DOOSAN
HF Controls

HFC-FPGA Control System of
HFC-6000 Safety Platform

HFC-FPGA Equipment Qualification Summary Test Report

TR901-302-02 Rev A

Effective Date 1 / 31 / 2020

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Revision History

Date	Revision	Author	Changes
1/29/2020	A	Yang Lu	Initial release

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1.0 PURPOSE

This document provides a summary of the Equipment Qualification (EQ) testing performed in accordance with the EQ Test Plans (References 1 and 2) on the HFC-FPGA Control System of HFC-6000 Safety Platform. The HFC-FPGA provides a generic digital safety Instrument and Control (I&C) platform to be used in mild environments as described in the EQ Test Plans.

This document summarizes the EQ test performed, test evaluation and test results required by the U.S. Nuclear Regulatory Commission (NRC) Interim Staff Guide DI&C-ISG-06 (Reference 3), item D.3.

The test results demonstrate that the HFC-FPGA platform perform its intended safety functions without experiencing environmentally induced common-cause failures during normal environmental conditions and anticipated operational occurrences.

2.0 ABBREVIATIONS AND ACRONYMS

AI	Analog Input
AO	Analog Output
BOE	Burst of Events
CR	Condition Report
DI	Digital Input
DO	Digital Output
EFT	Electrical Fast Transient
EMI	Electromagnetic Interference
EPRI	Electric Power Research Institute
EQ	Equipment Qualification
ESD	Electrostatic Discharge
ETL	Environmental Testing Laboratory
F-Link	Communication link between HFC-FPGA controllers and configured HFC-FPU I/O modules
FPGA	Field Programmable Gate Array
G-Link	Communication link between HFC-FPGA controllers and Communication Gateway controllers
HAS	Historical Archiving System
HFC	HF Controls
HPAT	HFC Plant Automated Tester
HSIM	High Speed Interface Module
I&C	Instrumentation and Control
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input / Output
M&TE	Measurement and Test Equipment
MCRT	HFC Graphic Display / Control Interface
NRC	Nuclear Regulatory Commission
NTS	National Technical Systems
OBE	Operating Basis Earthquake
PCB	Printed Circuit Board

QA	Quality Assurance
RIF	Redundancy Interface
RF	Radio Frequency
RFI	RF Interference
RG	Regulatory Guide
RH	Relative Humidity
RRS	Required Response Spectrum
RTD	Resistance Thermal Detector
SOE	Sequence of Events
SSE	Safe Shutdown Earthquake
TSAP	Test Specimen Application Program

3.0 SCOPE OF EQ TESTING

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The HFC-FPGA modules under the EQ testing are listed in Table 1.

Table 1. Qualification Modules

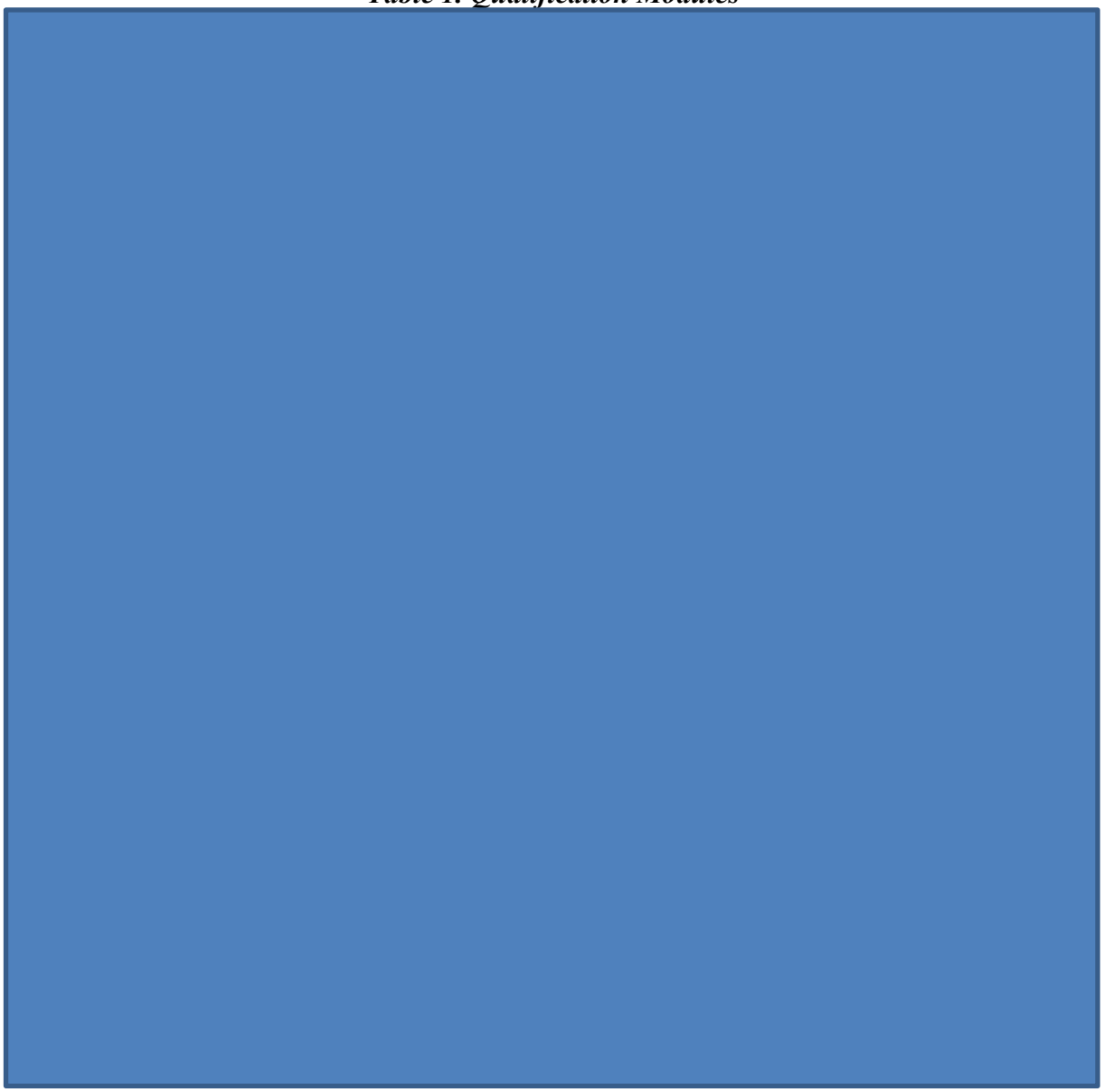

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Figure 1. Overall Test Arrangement and Sequence

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4.0 EQUIPMENT TESTED

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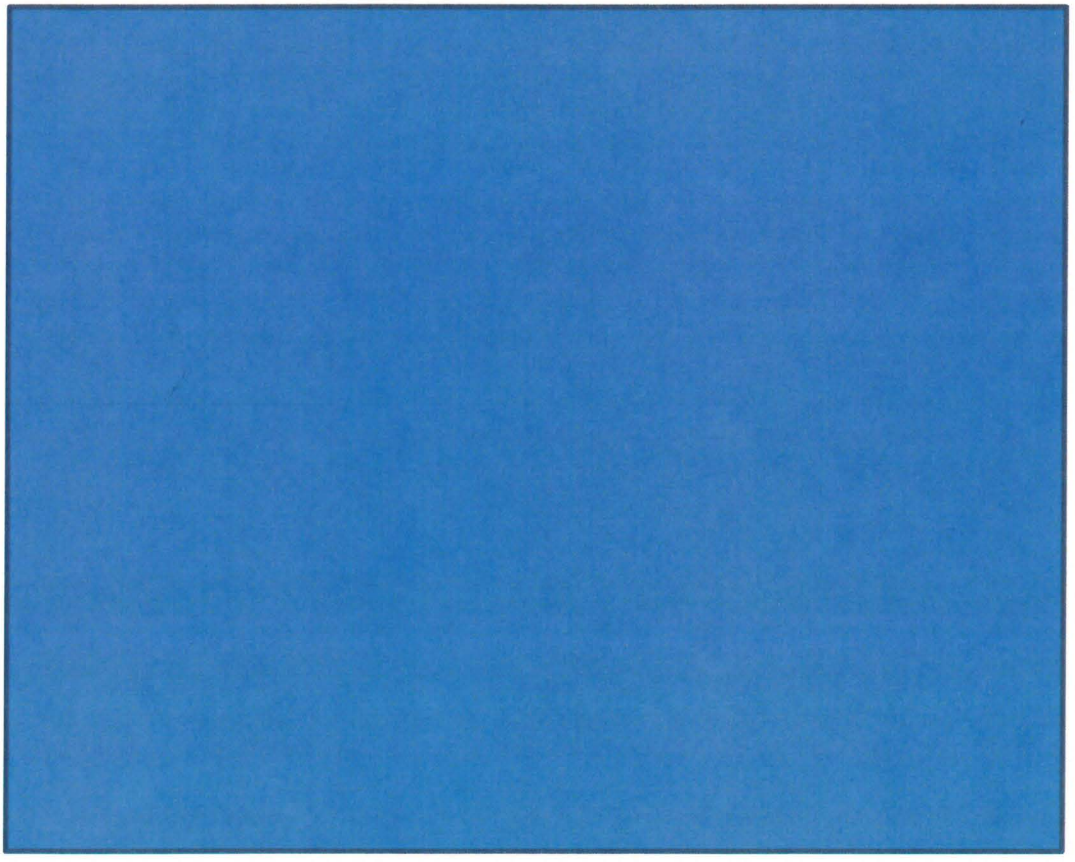
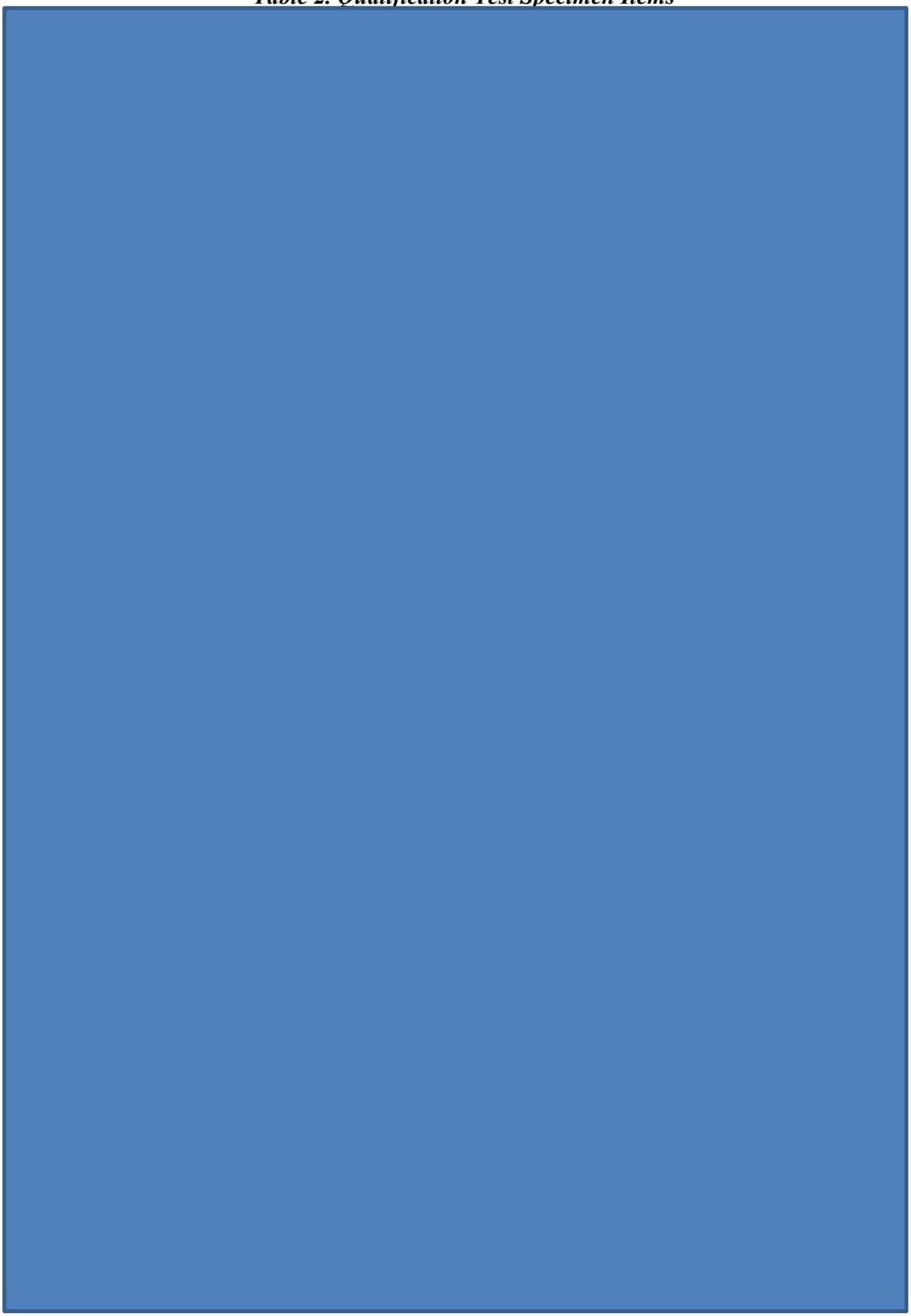


Figure 2. HFC-FPGA Qualification Test Specimen

Table 2 contains the Master Configuration List of equipment used in the VV0115 Qualification Test Specimen. Table 2 also describes functions of each module that were tested by the Qualification Test Specimen.

Table 2. Qualification Test Specimen Items



Detailed configuration information, a full list of included hardware, and a detailed description of the TSAP is described in VV901-300-10 (Reference 8).

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Table 3. FPGA Type and Quantity

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5.0 TEST SYSTEM

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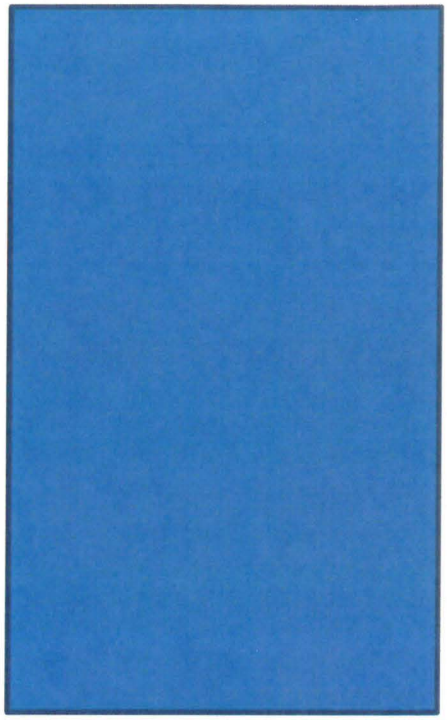

Figure 3. Typical HFC-FPGA Qualification Test System

Figure 4 shows the connection of the HFC-FPGA Qualification Test Specimen and Test System.

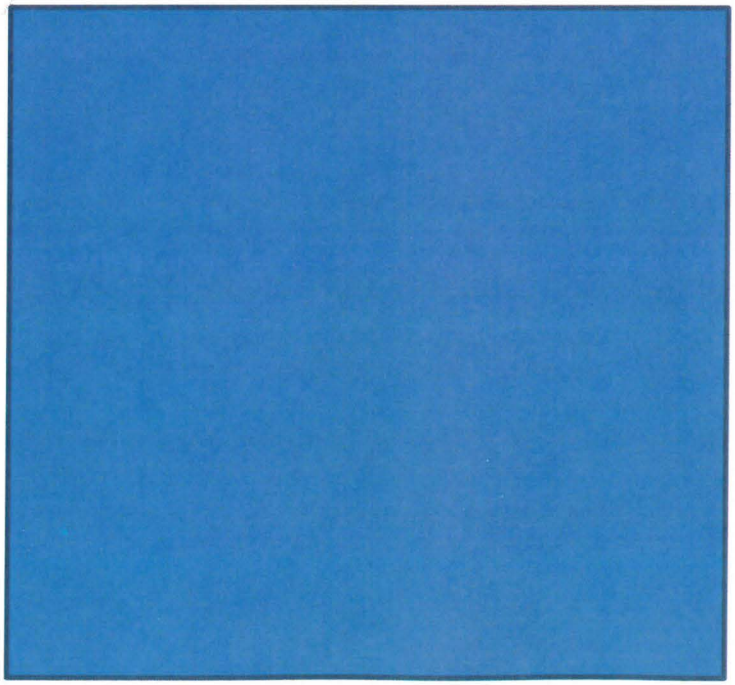

Figure 4. HFC-FPGA Qualification Test Specimen and Test System Connection

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6.0 TEST REQUIREMENTS AND ACCEPTANCE CRITERIA

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7.0 TEST PLANS AND TEST PROCEDURES

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8.0 TEST RESPONSIBILITIES

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9.0 TEST CONTROL

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10.0 MEASUREMENT AND TEST EQUIPMENT

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11.0 TEST SCHEDULE

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Table 4. Qualification Test Execution Schedule

12.0 TEST DOCUMENTATION

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13.0 EVALUATION OF TEST RESULTS

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14.0 AS-TESTED EQUIPMENT QUALIFICATION ENVELOPE

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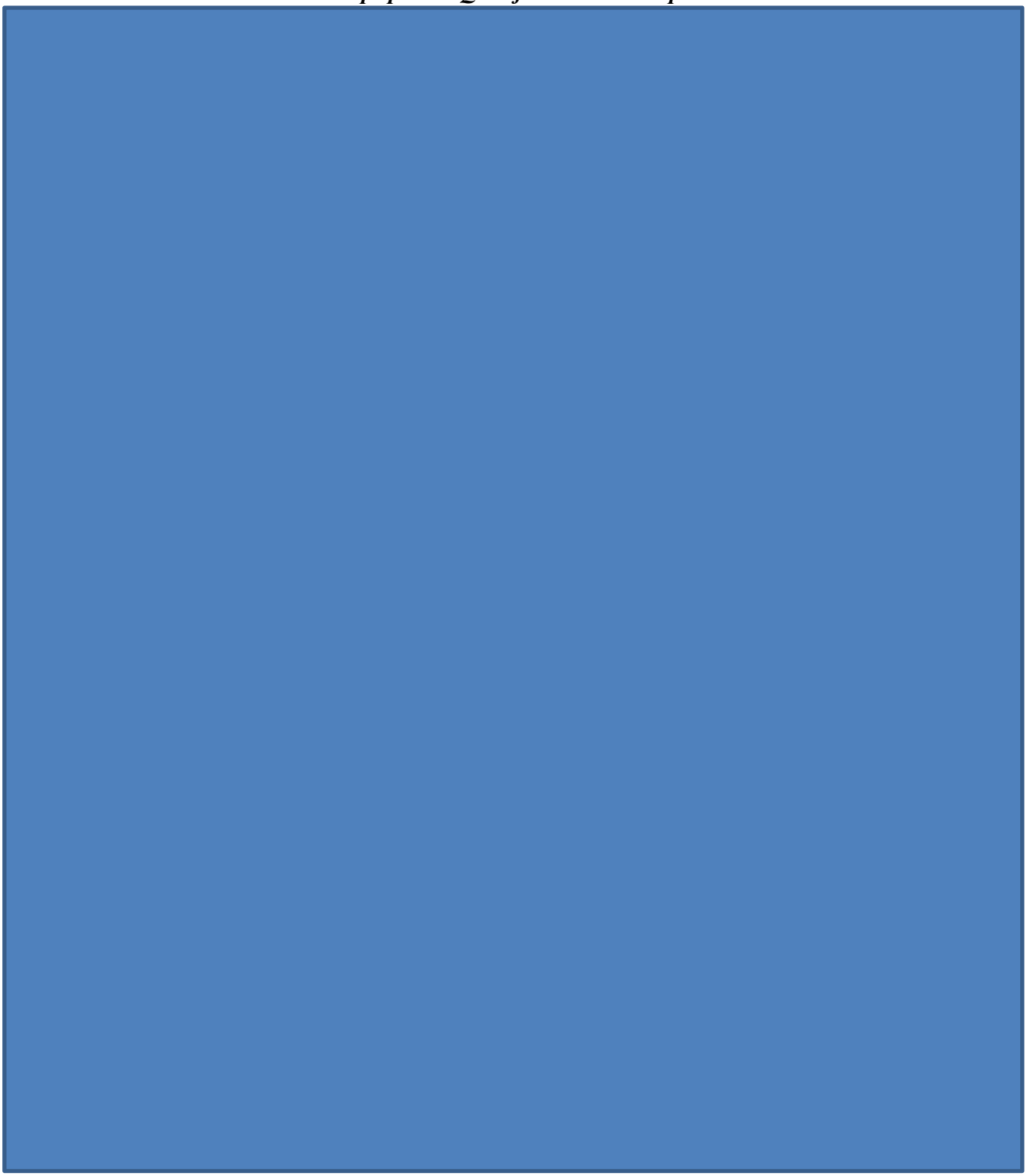
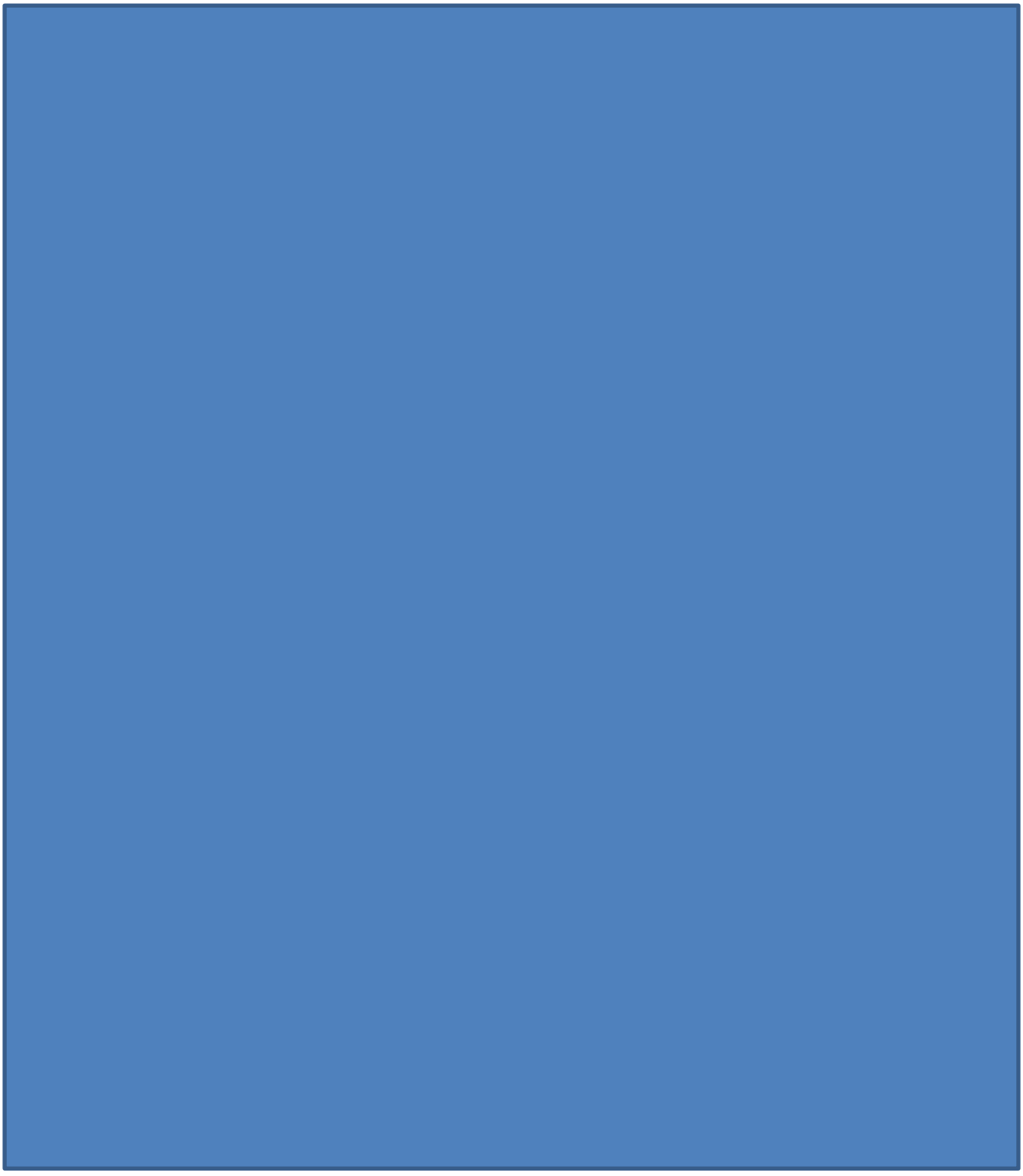
Table 5. Equipment Qualification Envelope





