ROVOR: PROTECTION FROM THE ELEMENTS
ENSURING SAFE OBSERVATIONAL CONDITIONS

By

Aaron Paget

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Abstact

In order to assure safe operational conditions for the ROVOR telescope, safe atmospheric conditions must be verified. An established weather station provides data valuable in verifying conditions. Using barometric, temperature, relative humidity, and sensors in conjunction with an anemometer interfacing with LabView, the weather station will determine 1) condensation temperatures to protect the mirrors, 2) Protection from wind and rain, 3) Using the adiabatic rate to determine cloud level in order to assess meaningful observational conditions. This demonstrates detectable atmospheric conditions for safe astronomical observations, allowing remote operation of ROVOR to proceed safely.

Acknowledgements

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Chapter 1: An Introduction to the ROVOR Weather Station

1.1 Weather as a Problem

In the Spring 2005 Conference, Robert P. Kirshner, the President of the American Astronomical Society (AAS), stated during an informal question and answer session his disappointment in the lack of remote operated, fully automated telescopes being used in research.[1] The Department of Physics and Astronomy at Brigham Young University has developed a Remote Operated Variable Object Observatory (ROVOR) for such purpose, but the telescope cannot operate currently due to certain risks. The greatest risk to the remote operated telescope is verifying safe weather conditions. No accepted safety protocol currently exists for inclement weather.

In 1957, Vannevar Bush, chairman of the Office of Scientific Research and Development in World War II, noted the possibility of controlling the environment and make it more suitable for his purposes. He said, "The first steps are clear. In order to control meteorological matters at all we need to understand them better than we now do. When we understand fully, we can at least predict weather with assurance for reasonable intervals in the future."[2] The advent of technology brings great advances to the field, but new advances still require more understanding and discovery in Meteorology.

1.2 Atmospherically Safe Astronomical Observations

No controllable, favorable effects exist for those operating remote operated, fully automated telescopes; however the potential for monitoring the atmosphere exists. By taking a simplistic and reductionary approach to verify safe weather conditions, the possibility for protection for such telescopes from inclement atmospheric conditions, or weather, persists. Various conditions limit the use of these telescopes. In the case of ROVOR, sustained wind speed and precipitation such as rain and snow pose the greatest threats to the safe operation.

With no site technician present for the observatory, an on site weather station for ROVOR became the solution to the problem of verifying atmospheric conditions. The station needed to interface with the observatory computer and maintain operational integrity to withstand conditions in a remote location for extended periods of time. While no prefabricated weather station met the rigorous demands of sustained use without regular maintenance, individual prefabricated components existed to meet the robust required specifications.

1.3 Instrumentation

Various aspects of ensuring safe observational conditions do not fall within the scope of the paper. Recent advances in atmospheric research do not find major significance. The determining factors in the probability of precipitation come from long established principles of Meteorology. Determining the probability of precipitation will use a simplistic approach rather than advanced Meteorology techniques. Other available instruments, such as the anemometer and weather vane measure wind speed. Current atmospheric research utilizes specialized instruments not available.

Clouds preventing adequate observational conditions present the foremost of the problems faced. Determining the presence of clouds, underling the problem of safe observation falls into advanced Meteorology or optical systems. For ROVOR, the problem resides for the programmers of the optical reading for the telescope. The process takes a known value for a celestial object and compares the observed value to determine cloud coverage. If clouds do not exist, the observation will take place, if not, conditions indicate a poor night for observing. For raining conditions, cloud coverage exists. This paper will not go into any detail regarding clouds existing in the sky, only precipitation and wind speed. The design of the telescope and the building structure do not affect potential precipitation but are affected by wind speed.

The issues of determining the probability of precipitation and wind speed for the area surrounding ROVOR provide concern for safe operation. Safe operation criteria and limits, established for the telescope, exist. [3] The limits placed provide protection for the equipment. Repairs to the expensive equipment on ROVOR pose a greater cost than to let a few nights of observing go unused due to inclement weather. The paper will cover the possibility of precipitation and wind speed.

In determining and predicting rain fall and wind speed, the weather instruments from Texas Electronics collect information to complete the task: a rain gauge for measuring rain fall, a relative humidity sensor for measuring the moisture content in the air, thermocouples which act as thermometers in measuring the ambient temperature of various locations, a barometer for measuring the change in barometric pressure, an anemometer, and a weather vane. By measuring current precipitation, determining the adiabatic rate, determining the barometric stability of the atmosphere, and the wind speed surrounding ROVOR indicates safe observational conditions.

Chapter 2: Determining Current Precipitation

2.1 Monitoring Precipitation

Precipitation, defined as water particles in the atmosphere, either solid or liquid, which falls to the ground or on the buildings, poses a great threat. Both rain and snow are a concern for ROVOR. Both will damage the system. Water causes damage in electrical systems. The telescope system comprises of motors, limit switches, and a CCD camera as well as mirrors with expensive finishes. Precipitation directly on any of these components would cause severe damage. Therefore, monitoring rain and snow fall allows for prevention of harm to the instruments.

2.2 Description of 525 Rain Gauge and Operating Range

A simple way to actively monitor current rain fall utilizes a rain gauge. The ROVOR weather station uses aTexas Electronics Series 525 Rainfall Sensor with a 6.25 in diameter funnel. (See Figure 1) The rain gauge consists of a tip bucket system. Rain falls into the top of the funnel and drains through a small opening at the base. The water drips into a small bucket which is mounted on a fulcrum. After accumulating 0.1 mm (0.004 in) of water in the bucket, gravity causes the bucket to tip and drain out. (See Figure 2) The tipping action causes a second bucket to move into place to catch the dripping water. The second bucket fills and tips, restoring the first bucket to the original position to catch water. Each tip triggers an electrical counter which sends an electric pulse to the computer.

Despite the advantages, the system presents limitations. The rain gauge only gives accurate readings when the rain falls at 10 mm/hr (1 in/hr) or less, considered heavy rain fall. The cause results from the frequency of the drips from the funnel to the bucket. If the drips come down at a rate faster than 10 mm/hr, the correct bucket might not catch the drip, causing a slight error. The rain gauge must also be mounted correctly horizontally so the buckets do not tip prematurely or overfill. The system remains accurate up to 125°F and down to 32°F.

