Operating Experience
with An Emissivity Measuring Laser Based Infrared Pyrometer
Non Contact Infrared Thermometer Temperature Measurement

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Introduction:

While in use in many industrial applications and research activities, the measurement of temperature utilizing infrared greatest deficiency is quite fundamental; IR thermometers measure radiance received from a target i.e. one variable, while integration of Planck's law governing the relationship between the radiance and temperature requires knowledge of a second variable, the target surface emissivity. Heretofore, the solution has been a combination of operator estimates based on experience, or use of dual and multi-wavelength pyrometers, which sidestep the mathematical problem by ratioing-out the emissivity using two or more simultaneous measurements of the radiance. The assumptions here are that the surface is a grey body, with constant emissivity (e) or fixed ratios between emissivities at two or more wavelengths. In many industrial applications these assumptions are not valid. Emissivity varies with surface condition, temperature, wavelength and indeed, with time. Industrial processes have dynamic characteristics and the targets have varying properties; the simple emissivity assumptions are not valid.

The second chronic error in industrial infrared temperature measurement is that caused by background radiation irradiance or energy reflected by the target to the measuring instrument. The instrument receives infrared energy from the target composed of the emitted energy plus that source by furnace walls or a combustion front and reflected by the target to the measuring instrument. We thus have a two-fold effect of target emissivity:

1. Reduction of black body radiance (W_λ) to $W = \int_{\lambda_1}^{\lambda_2} e_\lambda \, w_\lambda \, d\lambda$ where W_λ is Plank's equation, and
2. The addition of reflected energy from furnace walls ($r_\lambda . w_\lambda$) where $r_\lambda = (1 - e_\lambda)$

Where (r) is the target reflectivity and the subscript (l) refers to wavelength. Thus, if industrial targets had emissivity values of unity, the problem of irradiance would not occur. Knowledge of the target reflectivity is mandatory if one wishes to eliminate the error caused by irradiance.

The third problem regarding the use of the infrared radiation detection of temperature is that of interfering gases. Typically CO, CO_2, H_2O, the sulfur and nitrogen (oxide) gases are present in industrial applications. As is well known but frequently ignored, these gases absorb and re-radiate energy in the infrared spectrum. They thus contribute to temperature measurement inaccuracies. This error has been eliminated in the Pyrolaser® (1) technology by use of a narrow bandwidth plus minus (15) nm at the 865 nanometer wavelength. Exxon Research and Engineering Co. has shown this selection to be a virtually interference-free operating zone. In general, the wider the bandwidth of an infrared thermometer - the greater the possibility for the gas interference.

The technology discussed herein was first researched by Exxon in the early 1980's. An engineering survey of their worldwide pyrolysis furnaces revealed problems of short-furnace run lengths reduced product yields and excessive steam combustion. A major contributor to these problems was the uncertainty of the tube metal temperatures, which dictate the daily furnace operating conditions. From this, the need to measure the tube emissivities and to take into account the wall derived background radiation irradiance and to avoid the interfering gas problem was established. Exxon developed and patented (2) the concept of the laser-based infrared technology and licensed it to the Pyrometer Instrument Company, Inc. www.pyrometer.com in mid-1985. At this time, PYRO is pleased to report on some of the industrial applications and some of the research activities where the resulting product, Pyrolaser® has been effective. We will also point out areas where the technology needs further work and where significant problems remain.

Description:

In this section an overview of the laser-based infrared thermometer is presented; details are revealed in Appendix A including the specifications.

Classic infrared pyrometers are passive devices; they receive energy from a target, plus an emissivity selection by the user and calculate and present a temperature display. Assuming no other energy source, the radiance received by the instrument detector is independent of distance from the target as long as the target has a uniform temperature and emissivity. As the distance to the target increases, the target size enlarges (R^2) while the collected energy per unit area decreases ($1/R^2$). Thus no distance-to-target input is required; only the estimated emissivity value.

1. Pyrolaser® is a trademark owned by the Pyrometer Instrument Co.
2. U.S. Patent #4,417,822 granted to Exxon Research & Engineering Co., Nov. 1983

The new technology of Pyrolaser® incorporates the passive characteristics of conventional infrared pyrometers but in the precise wavelength restrictions previously mentioned. However, the emissivity-determining feature of Pyrolaser® is achieved via an active reflectometer technique. A low-powered pulsed GaAS is detected via the same optics as the conventional infrared signal: the laser signal being (AC) on top of the (DC) target signal. Having monitored the laser outgoing energy and knowing the geometry involved, the instrument can determine the reflectivity and thus the emissivity of the target-measuring zone. It should be noted that we must know the distance to the target since the laser energy is dispersed ($1/R^2$) on the return path. For this reason, Pyrolaser ® has a very sophisticated optical system which provides optical ranging to an accuracy of plus minus 0.5% of range. This system was developed by E. Leitz of Canada under contract to Pyrometer Instrument Company (3).

