TEST AND VERIFICATION PLAN

EVLA Correlator Rack: Thermal Mock-up Tests

TVP Document: **A25031N0001**

Revision: 1.0

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Table of Contents

List of Figures

List of Abbreviations and Acronyms

U – Unit of Measurement (1U = 1.75”)

lfm – linear feet per minute

A-Pli – Aavid manufacturer gap filler material

MTBF – mean time between failures

1 Revision History

Revision	Date	Changes/Notes	Author
Draft	Sept. 13, 2004	Initial Draft	Ralph Webber, Mark Halman
Draft	Oct. 13, 2004	Added test procedures	Mark Halman, Ralph Webber
Draft	Jan 18, 2005	Add section Further Testing and update design notes	Mark Halman, Ralph Webber
Draft	Feb 7, 2005	Format added section	Mark Halman
Rev 1.0	April 20, 2005	Added additional information on Single Circuit Cooling and re-edited document	Ralph Webber
Rev 1.0	April 29, 2005	Changed document to Rev 1.0	Mark Halman

2 Introduction

Accurate thermal performance of the racks containing the Baseline Boards is an extremely difficult parameter to calculate with any degree of certainty.

Brent Carlson has performed comprehensive software modeling[i]. In an effort to check the accuracy of this software modeling, it has been decided to construct a thermal test rack, containing a suite of thermal test correlator baseline boards. This will enable us to test assumptions and measure actual thermal performance.

This document details the procedures used to acquire thermal test data for the purposes of evaluating airflow cooling. Also included are details of the design of the thermal test rack, what the requirements are and the methods use to calculate heat sink selection and expected thermal performance.

Correlator components will be monitored at different thermal loads. Airflows and temperatures will be recorded at incremental power dissipations. The data gained will allow an estimation of final operating temperature. [once system component and power supply loads are established]

The test racks and board layout are, as far as is possible, as close to the intended final layout for the correlator. The thermal and airflow data gained will accurately represent the performance of the final rack design.

Initial thinking was to do thermal tests using a closed loop enclosure design with water-cooling due to the high [10kW] power dissipation of the enclosures. When calculations suggested that the air-cooled open loop enclosure design was a viable option, thoughts of proceeding with closed loop testing were put on hold. Testing then proceeded with open loop air-cooling in two different configurations.

Enclosure thermal testing described in this document was done with open loop air-cooling in a dual circuit design and then followed up with tests based upon a single circuit design. The single circuit design uses a single set of fans mounted at the bottom or on top of the enclosure, blowing or sucking air in a single vertical flow. The dual circuit airflow design uses a set of fans at the bottom of the enclosure to blow air into each of the 12 sub-racks independently through two different paths, exhausting to the rear of the enclosure towards an external duct to the outside of the enclosure.

For the dual circuit airflow method, cooling air is supplied from ducting under the [computer] floor, at a temperature to be determined by these tests, and exhausted to the Correlator room. This would require a room HVAC system capable of removing the >200kW of heat dissipated by the whole Correlator, in addition to other room loads estimated to be in the order of 50kW.

Note, total volumetric airflow required for this approach [250kW] is estimated at 26,000 CFM [1]. For a room of 25 ft square, the air velocity [vertical draft] is in the order of 3ft/s assuming ¼ of the ceiling area is ductwork

Boards are cooled in a vertical airflow pattern and will require solid front panels.

[1] http://www.elma.com/us/technical_data/technical_articles/techart_coolings.php

3 Document Organization

The testing in this document is quite extensive. For clarity it is divided into four sections;

Air Flow Measurement - Dual Circuit Cooling	Section 4
Temperature Measurement - Dual Circuit Cooling	Section 5
Air Flow Measurement - Single Circuit Cooling	Section 6
Temperature Measurement - Single Circuit Cooling	Section 7

Each test will show the test initialization, test procedure and the evaluation criteria.