15.0 SUMMARY

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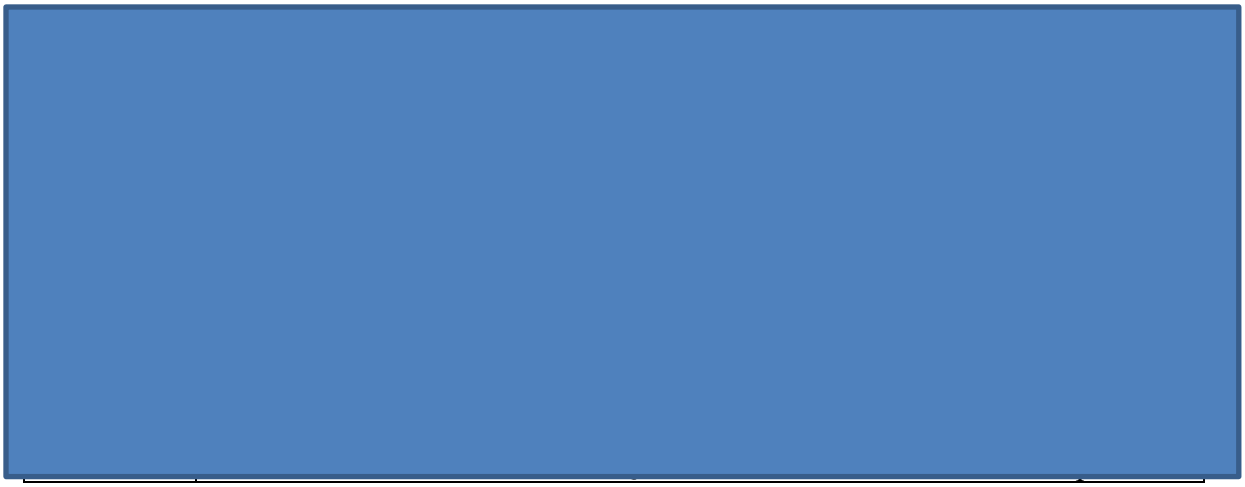
16.0 REFERENCES



Appendix A. Prequalification Test Summary

A.1. Purpose

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A.2. Objective

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A.3. Equipment Tested

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A.4. Sequence of Testing

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A.5. Procedures

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A.6. Test Specimen Mounting

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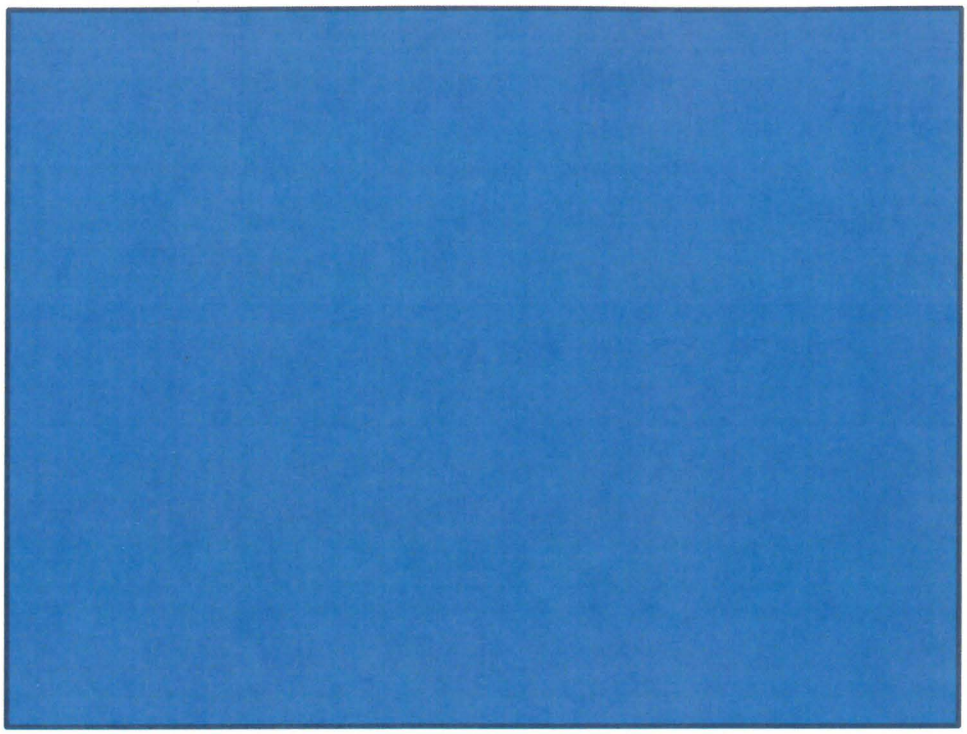

Figure 5. Test Specimen Mounting for Prequalification Test

A.7. Service Conditions

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A.8. Test Levels

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A.9. Performance Monitoring

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A.10. Acceptance Criteria

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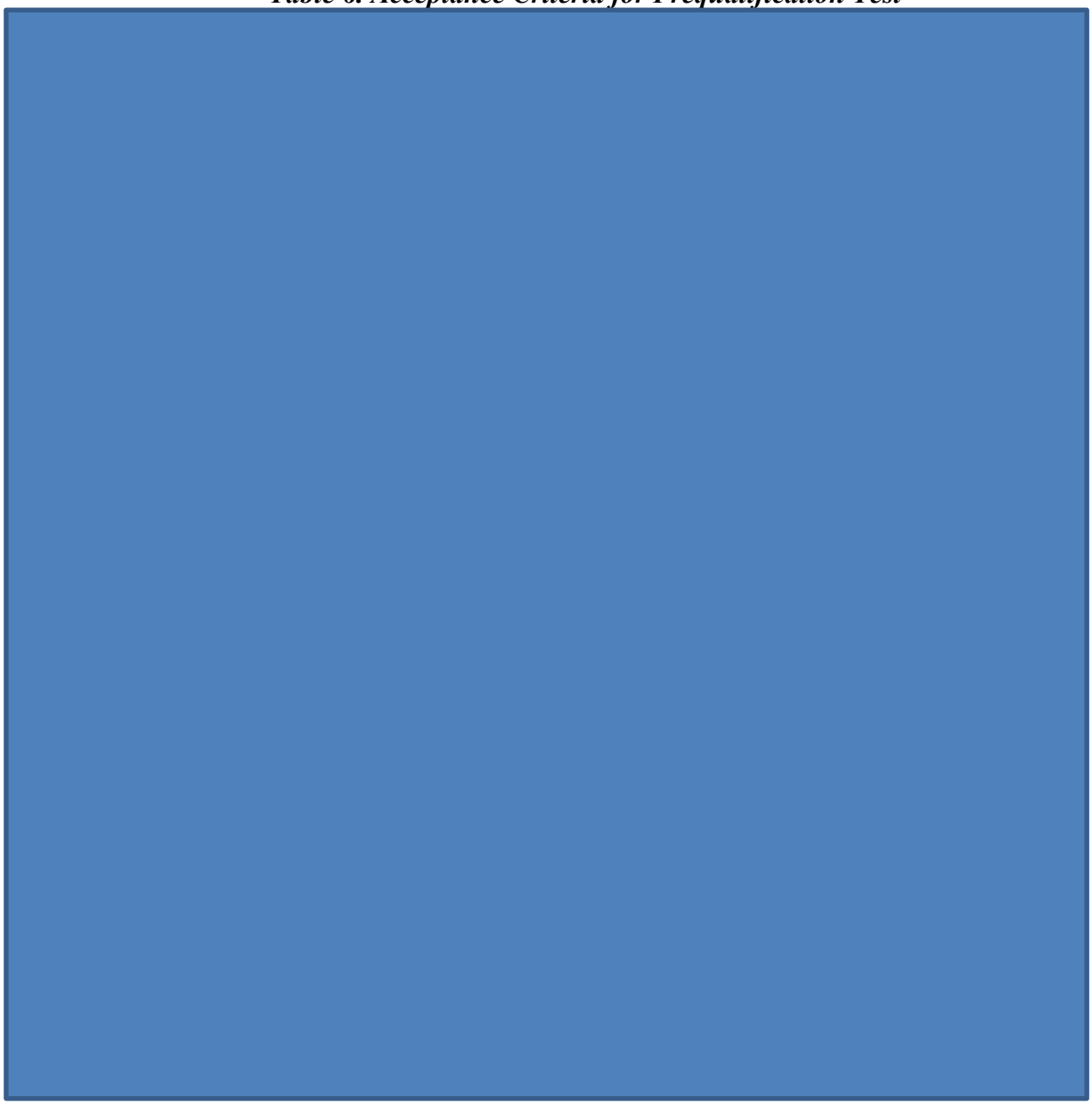
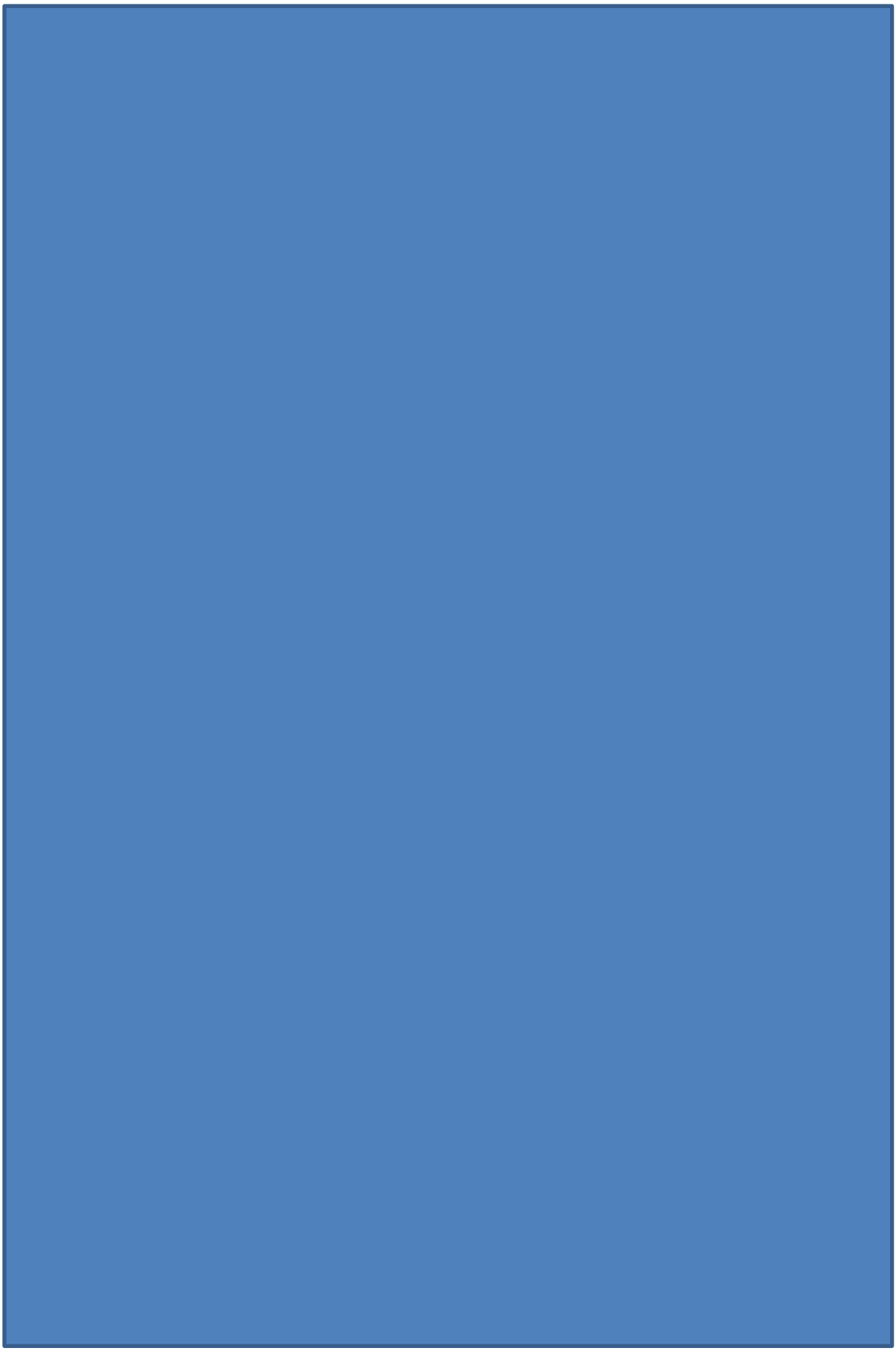
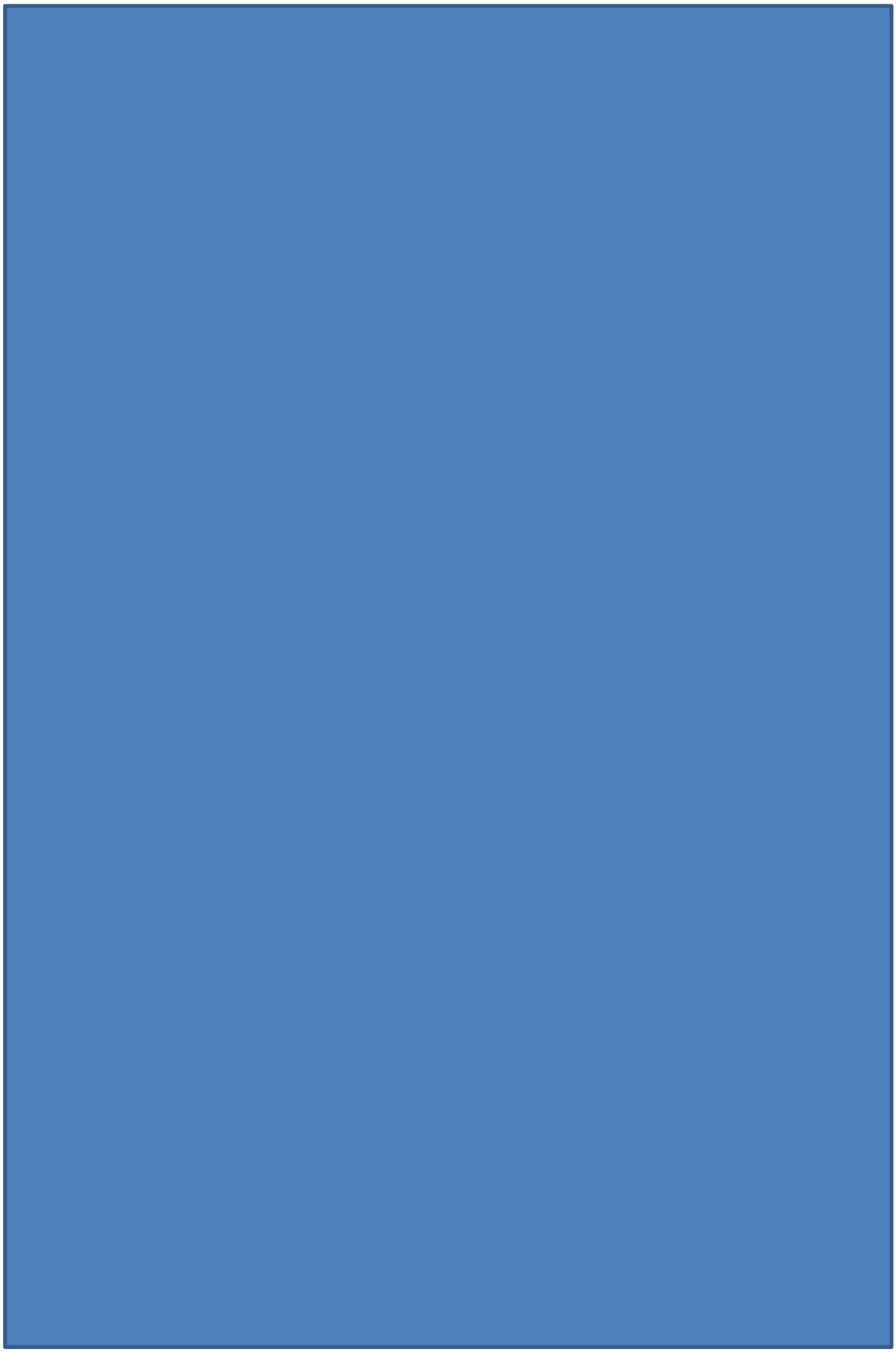
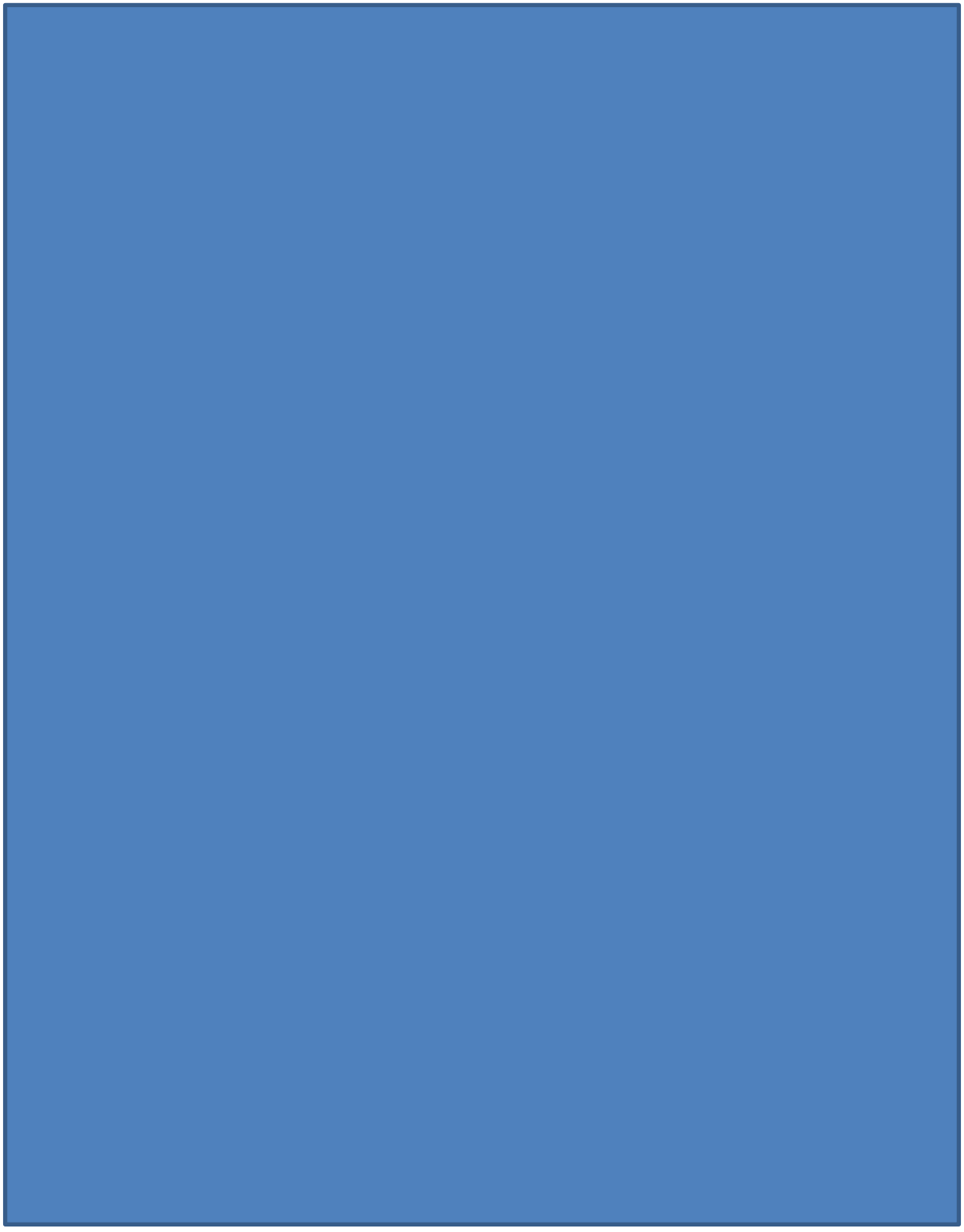
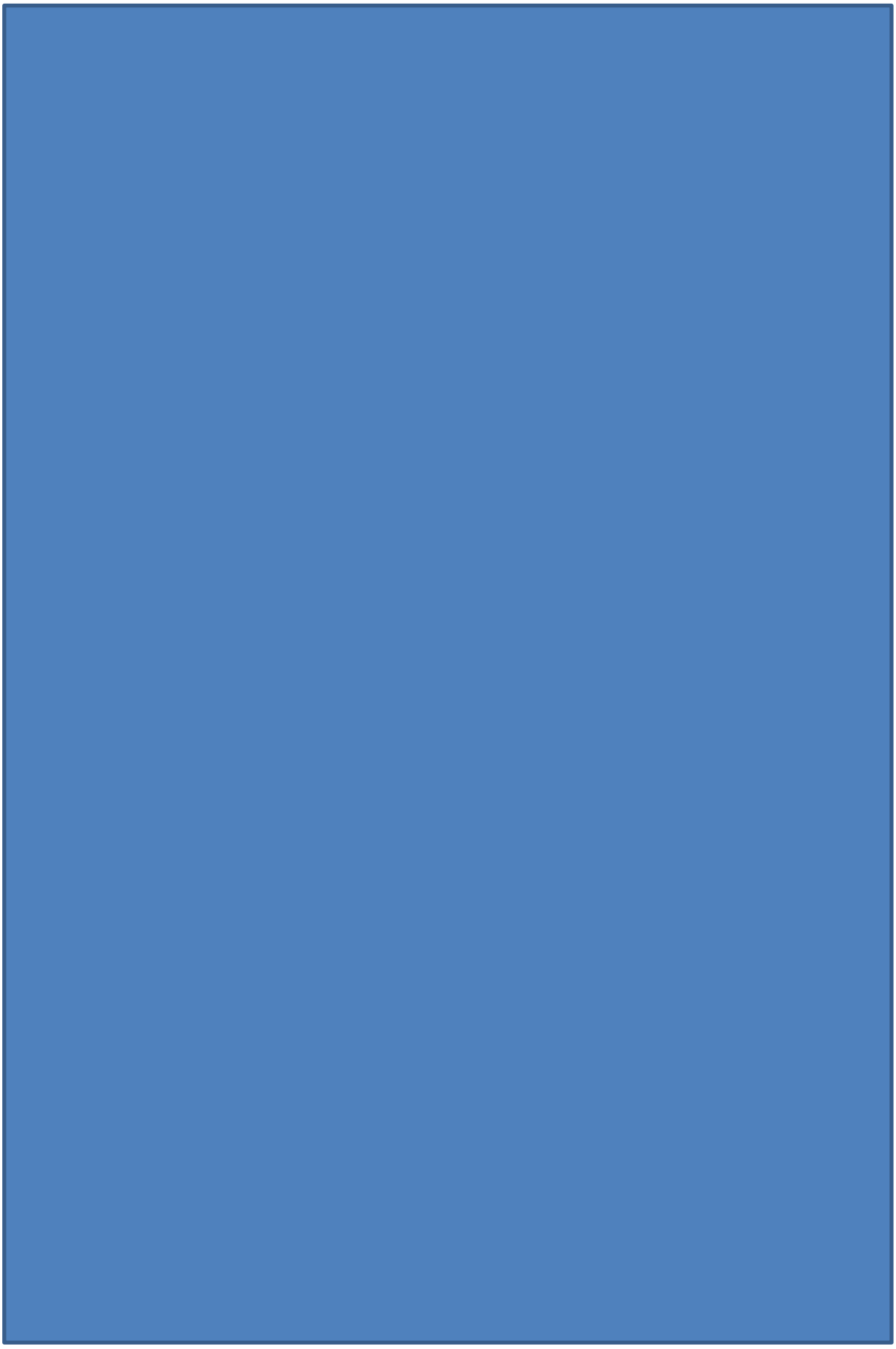
Table 6. Acceptance Criteria for Prequalification Test











