STAR Note Number	Engineering Note Number	STAR WBS Number	Pages
278			**8**

Author	Date
H. Matis and F. Bieser	**12/4/96**

Program - Project - Job

STAR Project

Title

Test of STAR Standard VME Crate and Heat Exchanger

REV A;
REV B;

Test of a STAR Standard VME Crate and a Heat Exchanger

STAR has tentatively selected a VME crate (manufactured by Wiener) and a heat exchanger (manufactured by Affiliated Steam). It was determined that several tests needed to be done to ensure us that these items will be adequate.

Setup of the Test

To simulate the STAR enclosure the items were put in a standard rack. The rack, which is shown in Figure 1, contains a 6U-9U crate. A heat exchanger is located below the VME

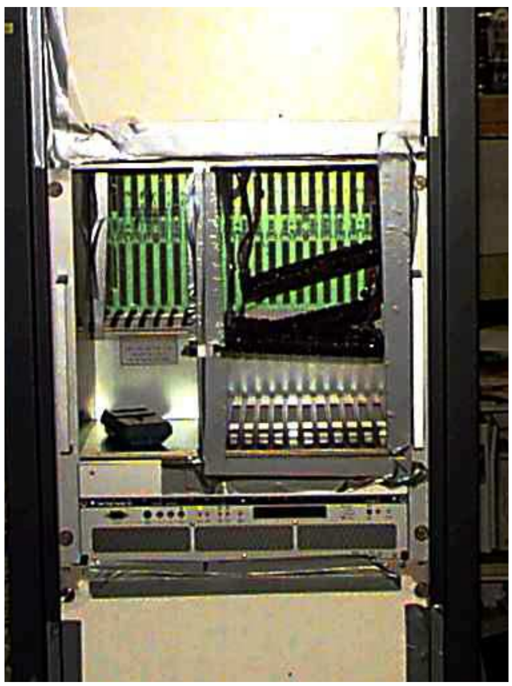

Figure 1 Front view of the rack test. The VME crate is shown. The heat exchanger is hidden in this picture. Several resistors are shown in the 9U section of the crate.

crate. The rack has an outside dimension of 24 1/16" which is about the size the STAR nominal width of 24". The outside depth of the rack is 36". The height of the rack is 89 3/8" which is slightly higher than the STAR specified height of 88". This rack has 84 1/8" of available panel space.

Power Tests for the VME Crate

To determine whether the crate could handle the requested power, we attached several resistors to the backplane of the crate. First four 0.1 Ω resistors were attached to the +5 V line. When the power supply was first switched on, it drew about 201 A. As the resistors heated, the current dropped to approximately 190 A. The crate operated for at least 5 days in this mode. There were no power supply trips.

To test the 12 V lines, we added a 0.6 Ω resistor to the +12 V and the -12 V lines for an expected current of 20 A. Initially, each line drew 20 A. However, the current dropped to 19 A when the resistors became warm. Because we connected the power supply to 117 V AC line, we did not want to draw more than 1000 W. Therefore, two of the + 5 V resistors were removed. The nominal operating conditions of the system are described in Table 1. The system ran for about five days without any noticeable crate problem.

Table 1 Nominal operating conditions for the heat exchanger tests.

Crate Parameters	Measurement
5 V	93 A
12 V	19.0 A
-12 V	18.9 A
Power	925 W

Noise Test

A digital scope was connected to the backplane of the crate. The +12 V and -12 V lines were operated at full load. The +5 V was operated at 1/2 the maximum load. There was a random trigger. Table 2 shows the results:

Table 2 Noise test on the Wiener VME Crate

Voltage - V	Sampling Time	Maximum V_{pp} - mV	Average V_{pp}-mV	Maximum V_{rms}-mV	Average V_{rms} -mV
+5	10 µs	62.5	39.9	19.2	5.0
-12	10 µs	93.1	52	7.8	5.4
+12	10 µs	78.7	55	9.5	5.6
+12	10 ms	78.1	54.8	12.2	6.1

The table shows that the average V_{pp} noise is slightly greater than the VME specification of 50 mv peak-peak. The VME specification does not define how Vpp should be measured. Because of that ambiguity, we will use the “average” measurement. Since the deviation is less than 10% for the 12 V supply, we declare that the crate passes the noise test. Our measurements are much higher than the specification of < 15 mV from Wiener’s manufacturing specification.

