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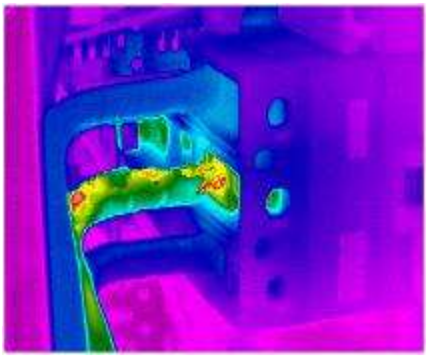

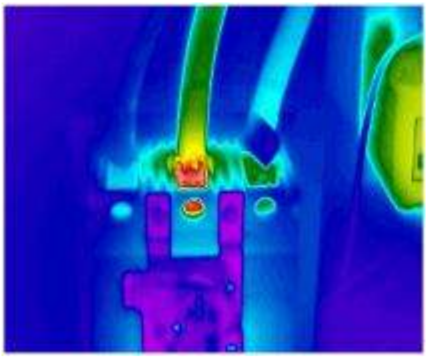

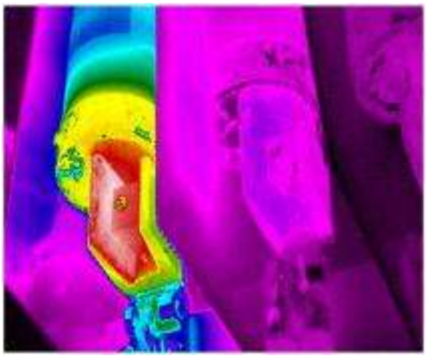

IR WINDOW TRANSMISSION GUIDEBOOK

PLANT ENGINEERING WEBCAST

ID 4015 Rev A

Content

Understanding Infrared Transmission

Infrared (IR) Windows and their Effects on IR Readings

This guidebook explains the factors affecting transmission through an Infrared (IR) window (as used in a practical electrical inspection application). Learn how different IR window types affect your readings and how to correct for transmission losses.

Introduction

Infrared thermography is a proven technique for inspecting live electrical equipment. With the installation of one or more IR windows, an infrared thermographer can examine live electrical equipment without removing panel covers.

The use of IR windows has become increasingly common over the past ten years. This is due primarily to the increase in electrical safety awareness caused by the widespread implementation of safety standards such as NFPA70E and CSA Z462. However, this guidebook introduces the theory behind infrared transmission.

There are two kinds of IR Window: crystal and reinforced polymer. How do these materials affect readings? What are the options available to thermographers to allow correction and more accurate problem diagnosis?

IR Windows are not 100% transmissive to infrared radiation and so the thermal imager will be inaccurate when viewing through an IR Window.

Thermographers want to measure temperature, if temperature measurement is not important why buy a radiometric camera?

Aims

This guidebook will:

- Explain the theory of infrared transmission as it applied in real life situations to IR Windows

- Explain the options available to thermographers when it comes to transmission correction

- Benefits and shortfalls of Single point (or coffee cup) calibration as opposed to multi point calibration

- Correction in practices determining a calibration range, and how Camera differences can affect Accuracy expectations

Lets get started

IR WINDOW TRANSMISSION

1

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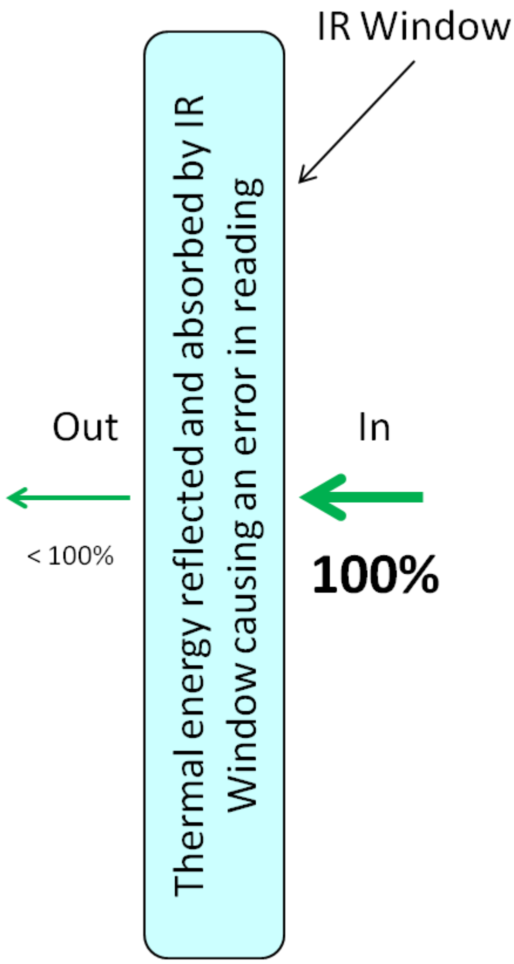
What is Infrared Transmission?

Infrared transmission can be defined as the proportion of infrared radiation emitted from a target which passes through the IR Window and reaches the thermal imager enabling a measurement.



IR Window manufacturers are often asked the question: “What is the transmission of your IR Window?”. Unfortunately, there is no simple answer. Most, if not all IR Windows used for electrical inspection, are “spectral” in nature: the transmission of the IR Window itself changes with wavelength and therefore target temperature.

Additionally, the apparent transmission of the IR Window depends, to some extent, on the spectral response of the camera. Since the majority of predictive maintenance (pdm) thermal imagers operate in the long wave (LW) band of 8-14µm, this guidebook will concentrate on the specific effect on this type of thermal imager.

It is not possible to achieve 100% transmission: where does the rest of the IR energy go?

Reflection and Absorption

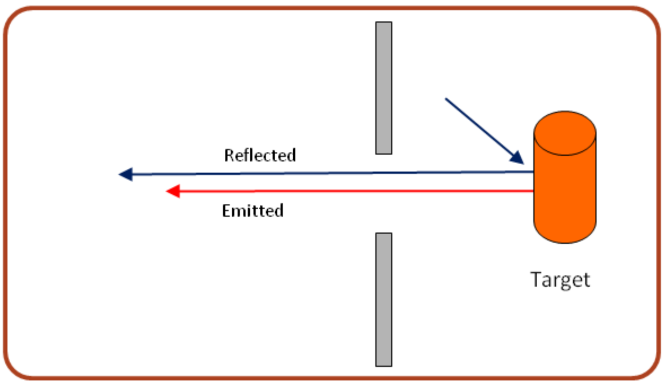
The total IR Energy an imager "sees" is made up of three components— Reflected, Absorbed and Transmitted energy:

$$R + A + T = 1$$

Thermographers are accustomed to the first two as these are input into a thermal imager to obtain a valid reading however the third is only used when there is a medium between the target and the camera. In this case an IR Window.

