IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

CASE STUDY OF AN ASTRONOMICAL TELESCOPE DEW REMOVAL SYSTEM WITH TEMPERATURE FEEDBACK AND MONITORING ON IOT.

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Abstract: The optical surfaces of amateur astronomical telescopes tend to get cooler than the ambient temperature and thus have dew condensation on them which ruins the observation session and if not taken care of can also damage the optics. The problem of dew condensation is quite serious with refracting and catadioptric telescopes which have their front optics at the top end of the tube. The problem is not very severe with the primary mirrors of Newtonian telescopes as they are situated at the bottom of a long tube but the secondary mirror and finder scope (which by default is a small refracting telescope) are prone to fogging up with condensed water. The system that we have designed and tested is a smart dew removal system which is an optics heating system that does not need adjustments by the telescope user once powered on and adjusts the temperature of the heat belts as required by calculating the dew point and the tube temperature with the help of appropriate sensors. The system also has an IoT interface wherein it can push the parameters measured and temperature changes made to a server of a free IoT app called Blynk from where the user can monitor the same on his smart phone.

Index Terms - **Amateur astronomy, Telescope, Dew-shield, Dew-heater, Microcontroller, IoT, Heat-belts**

I. INTRODUCTION

Dew formation on optical surfaces (the objective, secondary mirrors if any, finder scope objectives and even eyepieces) is common when the observation session is stretched late in to the night. Slight formation of dew will reduce the limiting magnitude of the scope by a full magnitude or more.

Mechanism of dew formation: Dew as such does not fall on telescope optics but rather condenses from the surrounding air when the temperature of the lens or mirror falls below what is called a dew point. The dew point is a temperature determined by the ambient temperature and humidity. Lower the humidity, lower the dew point temperature than the ambient temperature and lesser likelihood of condensation to occur. It seems counter intuitive on the basis of the Second Law of Thermodynamics that a telescope optics can cool below the ambient temperature but the fact that the telescope mirror is pointed skywards connects it to the sub-zero temperature of outer space via radiation. This is known as night radiative cooling. The sky temperature- as the astronomers call it, is in the rage of -5 to -10 degree Celsius on a very clear dry night. This will cool the optics below the ambient temperature very quickly and promote dew condensation.

Methods used to counter dew formation on telescopes: Amateur astronomers have been dealing with dew formation on their telescopes in various ways like using passive dew shields or using some active means like heating the optics with a heating belt or a hair dryer etc.

Dew shields are actually extension of the telescope tube beyond its optical surface thereby limiting the amount of sky to which the lens or mirror is exposed and thus reducing radiative cooling. This method offers a limited solution to the problem and the optics will be sure to fog up if the observing session is considerably long and goes on late into night.

The active method uses a heating element attached to the optics such that it is kept slightly above the ambient temperature. This is done by controlling the current to the nichrome heating belts using PWM technique but this requires constant adjustment of PWM levels according to the ambient temperature. Too much heating might damage the optics or will generate eddies of hot air that might deteriorate the seeing through it. This paper discusses a hybrid solution of a employing a heated dew shield in front of a telescope. For testing purposes, we have applied this solution to an 8-inch Celestron Schmidt Cassegrain (SCT) telescope.

II. SYSTEM DESCRIPTION AND WORKING

The prototype that we have designed has following features:

1. PWM heating output automatically controlled as per calculated dew point
2. Dew shield temperature sensor
3. Ambient temperature and humidity sensor
4. Can be operated on battery or a DC power supply.
5. Audible warning on dew point approach
6. Logging of ambient temperature, humidity and dew shield temperature on cloud
7. Manual over-ride of heat-belt control.

2.1 Architecture of the system

The course layout of the system can be explained as follows. The unit is made up of three main parts- the controller unit, the sensors and the heat belts. Two different sensors are used which measure three parameters which determine the working of the system. This includes an analogue temperature sensor mounted on the dew shield to measure its temperature and an ambient sensor that measures the ambient temperature and relative humidity. The data of these two parameters is used to calculate the dew point. Once the dew point temperature is calculated, it is compared with the temperature of the dew shield and result is then used to adjust the level of PWM that drives the heat belt so as to keep the dew shield above the dew point temperature. An IoT-ready MCU logs the temperatures and humidity on a cloud server via Wi-Fi connectivity that can be provided to the system from a mobile hotspot. The explanation of working of the system is given in subsections below.

