Astronomical Adventures

An Occasional Series on Building, Outfitting and Operating a Remote Observatory

By Manny Leinz

The first five parts of this series detailed the initial steps to realizing my dream of building a remotely operable astronomical observatory at our vacation home in Mariposa, Ca. Episodes 1 - 5 covered planning, building, initial outfitting and first steps toward autonomy and were featured in prior issues of Prime Focus, starting in 2019.

Episode 6 – Thermal Considerations

When we first purchased our Mariposa property in 2014, I assumed that — at an elevation of about 3,000 feet — the weather would be generally cooler than in Southern California. It snowed the first winter and I assumed summers would be cooler as well. In fact, summer temperatures are sometimes several degrees warmer than in Southern California, reaching temperatures of up to 106 F on the hottest days. As work has continued on the observatory, I've been concerned about how best to keep the sensitive optics and electronics inside thermally "happy" over this wide temperature range.

Recognizing that many others had already confronted this problem, I turned to online forums, such as "Cloudy Nights" to hopefully glean some wisdom. I found many different opinions on how best to implement observatory thermal design; what I did not find was any data to back up the assertions being made.

Rapid cool down is important to minimize the distorting effects of warm air currents on the imaging train. For this reason many people advocated leaving walls unfinished; others suggested that pegboard, with it's ability to 'breathe' is a good choice. Many people warned against using insulation in the walls, for fear of trapping heat, lengthening cool down times, and spoiling "seeing". They instead recommended leaving the walls unfinished and adding a window type air conditioner or heat pump to control inside temperature.

What to Do? - Time for Some Thermal Design

Given these conflicting points of view, what is the right answer for my situation? I'm an engineer by training and so naturally I gravitated to an engineering approach to the problem. We start with some basic requirements:

1 First and foremost, the design should mitigate extremes in temperature—keeping the observatory cooler on hot days and warmer on cold days.
2 The temperature of the structure should rapidly – preferably within an hour or less—adjust to ambient when the roof is opened.
3 The design should be aesthetically pleasing – no visible 2x4 studs, please.
4 A passive design – i.e., no heat pumps or air conditioners – is preferred.

Absent an air conditioner, insulation will be needed to keep the inside temperature under control – otherwise the observatory will trap heat and the internal temperature will soar above the outside air temperature, particularly in the hot summer months. The trick will be selecting the right kind of insulation.

Rapidly adjusting to ambient temperature is where insulation selection becomes important. Typical fiberglass or 'blown' insulation works by absorbing heat, which will be re-radiated to the environment when the roof is opened, extending the cooldown time. I quickly decided that a better approach is to use a 'radiant barrier', which insulates by reflecting solar radiation away from the interior space. A popular radiant barrier product is "Reflectix", which is effectively double layer "bubble wrap", with reflective surfaces on both sides.

In order to present a finished look to the observatory interior, some sort of wall board will be needed to cover the 2x4 studs. Once again, the key will be to avoid trapping heat. For this reason I selected 1/8 inch 'Masonite', rather than the typical drywall used in home construction.

Testing, 1, 2, 3

Once the materials had been selected, there were still important decisions to be made. I followed the manufacturer's recommendations for Reflectix installation: stapling between the wall studs while maintaining an air gap to both the observatory external siding and internal Masonite panels. Mounting of the Masonite panels presented a puzzle, however. Would observatory cooldown be enhanced by providing an air gap between the panel and the wall studs to release trapped heat? Before committing to a final design, I decided to test three separate Masonite panel mounting options:

1) Mounted flush to 2x4 studs
2) Mounted to 2x4 studs via nylon standoffs
3) Shorten panels to provide top and bottom vents

The mounting options are depicted in Figure 1. Option 1 is the simplest from an implementation standpoint, but results in a pockets of trapped air within the walls. Options 2 and 3 provide ventilation at the cost of some additional complexity. For aesthetic reasons I'm not a fan of the popular 'pegboard' option, so I didn't test that – options 2 and 3 should provide at least equivalent airflow. I temporarily mounted panels using all three options on the east wall of the observatory (see Figure 2).

In order to evaluate observatory thermal behavior against these options, I needed an effective method of measuring temperature simultaneously at multiple points. I bought a temperature logger, but it only supported four individual temperature sensors; plus getting the thermal data out of it for later analysis was cumbersome, so I returned it.