Figure 1. 525 Rainfall Sensor [4]

Figure 2. Tip Bucket Diagram

2.3 Conditions Relating to Rain Fall

Snow falling presents another issue. Snow forms from water and maintains a solid state. Water freezes at 32°F. The rain gauge reads water, not snow, rendering the gauge inoperable below 32°F. Snow will not run down the surface of the funnel like water from rain. To solve the problem, a heater coil resides in the rain gauge to heat the funnel and melt the snow. The heater contains an internal thermostat which turns on when the ambient temperature reaches 45°F. The snow melts and operates the tip buckets with water drips, just like rain. The power for the heater coil comes from 120 VAC power supply. [5]

The rain gauge, in conjunction with the heater system, determines the amount of precipitation in the form of rain and snow. The resolution and capacity of the rain gauge provide more than sufficient information for determining current precipitation. Determining the current precipitation, rain or snow, protects the telescope from potential water damage, helping to ensure safe operational conditions.

Chapter 3: Determining the Adiabatic Rate

3.1 Understanding the Adiabatic Process

Hot air rises, and cold air sinks. The adiabatic process operates on the basis of these two principles. A parcel of air seeks to reach equilibrium with its surroundings. Two different kinds of equilibrium exist, stable and unstable. For a parcel of air, arbitrary in size, stable equilibrium will maintain stability even under slight external influences. A parcel of air stays in unstable equilibrium only until slightly influenced away from equilibrium. The previously unstable parcel of air remains unstable and continues to move until reaching a stable environment. An unstable atmosphere leads to rain. Determining the stability of the atmosphere by the principles of the adiabatic rate helps to determine the cloud ceiling (the level at which clouds form) and potential for rain fall.

Determine the cloud ceiling and potential rain fall requires the relative humidity of the environment, the temperature, the dry adiabatic rate, and the environmental lapse rate. The parcel of air below the cloud ceiling in the atmosphere follows the dry adiabatic rate, rising and reaching the condensation level for the water in the air at about 100 % relative humidity. The ratio of water vapor content to the water vapor capacity of the parcel of air determines the relative humidity. The ratio establishes the percent of relative humidity. Using the dry adiabatic rate, the environmental lapse rate, the current ambient temperature, and the relative humidity gives an appropriate calculation for the cloud ceiling.

3.2 Description of TTH-1315 Temperature Humidity Sensor and Operating Range

The process of determining relative humidity and temperature uses the Texas Electronics TTH-1315 Temperature Humidity Sensor. (See Figure 3) Both the temperature and humidity sensors come mounted within a shielded, shaded container which allows air to aspirate and pass by the sensors. The TTH-1315 requires a power supply between 3.5 to 50 VDC to operate the sensors.

Figure 3. TTH – 1315 Temperature Humidity Sensor [6]

The relative humidity sensor consists of a hydrometer, to detect the amount of moisture in the air, and an interface, to change the detected humidity into an analog signal. The sensor outputs a DC voltage signal from 0 to 1 V. The signal has a linear relation to the percent of relative humidity for the air: 0 V corresponds to 0% relative humidity and 1 V corresponds to 100 % relative humidity. In case the relative humidity goes above 100 %; the sensor will still only output 1 V. The relative humidity sensor comes pre-calibrated and operational. The sensitivity varies no more than +/- 1.5% from the outputted relative humidity. The signal provides a resolution of 0.02 % for relative humidity.

The temperature sensor consists of a thermocouple. A thermocouple uses two metals placed together connected through a heat sensitive junction. As temperatures change, the resistance of the junction changes linearly. The temperature changes the output voltage signal from 0 to 1 V linearly corresponding to a range of -40 °C to 60 °C (-40 °F to 140 °C). The accuracy varies between +/- 0.5 °F. The thermocouple maintains a signal resolution of 0.1 °F for the system. Sampling time operates at less than 0.7 seconds. [7]

3.3 Calculating the Dew Point Temperature

High relative humidity indicates low clouds and a high chance from precipitation. Monitoring the relative humidity in conjunction with the temperature suggest the potential for rain or snow fall. Low relative humidity signifies high altitude clouds, which produce little ground reaching precipitation. Cloud levels compute by using the measured relative humidity and temperature in conjunction with the dry adiabatic rate and the environmental lapse rate.

The dry adiabatic rate, defined as 10 °C per 1000 m, holds constant below the condensation level. The environmental lapse rate, or the rate at which the air temperature decreases with altitude, varies slightly but normally stays at about 6.5 °C/ 1000 m.[8] The dew point lowers 2 °C/ 1000 m as a parcel of air rises in elevation. The relative humidity and the temperature factor into the calculation of the dew point temperature. The dew point temperature and the actual temperature indicate the cloud ceiling, or the height at which clouds form. (See Figure 4) To calculate the cloud ceiling, use the relative humidity (RH) and multiply by the vapor pressure temperature for the actual temperature.

$$\mathbf{RH - e_s = e} \qquad \text{(eq. 1)}$$

For instance, if the relative humidity reads 39 % and the thermometer indicates an ambient temperature of 16 °C, then reference the temperature with the Saturation Vapor Pressure, 17.7 (e_s). Multiply the Saturation Vapor Pressure with the relative humidity to calculate the actual vapor pressure. In this case, the actual vapor pressure calculates to 6.9 mb. After determining the actual vapor pressure, Table 1 indicates the air temperature of the dew point (T_d) or 2 °C for this case.

