

APPLICATION NOTE

AN108



Plastic Film Measurement



Introduction

This Application Note describes the critical factors to be evaluated in selecting the proper infrared thermometer for plastic film temperature measurements. Brief note is made of potential measurement interferences and the ways in which they are avoided at the outset by proper thermometer selection. The infrared transmission spectra of a broad and representative list of commercially important

plastics are presented and the rules for selection of the proper infrared thermometer are clearly illustrated.

It will be seen that the selection process is most critical for the thinnest films, yet even here the choice is simply between one of two thermometer series. Thicker sections of plastics permit a wider latitude in the thermometer selection.

Plastic Film Measurement

A film of a plastic or polymer, like all other materials, emits a continuous stream of thermal radiation from its surface. The spectral distribution and intensity of this thermal radiation are governed by the film's chemical composition and physical configuration, and by its temperature. This latter relationship permits temperature to be measured by a remote infrared thermometer which can quantitatively measure the radiation intensity. The temperature measurement is valid provided the following conditions are met:

1. The radiation streaming from the film must be wholly generated by the film itself as a consequence of its temperature. Specifically, it must not contain significant levels of the following:
 - a) Transmitted radiation generated by a hot object behind it. This is partly governed by the transmittance (t) of the film .*
 - b) Reflected radiation arising from a hot object in front of it. This is partly governed by the reflectance (r) of the film .
2. The stream of radiation from the measured film to the thermometer must be transmitted without absorption by the intervening atmosphere. Simply put - the thermometer must not operate in the spectral regions of atmospheric absorption bands (see Fig. 1).

* This is also partly governed by the temperature of the interfering hot object. The hotter the object, the greater the interference.

3. The correct value for the emittance (e) of the object must be known and correctly introduced into the thermometer calibration

The controlling factors in items 1 and 3 are the three optical properties of the film – emittance (e), reflectance (r) and transmittance (t). These factors are directly and simply related as follows:

$$(Eq. 1) \quad \epsilon = 1 - r - t$$

When “r” and “t” are zero, spurious radiation from nearby hot objects cannot interfere. Furthermore, under these same conditions, $e = 1$ which is characteristic of a blackbody or perfect radiator. This represents the exact conditions under which the thermometer is calibrated at the factory. Consequently when the object being measured is a blackbody the measurement accuracy is the highest and potentially serious Interferences from surrounding hot objects are eliminated.

It is clear, from the foregoing discussion, that infrared thermometry is most effectively applied to blackbody radiators. Ircon's broad product line offers the user a very practical way to approach the ideal goal. This is the case for most materials to be measured and controlled in industrial processes. The following section will show that it is especially true for thin film plastics.

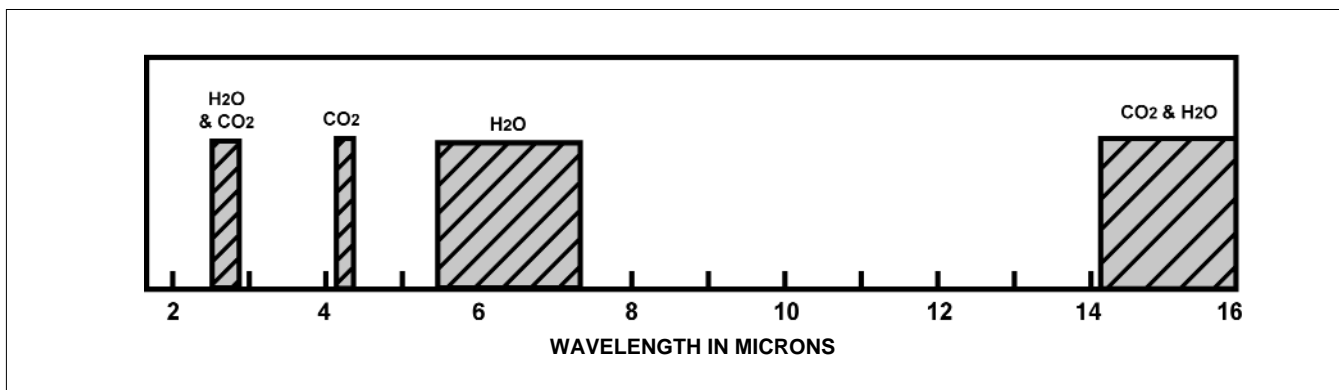


Fig. 1: Areas of significant atmospheric absorption over a path length of 10 feet

