inframetrics MODEL 760

IR Imaging Radiometer

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MODEL 760 OPERATOR'S MANUAL
Document #07137-000 REV C

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Model 760
IR Imaging Radiometer

TABLE OF CONTENTS

T A B L E O F C O N T E N T S

Page

TABLE OF CONTENTS

T A B L E O F C O N T E N T S

ILLUSTRATIONS

ILLUSTRATIONS

LIST OF TABLES

Introduction

System Overview

The Model 760 IR Imaging Radiometer, Figure 1-1, is designed for applications requiring accurate real-time analysis of static or dynamic thermal patterns. This high performance system combines superior image quality and thermal sensitivity with true temperature measurement display. The Model 760 is a completely self-contained thermal imaging, archival, and analytical system with an integral color LCD, micro floppy diskette drive and integrated cooler. It can be used with a video cassette recorder (VCR) to record thermal events in either color, or black and white for later analysis on playback. The system can also be interfaced with a computer or with an external thermal image processing system.

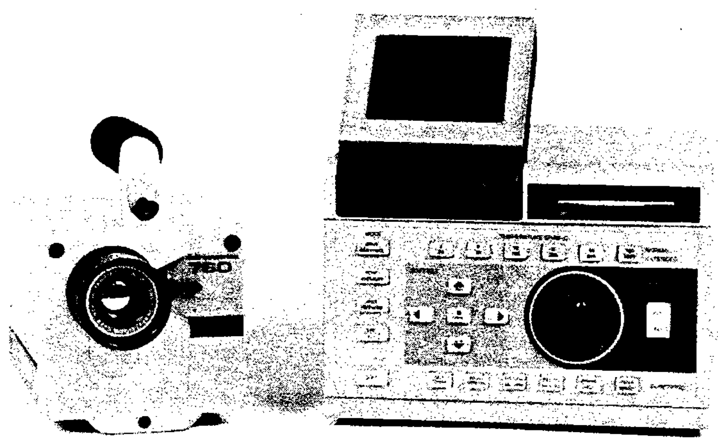

Figure 1-1
Model 760 IR Imaging Radiometer

Other notable features of the Model 760 include eight primary operating modes, a calibrated gray scale, eight color palettes, a 4:1 continuous electro-optic (E-O) zoom, optional remotely controlled optical filters, optional remote focus, and computer control via a serial port.

Specifications

NOTE: Addition of filters, especially narrow bandpass filters, will affect system performance.

Spectral Bandpass (Nominal). ......8-12 µm, 3-5 µm or 3-12 µm

Detector. ....Mercury/Cadmium/Telluride (HgCdTe); @ 77 K

Minimum Detectable Temperature Difference (typical)

@ 30°C (8-12 µm, 3-12 µm) ....0.1°C
@ 30°C (3-5 µm) ....0.2°C

Noise Equivalent Temperature Difference (typical)

@ 30°C (8-12, 3-12 µm) .... less than 0.2°C
@ 30°C (8-12, 3-12 µm with image averager, 16 fields)........... less than 0.05°C
@ 30°C (3-5 µm) .... less than 0.4°C
@ 30°C (3-5 µm with image averager, 16 fields) .... less than 0.1°C

Horizontal Resolution at 50% Slit Contrast (typical)

USA and International (8-12 µm) ....1.8 mRad, 194 IFOVs/Line
....256 Pixels/Line
USA and International (3-5 µm) ....3.5 mRad, 100 IFOVs/Line
....256 Pixels/Line

Accuracy (worst case)

Temperature Measurement Accuracy ....±2°C or ±2%

Scan Rate

USA ....7866 Hz Horizontal; 60 Hz Vertical
International ....7812 Hz Horizontal; 50 Hz Vertical

Output Rate

USA ....15,750 Hz Horizontal; 60 Hz Vertical
International ....15,625 Hz Horizontal; 50 Hz Vertical

Field of View (FOV). ....15° Vertical x 20° Horizontal
..............................4X Continuously Adjustable E-O Zoom
....(horizontal and vertical)

Output Format

USA .... RS-170, NTSC
International .... CCIR, PAL
Dynamic Range .... 8 Bit, 256 Levels, 48 dB

Temperature Reference

USA .... Internal Reference Sampled @ 60 Hz
International .... Internal Reference Sampled @ 50 Hz
Temperature Spans .... 2, 5, 10, 20, 50, 100 Normal Range
.... 20, 50, 100, 200, 500, 1000 Extended Range

Temperature Meas. Range. .... -20 to +400°C Normal Range
(for 8-12μm) .... 20 to +1500°C Extended Range

Temperature Readout Resolution. .... 3 Digits

Power Requirements

System 11-17VDC, 30W

AC Power Supplies

USA/International .... 95-250 VAC, 47-63 HZ

Ambient Operating Temperature .... -15 to +50° C

Dimensions (l x w x h), Weights

Scanner .... 10 1/8" x 5" x 5 1/8", 7.5 lbs.
Control/Electronics Unit .... 10 1/2" x 9 3/8" x 6 1/4", 12.0 lbs.

1.3 Purpose and Scope of the Manual

This manual describes the setup, operation, and maintenance of the Model 760 Thermal Imaging System. It includes system specifications and appendices containing fundamental radiometric concepts to help users identify the capabilities and limitations of the system when applied to a specific application. Maintenance is limited to troubleshooting procedures designed to isolate and/or remedy simple operational problems.

IMPORTANT

Because the key to the successful application of the Model 760 is the correct interpretation of the thermal images or thermograms produced, those responsible for operating the system should have a good working knowledge of the basic principles of both heat transfer and radiometry. To this end, and because of its commitment to its customers to provide whatever technical data and assistance are required to help them utilize the equipment to the fullest extent, Inframetrics offers a training course covering these topics and providing hands-on experience in equipment setup and operation. For more information, please contact our Commercial Marketing Group.

1.4 Inframetrics' Warranty Policy

1.4.1 One Year Original Purchasers Limited Warranty

Inframetrics warrants to the Original Purchaser that all instruments and equipment manufactured and supplied by Inframetrics will be free from defects in material and workmanship under normal storage, use and service for a period of one year after the shipment date.*

Inframetrics' sole responsibility under this warranty shall be to adjust, repair or replace, at its option, any part or component which is or becomes defective in materials or workmanship during said one- year period; provided that the Original Purchaser has promptly and completely reported such failure to Inframetrics and Inframetrics has, upon inspection, found such part or component to be defective in material or workmanship. Ordinarily, but solely at the option of Inframetrics, such adjustment, repair or replacement will be performed at the Inframetrics repair facility. The Original Purchaser must obtain shipping instructions from Inframetrics for the return of any item covered by this warranty. Compliance with such shipping instructions shall be a condition of Inframetrics' obligations under this warranty.

