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Event: SPIE Astronomical Telescopes + Instrumentation, 2014, Montréal, Quebec, Canada

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ABSTRACT

The Visible Integral-Field Replicable Unit Spectrograph (VIRUS) instrument will be installed at the Hobby-Eberly Telescope[†] in the near future. The instrument will be housed in two enclosures that are mounted adjacent to the telescope, via the VIRUS Support Structure (VSS). We have designed the enclosures to support and protect the instrument, to enable servicing of the instrument, and to cool the instrument appropriately while not adversely affecting the dome environment. The system uses simple HVAC air handling techniques in conjunction with thermoelectric and standard glycol heat exchangers to provide efficient heat removal. The enclosures also provide power and data transfer to and from each VIRUS unit, liquid nitrogen cooling to the detectors, and environmental monitoring of the instrument and dome environments. In this paper, we describe the design and fabrication of the VIRUS enclosures and their sub-systems.

Keywords: Telescopes: Hobby-Eberly, Astronomical instrumentation: Spectrographs—VIRUS, Spectrographs: Integral Field, Spectrographs: Assembly

1. INTRODUCTION

Visual Integral-Field Replicable Unit Spectrograph (VIRUS) is an instrument that will support observations for the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) Project[1]. HETDEX will use VIRUS with the upgraded Hobby-Eberly telescope (HET)[2] to probe the nature of Dark Energy at high redshifts[3]. VIRUS is comprised of 130 to 156 optical spectrographs, which are collaboratively built by the University of Texas, Texas A&M University and University of Potsdam[4]. The VIRUS units are projected to be completed by late 2014.

This paper describes the conceptual and prototyped designs along with fabricated components for the enclosures and its HVAC system that house and cool the VIRUS units. These enclosures are necessary to protect and cool the units as well as house the computer and electrical systems that power VIRUS and transfer its data.

1.1 VIRUS Instrument Overview

The VIRUS instrument consists of between 130 and 156 simple fiber fed optical spectrographs. The unit spectrographs are assembled in pairs, and consist of a simple Schmidt spectrograph (referred to as the "collimator") with an on-axis Schmidt vacuum camera. A volume phase holographic (VPH) grating provides a wavelength range of 350-550 nm. The detailed optical[5] and mechanical[6] designs of the instrument are described in more detail in other papers. The VIRUS unit spectrographs will be housed on the sides of the telescope structure, where each spectrograph is fiber-fed from the focal plane of the HET. Figure 1 shows a rendering of a pair of VIRUS unit spectrographs.

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[†] The Hobby – Eberly Telescope is operated by McDonald Observatory on behalf of the University of Texas at Austin, Pennsylvania State University, Ludwig-Maximillians-Universität München, and Georg-August-Universität, Göttingen.

Ground-based and Airborne Instrumentation for Astronomy V, edited by
Suzanne K. Ramsay, Ian S. McLean, Hideki Takami, Proc. of SPIE Vol. 9147,
91476U · © 2014 SPIE · CCC code: 0277-786X/14/$18 · doi: 10.1117/12.2057040

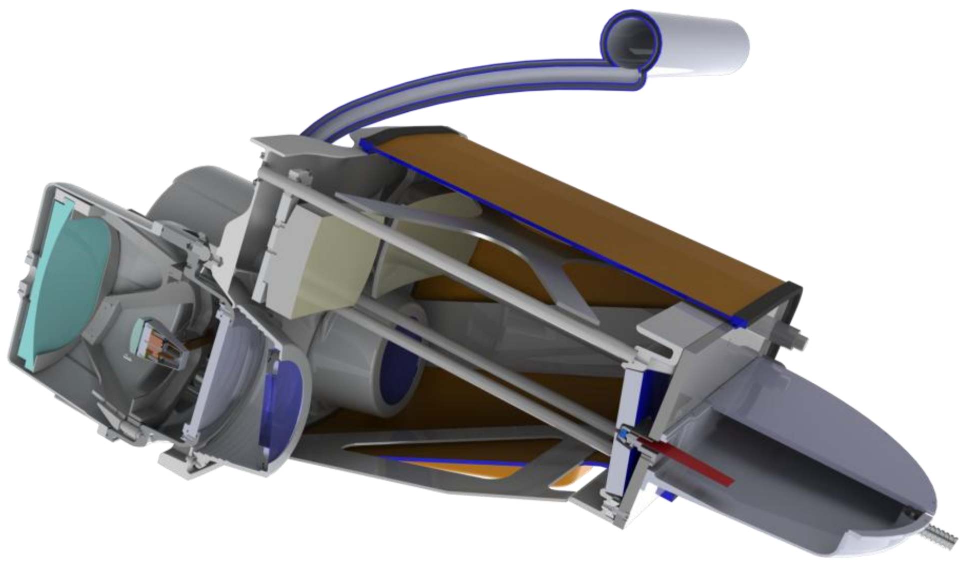

Figure 1. Section view of a pair of VIRUS spectrographs. The fiber head is shown on the right. Light from the fibers enters the instrument and is collimated by the oblong spherical collimator mirrors (upper center left). The light is reflected by a folding flat located around the fiber feed (center right), and into the grating (lower center left) which is mounted in front of the vacuum Schmidt cameras (left).