Evaluating the Infrared Transmission Spectrum

Fig. 2 shows the overall transmission spectra of 1, 10 and 100 mil * thick specimens of cellulose acetate as recorded with a standard laboratory infrared spectrophotometer. This example will be used to illustrate some basic optical properties of plastic films and at the same time serve as a rational basis for selecting the proper infrared thermometer.

The transmission as directly measured by the spectrophotometer may be considered approximately equal to the transmittance (t), as appears in Eq. 1.

We may assume (r) = 0.04 for all plastics throughout this spectrum. (This is not precisely true but is close enough for our purpose here.) Furthermore, (r) is independent of film thickness.

The cellulose acetate spectrum illustrates features that are generally true for all plastics. The value for (t) varies markedly with wavelength for very thin films. The value for (t) decreases rapidly with film thickness (it varies as a power function of the thickness). The spectral regions where (t) drops to low values are referred to as absorption bands and the positions of these bands identify certain chemical bonds appearing in the plastic molecule.

For 100 mil cellulose acetate t = 0.00 at all wavelengths shown and

$$\begin{aligned} \epsilon &= 1.00 - r - t \\ &= 1.00 - 0.04 - 0.00 \\ &= 0.96 \end{aligned}$$

which represents a near blackbody condition.

* 1 mil = 0.001 inch = 0.025 millimeters

However, for a 1 mil film of cellulose acetate there are only a few absorption bands strong enough to reduce (t) to a very small value. Note that these bands appear in the regions about 5.8, 7.3, 8.0 and 9.0 microns and it is only in these regions that 1 mil films will exhibit $\epsilon = 0.96$. In the regions between the absorption bands (e) falls to very low values.

Superimposed on the spectral transmission curves of Fig. 2 are the spectral response regions of available Ircon thermometer series. The infrared thermometer series shown by the shaded bands have a spectral response of $3.43 \pm 0.07\mu\text{m}$ and $7.92 \pm 0.15\mu\text{m}$ respectively. Each series operates in a narrow spectral region corresponding to a fundamental absorption band common to most plastics, making them particularly suited for thin film temperature measurements.

The composite figure clearly shows the 7.92 μm series to be an excellent choice for all thicknesses of cellulose acetate films. The 3.43 μm series is also suitable for films over about 2 mils thick.

Films 100 mils thick and above are opaque for all wavelengths between 2 and 16 microns. Consequently, additional Ircon thermometers are also suitable for these thicker films (see Fig. 7 for spectral response of these series).

