Sensor Technology Summary

1. Single-Wavelength Sensors
Single-wavelength sensors are available in short-wavelength, long-wavelength, and specific-purpose-wavelength versions. These sensors assume that the emissivity is constant and known. An error will occur if there is an emissivity change. The size of the error will be larger for longer wavelengths and higher temperatures.

1a. Short-wavelength sensors: Low-temperature, short-wavelength, single-wavelength sensors often provide an acceptable degree of accuracy even when there is a significant emissivity variation. Therefore, short-wavelength sensors are recommended when there is an emissivity variation or when the lens is likely to become soiled. Short-wavelength sensors are able to view through common infrared window materials [glass or quartz, for example], and are available in a fiber-optic configuration.

1b. Long-wavelength sensors: Long-wavelength sensors are recommended when measuring in the presence of infrared heaters, when it is necessary to measure near-ambient temperatures, when exceptionally broad temperature spans are required, or when measuring high-emissivity materials. Long-wavelength sensors view through more exotic infrared window materials and are significantly more sensitive to emissivity variation and optical obstruction.

1c. Specific-purpose-wavelength sensors: Specific-purpose wavelengths are used to view targets that are transparent or reflective at the general-purpose wavelengths, or to view through obstructions that are not transparent at the general-purpose wavelengths. Specific examples include gasses, flames, glass, thin plastics, and many crystalline materials.

2. Dual-Wavelength Sensors
Dual-wavelength sensors assume that the ratio of emissivity at wavelengths A and B is constant and known. A dual-wavelength sensor provides a very heavily-weighted average towards only the hottest temperature viewed. A dual-wavelength sensor will tend to ignore dirty optics, misalignment, obstructions, and scale. A dual-wavelength sensor is recommended for measurements above 150 C when there is an excessive emissivity variation, when the sensor lens is likely to become significantly dirty, when there is a significant temperature gradient, or when it is difficult to align the sensor to the measured target.

3. Multi-Wavelength Sensors
Williamson multi-wavelength sensors assume that a function describing signal strength vs. emissivity slope exists with a strong one-to-one correlation. These sensors are used when a single- or dual-wavelength sensor is not appropriate due to non-grey emissivity variation. Common materials requiring a multi-wavelength sensor include high temperature aluminum, copper, brass, zinc, cold-rolled steel, stainless steel and electrical steel. In addition, some materials with a constant emissivity slope will require a multi-wavelength sensor if they become coated with a material with a different emissivity slope.

4. Product Differentiation
Within each technology group, sensors are differentiated by temperature span and optical resolution in addition to wavelength, sensor packaging and product feature differences.

4a. Differentiating Wavelength Issues
Williamson is unique among the major manufactures of infrared thermometers because of our careful attention to wavelength selection. Most (but not all) Williamson sensors are filtered to view through water vapor, steam, flame and products of combustion without interference. Therefore, Williamson sensors can provide a

significant competitive advantage whenever these issues (or even an exceptionally long path of air!) are encountered.

Williamson places a high priority on short-wavelength sensors because of their better ability to tolerate emissivity variation and optical obstruction. As a result, Williamson is able to use these short wavelength sensors under a wider range of operating conditions than can other manufacturers. This usually results in a superior sensor performance under real-world operating conditions. Short-wavelength single-wavelength sensors measure 75 F / 25 C and above.

In addition, Williamson offers the widest range of special-purpose wavelength selections among major manufactures. This wide range of wavelength options provides some unique measurement capabilities. Some of the more popular specific-purpose wavelengths allow for the measurement of or through – plastics, glass and other optical materials, flames, combustion gasses, CO gas, CO_2 gas, fiberglass batting, plasma, silicon, germanium and other semiconductor materials and engineered ceramics. When competitive products are offered by others, the Williamson waveband tends to be narrower than the waveband offered by others. This narrower waveband allows the Williamson sensors to measure thinner plastics, lower concentrations of gasses and smaller flames, and to better view through flames, steam and products of combustion without interference. Custom wavelengths are available upon request.

Optimum wavelength selection is not limited to single-wavelength sensors. The stability of a dual-wavelength sensor is directly proportional to the separation of the wavelengths in much the same way as a table becomes more stable as the table legs are farther separated. The Williamson dual-wavelength sensors offer a clear separation between measured wavelengths. All major competitive two-color sensors use wavelengths that actually overlap with each other. As a result, the Williamson dual-wavelength sensors offer greater signal dilution capability, and are as much as 20 times better able to tolerate process variability from sources such as scale, oxides and temperature gradients. Williamson dual-wavelength sensors are available for measurement above 200 F / 95 C, multi-wavelength above 300 F / 150 C.

