SERIES 205 SPECTRAL EMISSOMETER

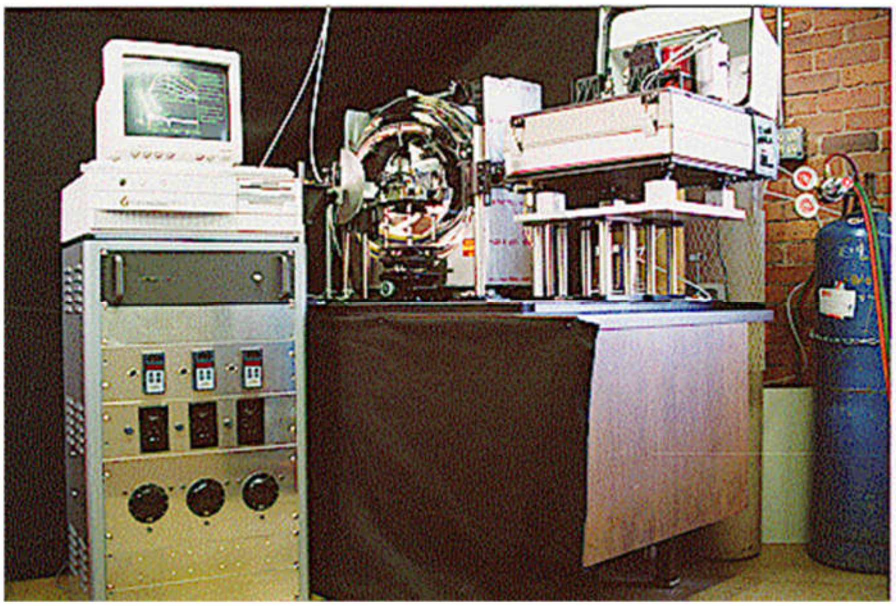

***Figure 1**. Series 205 Spectral Emissometer.*

An automated bench-top emissometer which measures spectral emissivity over a broad spectral range from the near to mid IR while simultaneously determining the surface temperature at the measurement location.

***The SERIES 205 SPECTRAL EMISSOMETER is currently not being built for sale.** Advanced Fuel Research, Inc. does offer a testing service using the instrument (where samples are sent to our Connecticut-based laboratories). If you have a need for Emissometer measurements, please contact us.*

Key Benefits

- Simultaneous Non-Contact Measurement of Spectral Emittance and Temperature
- 50°C to 2000°C Sample Temperature Measurement Range
- Typical Emissivity Measurement Accuracy within ± 3%
- Typical Temperature Measurement Accuracy within ± 5%
- 1-3 mm Variable Diameter Measurement Spot
- Spectral Data Obtained by FT-IR Spectroscopy
- Mid and Near Infrared Spectral Range, 500 cm^{-1} to 12,500 cm^{-1}
- 1 to 64 cm^{-1} Variable Spectral Resolution
- Patented Technology for Measurement Methodology and Apparatus
- 1994 R & D 100 Award Winner

MEASUREMENTS

The Model 205 NB and Model 205 WB Emissometers are Bench Top FT-IR based instruments designed specifically to facilitate simultaneous measurements of surface spectral emittance and temperature using optical techniques over the Near and/or Mid-IR spectral range at temperatures ranging from 50 to 2000°C. This patented technology (U.S. patent # 5,239,488) can be used to measure radiative properties (emittance, reflectance, transmittance) as a function of temperature for a wide range of materials such as:

- Silicon
- Glass
- Quartz
- Sapphire
- Metals
- Coal ash
- Slag
- Semiconductors
- Advance heat transfer materials

The system can also provide measurements of radiance as well as directional-hemispherical reflection and transmission over a wide spectral range from 12,500 to 500 cm^{-1} (0.8 to 20 microns) for the Model 205 WB, and from 6,000 to 500 cm^{-1} (1.7 to 20 microns) for the Model 205 NB.

The Model 205 WB Emissometer has additional extended capabilities to operate as a stand-alone FT-IR spectrometer covering the Near and Mid-IR spectrum from 12,500 cm to 500 cm^{-1} with up to 1 cm^{-1} resolution. The Model 205 NB covers the Mid-IR spectrum from 6,000 to 500 cm^{-1} .

