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To: EDGES Group

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Subject: Airflow test results and insulation mounting

Airflow Test Results

The EDGES experiment requires an extremely low noise environment and was determined that Western Australia gives the best chance to capture the very faint Epoch of Re-ionization signal. However, due to the high average temperatures of Western Australia special consideration for cooling must be taken into account. This memo will detail development of the special system designed to cool the EDGES antenna.

The EDGES antenna is planned to be installed atop a large ground plane mesh field with a control hut located some distance away. Internally the EDGES antenna electronic package is expected to generate ~100 watts of heat. The antenna will be covered with 1inch thick closed cell polyurethane foam to provide mitigation against condensation formation on the metal antenna panels and to limit coupling to the hot mid-day air. The antenna has been designed with an air flow path that will use a fan inside the control hut to pump air through buried pipes as well as into and across the EDGES antenna. Cooling for the system is provided solely by the long contact path the air tubes will have with the cooler ground from the antenna to the hut and back.

Previous air flow calculations indicated that a Sanyo San-Ace-60 fan would provide sufficient flow rates through the EDGES system to maintain electronics within operating temperatures. Verification tests were completed by assembling a representative EDGES antenna without electronics. As an attempt to simulate an environment similar to what the system will experience in Australia, the test was conducted midday outside during the summer months in Westford, Massachusetts. To simulate the heat produced by electronics, a 90-watt incandescent bulb was installed inside the antenna. To simulate the buried pipe, the piping was instead submerged in a bucket with ice water. This setup was not necessarily fully representative of the planned setup in Australia, but it allowed for sufficient analysis of the air flow through the system. Figure 1 below shows the test set up.



Figure 1: Outdoors Experimental Test with San-Ace-60 Fan

At three points the air temperature was measured using 12bit digital probes (DS18B20) sampled at .2Hz using a Raspberry Pi recording data to a SD card. The three temperature probes were located in the vacant side, lamp side, and upstream pipe as in Figure 2 below.

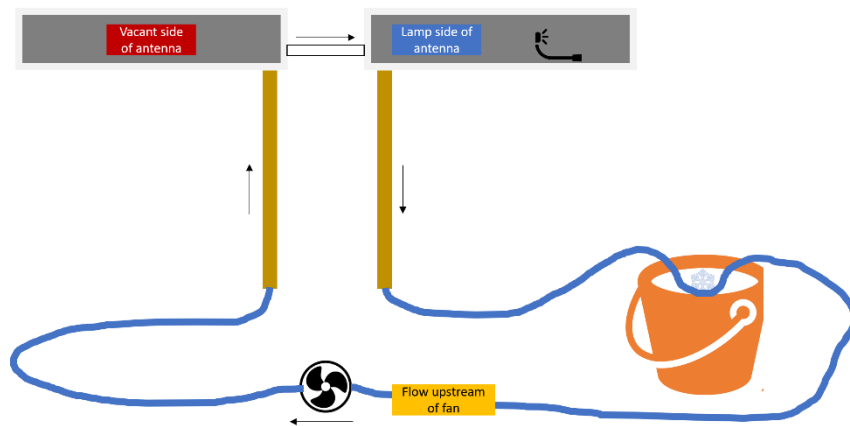


Figure 2: Temperature Probe Locations

Testing was completed on August 27th, 2021. Shown below in Table 1 were the weather conditions at start of testing which roughly remained constant for the duration of testing. Cloud coverage was partial.

Parameter	Value	Unit
Temperature	27	°C
Humidity	71	%
Wind speed	1.3	m/s
Visibility	10	mi

Table 1: Environmental Conditions for 08 12 2021 Testing

Figure 3 below shows the thermal test results from testing.