1.2 Current Enclosure Positioning

The two enclosure structures will mount to the VIRUS Support Structure (VSS)[7], which is made from free-standing frames, linked together by two trusses, as shown in Figure 2. The VSS is isolated from the telescope structure, which ensures loads are not transferred to the telescope by the enclosures during wind gusts. During rotation, the VSS will share the HET's azimuth drive to simplify the system, but will decouple after the rotation is complete.

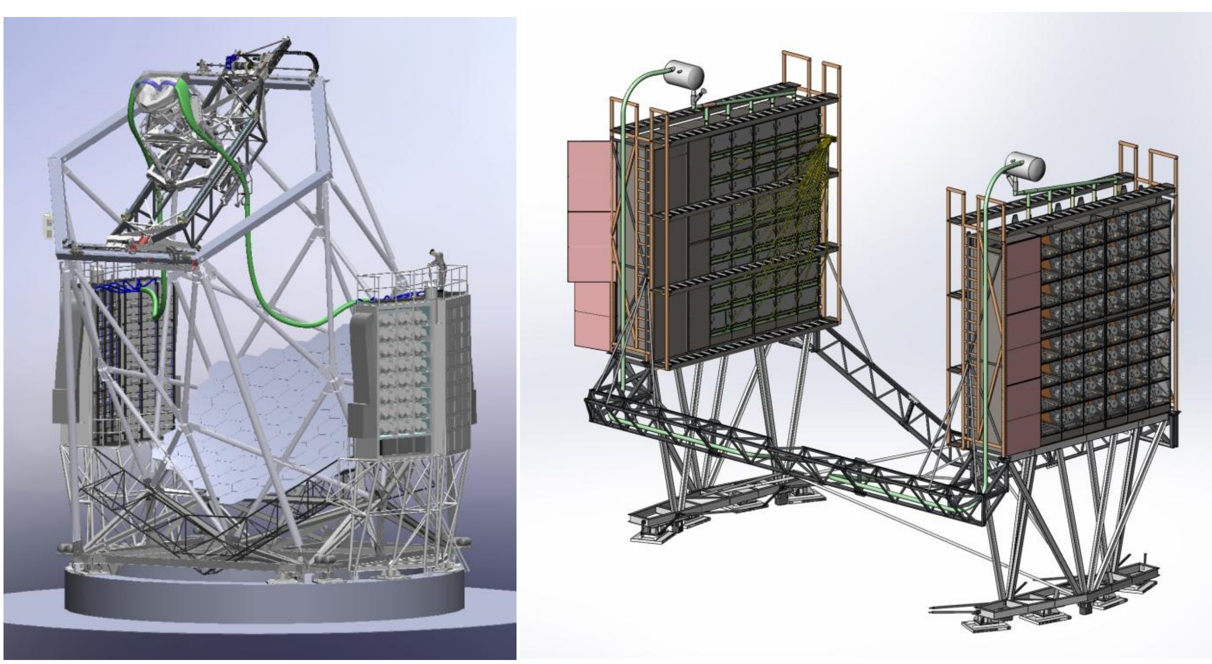

Figure 2. Left: a rendering of the HET with the VSS, enclosures, and IFUs. Right: the VSS and enclosures without HET for clarity.

The VSS holds the enclosures ~5m above the ground on either side of the telescope structure. They are held at this height to shorten the required length of the fiber bundles, but are not any higher which ensures the instruments and enclosures can easily be served with man lifts as well as reduce the complexity of the VSS. The enclosures are positioned 180° from each other around the telescope to create a more optimal path to run the fiber bundles as well as keeps sections of the telescope more accessible for maintenance. The VSS has already been fabricated and is installed and fully functional at HET[8].

1.3 Enclosure Structure

Each enclosure structure is primarily made of 4 weldments that are bolted together to form the area that houses up to 40 VIRUS units. The enclosure is broken into small weldments to reduce manufacturing cost and keep them small enough to easily transport. Two additional weldments are bolted to the side of the housing area to form the enclosure annex. The annex will hold the power, control and data systems that connect to the VIRUS units. The HVAC system for the enclosure and its annex will also be contained in the annex space. The enclosure weldments have already fabricated and are currently being assembled at Texas A&M University, as shown in Figure 3.

Figure 3. Left: the first VIRUS enclosure being stacked at Texas A&M University; right: a model of the enclosure with the added annex.