Easy As 'Pi'

A little online sleuthing turned up a better option. I found several projects that described a straightforward approach to making a 'DIY' temperature logger, using digital output temperature sensors and the popular "Raspberry Pi" single board computer (see the links at the end of this article for details). I happened to have a Raspberry Pi – a Pi3B – laying around, which I pressed into service. I found a pack of 10 digital

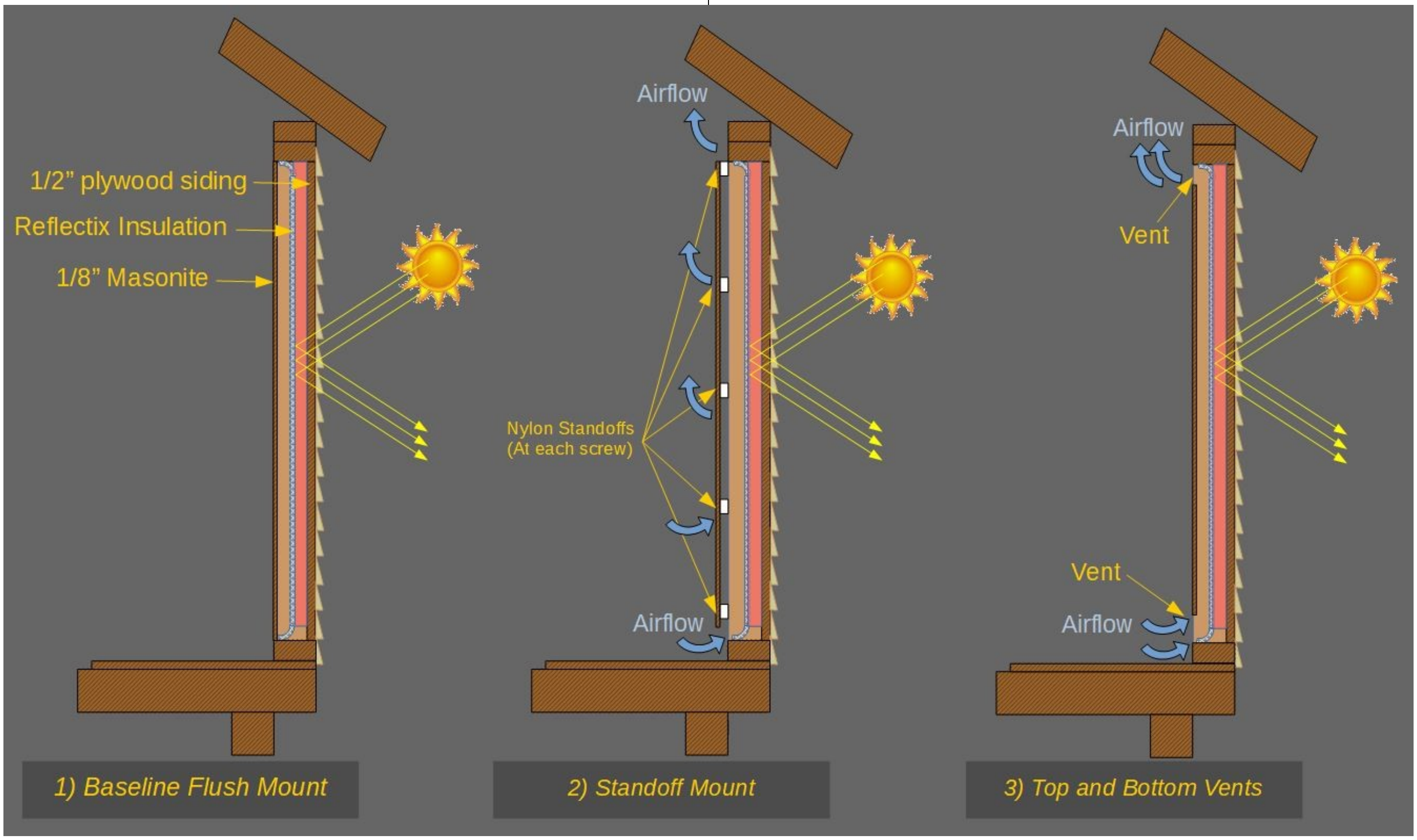

Figure 1. Masonite Mounting Options Tested

Figure 2. Observatory Sensor Wiring. Note Masonite Panels and Reflectix on Left (West) Wall.

temperature sensors – part No. DS18B20 – on 10 foot cables at Amazon for less than $30. I built a junction box to connect the temperature sensors in parallel to the Pi's General Purpose Input/Output (GPIO) bus. Then it just took a few lines of software code – and a bit of help from my software savvy son – to implement the logging function, and "Thermo-Pi", shown in Figure 3, was born.