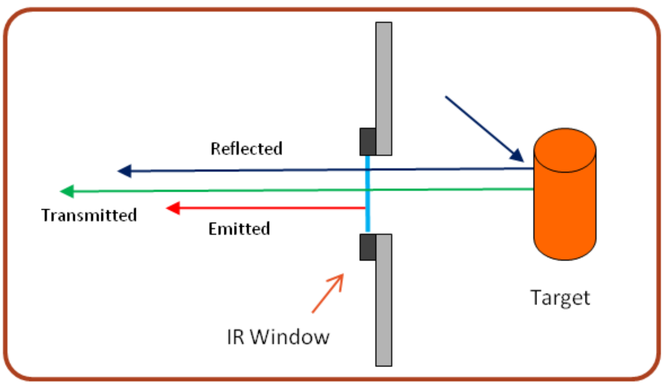
When setting up a thermal imager to take a reading without an IR Window, we make an assumption that there is zero transmission component as we have a direct line of sight to the target being measured. The energy measured by the imager (see Figure 1) is made up of:

- Energy reflected from the target
- Energy emitted by the target



Without IR Window

With IR Window



Crystal IR Window Transmission Schematic

When we add an IR Window to the system, we introduce additional radiation sources:

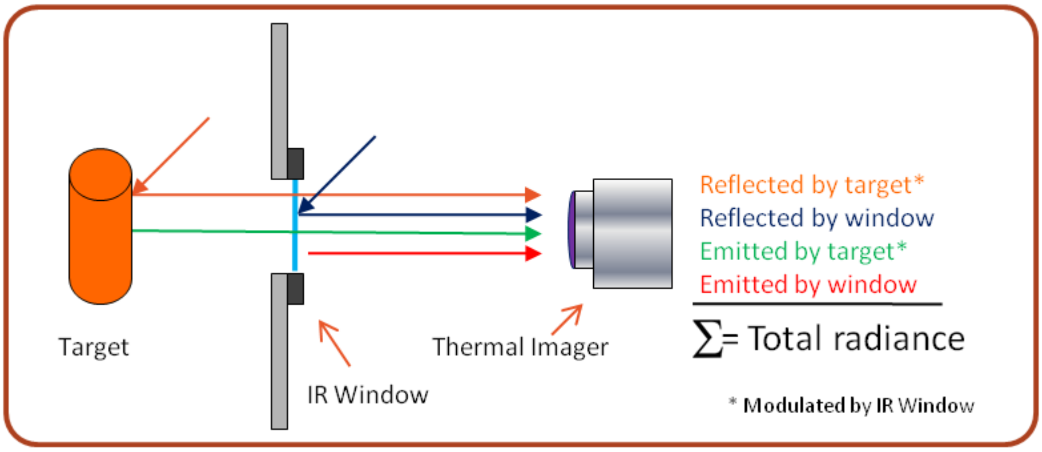
- Energy reflected from the target and transmitted by the IR Window
- Energy emitted by the target and transmitted by the IR Window
- Energy emitted by the IR Window
- Energy reflected from the IR Window

The sum of these four values is known as the *total radiance* and this is the amount of energy our thermal imager registers and converts into a temperature measurement value.

The overall effect can either be positive or negative depending upon the severity of the environment and the composition of the IR Window.

This standard crystal IR Window transmission schematic shows the four signals received by the thermal imager.

To calibrate an IR window, the goal is to isolate all signals other than the emitted by target signal, shown in green.

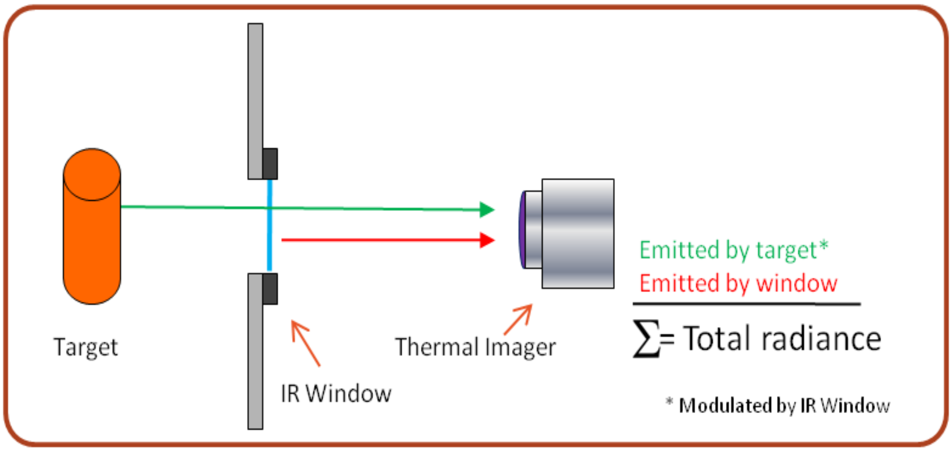


CorDEX Crystal IR Window Schematic

IW Series IR Windows with HydroGARD coating have almost zero surface reflectivity which means we can remove the Reflected by window signal, shown on the previous page in purple.

For real-time measurements we require high emissivity targets, therefore we can remove the Reflected by target signal, shown previously in orange.

This leaves only the Emitted by target and Emitted by window signals. As we are generally interested in higher temperatures the effect on reading by energy emitted from the window is minimal.