A.11. Documentation

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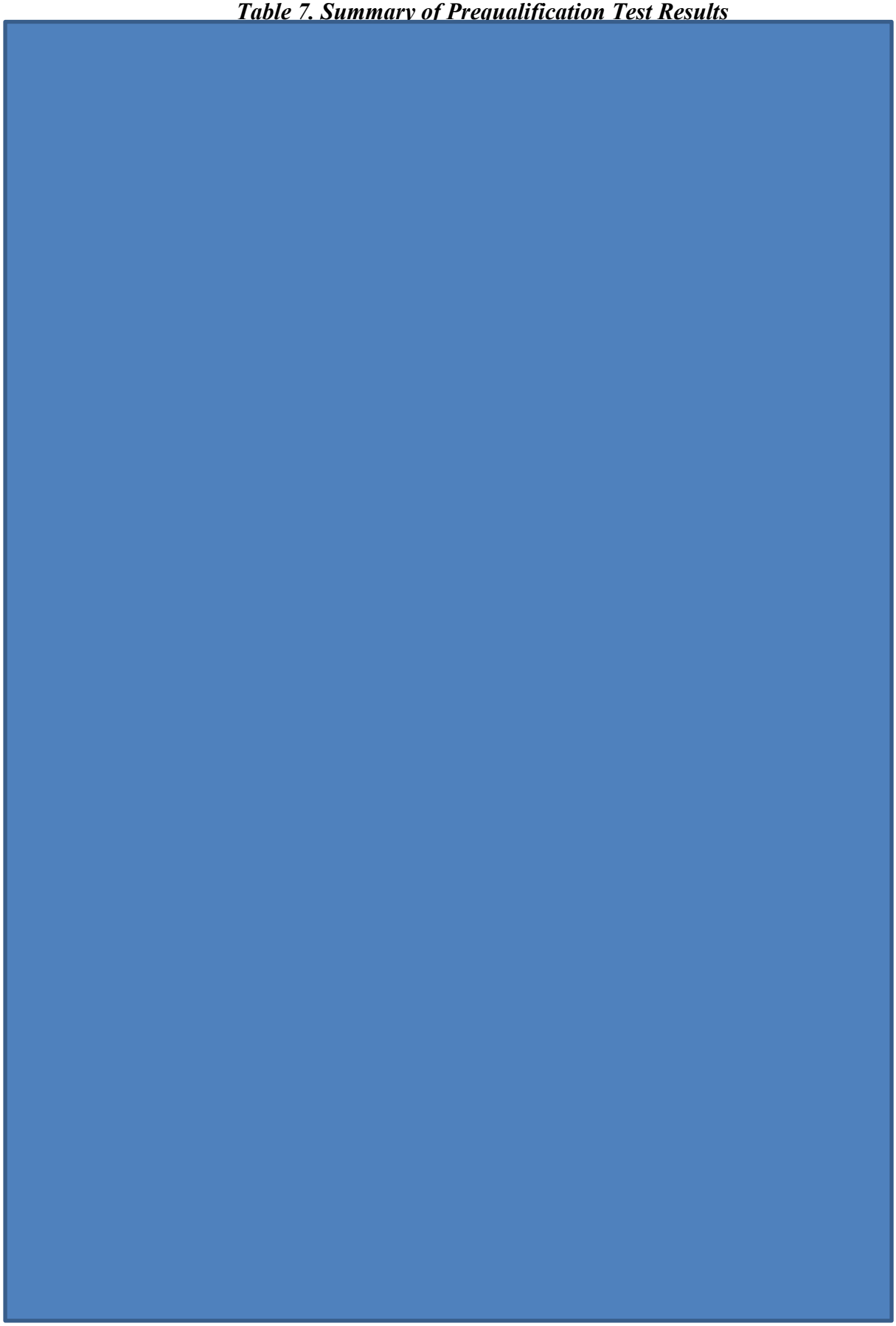
A.12. Test Results

Detailed test results of the Prequalification Test were reported in TR901-302-01 (Reference 9), which are summarized in Table 7.

Table 7. Summary of Prequalification Test Results



A.13. Resolution of Test Discrepancies

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Appendix B. Qualification Test Summary – Environmental Stress Test

B.1. Purpose

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B.2. Objective

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B.3. Equipment Tested

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B.4. Sequence of Testing

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Figure 6. Environmental Stress Test Profile

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B.5. Procedures

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B.6. Test Specimen Mounting

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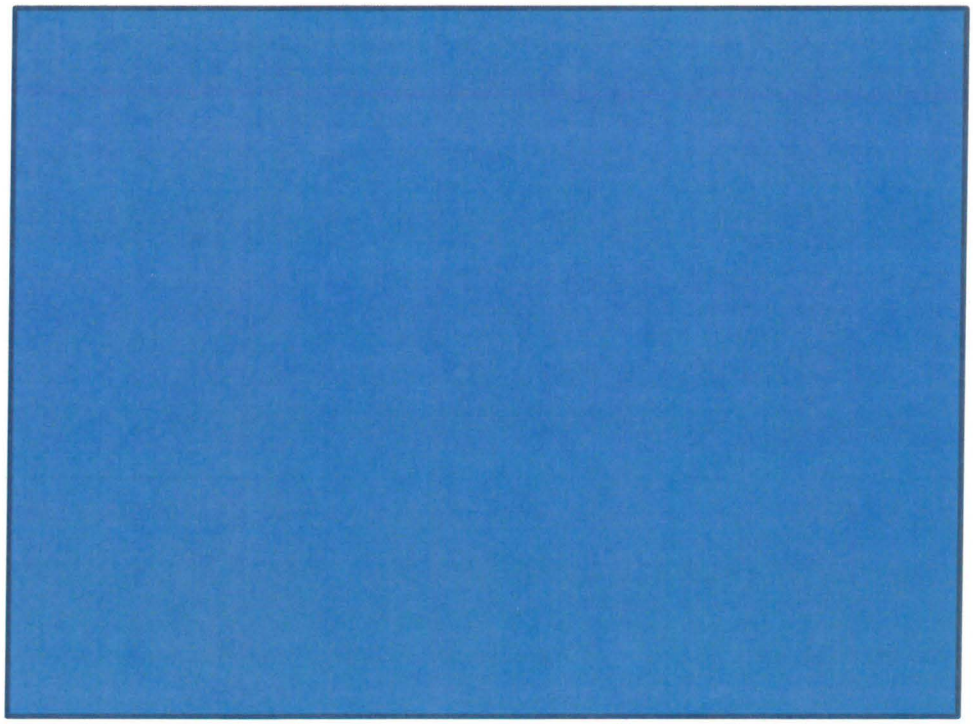

Figure 7. Test Specimen Arrangement in Environmental Stress Test Chamber

B.7. Service Conditions

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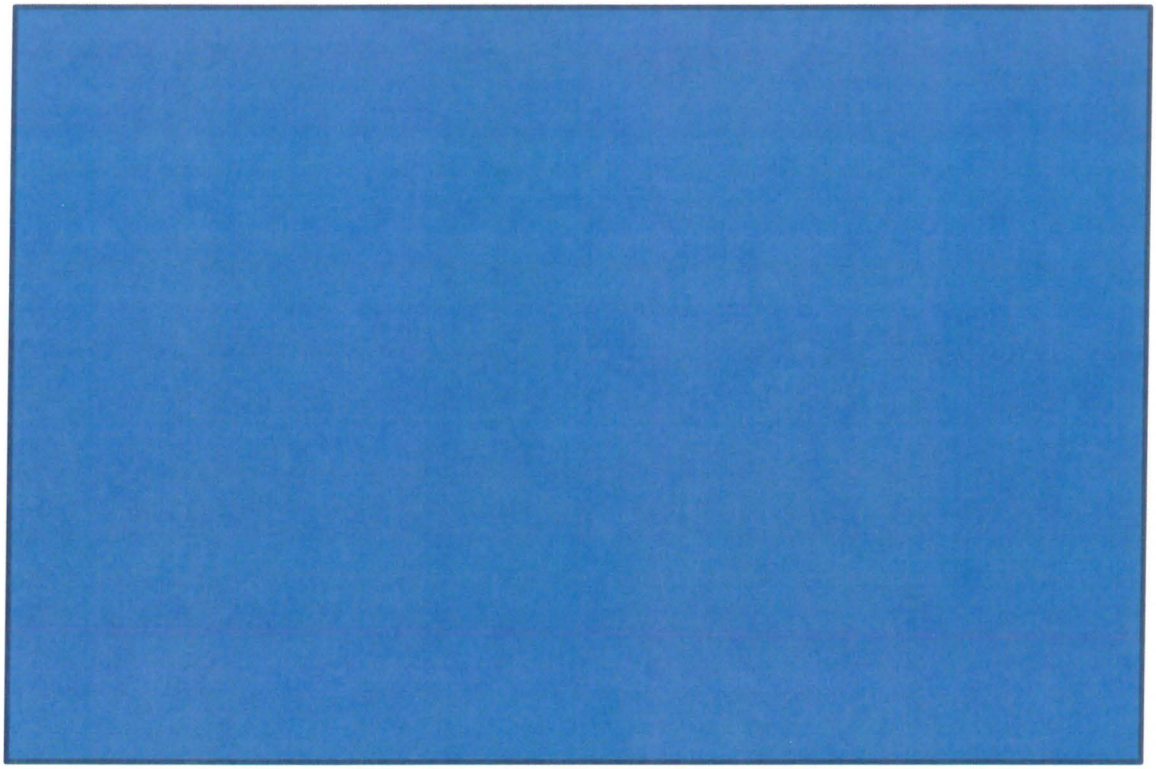

Figure 8. Record of Test Chamber Temperature/RH

B.8. Test Levels

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B.9. Performance Monitoring

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B.10. Acceptance Criteria

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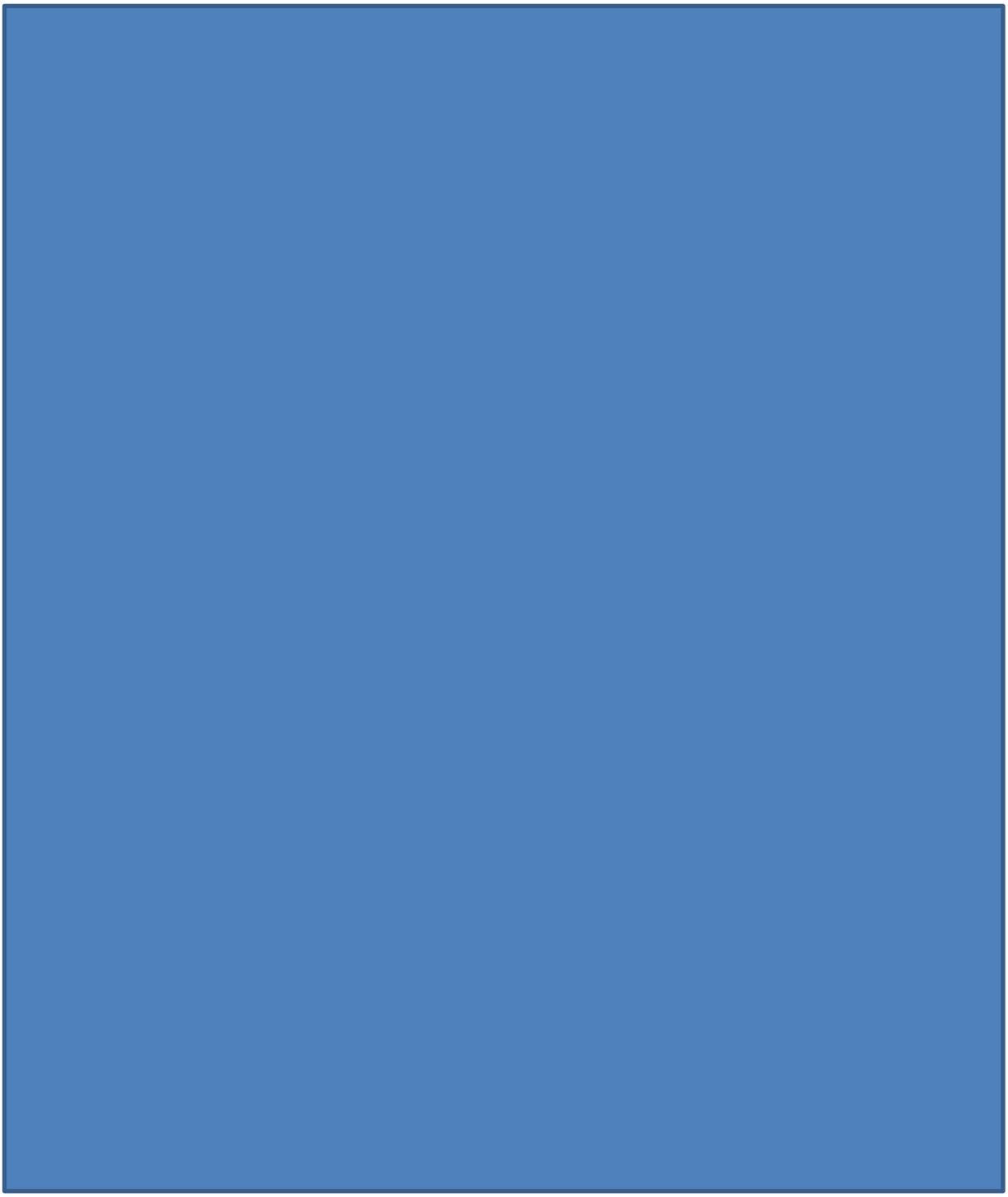
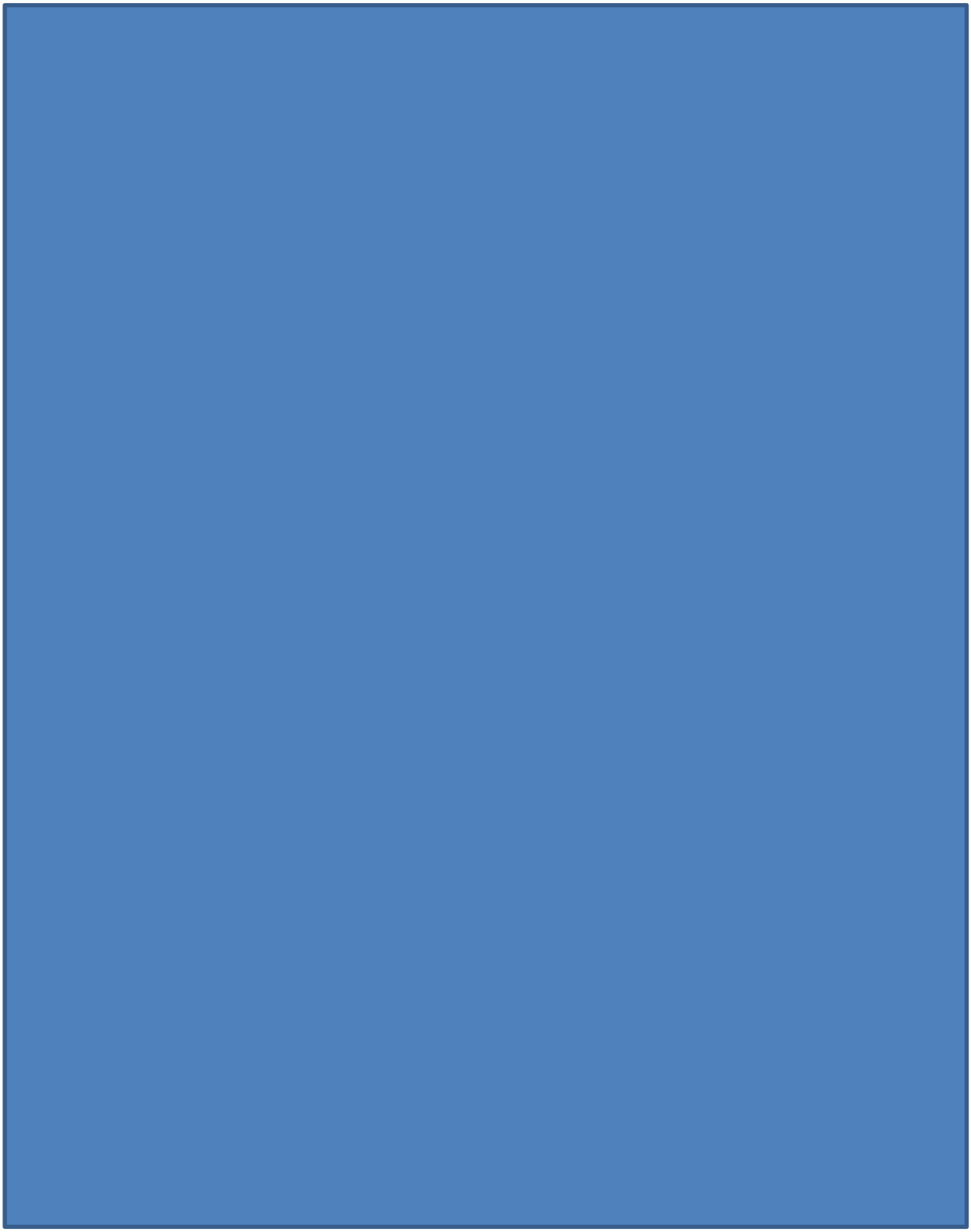
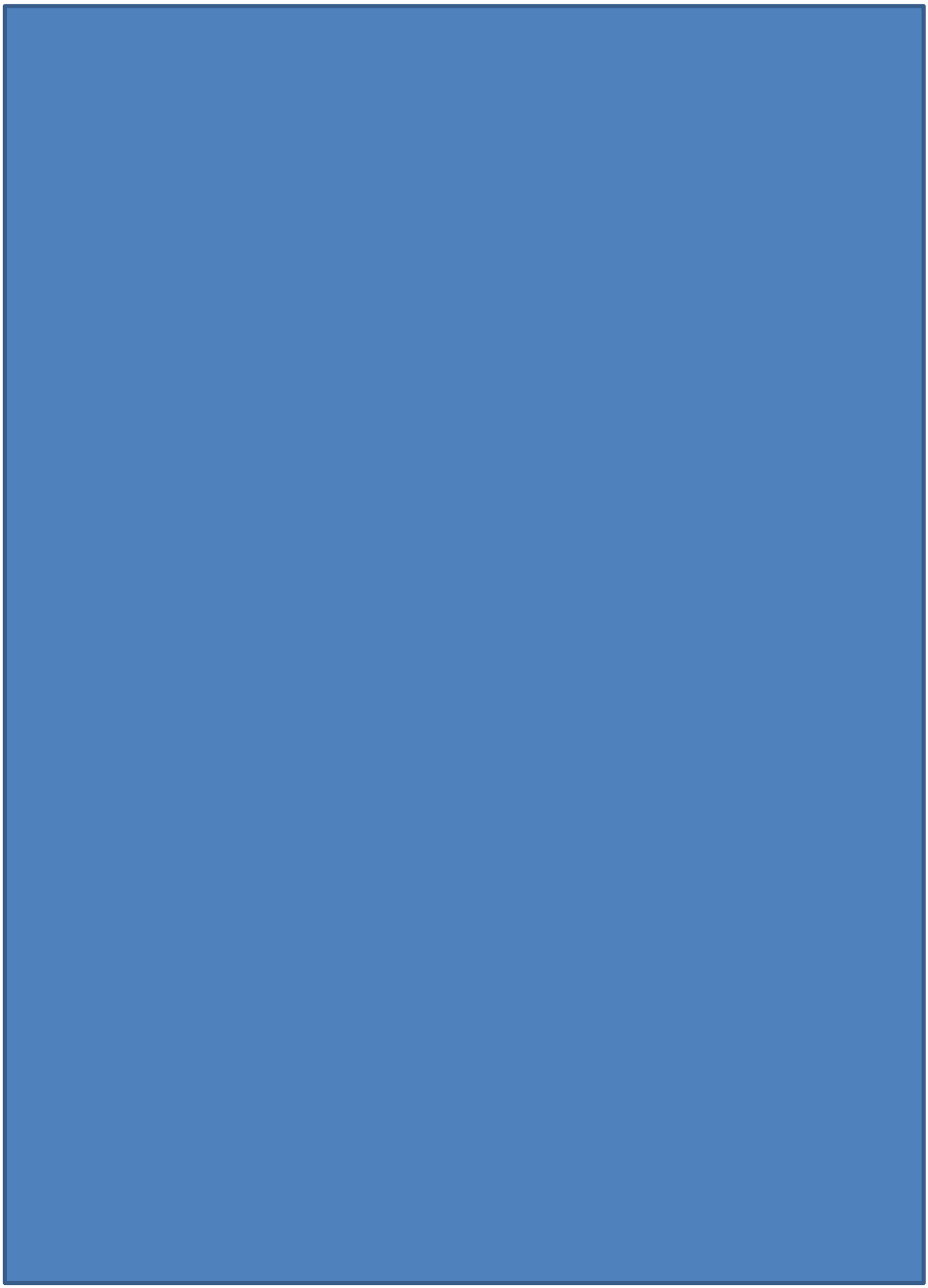
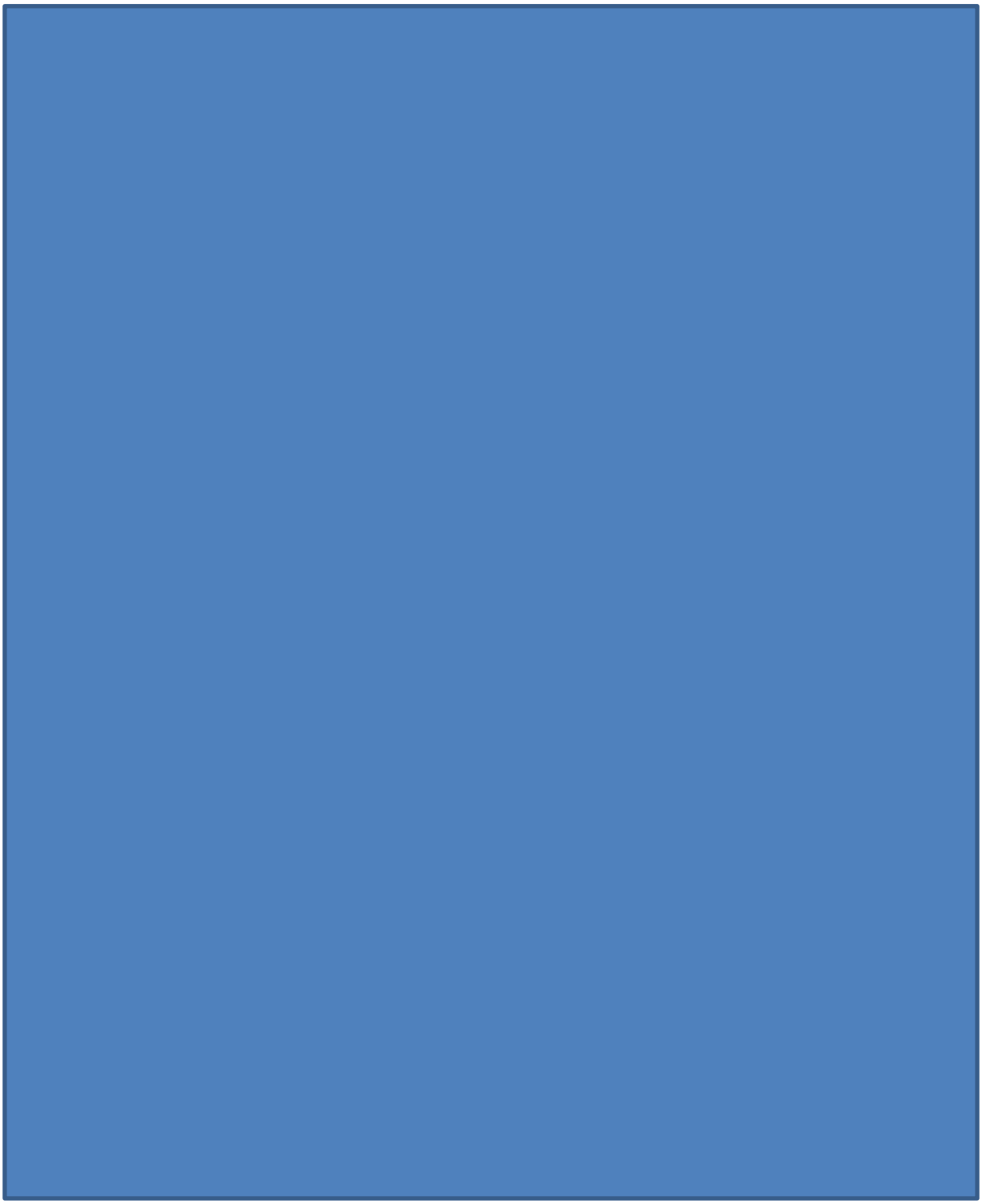
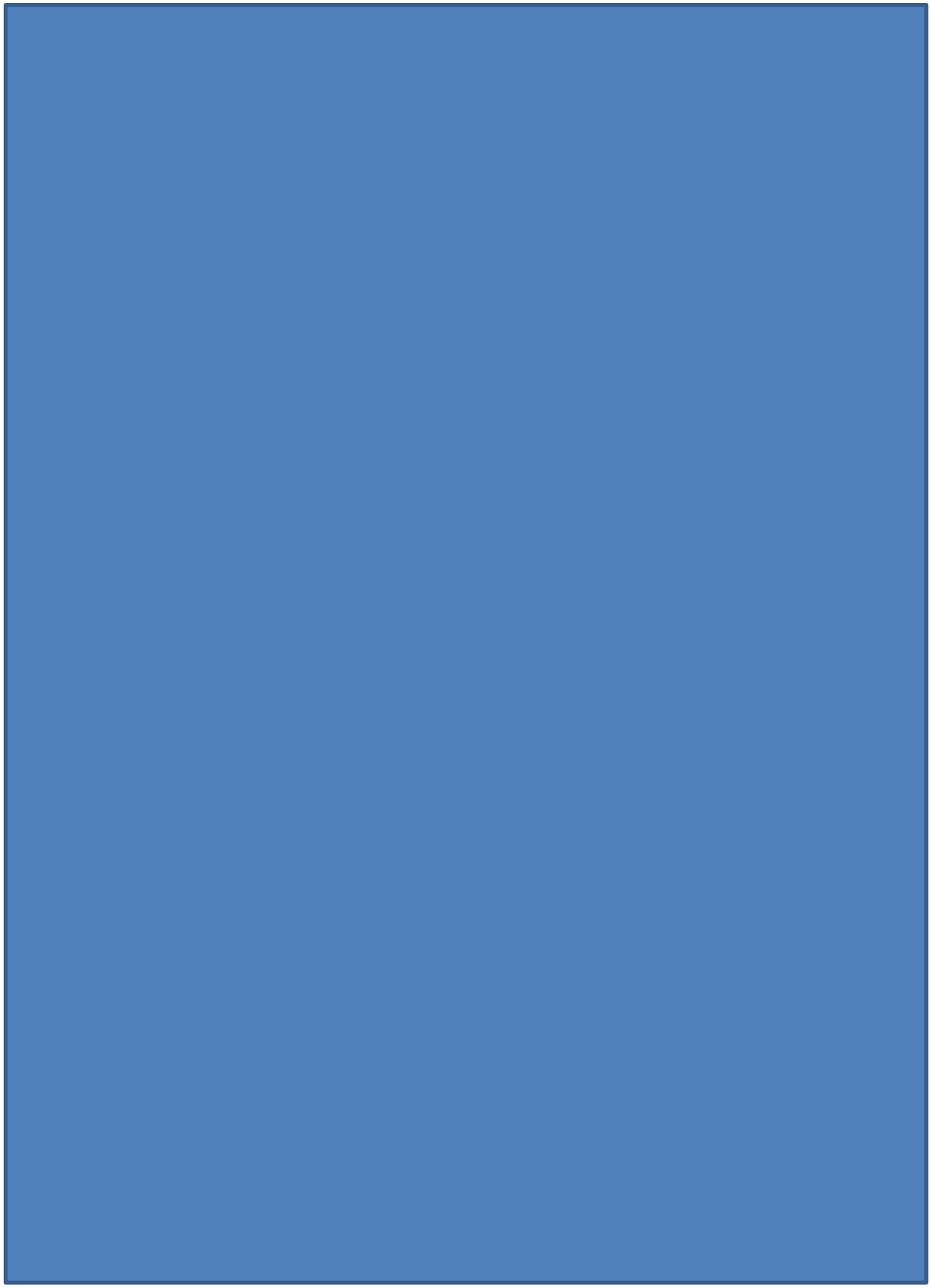
Table 8. Acceptance Criteria for Environmental Stress Test