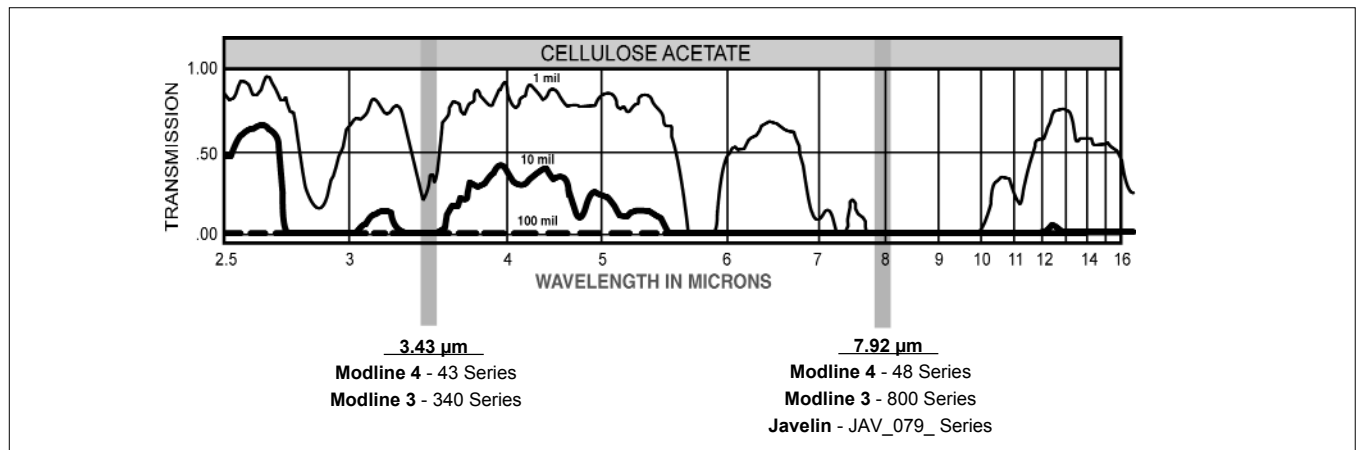


Fig. 2: Transmission spectra of 1, 10 and 100 mil. thick films of cellulose acetate

Representative Plastic Film Transmission Spectra

Transmission spectra of additional plastics films are shown in Figs. 3, 4 and 5. These films, all in commercial production, have been supplied through the courtesy of a number of plastics manufacturers. This list of plastics, though not complete, is sufficiently representative to illustrate the repetitive pattern showing two

key spectral regions for plastics. These are eminently satisfied by the 3.43 μ m series and 7.92 μ m series. Polymer chemists can readily identify the chemical bonds creating these absorption bands though we will not pursue this subject here.

