Comparison of RoadWatch® and Control Products, Inc., Model 999J Infrared Sensors

R. D. Tabler
Tabler & Associates
P.O. Box 483, Niwot, CO 80544
303-652-3921

Infrared sensors available from Commercial Vehicle Systems, Inc. (RoadWatch®) and Control Products, Inc.(Model 999J), were compared side-by-side as part of the instrumentation for the Interstate-80 and US 287 Safety Improvement Studies over the 2002-03 winter. The comparisons involved 3,941 miles of thermal mapping, consisting of more than 2.8 million measurements. Both instruments were installed forward of the front bumper, with the sensors at 21.5 inches above the surface (Figure 1). At this height, the diameter of the field of view for the Control Products sensor is approximately 1.0 inch, compared to 3.75 inches for the RoadWatch sensor. The sampling frequency for both sensors was ten samples per second.

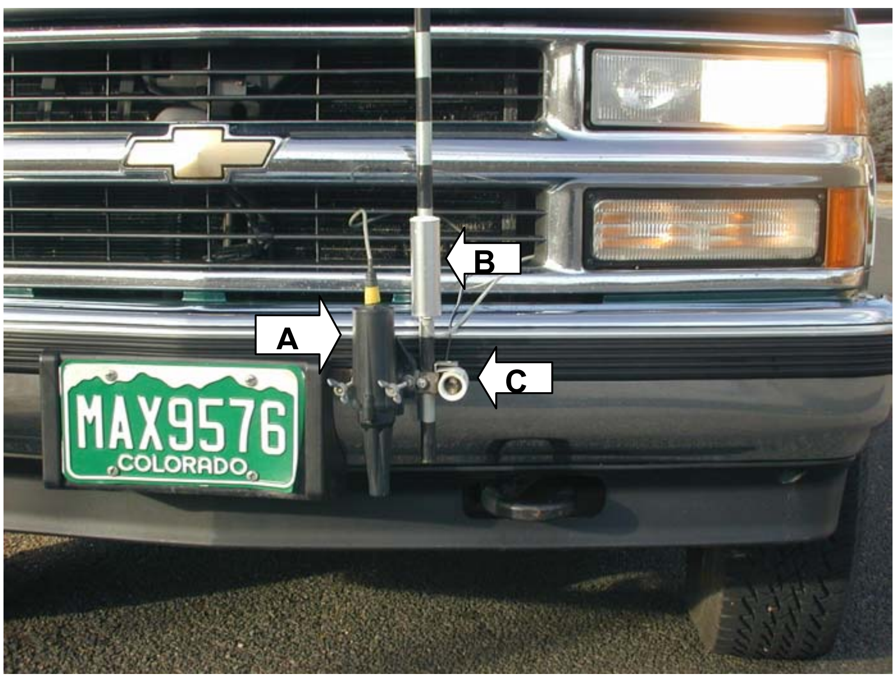

Figure 1. Location of instruments. A = Control Products infrared sensor. B = Roadwatch infrared sensor with internal air temperature sensor. C = Control Products air temperature sensor.

The output from the Control Products instrument was recorded using the Control Products, Inc., "Thermal Mini-Mapping®" software, which also records the location of each observation. The RoadWatch instrument was not equipped with an output other than the digital display, but the output of both instruments was recorded by digital video, allowing RoadWatch data to be transcribed from the video tapes (Figure 2).

Both infrared instruments integrate thermal energy over the 8- to 14-μ wavelengths. Surface temperature is determined from the Stefan-Boltzmann Law:

$R = \varepsilon \sigma T^4$

where *R* is the rate of radiant energy per unit area (watts per square meter), σ is a constant ($5.67051 * 10^{-8} \cdot W \cdot m^{-2} \cdot K^{-4}$), *T* is temperature in degrees Kelvin (K = °C + 273), and ε is emissivity, defined as the ratio of radiant resistance of the surface to that of a blackbody at the same temperature as the surface. The average emissivity of ice over this range is 0.965 (Figure 3), and both instruments are calibrated for an emissivity of 0.96.

Instrument calibration was checked daily with a water/ice mixture at 32°F (Figure 4).