Each enclosure will also hold a liquid nitrogen system on its roof. This system cools the VIRUS detectors so they can achieve their science goals. The liquid nitrogen will be gravity fed to a manifold and flow down vertical pipes terminating with a cold finger at the location of each spectrograph pair which will be plugged into a VIRUS unit during normal operation. These tanks will be refilled from a larger external tank via an automated control system. The exact method of attaching the tanks to the enclosure is still being developed at the moment.

2. INSTRUMENT HOUSING

2.1 Mounting Rails

One of the most fundamental requirements of the enclosure is to securely hold the VIRUS units once they are installed and operating at HET. The VIRUS units have two stainless steel rails on either side that are used to support their weight. These rails are used to hold each unit within the structure using a kinematic mounting system that will not induce any stress in the VIRUS instrument. The mounting system uses a v-groove for one rail and a piece of angle iron on a fulcrum for the other as shown in Figure 4 & Figure 5. A simple zip tie is used to secure the rails so the instrument cannot slide out of the enclosure.

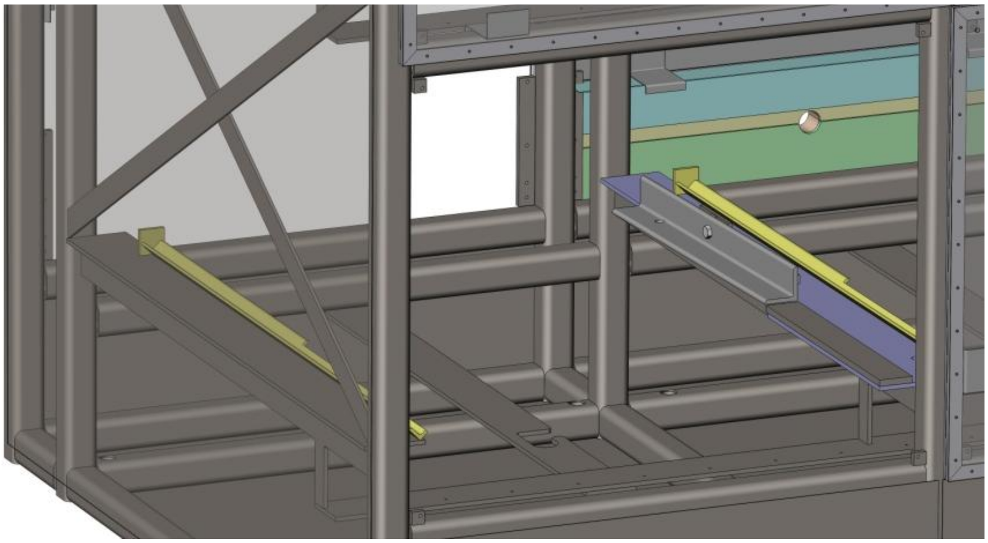

Figure 4. A model of the enclosure mounting rails that will hold the VIRUS units.

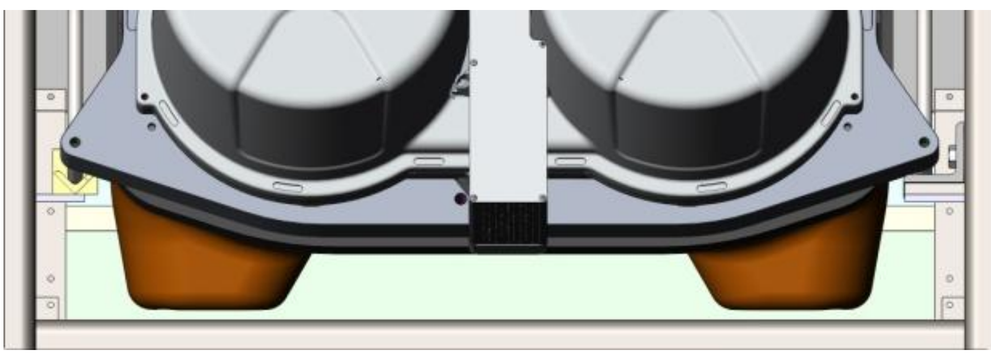

Figure 5. The VIRUS unit will sit on the v-groove and angle iron.

2.2 Enclosure Doors

Each instrument will have its own set of access doors, one that opens towards the dome and one that open towards the telescope. These doors are used to install, remove, and service the VIRUS instruments. These doors are required to be light weight for ease of use, have captured thumb screws to prevent hardware and tools falling from 12m (39ft) to the ground, be thermally insulative to help inhibit heat flow in and out of the enclosures, and have sealed edges to prevent dust in the air & with stray light from entering the enclosure.