B.11. Documentation

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B.12. Test Results

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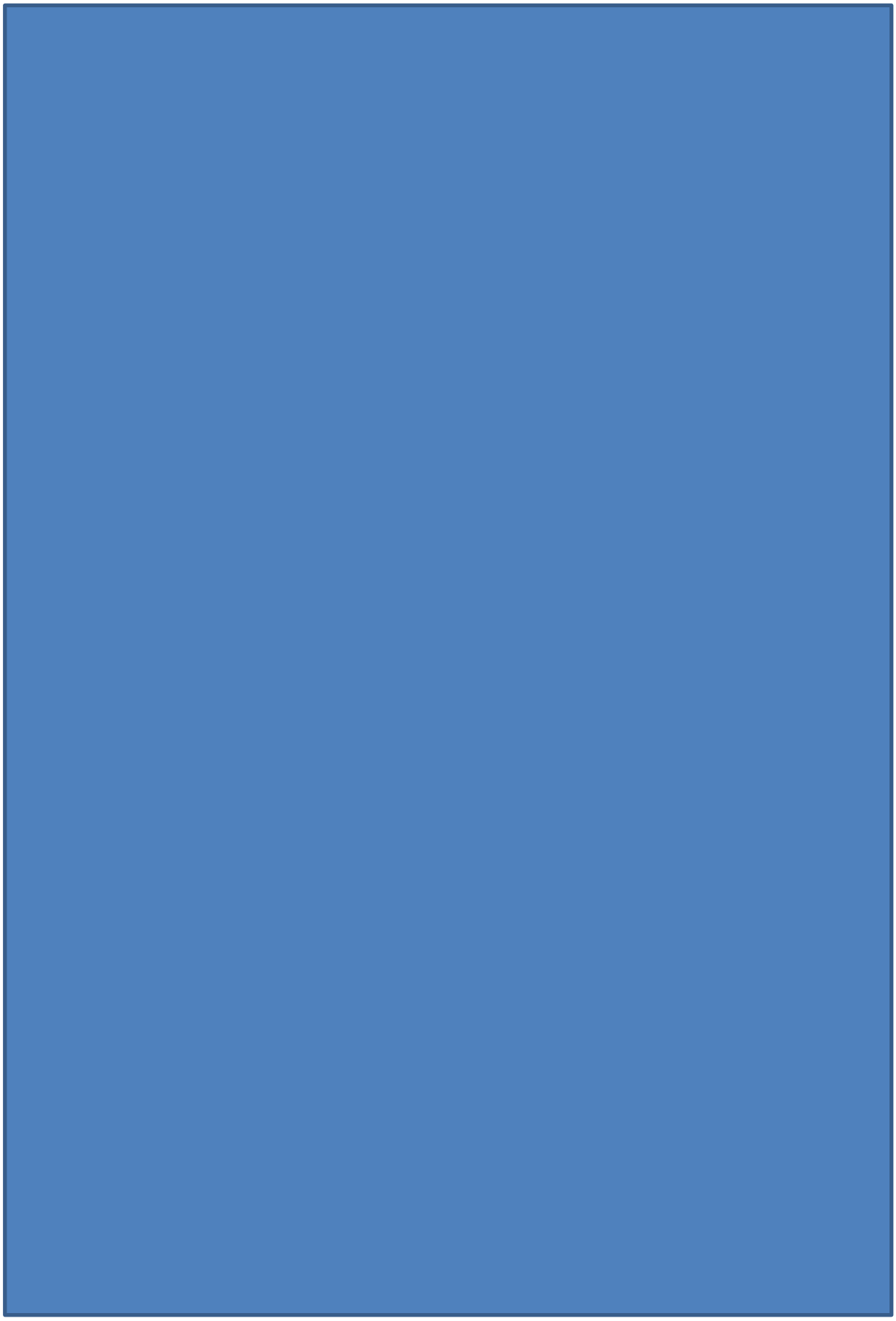
Table 9. Summary of Environmental Stress Test Results



B.13. Resolution of Test Discrepancies

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Appendix C. Qualification Test Summary – EMI/RFI Test

C.1. Purpose

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C.2. Objective

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C.3. Equipment Tested

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C.4. Sequence of Testing

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C.5. Procedures

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C.6. Test Specimen Mounting

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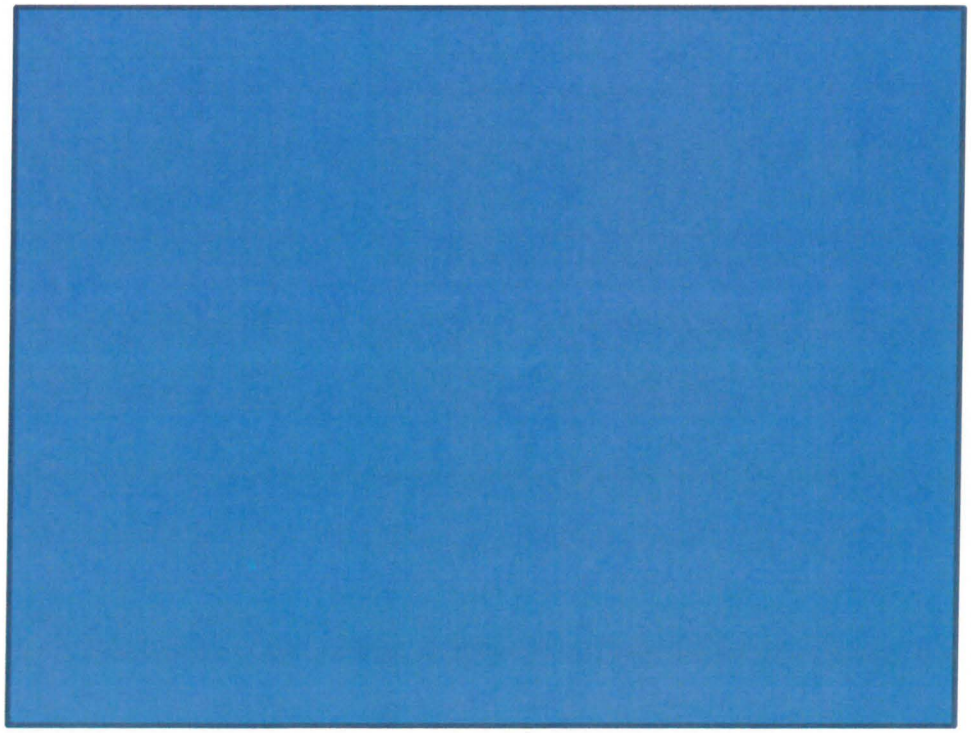