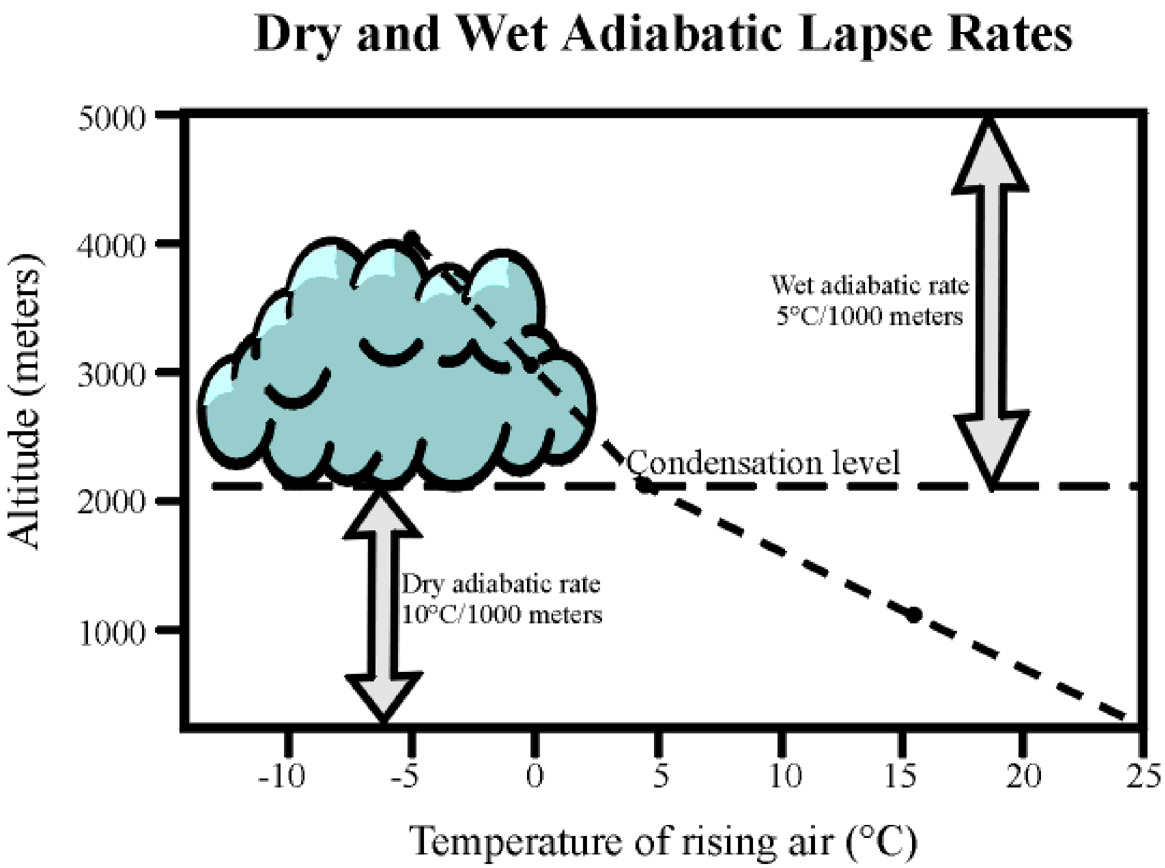
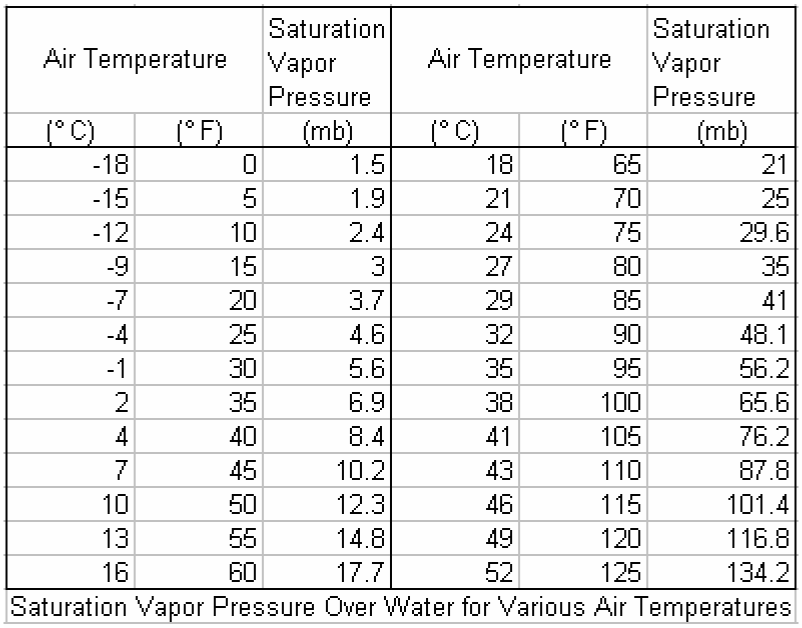


Figure 4. Condensation Level for Cloud Formation [9]



Air Temperature		Saturation Vapor Pressure	Air Temperature		Saturation Vapor Pressure
(° C)	(° F)	(mb)	(° C)	(° F)	(mb)
-18	0	1.5	18	65	21
-15	5	1.9	21	70	25
-12	10	2.4	24	75	29.6
-9	15	3	27	80	35
-7	20	3.7	29	85	41
-4	25	4.6	32	90	48.1
-1	30	5.6	35	95	56.2
2	35	6.9	38	100	65.6
4	40	8.4	41	105	76.2
7	45	10.2	43	110	87.8
10	50	12.3	46	115	101.4
13	55	14.8	49	120	116.8
16	60	17.7	52	125	134.2

Saturation Vapor Pressure Over Water for Various Air Temperatures

Table 1. Air Temperature vs. Saturation Vapor Pressure [8]

3.4 Calculating the Cloud Ceiling

The height of the cloud ceiling in meters is calculated by the taking the difference of the actual temperature (T) and the dew point temperature referenced from the actual vapor pressure (T_d) and then multiplying by 125. For the ambient temperature of 16 °C and the dew point temperature of 2 °C, the cloud ceiling calculates to 125 m. This works for degrees Celsius.

$$\mathbf{H_{meters} = 125\ (\ T - T_d\ )} \qquad \text{(eq. 2)}$$

The cloud ceiling in feet is calculated by taking the difference of the actual temperature (T) in degrees Fahrenheit and the dew point temperature referenced from the actual vapor pressure (T_d) in degrees Fahrenheit and then multiplying by 228. The cloud ceiling calculates to 5745.6 ft.

$$\mathbf{H_{feet} = 228\ (\ T - T_d\ )} \qquad \text{(eq. 3)}$$

While clouds might not form at the calculated altitude, the calculation determines the minimum height of the potential cloud ceiling. [8]

Accurately determining the relative humidity and ambient temperature with the dry adiabatic rate and the environmental lapse rate allows for calculation of the dew point and the cloud ceiling. The dew point and cloud ceiling help understand the stability of the atmosphere and the potential for cloud coverage and precipitation. The cloud ceiling determines the base of potential clouds which could cause rain. The relative humidity indicates the chance for rain to fall. The stability of the atmosphere helps to note the potential for precipitation.

Chapter 4: Determining Barometric Stability

4.1 Understanding Barometric Stability

The pressure of the atmosphere above a specified altitude defines barometric pressure. At sea level, under normal conditions, the atmosphere pressurizes the ground to 1028 mb. As elevation increases, the amount of atmosphere above the specified altitude decreases; in consequence, the barometric pressure also decreases. Stationary sensors measure the difference in atmospheric pressure with respect to the sensor at the altitude. Changes in air mass and temperature affect the barometric pressure. Therefore, monitoring changes in barometric pressure and temperature indicate potential for precipitation.

4.2 Description of TB-2012M Barometric Pressure Sensor and Operating Range

A digital barometer calibrated for the site serves to determine barometric pressure. The Texas Electronics TB-2012M Barometric Pressure Sensor provides the barometric pressure reading for the site. (See Figure 5) The sensor requires a power supply of 12 to 15 VDC. As a stock sensor, the TB-2012M reads barometric pressure from 878 mb to 1080 mb (26 in to 32 in). This can be used up to 548.64 m (1800 ft) in altitude above sea level before modification.[10] The site of Delta, UT requires the calculation of barometric pressure for 1372 m (4500 ft) above sea level with a pressure of 844 mb (25 in). The barometric pressure exceeds the range of the TB-2012M. The sensor requires adjustment to read a proper range for the given altitude. The sensor would then require recalibration for the altitude.