2.2.1 Material

The light weight and thermally insulative requirements were both solved by using a plastic-foam composite as the main door material. This material is made of 23.4mm (1in) extruded polystyrene (XPS) foam that is sandwiched between two

1mm thick sheets of PVC. This results in the complete doors being less than 2.55kg (5.6lb) with great thermal properties.

2.2.2 Seals

To keep the enclosures sealed, we place foam rubber seals on the inner side of the doors along its edges. These seals will press against the enclosure frame to keep the enclosure pressurized. Ultimately, the enclosures will be over pressurized by adding clean nitrogen at 2.36 x 10^{-3} m^3/s (5 scfm), so the doors are not required to make a perfect seal.

To select the appropriate seal, we tested a variety of seals on our enclosure prototype (Figure 6) and evaluated the complexity of their installation. To test a seal's efficacy we measured the pressure at various flow rates as well as timed how long the pressure took to reach zero from a set initial pressure after the air was shut off. We also tried several methods to attach the seal to the panel. We found that the seals with a pre-applied adhesive back were simpler to install than those that required glue to attach, and we found that seals which required 90° cuts at the corners were considerably easier to work with than those which required a 45° miter. From these trials we have decided to use the seal shown in Figure 7.

Figure 6. The enclosure door design installed on the enclosure prototype to test the amount of pressure it can hold with varying flow rates.

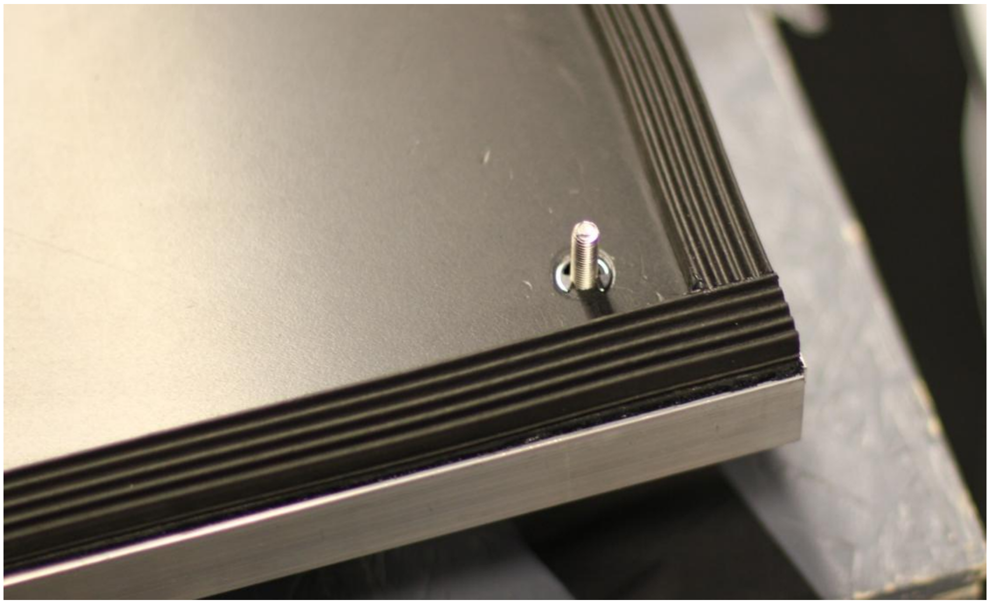

Figure 7. The seal selected for the enclosure door.

2.2.3 Hardware

We will assemble captured thumb screws using off the shelf components to avoid the expense of custom-made screws. We will use standard socket head cap screws (M6x1) with press on thumbscrew heads. Once the screws are inserted in the doors, an e-clip is placed on the threads to secure the screws from coming out of their holes, as shown in Figure 7.

When the foam-plastic panels arrive from the supplier, there is nothing protecting the exposed foam on the sides. To keep the foam in the panels from being damaged, angle aluminum will be glued to the outer edge. This edging also has the added benefit of stiffening the edges, which reduces the amount of bowing under pressure. This corrects a problem we found in previous sheet metal designs, where the doors would bulge open under pressure, losing their seal because the edges weren't stiff enough. Thin aluminum tubes will also be added inside the screw holes to protect the foam from wearing away around the screws.

3. THERMAL MANAGEMENT SYSTEM

The enclosure thermal management system has two main purposes: first, to keep the VIRUS electronics boxes and equipment from overheating; second, to prevent heat from escaping the enclosures' skin into the dome. To keep the VIRUS electronics boxes cool, air is sucked through the boxes via a vented duct system. This hot air then passes through a series of fin-tube heat exchangers to cool the air to ambient temperatures and returned to the open area of the enclosure. The heat exchangers are cooled with ethylene glycol and water (EGW), which is supplied by the telescope facilities and carries the heat outside of the dome environment. Matching the air temperature inside the enclosures to the ambient dome temperature eliminates heat transfer in or out of the enclosures under nominal conditions. As a backup, to ensure that large temperature swings do not induce heat transfer, insulation will be added to the enclosure walls and the openings will be sealed.