Fig. 1 Pyrolaser®

The Exxon survey highlighted numerous other weaknesses in industrial temperature measurement practices. Notably, in hostile environments, operators spend unnecessary time handwriting or tape recording temperature readings of various tube targets. The handwritten field notes must be 're-written' or entered into the process engineer's computing system. For this reason, a data-logger was incorporated into the electronics of Pyrolaser® This information can be immediately displayed or printed, or inputted directly to a computerized data base for furnace analysis and trending. All information in the data-logger is immediately available to the operator while making measurements via the 2x20 LCD display. In addition, the statistics of the run are also immediately available to the operator.

(3) Laser Assisted Remote Temperature Measurement, presented at the SPIE Conference, E.S. Cameron, January 1989

Major Applications:

This infrared technology was developed to provide an accurate temperature measuring capability for field measurements in large industrial furnaces. The information presented herein comes from plant tests and continuing plant uses of Pyrolaser® in refineries, petrochemical plants, steel mills and non-ferrous metals processing the U.S., Europe, and the Mid and Far East.

A. Petrochemical Furnaces:

Hydrogen and ethylene furnaces typically are very large installations with multiple furnace viewing ports on each of the four sides and on multiple levels. An example of a hydrogen furnace layout is shown in Fig. 2. The procedure is to first make the wall extraneous temperature readings shown as Tx and then to make true temperature measurement readings. Approximately (8-16) Tx readings are desired over each wall facing tubes before the tube temperatures are measured in the T_T , true temperature mode. Furnace dynamics change every 15-20 minutes so the Tx values which are used by Pyrolaser® to provide the background radiation irradiance correction are only valid for ten minutes. Figure 3 shows some typical readings of Tx, e, and T_T from Pyrolaser®. The column T_L from Pyrolaser®. The column T_L is using a [conventional[1]] non contact IR thermometer instrument which relies on a manual (e) setting and which does not account for reflected energy. The column (T_T - T_L) clearly shows that net error (emissivity and irradiance) from 8°C to 34°C (46°F to 93°F) in this test. It should be noted that the tube emissivities varied from 0.91 to 0.99, yet all tubes were of the same type and in-use for the same period of time. This is a striking example of why manual values of emissivity get one into trouble.

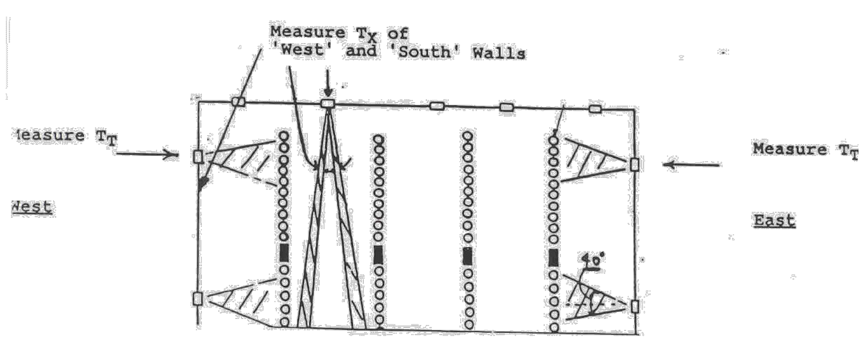


Figure 2. Typical Hydrogen Furnace

Figure 2. Typical Hydrogen Furnace

Hydrogen Furnace Data:

Tx (Wall Temp)	E (Emissivity)	T_T True Temp	T_L Conventional[1]	T_T -- T_L
896	0.95	761	795	-34
	0.91	779	790	-11
	0.93	780	790	-10
901	0.95	763	795	-32
	0.93	772	790	-18
	0.93	776	795	-19
920	0.93	782	812	-30
	0.95	777	806	-29
	0.99	760	789	-29
910	0.94	795	816	-21
	0.99	780	800	-20
	0.92	781	789	-08
890	0.94	777	787	-10
889	0.95	769	786	-17
890	0.96	761	778	-17
889	0.95	758	774	-16

Figure 3 Emissivity and True Temperature Values comparison of Pyrolaser® with a Conventional[1] IR non contact infrared thermometer instrument.

In hydrogen and ethylene furnace tests, we generally see tube emissivities ranging from 0.85 to 0.97; they increase with age. Typically, operators report that this is of little concern to them since "that's close to 1." Figure 4 shows measured values of the temperature correction associated with varying (e) values and varying wall vs. tube temperatures. AT (e) = 0.95 a 130°C wall-to-tube difference causes a 15°C (27°F) error. In a 500M metric ton/year ethylene furnace a 10°C (18°F) error is values at $500,000 loss of yield per year.