Figure 2. Temperature data acquisition system.

Figure 3. Spectral emissivity of smooth ice from 8- to 14 µ (From Moderate Resolution Imaging Spectrometer, Institute for Computational Earth System Science, University of California, Santa Barbara. Copyright © 2002, The Regents of the University of California).

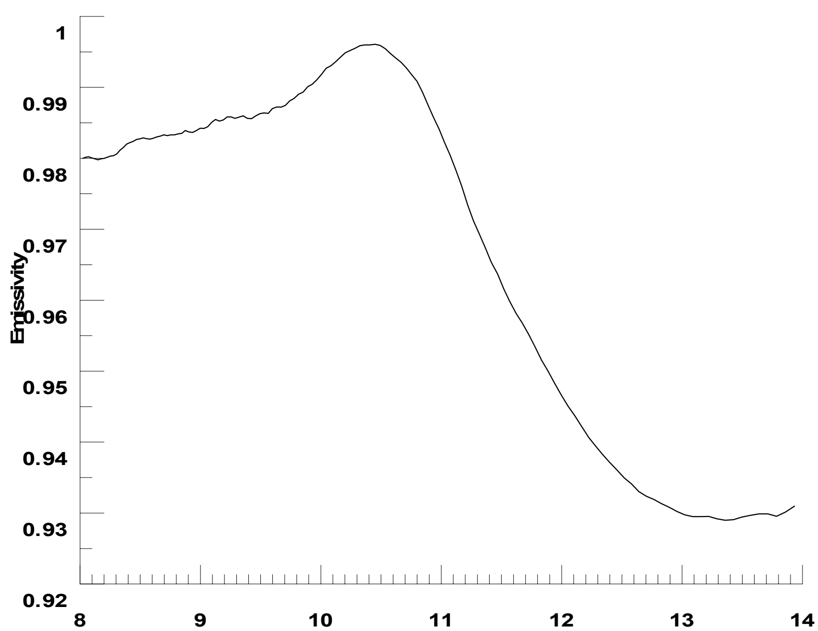

Figure 4. Calibration of instruments.

The basic requirement for accurate temperature measurement using infrared sensors is that the emissivity of the surface must be 0.96, the value for which the instruments are calibrated. This condition is met when the surface is covered with a thin film of ice; however, the emissivities of both Portland cement concrete and asphalt concrete are approximately the same as that of ice. A method used to validate temperature measurements over bare pavement was to compare indicated temperatures before and after spraying the pavement with ice water when pavement temperature was below freezing (Figure 5). For the study area pavements, measurements over bare pavement are within 2- to 3 °F of the true (ice-covered) temperature. The comparisons between the RoadWatch and Control Products sensors are not affected by differences in emissivities.

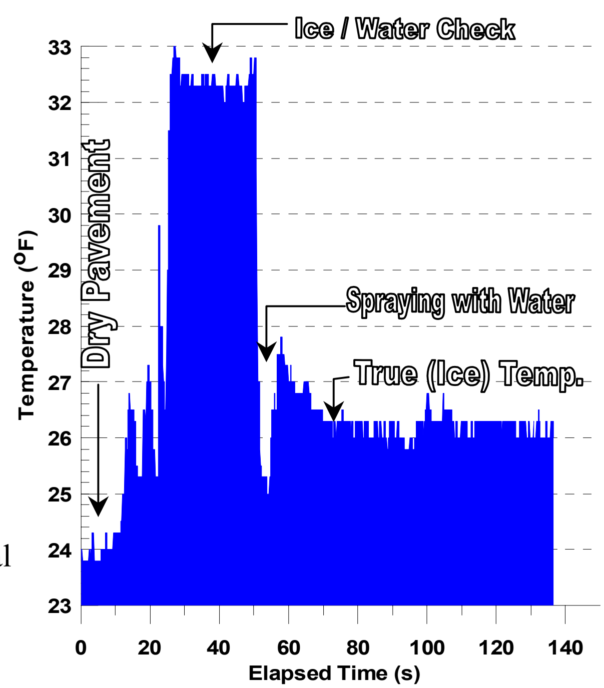

Figure 5. Method to determine effect of differential emissivity on accuracy of temperature measurements.

