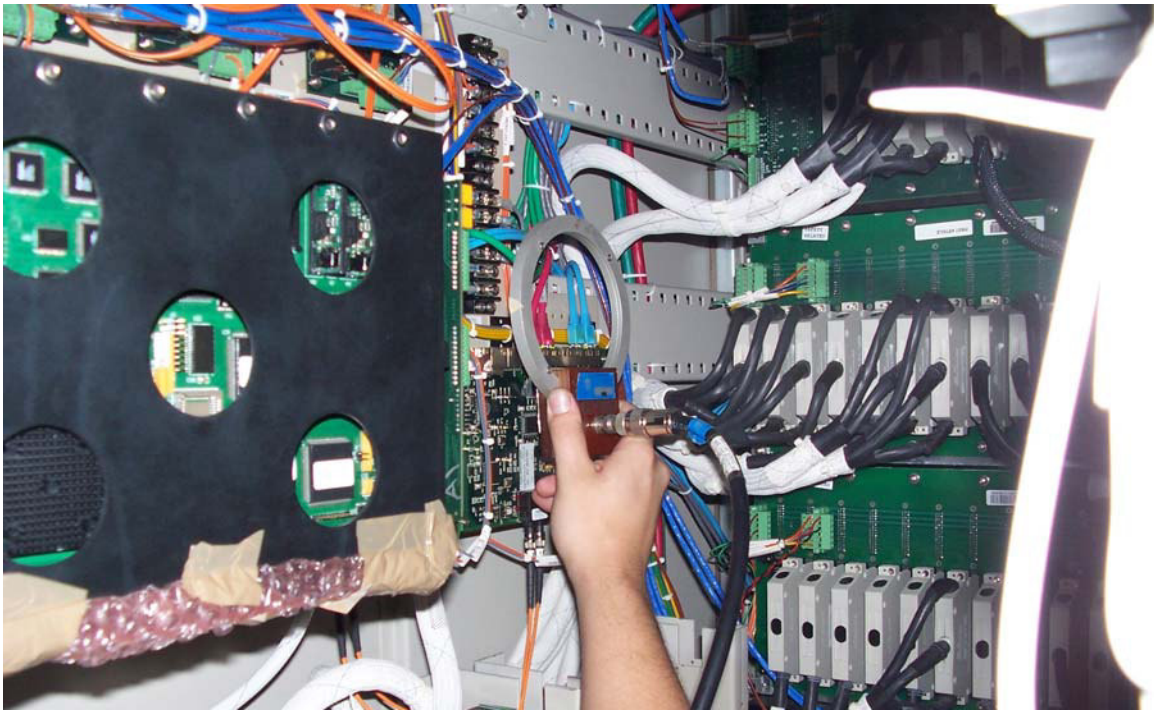
ERD921

ERD111

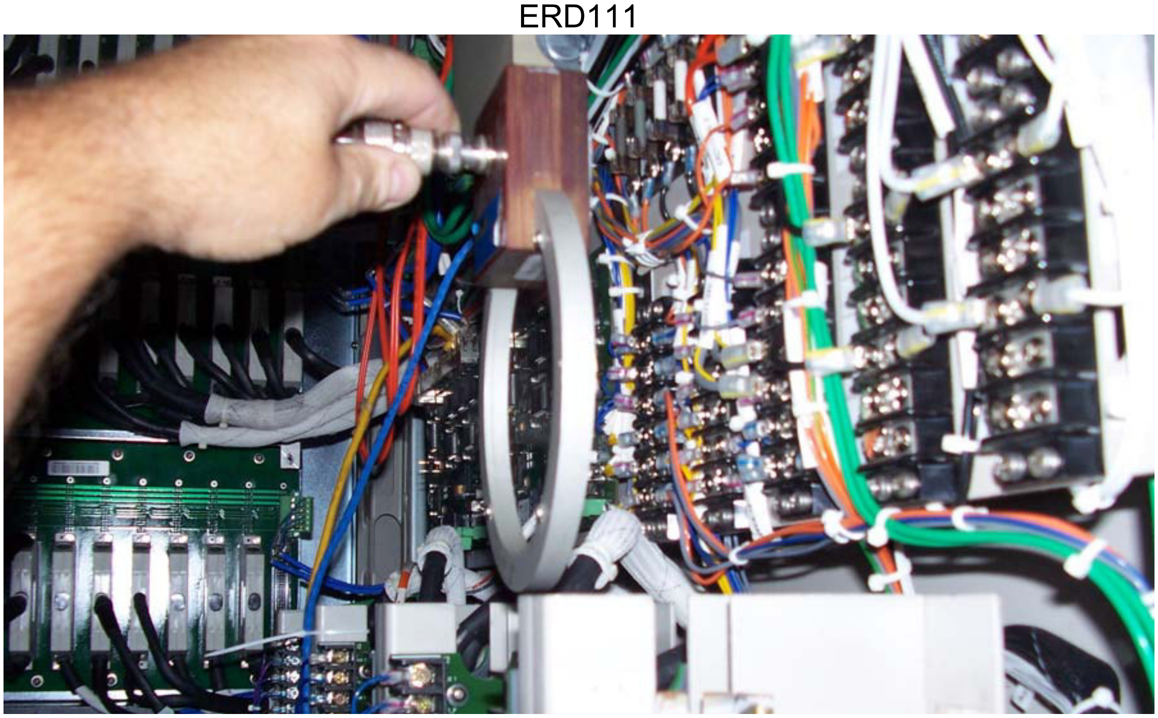


Radiated Emissions, Magnetic Field (RE101) Test Photographs

ERD921



ERD111



Section 6. High Frequency Radiated Emissions (RE102)

Purpose:

This test procedure is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Specification Limits:

Frequency range (MHz)	Limits (dBμV/m)
2 to 25	59
25 to10000	59 * to 80
Notes: *The limit increases linearly with respect to the log of the frequency	

Test : RE102

Tested By: D. Hartman

Dates of Tests: 07/28/10, 08/02/10

Test Conditions:

Test Voltage: 120VAC

Temperature: 22˚C

Humidity: 33%

Test Results:

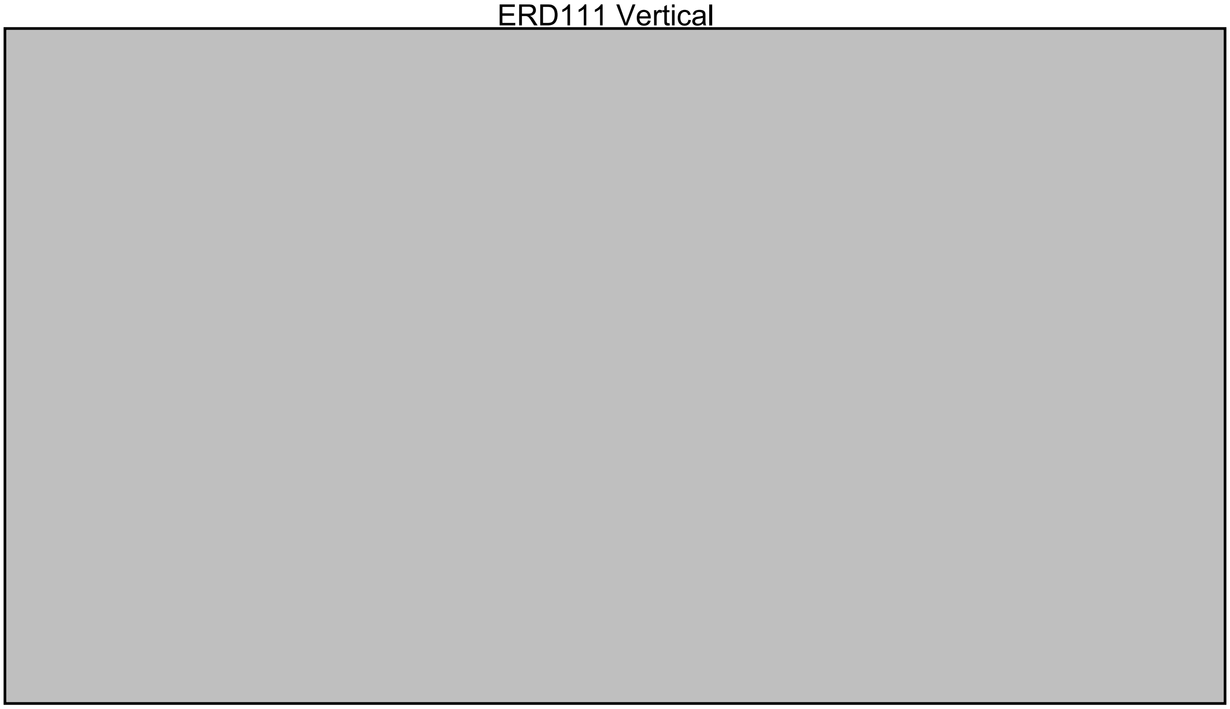
The E.U.T. Complies

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1143	ACTIVE MONOPOLE ANTENNA	A.H. SYSTEMS	SAS-200/550-1	718	05/24/10	05/24/11
707	Biconical antenna	EMCO	3104	3243	02/10/10	02/10/11
1621	Antenna, Double Rigid Guide	EMC Test Systems	3106	2815	01/06/10	01/06/11
1033	Horn antenna	EMCO	3115	8812-3035	09/09/09	09/09/10
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/10	02/27/11
1025	PREAMP	Nemko USA, Inc.	LNA25	398	02/19/10	02/19/11
1016	PREAMP	HEWLETT PACKARD	8449A	2749A00159	06/19/10	06/19/11
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1852	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	04/12/10	04/12/11
1811	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	04/12/10	0412/11
1812	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	04/12/10	04/12/11
1853	RG142B/U	Pasternack	N/A	N/A	08/18/09	08/18/10
1067	RG142	Storm	PR90-010-144	N/A	08/18/09	08/18/10
1528	RG142	Storm	PR90-010-144	N/A	08/18/09	08/18/10

Radiated Emissions (RE102) Test Data

ERD111 Vertical



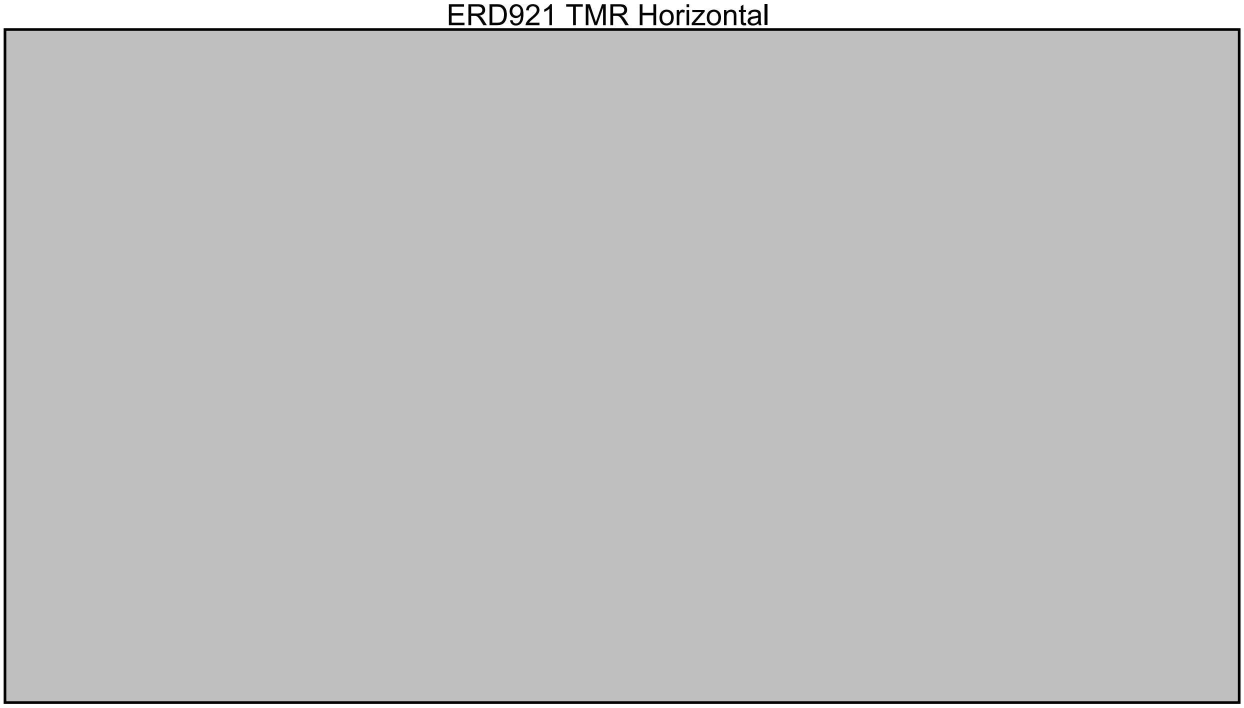
ERD111 Horizontal

ERD921 DMR Vertical

ERD921 DMR Horizontal

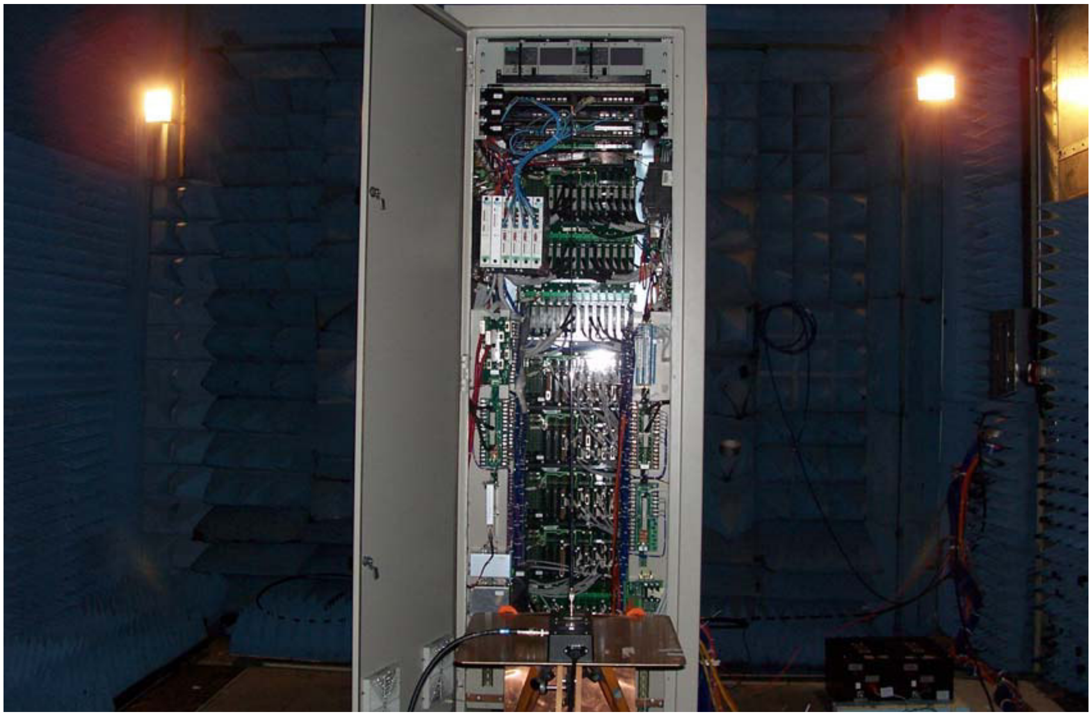
ERD921 TMR Vertical

ERD921 TMR Horizontal

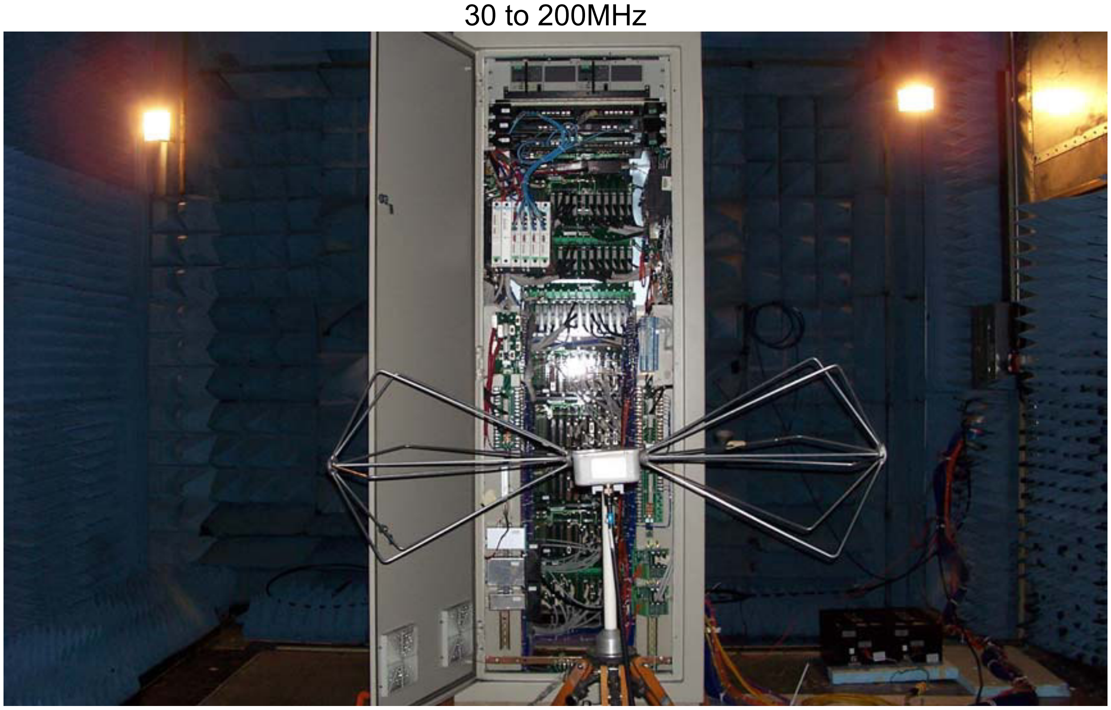


Radiated Emissions (RE102) Test Photographs

2MHz to 30MHz

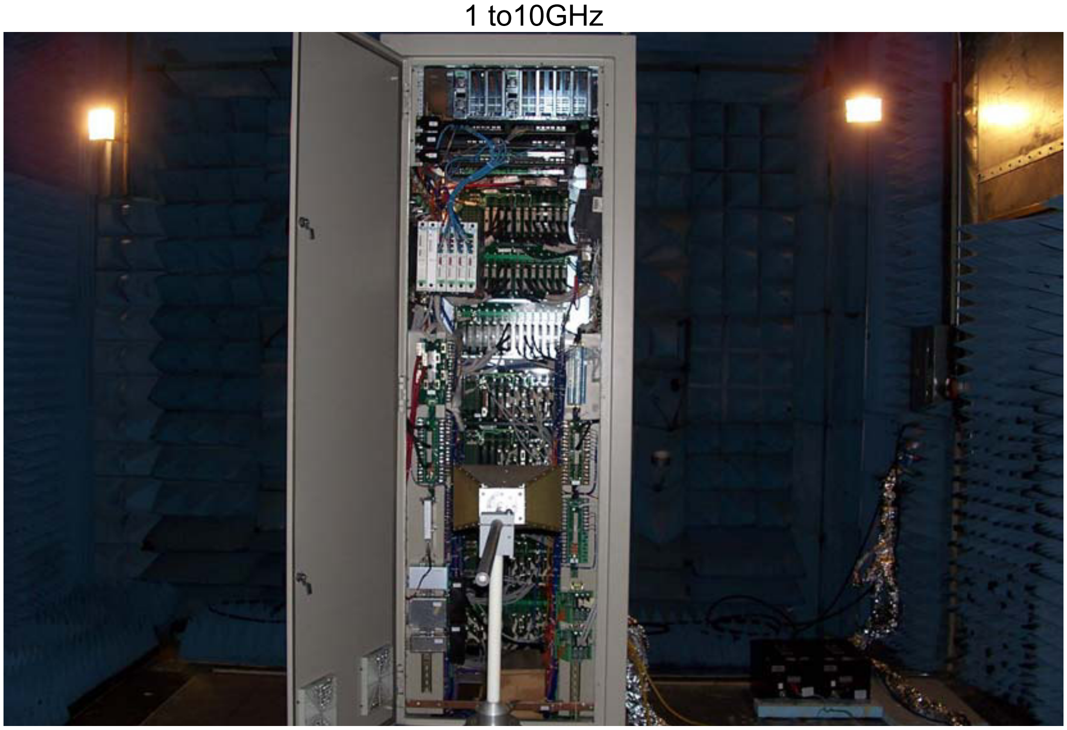


30 to 200MHz



200MHz to 1GHz

1 to10GHz



Section 7. RF Conducted Susceptibility (CS101)

Purpose:

The test is intended to verify the ability of the EUT (Equipment Under Test) to withstand signals coupled onto input power leads.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Test : CS101

Tested By: D. Hartman

Date of Tests: 08/06/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 22˚C

Humidity: 33%

Test Results:

The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
938	Audio signal generator	Hewlett Packard	205AG	NONE	CNR	N/A
1264	10uF capacitor	Solar	6512-106R	69	CNR	N/A
671	TRANSFORMER-AUDIO	SOLAR	6220-2	NONE	CNR	N/A
1463	Color 4 Ch Digitizing Oscilloscope	Tektronix	TDS684A	B010460	06/28/10	06/28/11
1842	Clamp on Meter	AEMC	514	19994GHCT	02/11/10	02/11/11

Conducted Susceptibility (CS101) Test Data

Conducted Susceptibility (CS101) Test Data

Complete X
Preliminary

Job # 47110 Test # : CIPV 01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : MIL-STD461E / RG1.180 Rev.1

Temp. (deg. C) : 22
Humidity (%) : 33
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: Mil Chamber

Date : 08/06/10
Time : 8:00
Staff : D. Hartman

Freq. Start (KHz)	Freq. Stop (KHz)	Test Level (dBuV) start / stop	Time Duration (Min)	Effect Qty	Effects Type	Pass or Fail	Comments:
0.03	5	136	20	0	N/A	Pass	120Vac High Line
5	150	136-106.5					

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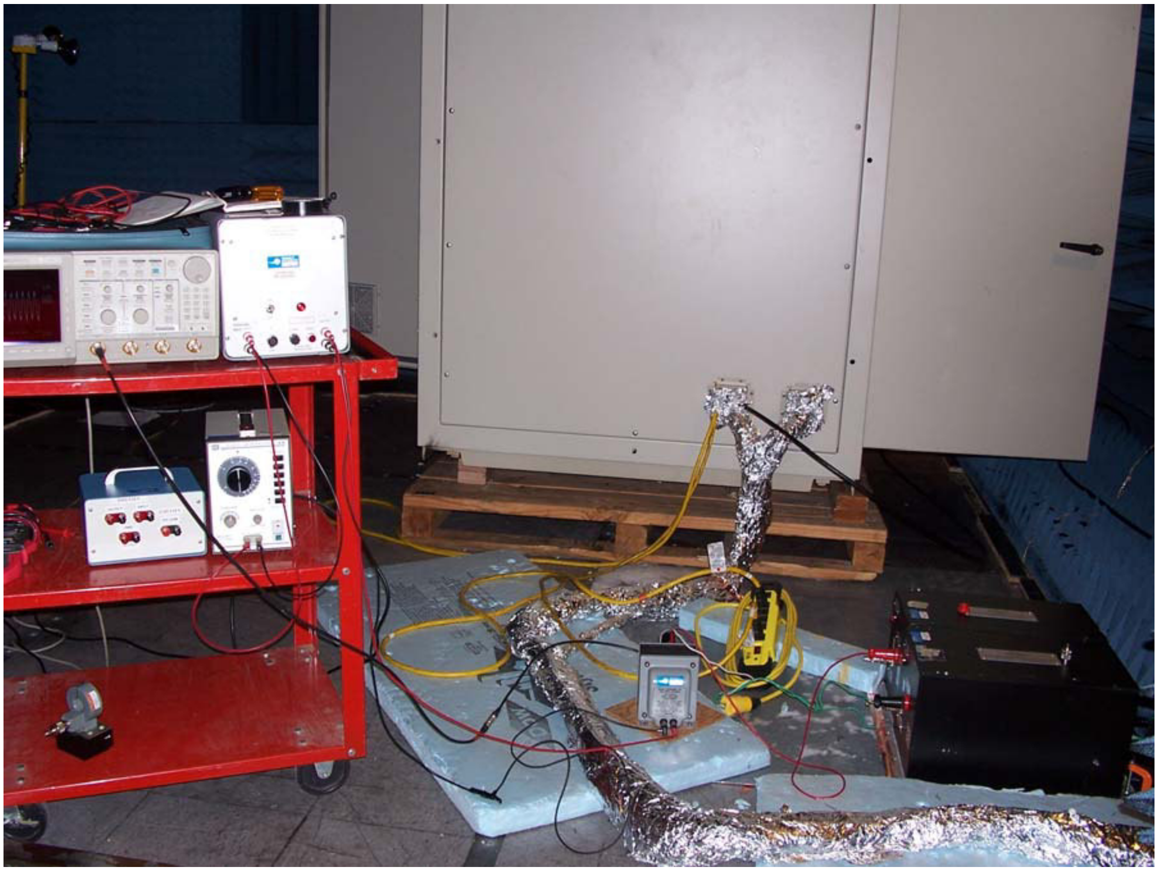
Conducted Susceptibility (CS101) Test Photographs



Section 8. RF Conducted Susceptibility (CS114)

Purpose:

The test is intended to verify the ability of the Equipment Under Test (E.U.T.) to withstand RF signals coupled onto EUT associated cabling.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Specification Limits:

Frequency range (MHz)	Limit	
	(dBuA)	(dBm)
0.010 to 1.0	*49 to 89	24 to 16
1.0 to 30	89	16
Notes: *The limit increases and decreases linearly with respect to the log of the frequency. The Software used is calibrated and tested in dBm units, the table above shows the conversion from dBm to dBuA.		