The Series 205 Emissometers significantly advance the state-of-the-art in emissivity measurements. Previous methods and instruments for measuring spectral emittance at elevated temperature required the precise knowledge of the sample temperature. The Model 205 overcomes these difficulties and provides all information necessary to simultaneously determine the precise temperature and emissivity for the same target spot on the sample.

OPTICS

The Emissometer is shown schematically in Fig. 2. All optical components, including the FT-IR spectrometer, are mounted on a 3 foot x 4 foot optical bench. The hemi-ellipsoidal mirror enables the measurement of radiation in a hemispherical-directional mode. The sample can be heated with an oxy/acetylene torch, CO_2 laser, or other means. The FT-IR spectrometer is utilized in the emission mode and can accept radiation from either side of the sample by positioning the selector mirror. The design of the spectrometer's interferometer allows for the incoming beam to be modulated and split into two outgoing beams. In the Model 205 WB Emissometer, two separate detectors are utilized to measure near and mid-IR energy in these two beams simultaneously. A room temperature indium-gallium-arsenide detector is used for the Near-IR (12,500 to 6,000 cm^{-1}), and a liquid nitrogen cooled mercury-cadmium-telluride detector is used for Mid-IR (6,000 to 500 cm^{-1}). For the Model 205 NB Emissometer, only the MCT detector is required.

The hemi-ellipsoidal mirror has both foci inside the mirror. A near-blackbody source is located at one of the foci and the sample is located at the other focus. This mirror geometry, combined with the radiating characteristics of the near-blackbody source, provides a means of measuring the hemispherical-directional reflectance of the front surface of the samples. Likewise, for transmissive samples, the hemispherical -directional transmittance can be measured from the back side.