2.2 System block description

The block diagram of the system is given in **Figure 1**. As a prototype, we have constructed a 4-channel system which is fully functional. As shown in the figure, the main controller section accepts inputs from 4 potentiometers-one for each channel, as well as 2 sensors. The PWM outputs of the controller drive heat-belts to keep the temperature of the parts to which they are connected, a bit above the ambient temperature to inhibit condensation. The controller also communicates with the ESP internet module for IoT monitoring. The PWM outputs of the main controller are accepted by the driver units for delivering power to the heat-belts.

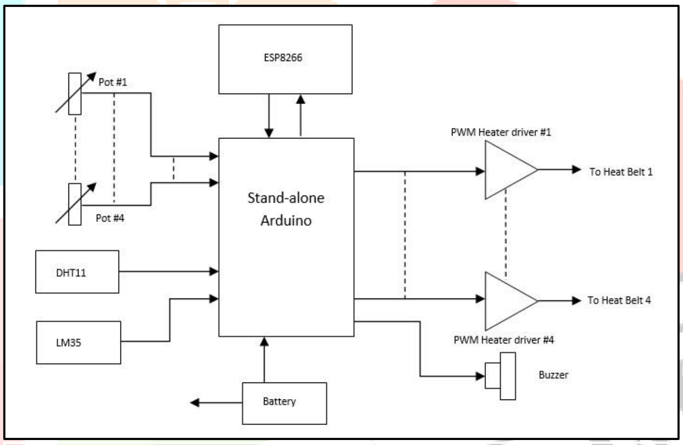


Figure 1: The system Block Diagram

2.3 System schematic description

For the sake of simplicity, the schematic diagram has been divided into smaller functional units. The description of these units is given below. The circuit diagram of the system is also given section by section in **Figures 2** to **4**.

2.3.1 The dew-shield temperature sensor

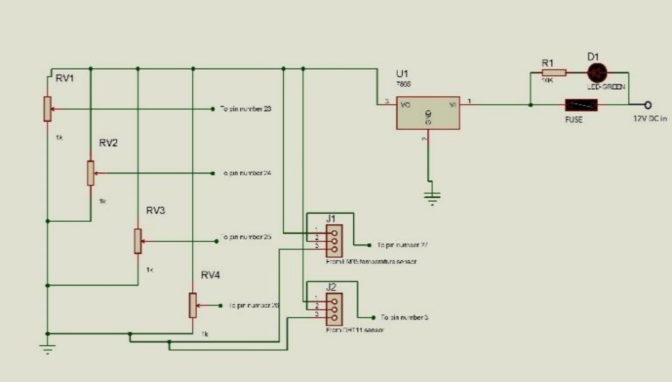
This sensor is an analogue temperature sensor LM35 which gives a calibrated output of 10 mV per degree Celsius and has an accuracy of 0.5 degree Celsius. This sensor is securely placed on the outer side of the aluminum dew shield under the thermal insulation to read the dew shield temperature. The output of this sensor is fed to an analogue input of the microcontroller.

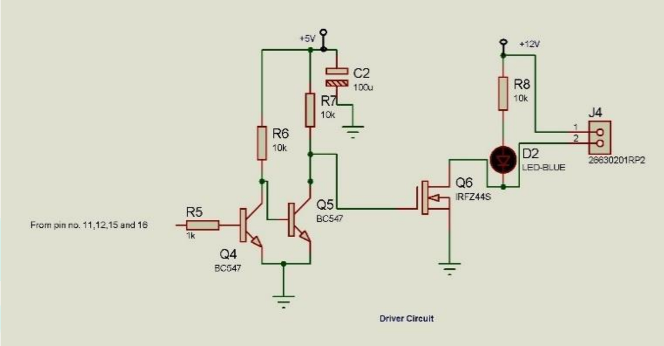
2.3.2 The ambient temperature and relative humidity sensor

Here we have used the popular DHT11 digital sensor which outputs both temperature and relative humidity in serial form. The accuracy of the sensor is 1 degree Celsius and 1% for temperature and relative humidity respectively. The output of the sensor is used to determine the ambient temperature and humidity so that dew point can be calculated.

2.3.3 The PWM level control potentiometers

There are four outputs for controlling heat-belts on our unit which are controlled by 4 potentiometers. These potentiometers control the duty cycle of the four PWM outputs so that current to the output channels and thus the heat can be controlled. The potentiometers are 10 k Ohms linear type.