Test : CS114

Tested By: D. Hartman

Dates of Tests: 08/6/10 to 08/10/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 22˚C

Humidity: 33%

Test Results:

The E.U.T. Complies

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1771	Signal Generator 9KHz to 2.4GHz	Marconi Instruments	2024	112211/052	02/08/10	02/08/11
1147	INJECTION CLAMP, .01-100MHz	TEGAM	Q5236-1	10985	CNR	N/A
1148	INJECTION CLAMP, 2-400MHz	TEGAM	95242-1	11670	CNR	N/A
780	Current clamp 1-1000mhz	Singer	94111-1	325	03/10/10	03/10/11
781	Current clamp 10khz-100mhz	Stoddart Aircraft Radio Co.	94550-1	421-90	03/10/10	03/10/11
1263	CALIBRATION FIXTURE	FISCHER	FCC-BCICF-2	69	CNR	N/A
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/09	02/27/11
1663	Spectrum Analyzer	Rhode & Schwarz	FSP	100073	08/23/10	08/23/11
0786	50dB Coupler	Amplifier Research	DC2600	N/A	CBU	09/10/10
1535	30dB Attenuator,	Bird Electronics	8322	469	CBU	08/10/10
1775	AR Amplifier 10KHz-220MHz	Amplifier Research	1000L	N/A	CNR	N/A
741	300Watt 50 Ohm Load	Philco	160B 300	557	CNR	N/A

R.F. Conducted Susceptibility (CS114) Test Data

Conducted Susceptibility (CS114) Test Data

Complete X
Preliminary

Job # 47110 Test # : CIPV 01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : MIL-STD461E / RG1.180 Rev.1

Temp. (deg. C) : 22
Humidity (%) : 33
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: Mil Chamber

Date : 08/10/10
Time : 8:00
Staff : D. Hartman

Freq. Start (MHz)	Freq. Stop (MHz)	Test Level (dBuA) start / stop	Time Duration (Min)	Effect Qty	Effects Type	Pass or Fail	Comments:
0.01	1	49 to 89	120	0	N/A	Pass	ERD911 120Vac Input Power line
1	30	89					
0.01	1	49 to 89	120	0	N/A	Pass	ERD921 120Vac Input Power line
1	30	89					
0.01	1	49 to 89	120	0	N/A	Pass	Signal Cable 1
1	30	89					
0.01	1	49 to 89	120	0	N/A	Pass	Signal Cable 2
1	30	89					
0.01	1	49 to 89	120	0	N/A	Pass	Signal Cable 3
1	30	89					

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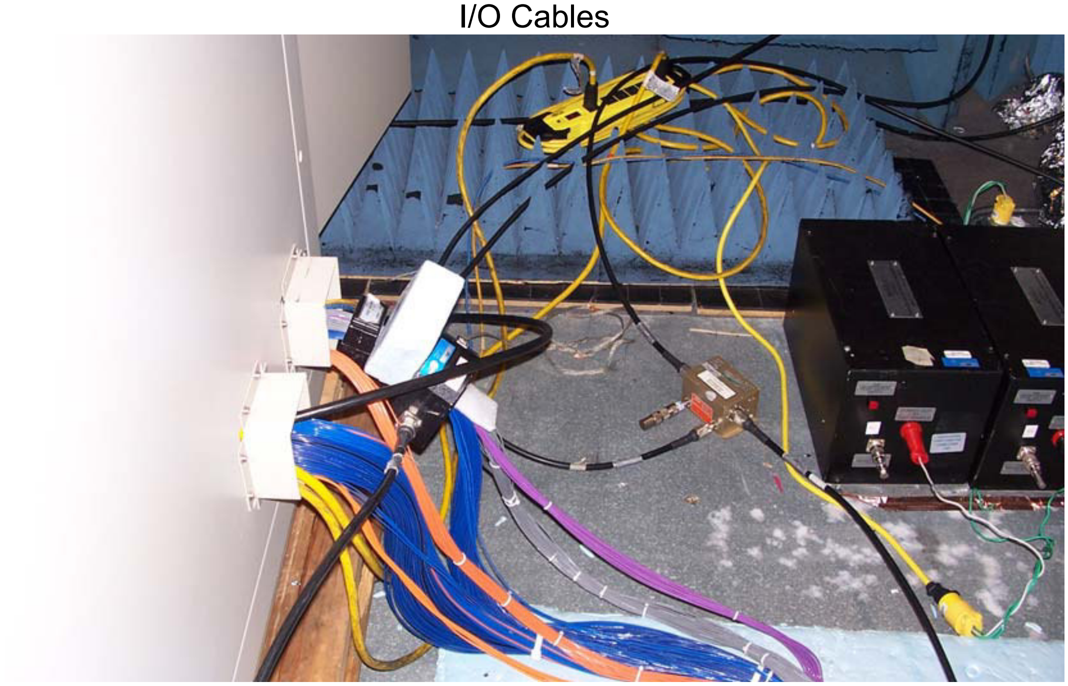
R.F. Conducted Susceptibility (CS114) Test Photographs

120Vac Power

I/O Cables



Section 9. Conducted Susceptibility, Damped Sinusoidal Transients (CS116)

Purpose:
This test procedure is used to verify the ability of the EUT to withstand damped sinusoidal transients coupled onto EUT associated cables and power leads.

Test :	CS116
Tested By:	D. Hartman
Date of Tests:	09/20/10
Test Conditions:	
Test Voltage:	28Vdc
Temperature:	22˚C
Humidity:	33%

Test Results:

The E.U.T. complies.

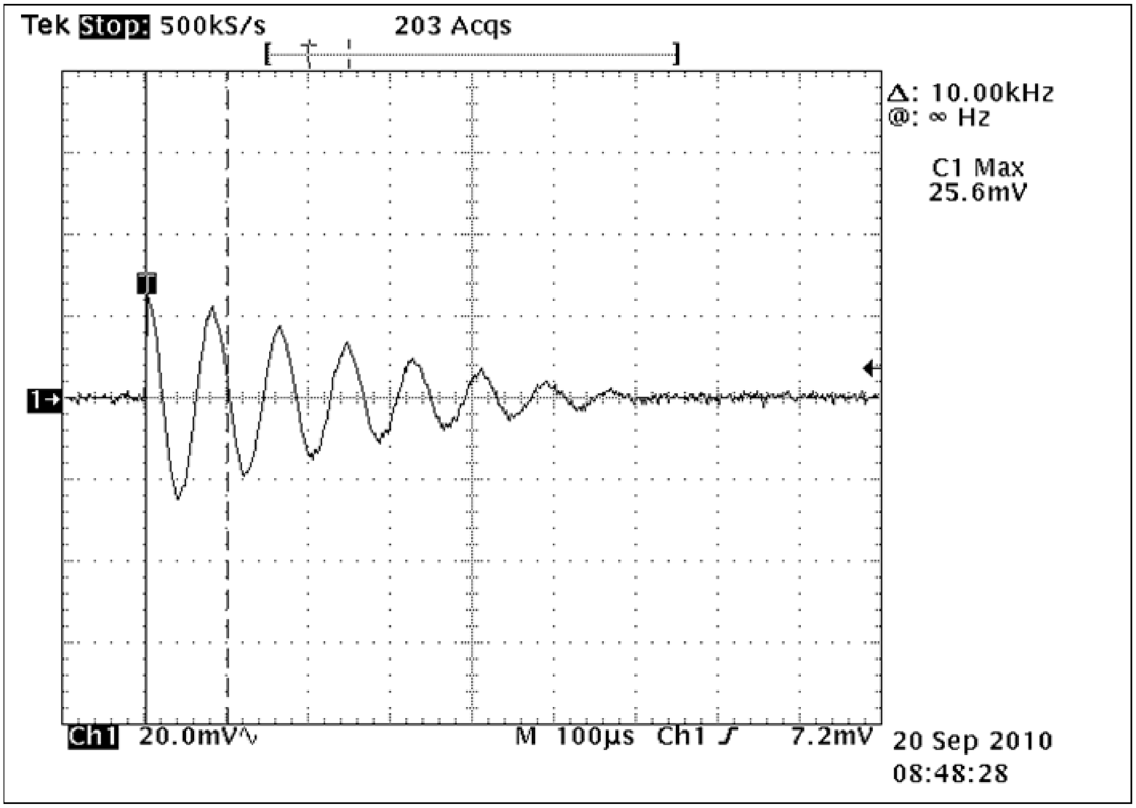
TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1777	Transient Pulse Generator	Solar	9354-2	N/A	CBU	9/20/10
1147	INJECTION CLAMP, .01-100MHz	TEGAM	Q5236-1	10985	CNR	N/A
1148	INJECTION CLAMP, 2-400MHz	TEGAM	95242-1	11670	CNR	N/A
781	Current clamp 10khz-100mhz	Stoddart Aircraft Radio Co.	94550-1	421-90	01/26/10	01/26/11
1263	CALIBRATION FIXTURE	FISCHER	FCC-BCICF-2	69	CNR	N/A
741	300Watt 50 Ohm Load	Philco	160B 300	557	CNR	N/A
1463	Color 4 Ch Digitizing Oscilloscope	Tektronix	TDS684A	B010460	6/28/10	6/28/11
1813	20db Attenuator	Weinschel	26-20-34	AG 2531	CBU	9/20/10
1814	20db Attenuator	Weinschel	24-20-34	BN9333	CBU	9/20/10

R.F. Conducted Susceptibility (CS116) Test Data

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	10 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

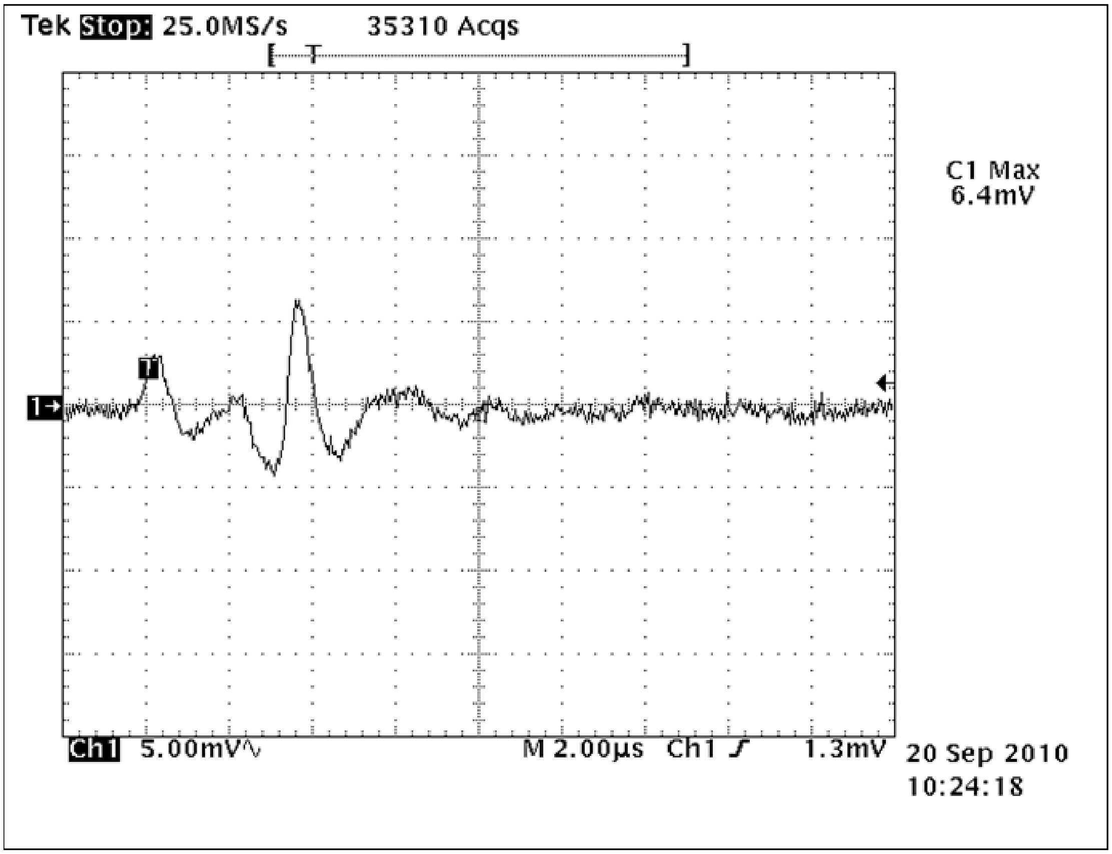


Required Ip:	0.05	**Measured Ip:**	0.05	**Attenuator Factor:**	40 dB = 100x
Required Vp:	0.025	**Measured Vp:**	0.025		
Required Q	15 ± 5	**Measured Q**	13.71	**Generator Setting, Volts:**	28% / 0010

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohm Cal Fixture
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	10 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

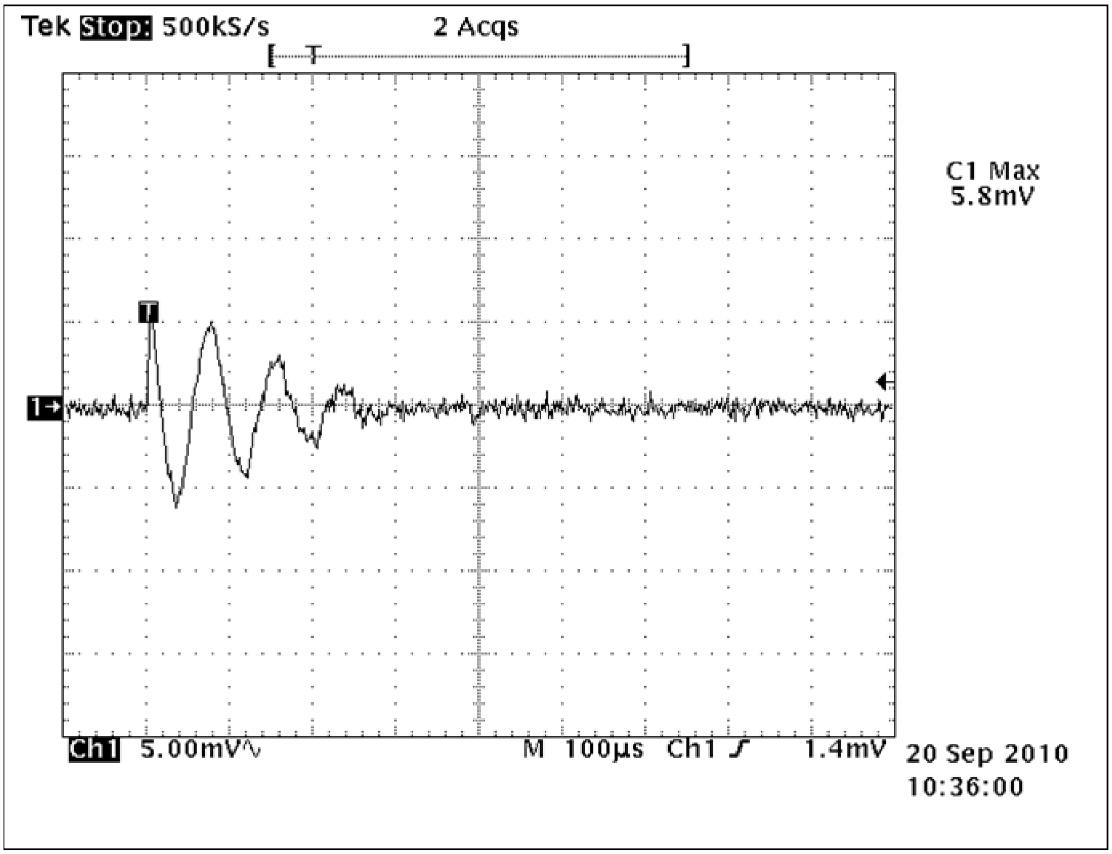


Required Ip:	0.05	**Measured Ip:**	0.055	**Attenuator Factor:**	40dB = 100x
Required Vp:	0.025	**Measured Vp:**	.0064		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	7% / 0010

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	10 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

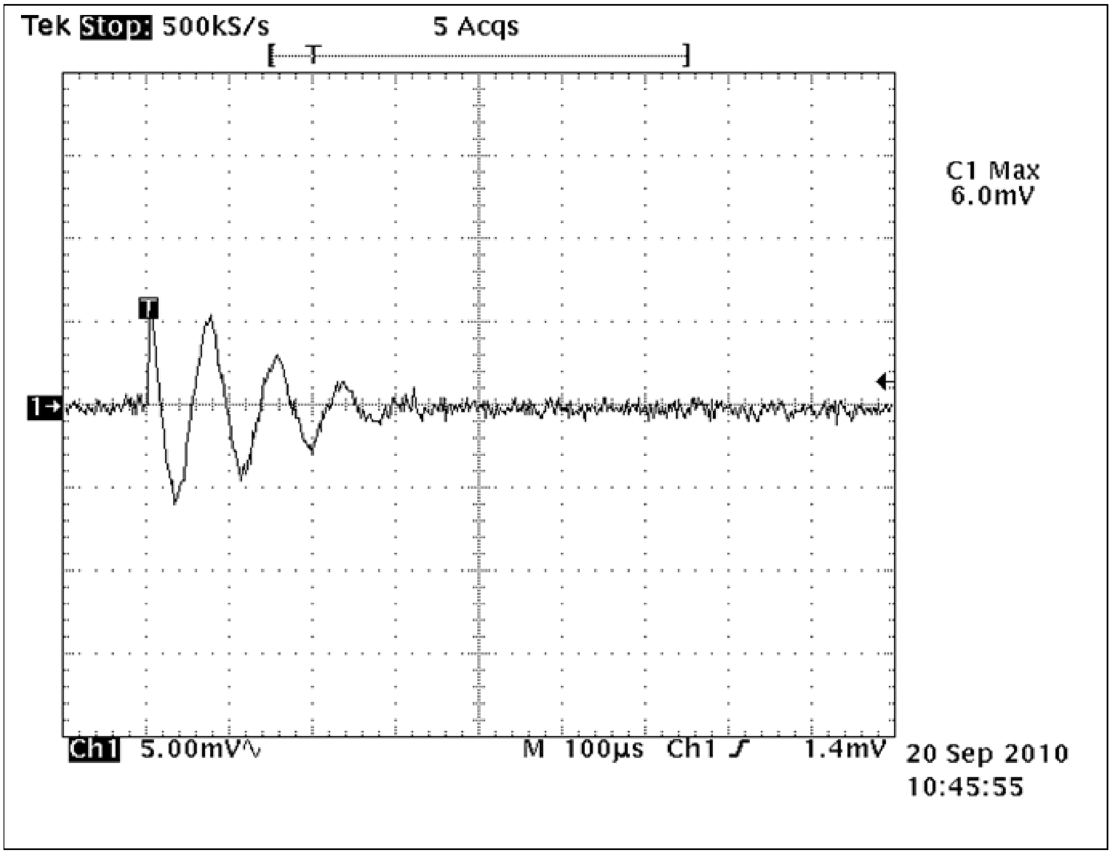


Required Ip:	0.05	**Measured Ip:**	0.052	**Attenuator Factor:**	40dB = 100x
Required Vp:	2.5	**Measured Vp:**	.0058		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	9% / 0010

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	10 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

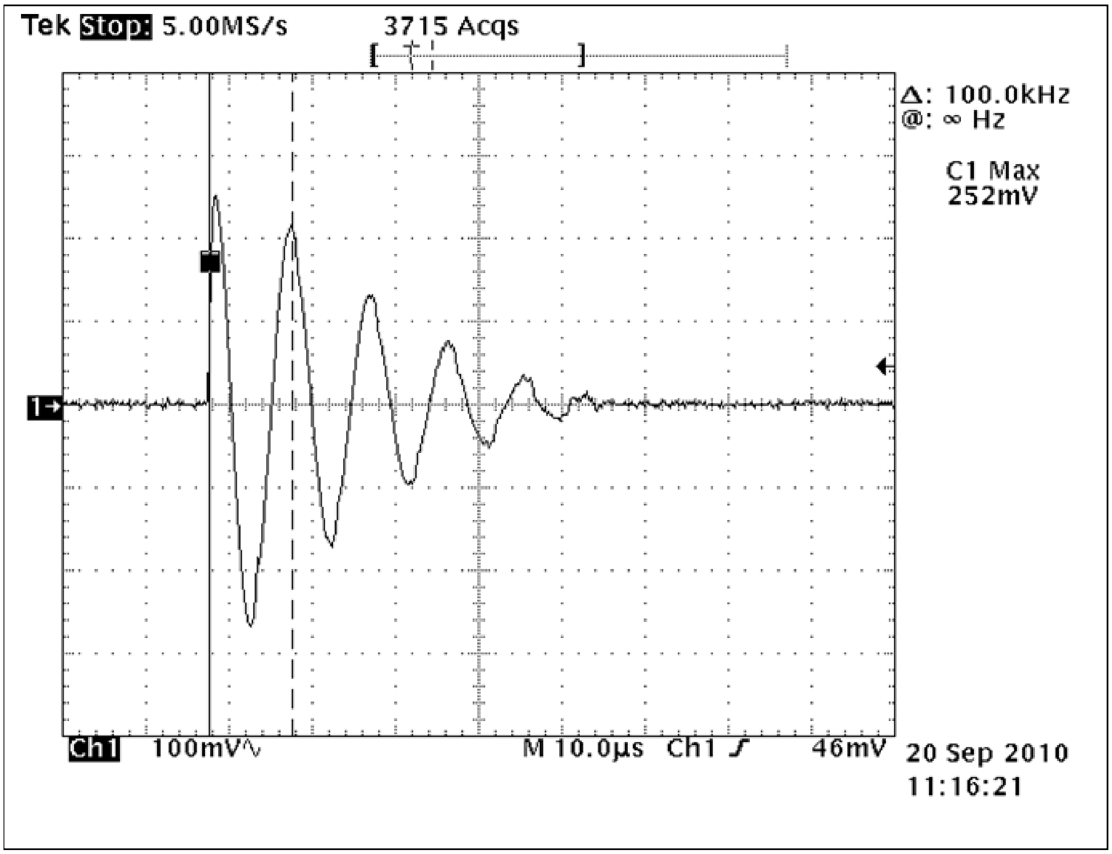


Required Ip:	0.05	**Measured Ip:**	0.053	**Attenuator Factor:**	40dB = 100x
Required Vp:	0.025	**Measured Vp:**	0.006		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	9% / 0002

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

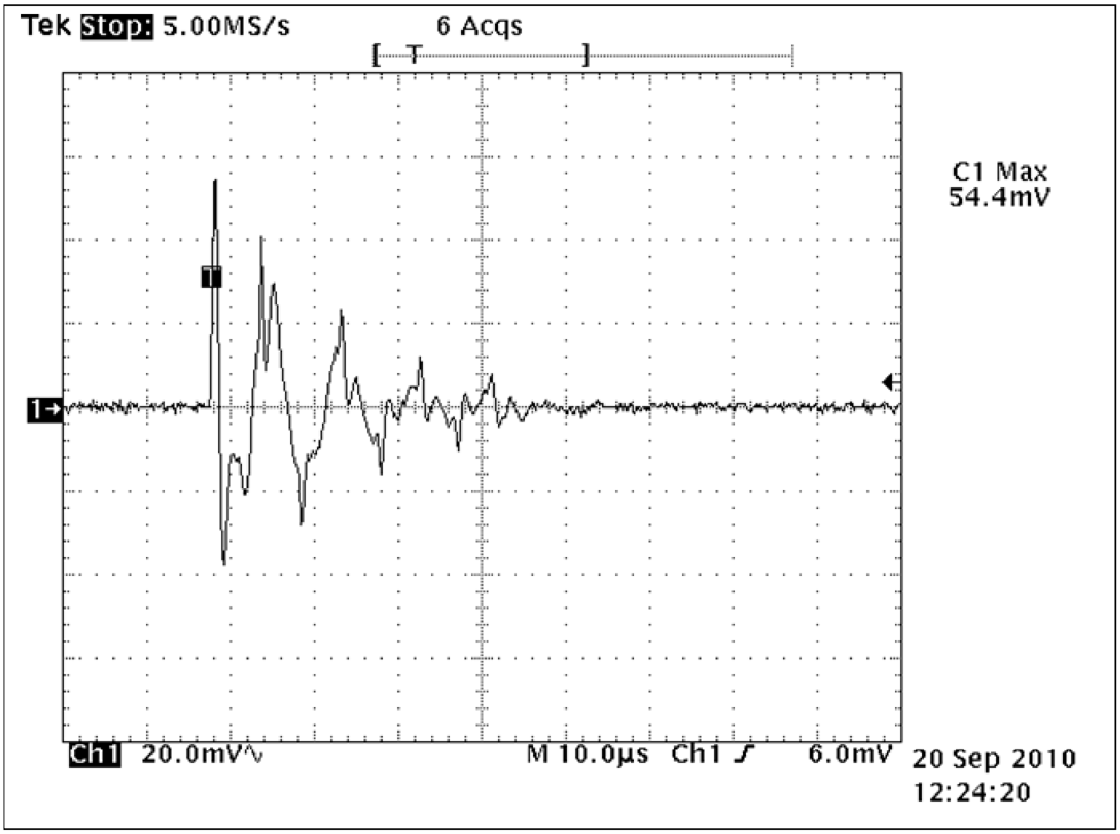


Required Ip:	0.5	**Measured Ip:**	0.5	**Attenuator Factor:**	40dB = 100x
Required Vp:	0.252	**Measured Vp:**	0.252		
Required Q	15 ± 5	**Measured Q**	10.14	**Generator Setting, Volts:**	014% / 0060

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohm Cal fixture
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100 kHz
Procedure:	TP901-200-05, Rev C	**Technician:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

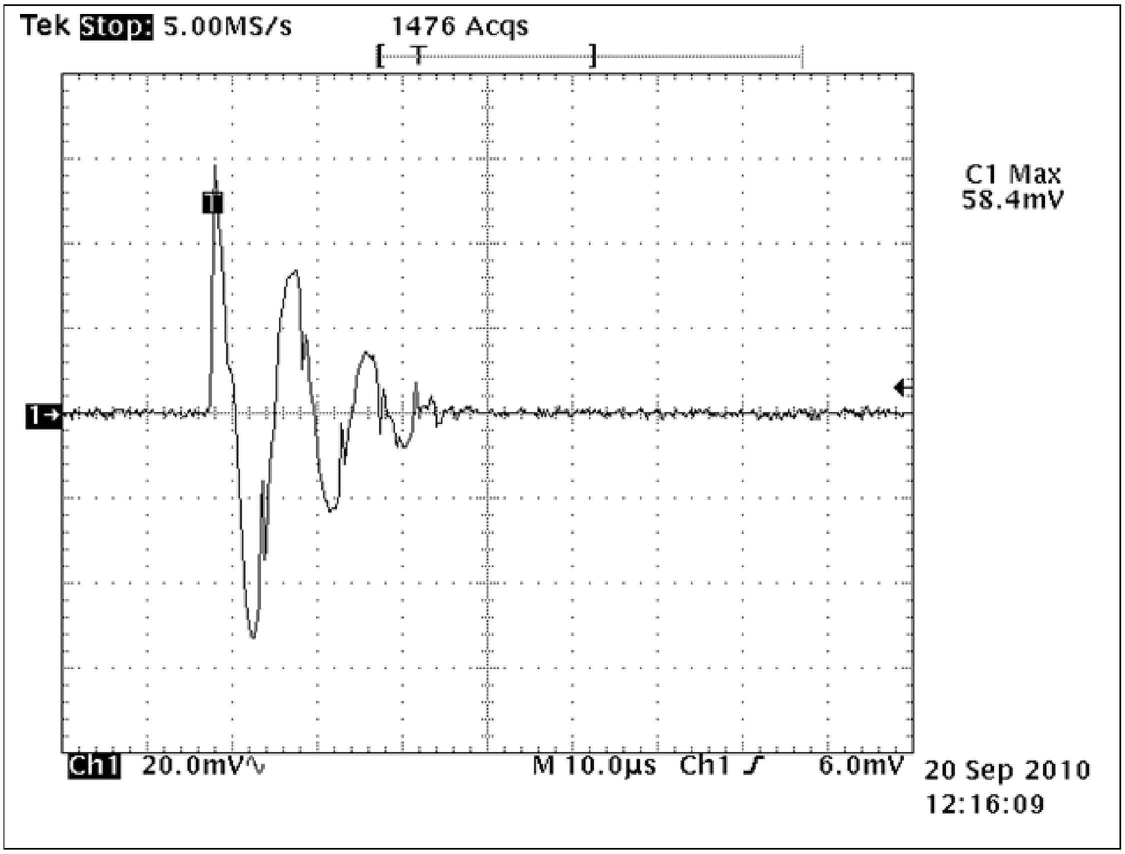


Required Ip:	0.5	**Measured Ip:**	0.503	**Attenuator Factor:**	40 dB = 100x
Required Vp:	2.5	**Measured Vp:**	0.544		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	10% / 0038