The data gained will be tabulated and graphed in the results document. [**TVP Document: A25031N0001**]

4 Test Overview - Dual Circuit Cooling

4.1 General Arrangement - Dual Circuit Cooling

The general arrangement of the proposed test enclosure [*Figure 4-1 General Arrangement*] shows placement the following major components:

Baseline board 12 U sub racks (qty = 2]

Fan-out board 6U sub rack,

Ethernet switches (qty = 2)

The position of fan trays, exhaust plenums and ducting [air management system].

Not shown is cabling. To be added as necessary.

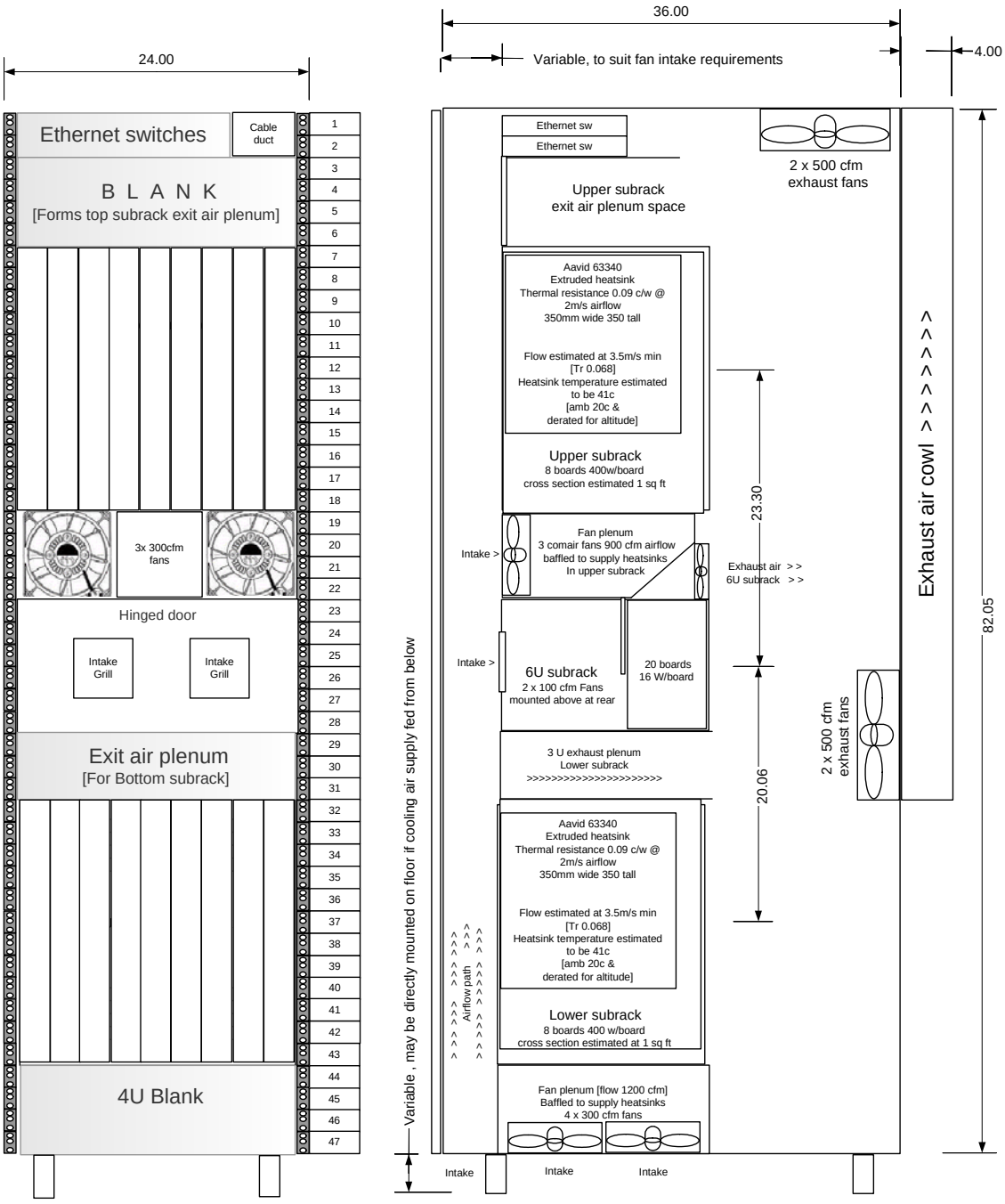

Figure 4-1 ***General Arrangement - Dual Circuit Cooling***

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4.1.1 Airflow Characterization