Air Flow tests

To ensure that the components on the VME are properly cooled we needed to measure the airflow of a fully loaded VME crate with a heat exchanger below it. First, we measured the flow into the heat exchanger with all slots empty. The crate and the front of the rack were sealed. Air flow was measured by opening the rear door and then inserting a probe under the heat exchanger. The crate fans were running at the maximum speed. Figure 2 shows the matrix of points that were measured. Note that near the back of the heat exchanger the air flow was low and varied rapidly. Typical values near the edge were 80 ft/min.

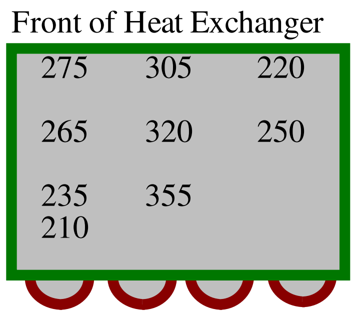

Figure 2 Air flow pattern entering the bottom of the heat exchanger. The units of the numbers are in ft/min. In the lower left corner, two measurements were taken at the same position. The difference shows the approximate systematic error of the measurement.

To calculate the effective area for the heat exchanger, we assume that air enters through a smaller area than the actual heat exchanger. The heat exchanger is 16.5" deep and about 17" wide. A VME card is 16". We take a smaller area, 15.5" x 14" to approximate the active area of air flow. From this number we get 1.5 ft^2. By taking the average of the flows from Figure 2, we get an average flow of 278 ft/min or 417 ft^3/min.

All of the 6U slots of the VME crate were then filled with off the shelf VME modules. The 9U slots were populated with either 9U modules or blank boards with several long strips of plastic. The front of the crate and the bottom of the rack was sealed. The rear door was closed. The area above the crate was opened. The crate fans were running at the maximum speed. Air flow was measured above the crate, directly above the card slots. Table 3 shows the measured air flow.

Table 3 Air flow above a fully loaded crate.

Slot	Front of Crate (ft/min)	Middle of Crate (ft/min)	Back of Crate (ft/min)
1 (6U)		600	
4 (6U)		520	
8 (6U)		610	
9 (partition)			
10 (9U)	540	610	610
14 (9U)	630	660	690
21 (9U)	620	720	570

The average flow is 615 ft/min. We estimate that the active surface area at the top of the crate is 0.76 ft^2. This gives a flow of 467 ft^3/min. This number is slightly higher by 10% of air flow measurement of 417 ft^3/min which was measured below the heat exchanger. However, these numbers agree well within the systematic errors.

Air Flow in a Full Crate

Measurements were done to see how an obstruction below the heat exchanger or above the crate affects the air flow. The obstacle completely covered the heat exchanger and crate and was placed parallel either to the region below the heat exchanger or above the crate. The crate fans were at their maximum speed. The rack and crate were completely sealed. The probe were placed inside the 9U compartment about 3" above the rails for slot 14. The probe was approximately 6" away from the front of the crate. Figure 3 shows the measurement with the obstruction below the heat exchanger.