The differences between the RoadWatch (RW) and Control Products (CP) sensors include the following:

1. The lens of the CP is recessed 4.5 inches from the end of the conical housing to protect the lens from contamination. The outer optical surface of the RW is flush with the end of the housing (Figure 6).

2. The CP instrument uses an external sensor for measuring air temperature, whereas the RW instrument utilizes a sensor inside the housing. For this reason, the RW sensor does not always provide an accurate measurement of air temperature. Because ambient temperature is a key variable for the algorithms used to compute infrared temperature, the air temperature error causes an error in indicated surface temperature.

3. The CP instrument utilizes a Germanium lens, which is more efficient in focusing radiant energy on the sensing element than the plastic Fresnel lens used in the RW instrument (Figure 7).

4. The Control Products sensor can be field calibrated for 32 °F. The RoadWatch sensor must be sent to the manufacturer for adjustment.

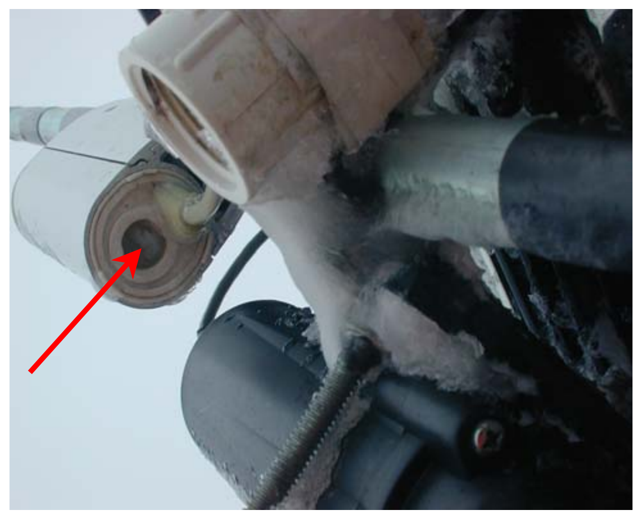

Figure 6 (Right). The outer optical surface of the RoadWatch sensor is subject to contamination. In this case, the indicated infrared temperature was actually that of the air temperature because of the accumulation of ice on the lens.

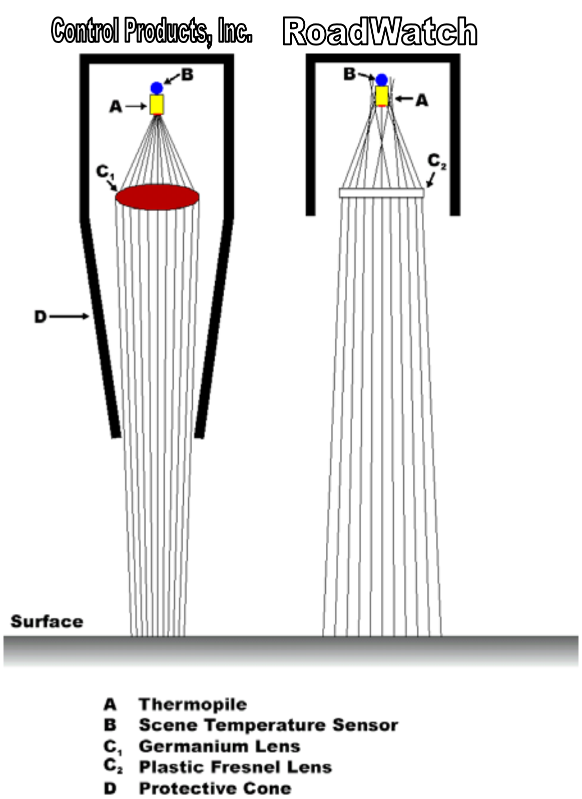

Figure 7 (Left). Conceptual illustration of the different optical lenses used in the Control Products and RoadWatch instruments. Illustration courtesy of Ed Rendon, Control Products Inc.