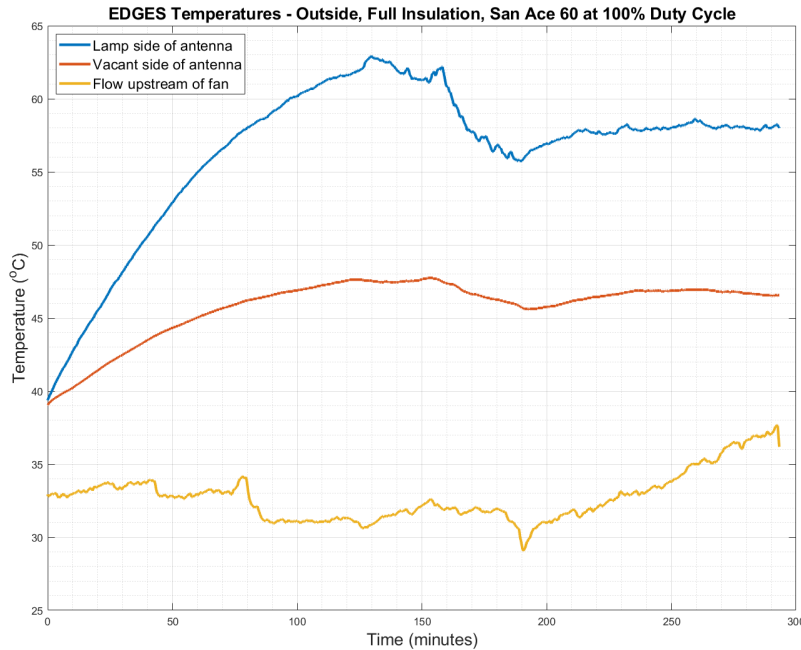


Figure 3: Outdoor Thermal Results with San-Ace-60 Fan

The 10 °C temperature difference between the two sides of the antennas is higher than acceptable and indicates that sufficient air flow is not achieved through the antenna using the San-Ace-60 Fan. As a result, two higher performance blower fans by Micronel (U100L-024K-4 and U100H4-024KA-4) were procured. Additionally during the test it was found that the spray glue method of bonding the insulation panels was insufficient, tape was used to make repairs to continue testing. Improvements for the insulation construction will be discussed at the end of this memo.

The testing was repeated in the same way as before with the new Micronel blower fans with the below configuration changes.

- Test conducted inside
- 90-watt lamp heat source moved to other side of antenna to appropriately resemble the field configuration of the electronics and flow path.
- Temperature probe added downstream of blower, only for test with U100H4-024KA-4

This updated test configuration is depicted in Figure 4 below. Figure 5 shows a diagram of temperature measurement locations used for testing. The thermal test with the U100L-024K-4 did not however have a temperature probe measuring temperature downstream of the blower.

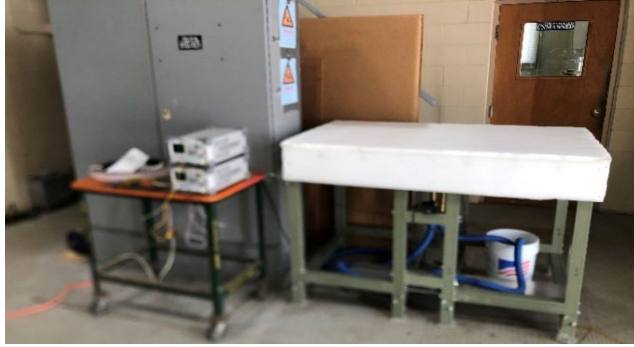


Figure 4: Indoor Test Setup with Micronel Blower Fans

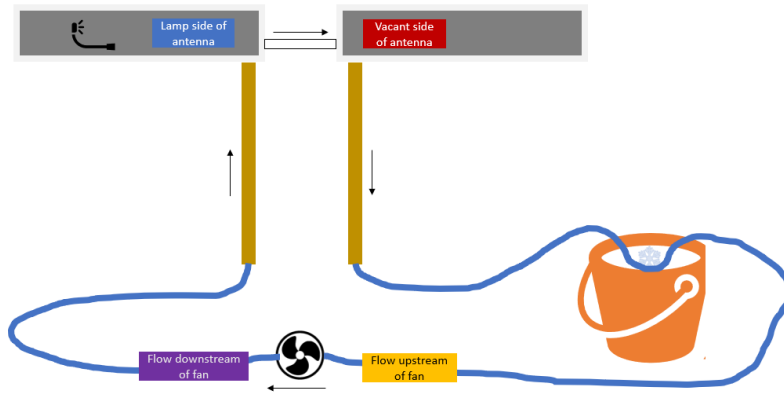


Figure 5: Temperature Probe Locations for Micronel Blower Fan Tests

Figure 6 shows thermal test results with the U100L-024K-4 blower and Figure 7 shows thermal test results with the U100H4-024KA-4 blower.