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

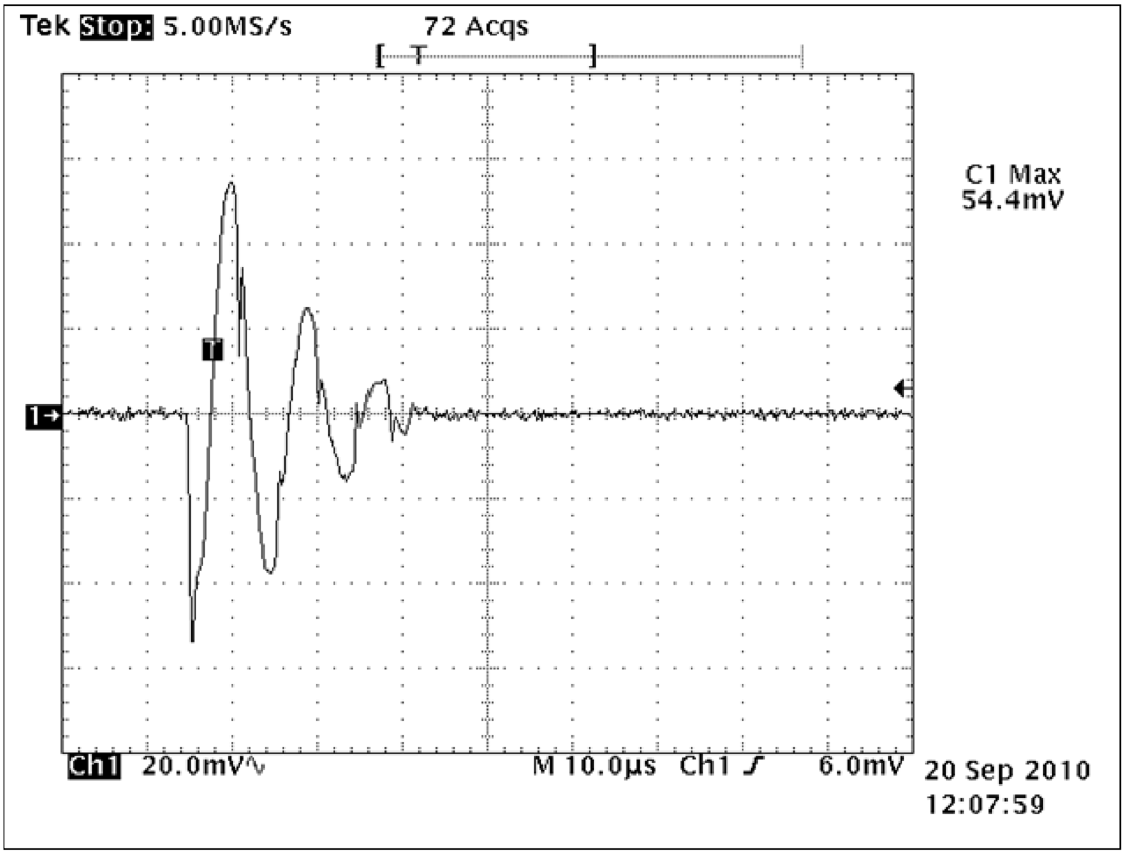


Required Ip:	0.5	**Measured Ip:**	0.540	**Attenuator Factor:**	40dB = 100x
Required Vp:	2.5	**Measured Vp:**	0.584		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	9% / 0027

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	100 kHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

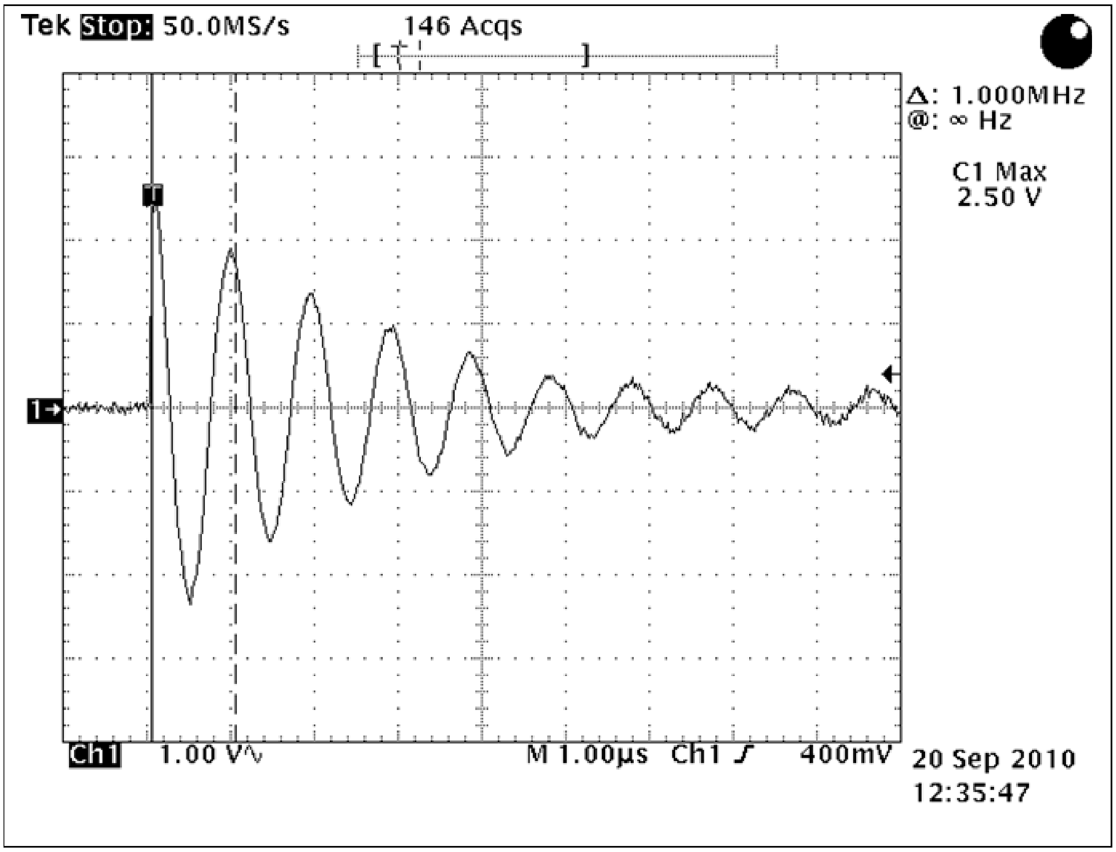


Required Ip:	0.5	**Measured Ip:**	0.509	**Attenuator Factor:**	40dB = 100x
Required Vp:	2.5	**Measured Vp:**	0.544		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	9% / 0027

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	1 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

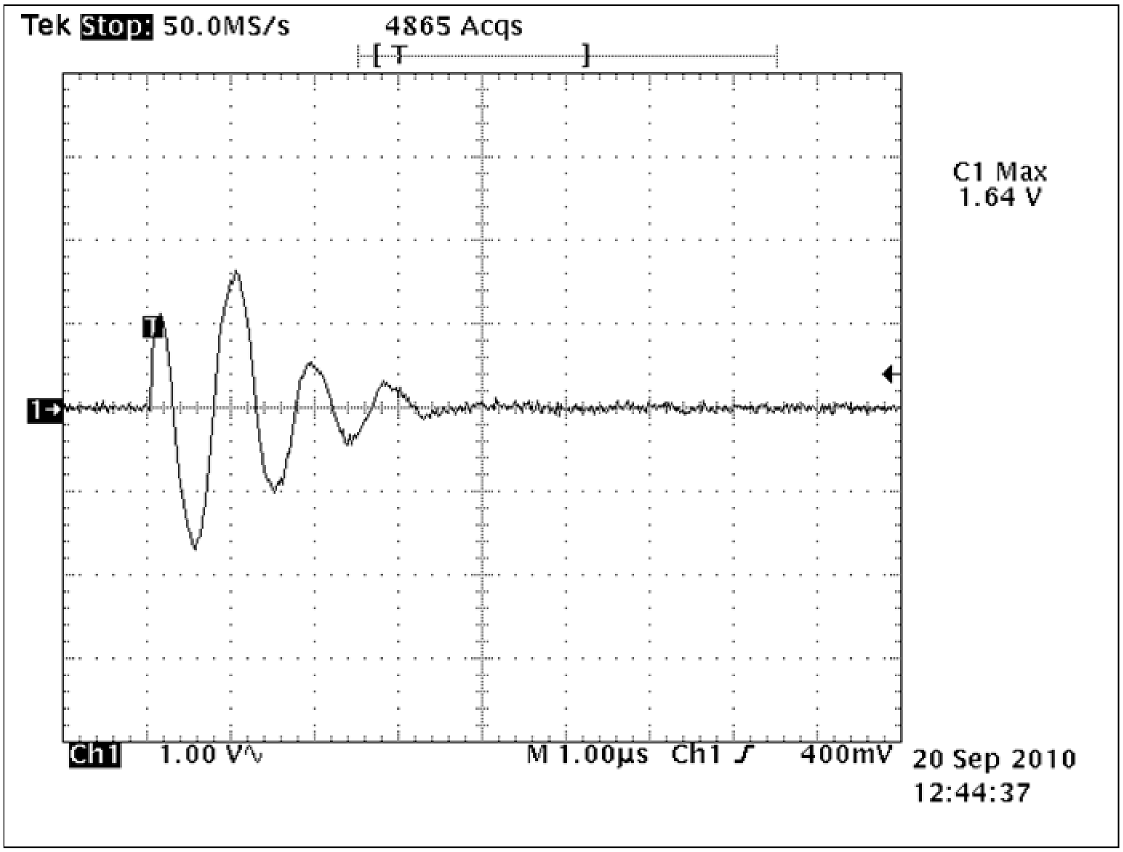


Required Ip:	5.0	**Measured Ip:**	5	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	2.5		
Required Q	15 ± 5	**Measured Q**	9.87	**Generator Setting, Volts:**	12% / 0558

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohm Cal Fixture
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	1 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

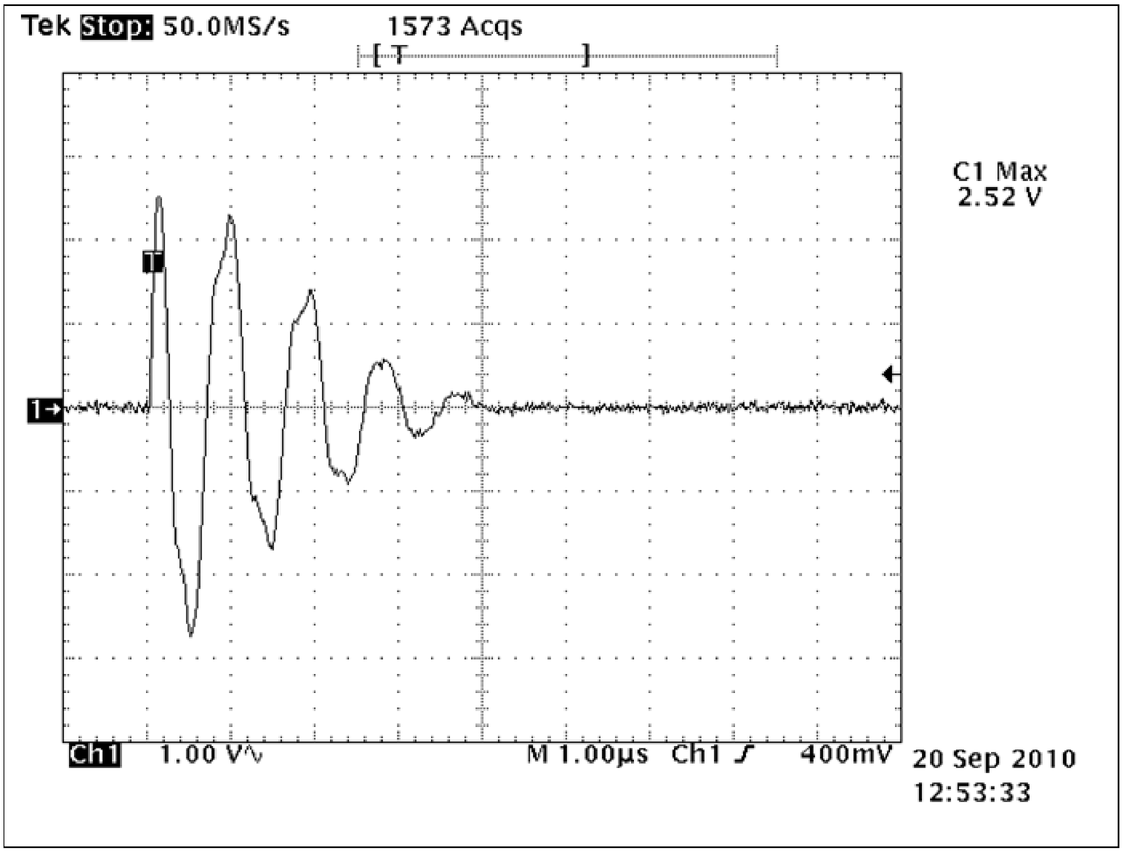


Required Ip:	5	**Measured Ip:**	0.343	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	1.64		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	12% / 0558

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	1 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

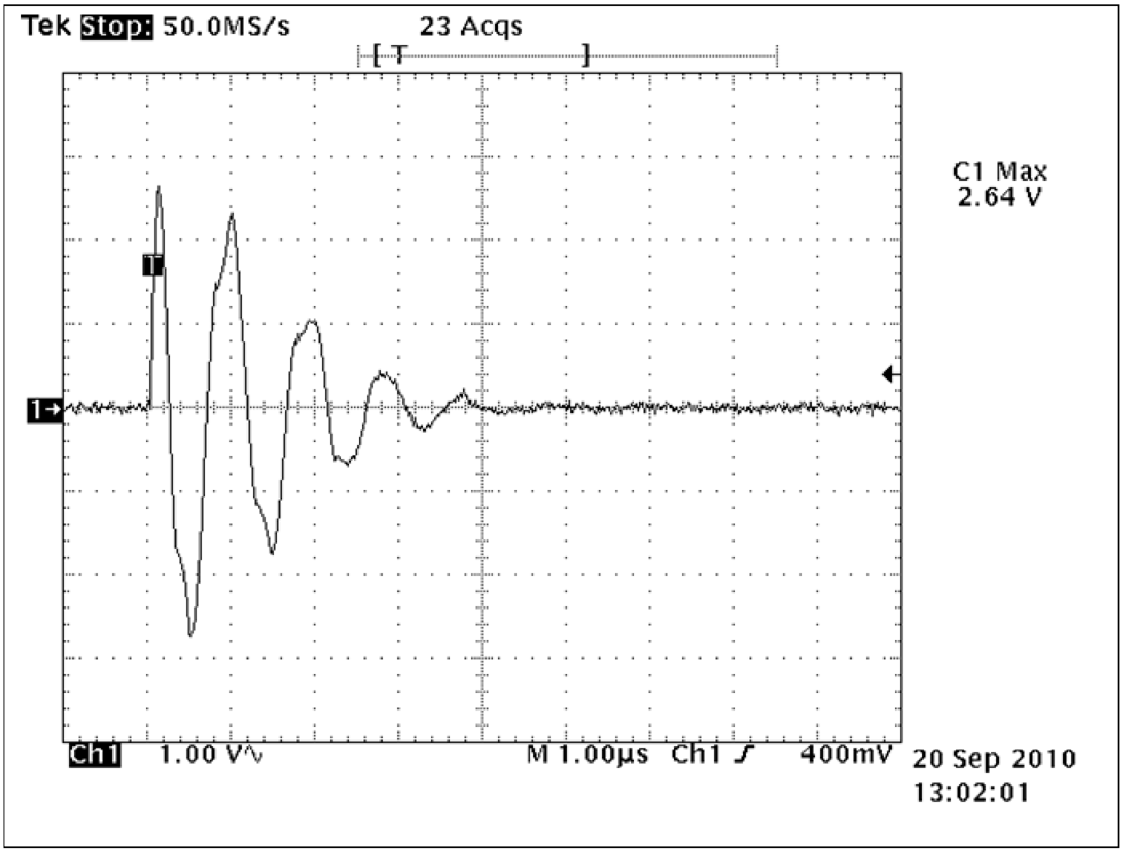


Required Ip:	5	**Measured Ip:**	0.524	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	2.52		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	12% / 0558

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	1 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

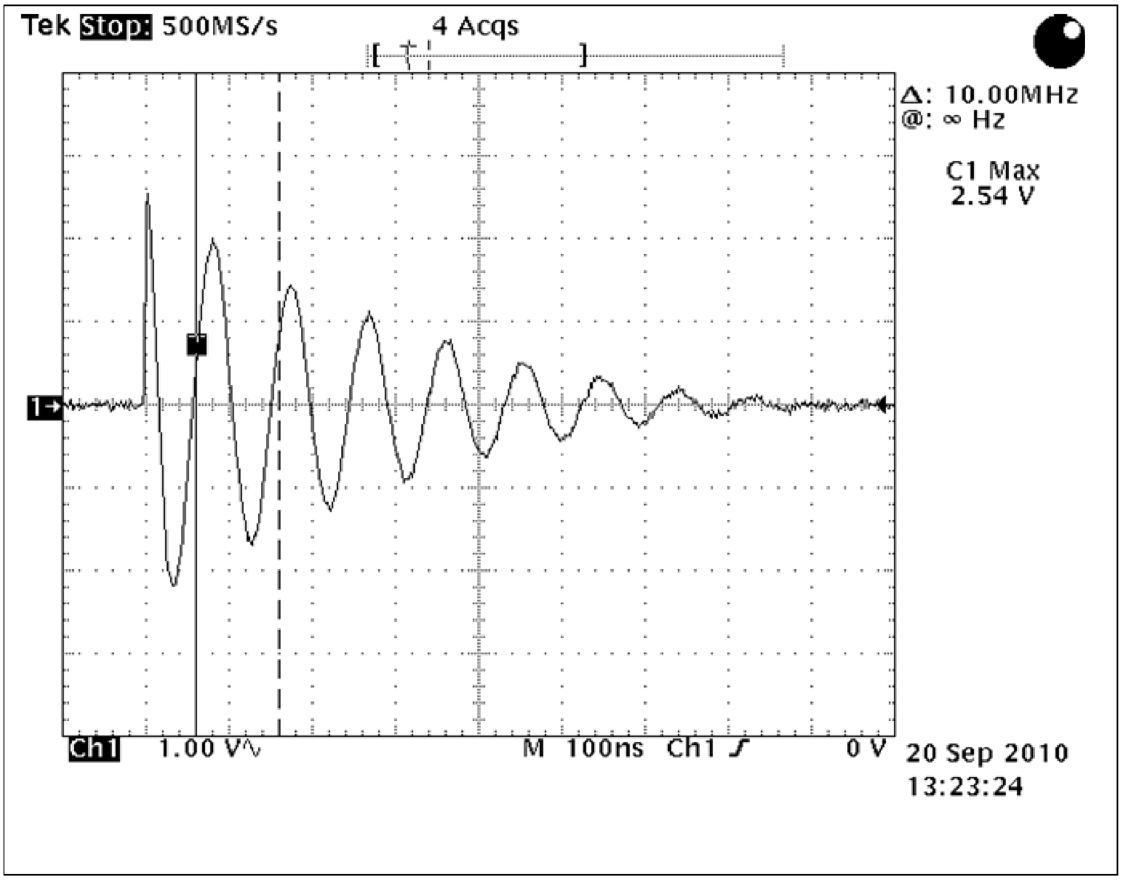


Required Ip:	5	**Measured Ip:**	0.553	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	2.64		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	12% / 0558

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	10 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

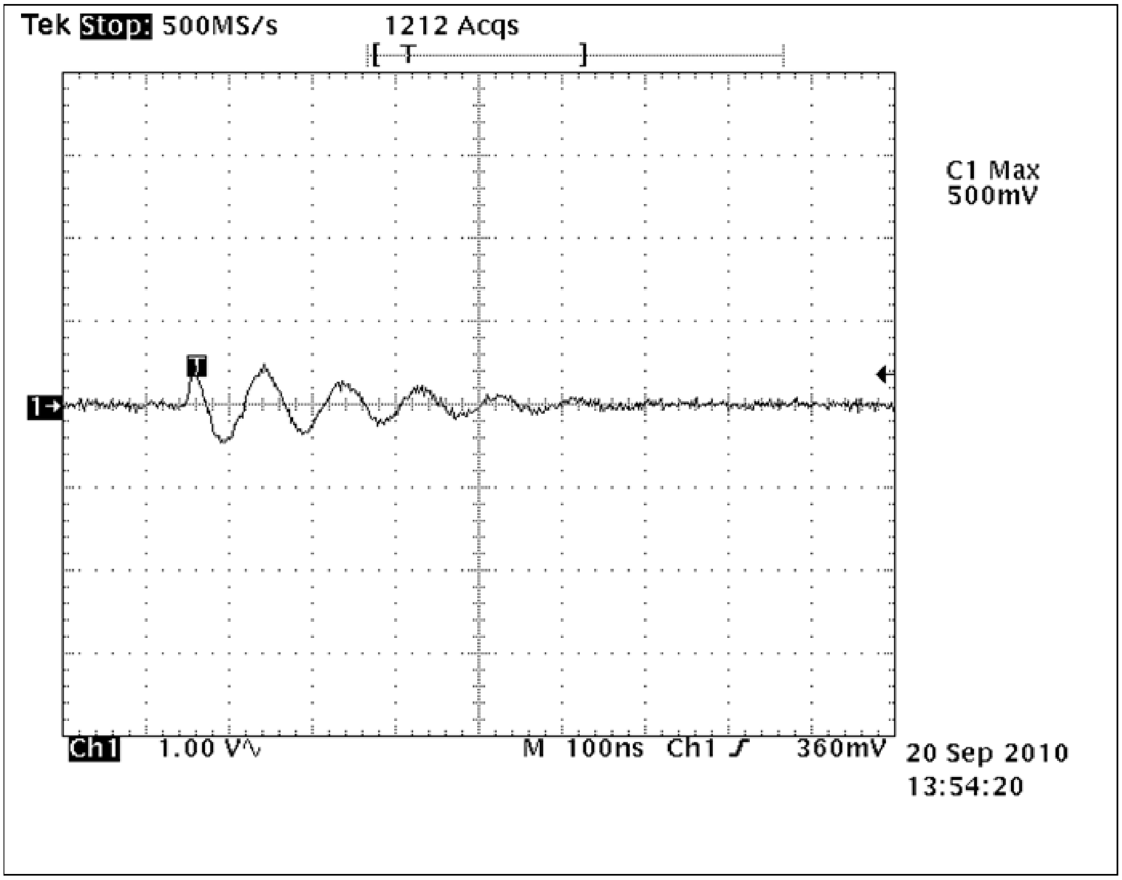


Required Ip:	5	**Measured Ip:**	5	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	2.5		
Required Q	15 ± 5	**Measured Q**	11.27	**Generator Setting, Volts:**	13% / 0523

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohms
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	10 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

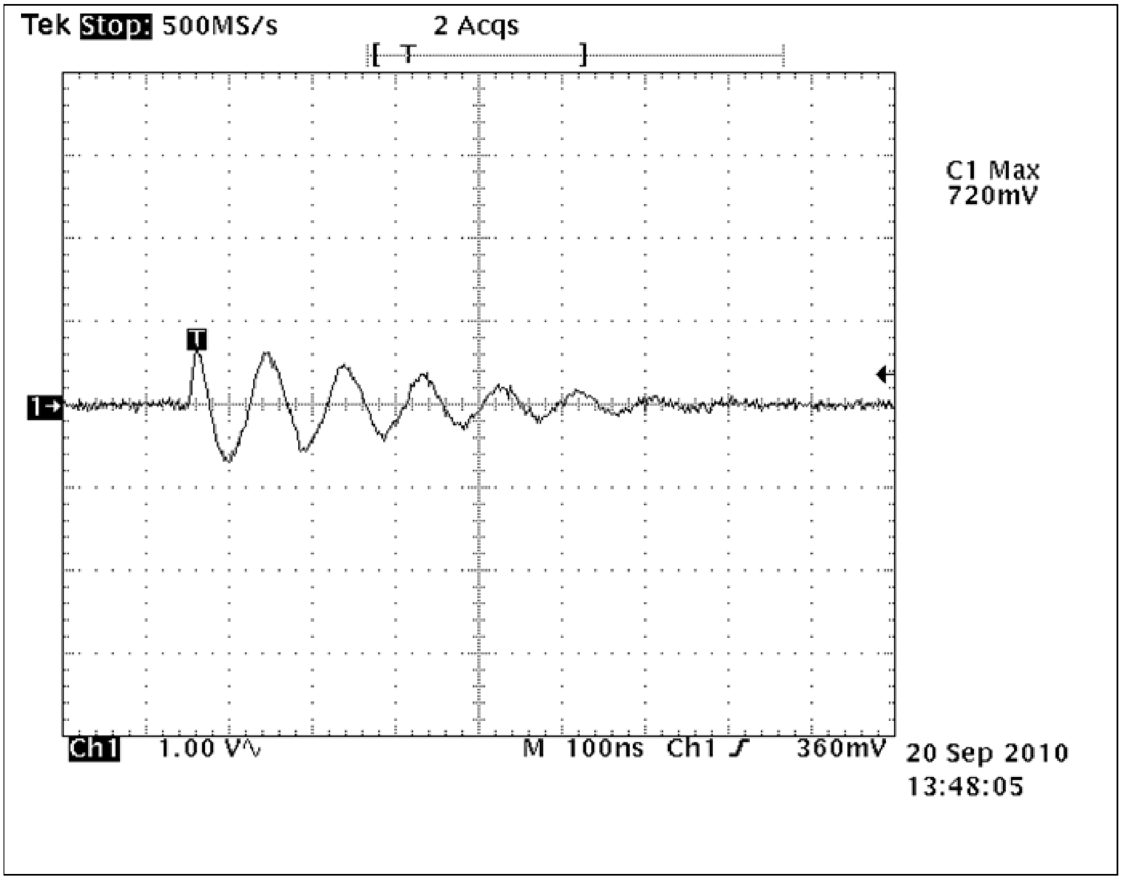


Required Ip:	5	**Measured Ip:**	0.088	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	0.5		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	13% / 0523

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	10 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