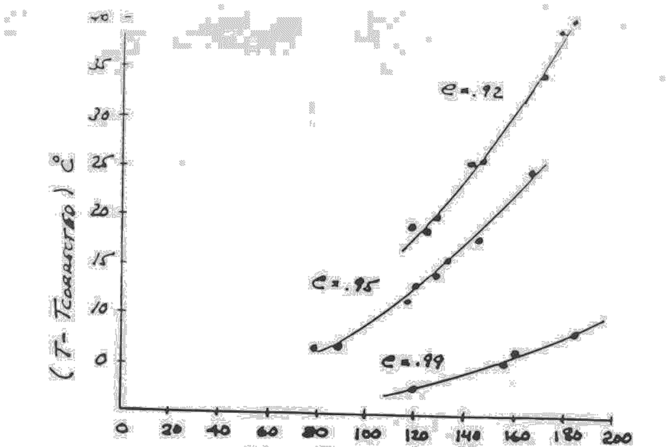


Figure 4. Temperature and Emissivity Values - Hydrogen Furnace

The following shows typical results in a European steam cracker.

Figure 5 Tube Metal Temperatures

All mean values are based on 6-10 measurements Pyrolaser®	**Cracker no. 5**	**Cracker no. 10**
Emissivity E	0.93	0.93
T_X " (°C)	1059	1072
T_E " (°C)	1004	1040
T_T " (°C)	998	1036
[Conventional [1], [2]		
E = 1.00	1015	1047
E = 0.93	1021*	1056*
	*Uncorrected for background thermal radiation. This must be done manually from tables' etc.)	

On cracker #5 the Pyrolaser® readings, taking into account the irradiance is 23°C lower than the emissivity corrected value of the [conventional instrument[1]]. For cracker #10 the difference is 20°C.

In hydrogen furnace operation, as the catalyst activity declines, tube temperature measurements rise and steam consumption must go up in order to produce the yield. Ultimately, a shutdown is required. Accurately monitoring the "hot" tubes is one way of prolonging a furnace run. A North American hydrogen furnace user of Pyrolaser® reported:

The benefits to date are from the extended run of a 96 MSCFD hydrogen unit operating with localized hot spots on 33 of 445 reformer tubes (total number of reformer tubes is 456 of which 11 isolated).The Pyrolaser® was used to monitor the progression of tube metal temperature rise at the hot spots as the reforming catalyst reached end of run. With the development of a serious problem on a parallel hydrogen unit, a unit risk assessment was done using the Pyrolaser® data to extend the current run length by five months. Monitoring of the hot spots had been ongoing for nine months during which six tubes were pinched. The pinched tubes all had hot spots operating above design temperature, and were bulging. With continuous monitoring of the known problem tubes, the risk of operating the unit for the additional five months was deemed acceptable. The parallel unit was allowed to go into a major turnaround, and a potential production loss was averted.

The above knowledge, and experience with the Pyrolaser® has been of great benefit to us."

B. Chemical Plant Reactor:

It is interesting to present the use of this technology to monitor the condition and temperature of an 8-foot diameter catalytic gauze on a chemical reactor processing highly toxic gases. Feed gas is introduced vertically downward and forced to pass through catalytic gauze. The temperature control process is exothermic so feed rate and catalyst activity affects the gauze temperature and process conversion rate. In this case Pyrolaser® was used to 1) obtain the temperature distribution of the gauze tray and to relate emissivity to "aging" of the gauze. The data in Figure 6 are typical data-logger "NOTEBOOK" outputs of Pyrolaser®.

					"Old Gauze"		
Location	**Date**	**Time**	**Distance**	**Mode**	**Nx/EM**	**Tunc.**	**Tcorr.**
00-00-0075	87-06-08	12:01:50	6.90 ft	E O	0.91	1095°C	1107°C
00-00-0074	87-06-08	12:01:48	6.90 ft	E O	0.90	1071°C	1082°C
00-00-0073	87-06-08	12:01:44	6.90 ft	E O	0.90	1086°C	1098°C
00-00-0072	87-06-08	12:01:36	6.90 ft	E O	0.90	1081°C	1092°C
00-00-0071	87-06-08	12:01:34	6.90 ft	E O	0.89	1092°C	1105°C
00-00-0070	87-06-08	12:01:32	6.90 ft	E O	0.92	1049°C	1058°C
00-00-0069	87-06-08	12:01:28	6.90 ft	E O	0.90	1089°C	1100°C
00-00-0068	87-06-08	12:01:26	6.90 ft	E O	0.90	1089°C	1100°C
00-00-0067	87-06-08	12:01:23	6.90 ft	E O	0.91	1078°C	1089°C
00-00-0066	87-06-08	12:01:22	6.91 ft	E O	0.89	1088°C	1101°C
00-00-0065	87-06-08	12:01:19	6.90 ft	E O	0.90	1097°C	1109°C
					"New Gauze"		
00-00-017	87-06-08	11:40:51	8.24 ft	E O	0.61	1079°C	1136°C
00-00-016	87-06-08	11:39:59	8.24 ft	E O	0.58	1085°C	1148°C
00-00-015	87-06-08	11:39:54	8.24 ft	E O	0.65	1082°C	1131°C
00-00-014	87-06-08	11:39:52	8.24 ft	E O	0.65	1080°C	1130°C
00-00-013	87-06-08	11:39:48	8.24 ft	E O	0.65	1079°C	1128°C
00-00-012	87-06-08	11:39:44	8.24 ft	E O	0.66	1085°C	1133°C