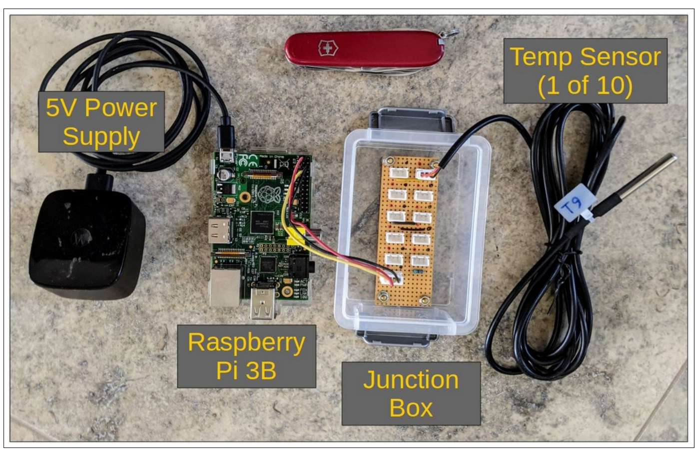

Figure 3. Thermo-Pi Temp Logger Ready for Action

Ten temperature sensors seemed like a lot, but – of course – I wound up using them all: three sensors (T4, T5 and T8, respectively) to monitor the aforementioned Masonite panel configurations, one for the telescope mirror housing (T9), one for the observatory air temperature(T10). The remaining five sensors monitored the interior roof and walls, which at the time had only some sections insulated with Reflectix. In addition, I collected data from our weather station to get an outdoor ambient temperature reading. The 'sensor spaghetti' can be seen in Figure 2. I collected data with Thermo-Pi in August of 2020, during which time the ambient temperature reached as high as 105 degrees. The findings were surprising.

And the Winner Is…

The first revelation, as shown in Figure 4, was that there is essentially *no difference* in thermal performance between the three paneling configurations – the three graphs (T4, T5 and T8) lie virtually on top of each other. Thus there is no benefit to the more complex mounting methods of options 2 and 3 – flush mounting works just as well. (For clarity, not all sensors are plotted on the graphs.)

Second, although the Reflectix insulation gets quite hot – note that T7 rose to a maximum of 118 degrees – heat is largely not transferred to the Masonite panels, which remained just two degrees above the outdoor ambient temperature.

Finally, and perhaps most importantly, when the roof was opened in the evening, observatory cooldown performance did not appear to be impacted by the Masonite/insulation wall covering. Again, all three panel mounting methods behaved similarly, as shown in Figure 4.   Note also that cooldown of the insulated and uninsulated walls (T3 and T1, respectively) tracked the walls covered with Masonite – *covering the walls didn't slow observatory cooldown at all!*

Figure 5 plots the difference between the observatory temperature sensors and the outdoor ambient temperature reported by our weather station. To determine telescope cooldown time, I used the observatory sensors' 'steady state' temperature as a baseline, rather than zero, since it appears there was about a 2.5 degree offset between the indoor and outdoor temperature sensors. Cooldown of the telescope primary mirror housing lagged cooldown of the walls, as expected. It took about 45 minutes for the mirror housing to cool to within five degrees of steady state. Unfortunately, I neglected to turn the telescope mirror fan on during the test. Had I done so, I expect that mirror housing cooldown time would have been shortened considerably.