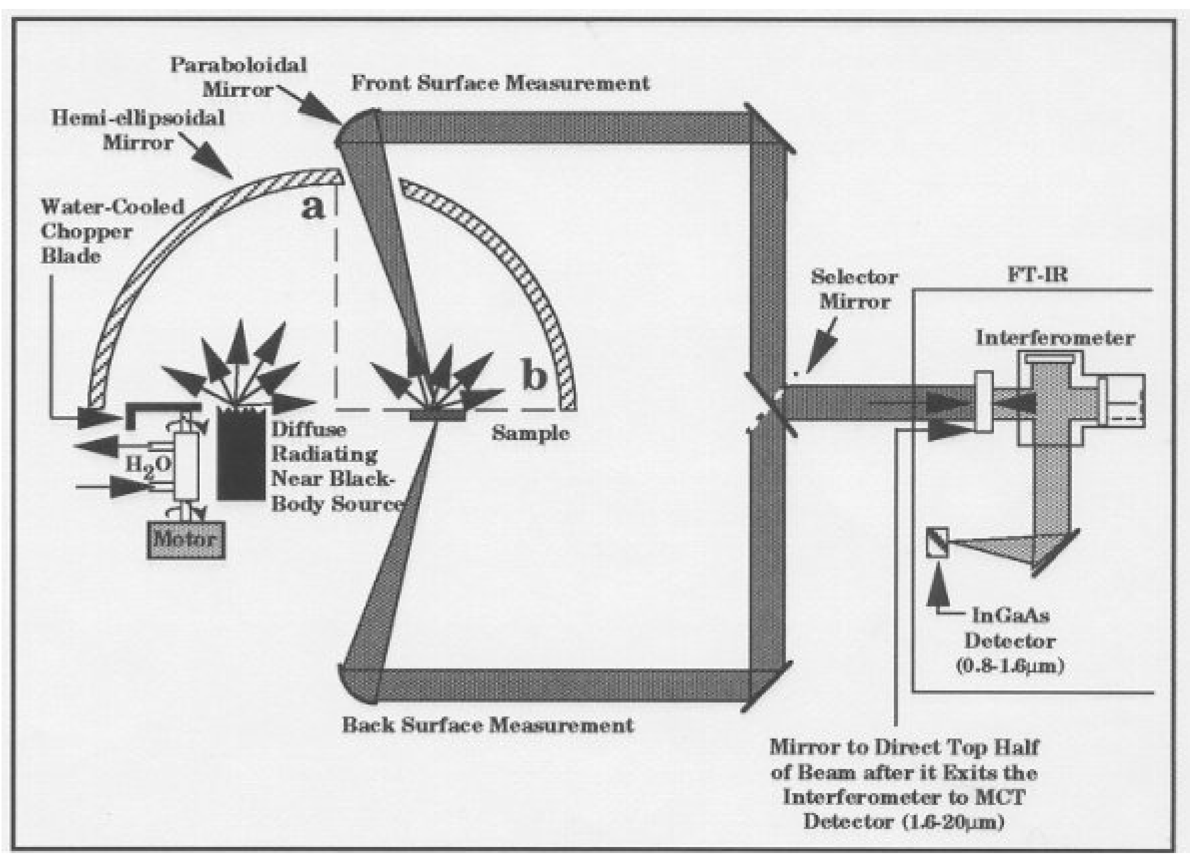

***Figure 2**. Schematic of Benchtop Emissometer.*

OPERATION

An integral part of the optical system is the rotating chopper system which moves either an aperture or a cold near-blackbody element in front of the source. The FT-IR data collection system is synchronized with these two states, and allows for the distinction of sample radiation from reflected/ transmitted radiation as follows. For the reflectance measurement, the IR beam originates at the near-blackbody source at one focus of the hemi-ellipsoidal mirror. The radiation reflects from the hemi-ellipsoidal mirror and is focused onto the sample at the other focus where it is reflected (scattered) by the sample into the interferometer. The reflectance and the sample radiance are measured together when the aperture on the chopper rotor is in place over the source (chopper open condition). This is shown by the top curve in Figure 3. When a cold near-blackbody is substituted for the aperture over the source (chopper closed condition), it is the sample radiance alone which is measured (bottom curve in Fig. 3). Both the radiance (r) and directional-hemispherical reflectance (R) can be obtained from these two spectra. Transmission measurements (T) are similarly obtained by repositioning the selector mirror.

The bidirectional scanning ability of the spectrometer's interferometer allows collection of sample radiance (chopper closed) in the "forward" scan, and sample radiance plus reflectance (chopper open) in the "reverse scan". At 32 cm-1 spectral resolution, a complete forward and reverse motion of the interferometer is accomplished in ~0.5 seconds, corresponding to a chopper rate of 2 Hz. Signal processing automatically separates forward motion scans from reverse motion scans and allows for signal averaging from sequential collection of data for each motion. Typically, a data set consists of 16 co-added scans of each component of the front surface measurement. For non-opaque samples, the selector mirror is flipped and 16 co-added scans of each component of the back surface are collected.

