Design and Performance of the Met3A Fan-Aspirated Temperature Probe System

This report discusses the design of the Met3A fan-aspirated temperature probe system and test results that prove greatly improved performance over non-aspirated designs. Issues discussed include:

- Aspirated versus Non-Aspirated Probes
- Paroscientific Met3A Design Features
- Solar Radiation Errors
- Transient Errors
- Calibration Verification

Aspirated versus Non-Aspirated Systems

It is generally accepted that aspirated temperature measurements are the most accurate available. Reference 1, the WMO "*Guide to Meteorological Instruments and Methods of Observation*", states in paragraph 2.5 "Best results are obtained with forced ventilation, by drawing air over the thermometer element with a fan . . .".
Non-aspirated temperature measurement systems that employ static radiation shields or louvered screens depend on wind to provide aspiration and can have large errors due to solar radiation.

In a discussion on louvered screens, the WMO "*Guide to Meteorological Instruments and Methods of Observation*" states in paragraph 2.5.1 "Thus, the temperature of the air in a screen can be expected to be higher than the true air temperature on a day of strong sunshine and calm wind, and slightly lower on a clear, calm night, with errors perhaps reaching 2.0 and -0.5 K, respectively, in extreme cases. Additional errors may be introduced by cooling due to evaporation from a wet screen after rain".

Further, in Reference 2, a report by Tage Andersson and Ingemar Mattisson, "*A field Test of Thermometer Screens*", differences over 3 degrees were noted in the Stevenson type of screen. Also, in their test, an aspirated temperature measurement was used as the reference. They correctly considered it to give the true air temperature over a non-aspirated system.

Paroscientific MET3A Design Features

The MET3A incorporates the Digiquartz® barometer offering the highest level of accuracy and stability available in pressure measurement. An aspirated temperature/humidity probe provides accuracy that conforms to the WMO guidelines for temperature and humidity measurements. A double-walled chamber is used to provide good isolation of the temperature probe from the outer wall. The inner chamber is aspirated by a fan and draws air from below the instrument. The outer wall is finished with a highly reflective paint to minimize solar heating. The outer wall is ventilated to exhaust the area between the chambers and drawing in cool air from below. The fan, mounted at the top of the chamber, draws air past the temperature/humidity sensor.

The temperature measurement system is calibrated as a system, in addition to calibration at a component level. This ensures that all error sources are factored into the calibration including errors in the electronic data acquisition circuitry and system wiring.

An isothermal block surrounds the temperature sensor and has a hole that is designed to receive a temperature reference standard probe for calibration and test purposes. This allows good thermal coupling between the reference probe and the MET3A temperature sensor. The system is placed in an environmental chamber where the unit is tested and calibrated over temperature. Correction coefficients are calculated and stored in the MET3A processor's memory. A verification run confirms that the calibration is within the 0.1 ºC specification and WMO guidelines.

Mesh screens provide protection to the internal components of the MET3A from insects and airborne debris.

The fan status is monitored by internal circuitry. The MET3A reports the status of any improper operation of the fan- aspiration system.

Solar Radiation Errors

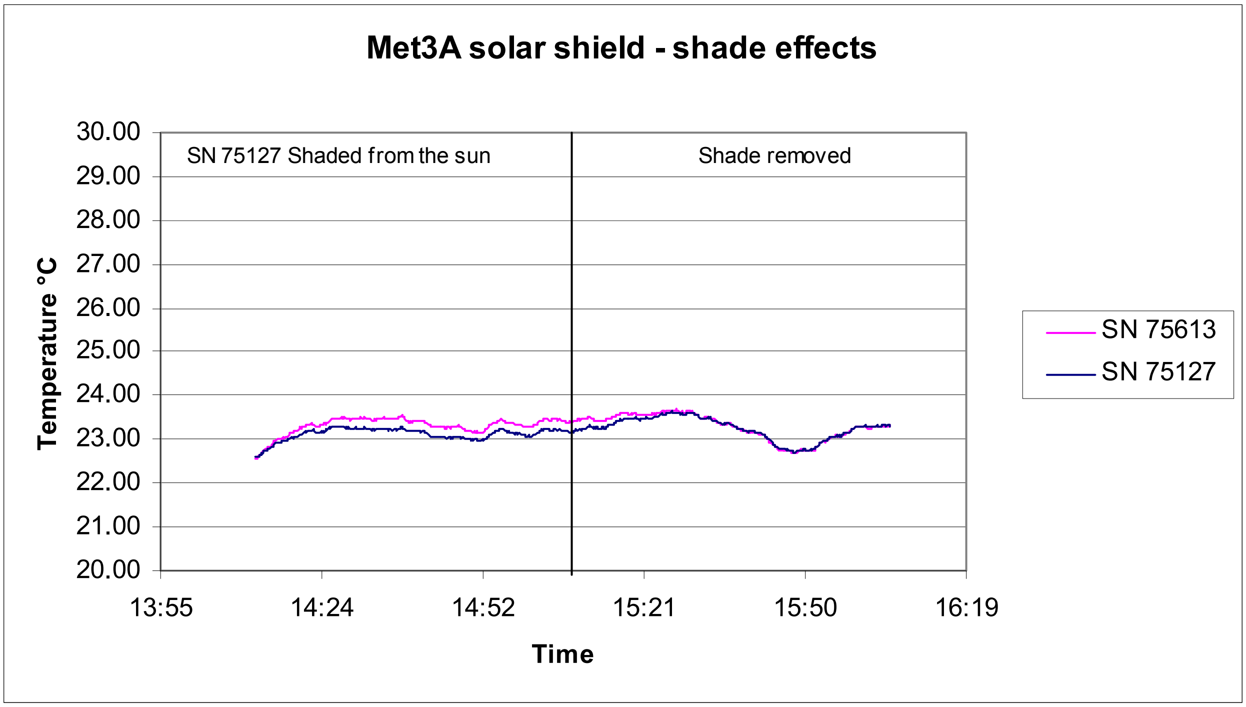
The MET3A is designed to provide highly accurate temperature measurements using a fan-aspirated ventilation system. Non-aspirated systems using radiation shields and louvered screens are subject to large errors.