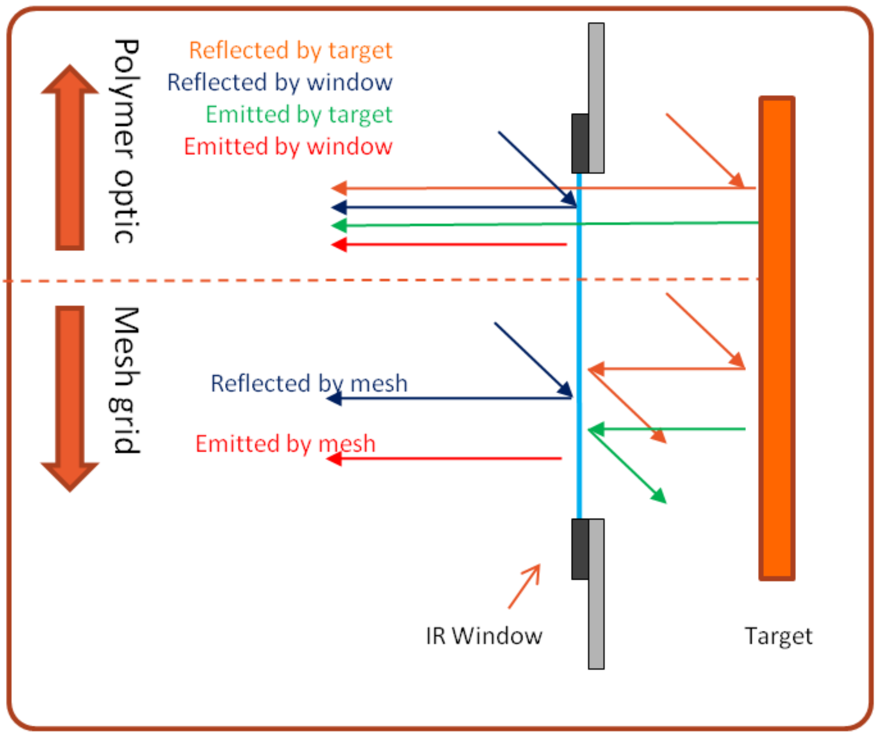


TOP TIP

If the IR window is hotter than the original target, then the amount emitted by the IR Window itself will be higher than the camera would originally have seen had the IR Window not been present. Therefore, the camera will read HIGH

Crystal or Mesh?

So far we have assumed that we have an uninterrupted path to our target, which is not always the case. Some IR Viewing panes use a combined polymer and mesh as the "optic", lets see how this combination affects the camera. In the schematic below, we can see that the opaque mesh (black) has totally different transmission characteristics to semi-opaque polymer (yellow). Inconsistency due to mesh/polymer combination, focus, target temperature and window temperature make polymer/mesh combination impossible to calibrate over standard pdm range.

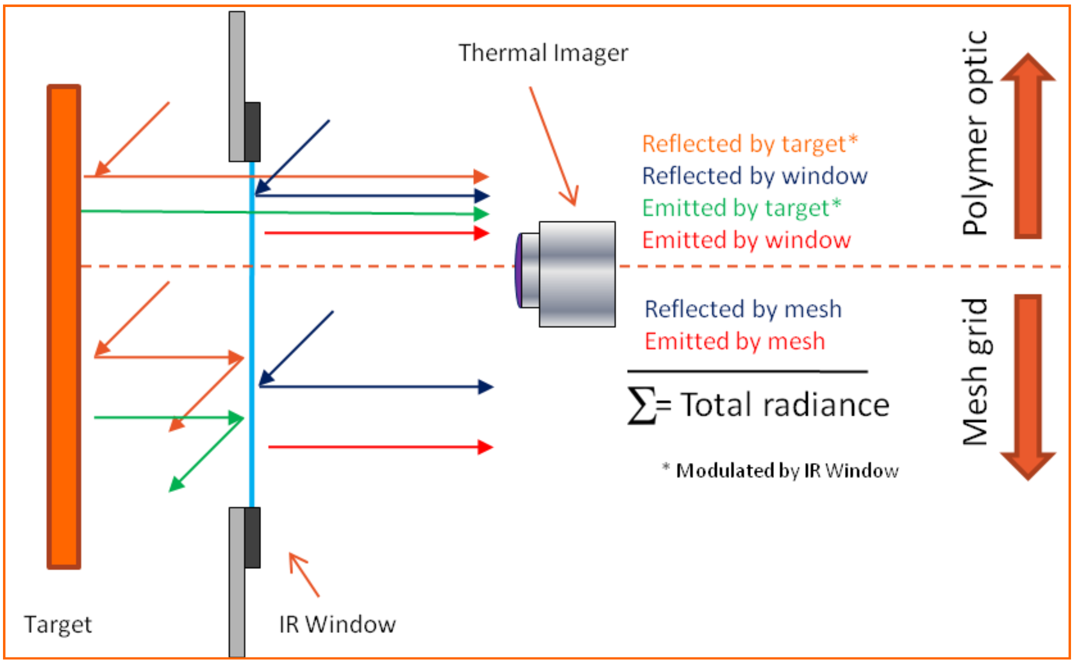


Polymer/Mesh Transmission Schematic

This polymer/mesh IR Window transmission schematic shows multiple signals received by the thermal imager.

For this model we have separated the signals to the camera from polymer optic and opaque mesh grid.

It is clear that there are now a minimum of six signals reaching the camera; four from the polymer optic and four from the mesh grid.



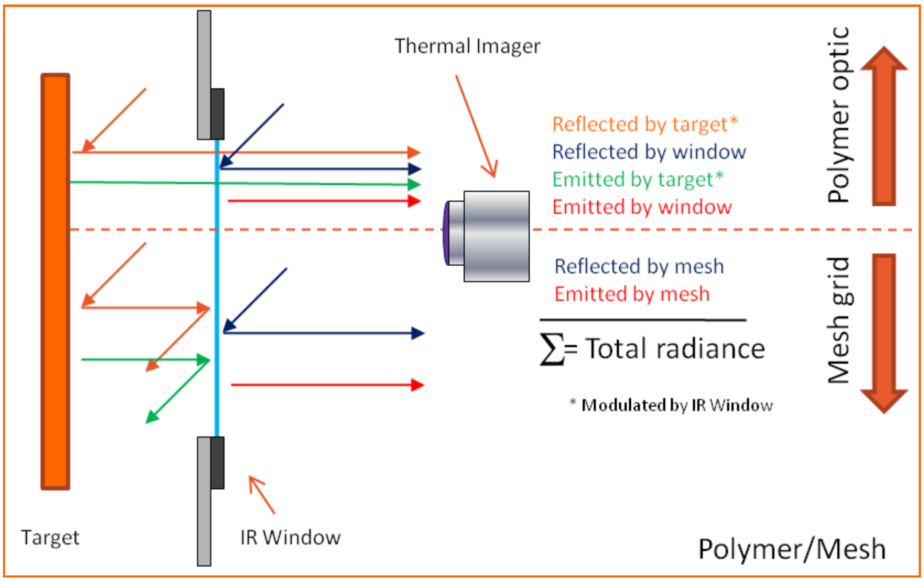
We can see that the mesh and polymer behave very differently. The polymer does allow some energy to pass but also reflects and emits its own energy. The mesh in contrast is totally opaque and therefore the signals it transmits to the camera are reflected and emitted.