This warranty is contingent upon proper use in the application for which the instruments or equipment were intended and does not cover products which have been modified or altered or which have been subjected to unusual physical or electrical stress or on which the original identification marks or serial or model numbers have been removed or altered. This warranty will not apply if adjustment, repair or replacement is required because of accidents, neglect, misuse, damage in transportation, functional difficulties or defects due to improper handling or maintenance, or any cause whatsoever other than normal use.

* Additional equipment purchased by Inframetrics for resale purposes after minor modifications, such as TV and/or video accessories, shall carry the same warranty conditions, provided by the particular manufacturer/supplier in lieu of Inframetrics' standard one-year limited warranty.

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Non-Warranty Repairs and Maintenance Service — *1.4.2*

Services for repair and maintenance of instruments and equipment not covered by the express limited warranty stated herein are available from Inframetrics at the expense of the Original Purchaser or any subsequent owner or user who contracts for such services. Ordinarily, but solely at the option of Inframetrics, these services will be performed at the Inframetrics repair facility. Charges for such services will be invoiced at the labor and material rates in force at the time of service, plus shipping costs.

Inframetrics offers a full range of maintenance contracts that will cover virtually any service requirement. Please contact Inframetrics Customer Service for details.

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Scanner

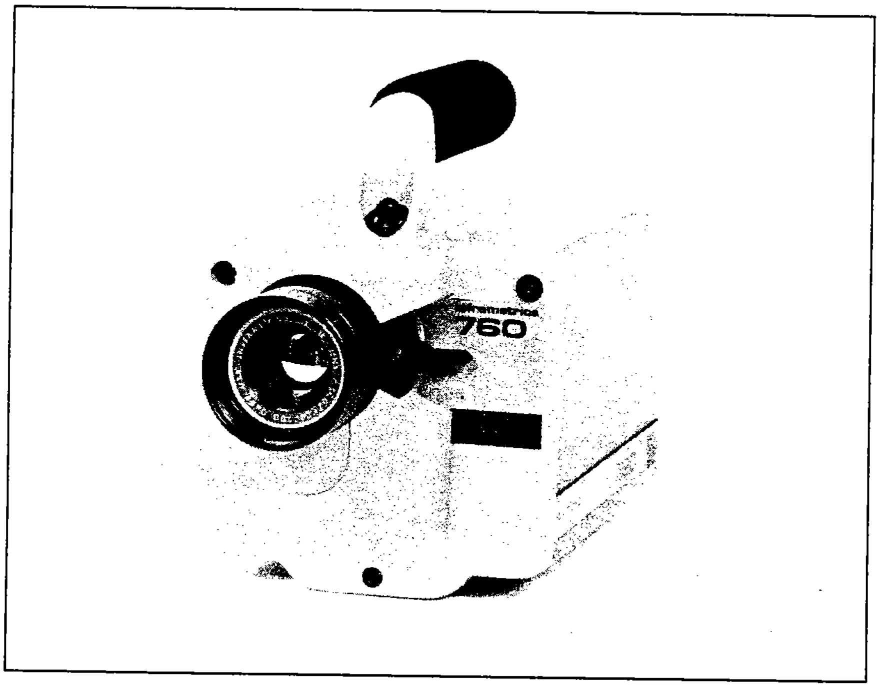


Figure 2-1
Model 760 Scanner

The Model 760 scanner incorporates electromechanical servos (galvanometers) to perform horizontal and vertical scanning. This scan concept produces the highest scan speed or frame update rate of any commercially available imaging radiometer permitting fast-moving targets to be viewed without distortion. It also provides exceptional reliability, shock resistance, and image stability in the presence of scanner motion. During system operation, a magnetic field oscillates a mirror against a torsional spring shaft under closed-loop electrical control. Horizontal scanning is performed at a 4 KHz rate in a resonant (sinusoidal) mode. Vertical scanning is done in a sawtooth pattern commensurate with standard TV formats.

The scan mirrors are contained in a sealed, evacuated module for increased efficiency. Optional motorized focus and optional filter mechanisms are operated within the scanner case by remote control. A rotating thermal reference target is viewed by the detector 60 (or 50) times per second.

A Mercury/Cadmium/Telluride detector is cooled by Inframetrics' integrated cooler to 77 Kelvin for maximum thermal sensitivity and high spatial resolution.

The optical path of the scanner is shown in Figure 2-2. Thermal radiation enters the evacuated scan module through a collimating lens, is deflected by the horizontal and vertical scan mirrors, and exits through a second window to pass through the detector lens on to the detector.