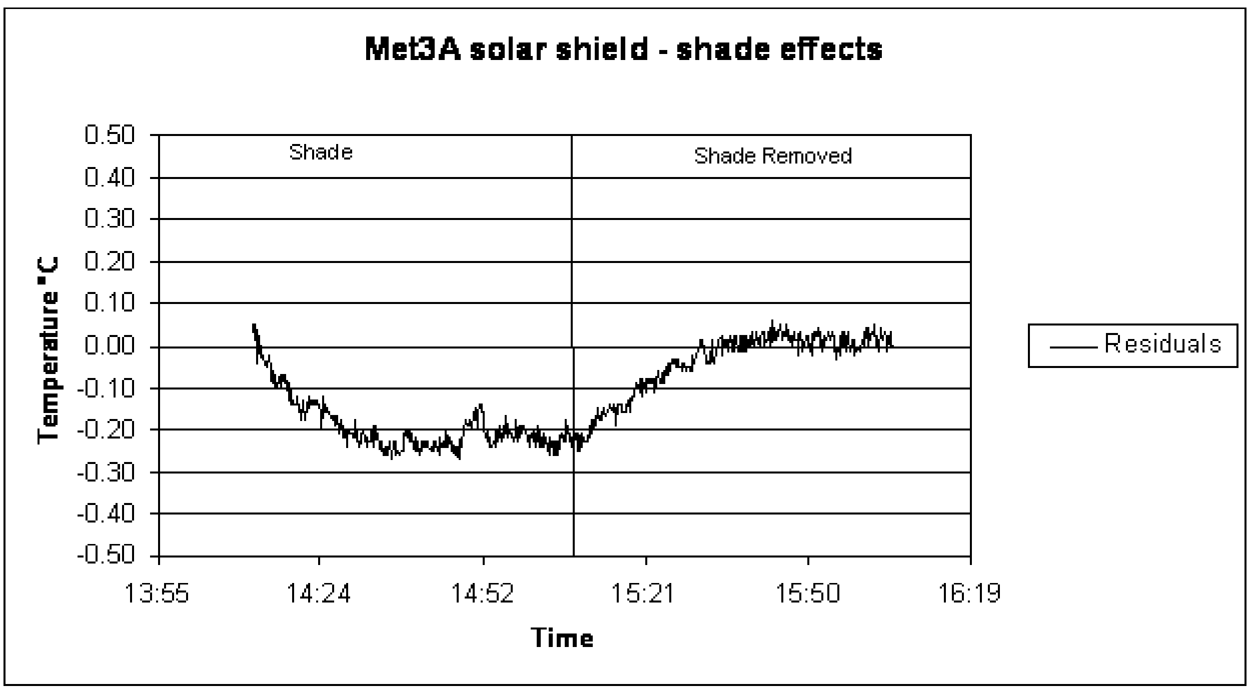
A MET3A was instrumented with temperature sensors and measurements were taken of the temperatures of the outer shield, inner shield and the isothermal block. The MET3A was placed in the sun and the temperatures were recorded. The solar radiation flux density at the time of the test was approximately 850 W/m^2. The wind speed was fluctuating between 0.4 and 1.0 meter/sec. The measured temperature rise of the outer shield was 3°C.

Tests were performed on the MET3A to determine the effects of solar heating on measurement accuracy. To accomplish this, a side-by-side comparison was made of two MET3As. These devices were mounted outdoors over a grassy area. Data was recorded continuously throughout the test. Both systems were exposed to the sun initially. After allowing time to confirm that they track each other, one unit was shaded from the sun. After an hour the shade was removed. The difference between the readings while the one unit was shaded is the error due to solar radiation.

The wind during this test fluctuated between 0.5 and 1.0 m/s. The solar radiation flux density ranged from 620 to 970 W/m^2 during the test with an average of 820 W/m^2.