This behaviour is repeated multiple times due to the mesh honeycomb. Additional problems arise when focus and angle are introduced into the model.

Crystal Optic Vs Polymer/ Mesh Optic

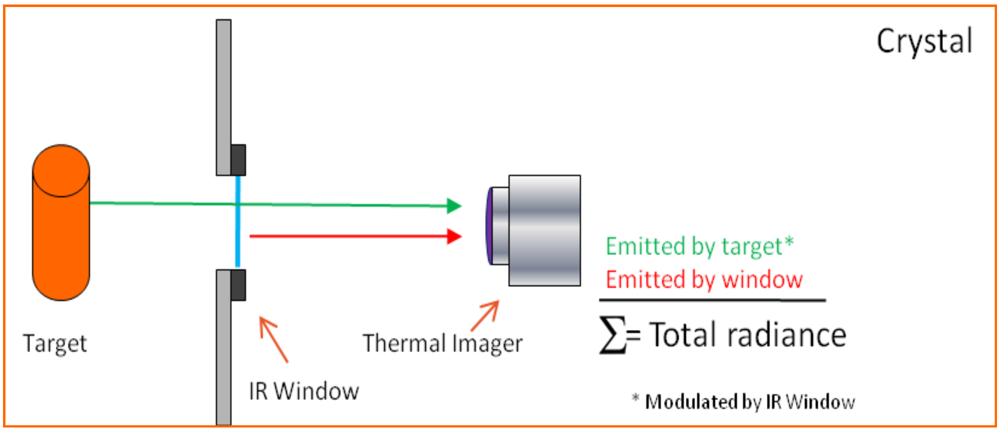
Polymer / Mesh Optics

- Multiple complex signals to thermal imager
- Severely affected by focus and angle
- Repeatable transmission correction is not possible
- Suitable for qualitive (non-measurement) based thermography only



Crystal Optics

- Suitable for quantitive (measurement) based thermography with transmission correction algorithm
- Simple, repeatable signals to thermal imager
- Minimal surface reflection
- Does not affect target focus



We have established it is not possible to correct through mesh

SO, WHAT NEXT?

2

Standard instrument calibrations are performed at set points across the process variable (PV) range. Traditionally, IR window calibrations have been related to a single point calibration also known as a 'coffee cup calibration'.

In order to obtain accurate readings across a range, a correction curve must be created. Typically, calibrations across a range of the following— 0%, 20%, 40%, 60%, 80%, 100%. This allows the instrument to be accurate at multiple points.

Since a thermographer is interested in trending temperature over time to extrapolate a failure before it occurs, calibration over a range is the ultimate goal when it comes to accuracy.

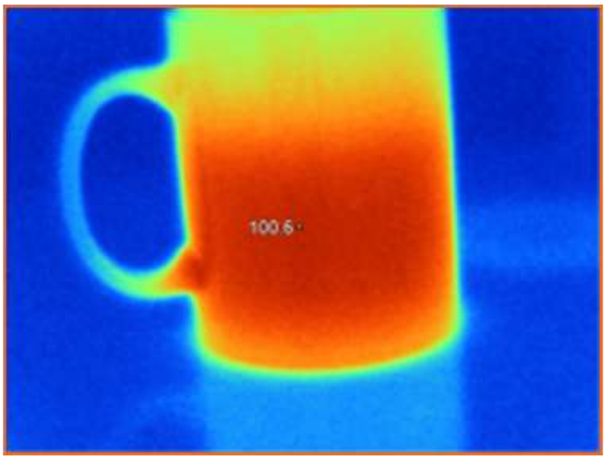
Calibrating for Transmission - Traditional

To highlight the limitations of single point calibrations, we will apply the coffee cup test to a range and measure the results using a IW series intelligent IR window and long wave thermal imager.

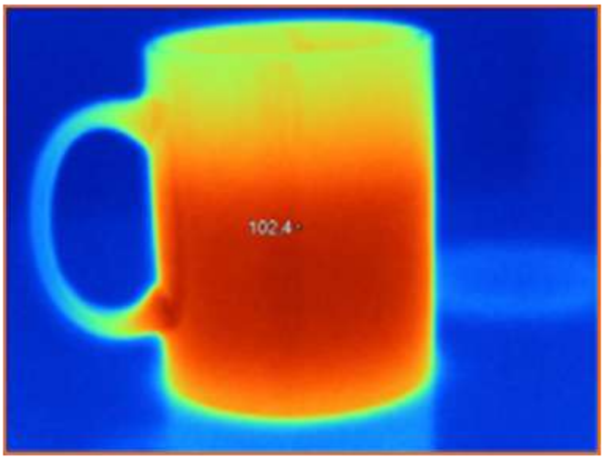
Coffee cup test procedure

- Set the camera emissivity to 1
- Point the camera at the hot cup of coffee , make sure it is in focus and record the temperature
- Insert the window between the cup and the camera and record the reading
- Alter the emissivity to bring the camera temperature reading back to pre-window
- Multiply the value shown by the emissivity of the next target and that it the transmission of the window

Results



No window
e =1



With Window
e =0.45

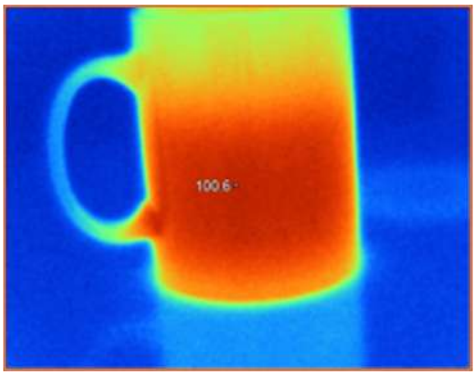
TRY IT FOR YOURSELF!

Coffee Cup Test Results at a Higher Temperature

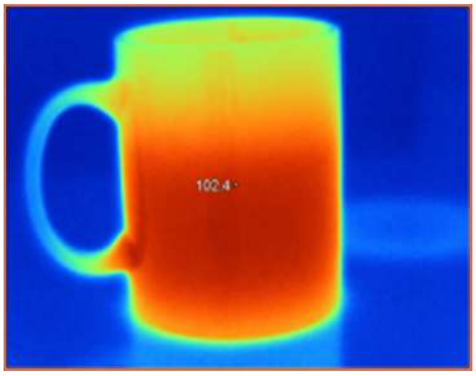
Below are two sets of results. One showing the initial calibration temperature where accuracy is 2°. The second set of results show the same calibration figure applied to a higher range, in this case 238F. In this case, the camera returns a temperature of 272F which is high by 34°.