Scanner

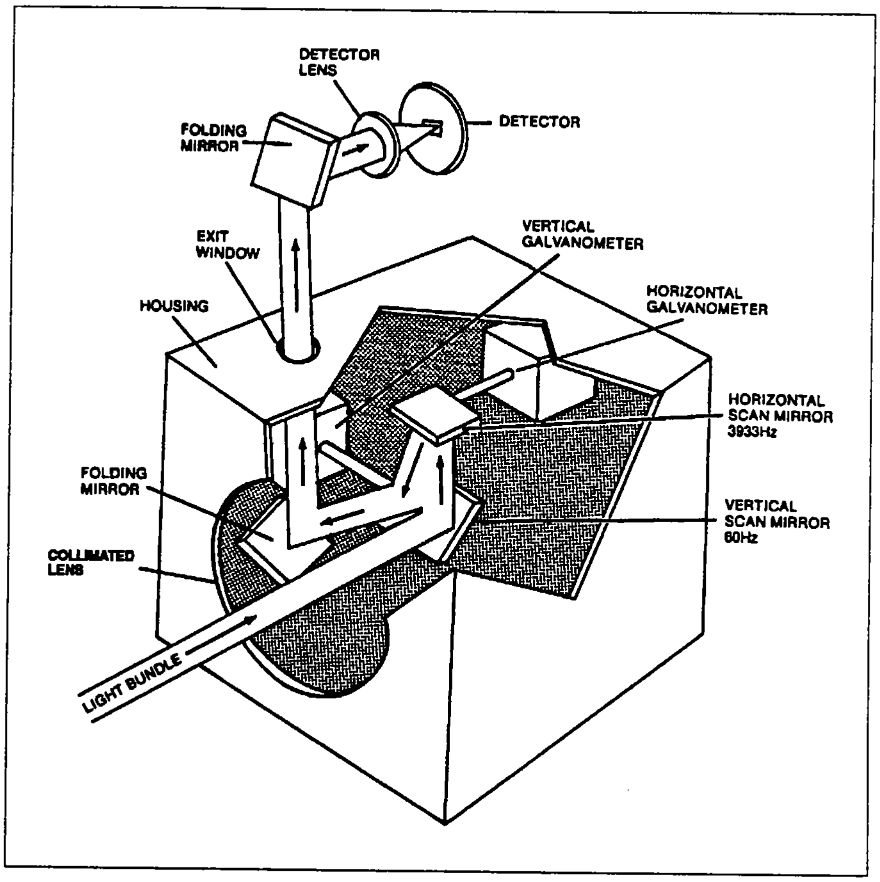


Figure 2-2
Conceptual Optical Schematic Model 760 Scanner

The Model 760 control/electronics unit contains circuits to process, digitize, reformat the IR signal for display in color or black and white on the LCD or external video monitor, Figure 2-3. A microprocessor performs internal calibration as the scanner temperature changes, lenses are installed, or settings are altered by the operator. The microprocessor accesses individual picture elements, then calculates temperatures using calibration tables corresponding to the optical filter/lens combination in use. A pulse-width modulated switching power supply accepts a wide range of DC input voltage with excellent noise immunity.

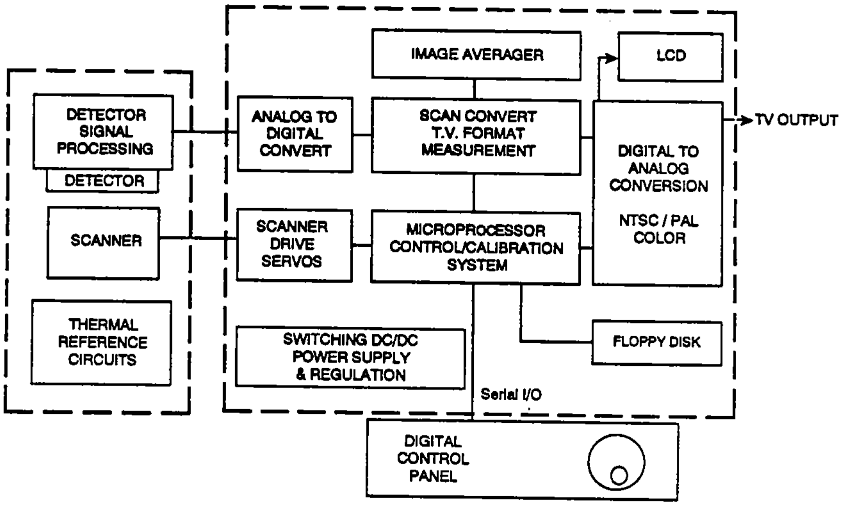


Figure 2-3
Block Diagram, Model 760 Electronics

The microprocessor-based digital control panel or keyboard, Figure 2-4, communicates with the electronics via a serial I/O format interface. The Keyboard consists of a CENTER TEMP control and five groups of keys: MODE, TEMPERATURE SPAN, SOFT-SET, FUNCTIONS, and FOCUS. The CENTER TEMP control and function keys are used to adjust the system to the desired operating conditions as described in the following paragraphs.

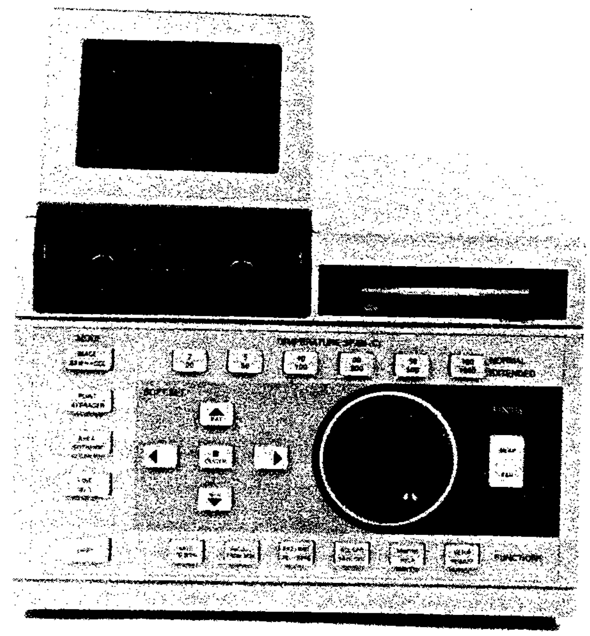


Figure 2-4
Model 760 Control/Electronics Unit

Control Panel

2.2.1

2.2.1.1

Mode Keys
The IMAGE, POINT, AREA and LINE modes of operation are selected by pressing the desired key. The B&W—COL, AVERAGER, ISOTHERM, and AUX modes of operation are selected by pressing the SHIFT key and the desired mode key simultaneously.

2.2.1.2

Temperature Span Keys
These keys select the desired temperature span in degrees C. If the extended temperature span is enabled, the value of each key is increased by a factor of ten, as indicated by the figures in the bottom row of each key. The maximum temperature span setting is 1000° C.

2.2.1.3

SOFT-SET Keys
The function of each of these five keys is mode-dependent. See section 4.3, "Operating Modes," for more information. In the IMAGE mode, as with several other modes, the MAX/MIN keys increase and decrease respectively the vertical field of view through a zoom range of 4 to 1.

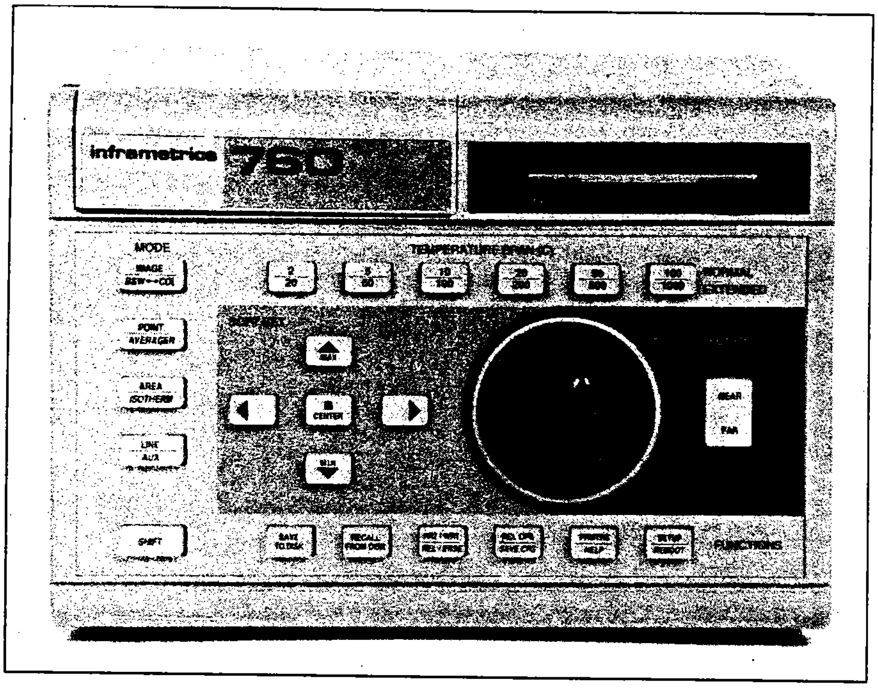


Figure 2-5
Model 760
Control Panel

When the E-O zoom feature is used, the resolution element size (detector size) remains constant. An "image enlargement" occurs with an increase in thermal sensitivity due to an increased detector dwell time. Telescopes and close-up lenses are also available as accessories to increase magnification.