Under favorable conditions, the Control Products and RoadWatch sensors give comparable results, with infrared temperatures within a degree (F) or two. Changes in air temperature as small as 2- or 3 °F, however, cause significant discrepancies as great as 15 °F or more, if the ambient temperature sensor in the RoadWatch instrument lags behind the actual air temperature change. In general, approximately 20 minutes are required before the RoadWatch begins to provide accurate readings. Many hours of such disparity were observed during last winter's measurements, and examples are shown in Figures 8 and 9. In Figure 8, video data had not commenced at the time a large discrepancy between the two instruments was noticed. As a result, only 7 minutes of data were recorded even though the disparity in output had likely been occurring for a much longer time. The initial temperature differences in both examples were caused by heating up of the RoadWatch housing while the data collection vehicle was stopped for pre-run calibration checks.

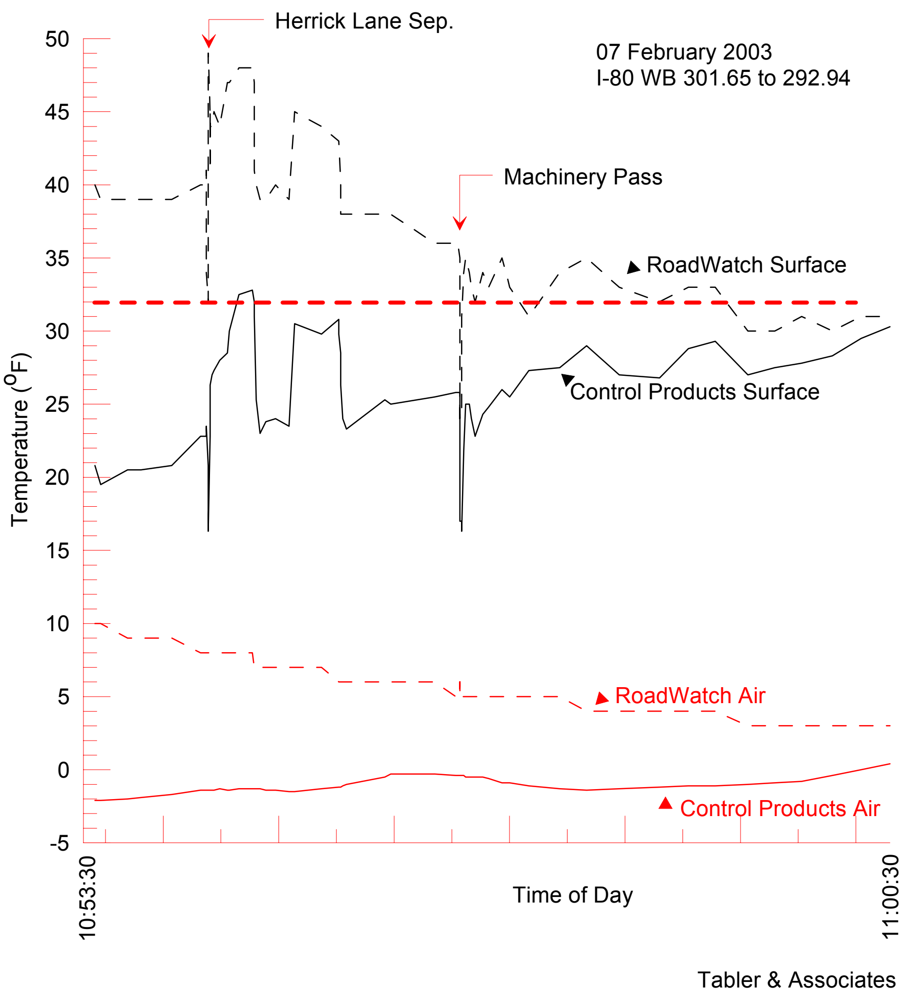

Figure 8. Comparison of output from Control Products, Inc., Model 999J, and the Commercial Vehicle Systems, Inc., RoadWatch sensor, on February 7, 2003.