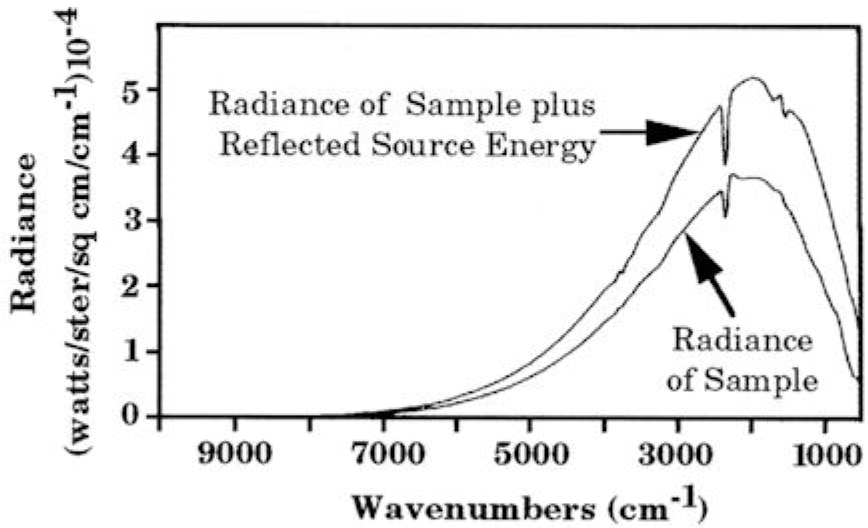

Figure 3. *Spectral Measurements Performed with the Emissometer.*

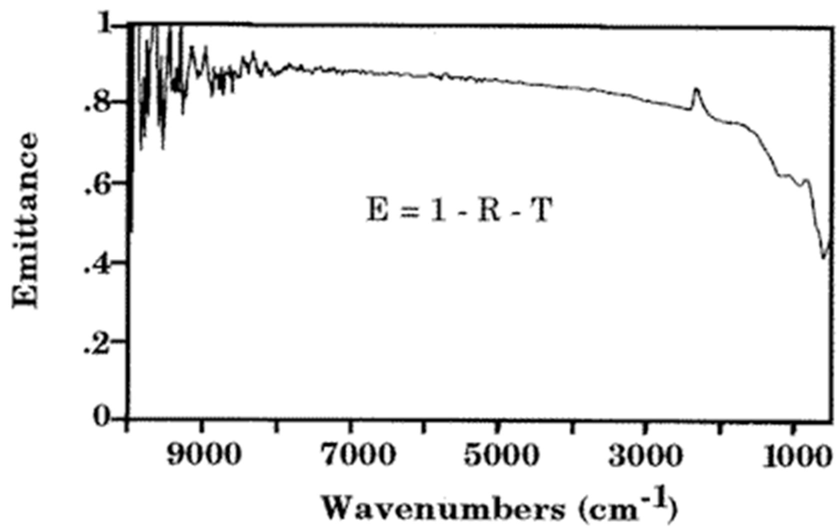

Figure 4. *Determination of Spectral Emittance from the Measured Hemispherical Reflectance (R) and Hemispherical Transmittance (T).*

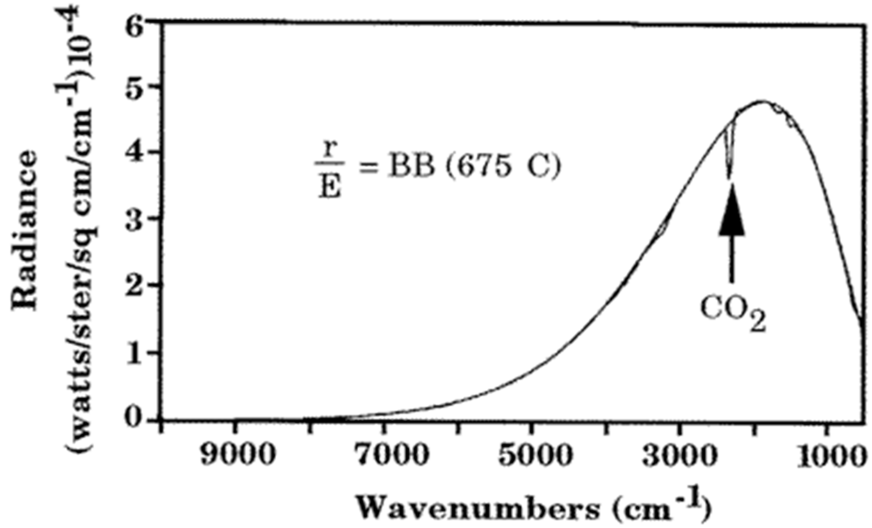

Figure 5*. Determination of Temperature by Matching (r/E) with a Blackbody Curve.*