2.2.1.4 Focus Keys

The NEAR/FAR keys control the scanner focus for instruments equipped with the remote focus option. Without this option these keys are inactive. (The lens is manually focused by rotating it similar to a camera lens.)

2.2.1.5 Center Temperature Control

This optically encoded rotary control allows high-resolution adjustment of the temperature setting corresponding to a mid-grey image intensity. The amount of change caused by each rotation of the control is adjusted to fit the current temperature span setting. Finer adjustment is possible on smaller temperature span settings.

2.2.1.6 Function Keys

The six function keys are grouped along the bottom edge of the control panel. Four of these keys have two functions: a primary function invoked by pressing the corresponding key, and an alternate function, invoked by pressing the SHIFT mode key while pressing the appropriate function key.

The SAVE TO DISK key saves the image on the display at the moment the key is pressed to the micro floppy diskette drive.

The RECALL FROM DISK key recalls an image that was previously saved to a diskette using SAVE TO DISK.

The FRZ/WRT/REL/ERSE key has two functions. When the 760 is in averager or image mode, this key freezes or releases the display. FRZ is the primary function in this mode, and REL the alternate. When the 760 is in line scan mode, this key writes or erases a labeled temperature axis on the screen. WRT is the primary function in this mode, and ERSE the alternate.

The RCL CFG/SAVE CFG key saves and recalls setup configurations that have been created using the Setup menus. RCL CFG is the primary function for this key and recalls a previously saved setup configuration. SAVE CFG is the alternate function of this key and saves the current setup configuration for later recall.

The PARAMETERS/HELP key is used to view the setup of the systems's parameters (mode, optical configuration, etc.). HELP (see Figure 2-6) is the alternate function of this key and is used to display the functions of the SOFT-SET keys for the current operating mode. Pressing any key then clears the HELP text and graphics and restores the screen to its previous state.

The SETUP/REBOOT key is used to access setup menus where secondary system parameters are set. There are four setup menus: "Measurement and Configuration Setup," "Processing Parameters Setup," "Display Options Setup," and "Auxiliary Mode Setup." The "Auxiliary Mode Setup" menu contains the modes which can be selected with AUX mode. Each of the four menus can be accessed by consecutive key presses. REBOOT is the alternate function of the SETUP/ REBOOT key and is used to reinitialize the 760.

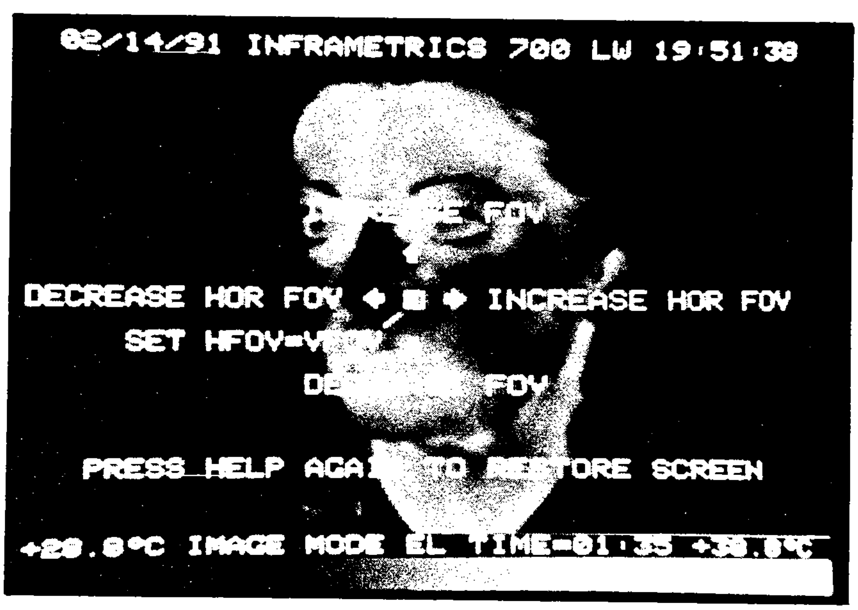
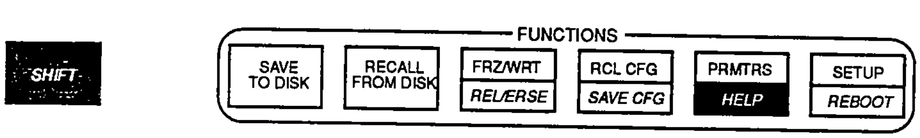


Figure 2-6
Help Display

Help Display is activated by simultaneously pressing shift and Prmtrs/Help keys



2.2.2 Back Panel

The Model 760 back panel provides connectors for attaching the scanner unit as well as ancillary equipment that may be required for a particular application. Connector locations are shown in Figure 2-7. A brief description and typical applications for each connector are given as follows:

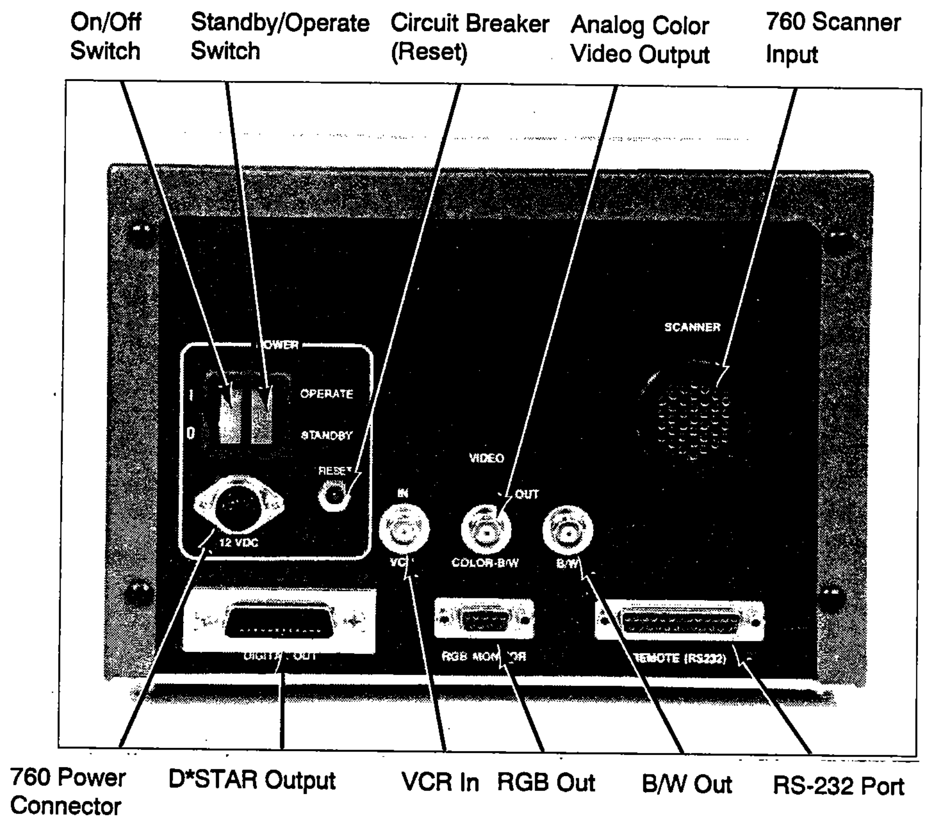


Figure 2-7
Back Panel

2.2.2.1 BNC Connectors

There are three BNC connectors on the back panel of the Model 760. Their functions are described below.

VCR IN —This input accepts images stored on a VCR or electronic camera for playback on the integral LCD display. Note that in VCR playback mode the display is black and white only.

B&W/COL—This output provides either a black & white or color TV compatible signal, corresponding to the output format selected by the operator.

B&W—This output provides a black & white TV signal irrespective of the output format selected. This output is typically used when recording video for image processing.

2.2.2.2 RGB Connector

This connector provides standard RGB (red, green, and blue) video output.

2.2.2.3 Serial Port (RS-232)

This connector allows serial communication to take place with the remote control panel or computer.

2.2.2.4 D*STAR Output

This output provides real time digital video data, and corresponding clock and synchronization information, so that the user may collect and analyze data associated with the event of interest. Inframetrics offers a turnkey real time data capture and analysis system (D*STAR), that interfaces with this output. This system is described in more detail in the System Options Section 2.5.11.

2.3 LCD Display

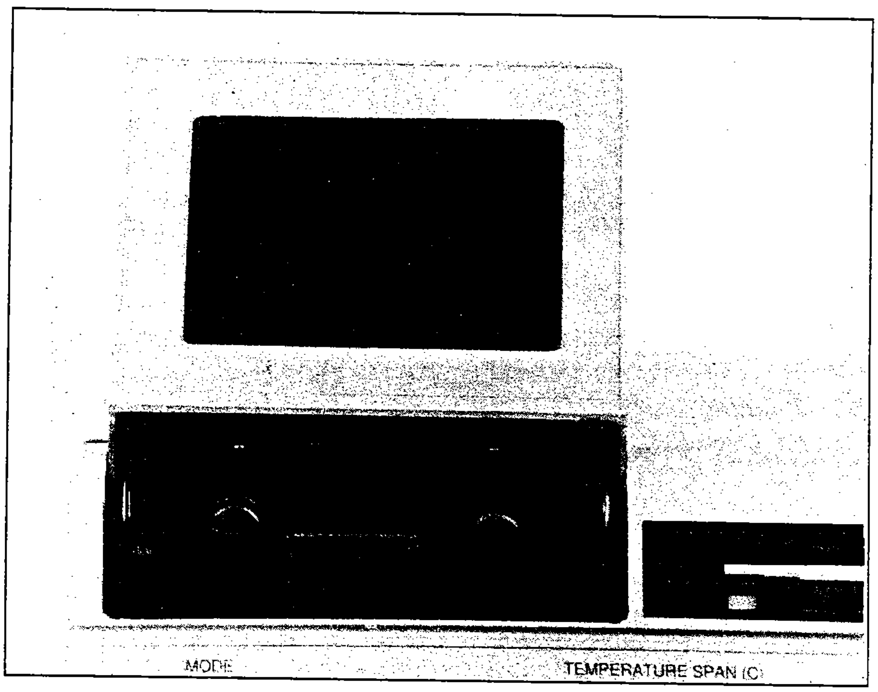


Figure 2-8
LCD Display

Pull the display toward you and rotate upward into position as shown

The Model 760 integral LCD display is a high resolution, color monitor that is compact and rugged. The display is a backlit TFT-active (thin film transistor) matrix LCD with a resolution of 234V x479H dots (112,086 total). To view the monitor, slide it forward and rotate it back until it is in the desired position. Reverse the process to lock the display inside the console. To conserve power, particularly in portable applications, an internal microswitch will disconnect power to the LCD when it is retracted. Power is applied when the LCD is placed in a viewing position.

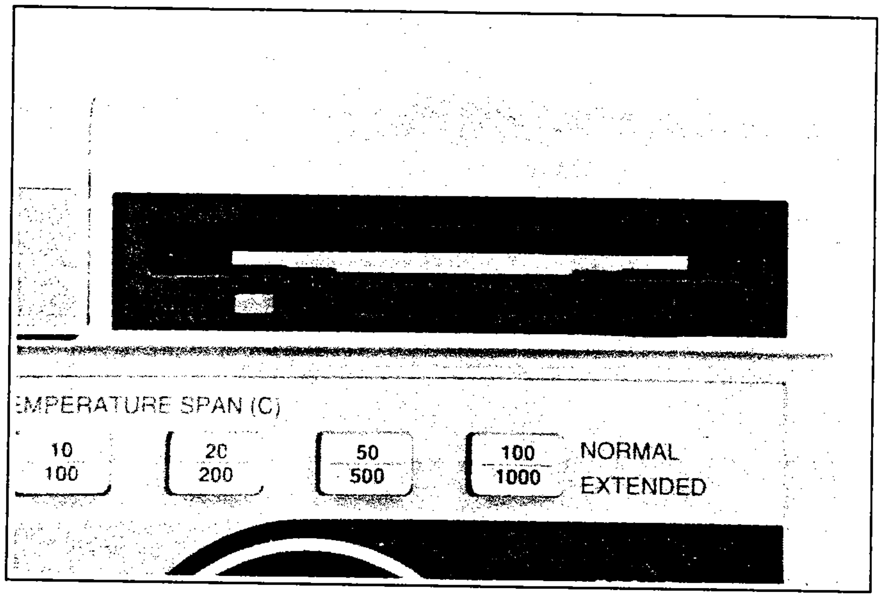
Use the brightness and contrast knobs located immediately below the display to adjust the image for best viewing.