Figure 9. Line Test Setup for CE101

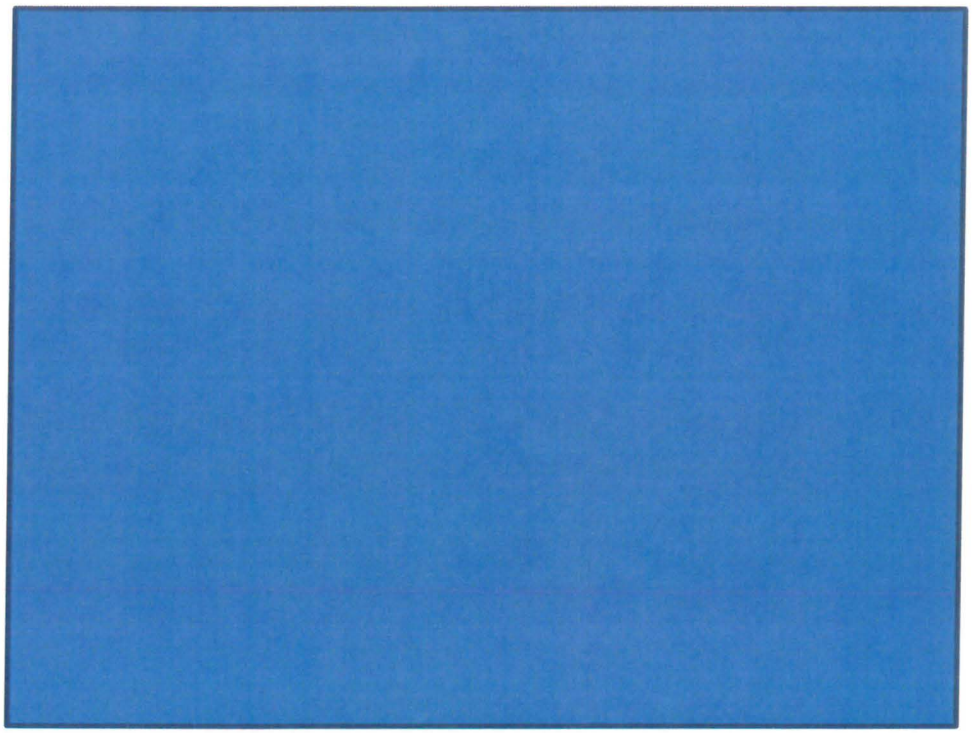

Figure 10. Line Test Setup for CE102

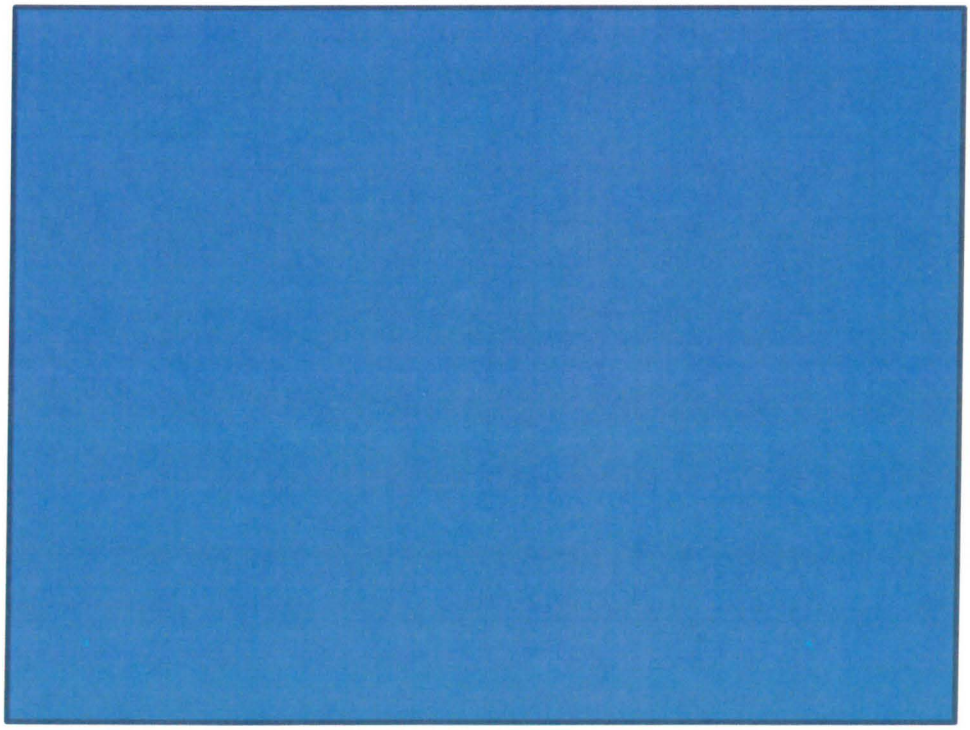

Figure 11. General Test Setup for RE101

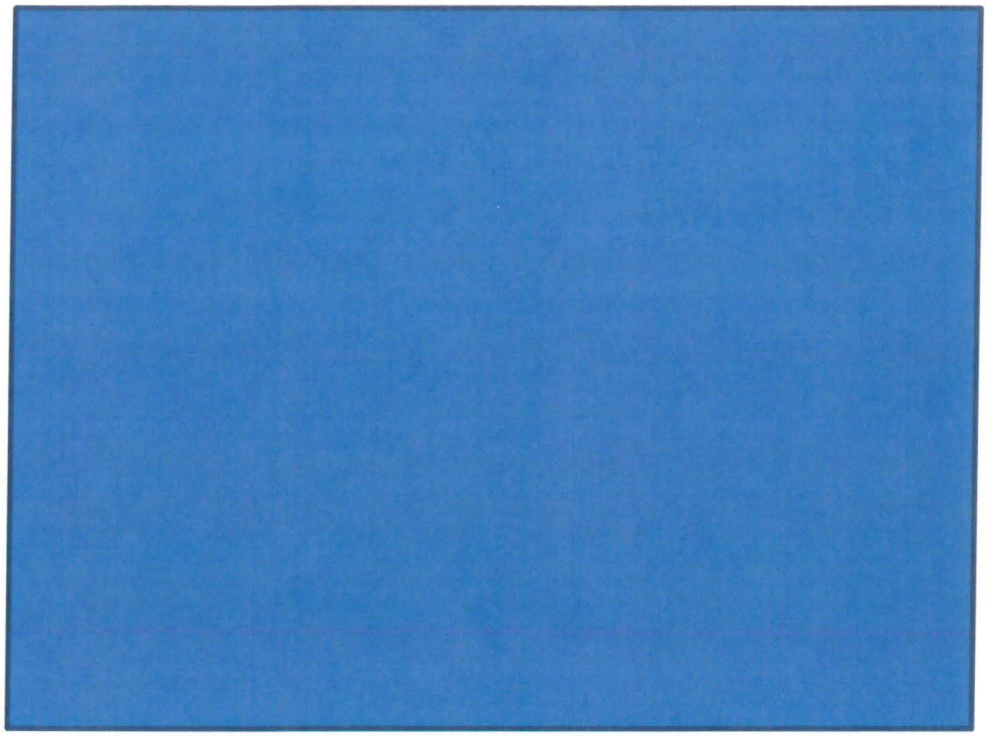

Figure 12. General Test Setup for RE102

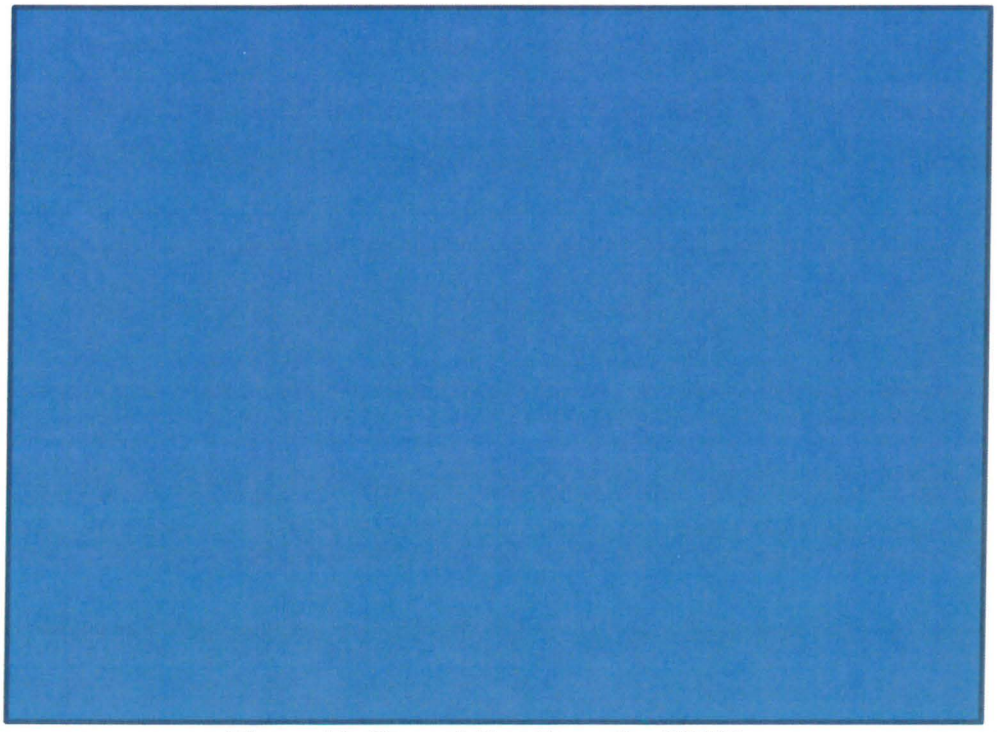

Figure 13. General Test Setup for CS101

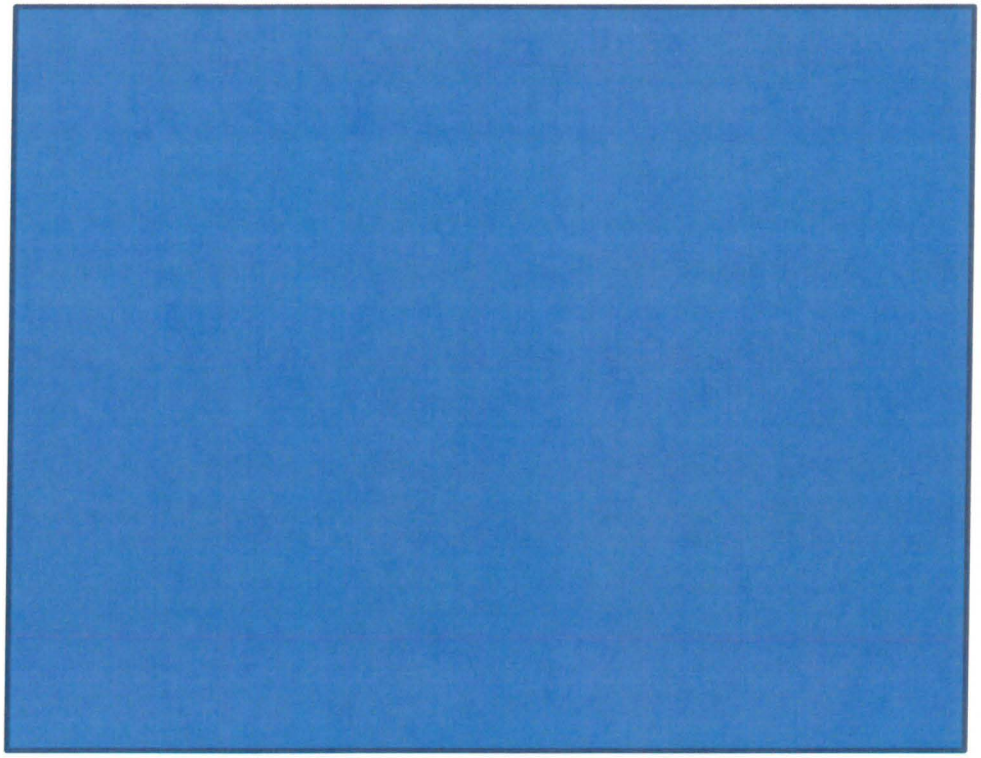

Figure 14. General Test Setup for CS114

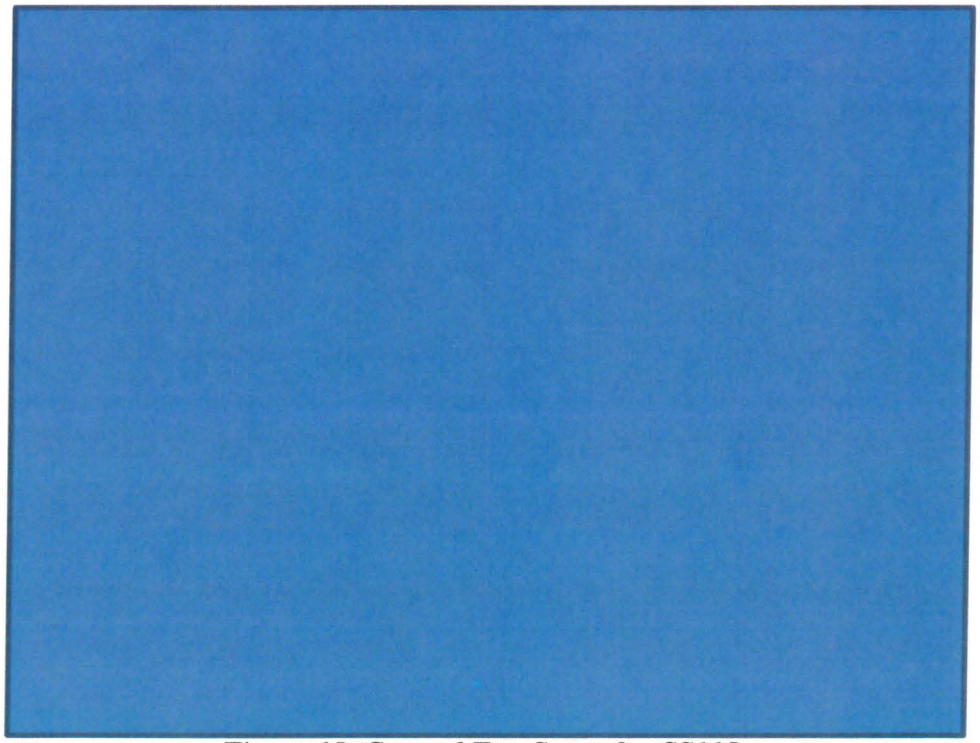

Figure 15. General Test Setup for CS115

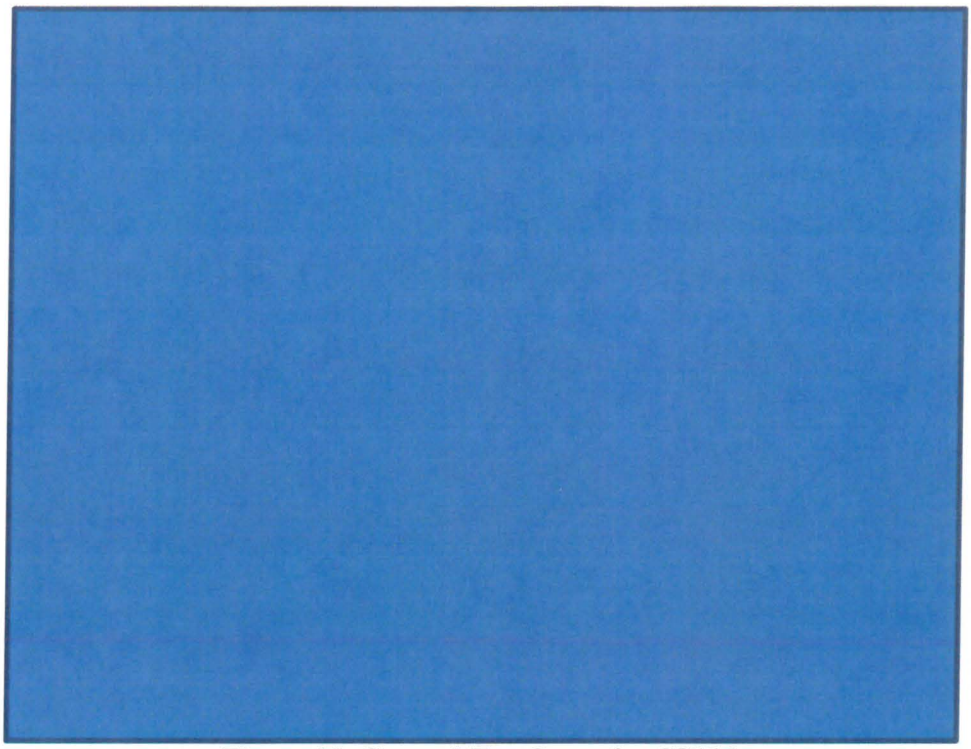

Figure 16. General Test Setup for CS116

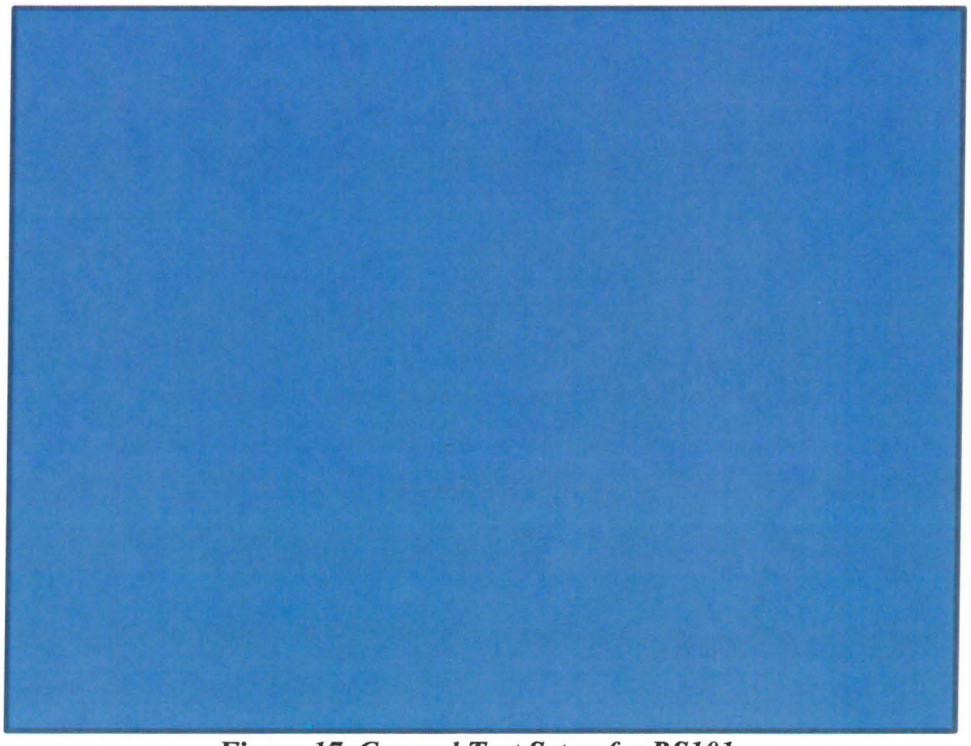

Figure 17. General Test Setup for RS101

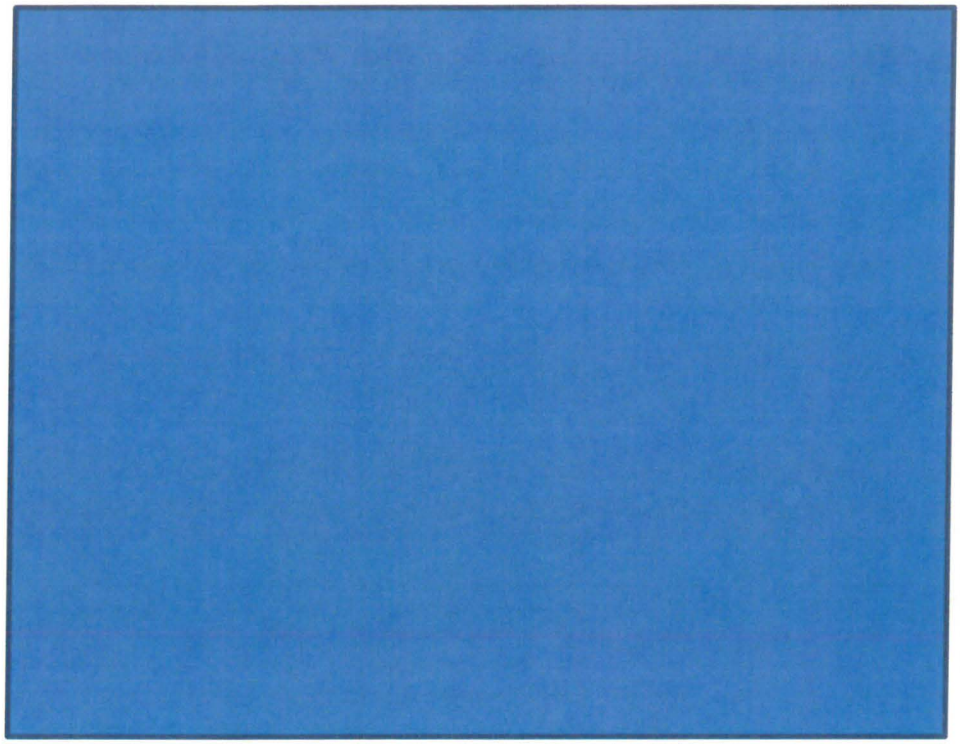

Figure 18. General Test Setup for RS103

C.7. Service Conditions

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C.8. Test Levels

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The specific EMI/RFI tests performed are shown in Table 10.

Table 10. EMI/RFI Test Requirements

C.9. Performance Monitoring

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C.10. Acceptance Criteria

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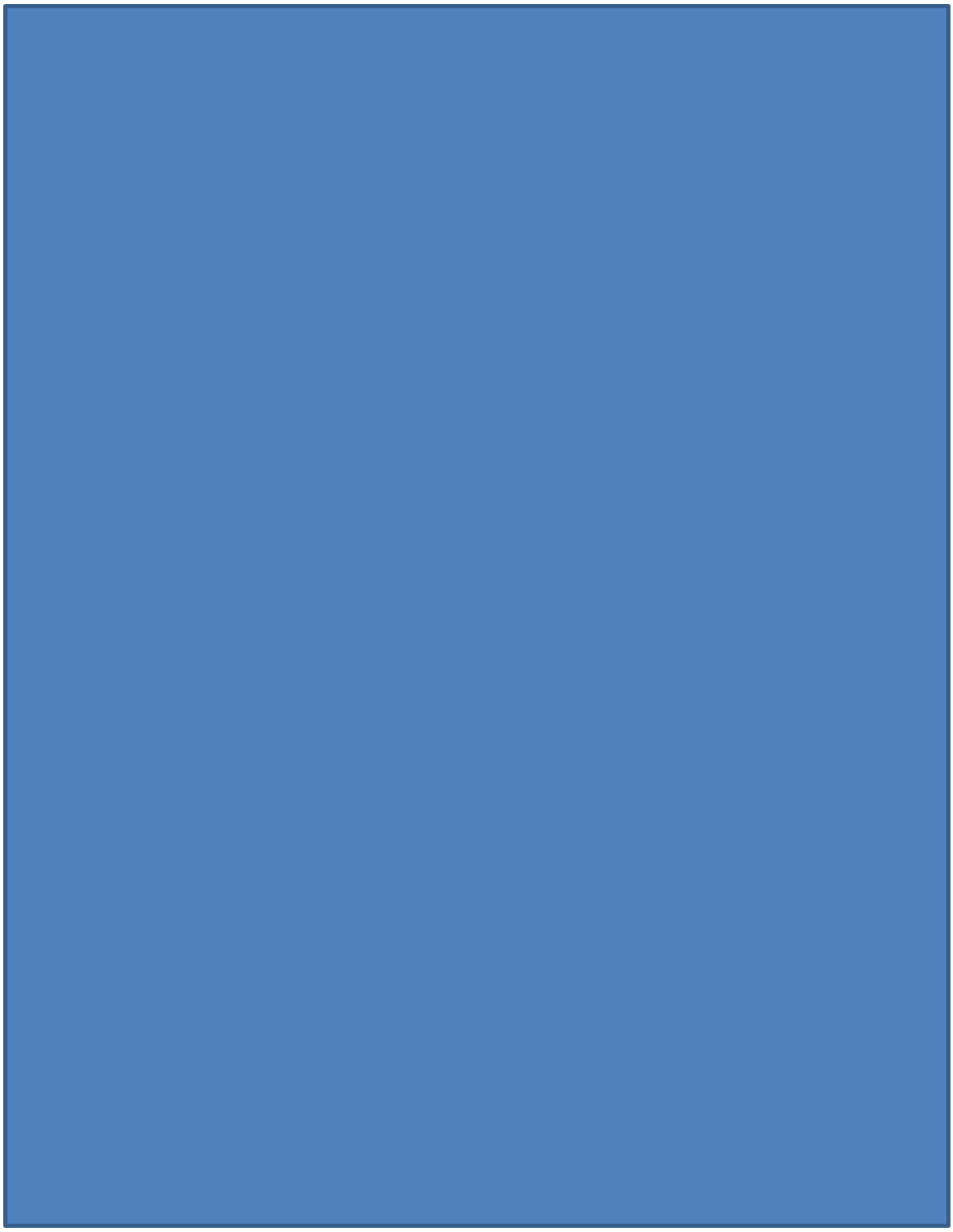
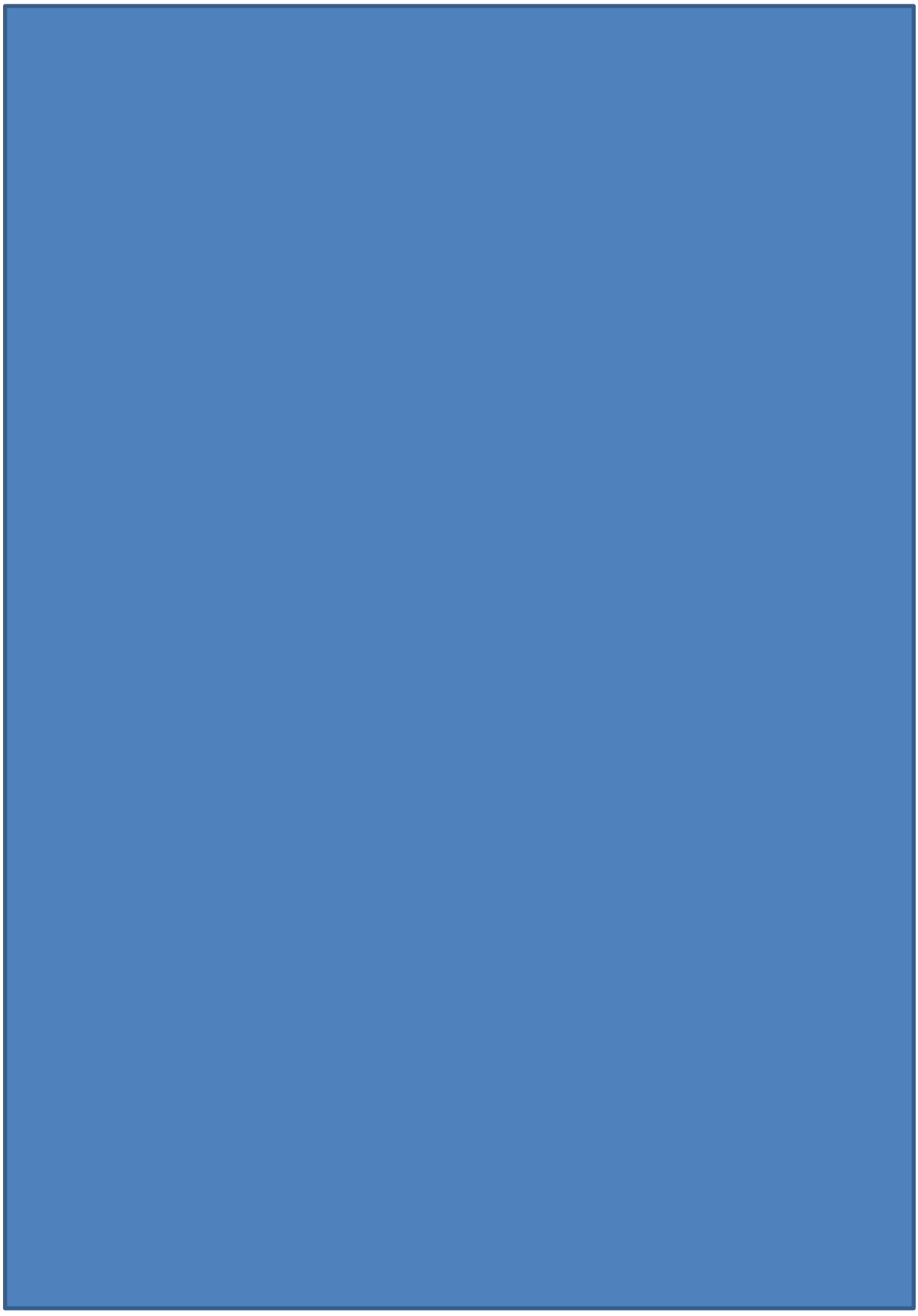
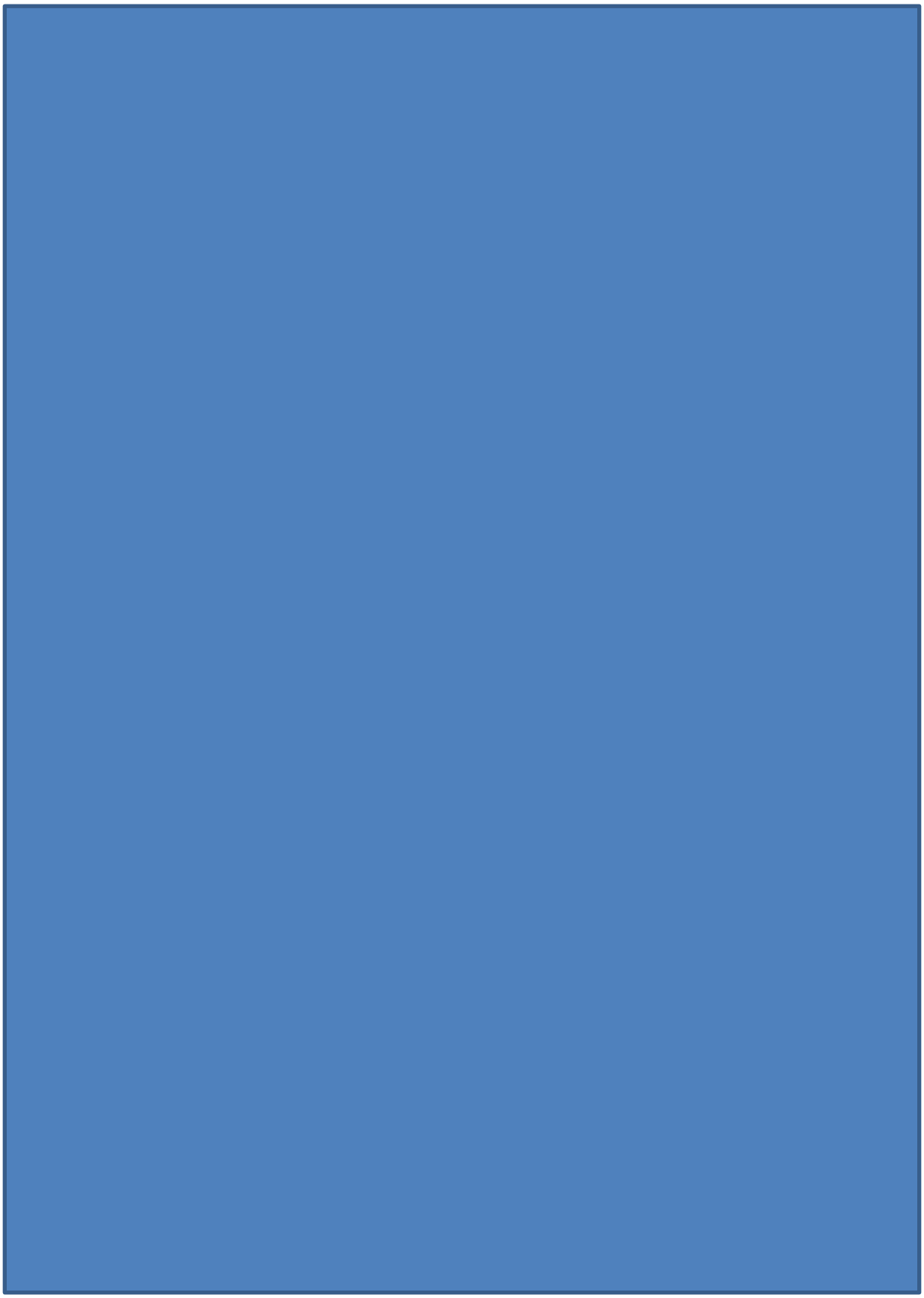
Table 11. Acceptance Criteria for EMI/RFI Test







C.11. Documentation

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C.12. Test Results

Detailed test results of the EMI/RFI Test were reported in TR901-302-01 (Reference 9), which are summarized in Table 12.