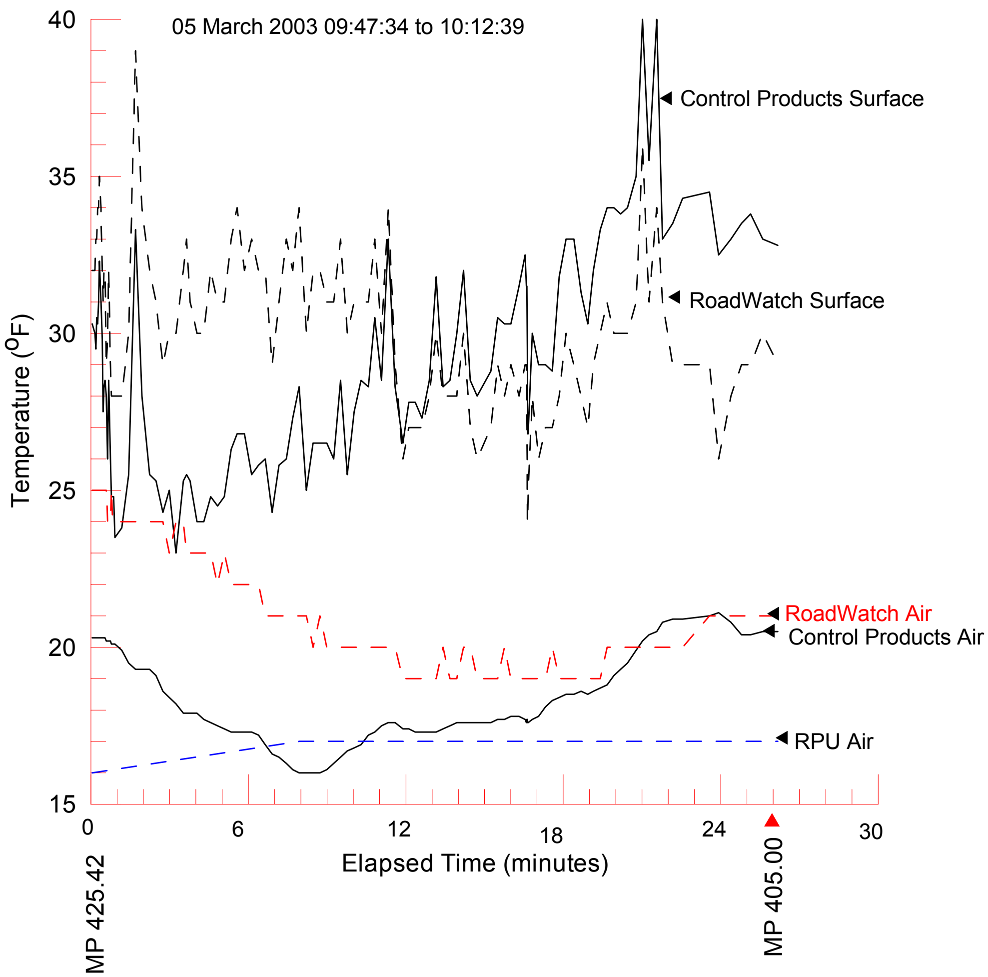

Figure 9. Comparison of output from Control Products, Inc., Model 999J, and the Commercial Vehicle Systems, Inc., RoadWatch sensor, on March 5, 2003 (Location: Wyoming US 287). RPU Air is the air temperature recorded at the Pumpkin Vine RWIS site, located at Mile 420.37. It should be noted that the air temperature at that location is not representative of locations more than a few miles away.

Figure 9 illustrates the tendency for the RoadWatch infrared temperature to drift in response to changes in air temperature. The rising air temperature beginning at 17 minutes causes the RoadWatch infrared temperature to begin under-reading.

The air temperature indicated by the Control Products instrument has been found to be in excellent agreement with both a digital thermistor thermometer, and the on-board vehicle temperature sensor.

Recommendations:

1. After leaving a heated garage, wait at least 30 minutes before assuming RoadWatch readings are correct.

2. After stopping for more than a minute or so, wait at least 15 minutes before assuming RoadWatch temperatures are correct.

3. Clean RoadWatch lens daily.

4. Check calibration of instruments frequently with an ice/water mixture at 32 °F.

5. Specify the Control Products Model 999J rather than the RoadWatch sensor for future procurement.