An optional sun shield is available for outdoor operation.

Disk Drive

The Model 760 includes a built-in disk drive for standard 3.5" high density micro floppy diskettes. Images can be stored from video memory onto diskettes. Later, these images can be recalled and analyzed using the Model 760 operating modes. The drive opening is located on the control panel as shown in Figure 2-9.

Figure 2-9
Disk Drive

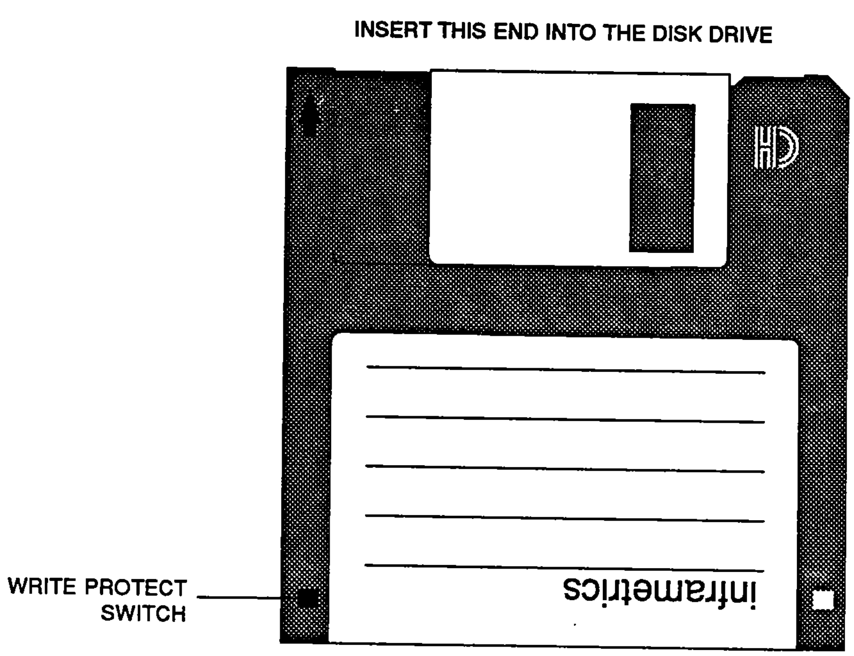


2.4.1

<u>The Diskettes</u>

The Model 760 uses the standard 3.5" DSHD (1.44 MB double-sided high density only) micro floppy diskette shown in Figure 2-10. The diskette write-protect switch is used to prevent the disk's contents from being replaced by new data. Any disk that contains images that must be kept for later use should be write protected.

Figure 2-10
HD Micro-floppy Diskette



Inserting the diskette

To store images on a diskette, ensure the diskette is not write protected. Orient the diskette so that the embossed arrow is on the top side and pointing toward the disk drive opening. Insert the diskette into the opening, pushing it until it is securely in the drive.

System Disks

2.4.2

The 760 system software is field upgradable. In the event that the software needs to be upgraded, a new System Disk containing the latest revision software will be made available.

All systems are shipped with a copy of the software for the 760 on a diskette labeled "System Disk." This software has been loaded on the 760 at the factory. This disk should be kept for reference only.

In the future, an upgrade or enhanced features may be provided on a new system disk. Should the upgrade disk be damaged, or the software load operation be disrupted, the software on the original system disk can be reloaded and the system continued to be used until the problem is resolved.

To load software from a system disk upgrade, insert the system disk prior to turning the system on. Once the system is powered up, the 760 will determine that a system disk is in the floppy drive and that a system software upgrade is intended by the operator. The new software will be loaded in approximately five minutes. Power should not be disrupted during the load operation. Once the new software is loaded, the 760 will place itself in normal operation. The system disk should then be removed and kept for reference only. The new software has replaced the old revision software and is now permanently resident on the 760.

Saving and Recalling Images

Up to 25 images can be saved on each micro floppy diskette for 60 Hz systems, and up to 20 images for 50Hz systems using the SAVE TO DISK function key. The Model 760 disk management software automatically numbers each image when it is saved so they can be retrieved easily.

2.5.1

Optical Filters

Optical filters can tailor the spectral response of the Model 760 to optimize measurement of (or transmission through) specific materials including gases, plastics, and flames. Low-pass, high-pass, band-pass/reject, and attenuating filters are available.

An optional mechanism within the scanner allows one of up to four assorted optical filters to be placed in the collimated optical path. The filter is selected by name in a SETUP menu as described later, and inserted automatically. A special calibration curve is accessed simultaneously to compensate for the variation in spectral response caused by the filter.

The basic calibration curve for the scanner is stored in memory in the control/electronics unit together with characteristic curves for installed optical filters. Up to seven separate calibration tables can be stored in memory.

2.5.2

Telescopes

The Model 760 must be used with a telescope for proper imaging. Two telescopes are available to accomodate the FOV and system resolution for a variety of applications. They are attached or removed through a quick-disconnect mounting system. (See Section 3.4 "Mounting the External Optics," for information on mounting.)

The 1X telescope is used for most applications and is standard with the Model 760. The afocal 3X telescope reduces the system FOV resulting in a magnification factor of 3.

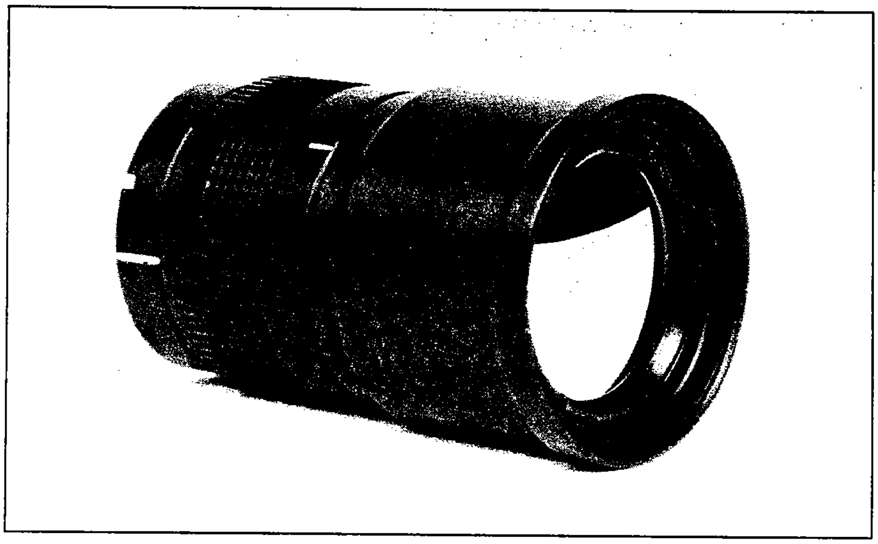


Figure 2-11
3X Telescope

The quick-disconnect mount is equipped with Hall-effect sensors which identify the telescope to compensate for different transmission factors. The transmission factor must be known by the system to maintain correct temperature measurement accuracy. It is marked on the top of every lens case. The factor should be entered into the "Measurement Configuration Setup Menu," for each lens before it is used.