Table 12. Summary of EMI/RFI Test Results

C.13. Resolution of Test Discrepancies

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Appendix D. Qualification Test Summary – Electrostatic Discharge Test

D.1. Purpose

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D.2. Objective

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D.3. Equipment Tested

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D.4. Sequence of Testing

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D.5. Procedures

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D.6. Test Specimen Mounting

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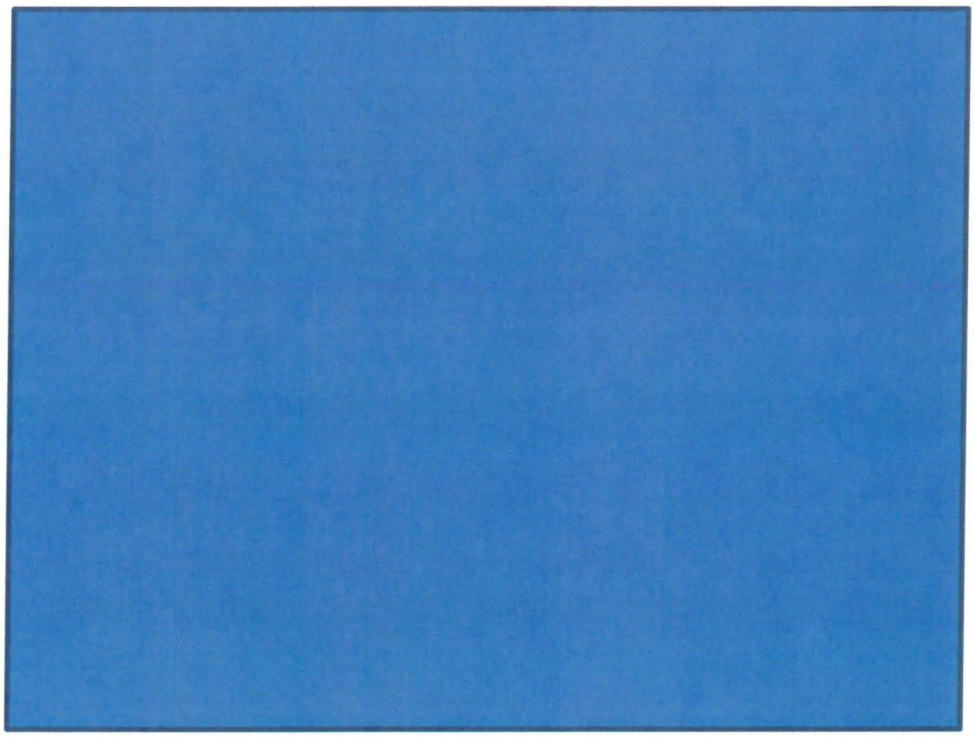

Figure 19. General Test Setup for ESD, Test Location 1

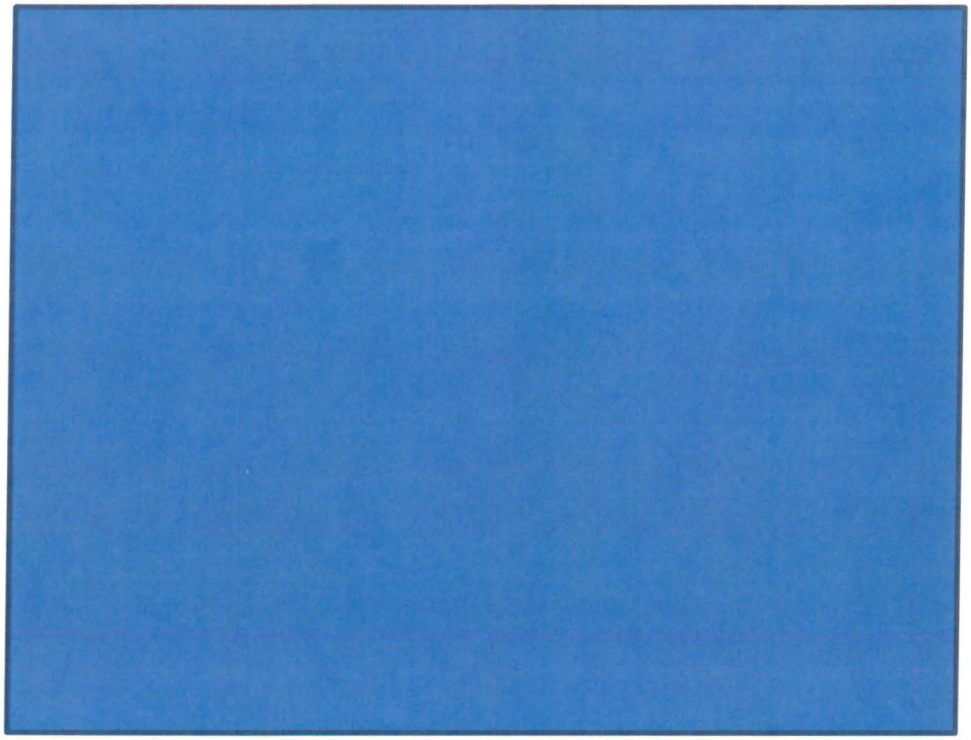

Figure 20. General Test Setup for ESD, Test Location 2

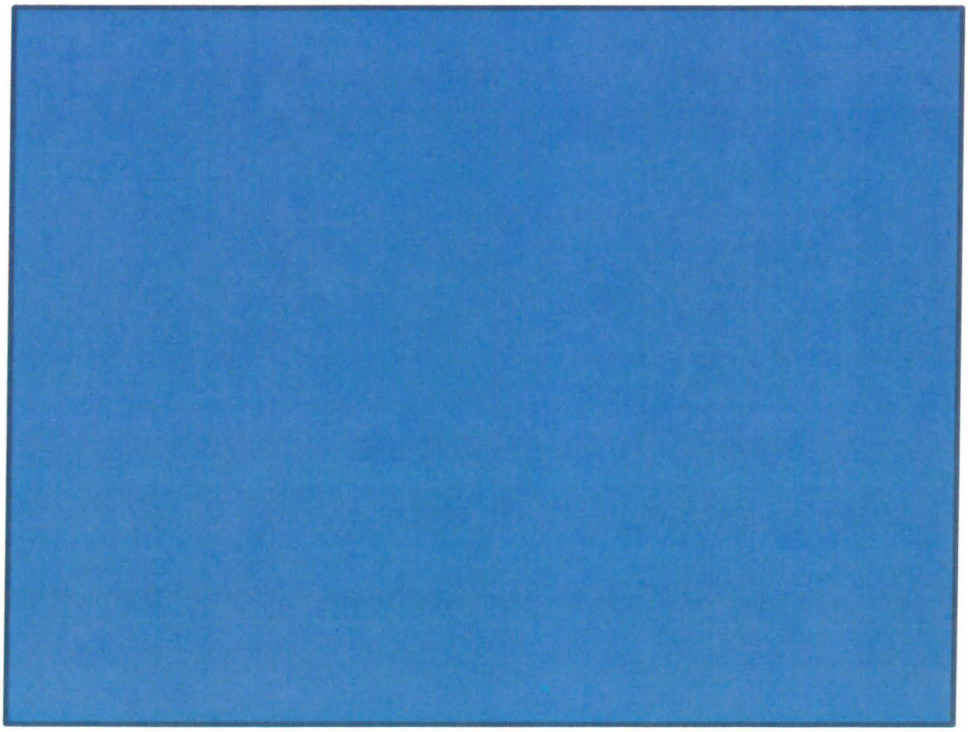

Figure 21. General Test Setup for ESD, Test Location 3

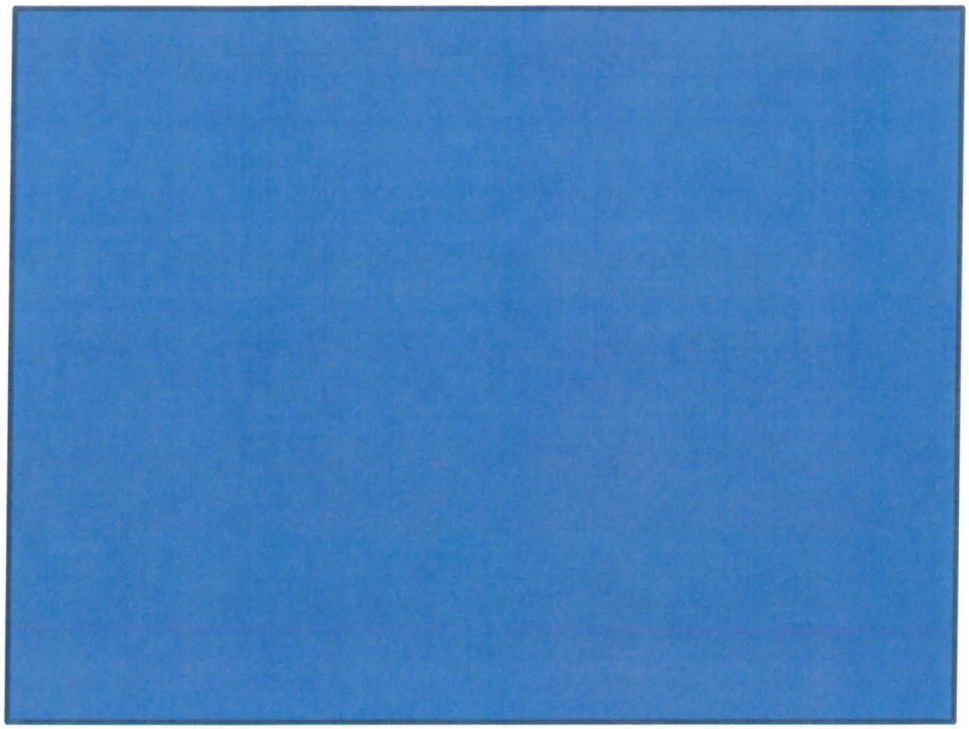

Figure 22. General Test Setup for ESD, Test Location 4

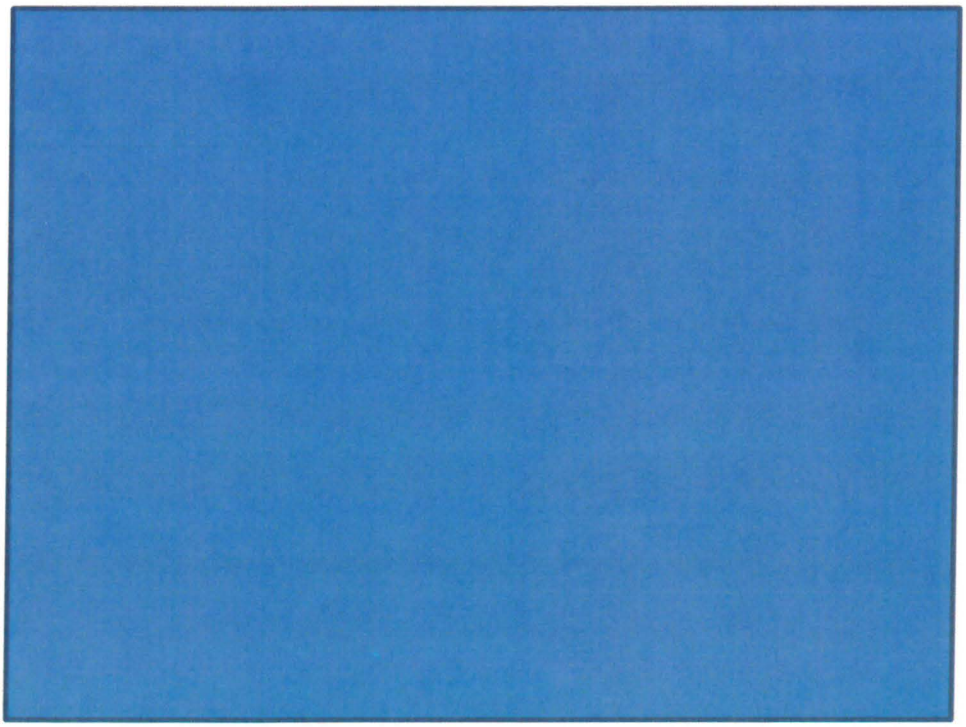

Figure 23. General Test Setup for ESD, Test Location 5

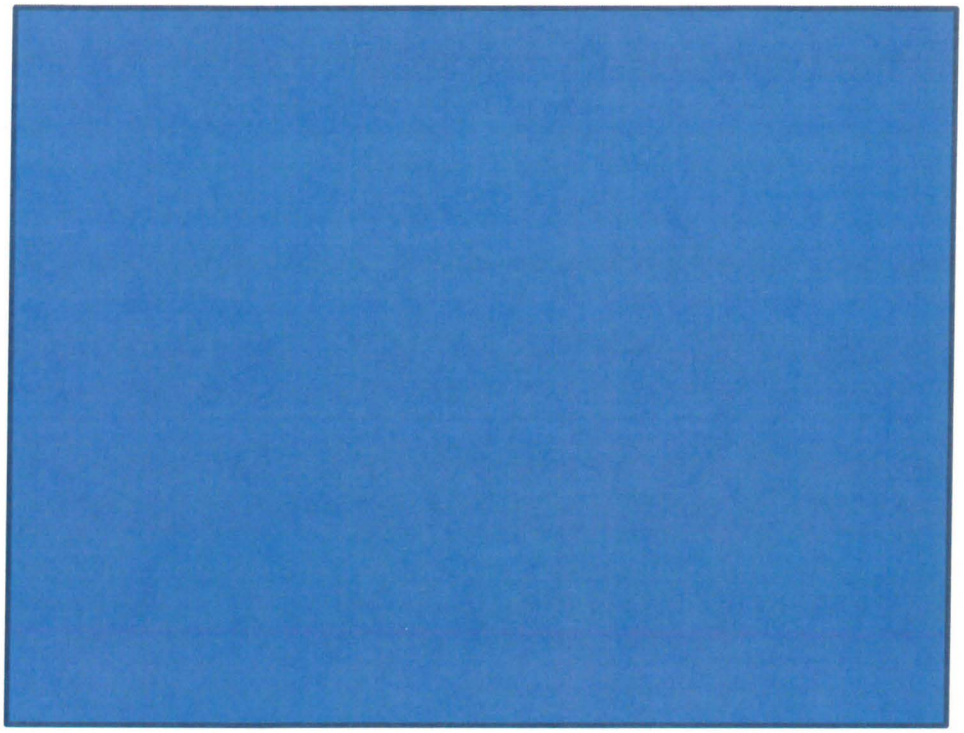

Figure 24. General Test Setup for ESD, Test Location 6

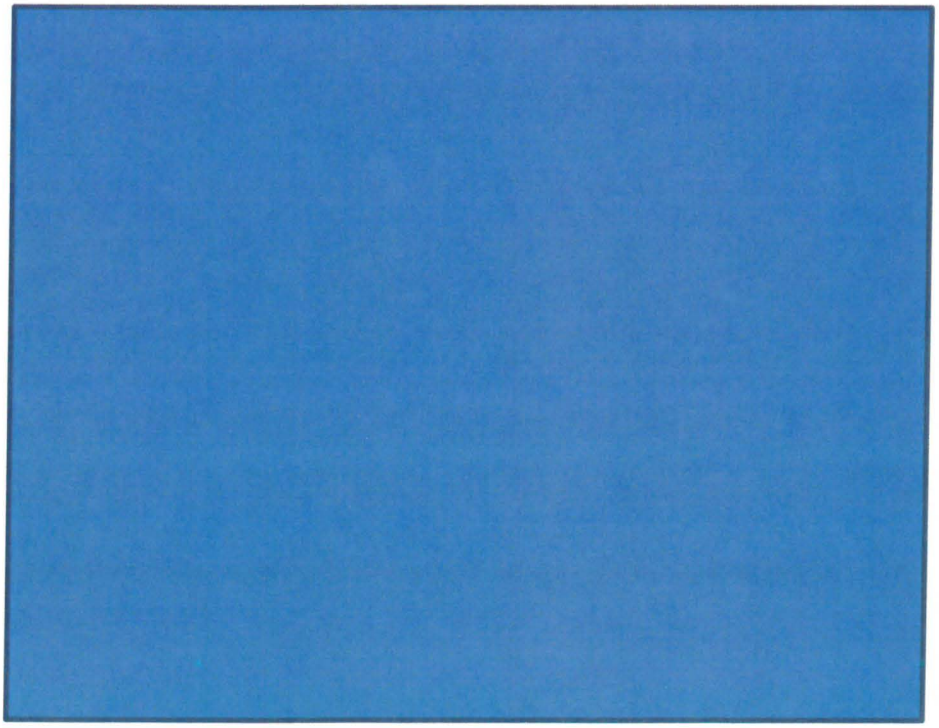

Figure 25. General Test Setup for ESD, Test Location 7

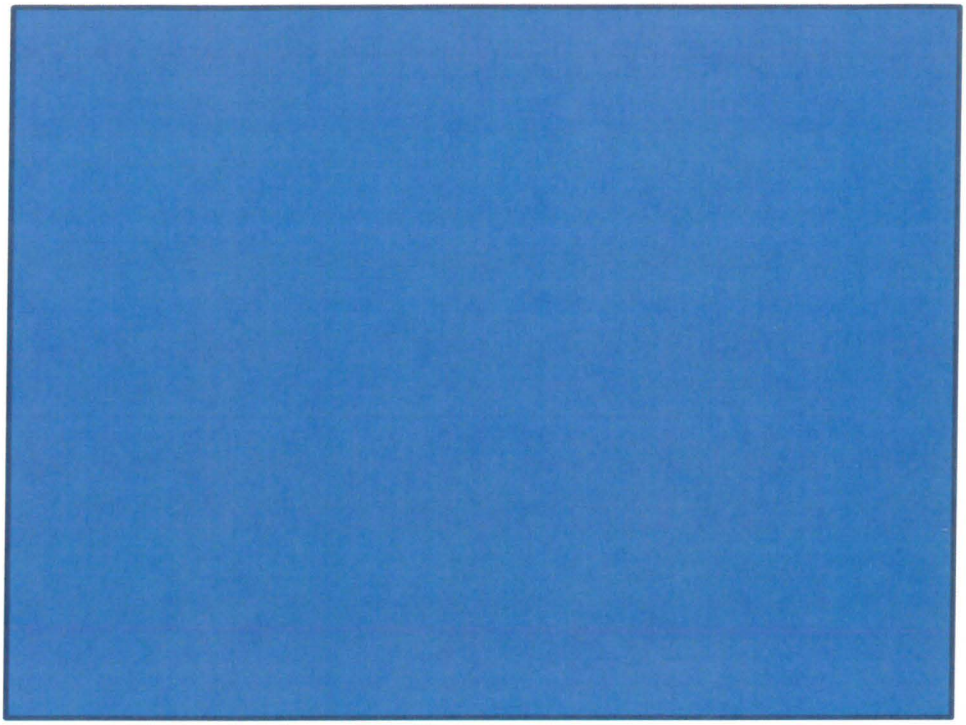

Figure 26. General Test Setup for ESD, Test Location 8

D.7. Service Conditions

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D.8. Test Levels

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Table 13. ESD Test Requirements

D.9. Performance Monitoring

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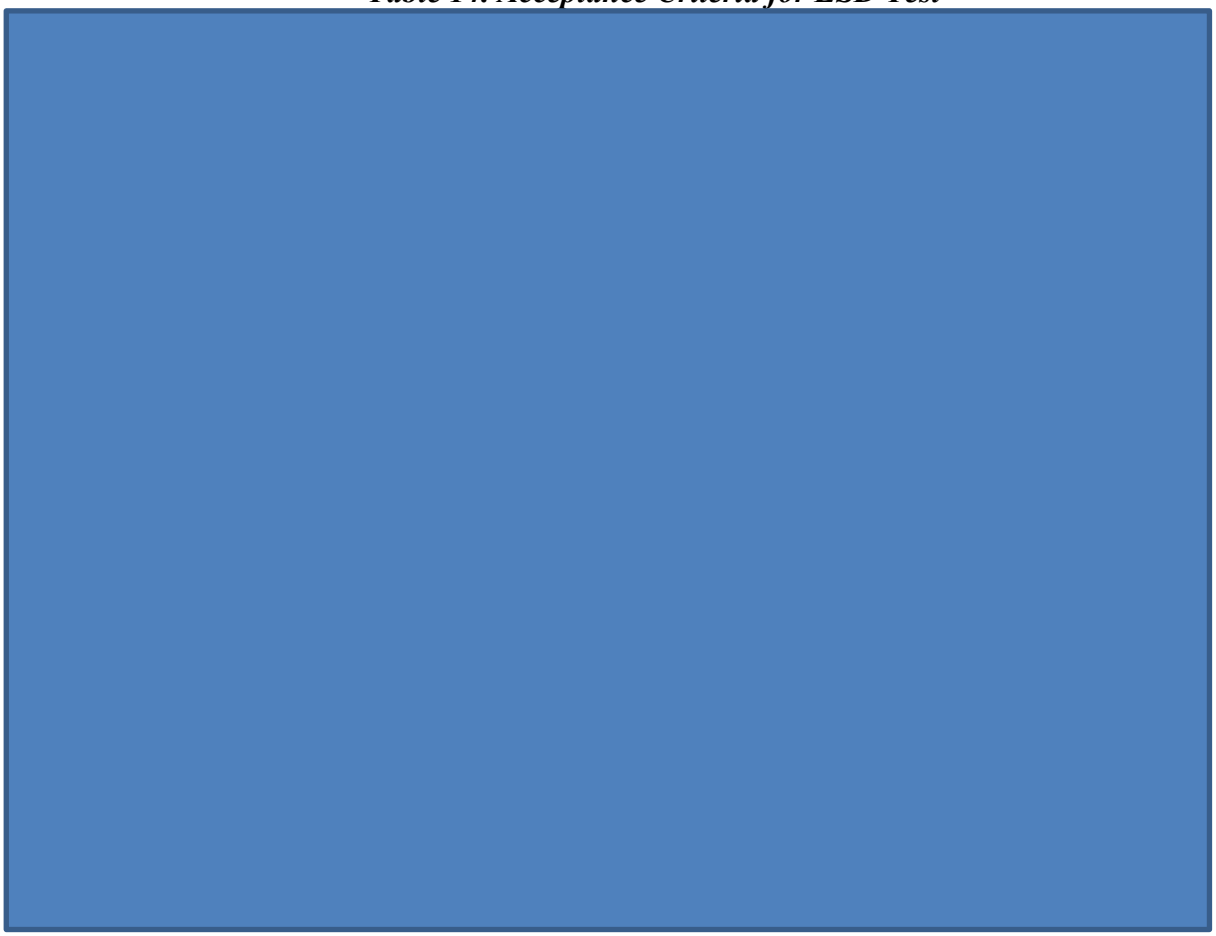
D.10. Acceptance Criteria

Acceptance criteria for performance monitoring of the HFC-FPGA Test Specimen during the ESD Test were set as specified in corresponding test procedures (References 13, 14, and 18). They are summarized in Table 14.

Table 14. Acceptance Criteria for ESD Test



D.11. Documentation

[

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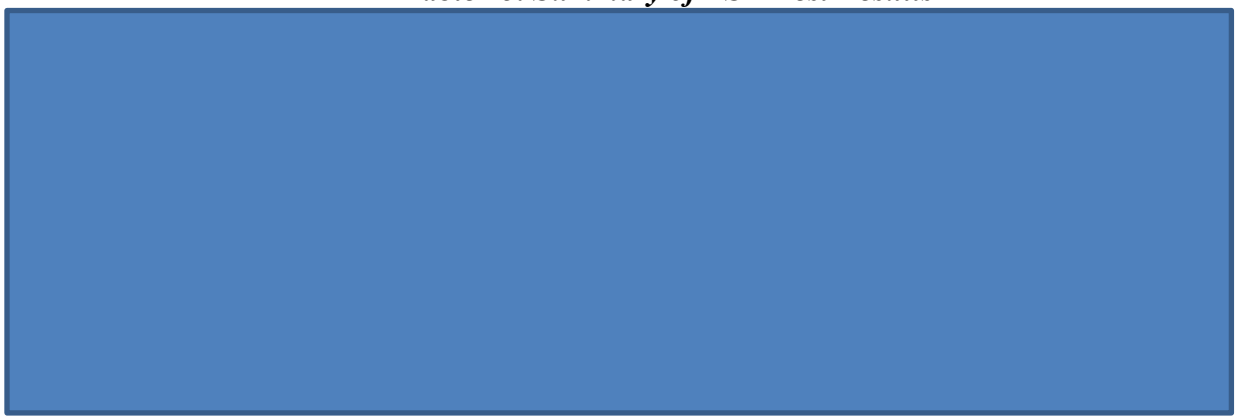
D.12. Test Results

Detailed test results of the ESD Test were reported in TR901-302-01 (Reference 9), which are summarized in Table 15.

Table 15. Summary of ESD Test Results



D.13. Resolution of Test Discrepancies

[

]

[

]

Appendix E. Qualification Test Summary – Surge Withstand Test

E.1. Purpose

[

]

E.2. Objective

[

]

E.3. Equipment Tested

The equipment tested were the HFC-FPGA Qualification Test Specimen. Table 2 identifies the specific items that are part of the Qualification Test Specimen.