Airflow testing will include airflow measurements across heat sinks and through all sub-racks using two hot wire anemometers. The positions of the anemometers and thermocouples are shown in Figure 4-2 *Monitoring Locations - Dual Circuit Cooling.*

Exit air temperature through the entire enclosure will also be recorded to give an indication of total system resistance.

4.1.2 Thermal Measurement

Thermal measurement testing will monitor heat sink performance and temperature rises through sub-racks at various system power levels. These tests will be recorded at the room ambient temperature. Together, both tests will allow the determination of operational boundaries.

The test enclosure shall be mountable on either a cold air supply duct with a room air conditioner, a heat exchanger or mounted in an environmental chamber.

4.2 Preparation and Schedule

Initial test preparation to obtain all necessary equipment will take 40 working days. This includes time to procure necessary rack components, make heat dissipating circuit boards and assemble the test rack.

Access to the environmental chamber is required. TBD

Execution of the airflow board tests and thermal system tests (load testing) should take less than 30 days each to complete.

4.2.1 Equipment

1 47U high, 36” depth, 30” width, 24” wide rack, Hammond enclosure

2 12U high, 400mm depth, sub-racks

18 12U high, 400mm depth, heat-dissipating test boards

1 6U high, 400mm depth, sub-rack

22 6U heat dissipating test boards

3 48VDC Power Supply(s) to supply 150A

2 Voltage, current measuring meters

2 Hot wire anemometers

1 6 - position multi temperature measurement equipment (thermocouples)