Figure 6. Emissivity and Temperature Measurement of a Catalytic Gauze

Looking at the average values we find:

	Ave E	Ave TUNC°C	Ave TCORR°C
New Gauze	0.63	1081	1134
Old Gauze	0.90	1083	1095

This shows that the emissivity increased with use, i.e. "aging." It also shows that using a fixed emissivity value would yield only a 2°C change between the new and the old gauze – whereas by having measured emissivity values the corrected temperature values indicate a 39°C decrease. Use of a manual or preset emissivity would not have revealed this drop in reaction temperature which would be masked by the changing emissivity value.

C. Metallurgical Applications

In this section a few examples of Pyrolaser® use in steel, aluminum and other non-ferrous metallurgical applications will be presented. But first, realize that neither Pyrolaser® nor other infrared instruments can be used indiscriminately on metals particularly freshly generated metal surfaces. The problem is the emission pattern of the energy from a surface.

In general, freshly prepared metal surfaces do not have the uniform emission patterns exhibiting either hemispherical or Lambertian distribution. These specular targets may or may not be measurable. Even for diffusely radiating metal, the energy-emitted normal (perpendicular) to the surface is typically less than at angles off the normal. Additionally, we do not advise use of Pyrolaser® within 7° of the normal, for we are concerned with the possible "bounce-back" of the laser beam. It is thus our procedure to examine the emissivity distribution as a function of incident angle early in programs involving metals. In many cases, the specular emission becomes Lambertian as the temperature of the metal increases and with exposure to oxygen. Pyrolaser® has a built-in cosine function allowing the user to enter the incident angle.

1. Steel Industry Applications

Pyrolaser® has been used to measure ingot temperatures in soaking pits, refractory and slabs in reheat furnaces, silicon and 301SS in rolling mills etc. For example, in this progress report, we present information concerning a normalizing process for 48" wide silicon steel sheeting. The process receives steel from a hot rolling mill which is passed through a three-zone heating oven, a holding chamber for controlled cooling and oxidation (to facilitate cleaning) and then to a cold rolling mill. The Pyrolaser® was particularly utilized at the exit of the heating oven and entry to the holding chamber. Emissivity readings laterally across the strip varied form 0.91 near the edges to 0.85 at the center. For a conventional pyrometer set at a constant (e) obviously an error occurs. This amounts to about 8°F. In this case with Pyrolaser®, the differences in emissivity paralleled differences in grain structure (alignment and size) which were vital to magnetic product quality properties. (Details are confidential to the steel company.)

2. Steel Fabrication

One application of Pyrolaser® has been in a critical steel fabrication operating in West Germany. In this case, the producer is endeavoring to shape an annular specialty steel having a rectangular cross-section. The temperature distribution within the member is vital; it being derived from non-contact surface temperature measurements. The company determined that neither the metals nor their oxides were grey bodies, and in October 1988, acquired a Pyrolaser®. Figures 6 and 7 show the configuration of the equipment and Figure 8, some example data.