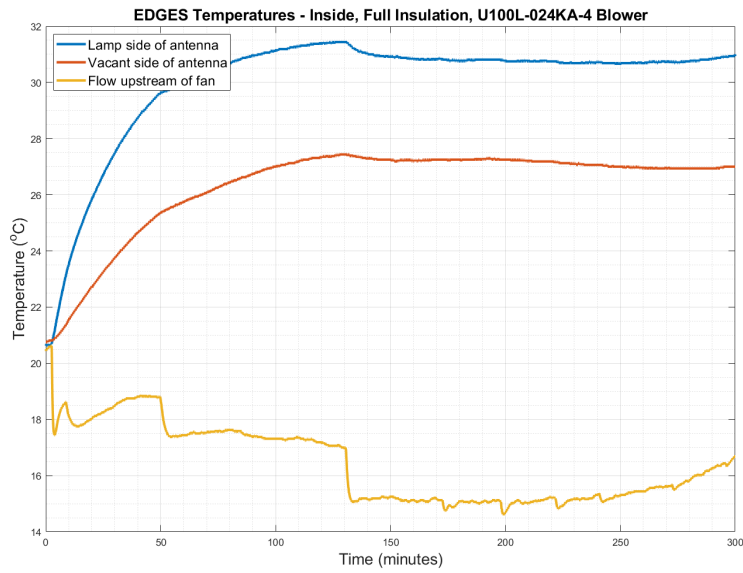


Figure 6: U100L-024K-4 Test Results

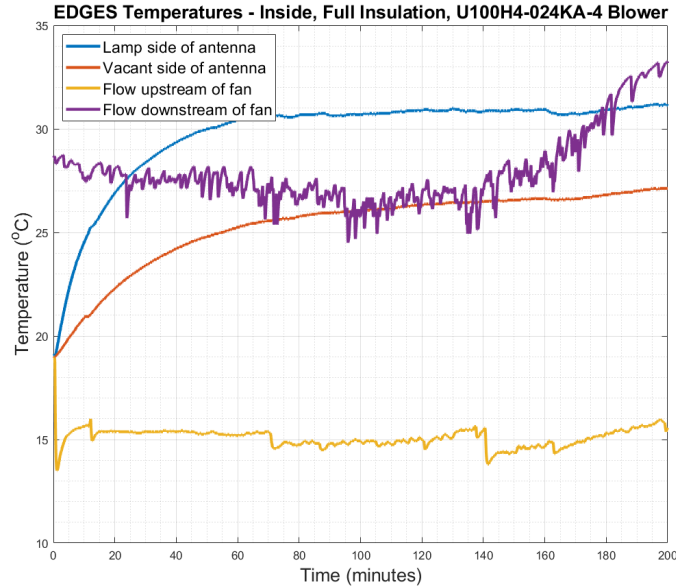


Figure 7: U100H4-024KA-4 Test Results

Table 2 shows fan & blower performance from each test discussed above:

Fan/Blower	V (V)	I (A)	P (W)	Fan Temp (°C)	Ambient Temp (°C)	Avg ΔT over antenna (°C)
San Ace 60	12	3.3	40	Not recorded	27	11.23
U100L-024K-4	24	5.6	124.4	Not recorded	21	3.67
U100H4-024KA-4	24	9	216	31	20	4.4

Table 2: Thermal Performance of Fans Used in Thermal Testing

Conclusions

Compared to the San-Ace-60 fan both of the Micronel blower fans yielded a clear improvement in air circulation and significantly better differential of $\sim 4^{\circ}\text{C}$ vs 20°C between the two sides of the antenna. This temperature differential of 4°C indicates a flow rate of approximately 1.1 m^3 per minute for both Micronel fans. When deciding between the lower or higher power Micronel blower fans if supply power is not a concern the higher powered U100H4-024KA-4 should be employed as it provides a higher static pressure than the U100L-024K-4 blower. If supply power is limited, test results indicated that the U100L-024K-4 will produce sufficient air flow for the EDGES system but we must be careful about keeping air resistance of the system in check. Future tests should now be conducted outside to accumulate data on representative temperatures of the system with Micronel blowers installed.

Additionally, the second Micronel test with the U100H4-024KA-4 blower gave some insight into the flow temperature downstream of the fan (purple line in Figure 7). The blower was turned on 15 minutes prior to the lamp and Raspberry Pi data logging being turned on. This could explain the high starting temperature of the downstream temperature sensor relative to the other sensors. An additional factor playing into the downstream flow temperature could be a temperature increase per the compression of air by the Micronel blower in accordance with the ideal gas law. It would be valuable to compare downstream flow temperatures for the U100H4-024KA-4 versus the U100L-024K-4 blower to investigate temperature rise as a function of static pressure, as the U100H4-024KA-4 produces a higher static pressure at the same flow rates relative to the U100L-024K-4 blower.

Insulation Mounting

The insulation pieces were initially held together with 3M Super 77 glue. Outdoor testing proved that the glue alone was not sufficient in holding the insulation tightly to the antenna. To eliminate the need for glue and simplify the assembly process, barbed pins (McMaster #92410A415) were used to fasten the insulation together. To hold the insulation to the antenna, 1.5" 3M Dual Lock hook and loop with acrylic adhesive was used. To fasten the hook and loop to the insulation, the insulation was first scratched with a steel brush to improve adhesion properties. The hook and loop was then installed on the foam with Loctite 454 in addition to the hook and loop adhesive to ensure adequate adhesion.