2 Voltage, current measuring meters

1 Environmental chamber or room chiller and plinth

Thermal Testing Rack Monitoring Locations

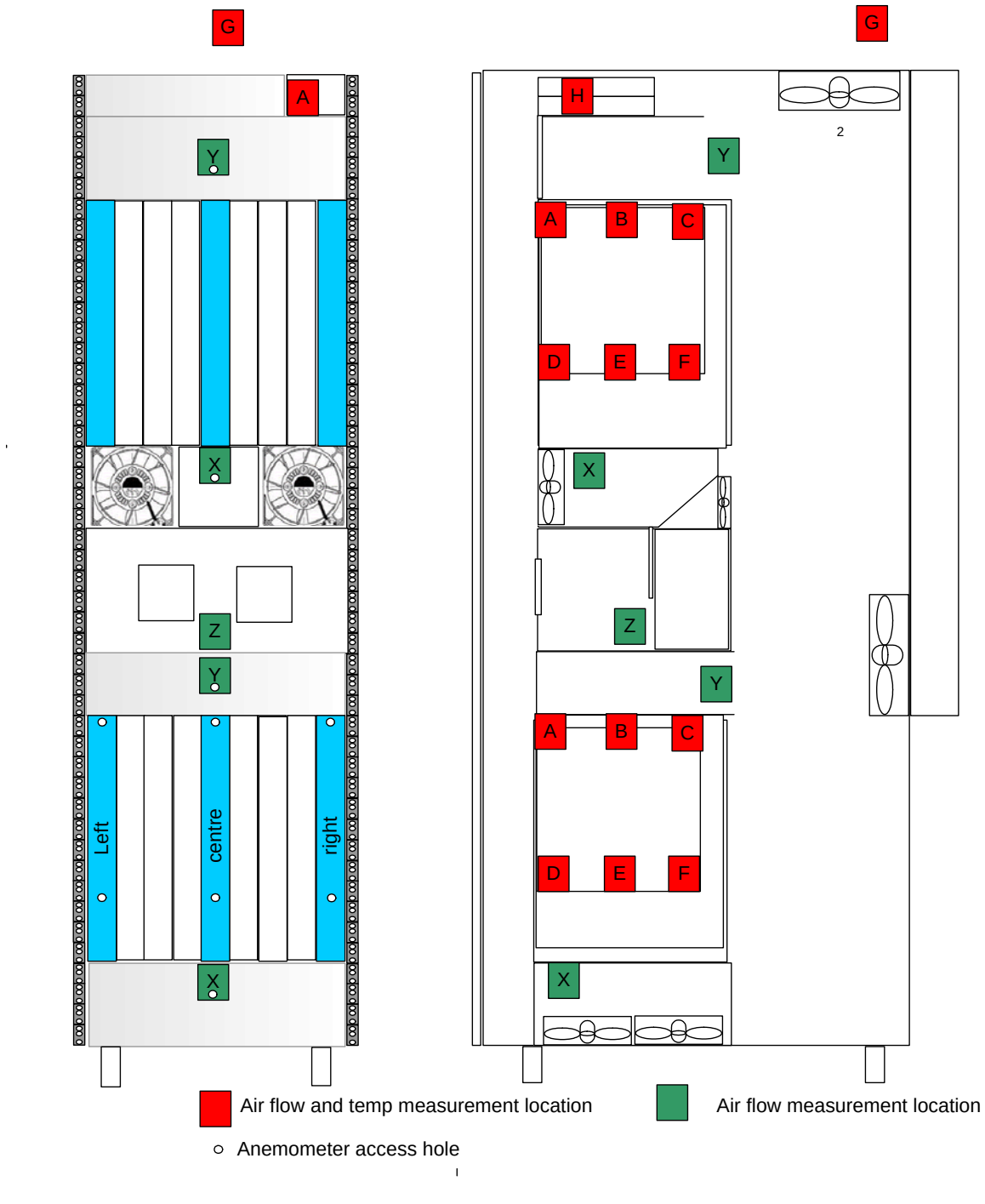

Figure 4-2 ***Monitoring Locations - Dual Circuit Cooling***

5 Air Flow Measurement - Dual Circuit Cooling

5.1 Upper 12U Sub Rack - Heat Sinks

The purpose of performing airflow measurements on the heat sinks of the upper 12U sub-rack is to record the variance in airflow across the horizontal distribution of heat sinks. This information can tell us if heat sinks are receiving the same flow of air required for sufficient thermal cooling. We are also interested in knowing if the top sub rack receives the same airflow as the lower sub rack.

5.1.1 Initialization

Setup rack electronic sub-components as per Figure 4-2 *Monitoring Locations - Dual Circuit Cooling*. Place sub-rack in **upper** sub rack location. Place instrumented board in slot 2.

5.1.2 Test Procedure

1) Apply power to rack fans.

2) Insert the anemometer into the top heat sink access hole of a 12U test thermal Baseline Board. Take readings at locations A, B, C, record in results document. [**TVP Document: A25031N0001**]

3) Insert the anemometer into the bottom heat sink access hole of a 12U test thermal Baseline Board. Take readings at locations D, E, F, record in results document. [**TVP Document: A25031N0001**]

4) Remove power.

5) Move instrumented board to slot 5.

6) Repeat points 1 – 4.

5.1.3 Evaluation Criteria

1. Air velocity over the entire heat sink should vary by no more than 10% corresponding to thermal resistance change of 0.01 °C/W.

2. Dead zones if found are to be investigated.

5.2 Upper Sub Rack - Total Air Flow

The purpose of performing total airflow measurements of the upper 12U sub-rack is to verify system airflow into and out of the sub-rack. This information can tell us how much

airflow resistance [thermal impedance] the sub-rack introduces to the total system airflow.

5.2.1 Initialization

No change.

5.2.2 Test Procedure

1) Apply power to rack fans.

2) Insert the anemometer into the fan plenum location X. Take readings and record in table [**TVP Document: A25031N0001**]. Repeat for Location Y.

5.2.3 Evaluation Criteria

Total airflow through a 12U test sub-rack should be between 900 lfm and 1200 lfm. This is required to meet the heat sinks required dT of 22 ^{o}C [at altitude] and hence the thermal resistance value of 0.06 ^{o} C/W, with the intended dissipated power of the load.