Single point, "coffee cup" calibration

No window – 100F



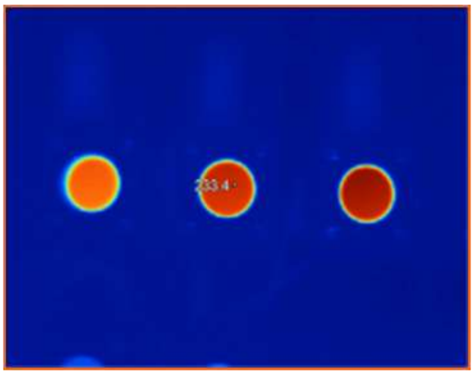
Window with calibration



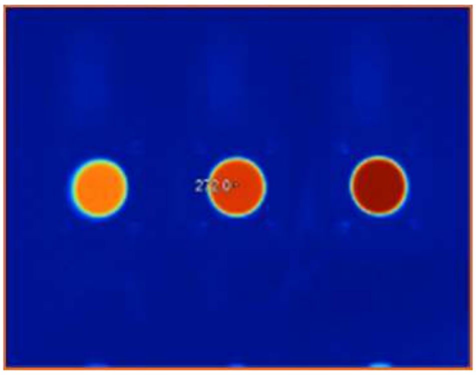
e = 0.45
Error @ 100F, 2°

Single point, "coffee cup" calibration at different temperature

No window – 238F

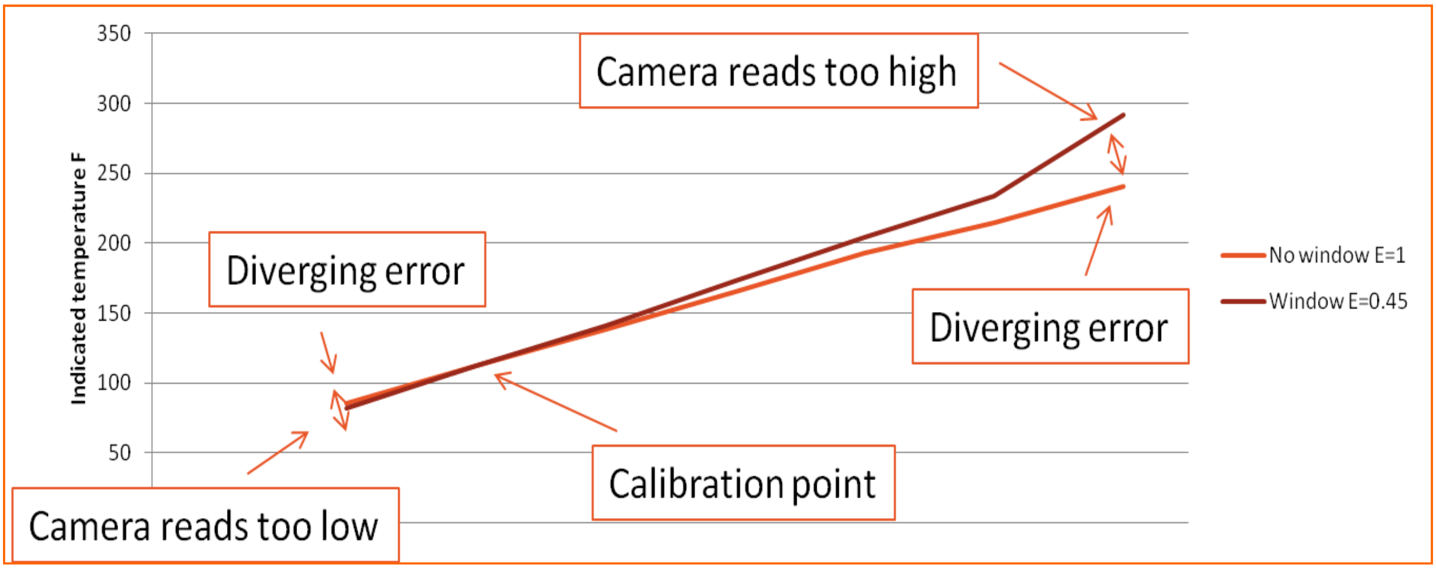


Window with calibration from above



e = 0.45
Error @ 238F, 34°
Camera reads <u>HIGH</u>

Coffee Cup Calibration Applied to a Range



The graph above shows the effect of a single point calibration over a range. At the calibration point, the camera is accurate. However, as the same calibration factor is applied to increasing and decreasing target temperatures, significant errors occur.

- Coffee cup calibration is only accurate at single point
- Readings are inaccurate as temperature changes
- If tested above coffee cup test temperature, camera reads high thus meaning potential false alarms
- If tested below coffee cup test temperature, camera reads low thus meaning potential missed problems