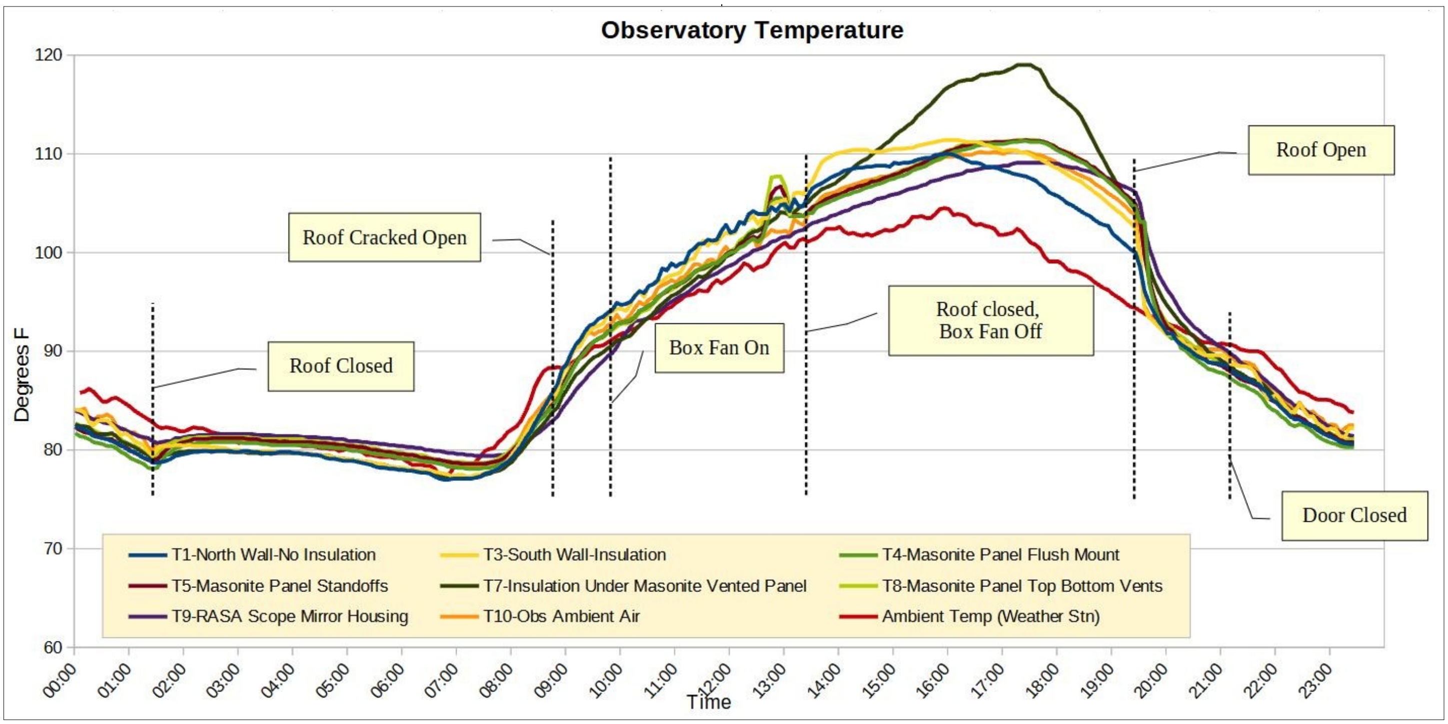

Figure 4. Observatory Thermal Performance Shows No Appreciable Difference Between the Three Paneling Configurations (August 17, 2020 Data)

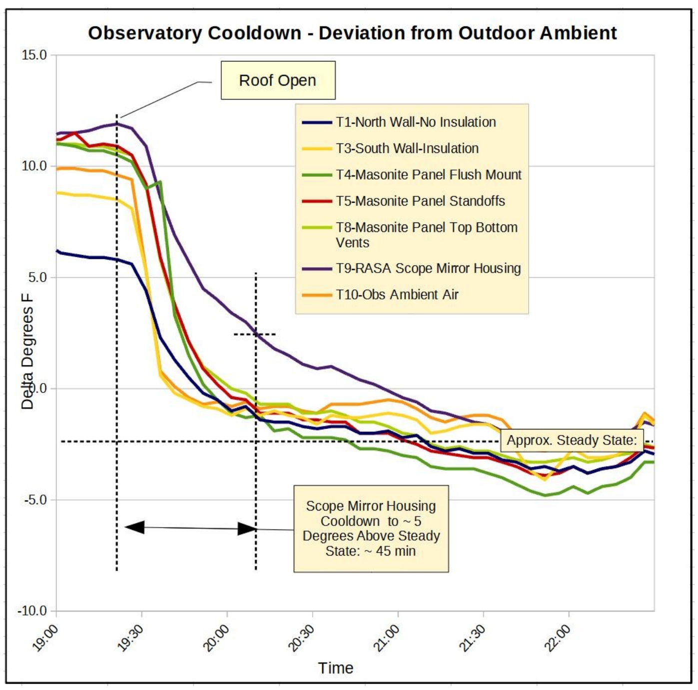

Figure 5. Observatory Cooldown Performance is Independent of Wall Covering.

Bottom Line and Way Forward:
A number of conclusions can be drawn from these experiments:

1. Insulation and wall coverings, done properly, do not adversely impact observatory cooldown performance. Venting is not required.
2. "Radiant Barrier' type insulation is an effective way to keep observatory interior temperature under control. (I performed later tests that showed observatory interior air temperature rises a maximum of about five degrees over outside ambient on the hottest days.)
3. I still need an air conditioner. Although the majority of the electronics in the observatory does not operate during the hot daytime hours, some systems, such as a UPS will need to operate and may be adversely effected.

I learned a lot doing these thermal experiments, and in the last year have nearly completed the observ-atory wall coverings. Yes, I know this seems like precious little progress in a year! The reason is that my priority has been on outfitting the observatory for remote operation. The next steps in that process will be the subject of Episode 7 in this series.

Next Episode: Moving Up the Autonomy Ladder

Links to online resources:
Reflectix Insulation: www.reflectixinc.com
Raspberry Pi General: www.raspberrypi.org
Raspberry Pi Temperature Logger (one of several): www.circuits.dk/temperature-logger-running-on-raspberry-pi
Questions? Feel free to contact me: manny.r.leinz@gmail.com