5.3 Lower Sub Rack - Heat Sinks

The purpose of performing airflow measurements on the heat sinks of the lower 12U sub-rack is to record the variance in airflow across the horizontal distribution of heat sinks. This information can tell us if heat sinks are receiving the same flow of air required for sufficient thermal cooling.

5.3.1 Initialization

Setup rack electronic sub-components as per Figure 4-2 *Monitoring Locations - Dual Circuit Cooling*. Place instrumented sub rack in **lower** rack location. Move instrumented board back to position 1.

5.3.2 Test Procedure

Repeat section 5.1.2

5.3.3 Evaluation Criteria

As per 5.1.3

5.4 Lower Sub Rack - Total Air Flow

The purpose of performing total airflow measurements of the lower 12U sub-rack is to verify system airflow into and out of the sub-rack. This information can tell us how much airflow resistance [thermal impedance] the sub-rack introduces to the total system airflow.

5.4.1 Initialization

No change

5.4.2 Test Procedure

1) Apply power to rack fans

2) Insert the anemometer into the fan plenum location X. Take readings and record in table. [**TVP Document: A25031N0001**] Repeat for Location Y.

5.4.3 Evaluation

As per section 5.2.3

5.5 Total Enclosure Air Flow

The enclosures total airflow is measured in order to determine total system airflow losses and if calculated airflow values of 5-6 m/s can be obtained thru the enclosure to verify calculated design values.

5.5.1 Initialization

Setup rack electronic sub-components as per Figure 4-1 *General Arrangement - Dual Circuit Cooling*.

5.5.2 Test Procedure

1. Place one anemometer into the lower 12U inlet (bottom) sub-rack and another into the upper 12U sub-rack outlet (top) plenum.

2. Apply power to rack fans.

3. Measure and record both anemometer readings.

4. Move the top anemometer to the lower 12U sub-rack outlet (top) plenum and repeat procedure. Repeat procedure by moving the top anemometer to each of the two enclosure exhaust fans and record readings.

5.5.3 Evaluation Criteria

Airflow through the enclosure allows for sufficient cooling of sub-rack components.

6 Temperature Measurement - Dual Circuit Cooling

6.1 Schedule of Tests

Execution of these tests will be performed after completion of the dual circuit airflow tests. This test will be completed at the following power levels:

60A, 4 W/chip ~ 7 kW total

100A, 6.7 W/chip ~10 kW total

Axial fan lower position blowing

Axial fans upper position sucking

Impellers lower position blowing

Impellers upper position sucking

Note, there will be multiple results for temperature measurement

See section 4.2.12 - in addition

6.1.1 Environment

Screened Room.

6.2 Upper 12U Sub Rack - Thermal Measurement

Since the input air temperature is known thermal measurements taken on the upper 12U sub rack will be used to calculate the overall temperature rise [dT] of the rack.

6.2.1 Initialization - 21°C Ambient

Place instrumented board in slot 2.

Note enclosure inlet air initial conditions [Temp].

Set total initial thermal test board power dissipation as per schedule of tests 6.1.

Set back of board supply to 56V [42A]

6.2.2 Test Procedure

1) Apply power. Allow temperature to stabilize. Record this time.
2) Monitor instrumented board thermocouple test points A to F.
3) Record readings on table [**TVP Document: A25031N0001**].
4) Remove power.
5) Move instrumented board to slot 5.
6) Repeat points 1 – 4.
7) Repeat points 1 –8 for power dissipation as per schedule 6.1.

6.2.3 Evaluation Criteria

The test board thermal measurements must be less than the specified maximum die temperature allowed.

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6.3 Lower 12U Sub Rack - Thermal Measurements

Thermal measurements taken on the lower 12U sub rack will be used to calculate its temperature rise[dT]. This information will also indicated hot spots on the test boards within the sub rack itself.

6.3.1 Initialization - 21^{o}C Ambient

Place instrumented board in slot 2.

Note enclosure inlet air initial conditions [Temp].

Set total initial thermal test board power dissipation as per schedule of tests 6.1.