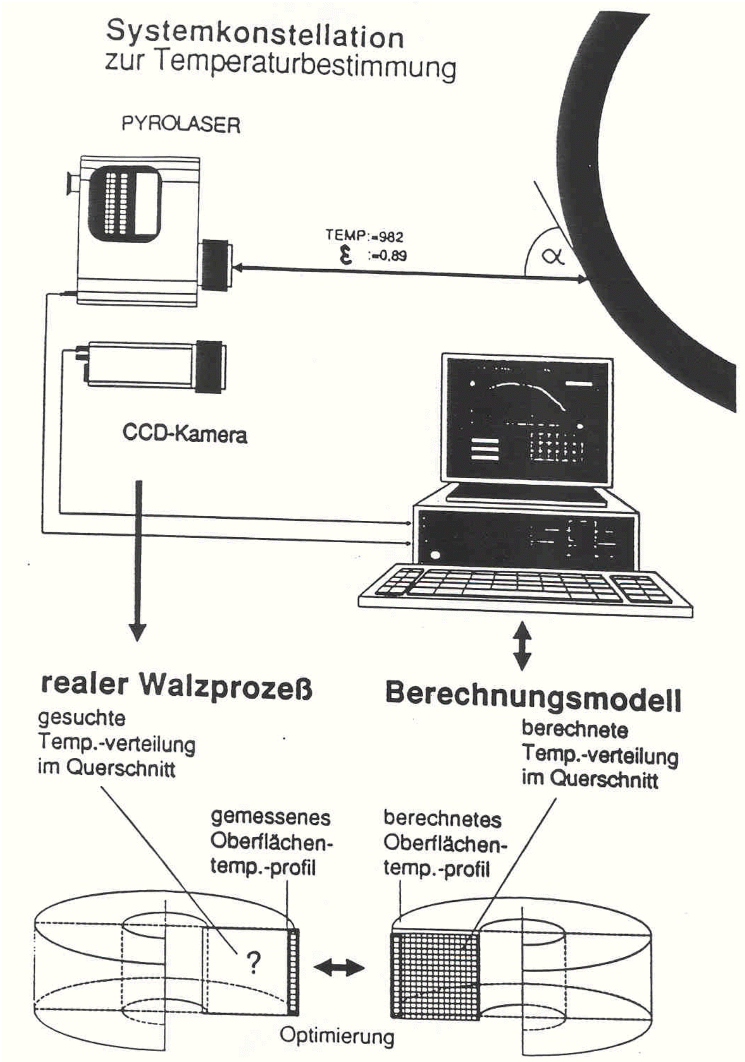


Figure 6

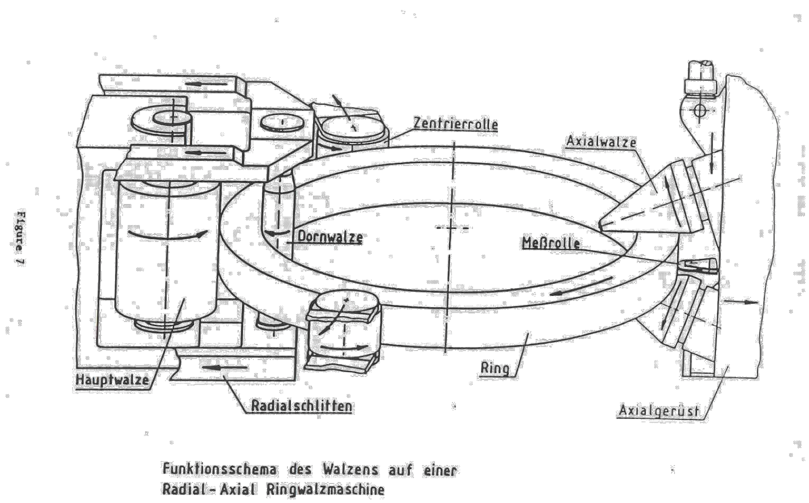


Figure 7

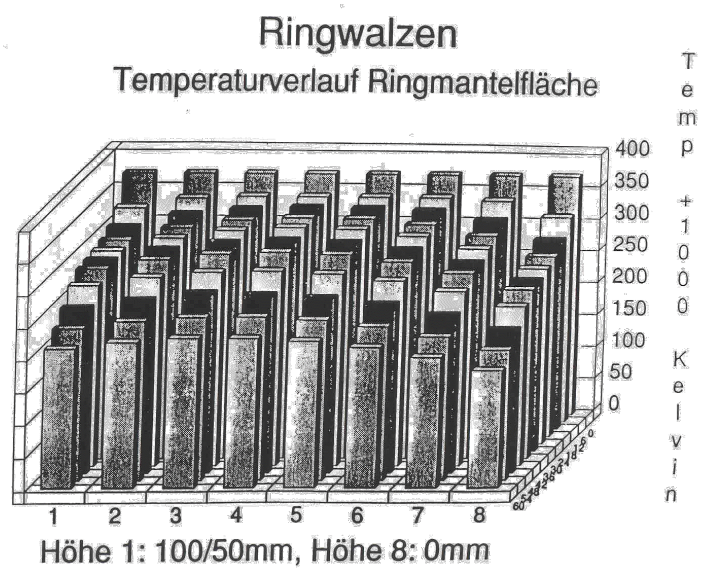


Figure 8

3. Aluminum

Field trials of Pyrolaser® in a major aluminum reclamation plant have yielded some interesting data. Typically, aluminum processing involves temperatures below the (1112°F/ 600°C) threshold of Pyrolaser® and typically aluminum surfaces have specular emission characteristics. In reclamation plants, some of the thermal treating reaches within the temperature ranges of Pyrolaser® so the remaining question is specularity. Three cases are shown in Figure 9 along with two sets of refractory data. In addition, Figure 10 is a plot of emissivity corrected temperatures of a flowing aluminum film; the line is that of thermocouples in the stream. Over a twenty-minute period when the (source) furnace operation was constant, the standard deviation was 18°F while the average temperature was 1838°F. This coefficient of variation of approximately 1% is encouraging in this case vis-a-vis little surface specularity.