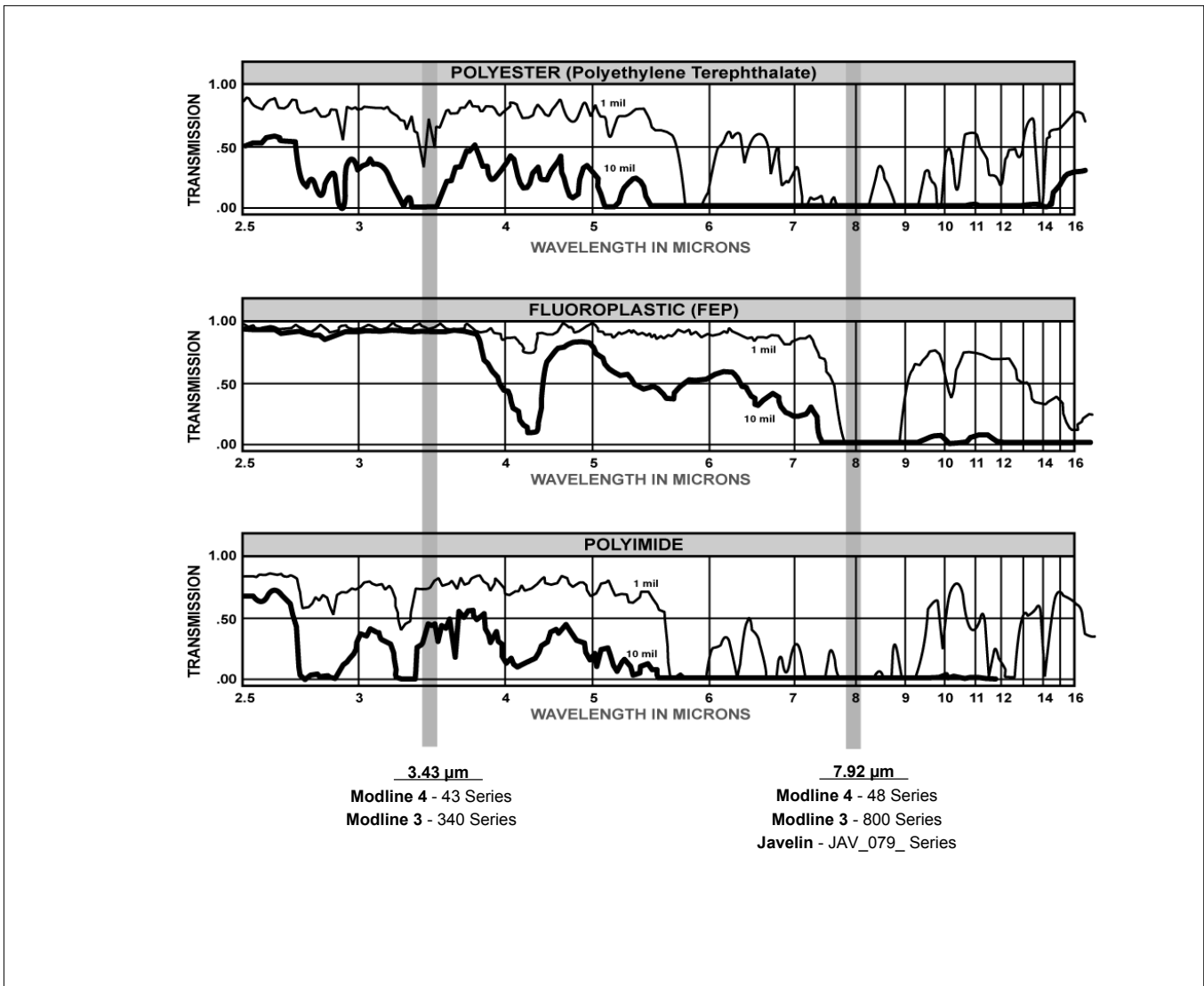


Fig. 3: Transmission spectra of several commercial plastics
(1 mil = 0.001 inches = 0.025 millimeters)