SINGLE POINT CALIBRATIONS ARE INACURATE WHEN APPLIED TO A RANGE

Putting theory into practice

MULTIPOINT CORRECTION

3

Goals

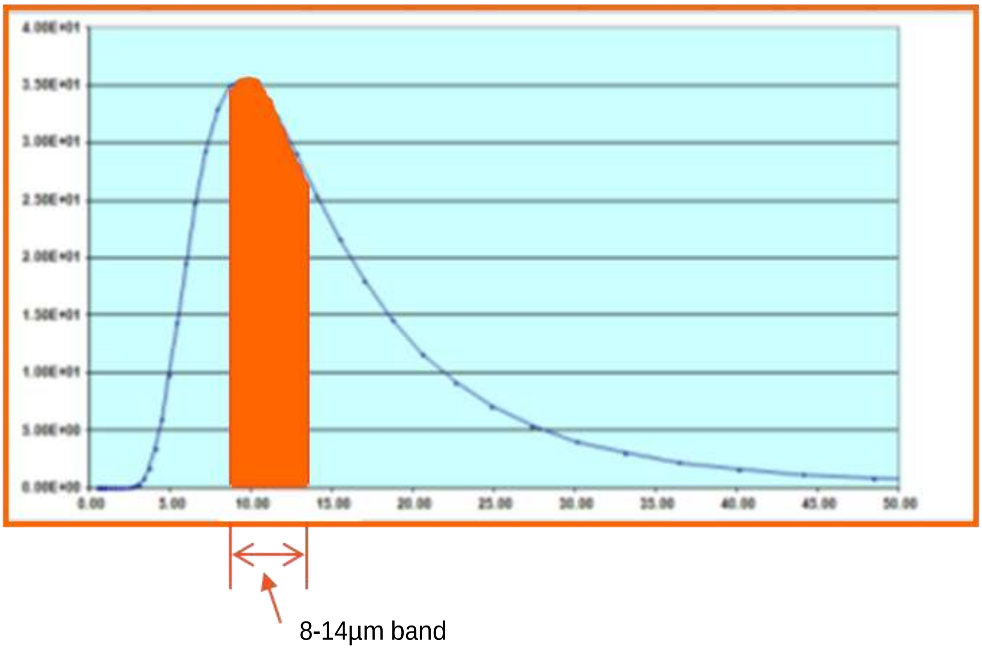
The ultimate goal is to create a correction map which provides accurate readings over a range of target temperatures. The aim is to achieve a ±5° target accuracy after calibration. Whilst this is outside the standard camera accuracy , it is more than adequate for electrical inspections. When creating the map, it is essential to isolate erroneous signals which will affect the result.

Challenges

All IR Windows – even those using the same material at the same thickness – will exhibit slight differences in transmission results. Transmission maps must be individual to each IR Window. A typical electrical pdm range of 85- 330F requires a minimum of five calibration points to be in line with standard instrument calibration protocol. Spectral responses of individual cameras change from one to another. This will always create an error but generally will be within the ±5° target accuracy.

What is Spectral Transmission?

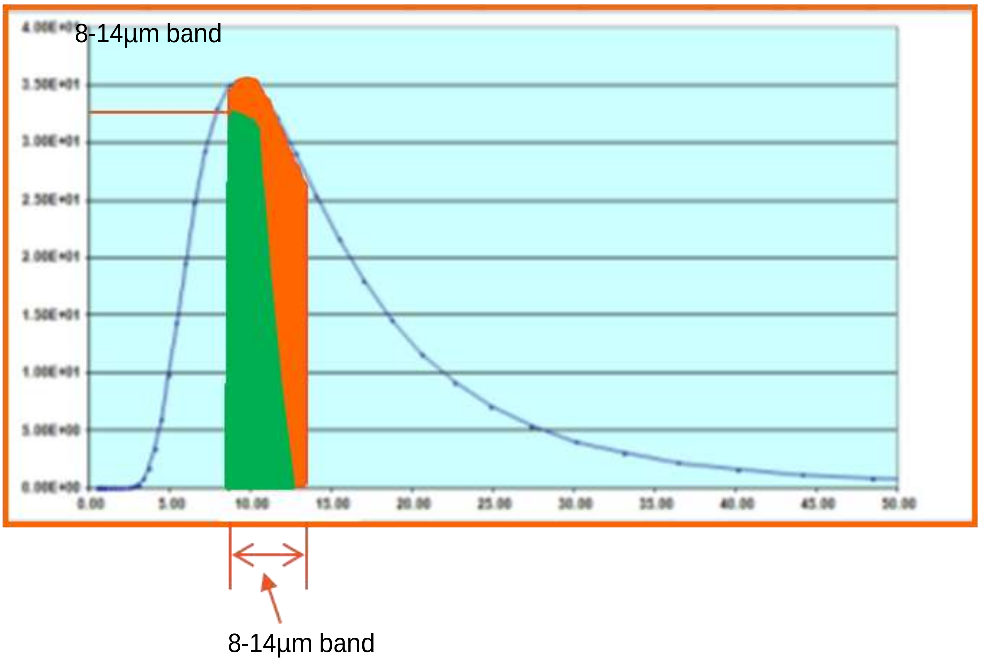
Plancks curve for blackbody at 95F



Total radiant energy detected by thermal imager in 8 – 14µm band is the area under the curve which equates to temperature when the imager is calibrated.

Plancks curve for blackbody at 95F

With an IR Window between the imager and the target, the amount of energy received by the thermal imager in this instance shown in green. The calibration factor is the multiplication value required to increase the green area to orange.



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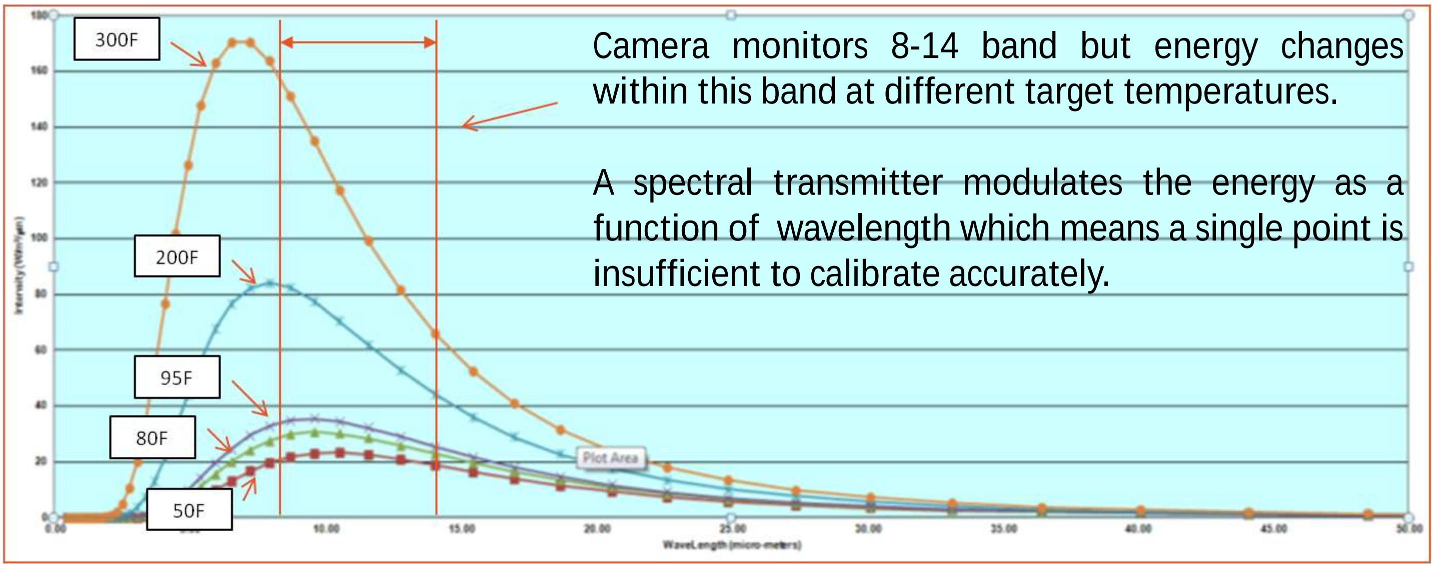
What is Spectral Transmission?