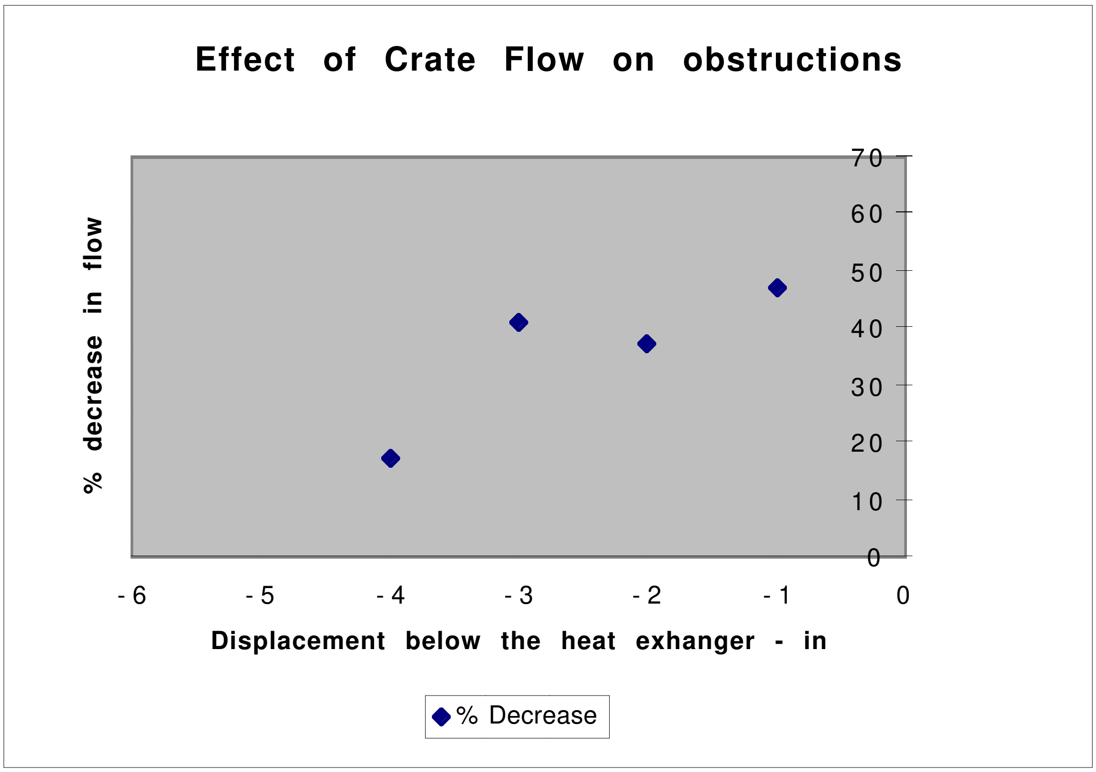

Figure 3 Measurements of the effect of an obstruction below the heat exchanger. A negative displacement means below the heat exchanger.

A similar measurement was done above the crate. The results which are plotted in Figure 4 show a similar effect as with the obstruction below the heat exchanger.

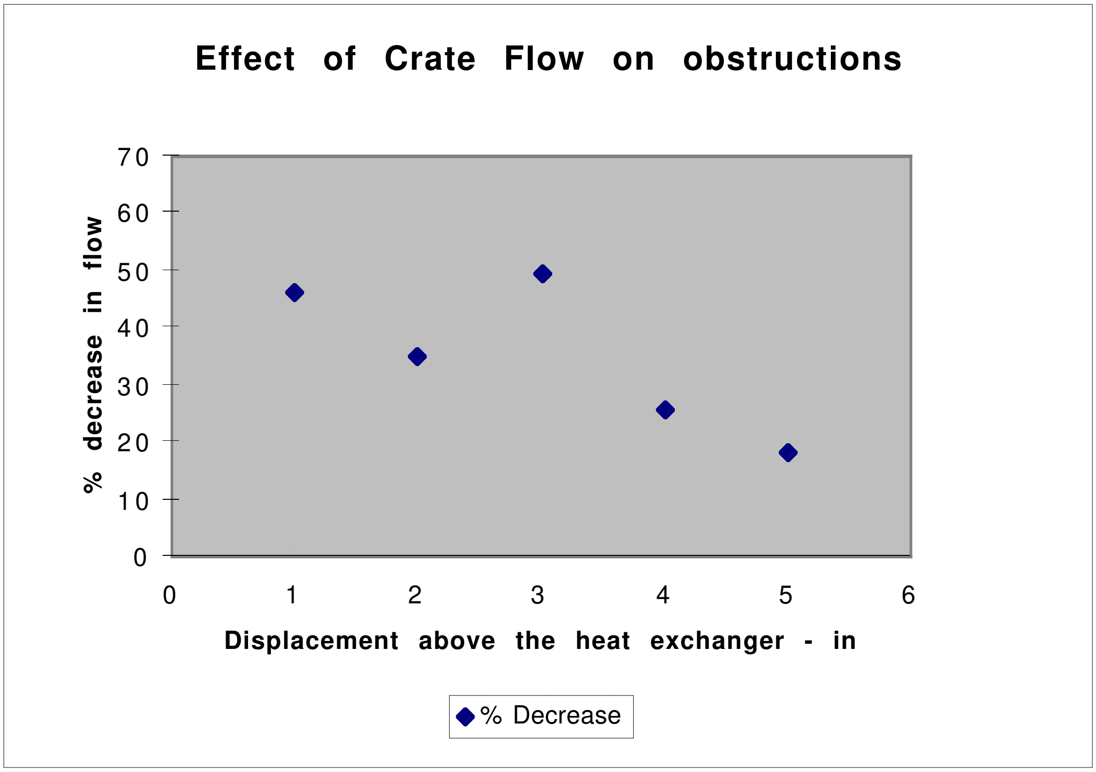

Figure 4 Measurements of the effect of an obstruction above the VME crate.