E.4. Sequence of Testing

[

]

E.5. Procedures

[

]

[

]

E.6. Test Specimen Mounting

[

]

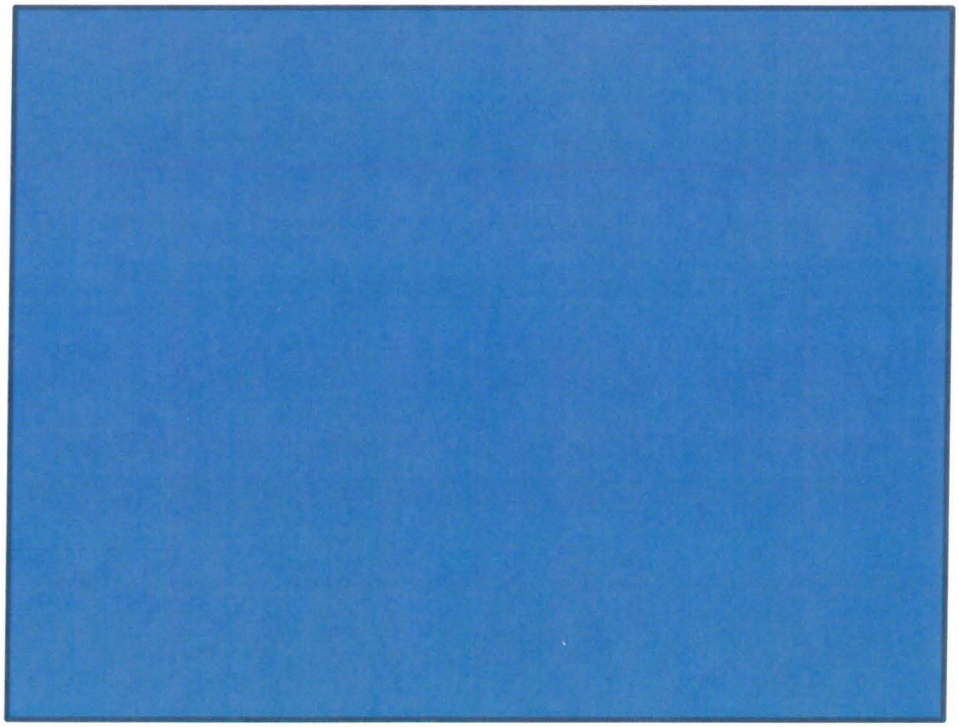


Figure 27. General Test Setup for EFT, AC Power Input

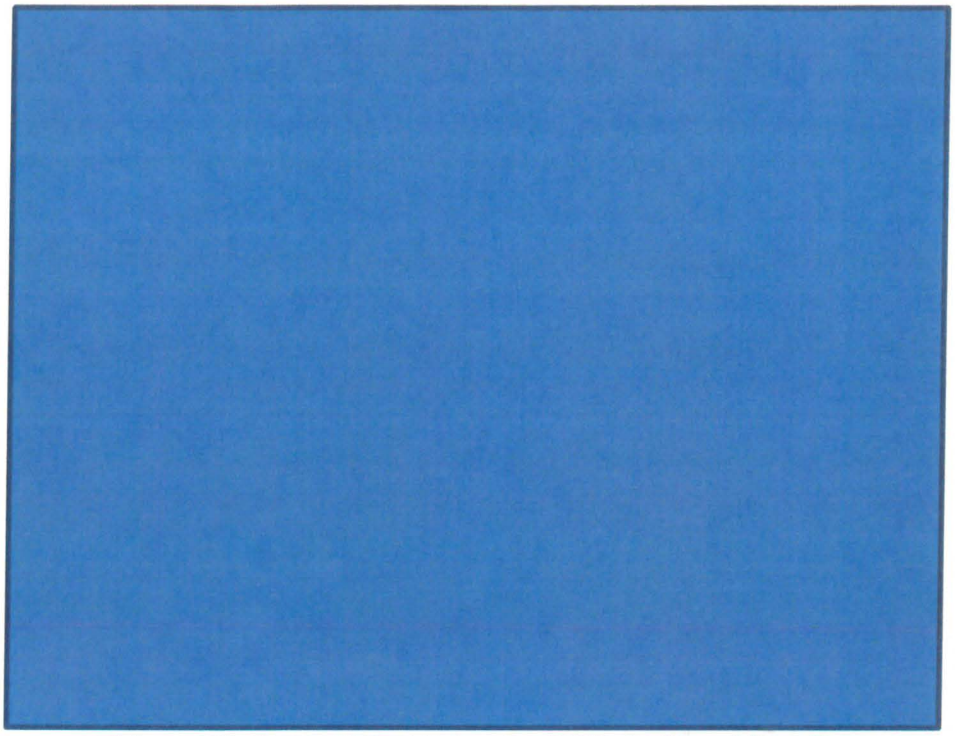


Figure 28. General Test Setup for EFT, J2 Signal Bundle

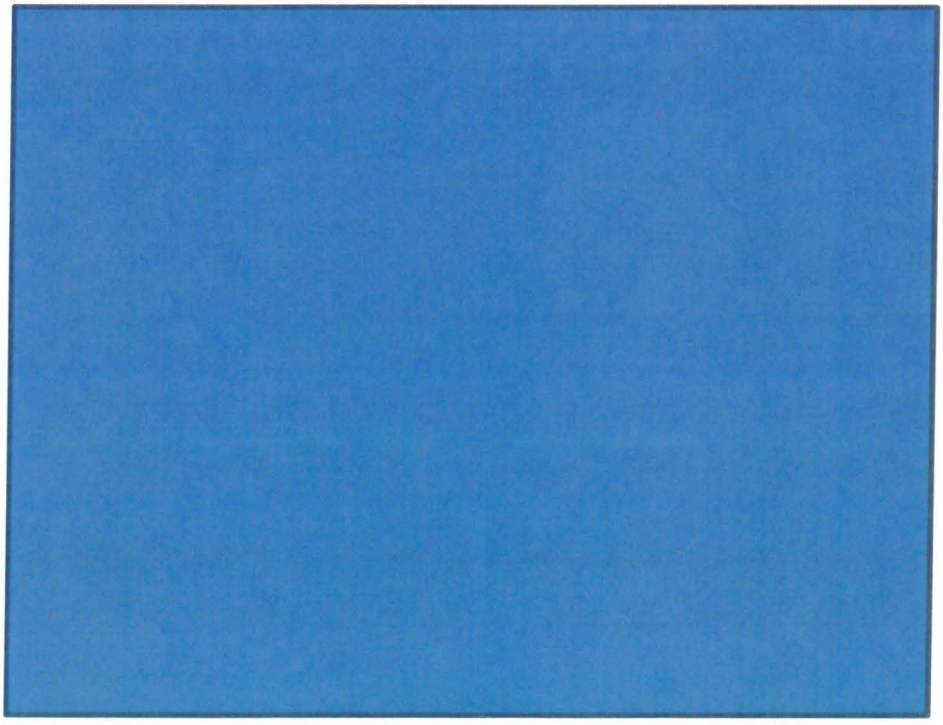


Figure 29. General Test Setup for EFT, J3 Signal Bundle

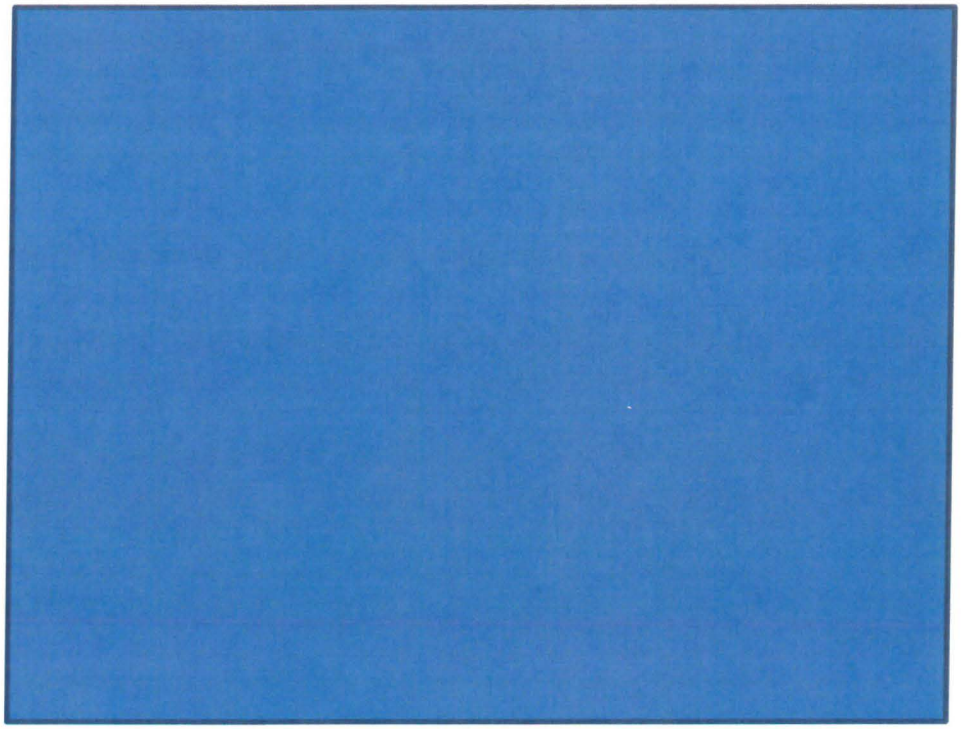


Figure 30. General Test Setup for EFT, J4 Signal Bundle

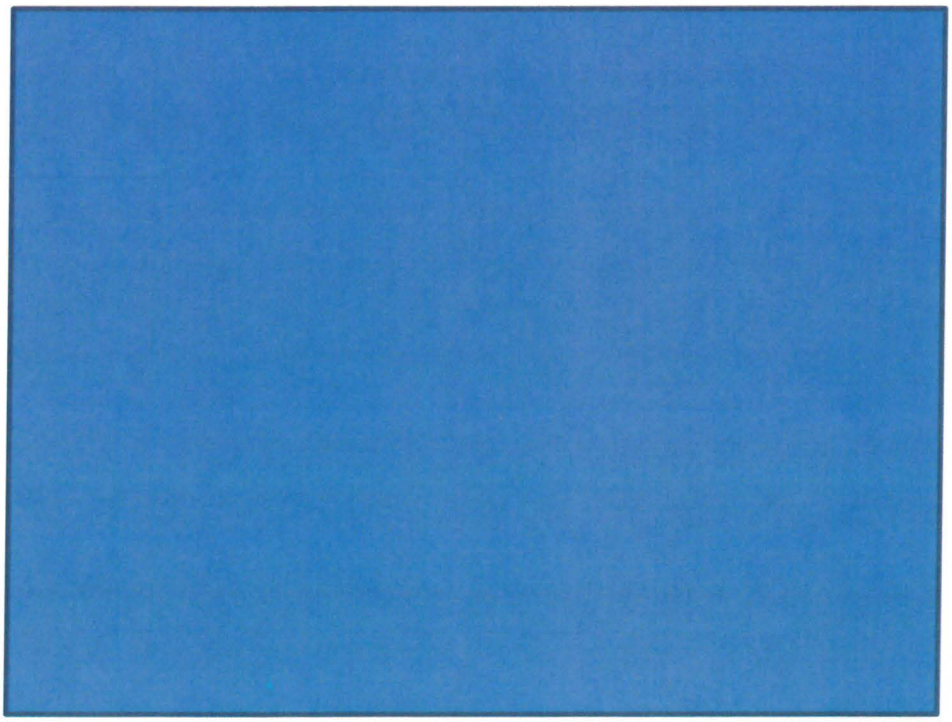


Figure 31. General Test Setup for Combination Waveform, AC Power Input

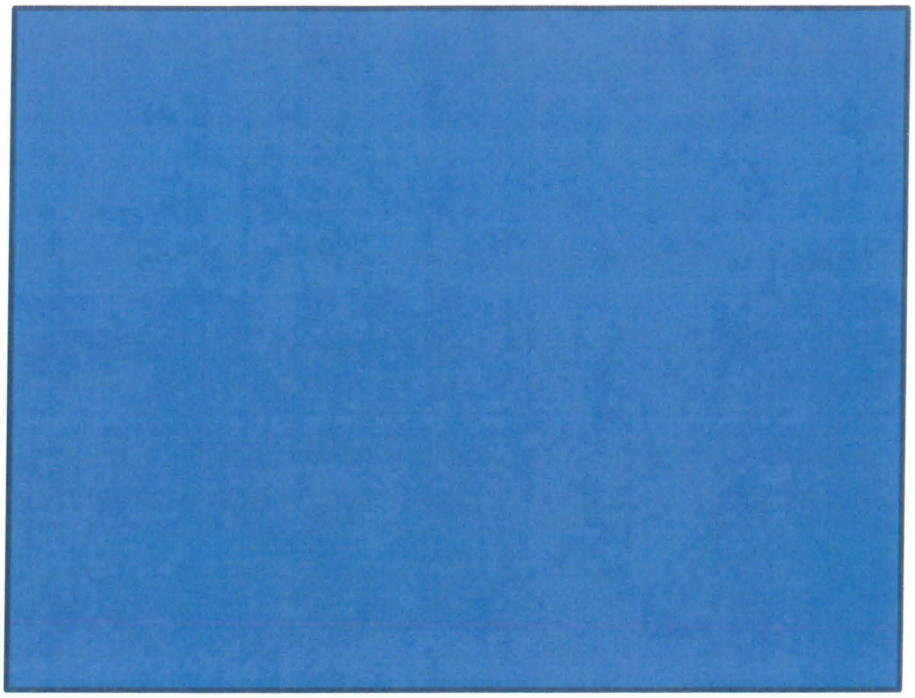


Figure 32. General Test Setup for Ring Waveform, AC Power Input

E.7. Service Conditions

[

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E.8. Test Levels

The test levels (supply power and I/O signal and load levels) applied to the HFC-FPGA Test Specimen during the Surge Withstand Test were set as specified in corresponding test procedures (References 13, 14, and 19).

The specific ESD tests performed are shown in Table 16.

Table 16. Surge Withstand Test Requirements

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Table 17. Surge Withstand Pulse Levels

E.9. Performance Monitoring

[

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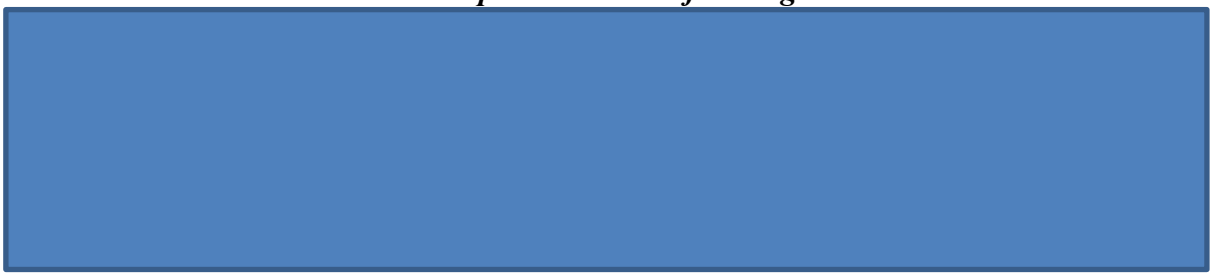
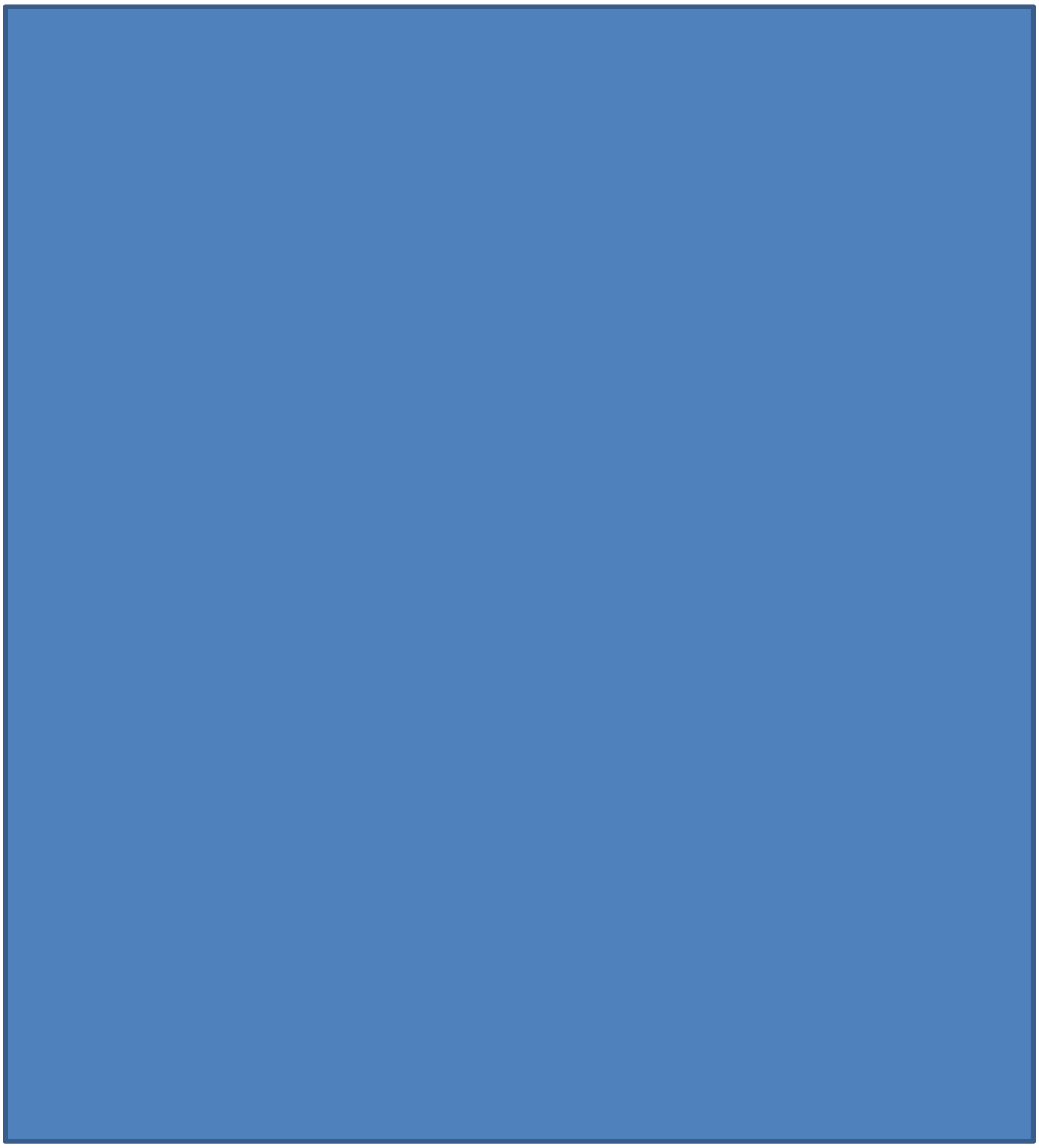
E.10. Acceptance Criteria

Acceptance criteria for performance monitoring of the HFC-FPGA Test Specimen during the Surge Withstand Test were set as specified in corresponding test procedures (References 13, 14, and 19). They are summarized in Table 18.

Table 18. Acceptance Criteria for Surge Withstand Test





E.11. Documentation

[

]

E.12. Test Results

Detailed test results of the Surge Withstand Test were reported in TR901-302-01 (Reference 9), which are summarized in Table 19.

Table 19. Summary of Surge Withstand Test Results

E.13. Resolution of Test Discrepancies

[

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Appendix F. Qualification Test Summary – Seismic Test

F.1. Purpose

[

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F.2. Objective

[

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F.3. Equipment Tested

The equipment tested were the HFC-FPGA Qualification Test Specimen. Table 2 identifies the specific items that are part of the Qualification Test Specimen.

F.4. Sequence of Testing

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]

F.5. Procedures

[

]

F.6. Test Specimen Mounting

[

]