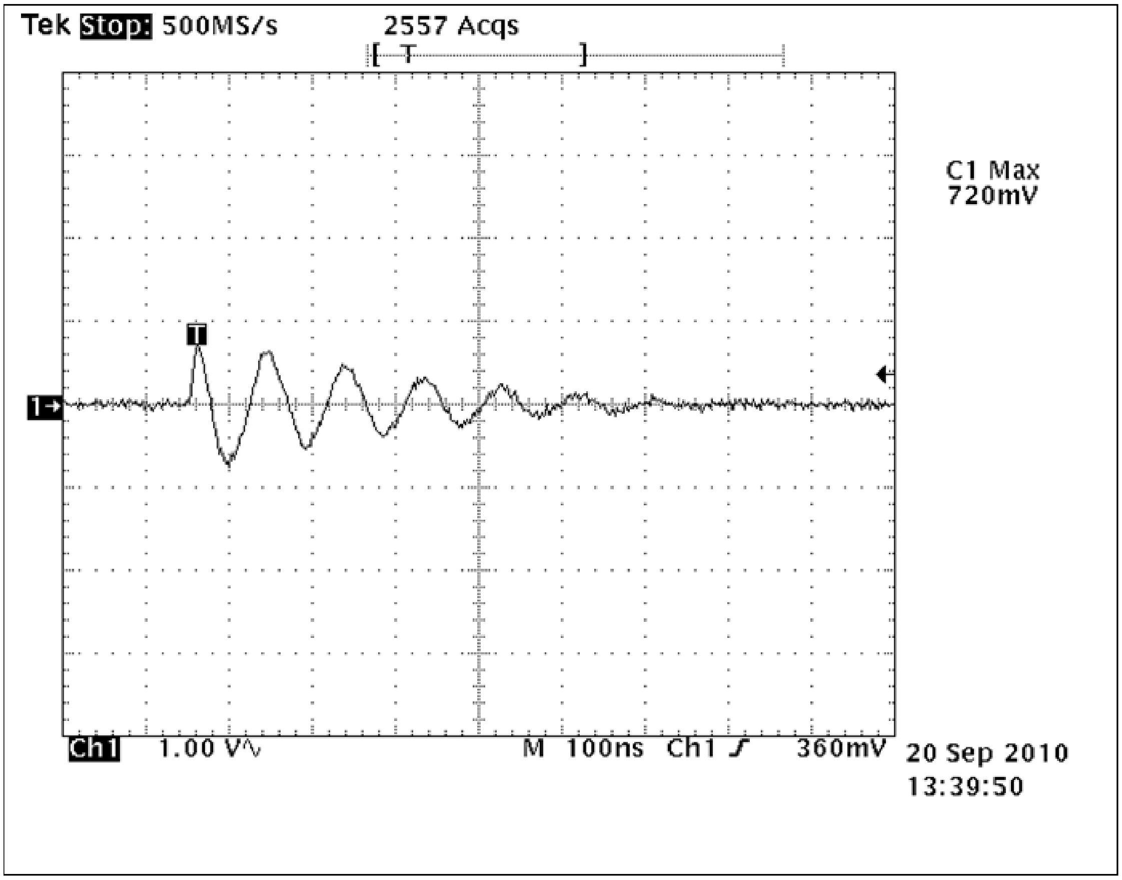


Required Ip:	5	**Measured Ip:**	0.127	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	0.720		
Required Q	15 ± 5	**Measured Q**	11.27	**Generator Setting, Volts:**	13% / 0523

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	10 MHz
Test Item:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

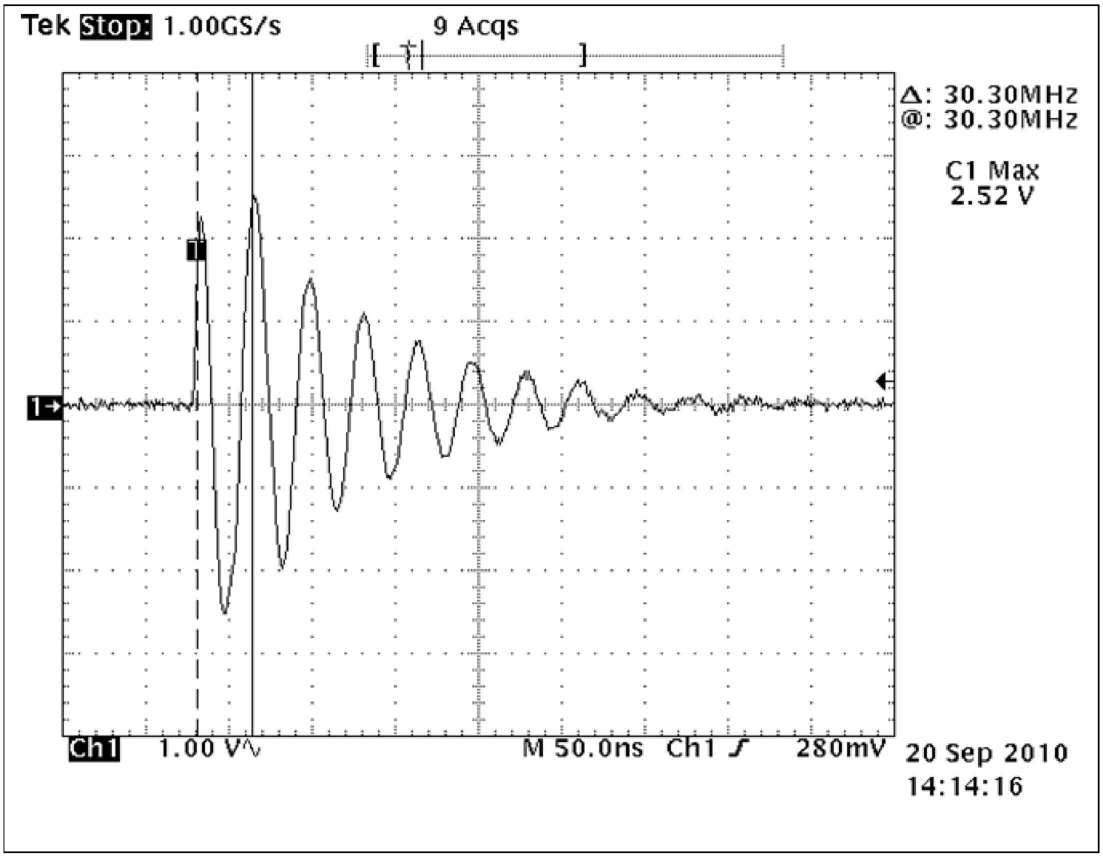


Required Ip:	5	**Measured Ip:**	0.127	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	0.720		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	13% / 0523

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	30 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

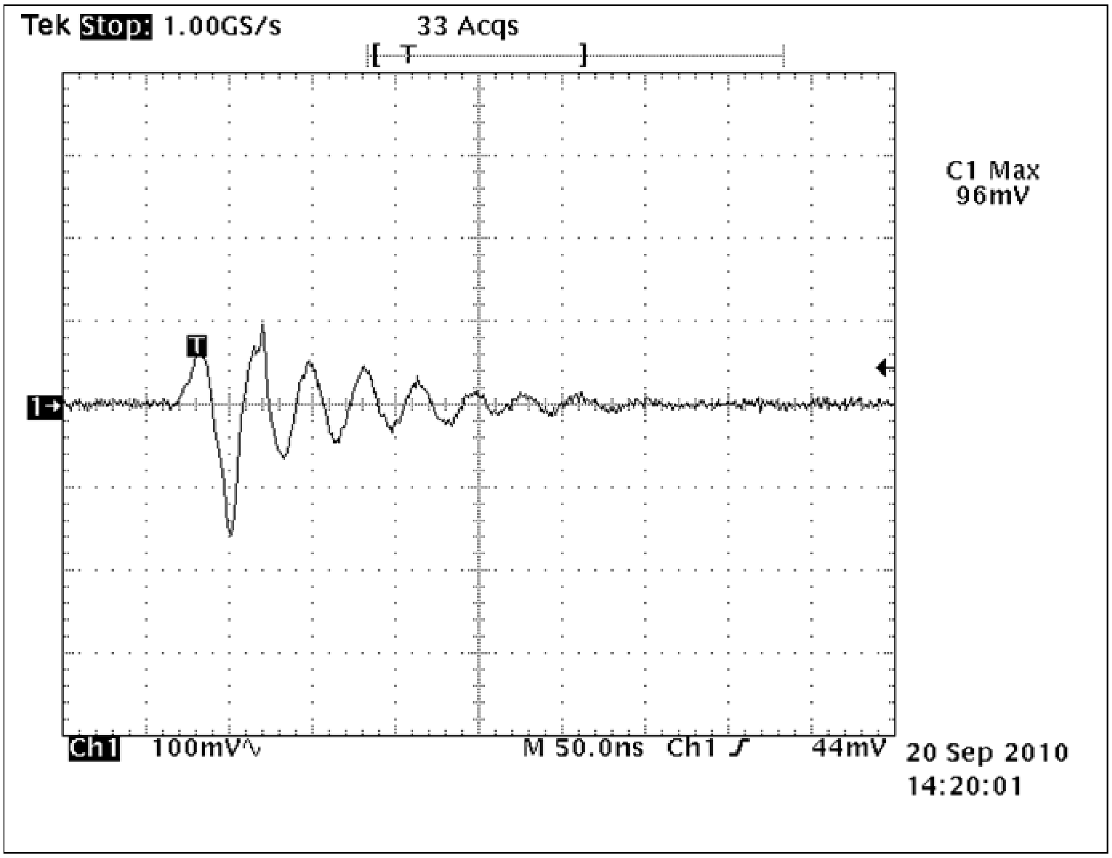


Required Ip:	5	**Measured Ip:**	5	**Attenuator Factor:**	40 dB = 100x
Required Vp:	250	**Measured Vp:**	2.52		
Required Q	15 ± 5	**Measured Q**	10.79	**Generator Setting, Volts:**	26% / 0442

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohms
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	30 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

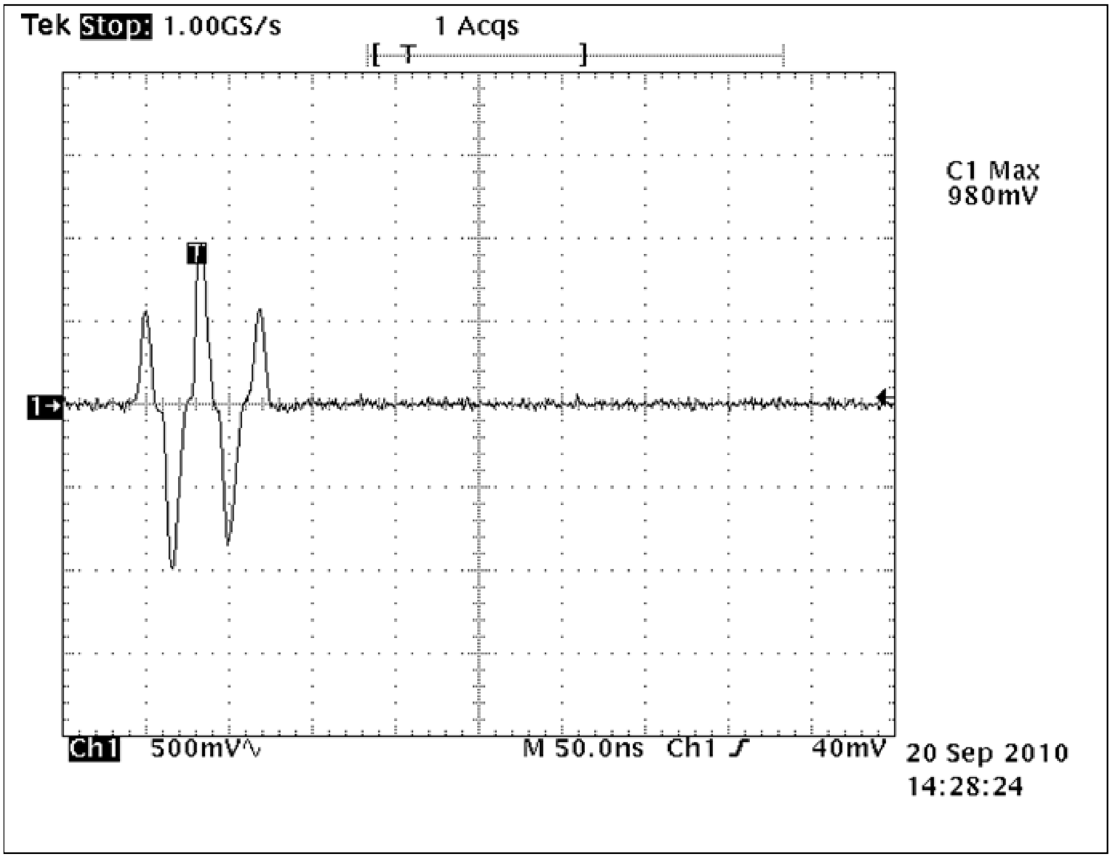


Required Ip:	5	**Measured Ip:**	0.018	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	0.096		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	26% / 0441

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	30 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

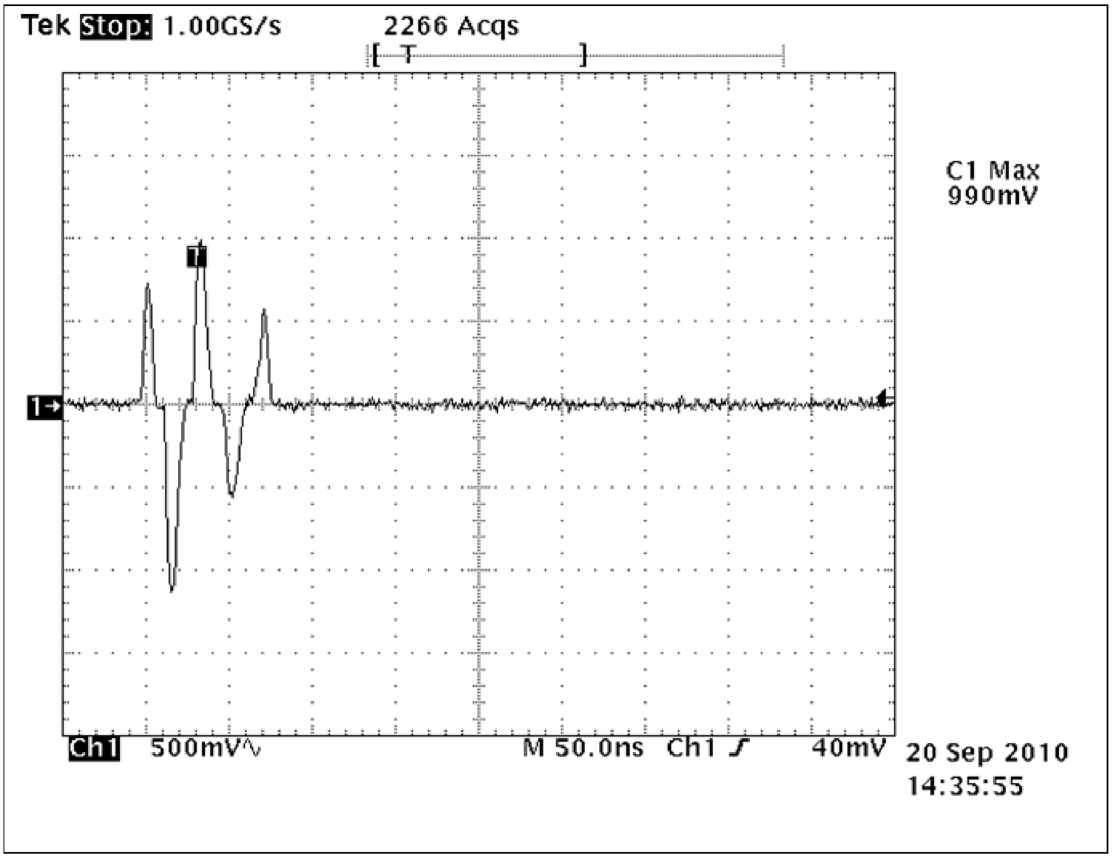


Required Ip:	5	**Measured Ip:**	0.185	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	0.980		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	26% / 0441

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	30 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

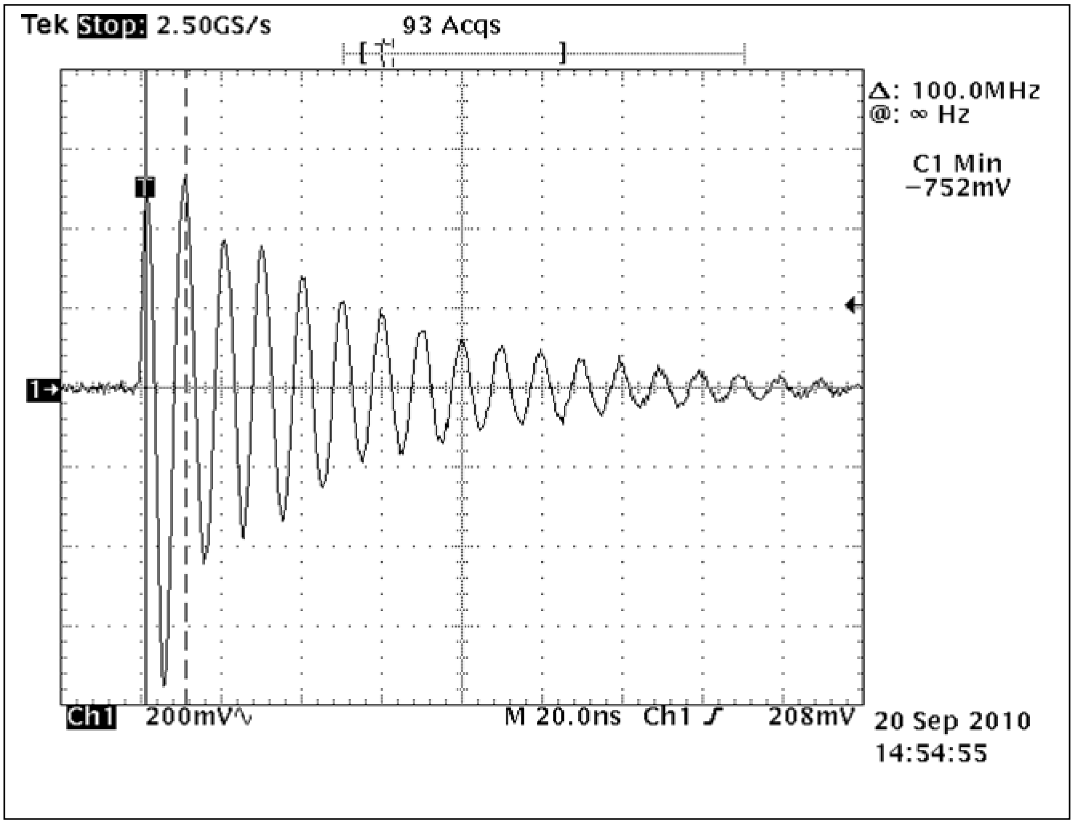


Required Ip:	5	**Measured Ip:**	0.019	**Attenuator Factor:**	40dB = 100x
Required Vp:	250	**Measured Vp:**	0.099		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	26% / 0441

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95236-1 (10KHz to 100MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Mode:	Calibration	**Job No.:**	47110
Specification:	MIL-STD-461E / RG.1.180 Rev. 1	**Test Frequency:**	100 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

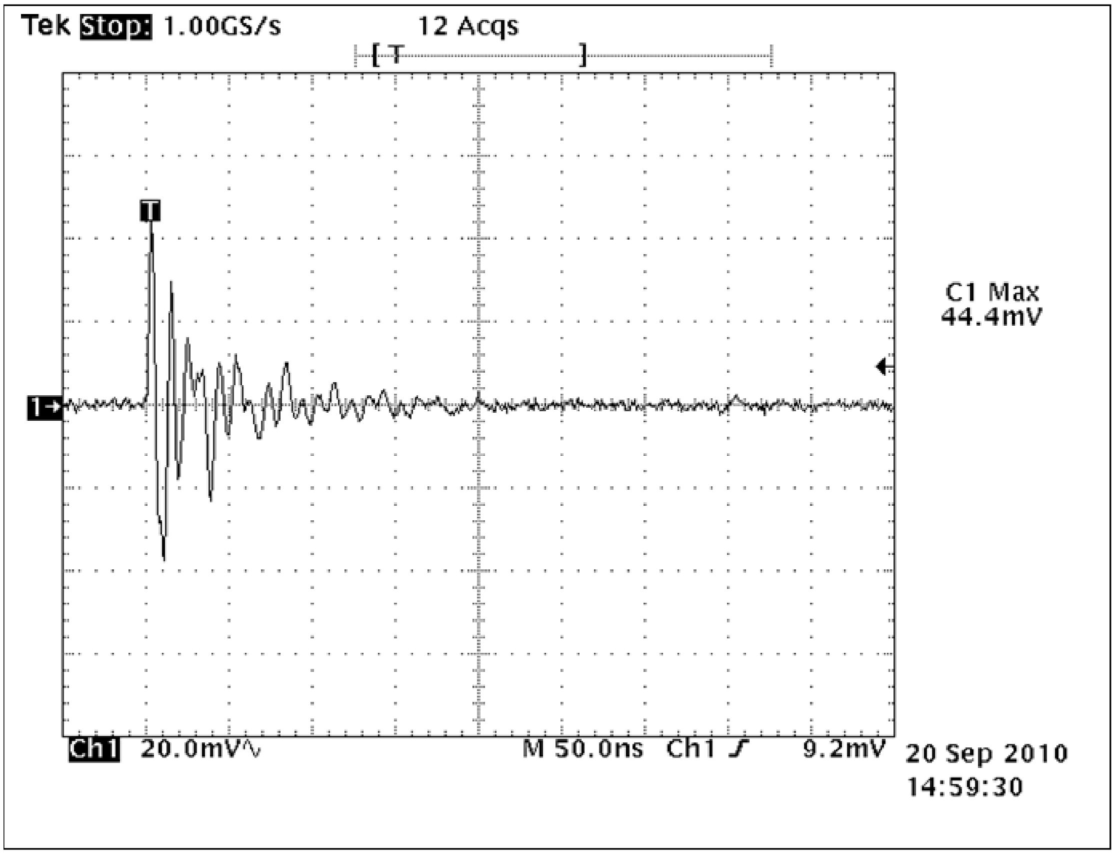


Required Ip:	1.5	**Measured Ip:**	1.5	**Attenuator Factor:**	40 dB = 100x
Required Vp:	1.5	**Measured Vp:**	0.752		
Required Q	15 ± 5	**Measured Q**	11.86	**Generator Setting, Volts:**	13% / 0102

Remarks: Measured Ip = (Measured Vp x Attenuation Factor) / 50 Ohm Calibration Fixture
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 3	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

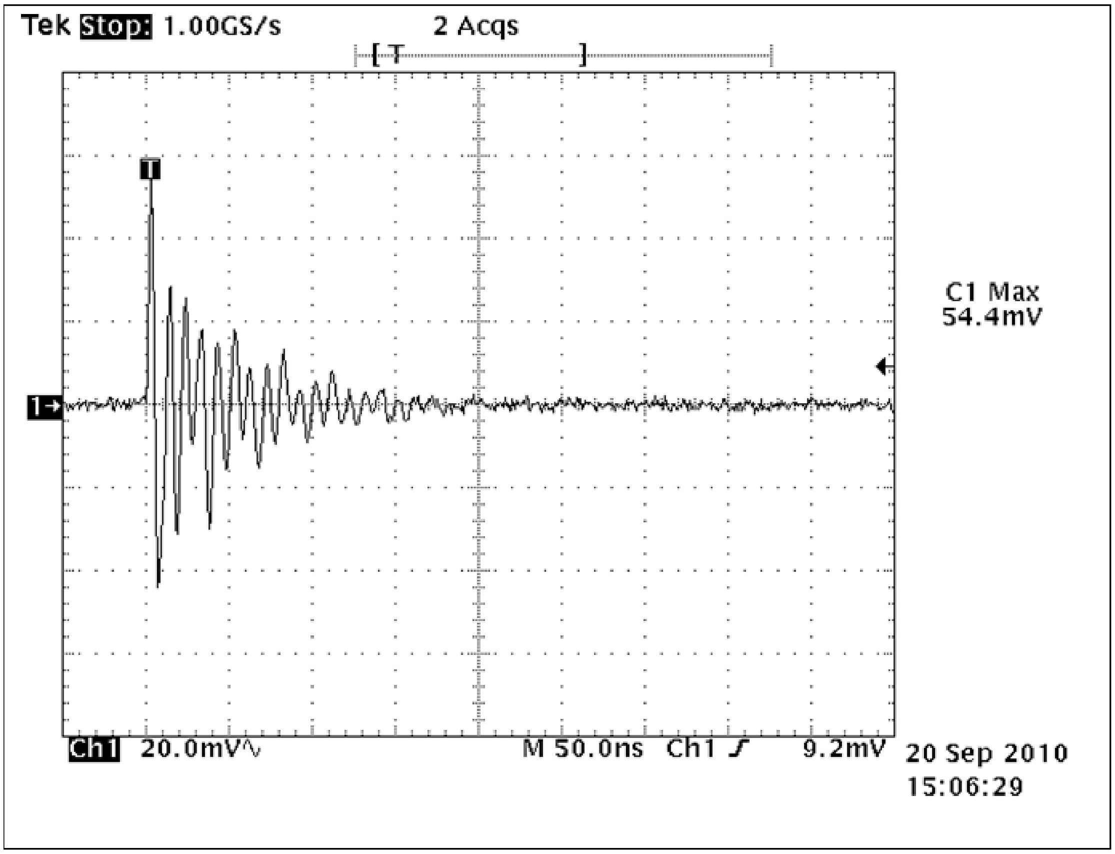


Required Ip:	1.5	**Measured Ip:**	0.019	**Attenuator Factor:**	40dB = 100 x
Required Vp:	75	**Measured Vp:**	0.044		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	13% / 0102

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 2	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients

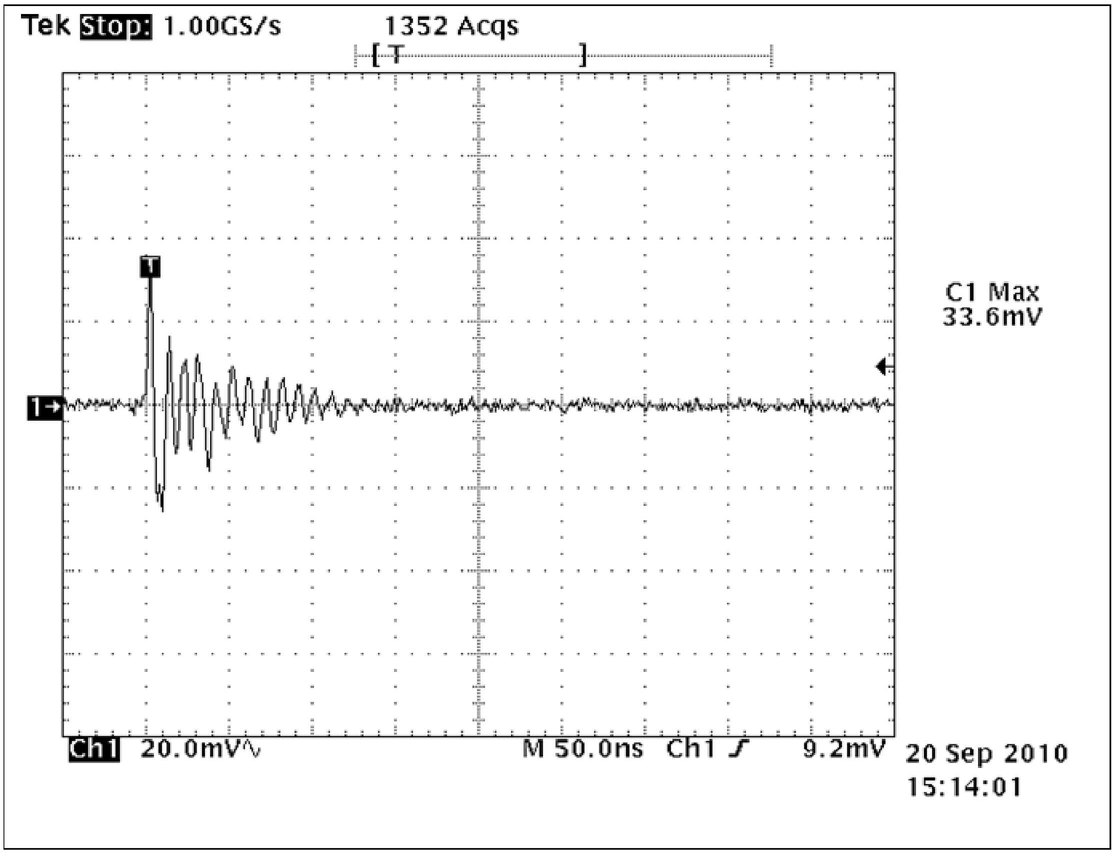


Required Ip:	1.5	**Measured Ip:**	0.023	**Attenuator Factor:**	40dB = 100 x
Required Vp:	75	**Measured Vp:**	0.054		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	13% / 0102