Target	Conditions	Emissivity	Tunc	Tcorr
Molten Aluminum tapping stream	Mixed Surface; some dross, some clear	.8 - .95	1240-1260°F	1250-1280°F
Refractory in furnace hearth	Clear and then obscured by burner flame	.69-.72	1500-2000°F	1650-2300°F
Refractory lining of crucible heater	No interfering impedance	.68-.70	1020-1040°F	1050-1070°F
Molten Aluminum surface in earth	Slag, dross	.6 - .8	1400-1800°F	1450-1900°F
Molten aluminum in surface hearth	Skimmed	.4 - .55	1350-1550°F	1500-1750°F

Figure 9. Data From Aluminum Reclamation Plant

Specialty Material – MONEL

A major U.K. metals manufacturer has completed System Evaluation Trials of Pyrolaser® on

MONEL samples. The evaluation included tests in a three-zone creep furnace and use of platinum/platinum-rhodium control thermocouples. The Pyrolaser® was evaluated over a range from 750°C to 1250°C and parallel data obtained with a [conventional[2]] infrared instrument. The maximum error of Pyrolaser® over the entire range was 3.2°C, which is within specification. The maximum error for the [conventional[2]] instrument reached 9.8°C. Figure 11 shows a plot of the percentage error and the values of emissivity as determined by Pyrolaser®. It is evident that the ability to measure emissivity at the same location, time, temperature, wavelength and surface condition provides a significant improvement in the measurement of temperature by infrared means

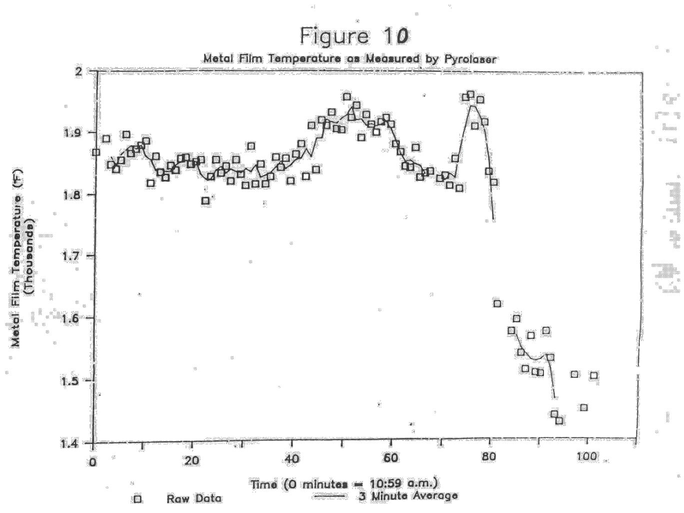
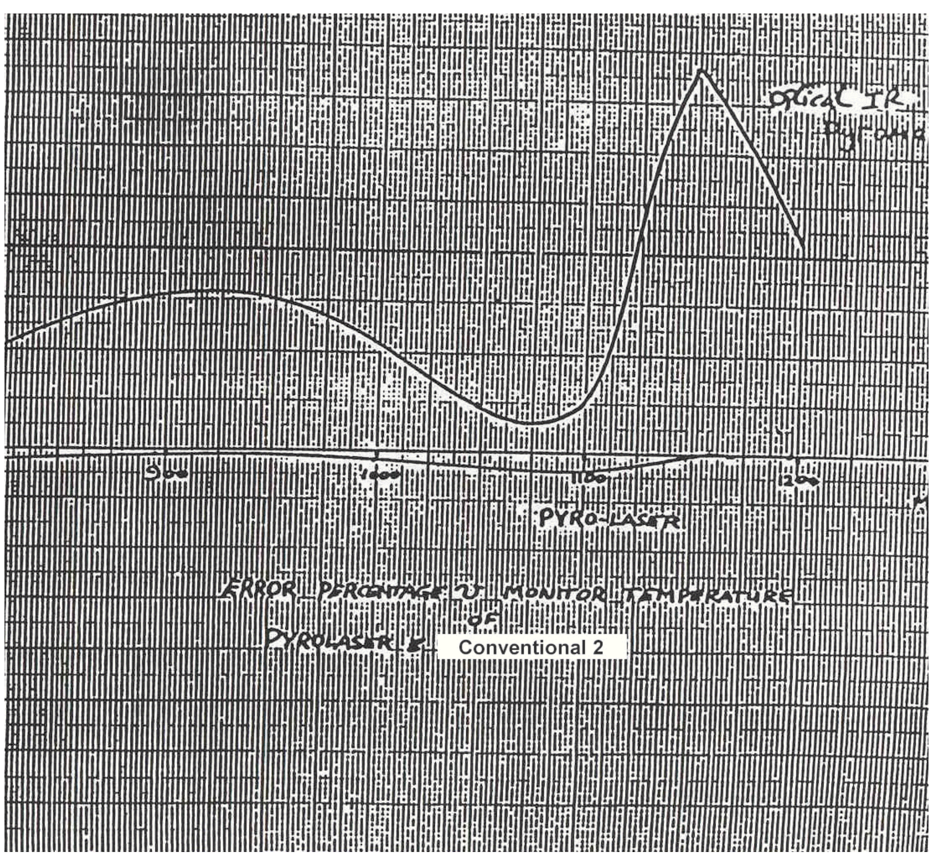


Figure 10. Metal Fil Temperature as Measured by Pyrolaser®.