4b. Differentiating Temperature Span and Low Temperature Issues
Williamson uniquely offers broad temperature spans and low-temperature operation using short wavelength single-wavelength sensors, dual-wavelength sensors, and multi-wavelength sensors. No other major manufacturer can make this claim. Other manufacturers rely on long-wavelength sensors to measure low temperatures and to produce broad temperature spans. Therefore, the Williamson products demonstrate a significant competitive advantage whenever a broad temperature span or low-temperature operation is required.

4c. Differentiating Optical Resolution Issues
Different manufacturers use different measurement standards for the specification of optical resolution. Most use 90% energy to define their optical resolution. Some use the 50% energy mark. At Williamson we use the 99% energy rule for all but our 8- to 14-micron sensors (for which we use the 90% rule). There have been documented cases where the Williamson optical resolution was found to be tighter than competitive brands claiming to offer twice the resolution of the Williamson sensor. With a Williamson sensor you can be confident that the stated optical resolution is true.

4d. Differentiating Packaging and Product Feature Issues
Williamson offers three tiers of products for general purpose, light industrial and heavy industrial use. Williamson offers the industry's most extensive range of dual- and multi-wavelength sensors, each able to measure emissivity and signal dilution, and each including Williamson's unique ESP filtering to eliminate intermittent interference sources. Williamson offers the industry's most extensive range of fiber-optic sensors, including light pipe, monofilament, SSB and ArmorGuard sheathings. Williamson offers the industry's most extensive range of short-wavelength single-wavelength sensors.

Infrared Thermometer Principles of Operation

All infrared thermometers measure infrared energy. Because infrared energy is emitted by an object as a function of temperature and emissivity, all infrared thermometers calculate a temperature value based upon an assumption concerning the emissivity character of the measured material.

Brightness Sensors (Single-Wavelength or One-Color Sensors)

Assumption: Emissivity is reasonably constant and known.

Brightness sensors measure the amplitude of infrared energy collected over a specific wavelength span. These sensors provide an average temperature, and are affected by changes in emissivity, dirty optics, and other optical obstructions. Stray infrared energy from background sources will affect the sensor reading if the energy is significant. Sensitivity to emissivity variation, optical obstructions, and background energy varies with wavelength. Wavelength selection can significantly impact the ability to view through certain intervening media, such as steam or combustion gasses. Similarly, wavelength selection can significantly impact the ability to measure transparent or reflective materials such as glass, plastic films, flames and thin coatings.

Ratio Sensors (Dual-Wavelength or Two-Color Sensors)

Assumption: The ratio of emissivity values at wavelengths A & B is reasonably constant and known (greybody materials).

Ratio sensors measure the ratio of energy collected at two adjacent wavelengths. The ratio value is not affected by so called "grey" obstructions (those that obstruct both wavelengths equally). As such, these sensors are able to correct for emissivity variations, and to view through smoke, dust, and most other optical obstructions, including dirty lenses. This sensor tends to provide a very heavily weighted average towards the hottest temperature viewed. Compared to a brightness sensor, stray infrared energy from a hotter background will affect the sensor reading more, and from a cooler background, less. Wavelength selection and wavelength separation influence the measurement range, the weighting towards the hottest temperature viewed, the sensitivity to e-slope variation (a variation in the ratio of emissivity values at wavelengths at the measured wavelengths), the signal dilution capability, and the sensitivity to some types of intervening media such as plasma, water, steam and combustion byproducts.

Multi-Variant Sensors (Multi-Wavelength Sensors)

Assumption: The effective target emissivity (or other emissivity-related parameter such as e-slope) is related to some measurable parameter (such as measured reflectivity, signal strength or signal dilution) with a strong one-to-one correlation.

A multi-variant sensor measures infrared energy at two or more wavelengths, and calculates the target temperature based upon an application-specific algorithm. This algorithm is based upon a one-to-one correlation between a corrective emissivity adjustment (or some other emissivity-related parameter, such as e-slope) and a meaningful measured parameter. Multi-wavelength algorithms vary from simple second-order corrections to complex multi-variant iterative programs, and may include additional application information, such as background temperature. The complexity of the sensor and the temperature algorithm varies according to the application requirements. These sensors are used for materials and applications where traditional brightness or ratio sensors are ineffective.