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Test Item:	HFC-6000 Qualifying Systems	**Date:**	09/20/10
Customer:	HF Controls, Inc.	**Part No.:**	N/A
Test Cable:	Bundle # 1	**Job No.:**	47110
Specification:	MIL-STD-461E	**Test Frequency:**	100 MHz
Procedure:	TP901-200-05, Rev C	**Engineer:**	D. Hartman

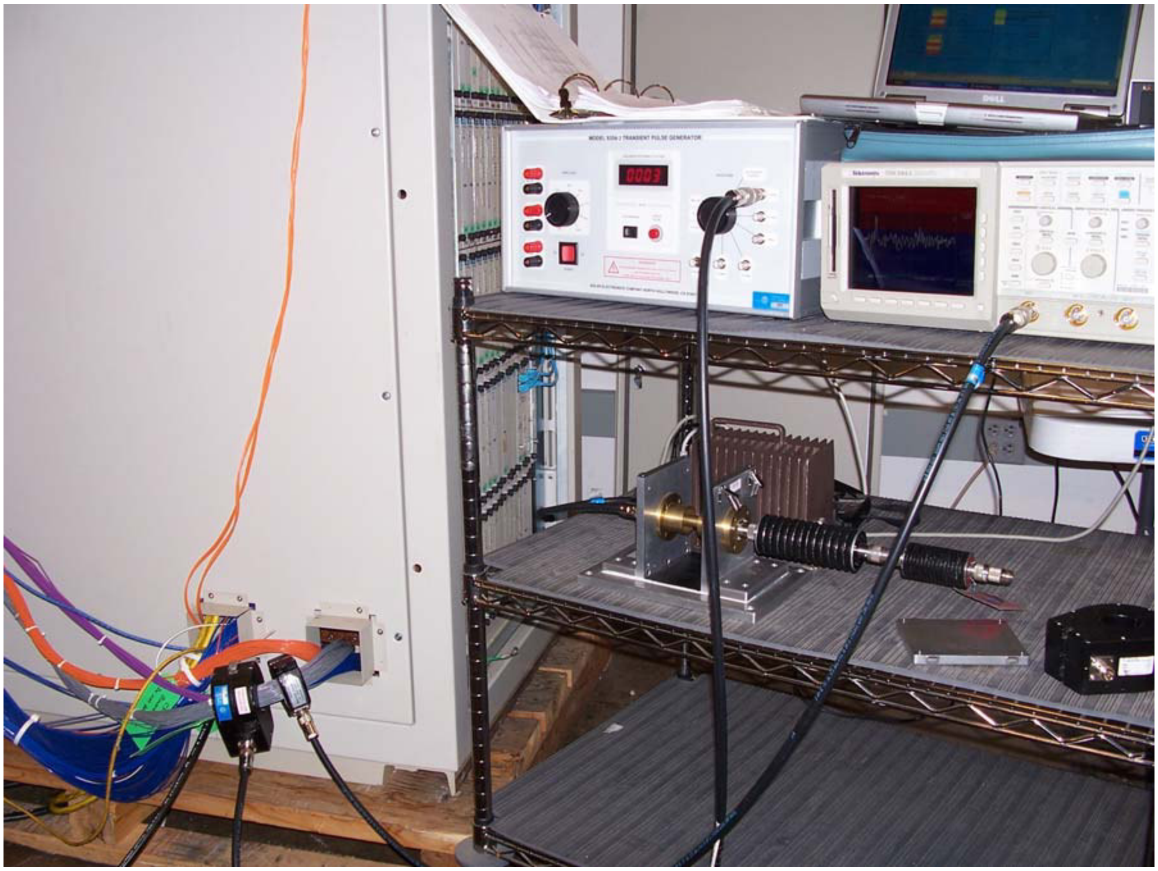
Conducted Susceptibility, Method CS116, Damped Sinusoidal Transients



Required Ip:	1.5	**Measured Ip:**	0.014	**Attenuator Factor:**	40dB = 100 x
Required Vp:	75	**Measured Vp:**	0.034		
Required Q	15 ± 5	**Measured Q**	N/A	**Generator Setting, Volts:**	13% / 0102

Remarks: Measured Ip = (Measured Vp x Attenuation) / Current Probe Factor
Injection Probe: TEGAM model # 95242-1 (2MHz to 400MHz)

Conducted Susceptibility (CS116) Test Photographs



Section 10. (RS101) Radiated Susceptibility, Magnetic Field

Purpose:

This test procedure is an alternative technique used to verify the ability of the EUT to withstand radiated magnetic fields.

Specification Limits:

Frequency range (Hz)	Limits (dBpT)
30 to 60	180
60 to 100000	*180 to 116
Notes: *The limit decreases linearly with respect with the log of the frequency	

Test : RS101

Tested By: S. Oates

Date of Tests: 08/06/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 22˚C

Humidity: 33%

Test Results:

The E.U.T. complies.

Test Equipment:

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1789	Audio Amplifier	Solar		NONE	CNR	N/A
1348	Audio Frequency Signal Generator	GW	GAG-808G	4700708	CBU	08/06/10
1463	Color 4 Ch Digitizing Oscilloscope	Tektronix	TDS684A	B010460	6/28/10	6/28/11
1145	1 Ohm Resistor	Nemko	N/A	N/A	CNR	N/A
2058	Radiating Loop	Nemko	N/A	N/A	CNR	N/A
1150	Loop Sensor	FCC	F-305	17	CBU	08/06/10
1152	PROBE	ELECTRO Metrics	PCL-11	1148	2/3/10	2/3/11
1663	Spectrum Analyzer	R & S	FSP	100073	4/20/10	4/20/11
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11

Radiated Susceptibility (RS101) Test Data

Radiated Susceptibility (RS101) Test Data

Complete: X
Preliminary:

Job # 47110 Test # : RIMF 01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : MIL-STD461E / RG1.180 Rev.1

Temp. (deg. C) : 22
Humidity (%) : 33
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: RFI Chamber

Date : 08/06/10
Time : 10:41am
Staff : S. Oates

Freq. Start (KHz)	Freq. Stop (KHz)	Test Level (dBpT) start / stop	Time Duration (Min)	Effect Qty	Effects Type	Pass or Fail	Comments:
0.03	0.06	180	10	0	N/A	Pass	The Loop Sensor was measured at 8 locations
0.06	10	180-116					4 on each side of cabinet

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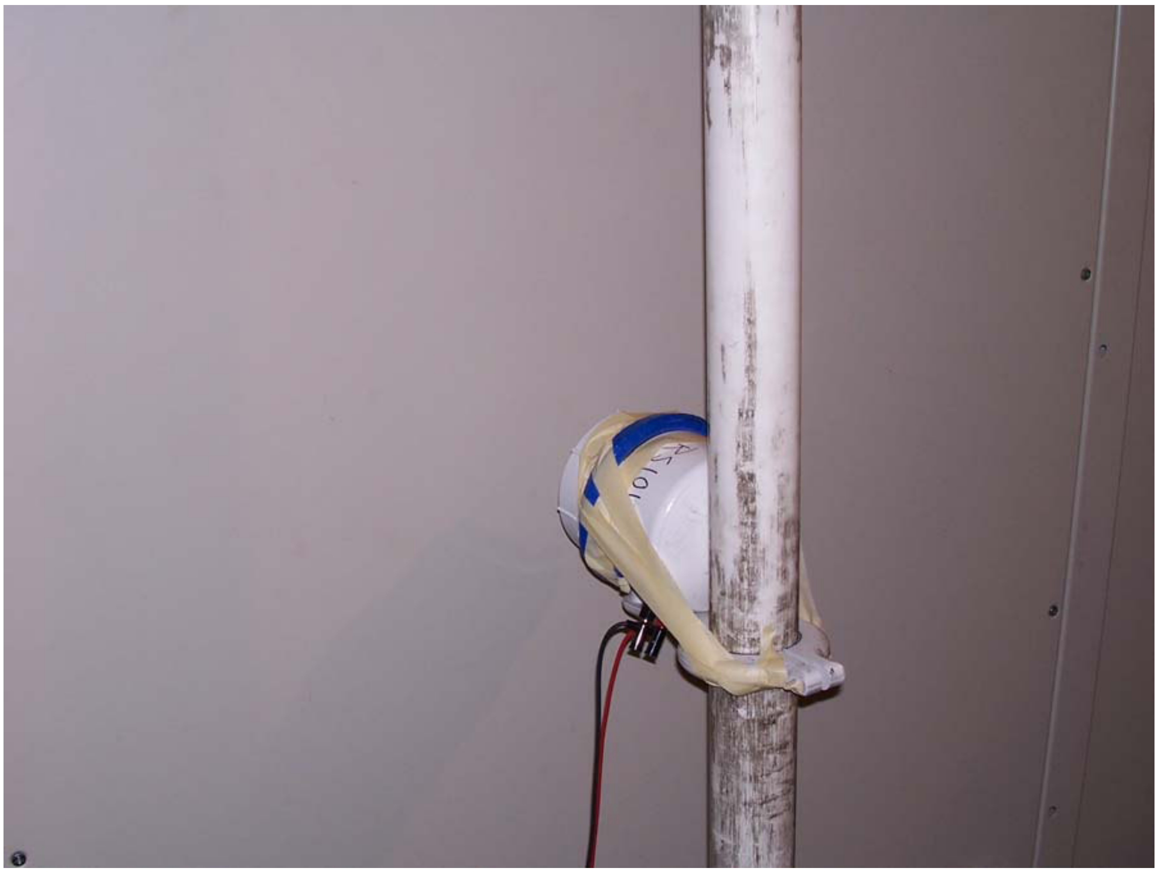
Radiated Susceptibility (RS101) Test Photographs



Section 11. High Frequency Radiated Susceptibility (RS103)

Purpose:

The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) to radiated electromagnetic field energy.

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Specification Limits:

Frequency range (MHz)	Limits (dB V/M)
30 -10000	10V/M

Test : RS103

Tested By: D. Hartman

Dates of Tests: 08/04/10 to 08/05/10

Test Conditions:

Test Voltage: 120VAC

Temperature: 22˚C

Humidity: 33%

Test Results:

The E.U.T. Complies

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1771	Signal Generator	MARCONI	2024	119223029	02/08/10	02/08/11
1769	Signal Generator	Giga-Tronics	GT9000	N/A	CBU	8/05/10
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/09	02/27/11
1775	Amplifier 10KHz-220MHz	Amplifier Research	1000L	N/A	CNR	N/A
Rental	Amplifier 1-3GHz	Amplifier Research	120S1G3	304908	CNR	N/A
1836	Amplifier 2.5-7.5GHz	Amplifier Research	300T2G8	324204	CNR	N/A
1861	Amplifier 7.5-18GHz	Amplifier Research	250T8G18	0330980	CNR	N/A
1836	Amplifier 80MHz-1GHz	OPHIR	5127	N/A	CNR	N/A
1204	50uH LISN	TEGAM	95300-50	T-171765	01/28/10	01/28/11
1205	50uH LISN	TEGAM	95300-50	T-171766	01/28/10	01/28/11
1818	Biconical Antenna 30-200MHz	T.D.K. RF Solutions	HBA-2030	130496	CNR	N/A
1621	Large Horn Antenna 200-1000MHz	EMCO	3106	1621	01/06/10	01/06/11
1837	Microwave Horn Antenna 1-5GHz	Amplifier Research	ATH800M5G	0331162	CNR	N/A
1838	Microwave Horn Antenna 4-8GHz	Amplifier Research	ATH4G8	0331162	CNR	N/A
1835	Microwave Horn Antenna8-18GHz	Amplifier Research	ATH7G18	0332368	CNR	N/A
1789	E-Field Monitor	Narda	NBM 520	B-0295	7/02/10	7/02/11
1790	E-Field Probe 100KHz-3GHz	Narda	EF 0391	A-0512	7/02/10	7/02/11
1791	E-Field Probe 300MHz-50GHz	Narda	EF 5091	01183	7/02/10	7/02/11

Radiated Susceptibility (RS103) Test Data

Radiated Susceptibility (RS103) Test Data

Complete X
Preliminary

Job # 47110 Test # : RIPV 01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : MIL-STD461E / RG1.180 Rev.1

Temp. (deg. C) : 22
Humidity (%) : 33
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: Mil Chamber

Date : 08/4/10 to 08/5/10
Time : 8:00
Staff : D. Hartman

Freq. Start (MHz)	Freq. Stop (MHz)	Test Level (V/M)	Polarization V/H	Effect Qty	Effects Type	Pass or Fail	Comments:
30	10000	10	Horizontal	0	N/A	Pass	Rear of EUT Open Door
30	10000	10	Vertical	0	N/A	Pass	Rear of EUT Open Door

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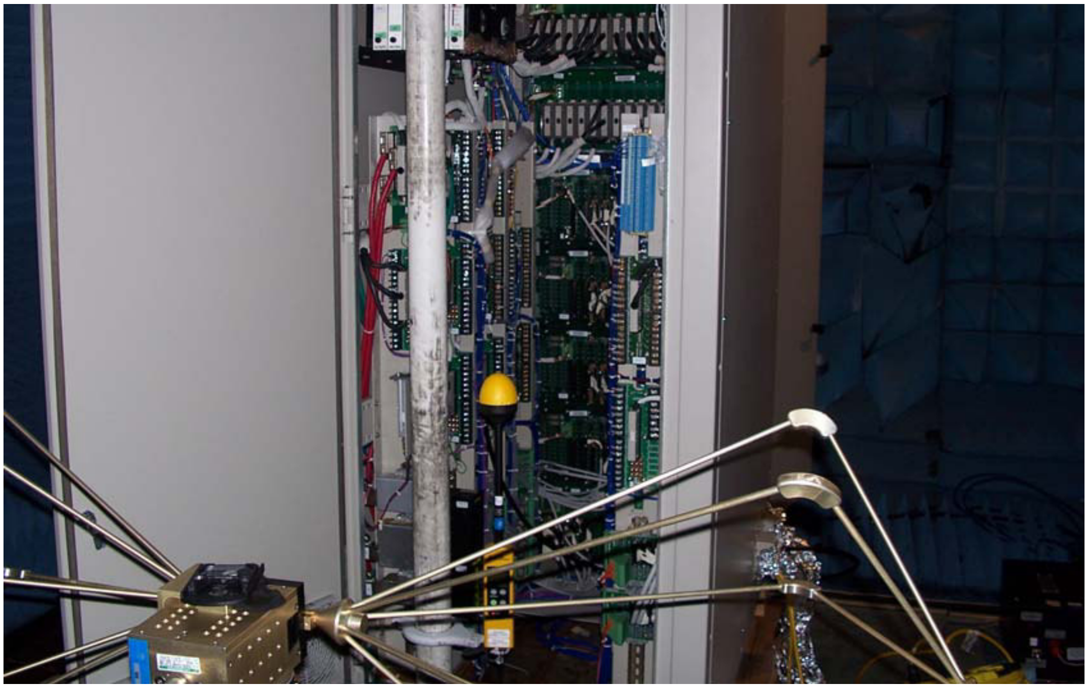
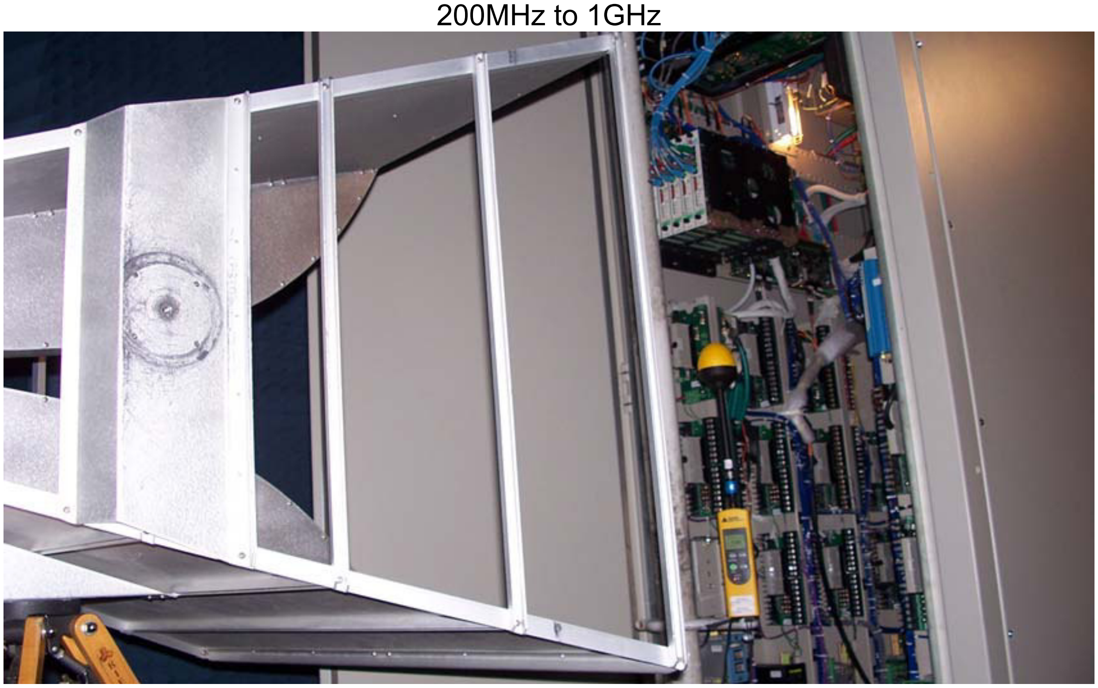
Radiated Susceptibility (RS103) Test Photographs

30 to 200MHz



200MHz to 1GHz



1 to 10GHz

Section 12. Electrical Fast Transient / Burst / (CS115)

Purpose:

The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) to repetitive electrical fast transients (bursts), on supply, signal, or control lines. IEC61000-4-4 corresponds to CS115 per RG.1.180.

Minimum Performance Criteria A

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Test : IEC61000-4- 4

Tested By: D. Hartman

Date of Tests: 08/09/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 23˚C

Humidity: 31%

Test Results:

The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
590	Generator, PEFT (EFT	Haefely	DGFT junior	589071-03	08/12/09	08/12/10
559	Clamp	Haefely	N/A	N/A	08/12/09	08/12/10

Electrical Fast Transients / Burst Test Data

Electrically Fast Transient / Burst Data

Complete X
Preliminary

Job # : 47110 Test # : EFTP-01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C
Reference : IEC61000-4-4 / RG1.180 Rev.1

Date : 08/09/10
Time : 2:30pm
Staff : D. Hartman
Photo ID: EFTP-01
Performance Criteria: A
Table Top or Floor Floor

Barometric pressure: 1016
Temp. (deg. C) : 23
Humidity (%) : 31
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: RFI Chamber

1. L X
2. N X
3. PE X
4. L+N X
5. L+PE X
6. N+PE X
7. L+N+PE X
8. I/O Cables X

Test Point	EFT Level (kV)	Direct or Capacitive	Polarity	Time Duration (min)	Effects Number	Effects Type	Pass or Fail	Comments:
1	2.0	Direct	+ / -	2	N/A	N/A	Pass	Test points 1 through 7 refer to 120Vac
2	2.0	Direct	+ / -	2	N/A	N/A	Pass	Power Inputs
3	2.0	Direct	+ / -	2	N/A	N/A	Pass	
4	2.0	Direct	+ / -	2	N/A	N/A	Pass	
5	2.0	Direct	+ / -	2	N/A	N/A	Pass	
6	2.0	Direct	+ / -	2	N/A	N/A	Pass	
7	2.0	Direct	+ / -	2	N/A	N/A	Pass	
8	1.0	Capacitive	+ / -	5	N/A	N/A	Pass	I/O Signal Cables

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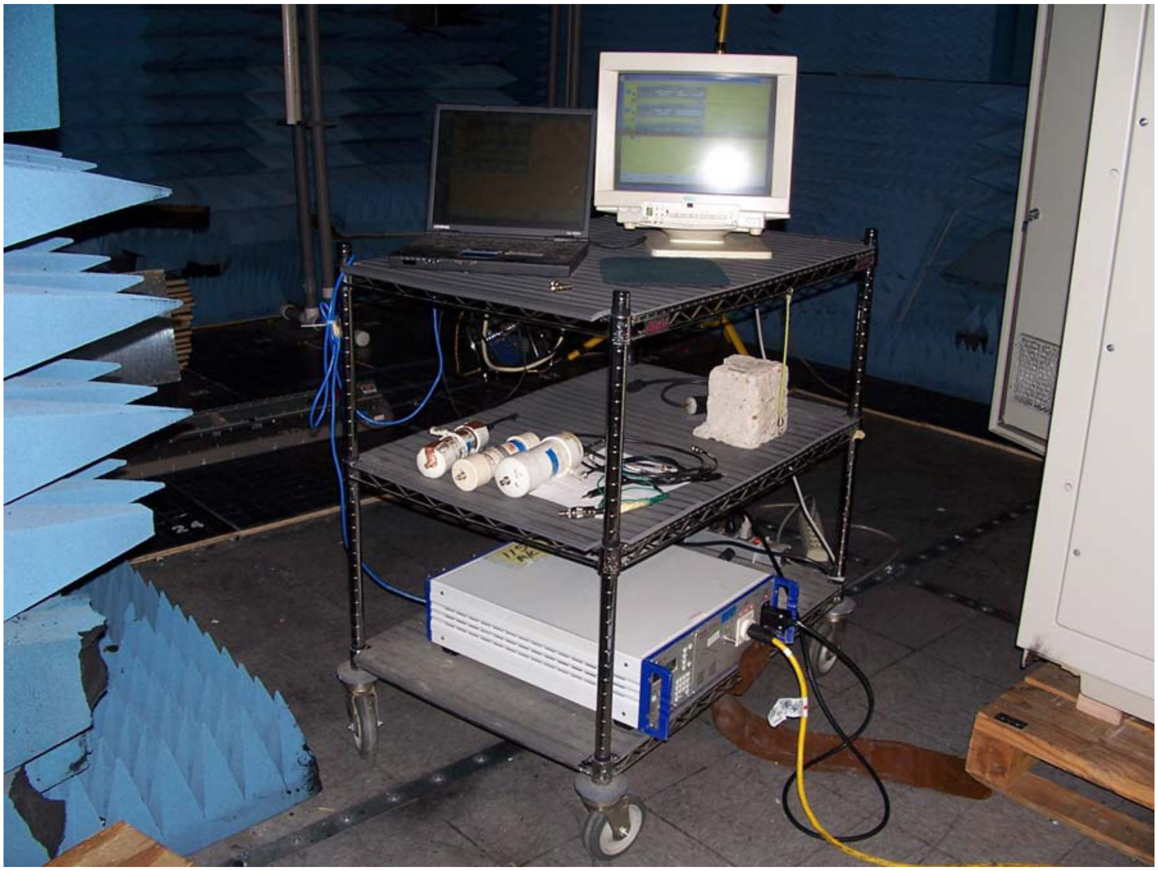
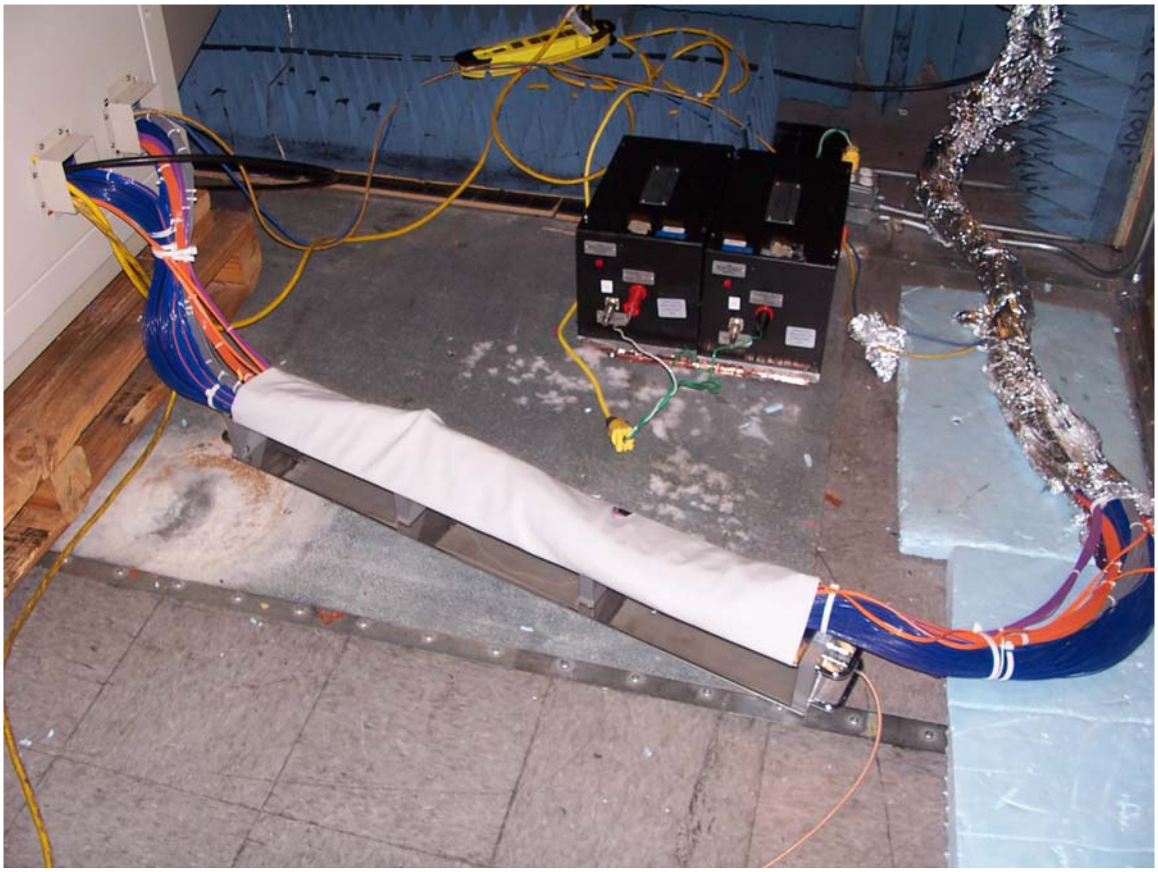
Electrical Fast Transients / Burst Test Photographs

120Vac Power



I/O Cables



Section 13. RF Common Mode (A.M.)