Graph. Error percentage Monitor Temperature Pyrolaser vs Conventional[2]

Zirconium

A series of Pyrolaser® tests were made at a large U.S. zirconium processing plant. The data presented below are from a heat cycling of a large zirconium billet. In this case, the target zone was initially a freshly cut surface which was tracked during the cycle.

Conditions	Emissivity Range	Corrected Temperature °C
Fresh Cut 8" Face	0.50 – 0.55	T= 20°C Ambient
Heating	0.44 – 0.46 0.38 – 0.42 0.35 – 0.40	673 – 683 835 - 848 930 – 940 1028 – 1038
Cooling	0.37 – 0.40 0.36 – 0.38 0.32 – 0.33	943 – 948 798 – 808 678 – 690
Cold	0.26 – 0.32	T = 22°C

The Pyrolaser® was hand-held in the tests and an attempt made to survey the target area. The results for zirconium appear contrary to other materials, which tend to increase in emissivity when heated while exposed to air. Additional tests during which the white oxide is removed may be justified.

Ceramics

Obviously, the ceramic industry, including that associated with the electronic components business, uses high temperature processing. Some manufacturing is done in open small tunnel kilns as well as vacuum furnaces. Due to secrecy agreement(s) with the manufacturer, at this time only "coded" data can be presented. It does, however, verify the large differences in target emissivities in ceramics and therefore the need to measure directly this vital variable.

Sample Code	**Emissivity**	**Tunc °C - °F**	**Tcor °C - °F**
"A"	.88 - .89	716 – 1321	723 – 1334
"B"	.50 - .52	784 – 1443	831 – 1528
"C"	.73 - .75	601 – 1114	619 - 1146

The emissivity corrections for sample "B", for example (47°C or 85°F), are significant and cannot be ignored in the control of the manufacturing process.

Small Target Applications

While the Pyrolaser® was initially designed for use in large industrial furnaces, soon after its introduction the need for small target measurements became evident. Most of the items were in R & D laboratories and they frequently involved specialty metals. To meet the small target requirements, modification of the optics and software were required. At this time, the following ranges are available in addition to the standard Pyrolaser®.

Target Size		**Target Distance**	
mm	Inch	Cm	inch
1	.039	20	7.9
2	.078	40	15.8
5	.195	100	39.4

The optical modification for each case is an add-on lens and the software change is now simply a Pyrolaser® keypad entry by the user. A Pyrolaser® can be outfitted with any two of the four ranges; if four ranges are needed, an EPROM substitution available from PYRO is required. This, too, can be installed by the user.

Titanium

The first application of the small target Pyrolaser® was on titanium strips in a vacuum. The transmission losses due to the glass bell jar wre calibrated (out) prior to making the following readings.

Emissivity	**Tuncorrected**		**Te (Corrected)**	
0.84	857°C	1575°F	870°C	1598°F
0.85	850°C	1562°F	863°C	1585°F
0.85	850°C	1562°F	862°C	1584°F

"Super Conductivity Material"

Preliminary tests using Pyrolaser® to monitor the temperature of a "material" being made (processed) for super conductivity evaluation have been run. The processing is accomplished in a vacuum and, in this case, the data are reported without correction for the viewport transmission losses.

Conditions	**Emissivity**	**Tuncorrected**		**Tecorrected**	
Ambient	0.65 – 0.67				
Time (minutes)		**°C**	**°F**	**°C**	**°F**
0	0.88	594	1101	600	1112
10	0.91	597	1107	602	1116
20	0.84	628	1162	637	1179

25	0.83	635	1175	642	1188

It is hoped that Pyrolaser® will provide the means to monitor and control the temperature during the processing of these materials.

Conclusions

An effective precision infrared pyrometer has been developed which has application in many industrial and R & D areas. The ability to measure emissivity and to account for irradiance are important for accurate surface temperature measurements. Practical use of the technology in the petroleum, chemical, steel, aluminum, ceramic and other industries verify the usefulness of the Pyrolaser® concept. The development is a major advance in infrared pyrometry. Additional work on lower temperature units, specular targets and on-line process control systems is foreseen.