Application Summary Sheet
Single-Wavelength Sensors
Wavelength Selection (Continued)

Short-Wavelength Sensors and Long-Wavelength Sensors

Single-wavelength sensors are available in short-wavelength, long-wavelength, and specific-purpose wavelength versions. All other things being equal, short wavelength sensors are significantly less sensitive to emissivity variation and optical obstruction. For example, a sensor filtered in the 2-micron range is about four times less sensitive to optical obstruction and 4 to 10 times less sensitive to emissivity variation compared to a sensor filtered at 8- to 14-microns. Whenever applicable, sensor performance in the 1-micron range improves performance by another factor of two.

Short-wavelength sensors: Low-temperature, short-wavelength, single-wavelength sensors often provide an acceptable degree of accuracy even when there is a significant emissivity variation. Therefore, short-wavelength sensors are recommended when there is an emissivity variation or when the lens is likely to become soiled. Short-wavelength sensors are able to view through common infrared window materials [glass or quartz, for example]. Most short-wavelength sensors are available in a fiber-optic configuration.

Short Wavelength Benefits -

- Most sensitive to changes in temperature
- Views through common window materials.
- Minimizes the influence of emissivity variation by a factor of 4 to 20,
- Minimizes the influence of dirty optics, misalignment and optical obstruction by a factor of 4 to 8.
- Short-wavelength Williamson sensors measure exceptionally low temperatures and offer broad temperature spans rivaling long-wavelength sensors.

Emissivity is the opposite of reflectivity. So, if a material is 80% reflective, then it is 20% emissive, and if a different material is 20% reflective, then it is 80% emissive. The selection of a short-wavelength sensor is critical for the measurement of highly reflective materials, because the reflectivity of a material tends to be lower at shorter wavelengths that at longer wavelengths. This is because the shorter wavelengths can better fit into the small microscopic nooks and crannies on the surface of the material. Those wavelengths that better fit into these nooks and crannies are better absorbed by the surface, and therefore the reflectivity is diminished and the emissivity enhanced. For many common low-emissivity materials such as aluminum and chrome, the emissivity value is increased by a factor of as much as 2.5 times. This increase in the emissivity value is important because the measurement error associated with an emissivity change is proportional to the percent change in emissivity. Therefore, any given change in emissivity will be a smaller percent change if the absolute emissivity value is higher.

Long-wavelength sensors: Long-wavelength sensors commonly used to measure high-emissivity materials at relatively low temperatures – typically below a few hundred degrees. These sensors are also recommended when it is necessary to measure near-ambient temperatures, or when exceptionally broad temperature spans are required. Long-wavelength sensors should be used when reflections from quartz heaters or open rod electrical element heaters can not be avoided. Long-wavelength sensors must view through more exotic infrared window materials, and are considerably more sensitive to dirty lenses, optical obstruction, and emissivity variation.

The advantage of selecting a short wavelength is clearly seen in the following graphs. The variation in infrared energy is significantly greater at the shorter wavelengths, and the shorter wavelengths are significantly less sensitive to emissivity variation and optical obstruction. In addition, the emissivity of low-emissivity materials is significantly higher at shorter wavelengths. Because measurement errors are proportional to the percentage change in emissivity, the sensitivity to emissivity variation is further reduced by selecting a wavelength where the emissivity is higher. When measuring low-emissivity materials, it is not uncommon to attain a ten- or twenty-fold increase in accuracy by selecting a short wavelength as compared to a long wavelength.

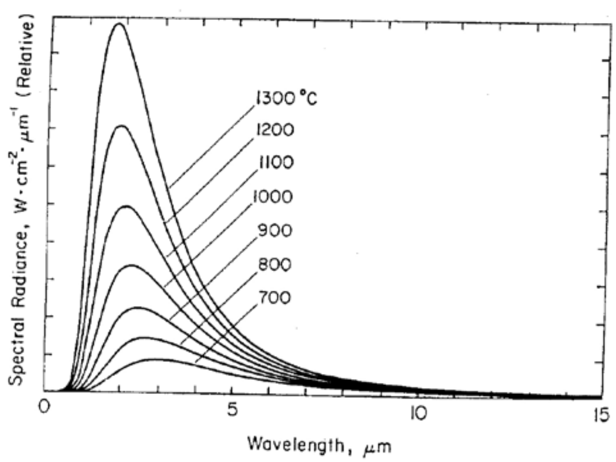

Figure 2 = Infrared Energy vs Temperature vs Wavelength Curve