2.3.4 Heater Outputs

As mentioned previously, there are four outputs out of which the "dew shield" output channel is the only channel that has been included in the feedback loop of temperature sensors. Multiple outputs are needed at the telescope so that different optics and accessories can be heated as needed. The outputs are used to heat the dew shield on the telescope corrector plate, the finder scope primary, the eyepiece and the scope mounted green laser which also seemed to die down with low temperatures. The output connector that we have used is the audio RCA connector which is also the standard connector used in commercially available dew-heaters

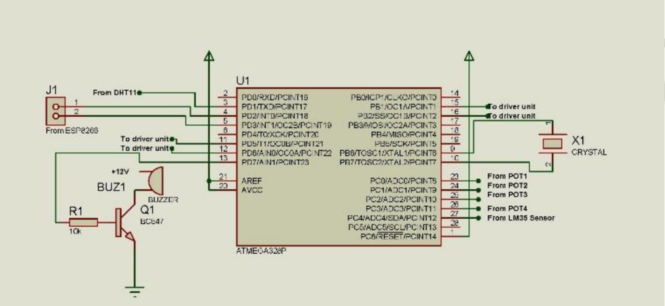


Figure 3: The main controller section

2.3.5 The main controller section

The controller that we have used is the stand-alone Arduino Uno using an ATMEGA 328 along with associated components. The controller has been programmed to accept the inputs from two temperature sensors, a relative humidity sensor and four potentiometers for PWM level control. The outputs of the controller are the PWM signals to the four heat belts. One of the four PWM outputs is the dew shield output. The duty cycle of this output is adjusted as follows. The controller calculates the dew point temperature from the temperature and relative humidity reported by the DHT 11 sensor and compares it with the dew shield temperature. It then adjusts the PWM level so as to put the dew shield temperature just a degree above the dew point temperature. This would ensure the dew doesn't condense on the corrector plate (or the primary of the telescope). The remaining three channels are not included in the feedback loop and are controlled solely by their associated potentiometers. The dew shield channel can also be controlled by its associated potentiometer. Apart from these, the controller also drives a small buzzer when the ambient temperature approaches the dew point giving the warning of proceeding condensation. The flow chart of the software is given in **Figure 5**.

2.3.6 The PWM heat-belt drivers

The controller PWM outputs are 5V outputs whereas the heat belts are to be driven by 12 volts. The current to be provided to the heat belts is also quite large. Each driver, lying between the controller PWM output and the heat belts is made up of a npn transistor for level conversion and an IRFZ44 n channel MOSFET as a current driver. The MOSFETs are capable of delivering a current of 49 A which is many times higher than the maximum current that is delivered by the entire system. The main heat belt of the system is rated at 36W thus drawing a current of 3 A.

Figure 4: The PWM heat-belt driver circuit

2.3.7 The Node MCU Wi-Fi gateway

This block is made up of an ESP8266 SOC in the form of NodeMCU development board. The chip has inbuilt Wi-Fi connection capability and complete IP stack on it. The gateway uploads the values of dew point and the dew shield temperature given to it by the main controller on cloud. For our prototype, we have used a free cloud service called Blynk. This service also has an app by same name which allows us to monitor these values on a smart phone. When a project is generated on Blynk app, it generates a unique auth token that has to be pasted in the sketch that is to be uploaded to the Node MCU. We programmed the ESP using Arduino IDE. Testing in field consisted of providing mobile based hot-spot to the ESP.

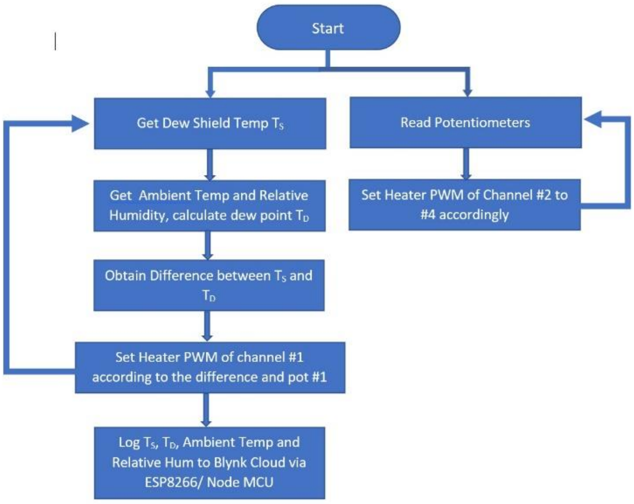


Figure 5: The software flow chart

2.3.8 The power supply section

The system operates from 12 to 15 V unregulated dc which can be applied either from a storage battery or an ac mains operated SMPS type power supply. SMPS is preferred as the current requirement of the system is about 3.5 to 4 A depending on the conditions and heater settings which make linear power supplies bulky and unmanageable. The drivers are fed with the input unregulated dc with a 5A fuse in series. The fuse also has a fuse failure LED installed which allows immediate trouble shooting in field. The remaining circuit operates at 5V dc which is obtained by a 7805 three terminal linear voltage regulator chip

2.3.9 The software

The code has been written in the Arduino IDE and has been uploaded to the Atmega 328 by putting it in an Arduino Uno board. The flow chart on which the software is based is shown in **Figure 5**.