Close-up Lenses 2.5.3

Five close-up lenses are available for individual coupling to the 3X telescope for high-resolution imaging at working distances from 6 to 48 inches. The shortest supplementary lens provides a virtual working distance of 2.25 mm. The FOV is narrowed correspondingly to provide a highly effective infrared imaging microscope.

10X and 30X Telescopes 2.5.4

10X and 30X telescopes are available for the Model 760, providing a magnification factor of ten and thirty, respectively. Enter the telescope selection and transmission factor for the appropriate telescope in the "Measurement Configuration Setup Menu."

0.5X and 0.25X Wide Angle Telescopes 2.5.5

The 0.5X and 0.25X wide angle lenses double and quadruple the field of view, respectively. They are mounted on the scanner in the same manner as the telescopes using the quick disconnect mount. Enter the transmission factor for the appropriate telescope in the "Measurement Configuration Setup Menu."

External Optics Temperature Probe 2.5.6

A temperature probe is available to measure and radiometrically account for the temperature differential between the external optics and the scanner. Enter the transmission factor for the external optics in the "Measurement Configuration Setup Menu."

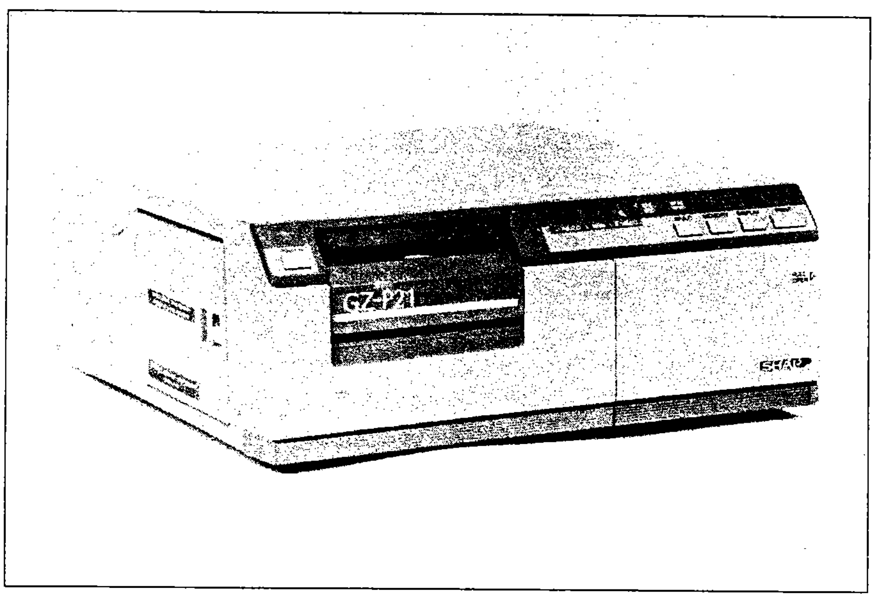


Figure 2-12
Color Video Printer

2.5.7 Color Video Printer

Color video printers are supported by the Model 760. They offer instantaneous storage of images via the analog RGB or composite video outputs. See the particular printer's instruction manual for operational details.

2.5.8 Transporter Cart

The lightweight transporter cart is designed for easy field and laboratory handling of a battery-powered Model 760 System including rechargeable 12 VDC battery and VCR. The cart is made of welded aluminum and features large pneumatic tires and height adjustments for the scanner and control/electronics unit. Unloaded, the cart folds for packing into its own shipping case.

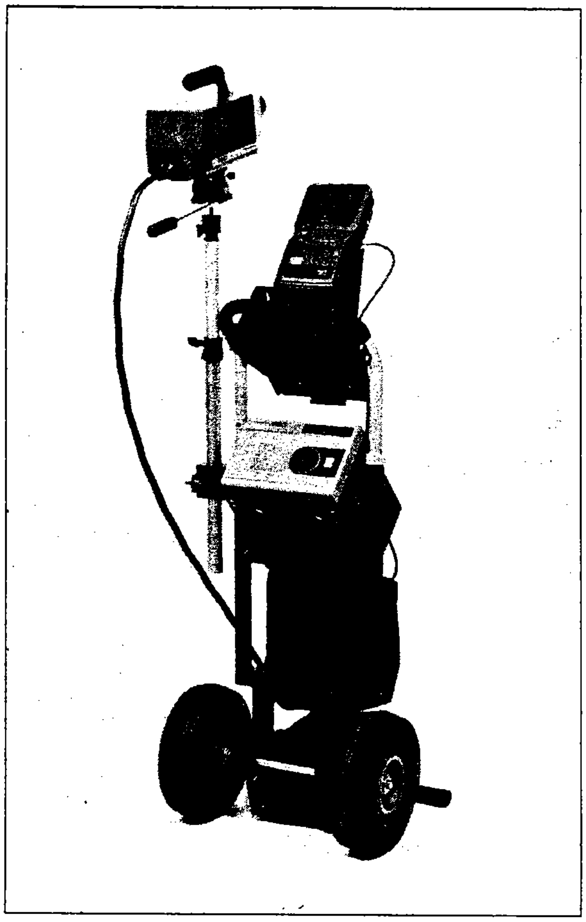


Figure 2-13
Transporter Cart

2.5.9 Remote Control Panel

The remote control panel provides all the control functions of the system keyboard in a separable unit. Using the system's RS232 connector, this accessory allows remote system operation from up to several hundred feet away.

2.5.10 Man Portability

The man portability kit includes a special vest for holding the Model 760 control electronics comfortably with a battery pack and scanner shoulder strap for convenient mobility. The vest is fully adjustable.

2.5.11

D*STAR - Digital Storage and Retrieval

The Inframetrics Digital Storage and Retrieval (D*STAR) System was designed to capture all IR image data generated by the 760, in digital format and in real time, directly to disk. The stored information includes the pixel temperature data, and radiometer setting information associated with each field, including calibration data for the selected range and filter. Radiometer settings may be changed during the capture sequence. Analysis features include facilities to playback stored sequences at variable speed both forward and reverse and view individual fields or frames. System parameters are displayed together with the viewed image. Spot temperatures can be taken and the emissivity, background temperature, and color palette can be modified. A frame or frame sequence can be converted to a series of 760 compatible TIFF files. 760 TIFF files can also be viewed and analyzed on D*STAR.