Both Figures 4 and 5 show that it is necessary to have obstructions at least 6" away from the heat exchanger and crate for there to be no significant effect on air flow. If obstacles are much closer than 6", we should consider adding fans to the rack.

Air Filter Test

To reduce dust collection in the racks, we believe it desirable to put a filter in the system. It is possible to put a filter inside the Wiener fan tray. Unfortunately, this involves removing and then installing many screws. Furthermore, dirty air would need to enter the heat exchanger and fans. A better solution is to use standard filters. One filter was placed below the heat exchanger. The air flow was reduced by approximately 10%.

Heat Exchanger Tests

Standard LBL tap water was used to cool the heat exchanger. We could flow water up to 1.5 gal/min. Water entered the heat exchanger from a pipe which was connected to cold "city" water. The output of the heat exchanger flowed into the sink. The temperature of the water was measured at the input and output. The crate fans were set a maximum speed. The test was started 10/8 at 1600. Water flow was 1 g/min. Table 4 shows these results.

Table 4 Temperature measurements for VME crate in an enclosed rack. Crate Air, Crate Power Supply and Crate Watts were measured directly from the crate's front panel

Test	Time	Crate Air - C	Crate Power Supply - C	Crate Watts	Water in - C	Water out.- C	ΔT water - C	Power Removed - W	Outside Air - C
1	10/8 1640	37	48	925	30.2	32.4	2.2	620	24.0
2	10/9 0900	31	42	925	22.8	25.0	2.2	620	23.5
3	10/9 0930?	34	45	925 + 1300 heater	22.9	27.1	4.2	1200	N/A
4	10/9 1200	35	46.5	925 + 1300 heater	22.8	27.2	4.4	1240	21.7
5	10/9 1660	29.5	40	927	21.2	23.6	2.4	670	21.6

To check on the performance of the heat exchanger, air temperature measurements were made just after Test 1. There was no heating in the 6U area. Table 5 shows the results:

Table 5 Temperature inside of rack for Test 1. There were no heaters in the 6U section so that the 6U temperature is equal to the temperature of the air leaving the heat exchanger.

Above 6U	33.3 C	91.9 F
In 6U	34.4 C	93.9 F
Above 9U	41.0 C	105.8 F
Just below radiator	35.6 C	96.1 F
Water in	30.2 C	86.4 F
Water out	32.4 C	90.3 F

The air temperature can be approximated by the temperature measurement in the 6U section

Comparison with Heat Exchanger Specifications

We asked the manufacturer to predict the performance of the heat exchanger test. The inputs to their calculation were taken from Table 5. Input temperature to the heat exchanger was 96.1 F. Entering water temperature was 86.4 F. The water flow was 1 gal/min. Air flow was 417 ft^3/min. The calculations predicted a water ΔT of 4.0 F or 2.2 C which was exactly the temperature rise for the test. It predicted that the air leaving the heat exchanger should be 91.6 F. This number is close to the above 6U number.

We then asked the manufacturer to predict the performance of the heat exchanger with the conditions that we expect at STAR. The input conditions were a water flow of 2 gal/min and an air flow of 417 ft^3/min. The temperature of the cooling water is 60 F. Table 6 shows the relationship between power dissipated in the crate versus temperature of the air after existing the heat exchanger. For each case the water pressure drop is 6.30 ft of water.

Table 6 Prediction of the performance of the heat exchanger.

Power Dissipated per heat exchanger	Air Temperature - into the heat exchanger	Air Temperature into the Crate	Exit Temperature of the water
1.9 KW	76.0 F	69.1 F	66.4 F
3.0 KW	82.0 F	73.2 F	70.2 F

The maximum power generated by the crate is 1.5 KW. The efficiency of the 5 volt supply is 83% and the efficiency of the 12V is 85%. Using an efficiency of 83%, we calculate that each crate generates 1.8 KW. STAR Note #220B requires that ΔT must be less than 18 F and that the maximum temperature in a crate is 90 F. An exit air temperature just less than 76 F or a ΔT of 7 F is very reasonable. Therefore, we should be able to use one of these heat exchangers for each VME crate.