Hotter temperatures curve moves into the shorter wavelength ←

Colder temperatures curve moves into the longer wavelength →



Planck's curve “moves” along the IR Spectrum depending upon target temperature.

Since the transmission of the IR Window is better in the shorter wave lengths, more energy is transmitted by the IR Window from hotter targets than for colder targets which transmit more on the longer wavelengths.

A material having the ability to change transmission rate as a function of target temperature is known as a *spectral transmitter*.

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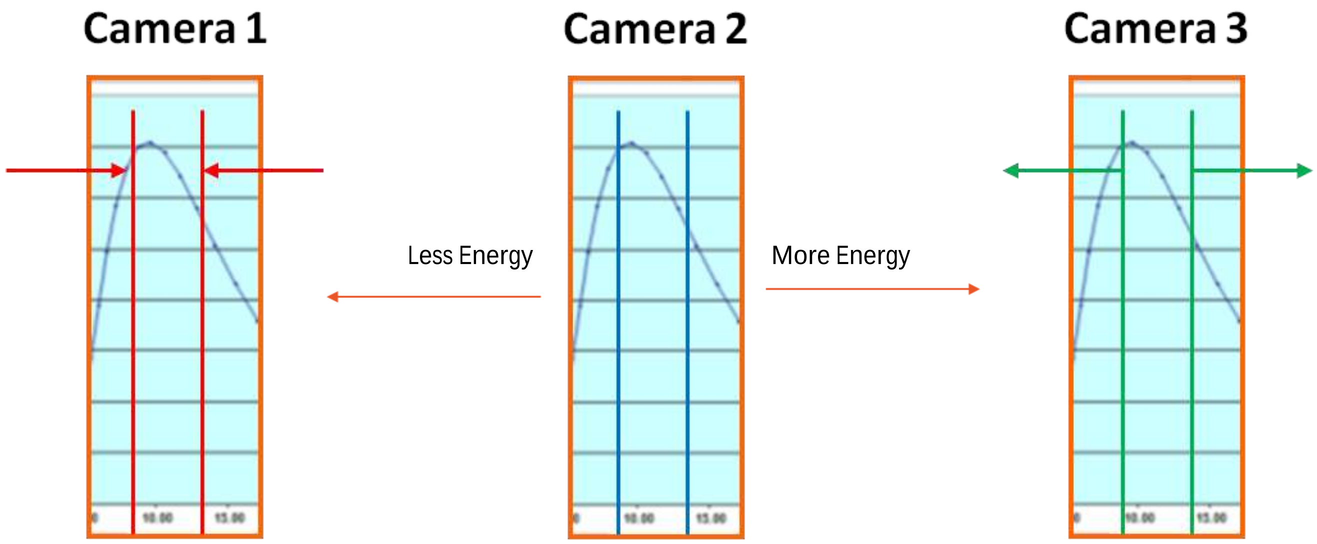
Changes in Camera Response

Individual thermal imagers all have different spectral responses. This is a characteristic of the individual detectors as they come off the production line. These differences do not affect thermographers' in general as the camera is calibrated. The affected only become "visible" when a spectral transmitter is placed between the thermal imager and the target.



Spectral Response 8.1-13.9µm   Spectral Response 8-14µm   Spectral Response 7.8-14.2µm

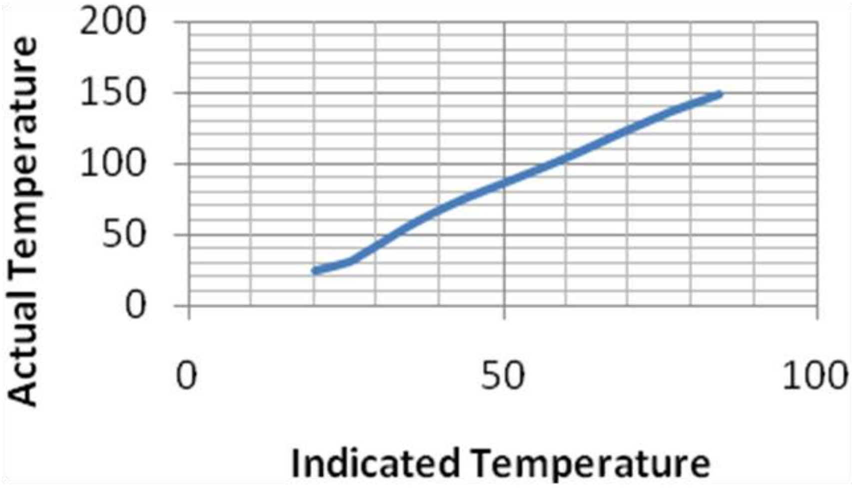
All three cameras "see" slightly different radiant energy levels for the same target temperature. The cameras all read the same as they are calibrated to "understand" that this specific level of intensity equates to a specific temperature, however this will cause an error when used with a spectrally transmitting IR Window.

CorDEX IW Series Correction Maps

Previously, infrared thermographers have requested transmission curves from IR window manufacturers. In reality, a transmission curve has little use as it doesn't provide the thermographer with the information required to obtain an accurate reading.

What the thermographer actually needs is a correction curve.