There is a separate and isolated cooling system for the enclosure annex. This cools the electronics used to run the VIRUS instruments as well as the blower used to circulate the air in the enclosure. This air will be several degrees above the dome ambient, so extra care will be taken to ensure the annex is well insulated and sealed from the dome and enclosure structures. The areas being cooled and air flow direction can be seen in Figure 8. The sections below will describe more details of the thermal management system.

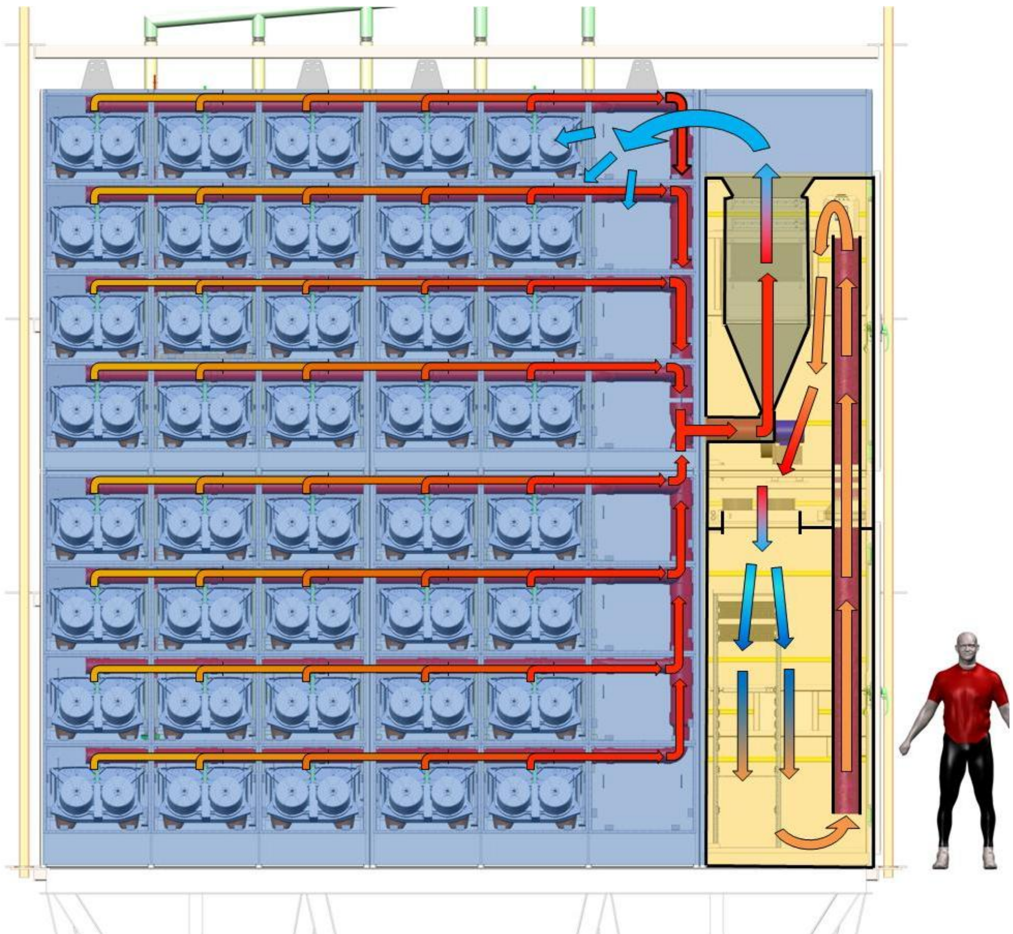

Figure 8. Illustration of the two HVAC zones. The blue area on the right is for the enclosure which houses the VIRUS units, and the yellow area is for the enclosure annex which holds the VIRUS electronics equipment and enclosure cooling system.

3.1 Expected Heat

Every VIRUS electronics box, the blowers, and other electrical equipment will generate heat that will need to be removed from the enclosure. In the main enclosure, each VIRUS unit will consume 20W of power, so for each enclosure 800W should be generated by the instruments. With a margin and adding extra power from the blower and wires, we estimate up to 1200W may need to be removed from the main enclosure area.

For the Annex, the primary heat sources are the VIRUS electrical equipment, and blower for the enclosure air. The electrical equipment and computers will consume 765W and the blower is rated for 1118W (1.5hp). Including the annex fans and adding a margin, we estimate up to 2770W will need to be removed from the annex area.

3.2 50/50 Ethylene Glycol & Water

The heat in the enclosures will be removed via 50-50 mixture of ethylene glycol and water. 1.01×10^{-3} m^3/s (16 gal/min) of EGW is provided by the telescope facilities to each enclosure and will be chilled to maintain temperature to match the ambient dome temperature. If additional cooling is required, the EGW temperature could be reduced by another 2°C, but any lower temperature could cause condensation on the fluid lines during humid weather.