For the sensor to read in the barometric pressure in Delta, UT correctly, the sensor requires modification. By changing the resistor R14 in the circuitry from a 26.1 K resistor to a 44.2 K resistor, the TB-2012M functions in the pressure range appropriate for 1372 m (4500 ft) in elevation. The sensor will operate in the range of -40˚C to 50˚C (-40˚F to 122˚F). The calibrated temperature range, or the range at which the sensor will operate with +/- 1.3 mb accuracy is -18˚C to 50˚C (-0.4˚F to 122˚F). The TB-2012M outputs an analog signal of 0-1 VDC corresponding linearly to the barometric pressure. [10]

Figure 5. TB – 2012M Barometric Pressure Sensor [11]

4.3 Conditions Relating to High and Low Pressure Systems

When the barometric pressure changes, a different pressure system, high or low, enters over the area. Typically high and low pressures characterize high and low pressure systems. High pressure systems tend to move air away towards a lower pressure much like a ball on a hill. High pressure systems typically signify clear skies with air in stable equilibrium and relatively low chance of rain and cloud coverage. Low pressure systems tend to attract the air. Clouds form in and along low pressure systems. (See Figure 6) The nature of the low pressure system leads to storms and high winds.

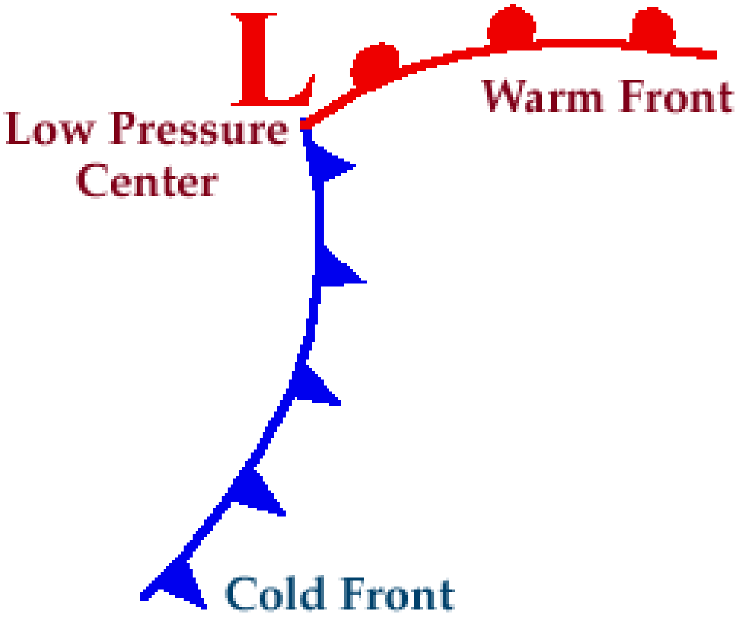


Figure 6. Occluded Front around Low Pressure [12]

Wind Circling Counter-clockwise

4.4 Conditions Relating to Warm and Cold Fronts

Rapid changes in the air temperature also indicate an increasing chance for rain. The TTH-1315, as discussed in Determining the Adiabatic Rate, helps to determine the air temperature. If air changes from warm to cold quickly, the chance of accompanying rain is probable. Since warm air rises, the warm air rides up the side of the incoming cold front. When warm, humid air and cold air meet, the relative humidity quickly rises and clouds form. Precipitation results from the cold air replacing the warm air. (See Figure 7)

Precipitation also results from a warm front overtaking a cold front. When rain precedes the change in temperature, a warm front moves in. High altitude clouds and seasonally cool temperatures indicate potential lower altitude, rain producing clouds and an approaching warm front. (See Figure 8) Keeping track of the fronts, both warm and cold, and the changes in temperature and barometric pressure aid in determining the barometric stability and potential precipitation.

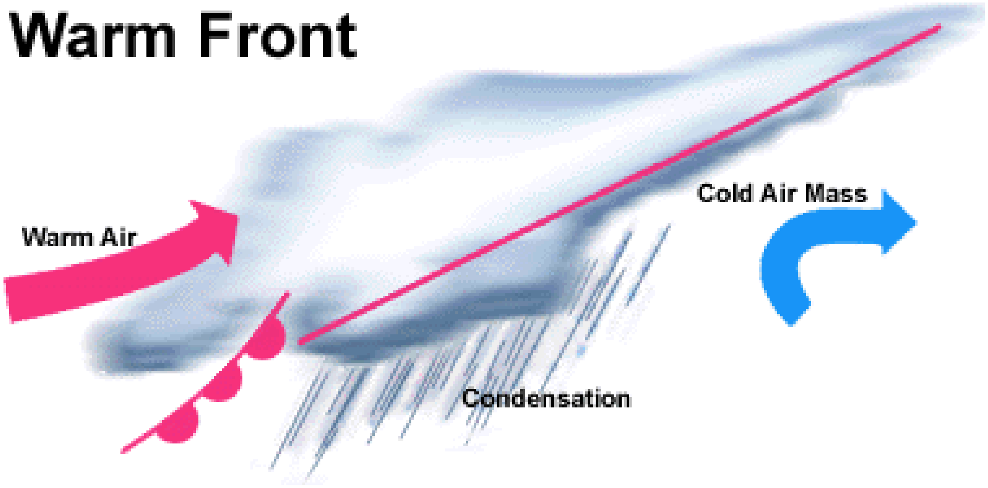


Figure 7. Warm Front Overtaking Cold Front [13]

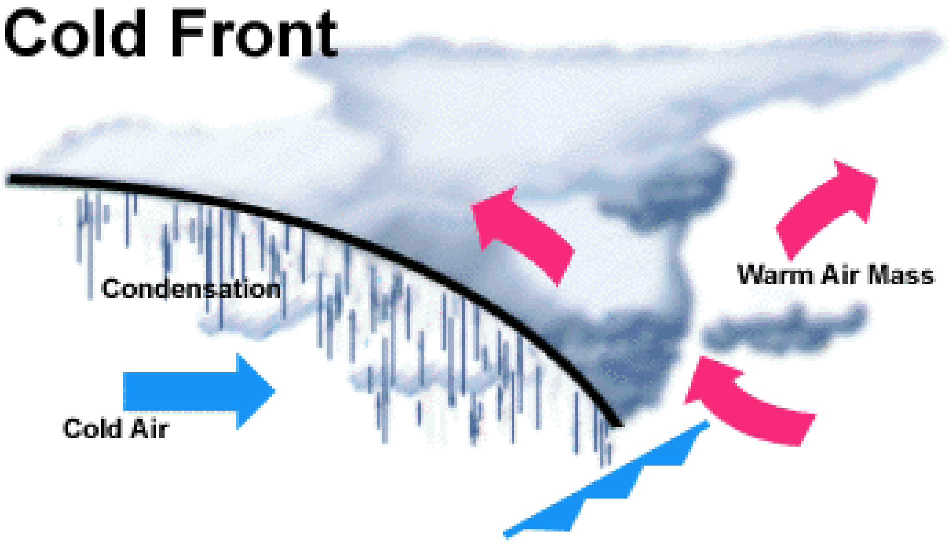


Figure 8 Cold Front Overtaking Warm Front [14]