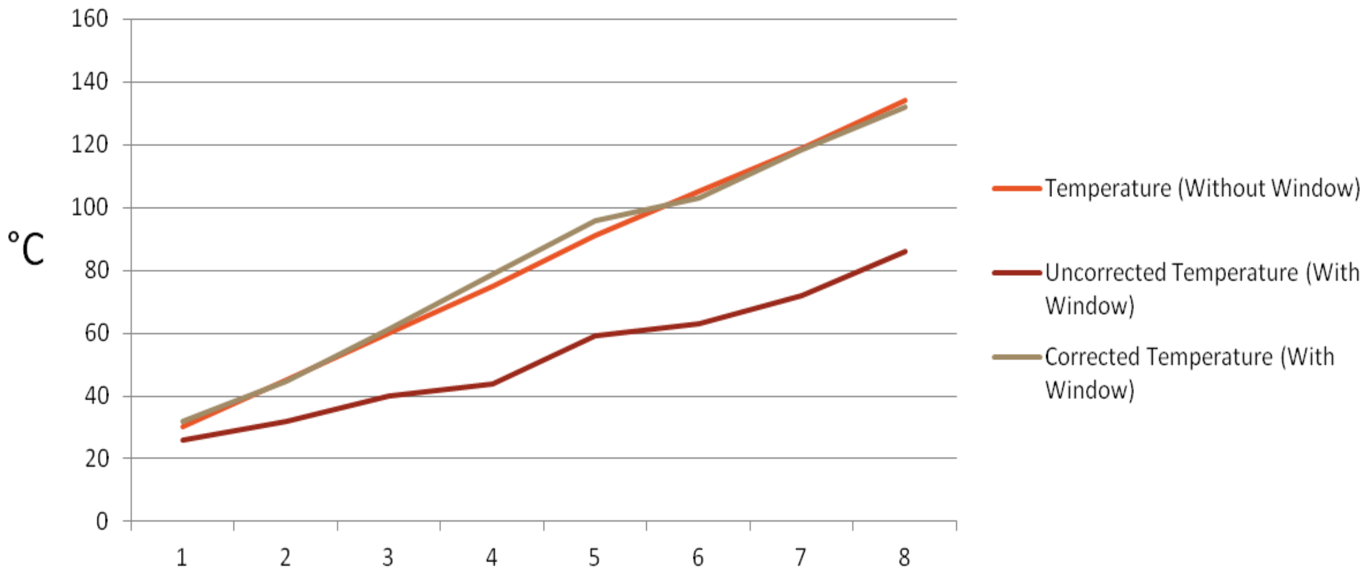
A typical CorDEX IR Window correction curve is shown opposite. This curve correlates indicated temperature as shown by the thermal imager and actual temperature of the target across a range.



- A multipoint correction map is created across the identified pdm range and made available to thermographers
- Distance to targets, ambient humidity and optic temperature are all considered and corrected for within the map
- Multiple points are considered when creating the map, far exceeding the standard five instrument calibration requirements

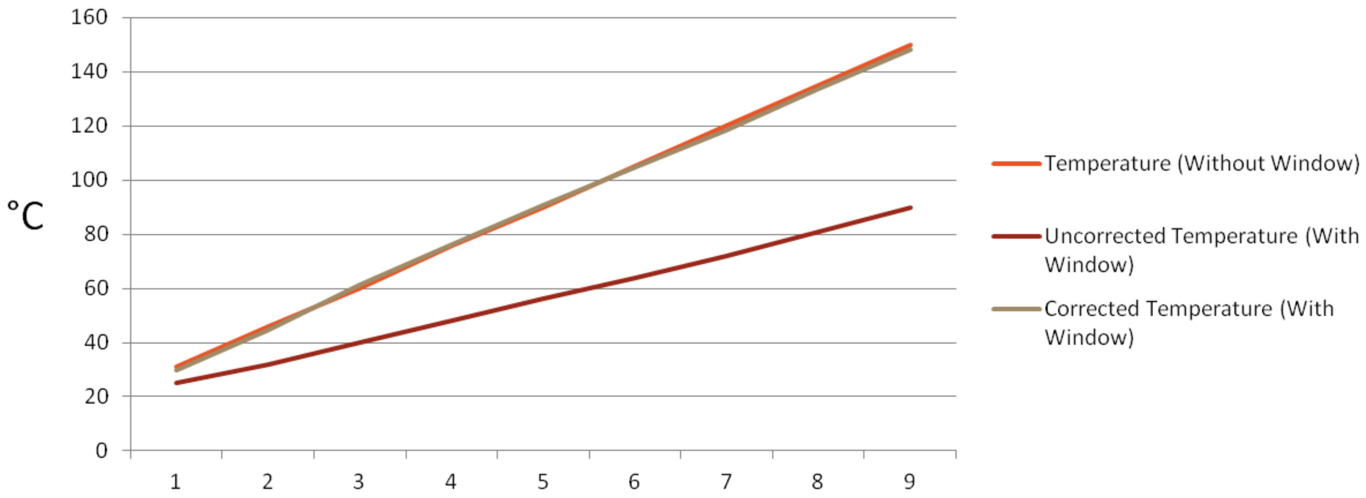
TARGET ACCURACY OF ±5° IS THE GOAL, BUT DOES IT WORK….

CorDEX Transmission Correction with Fluke Ti32



Fluke Ti25				
Temperature (Without Window)	No Correction	CorDEX Correction		
	Temperature (With Win-dow)	Temperature (With Window)	Error (C)	Error (%)
30	26	32	2	-7%
45	32	44.9	-0.1	0%
60	40	61.2	1.2	-2%
75	44	78.9	3.9	-5%
91	59	96	5	-5%
105	63	103	-2	2%
119	72	118.5	-0.5	0%
134	86	132	-2	1%
150	92	151.5	1.5	-1%

CorDEX Transmission Correction with FLIR A320



FLIR A320				
Temperature (Without Window)	No Correction	CorDEX Correction		
	Temperature (With Window)	Temperature (With Window)	Error (C)	Error (%)
31	25	29.8	1.2	4%
46	32	44.9	1.1	2%
60	40	61.2	-1.2	-2%
76	48	76.3	-0.3	0%
90	56	90.7	-0.7	-1%
105	64	104.7	0.3	0%
120	72	118.5	1.5	1%
135	81	133.8	1.2	1%
150	90	148.4	1.6	1%

Correction Tools

CorDEX Instruments provide a serials of transmission correction tools which are designer to operate with any longwave (8-14µm) thermal imager.

These tools are available at www.irwindows.com or alternatively as a iPhone app available on the Apple App Store.

CorDEX iPhone transmission correction app available on the Apple App Store.

Online transmission correction at www.irwindows.com

TO TRY THE CORRECTION ALOGORITHM, USE THE DEMO CODE 'MIEE' IN EITHER THE APP OR WEBSITE!

Conclusions

To conclude, traditional single point correction is unreliable when applied to a range of target temperatures. Conversely, multipoint correction maps will provide accurate results with different thermal imagers.

Typical target accuracy of ±5° is achievable using multipoint correction curves regardless of imager.

TEMPERATURE MEASUREMENT THROUGH AN IR WINDOW ACROSS A RANGE IS NOW POSSIBLE

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