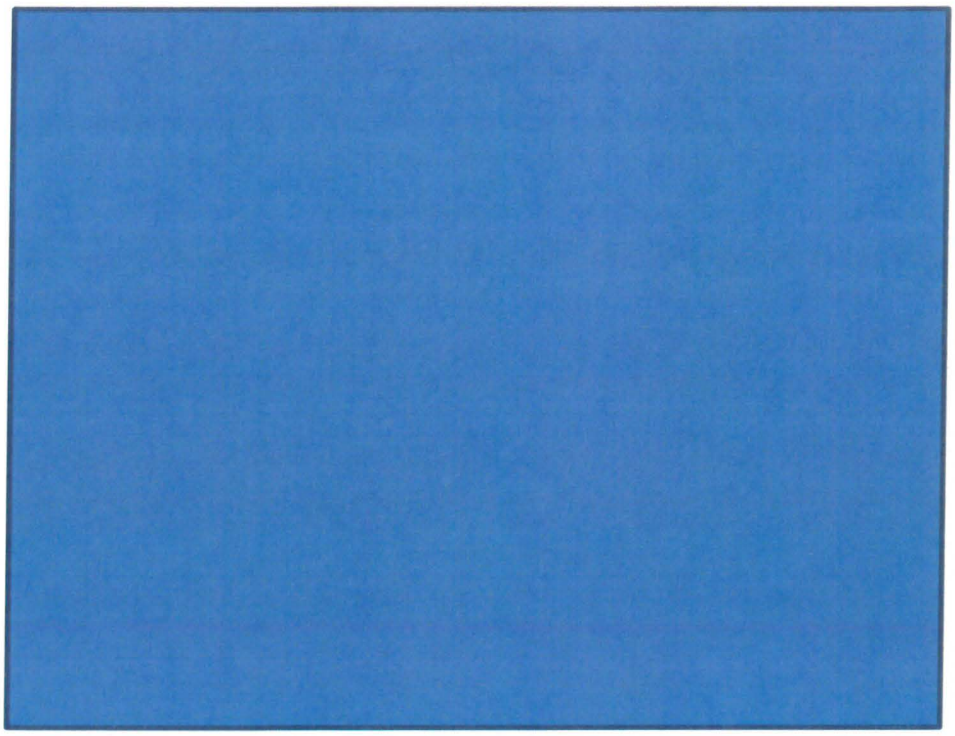

Figure 33. Seismic Test – Setup

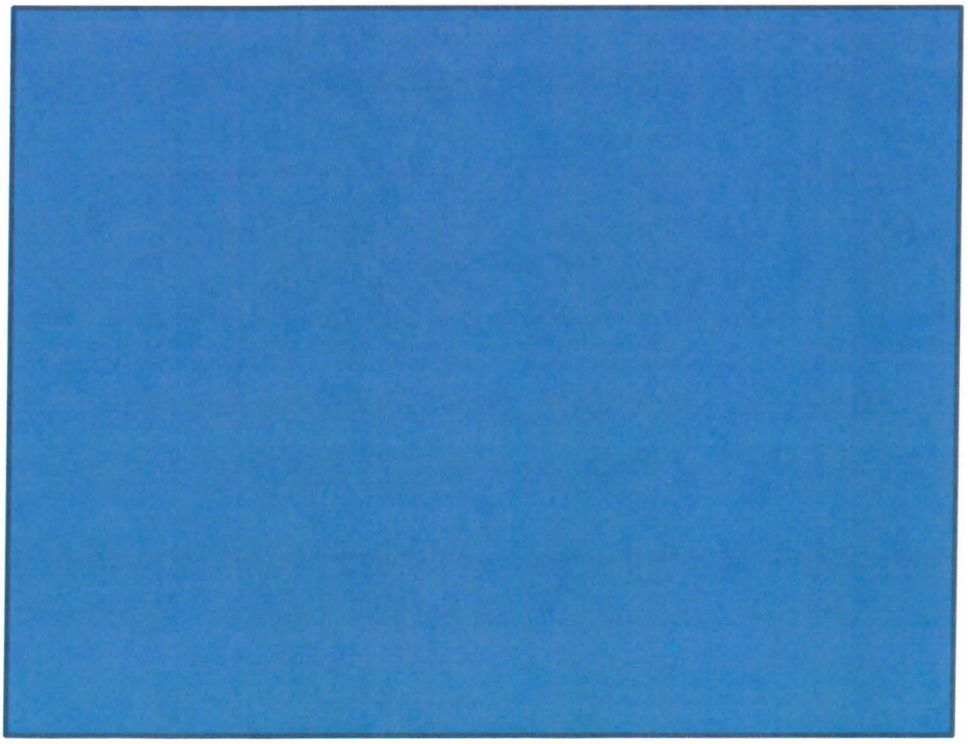

Figure 34. Seismic Test – Pre-Test 1

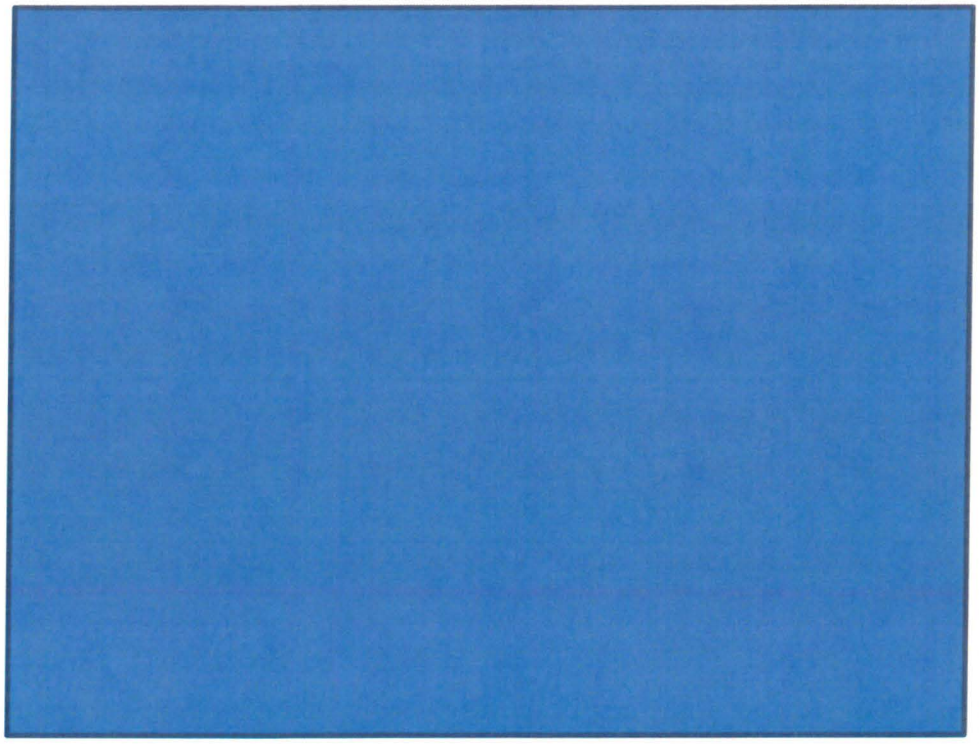

Figure 35. Seismic Test – Pre-Test 2

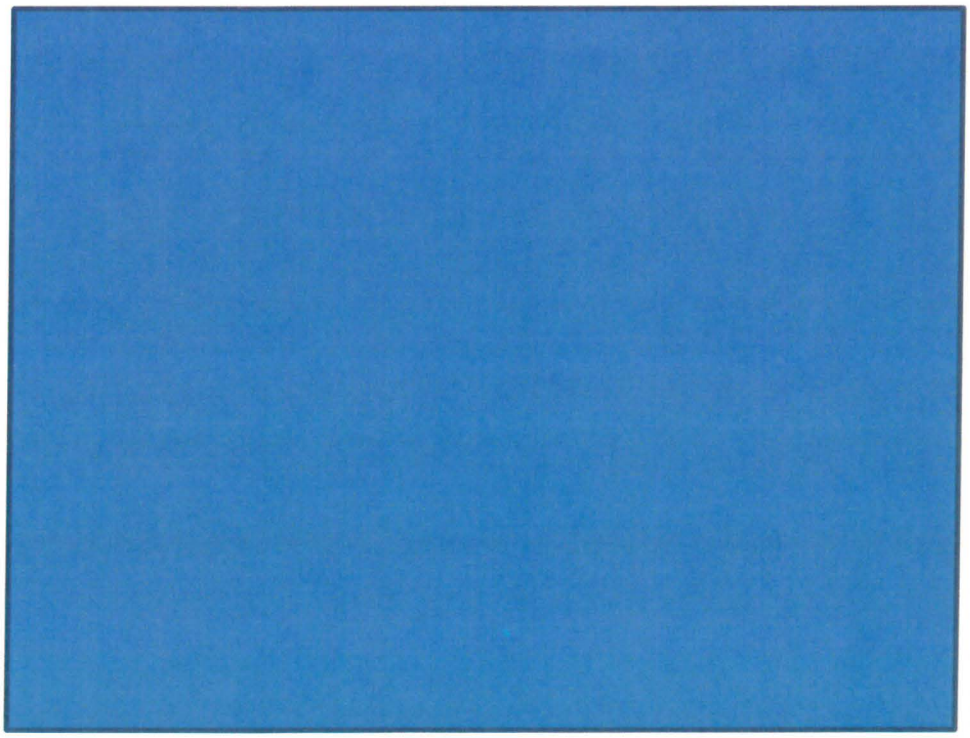

Figure 36. Seismic Test – Post-Test 1

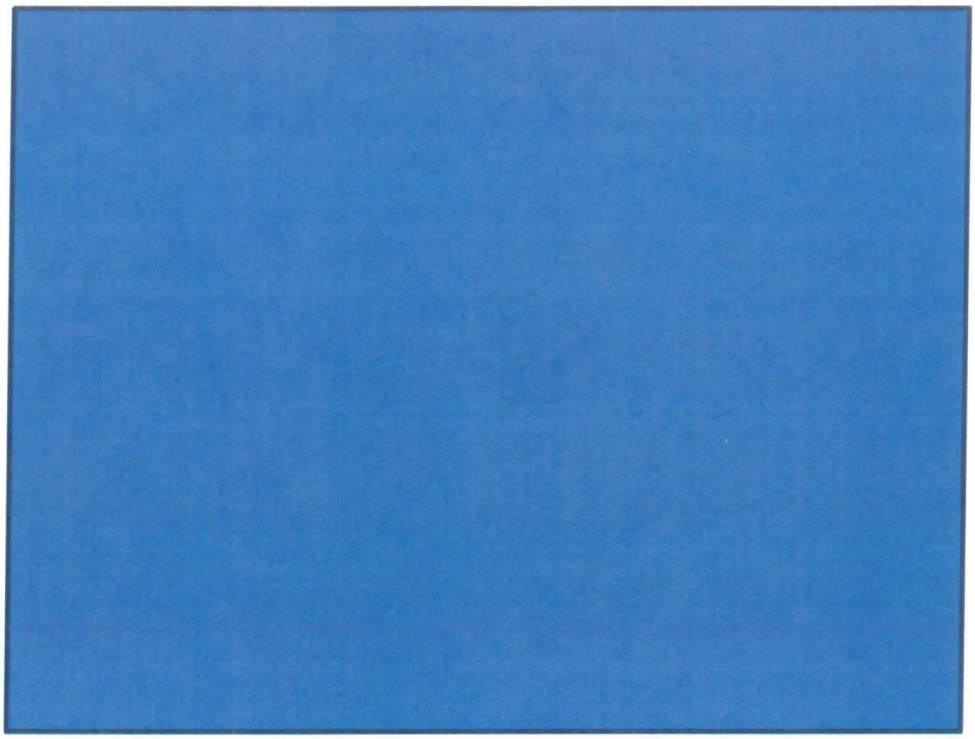

Figure 37. Seismic Test – Post-Test 2

F.7. Service Conditions

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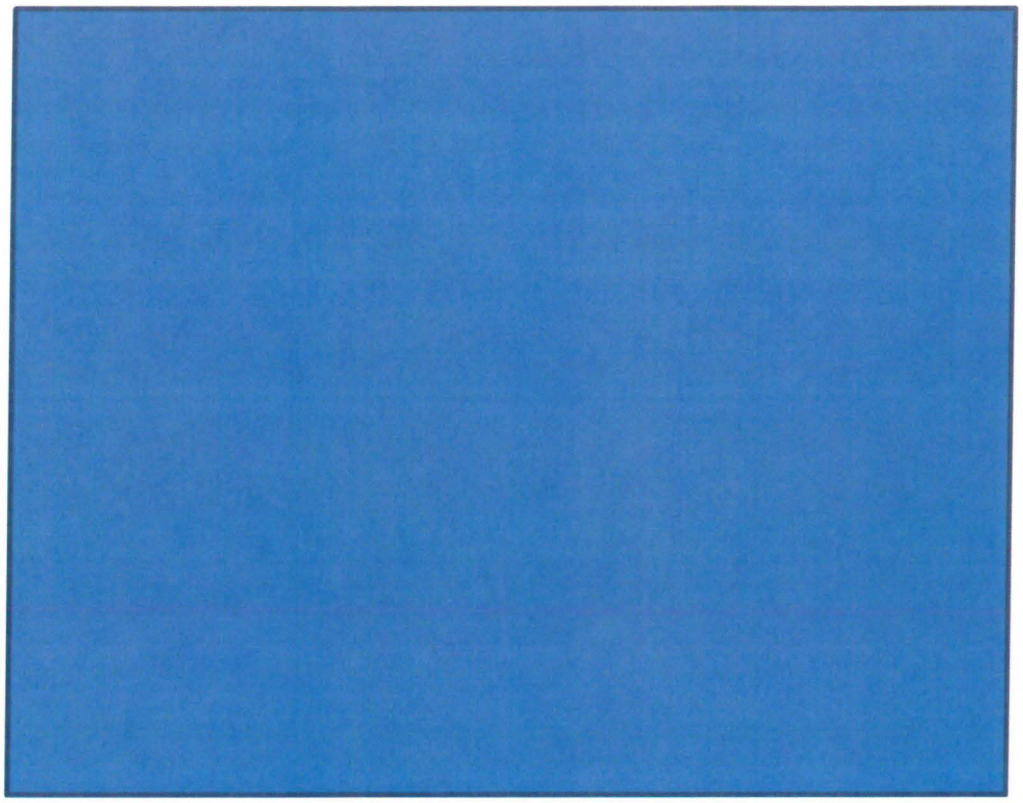

Figure 38. Seismic Test Spectrum

F.8. Test Levels

The test levels (supply power and I/O signal and load levels) applied to the HFC-FPGA Test Specimen during the Seismic Test were set as specified in corresponding test procedures (References 13, 14, and 20).

F.9. Performance Monitoring

Performance monitoring of the HFC-FPGA Test Specimen during the Seismic Test were set as specified in corresponding test procedures (References 13, 14, and 20).

F.10. Acceptance Criteria

Acceptance criteria for performance monitoring of the HFC-FPGA Test Specimen during the Seismic Test were set as specified in corresponding test procedures (References 13, 14, and 20). They are summarized in Table 20.

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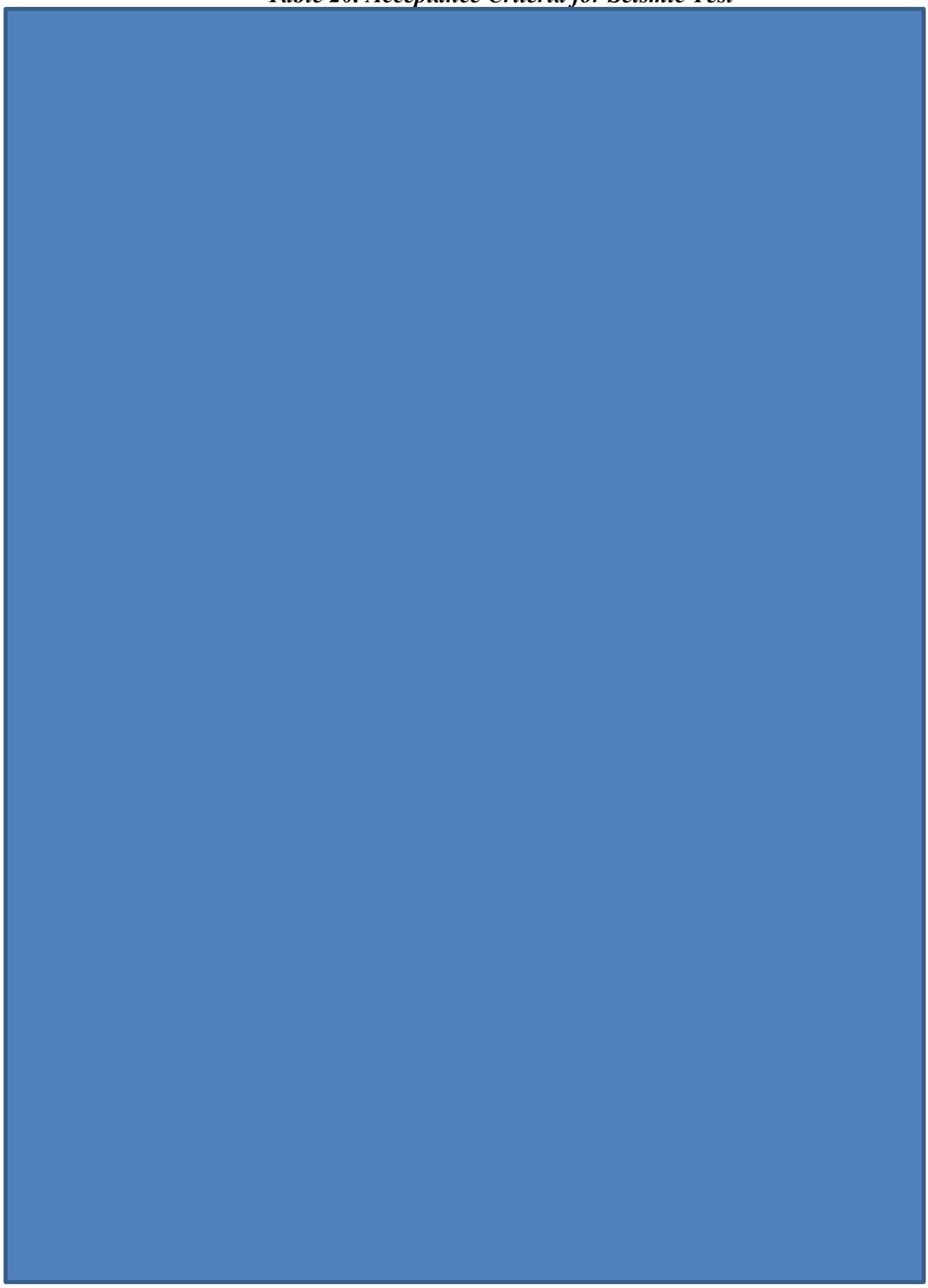
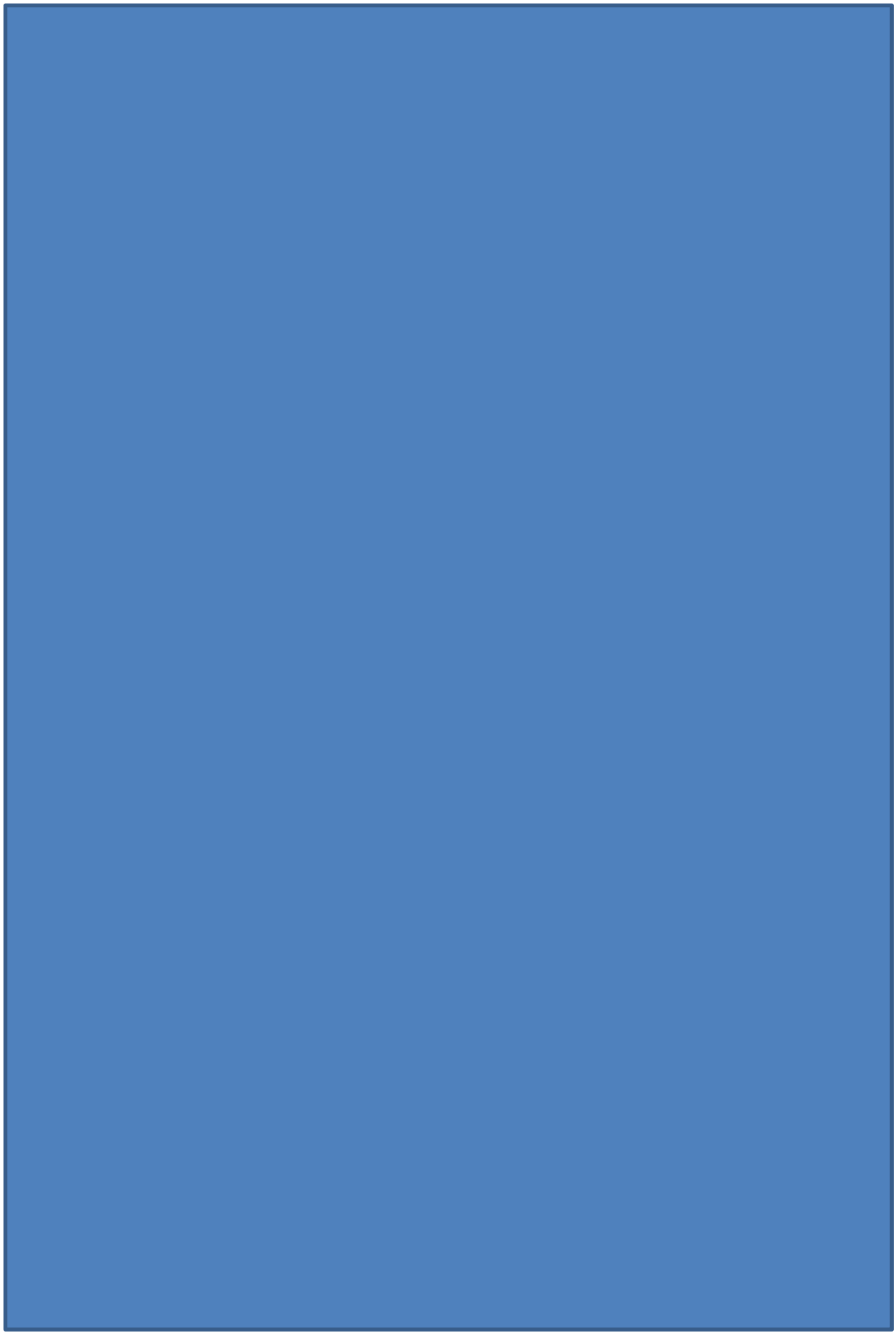
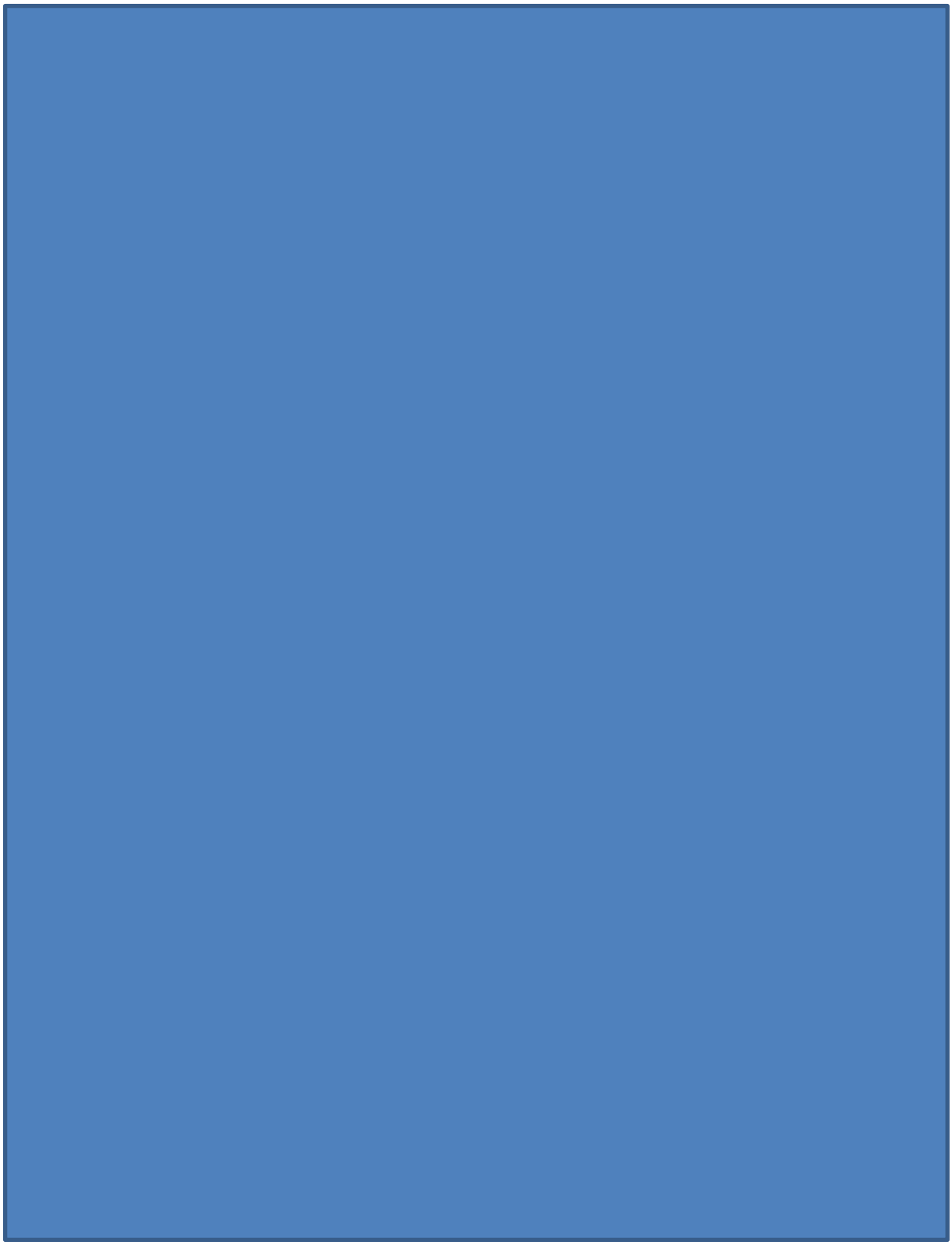
Table 20. Acceptance Criteria for Seismic Test







F.11. Documentation

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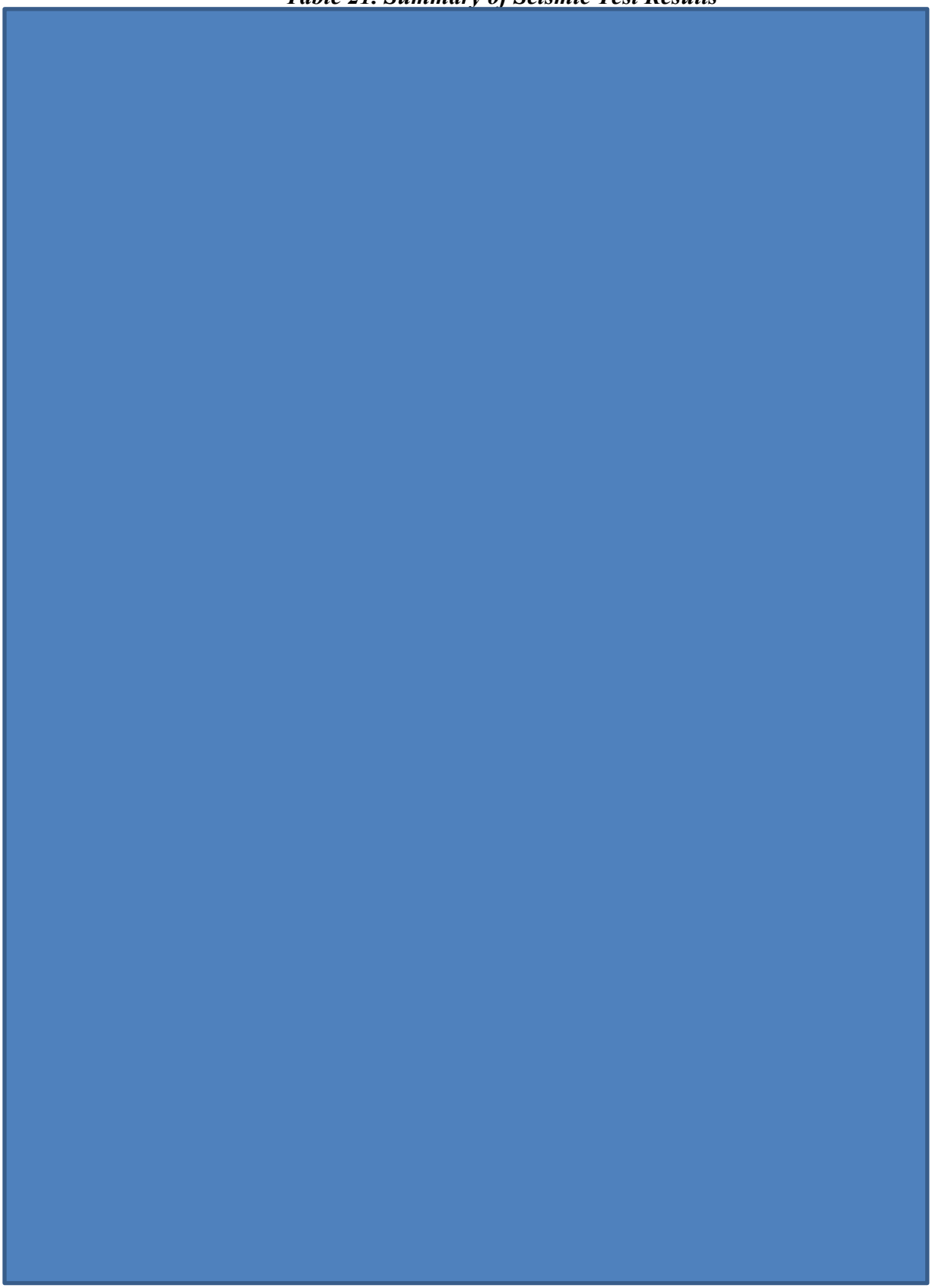
F.12. Test Results

Detailed test results of the Seismic Test were reported in TR901-302-01 (Reference 9), which are summarized in Table 21.

Table 21. Summary of Seismic Test Results



F.13. Resolution of Test Discrepancies

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