Purpose:
The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) to the electromagnetic fields generated from intentional radiators.

Minimum Performance Criteria A

Performance Criteria: per HF Controls Corp. Test plan TP901-200-05 Rev A

Test : IEC61000-4- 6

Tested By: D. Hartman

Date of Tests: 08/09/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 23˚C

Humidity: 31%

Test Method:
See Section 16.

Test Results:
The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
729	Signal Generator	HP	8656A	2402A05973	CNR	N/A
1811	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	04/12/10	0412/11
1812	RG214 CABLE	Nemko USA, Inc.	N/A	N/A	04/12/10	04/12/11
1833	Power Line Coupling/Decoupling Network	FISCHER	FCC-801-M5-50A	091580	9/10/09	9/10/10
1448	RF amplifier	EIN	3100LA	467	CNR	N/A
1284	Spectrum analyzer	Hewlett Packard	8563E	2283-327	02/27/09	02/27/11

Test Data –R.F. Common Mode (A.M.) Test# CIPV-01

Conducted Immunity Test Data

Complete: X
Preliminary:

Job # : 47110
Page 1 of 1
Test # : CIPC-01

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C
Reference : IEC61000-4-6 / RG1.180 Rev.1

Temp. (deg. C) : 23
Humidity (%) : 35
EUT Voltage : 120 VAC
EUT Frequency : 60Hz
Phase: Single
Location: RFI Chamber
Analyzer#: 1284
CDN#:

Date :
Time : 14:00
Staff : D. Hartman
Photo ID:
Performance Criteria: A
Table Top or Floor: Floor
Sweep rate: N/A
Step Size: 1%
Modulated: 80%

Freq. Start (MHz)	Freq. Stop (MHz)	Field Strength (Vrms)	Time Duration (min)	Effect Qty	Effects Type	Pass or Fail	Comments:
0.15	80	10	35	0	N/A	Pass	120Vac Power Lines

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Document Control #EMC DS IM COND

Test Photographs - Test # CIPV-01

Photo not available

Section 14. Surge Immunity

Purpose:

The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) to electrical surge on supply lines.

Minimum Performance Criteria A

Performance Criteria: per HF Controls Corp. Test plan TP901-200-06 Rev C

Test : IEC EN 61000-4-5, Level 3
IEC EN 61000-4-12, Level 3

Tested By: D. Hartman

Date of Tests: 8/12/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 23˚C

Humidity: 35%

Test Results:

The E.U.T. complies.

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1834	All-In-One Tester Pos. 01; TRA2000IN4	EMC-PARTNER/HV Technologies	TRA1Z221N	900	09/14/09	09/14/10

EN 61000-4-5, Level 3 Surge Immunity Combination Wave Test Data

Surge Immunity Combination wave Test Data

Complete X
Preliminary

Job # : 47110 Test # : SGIP-01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : IEC61000-4-5 / RG1.180 Rev.1
Barometric pressure: 1016 Phase: Single Date : 08/12/10
Temp. (deg. C) : 23 Location: RFI Chamber Time : 8:00
Humidity (%) : 35 Staff : D. Hartman
EUT Voltage : 120Vac Performance Criteria: A
EUT Frequency : 60Hz Table Top or Floor: Table

Coupling			L1-E			L2-E			L1-L2			Comments
			Surge	Effect	Efect	Surge	Effect	Efect	Surge	Effect	Efect	
Level	Phase	Polarity	QTY	QTY	Type	QTY	QTY	Type	QTY	QTY	Type	
0.5kV	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
1.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
2.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
4.0kv	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	

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EN 61000-4-5, Level 3 Surge Immunity Combination Wave Photographs

Photo not available

EN 61000-4-12, Level 3 Surge Immunity 100KHz Ring wave Test Data

Surge Immunity 100KHz Ring Wave Test Data

Complete X
Preliminary

Job # : 47110 Test # : SGIP-01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : IEC61000-4-12 / RG1.180 Rev.1

Date : 08/12/10
Time : 10:30am
Staff : D. Hartman
Performance Criteria: A
Table Top or Floor: Table

Barometric pressure: 1016
Temp. (deg. C) : 23
Humidity (%) : 35
EUT Voltage : 120Vac
EUT Frequency : 60Hz

Phase: Single
Location: RFI Chamber

Coupling			L1-E			L2-E			L1-L2			Comments
			Surge	Effect	Efect	Surge	Effect	Efect	Surge	Effect	Efect	
Level	Phase	Polarity	QTY	QTY	Type	QTY	QTY	Type	QTY	QTY	Type	
0.5kV	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
1.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
2.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
4.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	

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EN 61000-4-12, Level 3 Surge Immunity 1MHz Ring wave Test Data

Surge Immunity 1MHz Ring Wave Test Data

Complete: X
Preliminary:

Job # : 47110 Test # : SGIP-01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : IEC61000-4-12 / RG1.180 Rev.1

Date : 0812/10
Barometric pressure: 1016 Phase: Single Time : 10:30am
Temp. (deg. C) : 23 Location: RFI Chamber Staff : D. Hartman
Humidity (%) : 35 Performance Criteria: A
EUT Voltage : 120Vac Table Top or Floor: Table
EUT Frequency : 60Hz

Coupling			L1-E			L2-E			L1-L2			Comments
			Surge	Effect	Efect	Surge	Effect	Efect	Surge	Effect	Efect	
Level	Phase	Polarity	QTY	QTY	Type	QTY	QTY	Type	QTY	QTY	Type	
0.5kV	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
1.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
2.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
4.0kv	0 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	90 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	
	270 Deg.	+/-	5	0	N/A	5	0	N/A	5	0	Pass	

EN 61000-4-12, Level 3 Surge Immunity Ring Wave Test Photographs

Photo not available

Section 15. Electrostatic Discharge (ESD)

Purpose:

The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) from electrostatic discharge.

Minimum Performance Criteria A

Performance Criteria: per HF Controls Corp. Test plan TP901-200-03 Rev C

Test : ESD

Tested By: D. Hartman

Dates of Tests: 08/13/10, & 08/16/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 23˚C

Humidity: 33%

Test Points:

Component	Location	Discharge Type
Power Supply	Both sides of chassis frame	Contact
	Module A 24-vdc power supply front panel	Contact
Controller, I/O	Both sides of the controller chassis	Contact
	Both sides of the expansion chassis	Contact
	The front surface of bezel for each of the different circuit board types: AC36, AI16F, AI16FD, AI4K, AI4K2, AI8M, AI8LD, AO8F, DC33, DC34, DC35, DI16I, DO16C, DO16J, DO8J, PCC06, SBC06, SCG06 AI16RD, AI8MD, AI8LD, AO8FD, SBC04A, AC36FD	Contact
	SBC06 power toggle switch	Contact
	SCG06 power toggle switch	Contact
	HFC-DPM06 maintenance failover pushbutton	Air
	HFC-PCC06 power switch	Contact
	One of the two C-Link connector shells for controller A	Air
	AI4K Plastic Cover	Air
CSM HS-138, CSM HS-035	CSM Metal surface	Contact
	Top switch lens	Air
FAN	ON/OFF Switch	Air
HFC-FOT06	ON/OFF Switch	Contact
Cabinet	Cabinet Door Handles	Air
	Cabinet Sides	Contact
HUB06-16-01, HUB06-16-02, HUB06-16-EXT	C-Link Connectors	Air
	Metal container screws	Contact

Test Results:

The E.U.T. Complies

TEST EQUIPMENT

Asset Number	Description	Manufacturer	Model Number	Serial Number	Last Cal	Cal Due
1738	Gun	EMC Partner	ESD 3000	N/A	09/14/09	09/14/10
1754	Module	EMC Partner	N/A	N/A	09/14/09	09/14/10
1247	940 OHM GROUND STRAP	Nemko USA, Inc.	NONE	NONE	CNR	N/A

Electrostatic Discharge (ESD) Test Data

Electrostatic Discharge Data

Complete X
Preliminary

Job # : 47110 Test # : ESDI-01
Page 1 of 1

Client Name : HF Controls Corporation
EUT Name : HFC-6000 Quality Systems

EUT Config. : On

Specification : TP901-200-05 Rev. C Reference : IEC61000-4-2 / RG1.180 Rev.1
ESD Gun#: 1738
ESD Module#: 1754

Temp. (deg. C) : 23
Humidity (%) : 33
EUT Voltage : 120Vac
EUT Frequency : 60Hz
Phase: Single
Location: RFI Chamber

Date : 08/13/10 & 8/16/10
Time : 9:00am
Staff : B. Boyea
Photo ID:
Performance Criteria: A
Table Top or Floor Floor

Does product have any type of insulated coating on exterior surfaces? Yes ___ No X
If yes, indicate where:

ESD Level (kV)	Polarity	Contact or Air	Application Quantity	Effect Qty	Effects Type	Pass or Fail	**ERD921/TMR & DMR Power Supply:**
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	Both sides of chassis frame
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	Module A 24-vdc power supply front panel
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	
							Controller, I/O
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	Each side of the controller chassis
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	The front surface of bezel for each of the different circuit board types:
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	AI16RD, AI8MD, AI8LD, AO8FD, DI16I, DO16C, DO16J, SBC06, SCG06
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	HFC-SBC06 power toggle switch
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	
2	(+/-)	Contact	10 / EACH	0	N/A	Pass	HFC-SCG06 power toggle switch
4	(+/-)	Contact	10 / EACH	0	N/A	Pass	
4	(+/-)	Air	10 / EACH	0	N/A	Pass	HFC-DMP06 maintenance failover button
8	(+/-)	Air	10 / EACH	0	N/A	Pass	
4	(+/-)	Air	10 / EACH	0	N/A	Pass	One of the two C-Link cables to SBC06
8	(+/-)	Air	10 / EACH	0	N/A	Pass	
4	(+/-)	Air	10 / EACH	0	N/A	Pass	One of the two C-Link cables to SCG06
8	(+/-)	Air	10 / EACH	0	N/A	Pass	

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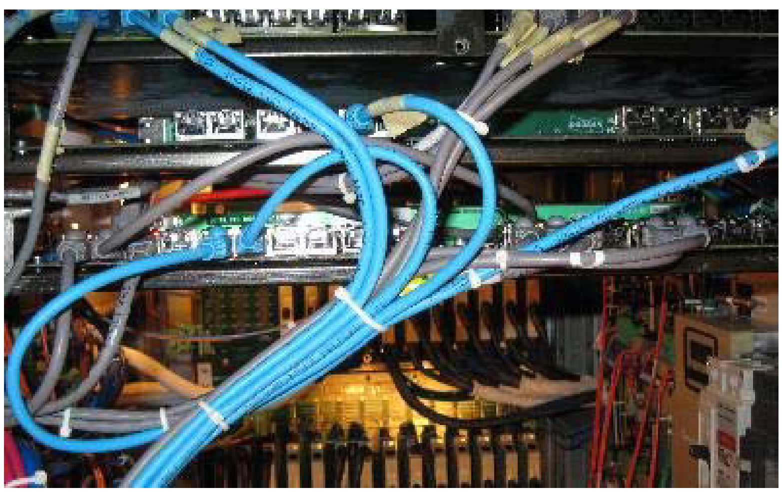
Electrostatic Discharge (ESD) Test Photographs



Snapshots of Test Points

Section 16. Isolation

Purpose:

The test is intended to demonstrate the compliance of the Equipment Under Test (E.U.T.) to electrical isolation of class 1E control equipment from non-class 1E equipment as well as isolation between different Class 1E channels.

Minimum Performance Criteria A

Performance Criteria: per HF Controls Corp. Test plan TP901-200-07 Rev C

Test : Isolation

Tested By: S. Oates

Dates of Tests: 08/13/10, 08/16/10

Test Conditions:

Test Voltage: 120Vac

Temperature: 23˚C

Humidity: 35%

Test Points:

Test Case	Test Channel		Alternate Channel	
	Channel ID	Cable Contacts	Channel ID	Cable Contacts
1E01 ISO1	1,AI,894 (AI16FD)	1-3-5-A21 (28)	1,AI,885	1-3-5-A7 (10)
		1-3-5-C21 (27)		1-3-5-C7 (9)
	1,AI,910 (AI16F)	1-3-6-A15 (20)	1,AI,911	1-3-6-A16 (22)
		1-3-6-C15 (19)		1-3-6-C16 (21)
	1,AI,983 (AC36)	1-3-10-A10 (24)	1,AI,984	1-3-10-A12 (27)
		1-3-10-C10(25)		1-3-10-C12 (28)
	2,AI,13 (AI16RD)	B1-R1-C7-P5+	2,AI,15	B1-R1-C7-P7+
		B1-R1-C7-P5-		B1-R1-C7-P7-
	L291,AI,21 (AC36FD)	4-9-1-A7,TB18	L291,AI,24	4-9-1-A12,TB27
		4-9-1-C7,TB19		4-9-1-C12,TB28
1E02 ISO2	1,AI,965 (AI8M)	1-3-9-A7 (17)	1,AI,964	1-3-9-A6 (10)
		1-3-9-C7 (18)		1-3-9-C6 (11)
	2,AI,19 (AI8MD)	B1-R2-C7-P3+	2,AI,24	B1-R2-C7-P8+
		B1-R2-C7-P3-		B1-R2-C7-P8-
1E03 ISO3	1,AI,1044 (AI8L)	1-3-13-A6 (10)	1,AI,1045	1-3-13-A7 (13)
		1-3-13-C6 (11)		1-3-13-C7 (14)
	2,AI,27	B1-R3-C7-P3+	2,AI,31	B1-R3-C7-P7+
		B1-R3-C7-P3-		B1-R3-C7-P7-
1E04 ISO4	N/A		N/A	
1E05 ISO5	N/A		N/A	
1E06 ISO6	1,DI,332 (DC34)	1-2-5-A6	1,DI,335	1-2-5-A10
		1-2-5-C6		1-2-5-C10
	1,DI,265 (DC33)	1-2-2-A7	1,DI,270	1-2-2-A15
		1-2-2-C7		1-2-2-C15
	1,DI,311 (DI16I)	1-2-4-A16	1,DI,312	1-2-4-A18
		1-2-4-C16		1-2-4-C18
	1,DI,1047 (DC35)	1-2-3-A10	1,DI,1048	1-2-3-A12
		1-2-3-A10		1-2-3-C12
	L291,DI,2 (SBC04A)	4-9-2-C12,TB17	L291,DI,12	4-9-2-C2,TB32
		4-9-2-B12,TB16		4-9-2-B2,TB31

Test Case	Test Channel		Alternate Channel	
	Channel ID	Cable Contacts	Channel ID	Cable Contacts
1E07 ISO7	1,AI,1023 (AI4K)	1-3-12-A3 (4)	1,AI,1027	1-3-12-A6 (10)
		1-3-12-C3 (5)		1-3-12-A7 (11)
	1,AI,1063 (AI4K2)	1-2-14-A3 (4)	1,AI,1067	1-2-14-A5 (10)
		1-2-14-C3 (5)		1-2-14-C5 (11)
1E08 ISO8	1,AO,821 (AO8F)	1-3-2-A1 (1)	1,AO,822	1-3-2-A3 (4)
		1-3-2-C1 (2)		1-3-2-C3 (5)
	1,AO,802 (AC36)	1-2-12-A3	1,AO,803	1-2-12-A4 (7)
		1-2-12-C3		1-2-12-C4 (8)
	2,AO,5 (AO8FD)	B1-R6-C7-P5+	2,AO,6	B1-R6-C7-P6+
		B1-R6-C7-P5-		B1-R6-C7-P6-
	L291,AO,21 (AC36FD)	4-9-1-A1,TB1	L291,AO,24	4-9-1-A6,TB10
		4-9-1-C1,TB2		4-9-1-C6,TB11
1E09 ISO9	1,DO,262 (DC33)	1-2-2-A24,25		
		1-2-2-C24.25		
	1,DO,1042 (DC35)	1-2-2-A24,25		
		1-2-2-C24,25		
1E010 ISO10	1,DO,82 (DC34)	1-1-3-A24,25		
		1-1-3-C24,25		
	1,DO,1008 (DC16C)		1,DO,1009 (DO16C)	
	L291,DO,2 (SBC04A)	4-9-2-A16,TB13	L291,DO,3	4-9-2-A18,TB5
		4-9-2-B16,TB14		4-9-2-B18,TB6
1E011 ISO11				
1E012 ISO12	1,DO,169 (DO16J)	1-1-8-A17 (17)	1,DO,170	1-1-8-A19 (19)
		1-1-8-B17 (18)		1-1-8-B19 (20)
	1,DO,148 (DO8J)	1-1-7-A11 (15)	1,DO,147	1-1-7-A14(13)
		1-1-7-A10 (16)		1-1-7-A13(14)

Test Results:

The E.U.T. complies.

TEST EQUIPMENT

Asset	Description	Manufacturer	Model	Serial	Last Cal	Cal Due

Number			Number	Number		
795	Power Supply	Elgar	NONE	NONE	CBU	08/19/10
1842	Clamp on Meter	AEMC	514	19994GHCT	02/11/10	02/11/11

Isolation Test Data

Class 1E Isolation Data

Complete X
Preliminary

Job # : 47110 Test # :
Page 1 of 4

Client Name : HF Controls
EUT Name : HFC-6000 ERD111/ERD921 Qualification Cabinet
EUT Model # : HFC-6000
EUT Part # : Various
EUT Serial # : Most individual components in the cabinet have unique serial numbers.
EUT Config. : SLC

Specification : EPRI TR-107330, 1996 Reference EPRI TR-107330,1996

Temp. (deg. C) : 22
Humidity (%) : 31
EUT Voltage : 120 Vac
EUT Frequency : 60 Hz
Phase: Single
Location: RFI Chamber
Barometric pressure: 1016

Date :
Time :
Staff Scott Oates
Photo ID:

Test Case	Test Channel ID	Channel Cable Contacts	Alternate Channel ID	Channel Cable Contacts	Monitor Channel ID	Pass or Fail
1E08	L291,AO,21	4-9-1-A1,TB1	L291,AO,24	4-9-1-A6,TB10	L291,AO,23	Pass
ISO8		4-9-1-C1,TB2		4-9-1-C6,TB11		
`1E010	L291,DO,2	4-9-2-A16,TB13	L291,DO,3	4-9-2-A18,TB5	L291,DO,1	Pass
ISO10		4-9-2-B16,TB14		4-9-2-B18,TB6		
`1E01	L291,AI,21	4-9-1-A7,TB18	L291,AI,24	4-9-1-A12,TB27	L291,AI,23	Pass
ISO1		4-9-1-C7,TB19		4-9-1-C12,TB28		
`1E06	L291,DI,2	4-9-2-C12,TB17	L291,DI,12	4-9-2-C2,TB32	L291,DI,1	Pass
ISO6		4-9-2-B12,TB16		4-9-2-B2,TB31		

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Class 1E Isolation Data

Complete: X
Preliminary:

Job # : 47110 Test # :
Page 2 of 4

Client Name : HF Controls
EUT Name : HFC-6000 ERD111/ERD921 Qualification Cabinet
EUT Model # : HFC-6000
EUT Part # : Various
EUT Serial # : Most individual components in the cabinet have unique serial numbers.
EUT Config. : TMR/DMR

Specification : EPRI TR-107330, 1996 Reference :

Test Case	Test Channel ID	Channel Cable Contacts	Alternate Channel ID	Channel Cable Contacts	Monitor Channel ID	Pass or Fail
`1E01	2,AI,13	B1-R1-C7-P5+	2,AI,15	B1-R1-C7-P7+	2,AI,5	Pass
ISO1		B1-R1-C7-P5-		B1-R1-C7-P7-		
`1E02	2,AI,19	B1-R2-C7-P3+	2,AI,24	B1-R2-C7-P8+	2,AI,17	Pass
ISO2		B1-R2-C7-P3-		B1-R2-C7-P8-		
`1E03	2,AI,27	B1-R3-C7-P3+	2,AI,31	B1-R3-C7-P7+	2,AI,32	Pass
ISO3		B1-R3-C7-P3-		B1-R3-C7-P7-		
`1E06	Tested in		Tested in			
ISO6	ERD111		ERD111			
`1E08	2,AO,5	B1-R6-C7-P5+	2,AO,6	B1-R6-C7-P6+	2,AO,1	Pass
ISO8		B1-R6-C7-P5-		B1-R6-C7-P6-	(2,AI,5)	
`1E010	Tested in		Tested in			
IS010	ERD111		ERD111			

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Class 1E Isolation Data

Complete X
Preliminary

Job # : 47110 Test # :
Page 3 of 4

Client Name : HF Controls
EUT Name : HFC-6000 ERD111/ERD921 Qualification Cabinet
EUT Model # : HFC-6000
EUT Part # : Various
EUT Serial # : Most individual components in the cabinet have unique serial numbers.
EUT Config. : ERD111

Specification : EPRI TR-107330, 1996 Reference :

Test Case	Test Channel ID	Channel Cable Contacts	Alternate Channel ID	Channel Cable Contacts	Monitor Channel ID	Pass or Fail
`1E01	1,AI,894	1-3-5-A21 (28)	1,AI,885	1-3-5-A7 (10)	1,AI,889	Pass
ISO1	(AI16FD)	1-3-5-C21 (27)		1-3-5-C7 (9)		
	1,AI,910	1-3-6-A15 (20)	1,AI,911	1-3-6-A16 (22)	1,AI,901	Pass
	(AI16F)	1-3-6-C15 (19)		1-3-6-C16 (21)		
	1,AI,983	1-3-10-A10 (24)	1,AI,984	1-3-10-A12 (27)	1,AI,981	Pass
	(AC36)	1-3-10-C10(25)		1-3-10-C12 (28)		
`1E02	1,AI,965	1-3-9-A7 (17)	1,AI,964	1-3-9-A6 (10)	1,AI,963	Pass
ISO2	(AI8M)	1-3-9-C7 (18)		1-3-9-C6 (11)		
`1E03	1,AI,1044	1-3-13-A6 (10)	1,AI,1045	1-3-13-A7 (13)	1,AI,1041	Pass
ISO3	(AI8L)	1-3-13-C6 (11)		1-3-13-C7 (14)		
`1E06	1,DI,332	1-2-5-A6	1,DI,335	1-2-5-A10	1,DI,329	Pass
ISO6	(DC34)	1-2-5-C6		1-2-5-C10		
	1,DI,265	1-2-2-A7	1,DI,270	1-2-2-A15	1,DI,261	Pass
	(DC33)	1-2-2-C7		1-2-2-C15		
	1,DI,311	1-2-4-A16	1,DI,312	1-2-4-A18	1,DI,310	Pass
	(DI16I)	1-2-4-C16		1-2-4-C18		
	1,DI,1047	1-2-3-A10	1,DI,1048	1-2-3-A12	1,DI,1043	Pass
	(DC35)	1-2-3-A10		1-2-3-C12		
`1E07	1,AI,1023	1-3-12-A3 (4)	1,AI,1027	1-3-12-A6 (10)	1,AI,1021	Pass
ISO7	(AI4K)	1-3-12-C3 (5)		1-3-12-A7 (11)		
	1,AI,1063	1-2-14-A3 (4)	1,AI,1067	1-2-14-A5 (10)	1,AI,1061	Pass
	(AI4K2)	1-2-14-C3 (5)		1-2-14-C5 (11)		
`1E08	1,AO,821	1-3-2-A1 (1)	1,AO,822	1-3-2-A3 (4)	1,AO,828	Pass
ISO8	(AO8F)	1-3-2-C1 (2)		1-3-2-C3 (5)		
	1,AO,802	1-2-12-A3	1,AO,803	1-2-12-A4 (7)	1,AO,801	Pass
	(AC36)	1-2-12-C3		1-2-12-C4 (8)		

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Class 1E Isolation Data

Complete X
Preliminary

Job # : 47110 Test # :
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Client Name : HF Controls
EUT Name : HFC-6000 ERD111/ERD921 Qualification Cabinet
EUT Model # : HFC-6000
EUT Part # : Various
EUT Serial # : Most individual components in the cabinet have unique serial numbers.
EUT Config. : ERD111

Specification : EPRI TR-107330, 1996 Reference :

Test Case	Test Channel ID	Channel Cable Contacts	Alternate Channel ID	Channel Cable Contacts	Monitor Channel ID	Pass or Fail
`1E09	1,DO,262	1-2-2-A24,25			1,DO,261	Pass
ISO9	(DC33)	1-2-2-C24.25				
	1,DO,1042	1-2-2-A24,25			1,DO,1041	Pass
	(DC35)	1-2-2-C24,25				
`1E010	1,DO,82	1-1-3-A24,25			1,DO,81	Pass
ISO10	(DC34)	1-1-3-C24,25				
	1,DO,1008		1,DO,1009		1,DO,1001	Pass
	(DC16C)		(DO16C)			
`1E011	Station 2B	01-1-10-A26	Station 3B	01-1-10-A28	1,DI,1225	Pass
ISO11		01-1-10-C26		01-1-10-C28		
`1E012	1,DO,169	1-1-8-A17	1,DO,170	1-1-8-A19 (19)	1,DO,168	Pass
ISO12	(DO16J)	1-1-8-B17		1-1-8-B19 (20)		
	1,DO,148	1-1-7-A11	1,DO,147	1-1-7-A14(13)	1,DO,141	Pass
	1,DO,148	1-1-7-A10		1-1-7-A13(14)		

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Isolation Test Photographs

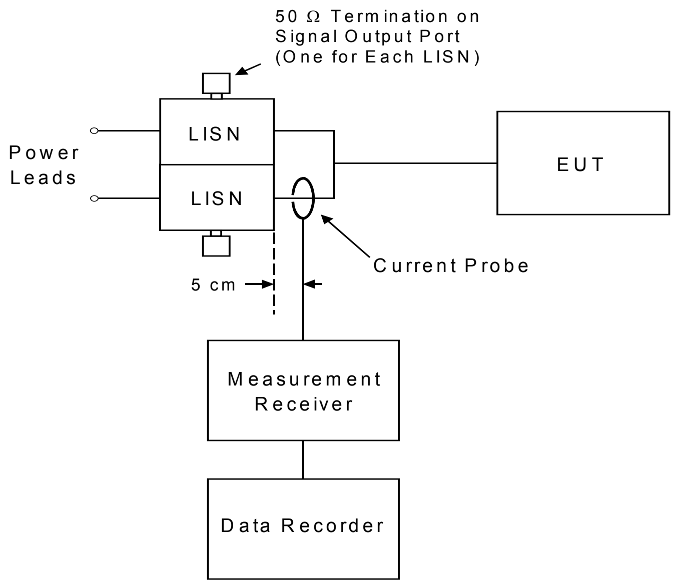
Photo not Available

Section 17. Test Methods and Block Diagrams.