3.3 Heat Exchangers

To move the heat in the air to the EGW and out of the enclosures, fin-tube heat exchangers are used in the system. In the main enclosure HVAC system we use two heat exchangers in series to remove the heat and match the air temperature to the ambient dome temperature. Two heat exchangers are used because the EGW temperature is at ambient temperature;

if only one heat exchanger were used, the exiting air temperature could never reach ambient. To overcome this problem, we use a second heat exchanger that has EGW cooler than the standard facility EGW to bring the air temperature down to dome ambient temperatures. This cooled EGW is on a separate loop and is chilled by a thermoelectric cooler (TEC) system.

3.4 Thermoelectric Cooler

The thermoelectric cooler used to cool the secondary heat exchanger is an off the shelf system called the Thermocube® made by Solid State Cooling Systems© as seen in Figure 9. This system can remove up to 600W from its processed fluid and move it directly to the facility EGW. This TEC has its own fluid reservoir and pump that will move its EGW at 6.31 x 10^{-5} m^3/s (1 gal/min) through the heat exchanger. It also has a built in PID controller that can hold the processed fluid temperature to with ±0.05°C of the set point temperature.

Figure 9. The thermoelectric cooler used in the enclosure HVAC system.

Ultimately, to keep the exiting heat exchanger air temperature tracking the dome ambient temperature, we could not use the standard set point input controller. We developed a custom controller that can properly track the ambient temperature. This controller uses a National Instruments CompactRIO® real time controller with an RTD module. We currently use two air RTDs on the controller, one measuring the enclosure's temperature and one measuring the dome's temperature. With the temperature data our controller will iteratively calculate the set point temperature which the TEC will use to cool its fluid.

To check the validity of the controller and TEC before we integrate them into the actual system, we set up a smaller HVAC system to run the TEC, controller and heat exchanger. We built a closed loop air flow system incorporating one of the heat exchangers, fans and a space heater. The heat exchanger was plumbed to the TEC with our controller. Another heat exchanger, fan and pump were set up to simulate the facility EGW and carried the heat into the room. With this setup we could monitor the temperature inside and out of the loop as we activate our TEC/controller system and add more heat with the space heater. Figure 10 and Figure 11 show the TEC & controller's ability to track the ambient room temperature and heat is added to the closed loop test system. In the figures, the large bump is caused by the addition of 220W when the heater was activated. This brought the total power up to 370W, since 150W were already being generated by the fans. These graphs show that after a couple of minutes the TEC was able to remove enough of the additional heat and bring the temperature back down to the ambient temperature where it continued to track ambient within 0.1°C.

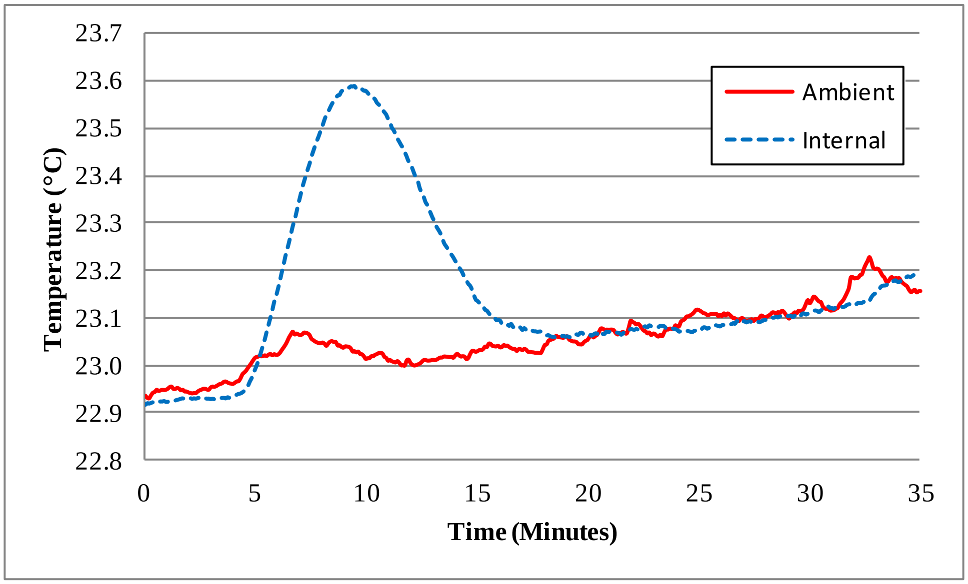

Figure 10. Temperatures of the air inside and out of the closed loop test system. The bump in internal temperature starts when the 220W heat is activated.