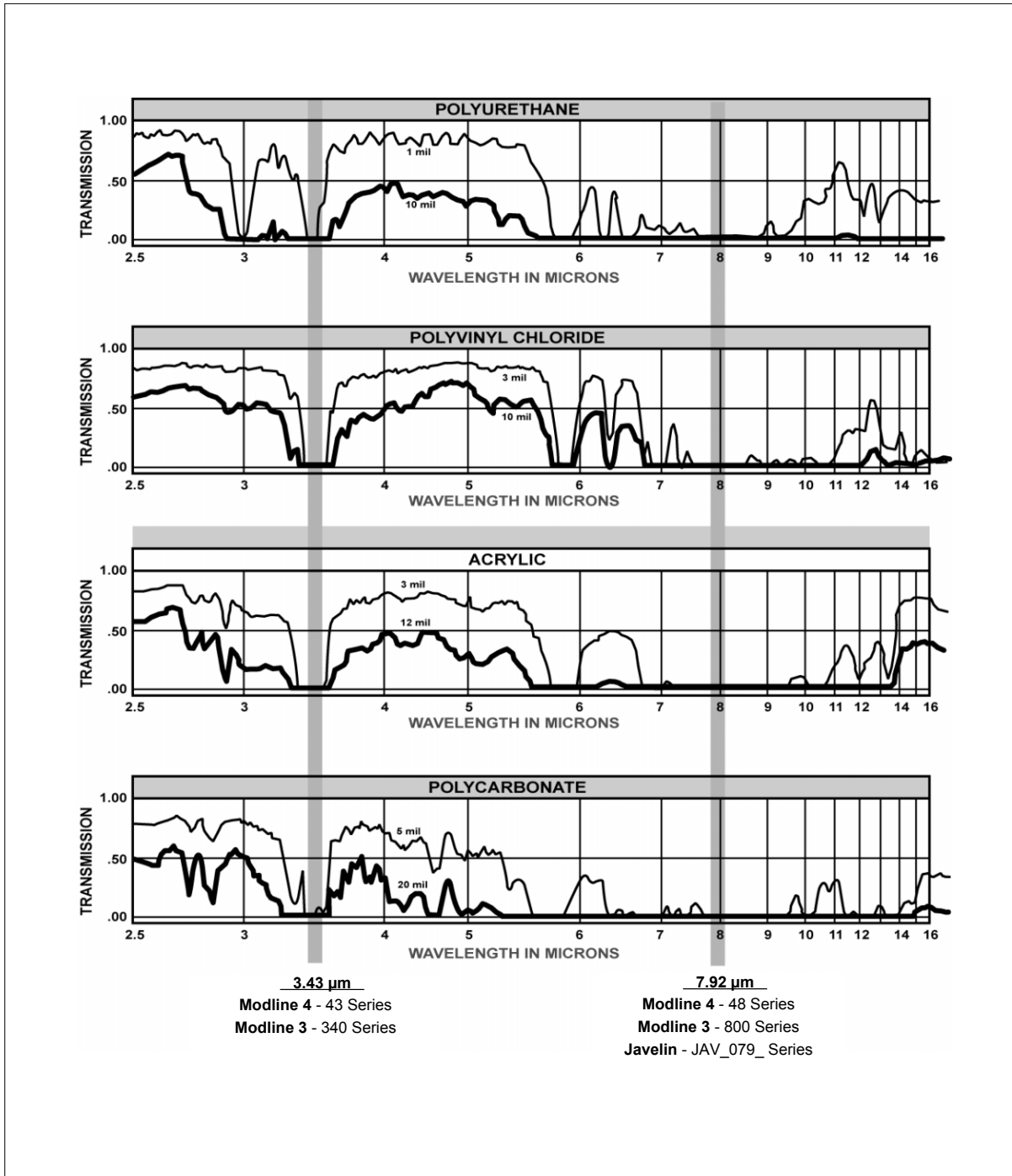


Fig. 4: Transmission spectra of several commercial plastics
(1 mil = 0.001 