Chapter 5: Determining the Wind Speed

5.1 Potentially Damaging Wind

The velocity and direction (or speed) of the wind around the structures creates great concern. High wind speeds can potentially propel materials hazardous to the telescope, namely dust and dirt which damage the mirrors and create an unclean surface for the tracking motors to operate. Safe operation of the dome also depends on wind speed. Winds may render the parachute-like dome unsafe to operate because of stress on the mechanical system. In order to determine safe operational conditions, the wind speed must be monitored.

5.2 Description of TV-114 Wind Speed Sensor and Operating Range

Determining the wind speed requires the wind direction and the wind velocity. An Anemometer is used to determine the wind speed. The TV-114 Wind Speed Sensor contains three cups attached to armatures connected at a central rotating cap. (See Figure 9) The cap is mechanically fastened to an AC brushless generator. (See Figure 10) As the wind blows the cups move and turn the generator. The AC generator produces an AC sine wave where the amplitude and frequency are proportional to the wind speed. The operating range is intended to be 0-100 mph with 1 mph associated with 10 rpm and 1.33 Hz. The scale increases linearly. The operational envelope is 0-135 mph before potential damage. The Starting Threshold is 2 mph. Operating temperatures range from -40˚C to 160˚C (-40˚F to 160˚F). [15]

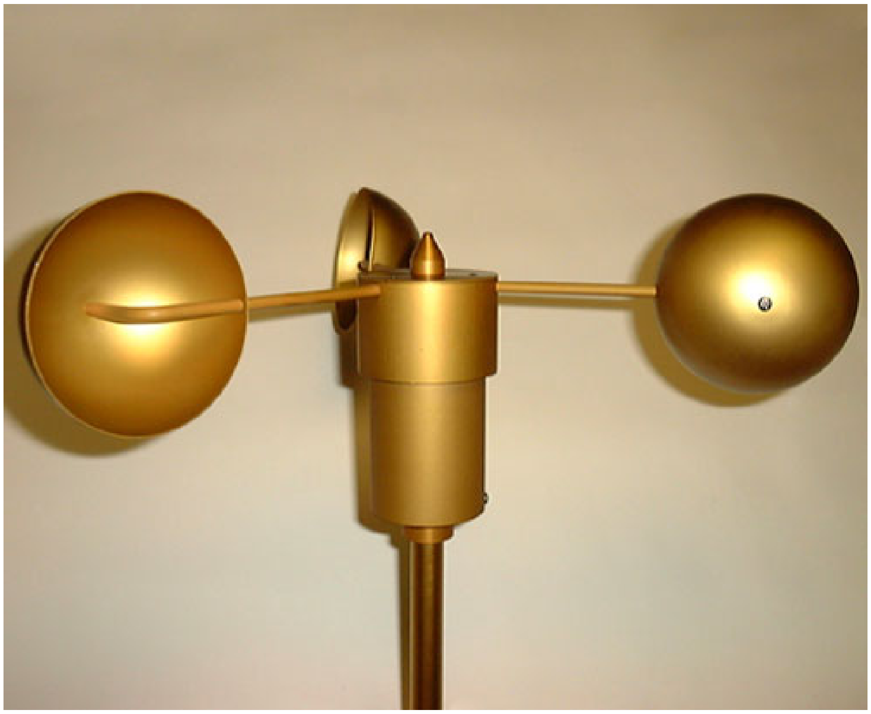


Figure 9. TV – 114 Wind Speed Sensor [16]

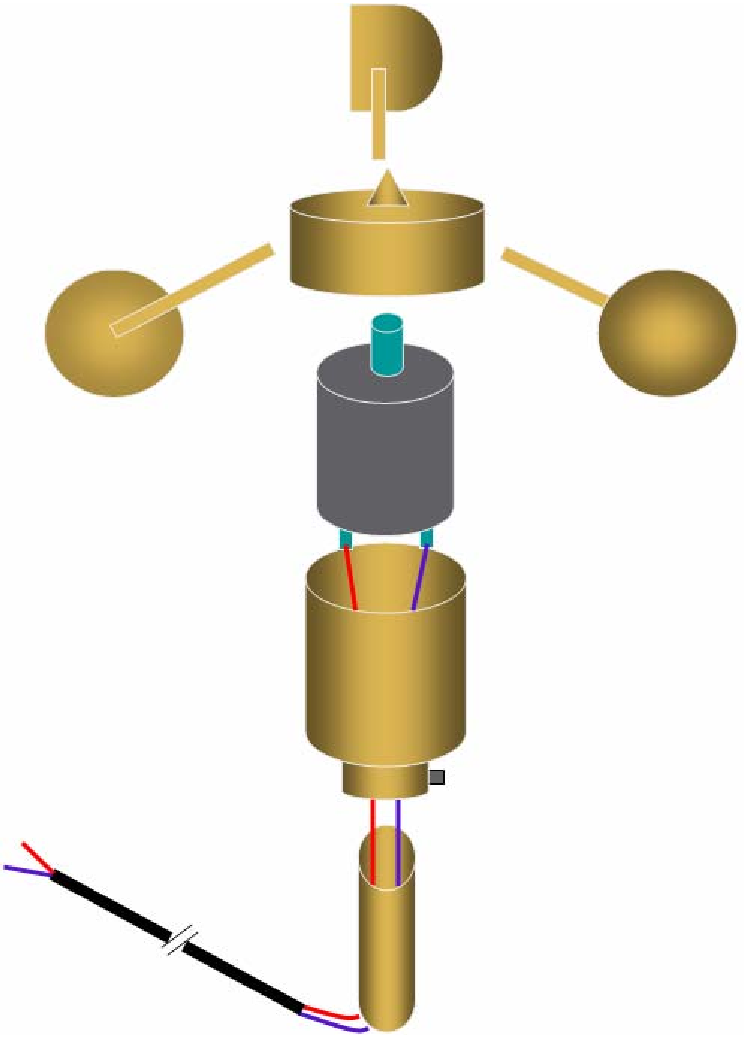


Figure 10. TV – 114 Diagram

5.3 Description of TD-104-5D Wind Direction Sensor and Operating Range

A weather vane determines the wind direction. The TD-104-5D Wind Direction Sensor uses a vane and counterbalance to rotate an 8.8 KΩ potentiometer (pot). (See Figure 11) The pot operates from 0-360˚ mechanically and 0-357˚ electrically. The pot requires a supply current over the resistor. As the armature of the weather vane turns the pot sweeps varying the resistance. The resistance varies within .5% linearity and resolves to 1˚. The TD-104-5D operated from 0-135 mph with a starting threshold of 2.5 mph. Operating temperatures range from -40˚C to 160˚C (-40˚F to 160˚F). [17]