Set back of board supply to 56V [42A]

6.3.2 Evaluation Criteria

The test board thermal measurements must be less than the specified maximum temperature allowed.

7 Further Testing

As a result of testing, and unacceptable results (see A25031N0001) it was decided to try an alternate airflow scheme. (see Figure 7-1 *Single Air Entry Arrangement*)

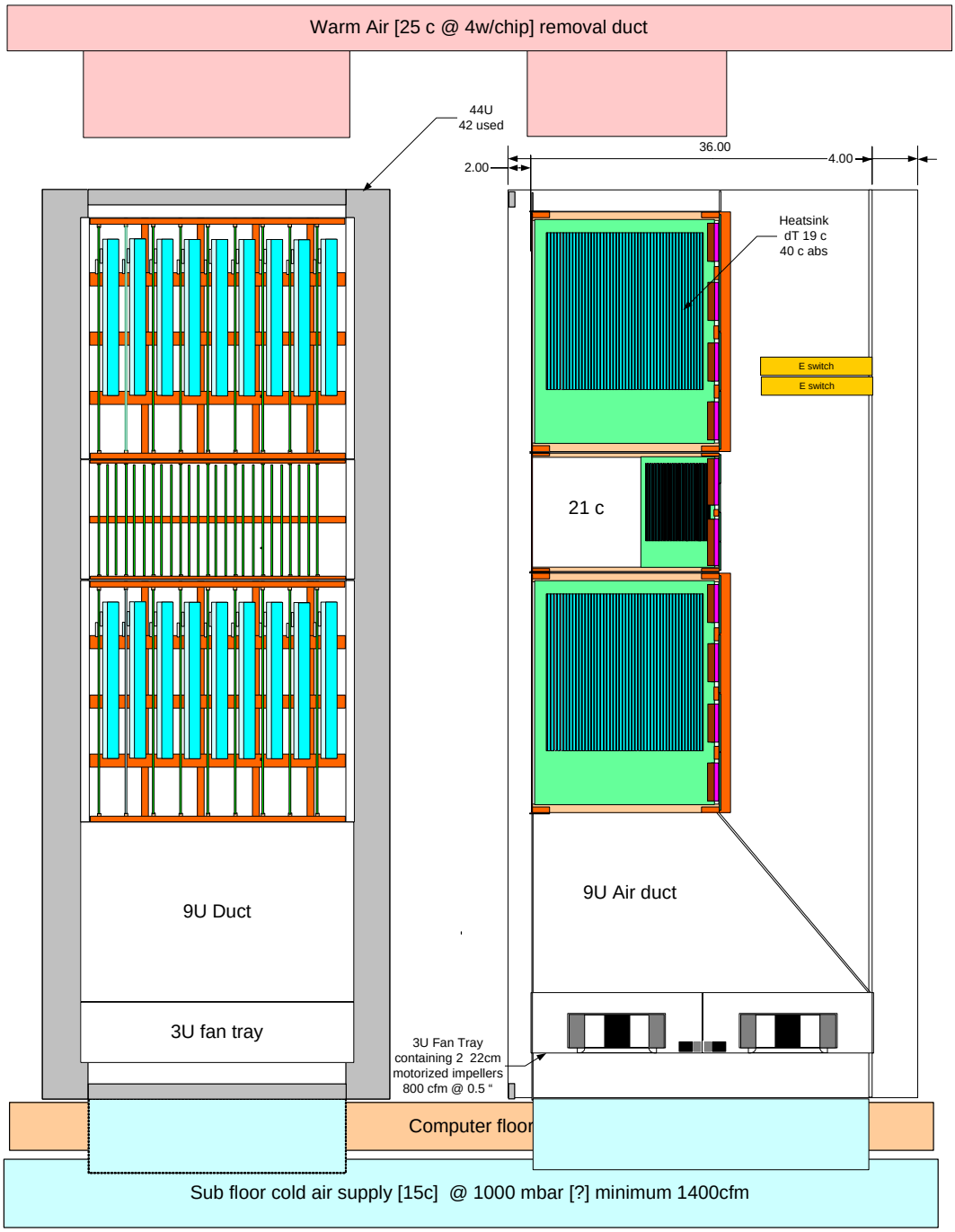

Figure 7-1 *Single Air Entry Arrangement*

8 Air Flow Measurement - Single Circuit Cooling

8.1 Upper 12U Sub Rack - Heat Sinks

The purpose of performing airflow measurements on the heat sinks of the upper 12U sub-rack is to record the variance in airflow across the horizontal distribution of heat sinks. This information can tell us if heat sinks are receiving the same flow of air required for sufficient thermal cooling.

8.1.1 Initialization

Setup rack electronic sub-components as per *Figure 4-2 Monitoring Locations - Dual Circuit cooling*. Place sub-rack in **upper** sub-rack location. Place instrumented board in slot 2.

8.1.2 Test Procedure

1) Apply power to rack fans.

2) Insert the anemometer into the top heat sink access hole of a 12U test thermal baseline board. Take readings at locations A, B, C record in results document. [**TVP Document: A25031N0001**]

3) Insert the anemometer into the bottom heat sink access hole of a 12U test thermal baseline board. Take readings at locations D, E, F record in results document. [**TVP Document: A25031N0001**]

4) Remove power.

5) Move instrumented board to slot 5.

6) Repeat points 1 – 4.

8.1.3 Evaluation Criteria

1. Air velocity over the entire heat sink should be no less than 3 m/s.

2. Dead zones if found are to be investigated.

8.2 Upper Sub Rack - Total Air Flow

The purpose of performing total airflow measurements of the upper 12U sub-rack is to verify system airflow into and out of the sub-rack. This information can tell us how much airflow resistance [thermal impedance] the sub-rack introduces to the total system airflow.

8.2.1 Initialization

No change.

8.2.2 Test Procedure

1) Apply power to rack fans.

2) Insert the anemometer into the fan plenum location X. Take readings and record in table [**TVP Document: A25031N0001**]. Repeat for Location Y.