inches = 0.025 millimeters)

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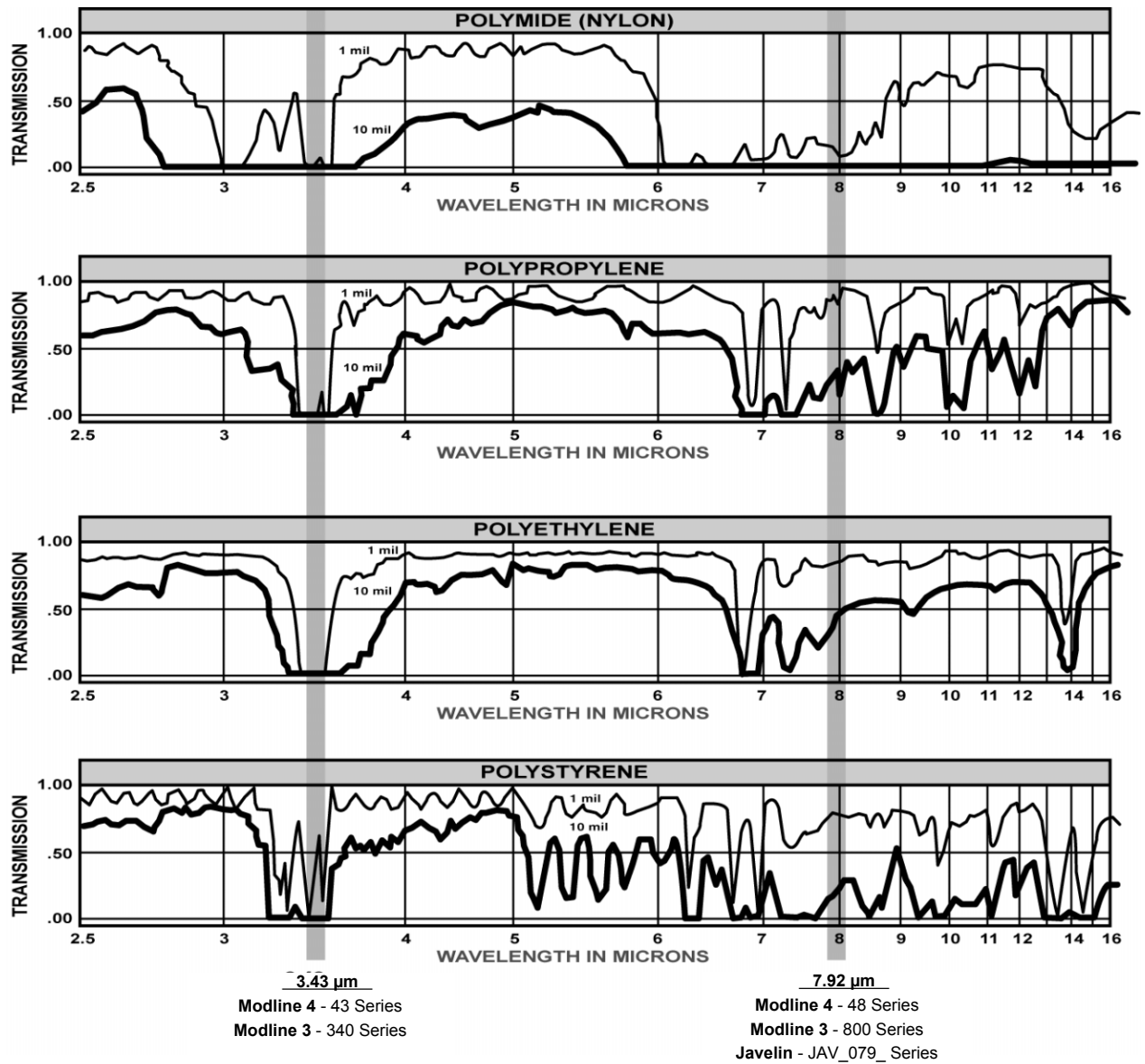