Figure 11. TD – 104 – 5D Wind Direction Sensor [18]

5.4 Conditions Relating to Wind Speed

Together, the wind velocity and wind direction determine the wind speed. For the ROVOR site in Delta, UT, the maximum sustained wind speed is 20 mph (350 rpm or 46.55 Hz). Sustained wind is considered to be wind lasting longer than 3 minutes. By maintaining a maximum acceptable wind speed of 20 mph, the debris from the nearby farms and fields should not affect the mirrors or motors. The motor which powers the dome should also operate safely with a sustained wind speed of 35 mph.

Chapter 6: Conclusion and Future for Safe Remote Observations

Precipitation and wind pose significant dangers to ROVOR. The danger reduces significantly by using proper equipment to verify safe observational conditions. Monitoring the current precipitation, rain or snow, protects the expensive electronics of ROVOR against damage. Determining the stability of the atmosphere by using the temperature and relative humidity with the adiabatic rate identify the dew point and cloud ceiling. Monitoring the stability of the barometric pressure and the temperature indicate the possibility for precipitation. Determining the wind speed ensures protection from debris and safe mechanical operational for the dome. Together, ROVOR can operate with reduced risk of damage from potential precipitation.

Safe observing conditions exist. In determining safe observational conditions, the possibility exists to safely operate a fully automated, remote telescope like ROVOR. Operating ROVOR does not require full comprehension and control of the weather. Simple verifications of the current precipitation, the adiabatic rate, barometric stability, and sustained wind speed adequately supply the necessary information to determine safe observational conditions. Equipment exists to perform the needed measurements to make the determinations.

The possibility for safe operation of telescopes like ROVOR exists today. Development continues with remote operated, fully automated telescopes. Unsafe observational conditions due to precipitation and wind no longer factor into the operational risks. As development continues, remote observatories will dot the globe and operate independently, automatically, without supervision, and free from the risks of damage from potential precipitation and wind. Protection exists with verified atmospheric conditions.

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Appendix A: Logic Tree for Weather Station for ROVOR Dome Operation

When do we want to close the dome?

High winds sustained> 20mph for 15minutes

Sustained wind speed is defined to be the average speed the wind over a period of 15 minutes. High wind speeds refers to an average wind speed of 20 mph. This wind speed was proposed by Dr. Moody who has experience with the site and creates a buffer to lower the chance of aerosols (such as dirt and sand) from causing damage to the equipment. The speed may be adjusted as appropriate.

Sample code

```
If  Vwind < 20 mph
        then dome open = ok
        else close dome
end
```

Rain falling currently

Rain fall is defined to be the tipping of the rain gauge bucket a minimum of once. Current Rainfall refers to at least one tip of the bucket in the last hour. The time frame criterion was proposed by Dr. Moody to ensure any stray precipitation from effecting the equipment. The time may be adjusted as appropriate.

<u>Sample code</u>

```
If Rain fall = False in last 1 hour
        then dome open = ok
        else close dome
end
```

RH > 70%

Relative Humidity is the amount of water in the air divided by the potential amount of water in the air before condensation occurs. As the fraction nears 100% the possibility of rain increases. Historical data from Central Utah shows rainfall occurring as low as 76% Relative Humidity. For ROVOR a 70% Relative Humidity level in the last 20 minutes indicates unsafe conditions. A buffer of 6 % maintains a safety margin for the telescope and should allow sufficient time for the telescope shutdown sequence to finish and for the dome to close. The 70% Relative Humidity should not be exceeded.

Sample code

```
If RH < 70 % in last 20 minutes
        then dome open = ok
        else close dome
end
```

Condensation on mirrors

Determining the possibility of condensation forming on the mirrors, three values must be known: Relative Humidity, the temperature in the dome, and the ambient temperature outside. The dew point of the outside air is calculated and compared to the air temperature in the dome. If the temperature in the dome is 3˚C greater than the temperature outside, the operation is permitted; otherwise, the dome should be closed. This equation will also function while the dome is open to monitor the chance of dew on the equipment. The buffer of 3˚C may be raised to a degree or two but will not need any higher adjustment.

The equations for calculating the dew point and are as follow.

According to an approximation of the Clausius-Clapeyron equation which uses absolute temperature (K):

$$\mathrm{RH} = 100\% \cdot \left(\frac{\mathrm{E}}{\mathrm{Es}}\right)$$

$$\mathrm{E} = \mathrm{E0} \cdot e^{\left[\frac{\mathrm{L}}{\mathrm{Rv}} \cdot \left(\frac{1}{\mathrm{T0}} - \frac{1}{\mathrm{Tdew}}\right)\right]}$$

$$\mathrm{Es} = \mathrm{E0} \cdot e^{\left[\frac{\mathrm{L}}{\mathrm{Rv}} \cdot \left(\frac{1}{\mathrm{T0}} - \frac{1}{\mathrm{T}}\right)\right]}$$

$$\mathrm{E0} = 0.611\ \mathrm{kPa}$$

$$\mathrm{T0} = 273\ \mathrm{K}$$

$$\frac{\mathrm{L}}{\mathrm{Rv}} = 5423\ \mathrm{K}$$

T is temperature (in Kelvin), and Tdew is dew point temperature (also in Kelvin)

$$Tdew = -\left(\frac{5423 \cdot T}{\ln\left(\frac{RH}{100}\right) \cdot T - 5423} \right)$$

(All units of temperature in Kelvin)

Basic code

```
If Tdome – 3(˚C or K) > Tdew
then dome open = ok
        else close dome
end
```

Appendix B: Putting the Station Together

Using the NI USB-6009

In order to set up channels with the NI USB-6009, you must go onto the computer, open Measurement and Automation Explorer. Select “Data Neighborhood” in the “Configuration” window. Select “NI-DAQmx Global Virtual Channel”. Choose the channel, name the channel, and select the range (note it appears the range must be within -10V to 10V to work right.) Choose the terminal Configuration to be RSE which means you reference off ground instead of off the other end of the wire (when there are two.) Remember to save by clicking on the Save “Disk”.