Conducted Emissions, Power Leads (CE101)

Test Method:

1. Applicable Test Standard: MIL-STD-461E.
2. Perform emission data scans using the measurement setup of Fig. CE101-6.
3. Turn on the EUT and allow a sufficient time for stabilization.
4. Select an appropriate lead for testing and clamp the current probe into position.
5. Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the general section of this standard.
6. Repeat steps 4 and 5 for each power lead.



Conducted Emissions, Power Leads (CE102)

Test Method:

7. Applicable Test Standard: MIL-STD-461E.

8. Perform emission data scans using the measurement setup of Figure CE102-3.

9. Turn on the EUT and allow a sufficient time for stabilization.

10. Select an appropriate lead for testing.

11. Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the general section of this standard.

12. Repeat steps 4 and 5 for each power lead.

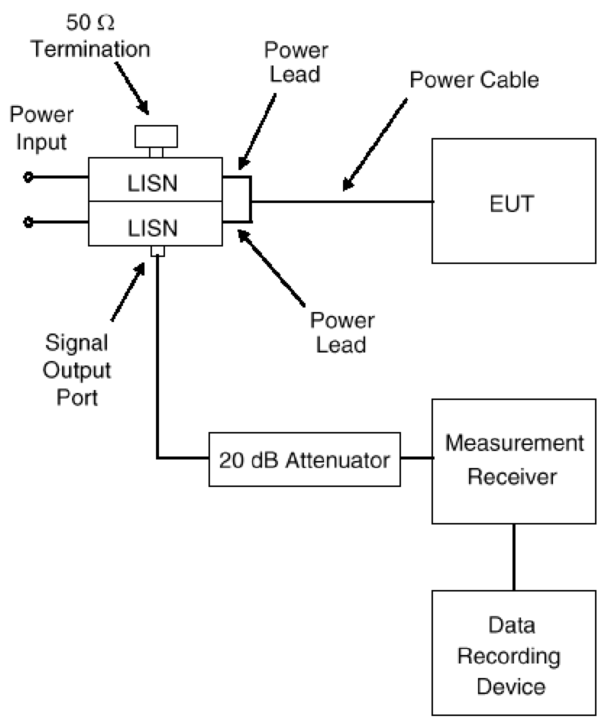


FIGURE CE102-3. Measurement setup.

Radiated Emissions, Magnetic Field (RE101)

Test Method:

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. EUT Testing.

(1) Turn on the EUT and allow sufficient time for stabilization.

(2) Locate the loop sensor 7 cm from the EUT face or electrical interface connector being probed. Orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.

(3) Scan the measurement receiver over the applicable frequency range to locate the frequencies of maximum radiation, using the bandwidths and minimum measurement times of Table II.

(4) Tune the measurement receiver to one of the frequencies or band of frequencies identified in 5.15.3.4c(3) above.

(5) Monitor the output of the measurement receiver while moving the loop sensor (maintaining the 7 cm spacing) over the face of the EUT or around the connector. Note the point of maximum radiation for each frequency identified in 5.15.3.4c(4).

(6) At 7 cm from the point of maximum radiation, orient the plane of the loop sensor to give a maximum reading on the measurement receiver and record the reading.

(7) Repeat 5.15.3.4c(4) through 5.15.3.4c(6) for at least two frequencies of maximum radiation per octave of frequencies below 200 Hz and for at least three frequencies of maximum radiation per octave above 200 Hz.

(8) Repeat 5.15.3.4c(2) through 5.15.3.4c(7) for each face of the EUT and for each EUT electrical connector.

Data Presentation.

Data presentation shall be as follows:

a. Provide graphs or a tabular listing of each measurement frequency, mode of operation, measured magnetic field, and magnetic field limit level.

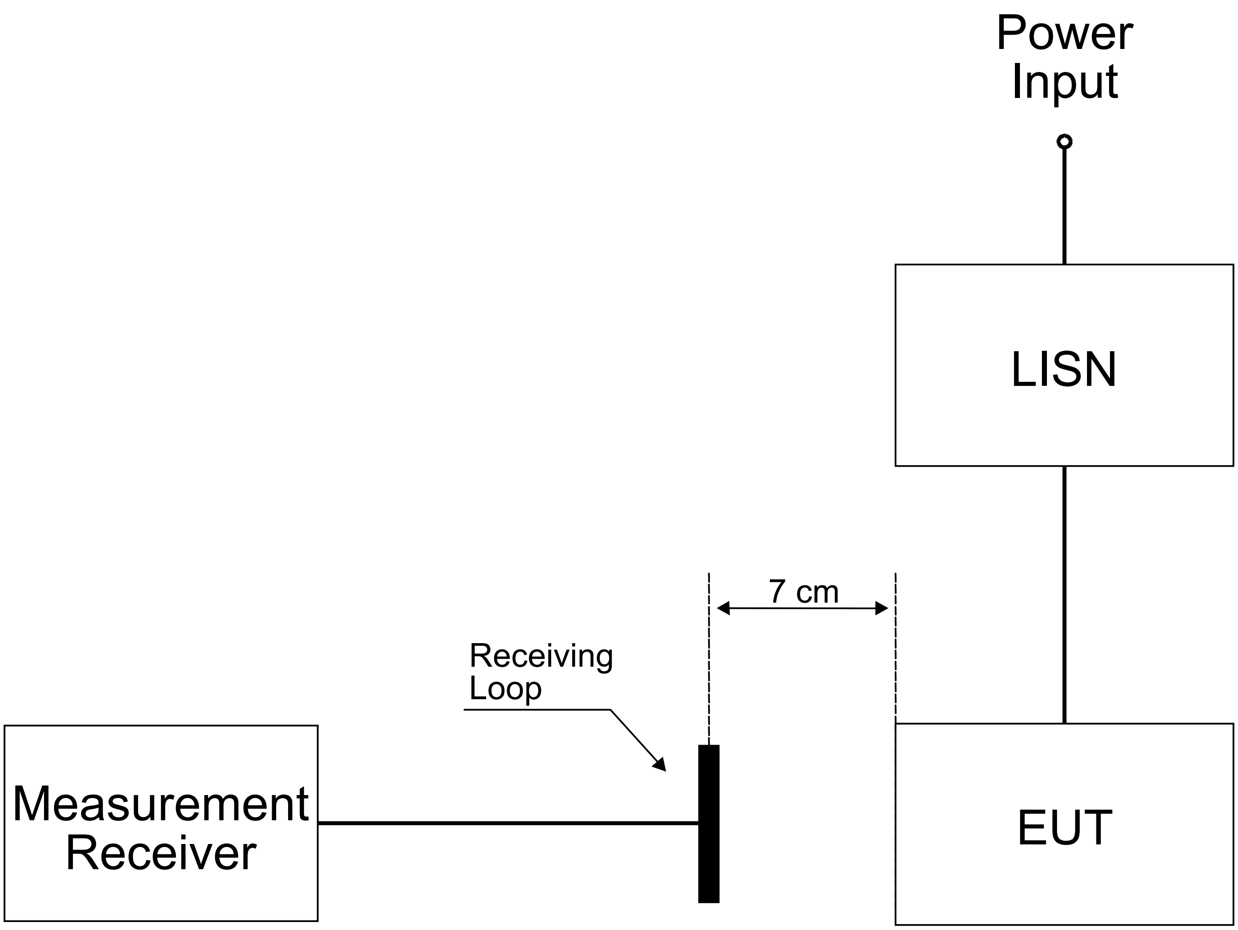


FIGURE RE101-4. Basic test setup.

Radiated Emissions, Electronic Field (RE102)

Test Method:

1. Applicable Test Standard: MIL-STD-461E.
2. For shielded room measurements electrically bond the rod antenna counterpoise to the ground plane using a solid metal sheet the same width as the counterpoise. The maximum DC resistance between the counterpoise and the ground plane shall be 2.5 milliohms. For bench top setups using a metallic ground plane, bond the counterpoise to this ground plane. Otherwise, bond the counterpoise to the floor ground plane. For measurements outside a shielded enclosure, electrically bond the counterpoise to earth ground.
3. Antenna Positioning.

   (a) Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.

   (b) Use the physical reference points on the antennas shown in Figure RE102-6 for measuring heights of the antennas and distances of the antennas from the test setup boundary.

   1. Position antennas 1 meter from the front edge of the test setup boundary for all setups.
   2. Position antennas other than the 104 cm rod antenna 120 cm above the floor ground plane.
   3. Insure that no part of any antenna is closer than 1 meter from the walls and 0.5 meter from the ceiling of the shielded enclosure.
   4. For test setups using bench tops, additional positioning requirements for the rod antenna and
      a. Distance above the bench ground plane is shown in Figure RE102-6.
   5. For free standing setups, electrically bond and mount the 104 cm rod antenna matching
      a. Network to the floor ground plane without a separate counterpoise.
   6. The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup.
   7. For testing below 200 MHz, use the following criteria to determine the individual antenna positions.
   8. For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
   9. For setups with the side edges of the boundary greater than 3 meters, us multiple antenna positions at spacing as shown in Figure RE102-7. Determine the

number of antenna positions (N) by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.

10. For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of Positions such that the entire width of each EUT Enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

For testing at 1 GHz and above, place the antenna in a sufficient number of positions such

a. That the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing
b. With the EUT enclosure are within the 3 dB beamwidth of the

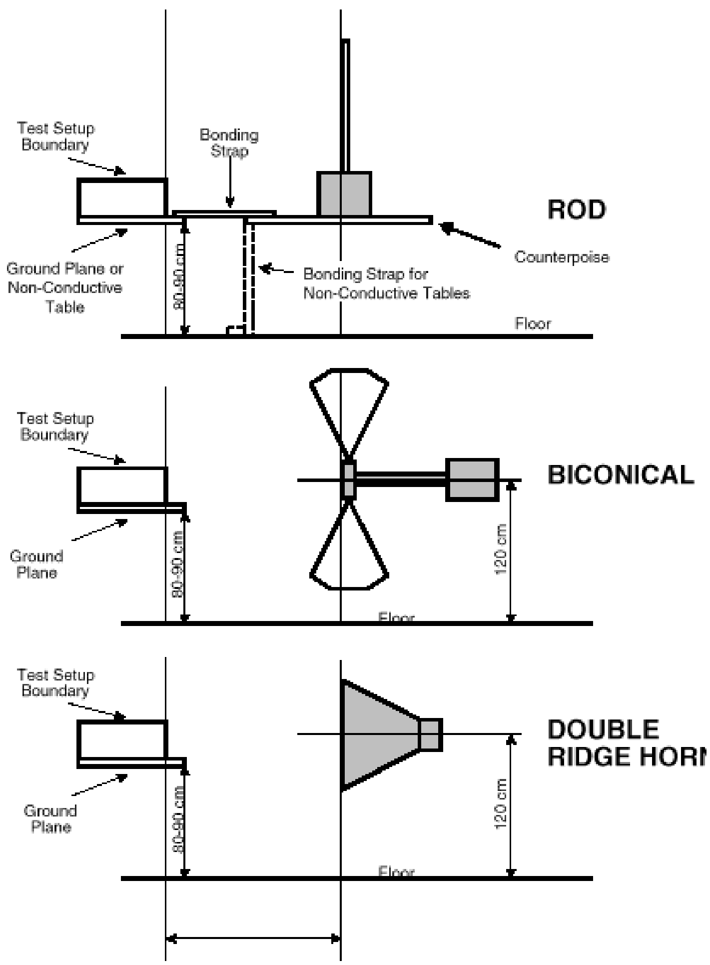


FIGURE RE102-6. Antenna positioning.

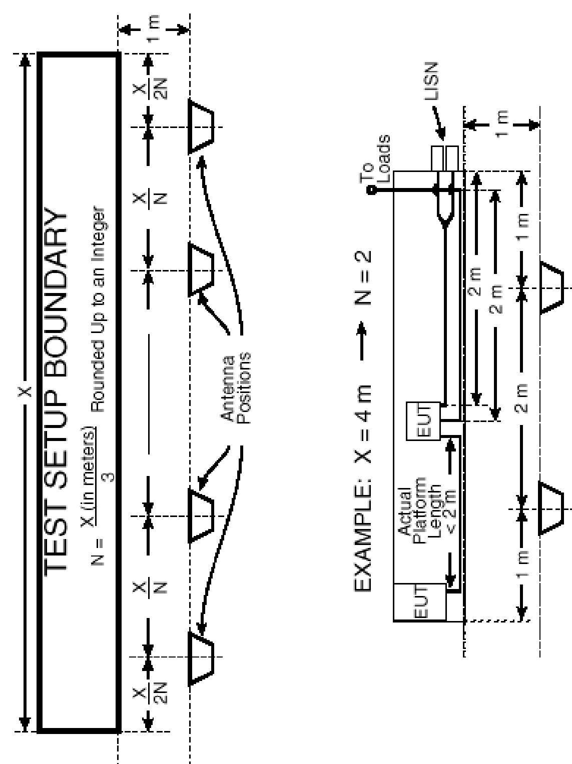


FIGURE RE102-7. Multiple antenna positions.

Conducted Susceptibility, power leads (CS101)

Test Method:

1. Applicable Test Standard: MIL-STD-461E.
2. Connect test sample and test instrumentation as shown in Figure CS101-4.
3. Apply test signal to power leads. AC and DC input power leads, not including returns. For DC operated units, apply the test frequency from 30Hz to 50 kHz. For AC operated units, apply the frequency from the second harmonic of the EUT power frequency.
4. If susceptibility occurs, determine and record its threshold level of susceptibility.

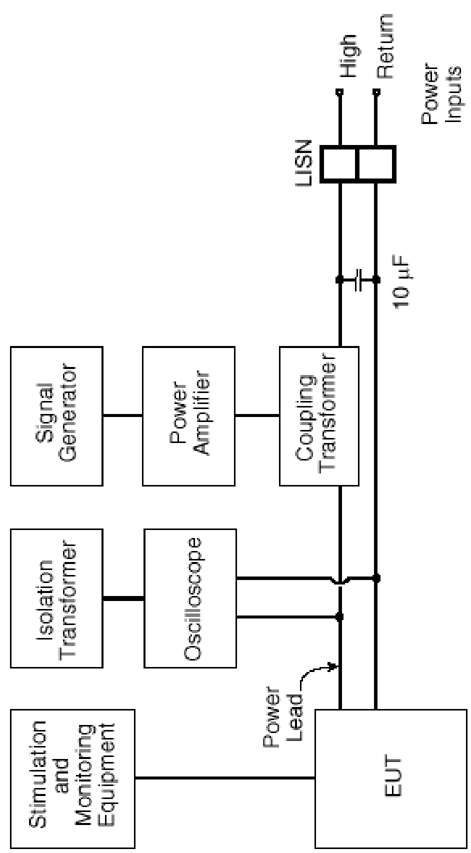


FIGURE CS101-4. Signal injection, DC or single phase AC.

Conducted Susceptibility Bulk Cable Injection (CS114)

Test Method:

1. Applicable Test Standard: MIL-STD-461E.
2. Connect test sample and test instrumentation as shown in Fig. CS 114-4.
3. Place the injection and monitor probes around a cable bundle interfacing with a EUT connector.
4. Locate the monitor probe 5 cm from the connector. If the overall length of the connector and back shell exceeds 5 cm, position the monitor probe as close to the connector's back shell as possible.
5. Position the injection probe 5 cm from the monitor probe.
6. Scan the required frequency range while monitoring the performance of the EUT.

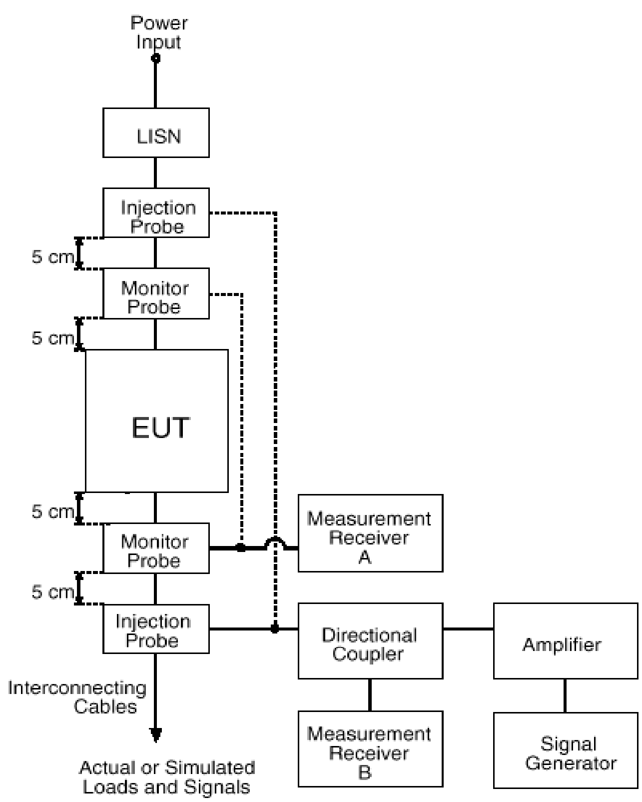


FIGURE CS114-4. Bulk cable injection evaluation.

Conducted Susceptibility, damped sinusoidal transients, cables and power leads (CS116)

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. Calibration. Perform the following procedures using the calibration setup for waveform verification.

(1) Set the frequency of the damped sine generator at 10 kHz.

(2) Adjust the amplitude of the signal from the damped sine generator to the level specified in the requirement.

(3) Record the damped sine generator settings.

(4) Verify that the waveform complies with the requirements.

(5) Repeat 5.14.3.4b(2) through 5.14.3.4b(4) for each frequency specified in the requirement and those identified in 5.14.3.4c(2).

c. EUT testing. Perform the following procedures, using the EUT test setup on each cable bundle interfacing with each connector on the EUT including complete power cables. Also perform tests on each individual high side power lead (individual power returns and neutrals are not required to be tested).

(1) Turn on the EUT and measurement equipment to allow sufficient time for stabilization.

(2) Set the damped sine generator to a test frequency.

(3) Apply the test signals to each cable or power lead of the EUT sequentially. Slowly increase the damped sinewave generator output level to provide the specified current, but not exceeding the precalibrated generator output level. Record the peak current obtained.

(4) Monitor the EUT for degradation of performance.

(5) If susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the specified requirements.

(6) Repeat 5.14.3.4c(2) through 5.14.3.4c(5) for each test frequency as specified in the requirement. Repeat testing in 5.14.3.4c for the power-off condition.

Data presentation shall be as follows:

a. Provide a list of the frequencies and amplitudes at which the test was conducted for each cable and lead.

b. Provide data on any susceptibility thresholds and the associated frequencies that were determined for each connector and power lead.

c. Provide indications of compliance with the requirements for the susceptibility evaluation specified in 5.14.3.4c for each interface connector.

d. Provide oscilloscope photographs of injected waveforms with test data.

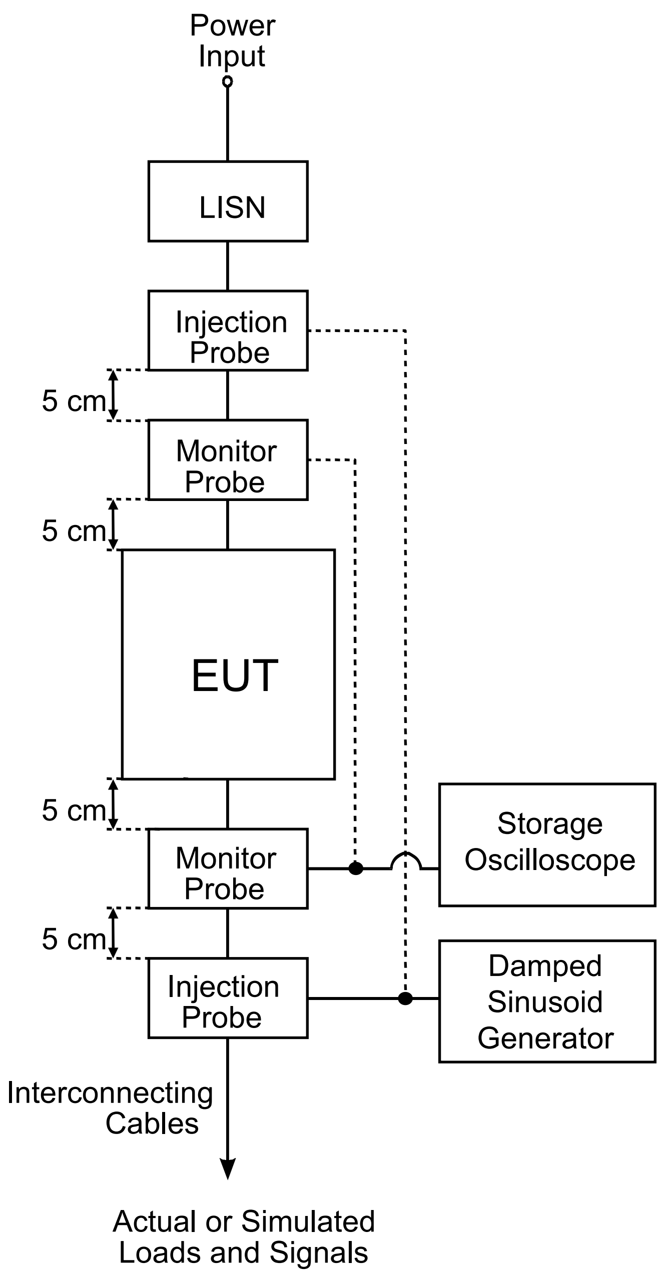


FIGURE CS116-4. Typical set up for bulk cable injection of damped sinusoidal transients

Radiated Susceptibility, Magnetic Field (RS101)

Test Method:

Applicable Test Standard: MIL-STD-461E.

(1) Turn on the EUT and allow sufficient time for stabilization.

(2) Select test frequencies as follows:

(a) Locate the loop sensor 5 cm from the EUT face or electrical interface connector being probed. Orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.

(b) Supply the loop with sufficient current to produce magnetic field strengths at least 10 dB greater than the applicable limit but not to exceed 15 amps (183 dBpT).

(c) Scan the applicable frequency range. Scan rates up to 3 times faster than the rates specified in Table III are acceptable.

(d) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.

(e) Reposition the loop successively to a location in each 30 by 30 cm area on each face of the EUT and at each electrical interface connector, and repeat 5.18.3.4c(2)(c) and 5.18.3.4c(2)(d) to determine locations and frequencies of susceptibility.

(f) From the total frequency data where susceptibility was noted in 5.18.3.4c(2)(c) through 5.18.3.4c(2)(e), select three frequencies per octave over the applicable frequency range.

(3) At each frequency determined in 5.18.3.4c(2)(f), apply a current to the radiating loop that corresponds to the applicable limit. Move the loop to search for possible locations of susceptibility with particular attention given to the locations determined in 5.18.3.4c(2)(e) while maintaining the loop 5 cm from the EUT surface or connector. Verify that susceptibility is not present.

Test Configuration – Radiated Susceptibility, Magnetic Field

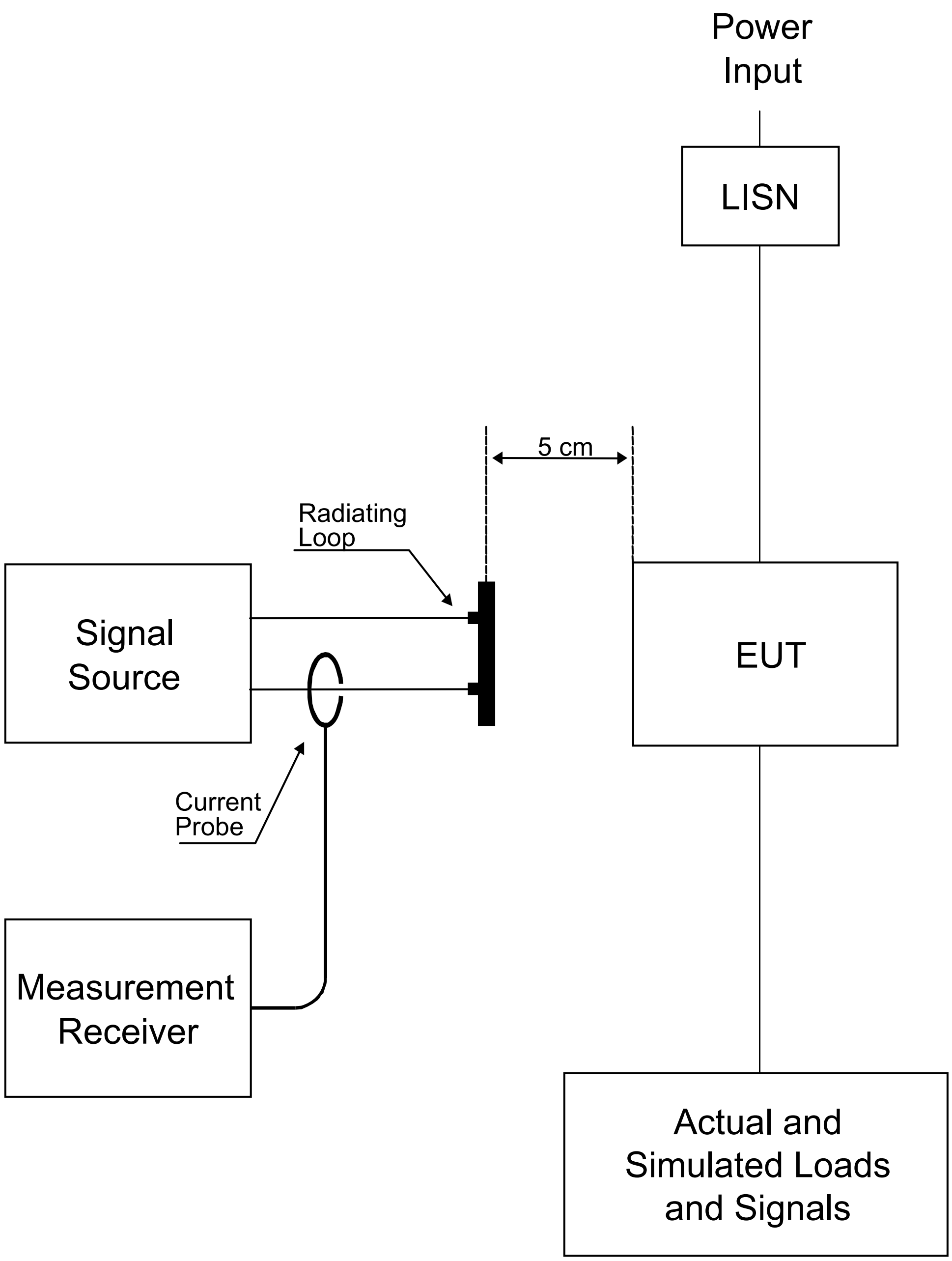


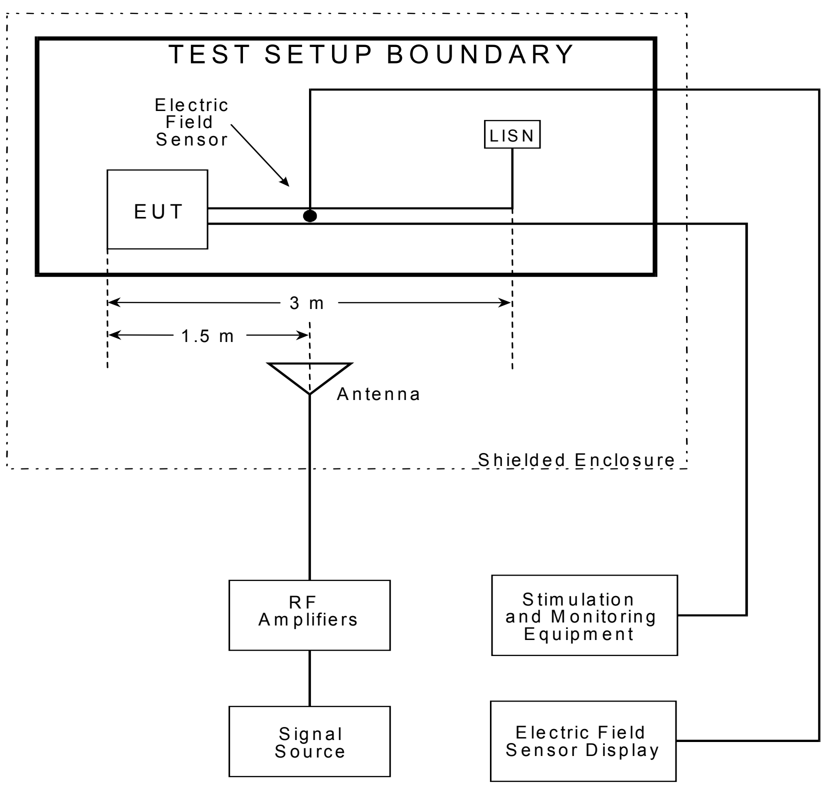
FIGURE RS101-4. Basic test setup

Radiated Electric Field (RS103):

Test Method:

- Applicable Test Standard: MIL-STD-461E.
- Test facilities are permitted to select appropriate electric field generating apparatus. Any electric field generating device such as antenna, long wire, TEM cell, reverberating chamber (using mode tuned techniques) or parallel strip line capable of generating the required electric field may be used. Fields should be maintained as uniform as possible over the test setup boundary.
- Above 30 MHz, both horizontally and vertically polarized fields must be generated. This requirement may limit the use of certain types of apparatus.
- Only vertically polarized measurements are required below 30 MHz due to the difficulty of orienting available test equipment for horizontal measurements.
- The modulation is 99% AM with a 1 kHz pulse and 50% duty cycle.
- The step size is 1% of previous frequency (i.e. previous frequency * 1.01).
- The E.U.T is exercised and monitored during testing.