8.2.3 Evaluation Criteria

Total airflow through a 12U test sub-rack should be between 1200 lfm and 1800 lfm. This is required to meet the heat sinks required dT of 22 ^{o}C [at altitude] and hence the thermal resistance value of 0.06 ^{o} C/W with the intended dissipated power of the load.

8.3 Lower 12U Sub Rack - Heat Sinks

As the airflow arrangement is now a simple series arrangement

No measurements are taken. It is assumed that the airflow will be similar and hence thermal rise will be much lower than the upper sub rack

9 Temperature Measurement - Single Circuit Cooling

9.1 Schedule of Tests

Execution of these tests will be performed after completion of the open circuit airflow tests. This test will be completed at the following power levels.

60 A total or 4W/chip

100A total or 6.7W/chip

Note, there will be multiple results for temperature measurement

See section 4.2.1 - in addition

9.1.1 Environment

Screened Room.

9.2 Upper 12U Sub Rack - Thermal Measurement

Since the input air temperature is known thermal measurements taken on the upper 12U sub rack will be used to calculate the overall temperature rise [dT] of the rack.

9.2.1 Initialization - 21°C Ambient

1) Fit axial fans to lower position
2) Place instrumented board in slot 2.
3) Set total initial thermal test board power dissipation as per schedule of tests 6.1
4) Set back of board supply to 56V axial fans or 48V for impellers.

9.2.2 Test Procedure

1) Apply power. Allow temperature to stabilize. 30 mines.
2) Record enclosure inlet air temperature.
3) Record enclosure exhaust air temperature.
4) Monitor instrumented board thermocouple test points A to F.
5) Record readings on table [**TVP Document: A25031N0001**].
6) Repeat points 1 – 5 for power dissipation as per schedule 6.1.
7) Repeat points 1 – 6 for fan type and position as per schedule 6.1

9.2.3 Evaluation Criteria

The test board thermal measurements must be less than the specified maximum die temperature allowed.

[i] http://www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/widar/private/Memos/NRC-EVLA_Memo017.pdf