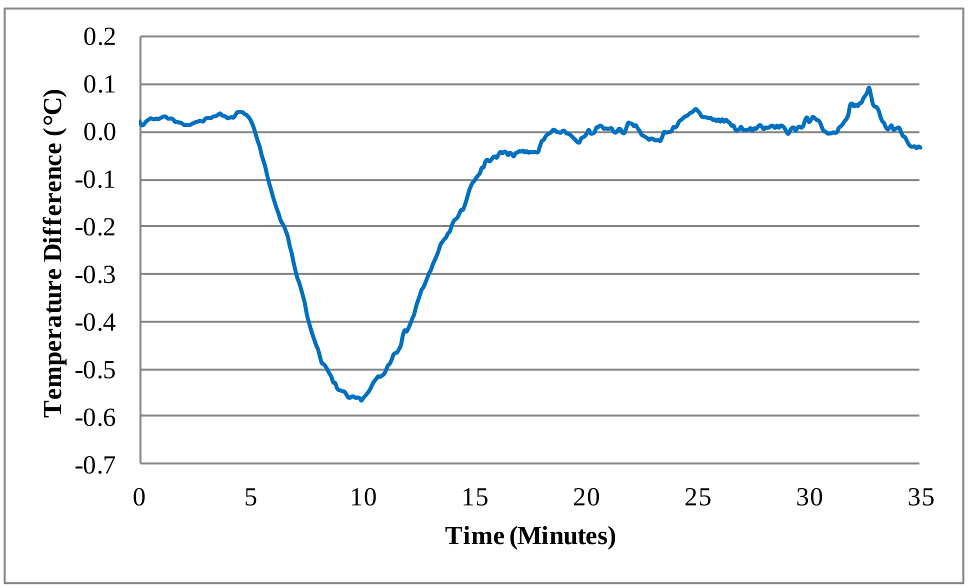

Figure 11. Differential temperatures of the air inside and out of the closed loop test system. The bump in internal temperature starts when the 220W heat is activated. This shows that for the test loop, it was able to track the temperatures within 0.1°C.

3.5 Blower

The suction used to pull air through the 40 VIRUS electronics boxes will be generated by a single blower placed in the annex. The blower selected is a 1.11kW (1.5hp) direct drive centrifugal blower with radial impellers. According to its performance curves and the data we have collected, the blower should move 0.28 m^3/s (600 CFM) at 1kPa (4" H_2O) to 0.35 m^3/s (750 CFM) at 0.5kPa (2" H_2O), which is the range at which we estimate the system will run. This results in approximately 7.08 x 10^{-3} m^3/s (15 CFM) flowing through each box which will increase the exiting air temperature by ~7°C.

3.6 VIRUS Electronics Box Airflow Adapter

In order to attach the VIRUS electronics boxes to the ventilation system a unique adapter had to be designed. There were no attachment hardware or features on the electronics boxes, and the airflow slots could not be obstructed. We designed an adapter that could hold onto the bare metal on the side of the box without blocking the slots. The inside of the adapter is lined with a silicon foam rubber seal that grips the box and ensures that the air flowing into the adapter is only coming from the electronics boxes, as shown in Figure 12.

The adapter will connect to the rest of the HVAC duct work via a flexible hose as shown in Figure 12. This hose allows the adapter to be moved out of the way when a VIRUS unit is added or removed from the enclosure. It also acts like a spring and pushes the adapter against the electronics box, giving it a better seal.