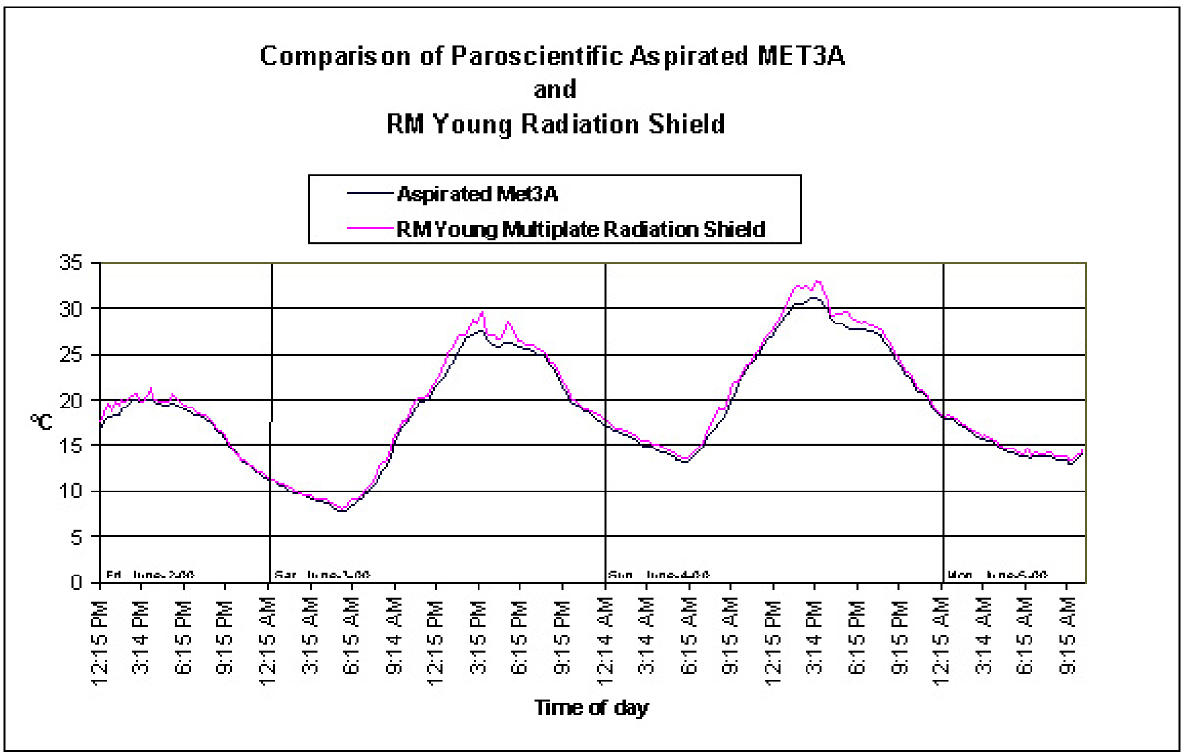
The following graphs show the effects of solar radiation equal to 0.2ºC.





Reviewing specifications from the RM Young multi-plate radiation shield, the errors in equivalent conditions (wind speed 0.5 to 1 m/s and solar energy of 820 W/m2) are between 1 to 1.5 ºC. With wind of less than 0.5 meter/sec, the errors increase dramatically. These numbers are confirmed by the Andersson/Mattisson report, Reference 1.

Paroscientific has tested the multi-plate radiation shield and observed similar results. A comparison with the MET3A shows daily overshoots that can exceed 2 ºC during calm and sunny periods. It can be seen on the following graph that the solar heating of the shields cause the temperature reading to increase more rapidly than the actual air temperature and to overshoot by over 2 ºC.



The conclusion is the aspirated MET3A is 5 to 7 times more accurate than the non-aspirated systems.

Transient Errors

The thermal time constant of the MET3A is approximately 12 minutes. This is largely due to the isothermal block. The advantage of the isothermal block is that it provides good thermal coupling between the calibration reference probe and the MET3A temperature sensor, ensuring an accurate calibration. It also provides some averaging of the temperature value.

The thermal time constants of non-aspirated systems are very dependent on wind. Comparing the MET3A with the non-aspirated shields and screens, the non-aspirated screen heats at a rate faster than the air temperature is increasing giving the false impression of a fast response time.

Calibration Verification

The MET3A temperature probe is factory calibrated to 0.1ºC. The calibration can be verified against a laboratory standard by inserting a reference probe into the MET3A's isothermal block (after removing the bottom screen) and comparing the readings over the range of temperatures.

Performing this verification is best done in an environmental chamber. A comparison test could be done in-situ, logging the temperature readings of the MET3A and reference probe over time and comparing the results..

If an adjustment to the MET3A calibration is required to achieve agreement, changes to the zero and span calibrations can be made using available software.

CONCLUSIONS

The fan-aspirated MET3A is 5 to 7 times more accurate than non-aspirated systems. The design minimizes the effects of solar radiation. The use of an isothermal block to keep the temperature probe and reference standard in thermal equilibrium makes the calibration accuracy better than 0.1 °C.

REFERENCES

1. Andersson, T and Mattisson, I. (1991)
   "A field test of thermometer screens"
   Swedish Meteorological and Hydrological Institute (SMHI) Report number RMK 62

2. World Meteorological Organization (WMO) (1996)
   "Guide to Meteorological Instruments and Methods of Observation"
   WMO-No. 8, Sixth edition