III. IMPROVEMENTS TO THE FIRST PROTOTYPE

The most important correction that we found during on-field trials was the amount of power required to produce sufficient amount of heat. From literature survey it was found that about 6 W of dissipation would suffice for an 8-inch primary that we used for testing. The installation of this first heating belt is shown in the photograph labelled figure 4. It was found that this was far underrated and experimentally we found that about 36 W, that is more than four times the power found in literature was needed to stop condensation.

The presently working control unit of the system is shown in figure …... Also, the literature survey mentioned that the heater temperature of just a degree higher than the ambient would be enough to prevent condensation. Our on-field trials suggested that this is not enough and we had to go for temperatures that were about 2 to 2.5 degrees above the ambient. This might have been due to the fact that we are not using direct heating technique on an optical surface but heating by radiation from a heated dew shield.

Initially we had built the first system with just three outputs but it during on-field trials we found that the telescope mounted green laser suddenly stopped working. It was found that this happened due to low temperature of the Li-Ion battery inside the laser. Tying one of the heat belts to the laser solved this immediately and thus we opted for four outputs with one dedicated to heating the laser casing.

Figure 6: Installation of the heat belt on telescope primary

IV. SHORTCOMINGS OF THE SYSTEM THAT NEED TO BE CORRECTED BY BOTH ON-WORKBENCH AND IN-FIEND TRIALS

There are some shortcomings regarding which more work both on-field and on work bench has to be done.

1. The heated dew shield will definitely cause eddies when radiating heat on to the telescope corrector plate. Although no such thing was noticed during the testing of the system when the telescope was used for visual observation. The effect of eddies on long exposure astrophotography is yet to be evaluated.
2. This system has been effectively tested for ambient temperatures as low as 5 degrees Celsius and thus its testing under lower temperature still remains untested.
3. Technically, the temperature of optics needs to be just a fraction (1 to 1.5 degrees) above the calculated dew point. Here the temperature sensor is placed on the dew cap and thus it doesn't directly measure the optical surface temperature but the dew shield temperature. At present the system tries to overcome this by keeping the dew cap temperature 2 to 3 degree higher than the dew point. A possible solution would be to use an infrared type thermometer sensor directly looking at the optical surface.
4. Better precision in maintaining temperature can be obtained by applying the PID control loop which has not been done in the prototype.

V. CONCLUSIONS

As mentioned above, the system was tested on a Schmidt Cassegrain 8-inch telescope for about 8 full night observation during different seasons and locations. The minimum temperature for which the system was used was at Gir forest in January 2020 where ambient temperature was 6 degrees Celsius and the sky temperature measured with a sky quality meter was -9 degrees Celsius. It was observed that this method, which is a cross of passive dew control and active dew control is far more effective than any single method by itself.

VI. ACKNOWLEDGEMENT

We would like to present our sincerest thanks to Dr. Kiran Parmar allowing us to experiment with our system on his precious 8-inch Celestron SCT Telescope.

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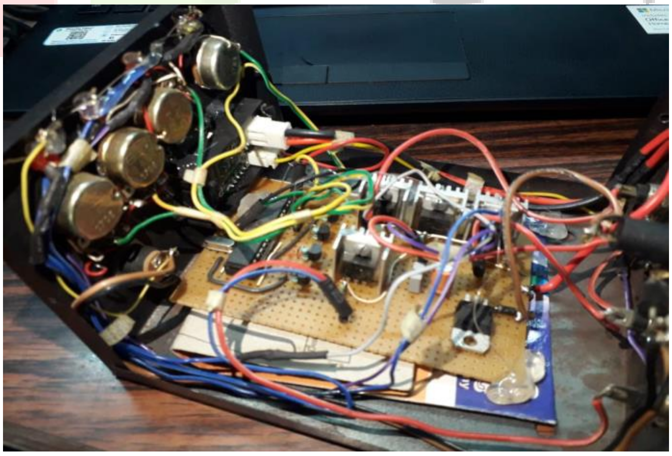

Figure 7: Fully operational prototype