Test Equipment Configuration – Figure RS103-1

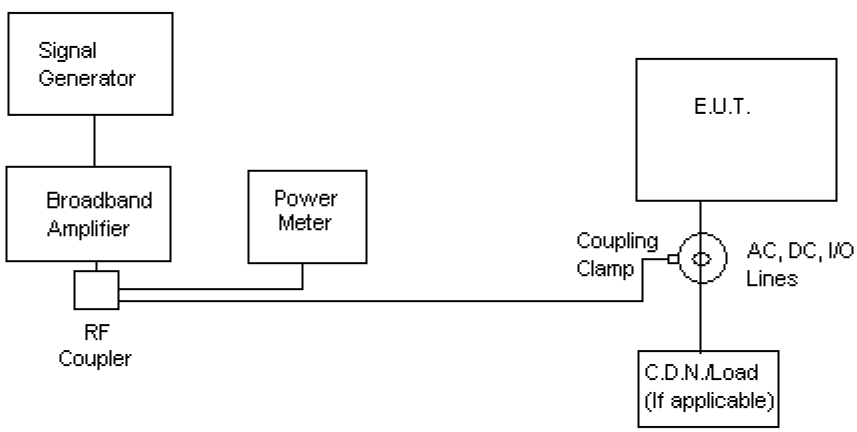


R.F. Common Mode (A.M)

Test Method - R.F. Common Mode (A.M.):

- Applicable Test Method: IEC61000-4-6.
- The E.U.T. is configured as shown in the test configuration diagram.
- The frequency range is swept from 150 kHz to 80 MHz.
- The disturbance signal is 80% amplitude modulated with a 1 kHz sine wave.
- The frequency is incremented at 1% of the start and thereafter 1 % of the preceding frequency value.

Test Configuration - R.F. Common Mode (A.M.):

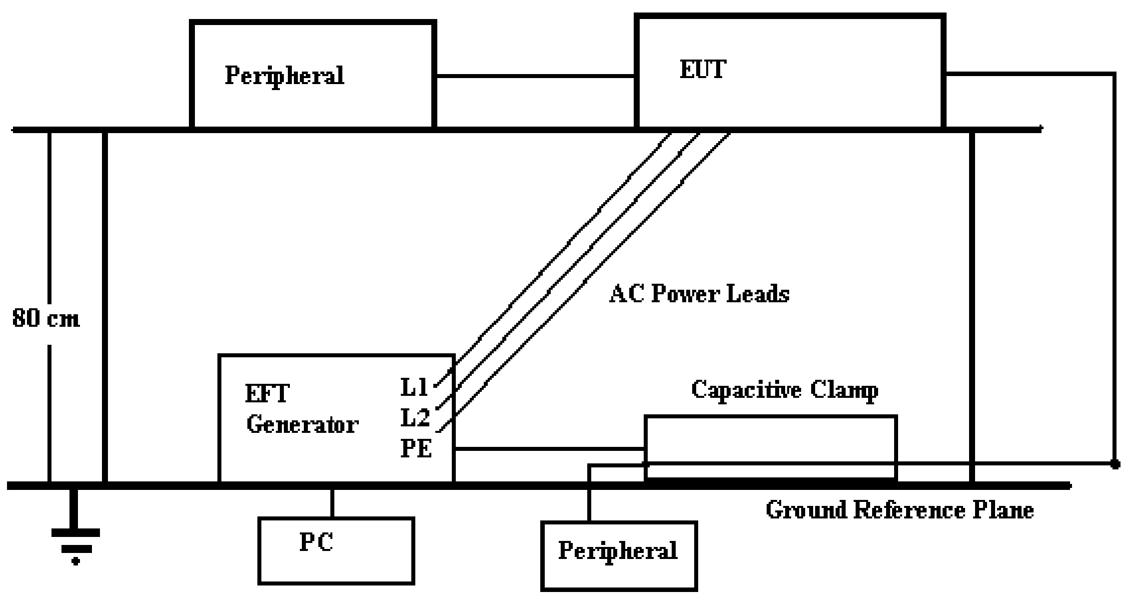


Electrical Fast Transient / Burst and Surge

Test Method - Electrical Fast Transient / Burst and Surge:

- Applicable Test Method: EN61000-4-4: 1995, EN61000-4-5, and EN61000-4-12 : 1995.
- The E.U.T. is configured as shown in the test configuration diagram.
- The waveform is verified before testing commenced.

Test Configuration – Electrical Fast Transient/Burst, and Surge:



The EFT/Burst/Surge waveform is directly coupled to the AC mains cable of the E.U.T. via Mains Coupler E4551. EFT/Burst only are indirectly coupled to the data I/O cables via the CCL-4/S Capacitive Clamp.

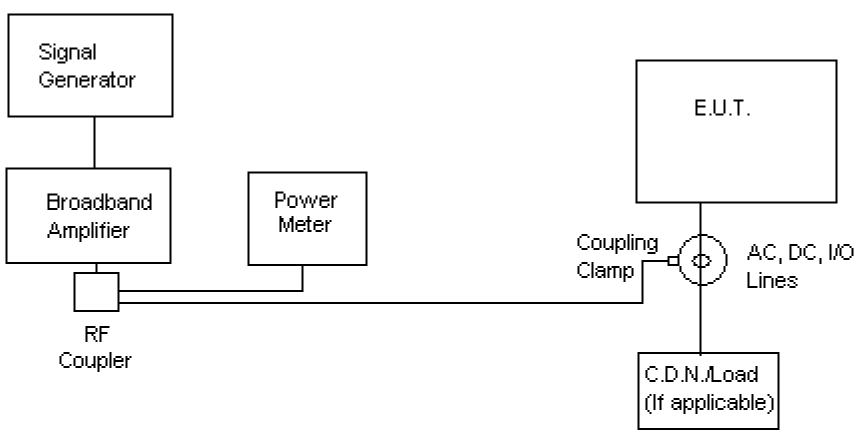
R.F. Common Mode (A.M)

Test Method - R.F. Common Mode (A.M.):

- Applicable Test Method: IEC61000-4-6.
- The E.U.T. is configured as shown in the test configuration diagram.
- The frequency range is swept from 150 kHz to 80 MHz.
- The disturbance signal is 80% amplitude modulated with a 1 kHz sine wave.
- The frequency is incremented at 1% of the start and thereafter 1 % of the preceding frequency value.

Test Configuration - R.F. Common Mode (A.M.):

Setting Immunity Levels:

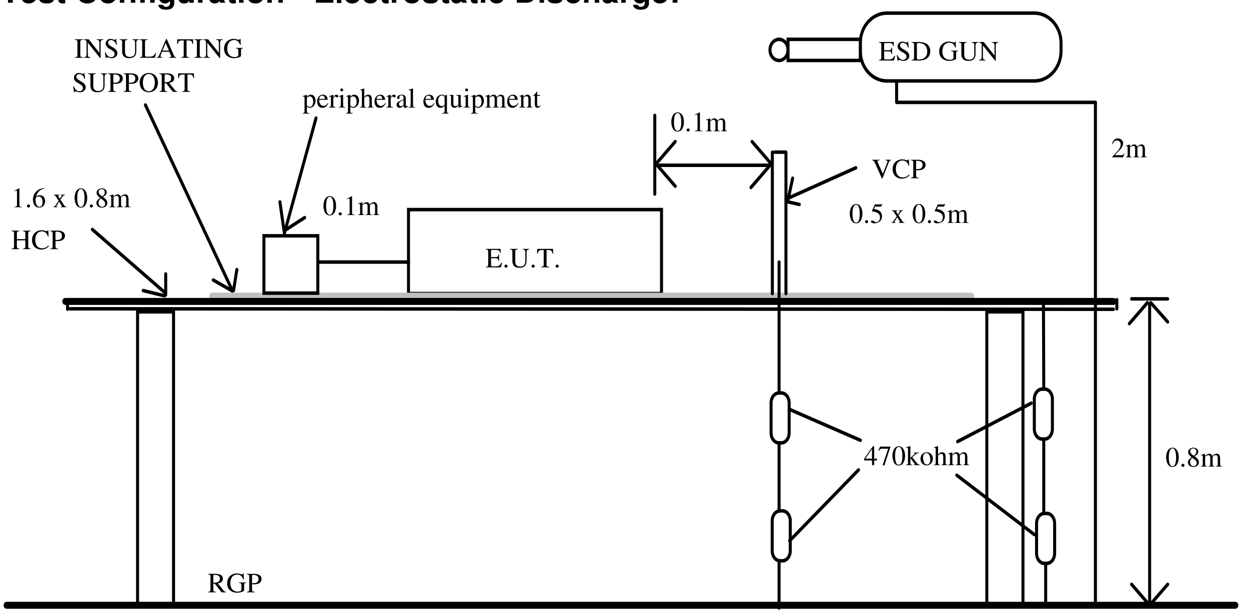


Electrostatic Discharge

Test Method - Electrostatic Discharge:

- Applicable Test Method: EN61000-4-2: 1995.
- The test set-up is as per the test configuration diagram.
- The electrostatic discharge has been applied to all points and surfaces which are accessible to personnel during normal usage of the E.U.T. (refer to test data table for a listing).
- The generator is re-triggered for a new single discharge.
- This procedure is repeated ten times in each polarity for each point.
- The E.U.T. is exercised during testing.

Test Configuration - Electrostatic Discharge:



The reference ground plane size projects beyond the horizontal coupling plane by at least 0.5 m on all sides.

HCP - Horizontal Coupling Plane   VCP - Vertical Coupling Plane   RGP - Reference Ground Plane

HF Controls

Responses to RAI (ML14041A002) From NRC in correspondence to HFC Amendment (ML11199A098) to Safety Evaluation (ML110831014)

RR901-001-05 Rev. A

Effective Date: 4/30/2014

Prepared By: Yang Lu

Reviewed By: Ivan Chow

Approved By: Steve Yang

[ ]

Revision History

Date	Revision	Preparer	Changes
4/30/2014	A	Yang Lu	Initial Revision

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1.0 Introduction

This document contains the responses to the Request for Additional Information (RAI) ML14041A002, issued by the Office of Nuclear Reactor Regulation in correspondence to the HFC amendment, ML11199A09, to safety evaluation (SE), ML110831014 for HFC-6000 platform.

The complete RAI is listed in section 2.0. Response to a particular RAI question is listed immediately following the RAI with the heading "HFC Response:" and in blue color font.

In section 3.0, the supporting documents to the responses are listed.

2.0 Complete RAI ML14041A002 and Responses

<u>REQUEST FOR ADDITIONAL INFORMATION</u>
<u>FOR SIX OPEN ITEMS OF DOOSAN HF CONTROL CORP.</u>
<u>TOPICAL REPORT PP901-000-01, REVISION C, "HFC-6000 SAFETY SYSTEM"</u>
<u>(TAC NO. ME7577)</u>

RAI-1

HF Corporation (HFC) uses Electric Power and Research Institute Topical Report 107330 Figure 4-4 to demonstrate compliance with environment stress requirements as described on page 6 of "Qualification Retest Summary Report", RR901-001-04, ERD111 Rev. A. The Figure shows the tests include maintaining 40 ºF and 5% relative humidity conditions for at least 8 hours. The staff noted that the test conducted by the Environmental Testing Laboratory (page 5 of Attachment 7.1 of RR901-001-04) only maintained conditions of 4 ºC (40 ºF) for 4 hours.

Please provide additional testing results, or justification for qualification of the HFC-6000 platform under different environmental stress conditions than those conditions defined in EPRI TR-107330.

HFC Response:

The test periods captured on page 5 were for different tests required by IEC 61508 certification of a subsystem in the test set. The Triple Modular Redundant configuration of HFC-6000 system was also being tested in the same environmental chamber 'after' the EPRI TR-107330 environmental tests were completed. IEC 61508 requires these tests to be compliance with IEC 60068-2-14 Test Nb: Change of temperature tests in operation which requires a 3-hour minimum at those temperatures. The minimum 8-hour 40 ºF and 5% conditions for EPRI TR-107330 environmental tests were performed in hours: 2010, July 15, 3:51am to 2010, July 15, 02:11pm which was 9.33 hours (adjusted for sudden rise of temperature due to operator's error). The details were documented in TR901-200-03-PI, ERD111 Environment Stress Retest Detail Report, Rev. A, which was included in the submittal of ML11199A09.

RAI-2

HFC uses NRC Regulatory Guide 1.180 Rev. 1, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems" to comply Electromagnetic Interference/ Radio-Frequency Interference tests as stated in page 6 of "Qualification Retest Summary Report", RR901-001-04, ERD111 Rev. A. However, the staff noted the following discrepancies between RG1.180 and Nemko tests:

Emissions:

Name of Test	Standard	Limits	Discrepancies	Nemko Test Report Page Number
CE101 Low Frequency Conducted Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	60 Hz – 10 kHz For AC Power ≤ 1kVA	Missing test for 60Hz – 120 Hz	Pages 14 –16
RE102 High Frequency Radiated Emissions	MIL-STD-461E as modified by RG 1.180 Rev. 1	2MHz – 10 GHz	Missing test for Horizontal 2 MHz– 30 MHz	Pages 26 – 32

Immunities:

Name of Test	Standard	Limits	Discrepancies	
CS114 Conducted Susceptibility, Power & Signal Leads	MIL-STD-461E as modified by RG 1.180 Rev. 1	10kHz – 30 MHz 10 kHz – 0.2 MHz, 100 dBµA; 0.2 Mz – 30MHz, 97 dBµA	dBµA values are lower than the required values. (No operating envelopes Figure provided)	Pages 36 - 39
RS101 Radiated Susceptibility, Magnetic Field	MIL-STD-461E as modified by RG 1.180 Rev. 1	30 Hz – 100 kHz	Missing 10 kHz – 100 kHz (No operating envelopes Figure provided)	Pages 67 – 70 (See page 69)

Please provide additional testing results, or justification for qualification of the HFC-6000 platform under different EMI/RFI conditions than those conditions defined in NRC RG 1.180.

HFC Response:

CE101

Based on CE101 specification in MIL-STD-461E, see the following excerpts from page 28 section 5.4,

> "&For AC applications, this requirement is applicable starting at the second harmonic of the EUT power frequency."

Since HFC-6000 power frequency starts at 60Hz, the emission profile captured was started at 2x60Hz = 120Hz.

RE102

In section 3.4, of NRC RG 1.180 Rev. 1, on page 15, it is stated:

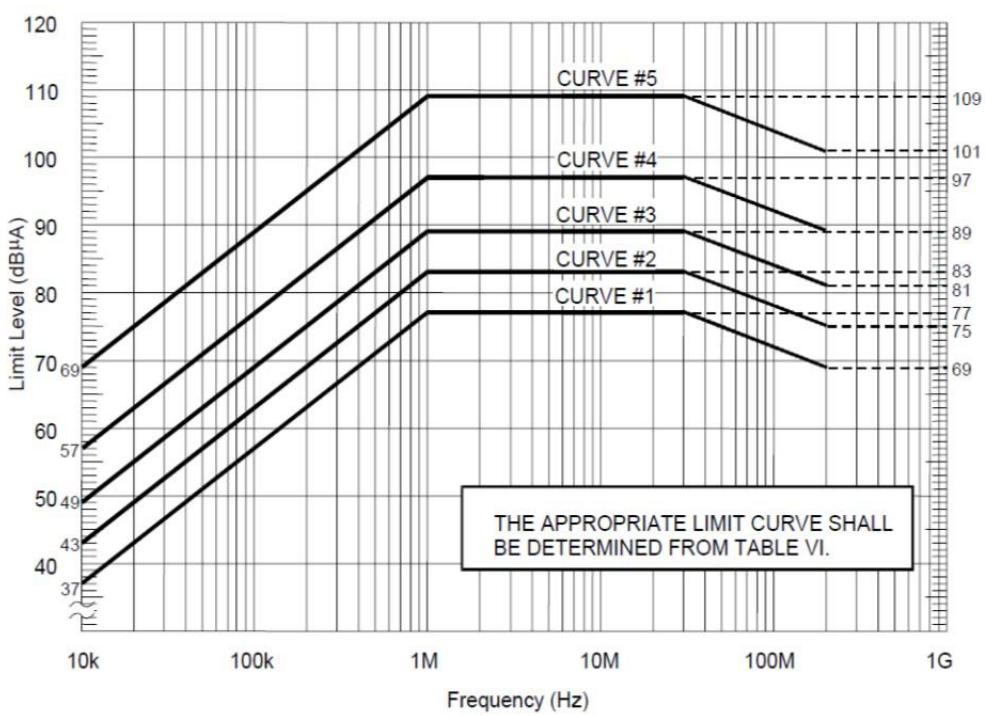
"Electric field emissions should not be radiated in excess of the rms values shown in Figure 3.4. At frequencies above 30 MHz, the test method should be performed for both horizontally and vertically polarized fields."

The text clearly stated, both horizontal and vertical polarized field tests are required only for frequencies above 30MHz. HFC performed horizontal and vertical polarized tests for frequencies over 30MHz and only performed vertical polarized tests for 2MHz to 30MHz. However, the test results did not deviate from the requirements as stated in RG 1.180 Rev. 1 and indeed complied with the regulatory guide.

CS114

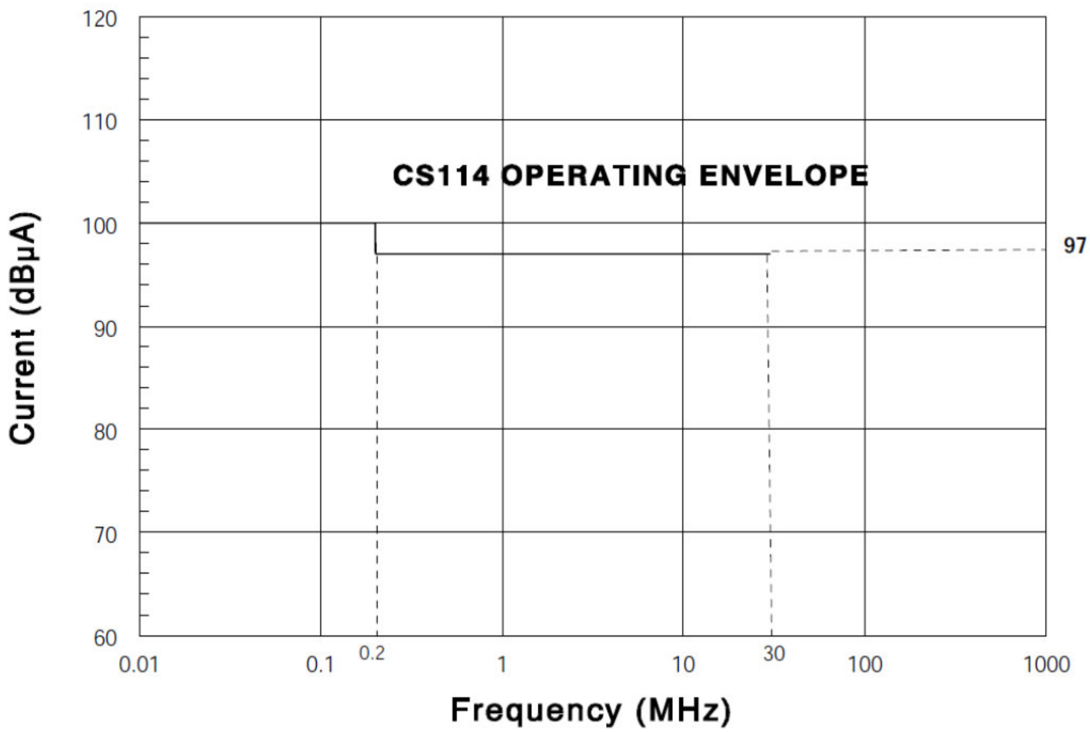
Due to the limitation of test equipment at Nemko laboratory, the calibrated test signals could not reach the signals as depicted in figure 4.2 in RG 1.180 Rev. 1. HFC could only use the limit curve number #3 for the CS114 tests as specified in MIL-STD-461E. See the following figure as extracted from MIL-STD-461E figure CS114-1.

Figure 1 – CS114 calibration limits



HFC had contracted NTS Corporation at Plano to perform CS114 tests again on the same set on April 25, 2014. Test signals as shown in figure 4.2 of NRC RG 1.180 Rev. 1 was used. Test results showed that HFC-6000 safety equipment did not exhibit any malfunction or degradation of performance when subjected to the test signals. The following figure is excerpted from NRC RG 1.180 Rev. 1 figure 4.2.

Figure 2 – HFC CS114 Operating Envelope



HFC CS114 operating envelope is also defined by the same limits as shown in the above figure.

Analog I/O channels

The maximum variations of the analog I/O channel levels are shown in the following table.

Table 1 – Analog I/O channel variation during CS114 test

AO/AI Card	Maximum Variation	
AI16F	[ ]	[ ]
AI8M	[ ]	[ ]
AO8F	[ ]	[ ]

Negligible changes in values for AI4K were detected. See the following figures for AI16F, AI8M, AO8F variations.

Figure 3 – AI16F BOE Data for CS114

Figure 4 – AI8M Data during CS114 test

Figure 5 – AO8F Data during CS114 test

System Response Time

As shown in the following table, the response times are within the acceptance ranges. No anomalies were detected.

Table 2 – System Response Time during CS114 Power Line Test

I/O Card	State	Average Response Time
AI16F– AO8F (Analog)	ON	[ ]
	OFF	[ ]
DI16I – DO8J (Digital)	ON	[ ]
	OFF	[ ]

Timer

As shown in the following table, the timer functions are within the acceptance ranges. No anomalies were detected.

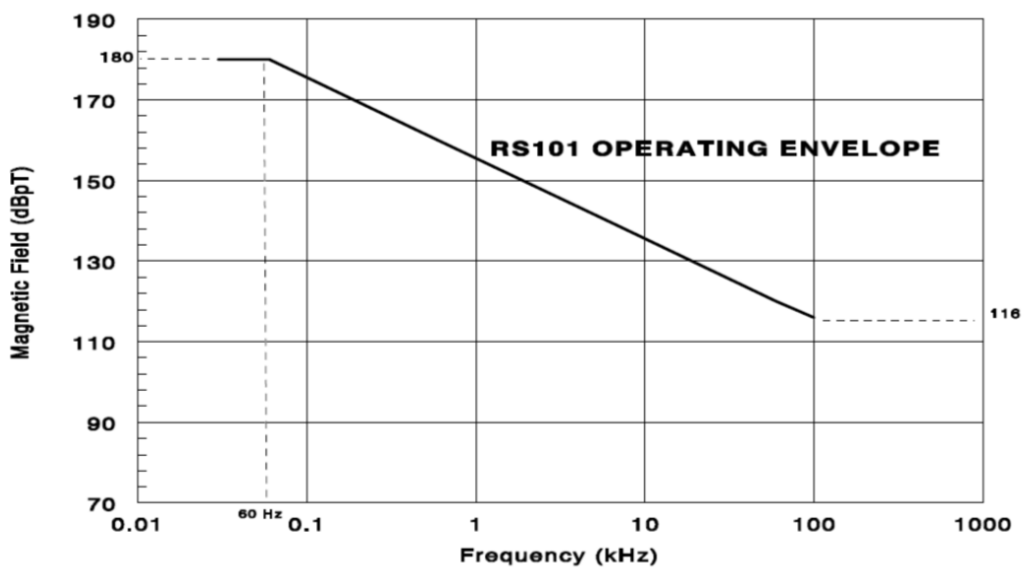
Table 3 – Timer Accuracy during CS114 Test

CS114 (Power lines)	Averaged Period	2,DI,151		2,DI,152	
		Avg Value	Accuracy (%)	Avg Value	Accuracy (%)
Timer	On	[ ]	[ ]	[ ]	[ ]
	Off	[ ]	[ ]	[ ]	[ ]
	Total	[ ]	[ ]	[ ]	[ ]

RS101

The raw data on page 69 had a recording error. HFC had performed and passed RS101 tests of range 30 Hz – 100 kHz for HFC-6000 safety platform equipment for many other projects. See attachment for a RS101 test report for HFC-6000 platform performed at Wyle Laboratory. HFC had contacted Nemko to confirm the recording error and revise the test report. As soon as the revised report is ready, HFC will submit the test report confirming the RS101 operating envelop for HFC-6000 Safety Platform specified in the topical report is the same as the one shown in RG 1.180 Rev. 1. See the following figure.

Figure 6 – HFC RS101 Operating Envelope



3.0 List of Supporting Documents for the RAI Responses

Table 4 shows the list of supporting documents for the RAI Responses.

Table 4 – List of Supporting Documents

Document	Related RAI
NTS Plano Test Report for CS114 test signal using figure 4.2 RG 1.180 Rev.1	RAI-2
Wyle Test Report for HFC-6000 Control Systems for RS101 tests in RG 1.180 Rev.1	RAI-2