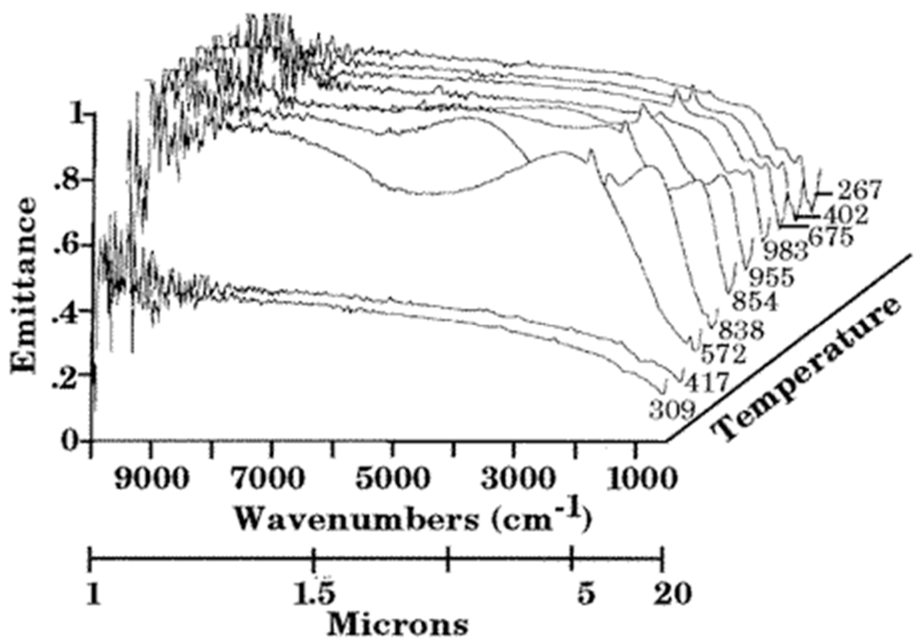

Figure 6*. The Radiative Property Change of a Metal Alloy as it is Heated in Air.*

Once the spectra are acquired, Spectral emittance (E) of the hot sample is determined by conservation of energy: E = 1 - R - T (Fig. 3). The precise sample temperature is simultaneously determined by the Planck "Blackbody"

(BB) relationship: r/E = BB. Hundreds of spectral data points or "colors" are used to match the shape and amplitude of the Planck temperature curve as shown in Figure 4. As shown in Figure 5, the emissometer can rapidly monitor spectral emittance as a function of temperature and time.

SAMPLES

Samples are mounted into position with a clamping devices which is arranged so as not to contribute extraneous radiation into the measurement. Three intersecting visible lasers beams are utilized to ensure correct positioning of the sample. Sample sizes on the order of 1 to 1-1/2 inches square or diameter are convenient, although samples as small as 1/4" square have been measured. The measurement spot on the sample is variable from 1 millimeter diameter to 3 millimeters in diameter. Samples have been heated by a variety of methods. These include: i) torch flames (propane, hydrogen, oxy/acetylene), ii) focussed infrared radiation from high intensity lamps, and iii) infrared radiation from a CO_2 laser (25 W, continuous wave). Sample thickness of less than 1/4" is con-venient for sample heating in order to achieve uniform sample surface temperatures when heating on the back surface. Torch heating allows the sample to be heated from the back, the front, or both surfaces. The influence on the measurements due to the radiation contributions from the combustion products of a torch flame is not a problem as it is limited to narrow spectral regions.

SPECIFICATIONS

EMISSOMETER PERFORMANCE	Model 205 WB	Model 205 NB
Spectral Range	Near- and Mid-IR	Mid-IR
Spectral Range	12,500 to 500 cm-1	6,000 to 500 cm-1
Emissivity Measurement Accuracy (typical)	± 3%	± 3%
Temperature Measurement Accuracy (typical)	± 5°C	± 5°C
Temperature Range	50 to 2000°C	50 to 2000°C
Sample Size	10 mm to 40 mm	10 mm to 40 mm
Measurement Spot Diameter	1 mm to 3 mm	1 mm to 3 mm
NEAR BLACKBODY SOURCE		
Source Surface Area	6.45 cm-1	6.45 cm-1
Surface Temperature Control	± 2°C	± 2°C
Surface Temperature Uniformity over Full Source	±10°C	± 10°C
Surface Temperature Uniformity over Measurement Spot Diameter	± 2°C	± 2°C

Chopper Type	water-cooled rotating shutter	water-cooledrotating shutter
SAMPLE HEATING OPTIONS		
Oxy/Acetylene Torch and High Intensity Lamps	Standard	Standard
Propane, Hydrogen Torch and 25 W Continuous Wave CO2 Laser	Optional	Optional
STAND-ALONE FT-IR SPECTROMETER		
FT-IR Model	Bomem MB 155	Bomem MB 100
Spectral Range	12,500 to 500 cm-1	6,000 to 500 cm-1
Near IR Detector	InGaAs 12,500 to 6,000 cm-1	
Mid-IR Detector	MCT 6,000 to 500 cm-1	MCT 6,000 to 500 cm-1
DATA SYSTEM		
Computer	Pentium PC	Pentium
PHYSICAL CHARACTERISTICS		
Optical Platform	4' x 3' x 1"	4' x 3' x 1"
Computer and Monitor Foot Print	17" x 17"	17" x 17"
Keyboard Foot Print	20" x 8"	20" x 8"
Input Voltage	120 VAC	120 VAC