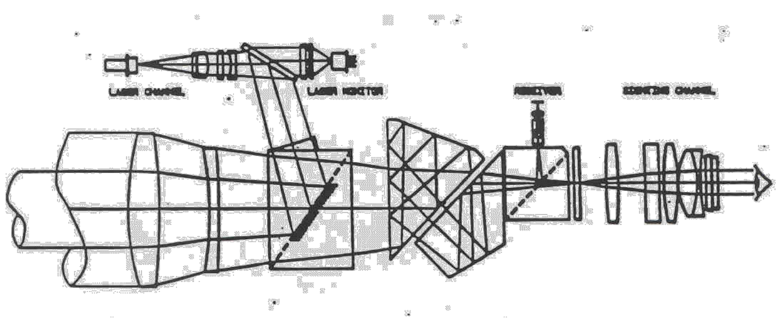
Appendix A

Details of Pyrolaser®

Optical System

The optical sensor system is of single axis configuration with the viewing focusing (distance measuring), laser transmit, laser receive and radiance receive, all being coincident through the objective lens. The laser transmit energy is introduces via a beam splitter and filters protect the operator from any laser energy. The field of view is 7 degrees; the measuring cone 1/3 degree with measuring range 6 to 30 feet (2 – 10m). Lenses for measuring zones of 1, 2 and 5 mm diameter are available.

The optical configuration of the Pyrolaser®, comprising transmit optics, receive optics, radiance channel and sighting system are all operating through a common objective lens. The lay-out of the laser monitor channel is also shown.



Laser

The measuring instrument uses a solid state GaAS three stack laser with peak power of 25 w. The laser is pulsed to distinguish between reflected laser (AC-signal) and emitted radiance (DC-signal) from the target. The large changes of radiant laser power with ambient temperature are roughly compensated for by changing the supply voltage of the storage capacitor. The final precision is achieved by referring the laser return signal to the monitored laser output signal.

Electronics:

Besides communicating with the operator via keypad, LCD digital display, in-view-finder LED-display, and/or RS232 communication line, the electronics measure the distance to the target by detecting

the lens position after focusing manually, provides power and fires the laser, monitors and the outgoing signal, and detects the returning laser signal and the radiance emitted from the target, finally calculates from these raw data the temperature and emissivity and stores the results.

In the electronic design and fabrication special care has been taken to protect the very sensitive detector amplifier circuit from microprocessor noise. The noise has nearly been brought down to

the level of the Noise Equivalent Power of the PIN-photodiode detector itself. The dark current of this detector diode is brought to zero by keeping the bias voltage across the diode smaller than1uV.

Specifications

• **Selectable Readout:**	°F,°C
• **Standard Temperature Range:**	1100°F - 2730°F (600°C - 1500°C)
• **Optional Extended Temperature Ranges:** See Calibration Lens & Filter Table	1300°F - 3600°F (700°C - 2000°C) 1450°F - 4500°F (790°C - 2500°C) 1550°F - 5400°F (850°C - 3000°C)
• **Calibration Ranges:**	(4) Ranges Available
• **Accuracy:**	± 5°F (3°C)
• **Resolution:**	± 1°F (1°C)
• **Repeatability:**	± 1°F (1°C)
• **Effective Wavelength:**	0.865 mm ±0.015
• **Bandwidth:**	0.055 mm
• **Automatic Emissivity Measuring Range:**	0.01 -1.0 (Increments 0.01)
• **Aquisition Time:**	1ms - 2000ms Selectable
• **LED Display In Viewfinder:**	4 Digit Corrected Temperature (Tt)
• **LCD Disply**	40 Digit Readout of Target Distance Emissivity Value (E), Uncorrected Temperature (Tu), & Corrected Temperature (Tt)
• **Standard Target Distance:** Optional Target Distances Available	2-10 meters
• **Target Size vs. Distance:**	**Target Size** **Target Distance**

Standard 2 - 10 meter Range Optional Target Size/Distances Available	(Target Size = 1/200 of Target Distance)			
	Min	Max	Min	Max
	0.39" (5cm)	1.96" (5cm)	6.56' (2m)	32.8' (10m)
• **Visual Field Of View:**	7°			
• **IR Field Of View:**	0.333° (1mm @ 20cm; 0.04" @ 8")			
• **Sample Rate**	1, 2, 4, 8, 21, 23, 37 Readings/sec Selectable			
• **Maximum Equipment Operating Temperatures:**	32°F - 125°F (0°C - 32°C)			
• **Display Output:**	LCD 3.5" x 0.75" Target Emissivity Target Uncorrected Temperature Target Emissivity Corrected Temperature			
• **Instrument Enclosure:**	Cast Aluminum			
• **Auxiliary Output:**	Single Analog Output: 0 -5vdc or 0-20mA Single Digital Output : RS232C			
• **Power Supply:**	(3) x 9v Rechargeable Ni Cad Batteries 115v/60Hz or 230v/50Hz Charger 2 Hours Operating Time w/Batteries - Unlimited Operating Time With Charger.			
• **Dimensions:**	12.5" x 8.0" x 3.0" (318mm x 211mm x 74mm)			
• **Weight Including Batteries:**	7lbs. (3.5kg)			