To delete a channel, select the channel in the “NI-DAQmx Global Virtual Channel”, and press “Delete”. Confirm deletion.

To update Signal Input Range, select the channel in the “NI-DAQmx Global Virtual Channel” and proceed to update. Remember to save by clicking on the Save “Disk”.

Connecting the wires to the DAQ

The following is a list of where to attach the wires:

	What it measures	Comes from	Power Req's
ai0:	Temperature	TTH-1315	12-15 V
ai1:	Relative Humidity	TTH-1315	12-15 V
ai2:	Windspeed	TV-114	none
ai3:	Temperature Doghouse	(a thermocouple)	none
ai4:	Wind Direction	TD- 104-5D	1 V
ai5:	Barometer	TB- 2012M	12-15 V
ai6:	Solar IR	SP Lite	none
pfi0:	Rain Gauge	Series 525	120 VAC (heater)

Installation Needs for the Weather Station

Rain Gauge:

I welded a metal stand for the rain gauge. I though that the best place to put it would be on the side of the outhouse. I made a mound which will attach to the outer wall of the outhouse. The rain gauge must be installed so the rain from the roof does not enter the bucket assembly. Attach the one of the two wires to the PFI0 as noted above. The other wire can be attached to ground but does not need to be.

Solar IR Sensor:

This device should be pointed perpendicular to the ground so the sensor “sees” directly up. This device can be placed on the south facing side of the outhouse. The signal needs to be amplified to get to the 1V range. I suggest a .5V range to add a buffer zone. The scale is not important. The general relation to the time of day is. An uneven pattern indicates clouds.

Barometric Pressure Sensor:

This device should be placed on the shady side (north) of the outhouse, away from the air conditioner. The shade is important for this to function correctly. This requires a 12-15 V power supply. Attach the wires.

Everything Else:

Dr. Moody chose one of the fence posts to use as a mounting point. A mast will be required for the rest of the equipment. A U-shaped mast is already assembled for the

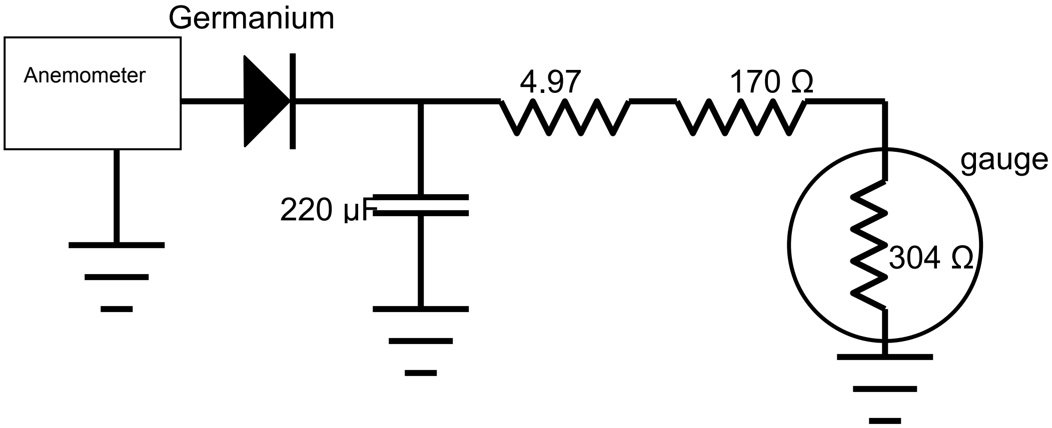
Anemometer and the Wind Vane. Mount this to the mast. Fasten the mast to the fence post. Also fasten the TTH-1315 to the mast. Run and connect the wires securely. It is very important that the anemometer and the wind vane are parallel to the ground so the bearings will function properly ensuring accurate readings. The mast should be raised enough as to allow the anemometer to be at least 2 feet above any nearby structure, namely the doghouse with the lid on.

The weather vane will need to be adjusted to 0deg (minimum Voltage) = North. A set screw at the base of the TV-114 allows you to make this adjustment.

Formulas that need calibration

The wind speed needs calibration. The anemometer is an AC generator. It needs to be attached to a half wave rectifier. A germanium diode provides the least voltage drop. Use an RC circuit as to make the system have a RC time of about 1 second. John Ellsworth has a product by Kestrel which is a small anemometer. Get a few wind speeds, gather the corresponding voltage and make a linear equation to make it all work.

Half Wave Rectifier for Anemometer



This half wave rectifier circuit will provide sufficient rectification for the anemometer and just over a 1 second RC time. The equation is as follows:

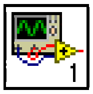
$$mph = -0.4454 + 331.44 * Voltage$$

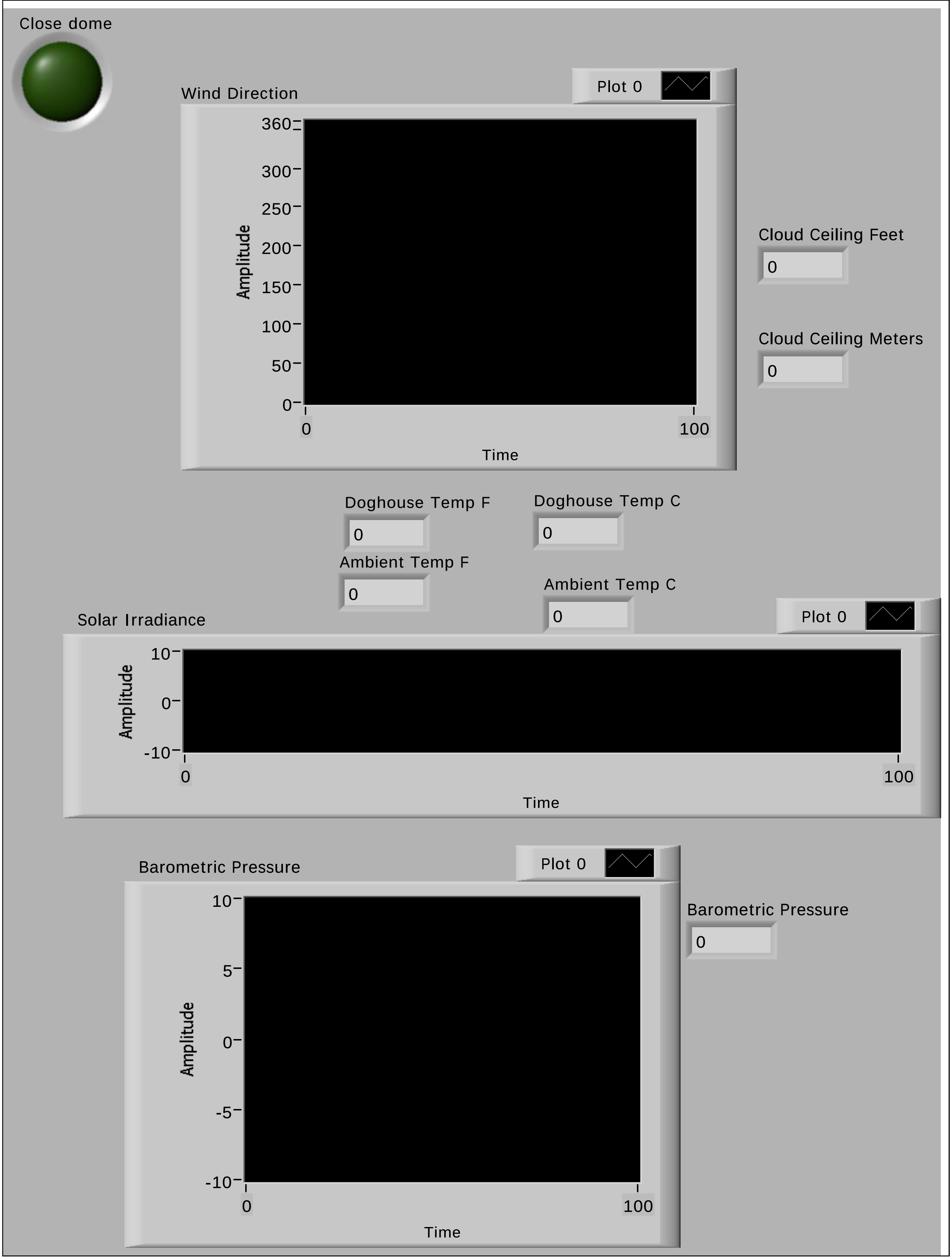
This provides an R^2 value of .99981

Vanemometer	mph
0	0
0.076	25
0.156	50
0.228	75
0.301	100

The barometer is currently circuited to be at sea level. If you read that instruction manual from Texas Electronics, you will find the diagram and how to adjust the circuitry to make it work for our altitude. Use a local station for reference when calibrating. This will be a linear equation. 3 or 4 different barometric pressures and their corresponding voltage readings should be enough to find an adequate equation.

Test1.vi





Cloud Ceiling Feet 0

Cloud Ceiling Meters 0

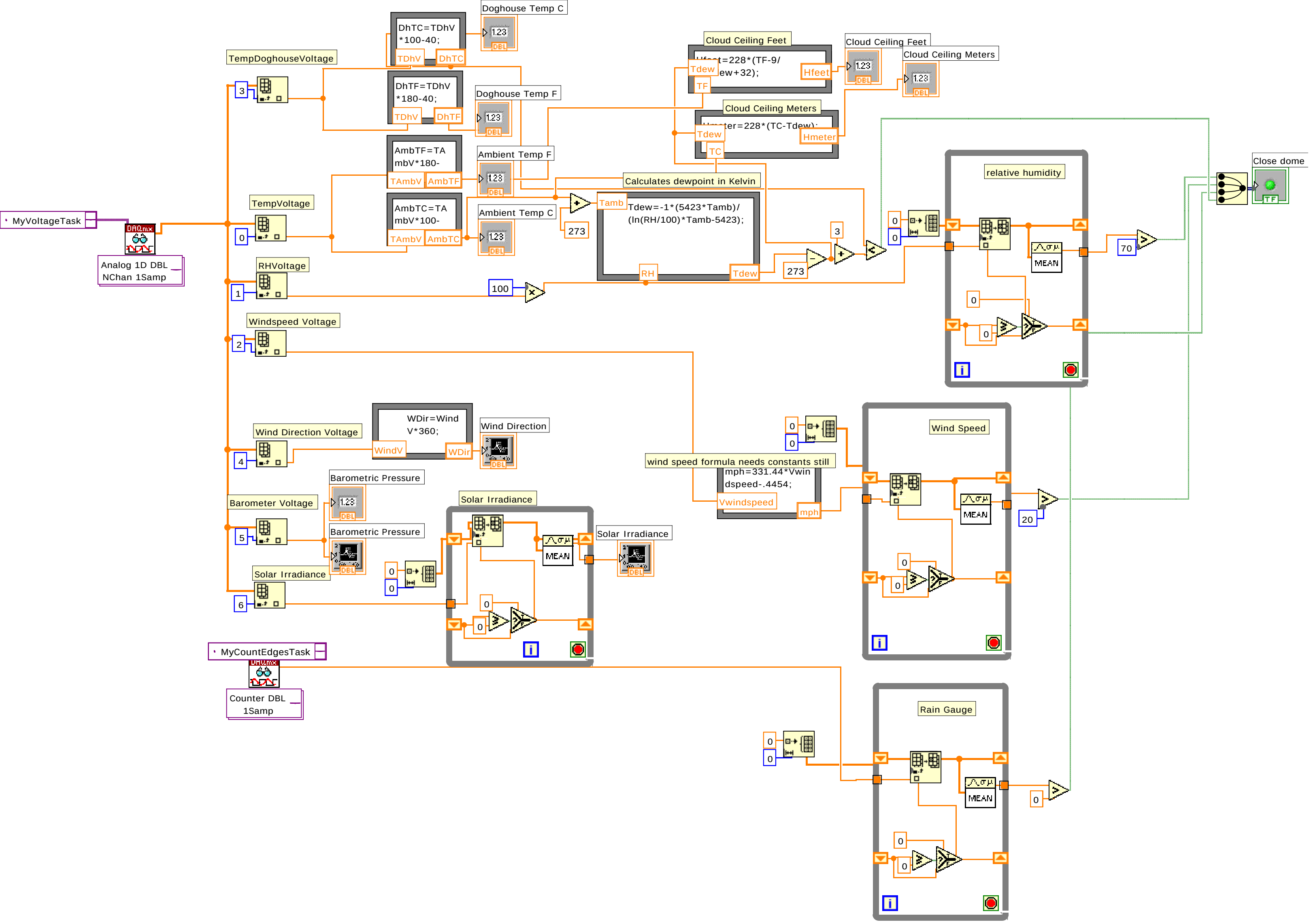
Doghouse Temp F 0

Doghouse Temp C 0

Ambient Temp F 0

Ambient Temp C 0

Barometric Pressure 0



```
DhTC=TDhV*100-40;
DhTF=TDhV*180-40;
AmbTF=TAmbV*180-
AmbTC=TAmbV*100-
Hfeet=228*(TF-9/ ew+32);
Hmeter=228*(TC-Tdew);
Tdew=-1*(5423*Tamb)/(ln(RH/100)*Tamb-5423);
WDir=WindV*360;
mph=331.44*Vwindspeed-.4454;
```