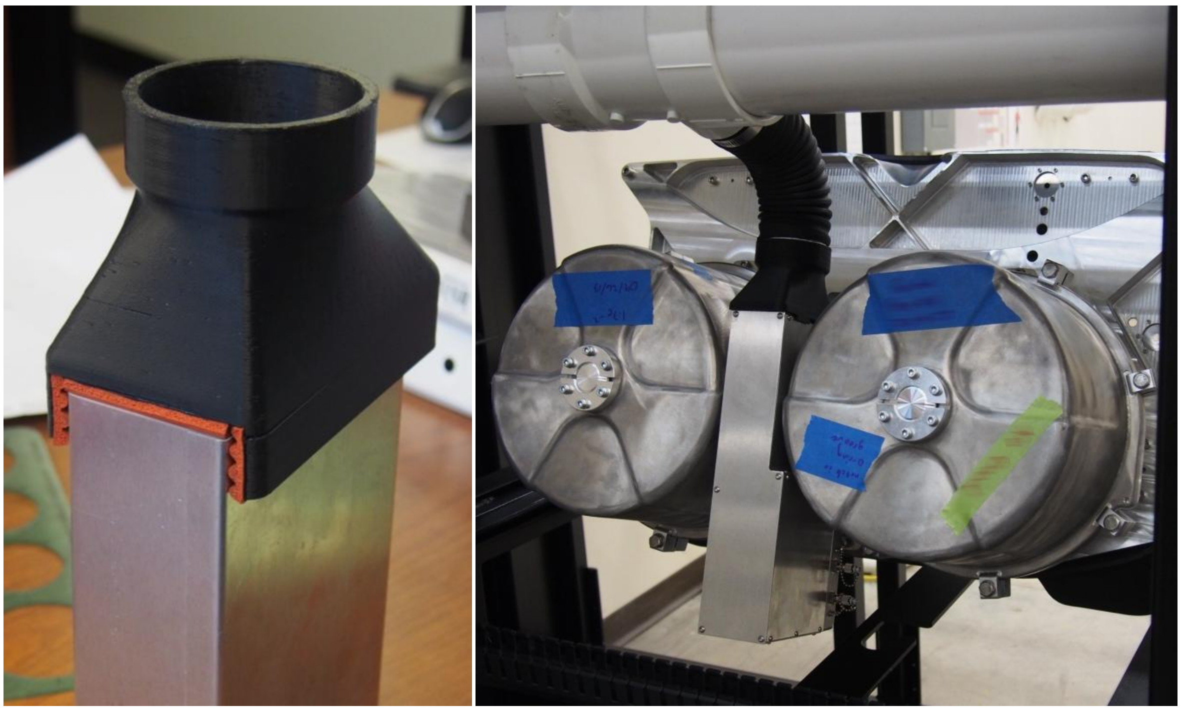

Figure 12. Left: the VIRUS electronics box airflow adapter sitting on a mock electronics box. Right: the adapter on a production electronics box in the enclosure, attached to the flexible hosing and duct work.

3.7 Filtration

Air filters will be added to the airflow system primarily to prevent dust and other particles from settling on the instruments' optics and eventually reducing instrument throughput. These filters will also have the added benefit of reducing dust build up on the heat exchanger fins and electrical components which will prevent the thermal conductivity from deteriorating over time. The filter selected will remove 99% of the particles down to 0.3 microns in size. There will also be a pre-filter to remove a majority of the large particles to extend the life of the high efficiency filters.

3.8 Insulation

Insulation will be added to the interior faces of the walls to dampen temperature changes of the system. It also reduces the heat transferred in case the TEC and controller do not properly track the ambient temperature as expected. A majority of the surface is already insulated by the foam from which the enclosure doors are made, as described above. The rest of the walls, floors and roofs will be insulated by 50.8mm (2in) thick extruded polystyrene (XPS). This foam has a thermal resistance rating of 1.76 $°C \cdot m^2/W$ (R-10) and should fit flush between the 50.8mm (2in) box beams in the frame.

3.9 Annex Cooling

The enclosure annex will have its own cooling system separate from the enclosure's. This system uses a similar heat exchanger as used in the enclosure, but has four 25.4cm (10in) fans mounted directly to it. To force the air to circulate completely in the annex, the top and bottom halves of the annex are sectioned off with only the heat exchanger and a larger section of duct going through, as shown on the right side of Figure 8. This forces the air to enter the duct at the bottom of the enclosure and exit at the top, ensuring that the air is properly circulating and passing over heat generating equipment. In the annex cooling system, our calculations show that with the estimated 2770W generated the annex's temperature will be about 10°C above ambient.

4. CONCLUSIONS

With the VIRUS unit assembly finishing before the end of 2014, the instrument enclosures must be installed at the HET soon. Construction of the enclosures is well underway, with all of the major components designed and many of them fabricated. We plan to deliver the first enclosure to HET by early September 2014 and the second enclosure in October. The delivered enclosures will be able house up to 80 fiber-fed VIRUS units and cool them without leaking an adverse amount of heat into the dome environment.

ACKNOWLEDGEMENTS

Texas A&M University thanks Charles R. and Judith G. Munnerlyn, George P. and Cynthia W. Mitchell, and their families for their support of astronomical instrumentation activities in the Department of Physics and Astronomy.

HETDEX is run by the University of Texas at Austin McDonald Observatory and Department of Astronomy with participation from the Ludwig-Maximilians-Universität München, Max-Planck-Institut für Extraterrestriche-Physik (MPE), Leibniz-Institut für Astrophysik Potsdam (AIP), Texas A&M University, Pennsylvania State University, Institut für Astrophysik Göttingen (IAG), University of Oxford and Max-Planck-Institut für Astrophysik (MPA). In addition to Institutional support, HETDEX is funded by the National Science Foundation (grant AST-0926815), the State of Texas, the US Air Force (AFRL FA9451-04-2-0355), by the Texas Norman Hackerman Advanced Research Program under grants 003658-0005-2006 and 003658-0295-2007, and by generous support from private individuals and foundations.

We thank the staffs of McDonald Observatory, AIP, MPE, TAMU, Oxford University Department of Physics, and IAG for their contributions to the development of VIRUS.

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