Fig 5 – Transmission spectra of several commercial plastics
(1 mil = 0.001 inches = 0.025 millimeters)

Additional Factors Affecting Thermometer Selection

The spectral regions covered by atmospheric absorption bands are illustrated in Fig. 1. Atmospheric water vapor and carbon dioxide absorb strongly in these regions and can cause serious errors with thermometer operating therein. Ircon's thermometer series do not operate in any of these regions and do not encounter atmospheric transmission problems.

One additional interfering situation sometimes encountered in plastic processing plants is worthy of mention here. This occurs when the product is heated with high intensity, tungsten filament quartz lamps. The extreme temperatures of

the filaments of these lamps provide radiation levels that can cause severe interference with thermometers operating at wavelengths shorter than about 4.7 microns (see Fig. 6). Beyond this region the quartz envelope becomes opaque and eliminates the interference. These installations may cause severe lamp interference problems with the 3.43 μ m series and model series operating at 2.0 to 2.6 μ m. However, Ircon model series operating at 4.8 to 5.3 μ m, 7.92 μ m and 8 to 14 μ m are completely immune to these effects.

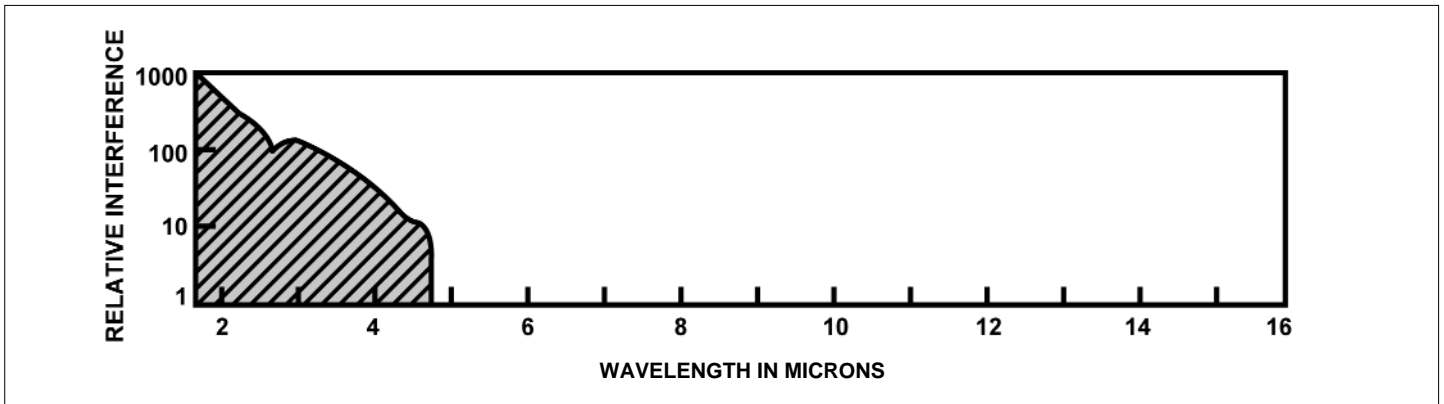


Fig.6 – Relative interference caused by quartz lamp infrared heaters

Additional Infrared Thermometers Available

IRCON offers a variety of Model Series operating in the spectral regions shown in Fig.7. Each of these Series has its own special advantages for various industrial

applications. Though these three series do not excel for the thinnest plastic films, each has special advantage in applications on thicker pigmented plastic sections.

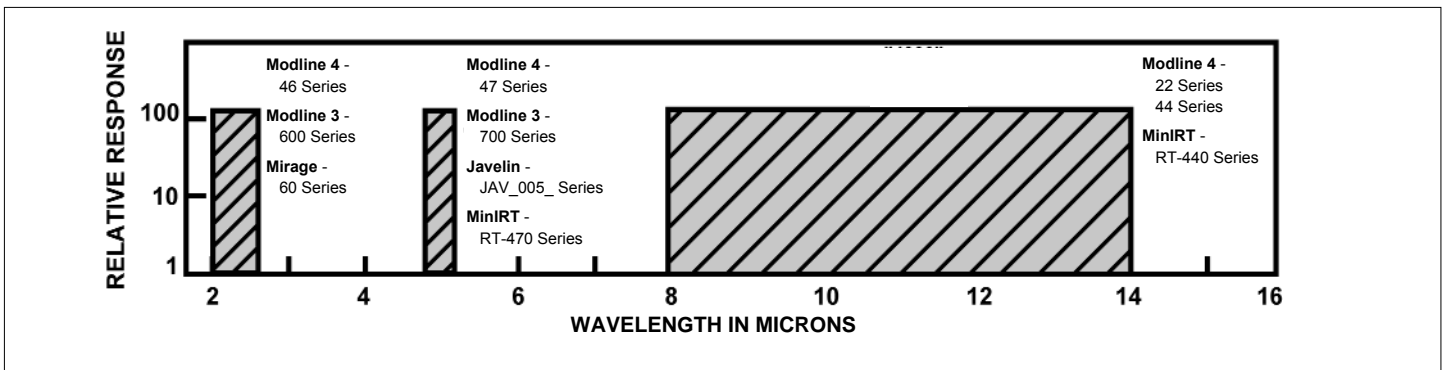


Fig. 7 – Spectral response regions of additional Ircon infrared thermometers

Plastic Film Measurement

Summary

The fundamental factors to be evaluated in selecting the proper infrared thermometer for plastics measurements have been described. The detailed characteristics of a broad list of commercially important plastics have been presented and the thermometer selection process revealed in simple graphical form.

We recognize that the current list of important plastics is far larger than presented here and growing each year. However, the underlying principles governing the spectral location of strong absorption bands and attendant high emittance values in thin films guarantees that standard Ircon products are available for virtually all plastics on the list.

We have described the evaluation process for selection of the correct infrared thermometer for various thin plastic films. IRCON will confidentially and without charge, run an evaluation of your specific plastics application. This will include a spectrophotometer analysis of your plastic samples. Just send us a brief letter telling us the approximate minimum and maximum temperatures, method of heating, minimum and maximum film thicknesses and include 2 or 3 samples (approx. 3" x 3") of your film. If possible, the samples should include both the thickest and thinnest examples of your production.

We will send you the infrared transmission curves and our recommendation for the correct instrument.

ISO 9001 : 2000

Quality System
Certified

NIST Calibration Provider



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