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The Model 760 is packed in a reusable shipping case as shown in Figure 3-1 and includes the control/electronics unit, scanner, AC power supply for the control/electronics unit and scanner cable.

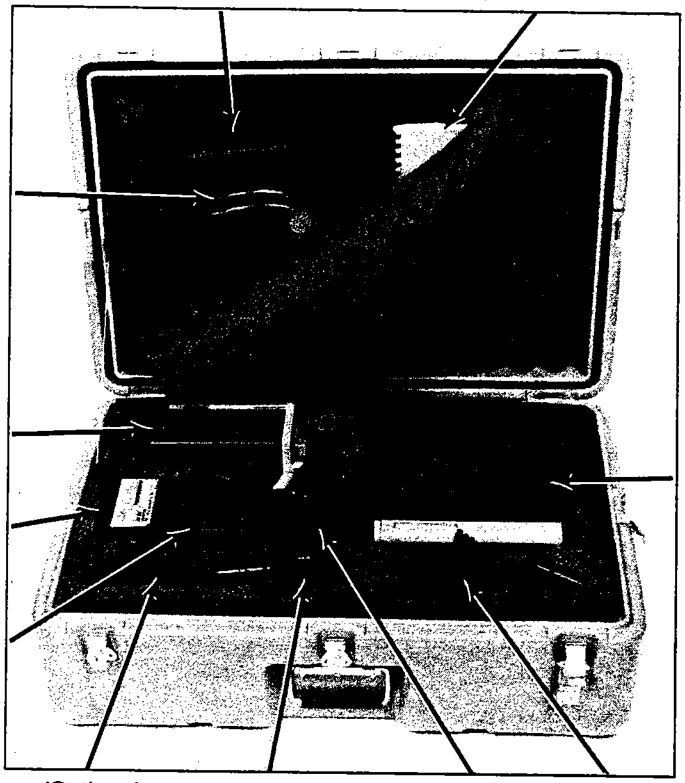


Figure 3-1
Model 760 System Case

Unpack the equipment carefully and account for all items. Inspect the components for damage but avoid touching the germanium window on the front of the scanner. If shipping damage is evident, notify the freight carrier and Inframetrics Customer Service personnel immediately. If the system is to be stored or shipped after inspection, repack it in accordance with Figure 3-1.

Check to see that all items are present and damage-free

Check List

System Components	Optional Accessories
❑ Scanner	❑ Telescope
❑ Control/Electronics Unit	❑ Batteries
❑ Scanner Cable	❑ Man-portability Package
❑ Power Supply	❑ Sun Shield
❑ Operator's Manual	❑ HD Diskettes
	❑ Battery Charger

3.2.1 Typical AC Operation

The most common configuration of system components for operation on AC power is shown in Figure 3-2. The Model 760 control/electronics unit requires 12 VDC power. An AC power supply is provided and plugs directly into a standard electrical outlet.

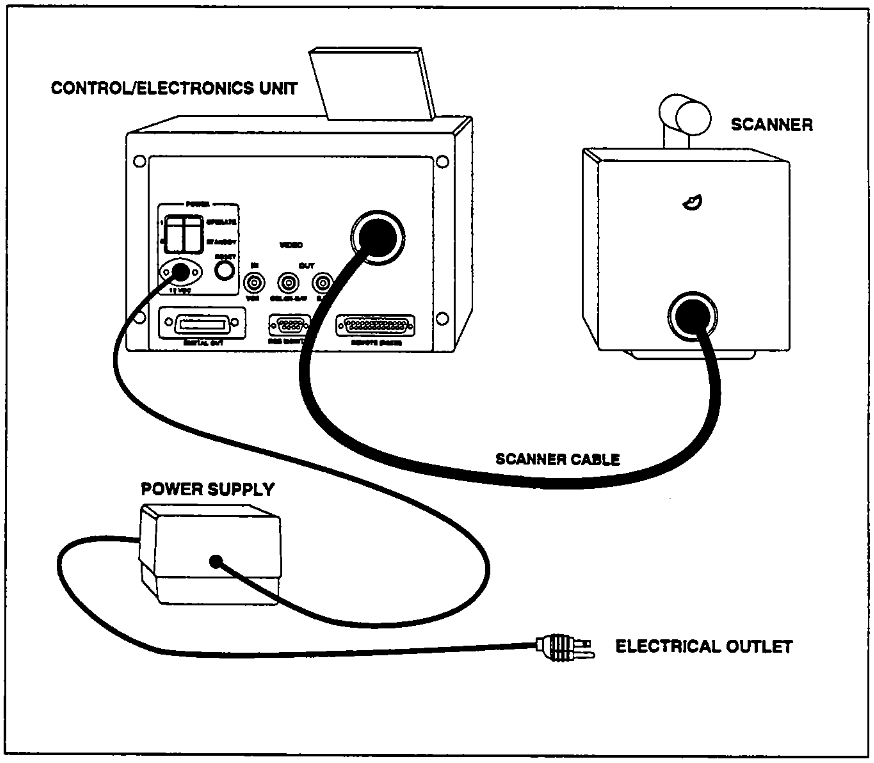


Figure 3-2
Electrical Connections for AC Operation

CAUTION

All power switches must be OFF when making power or scanner connections to avoid the possibility of severe system damage.

All connectors must be firmly seated in their sockets. The scanner cable is equipped with a screw type connector that must be tightened firmly before use. The 12 VDC plug from the power module is polarized and fits into the outlet in only one position.

Several monitors may be connected in series to the COLOR output by adding a cable with an RCA-type connector to the video output connector of the standard monitor. In such cases the 75 /high-impedance Z switch should be turned OFF for all monitors except for the last one which should be terminated (75 ohms.). Most monitors are equipped with a switch for this purpose. The output to the monitor is switched between color and black-and-white by means of the IMAGE/COLOR (MODE) key on the front panel.

3.2.2

Using a VCR

A video cassette recorder (VCR) may be connected to the control/electronics unit as shown in Figure 3-3 to record color and black-and-white images. Here, the signal is routed through the VCR so that live information is normally displayed and recorded images are shown automatically when the VCR is set in the standard play (SP) mode. The VCR must be ON at all times to display an image in this configuration.

When a video recording is made for image processing at a later time, connect the VCR directly to the BLACK/WHITE output of the control electronics unit so as to record black-and-white data under all circumstances. The Data Acquire Mode should be used to insure that the image areas of interest are within the dynamic range of the system . Colorizing can be performed through the ThermaGRAM Image Processor.

Helpful Tip:
Be sure to use a quality brand of video tape to prevent the possibility of data corruption

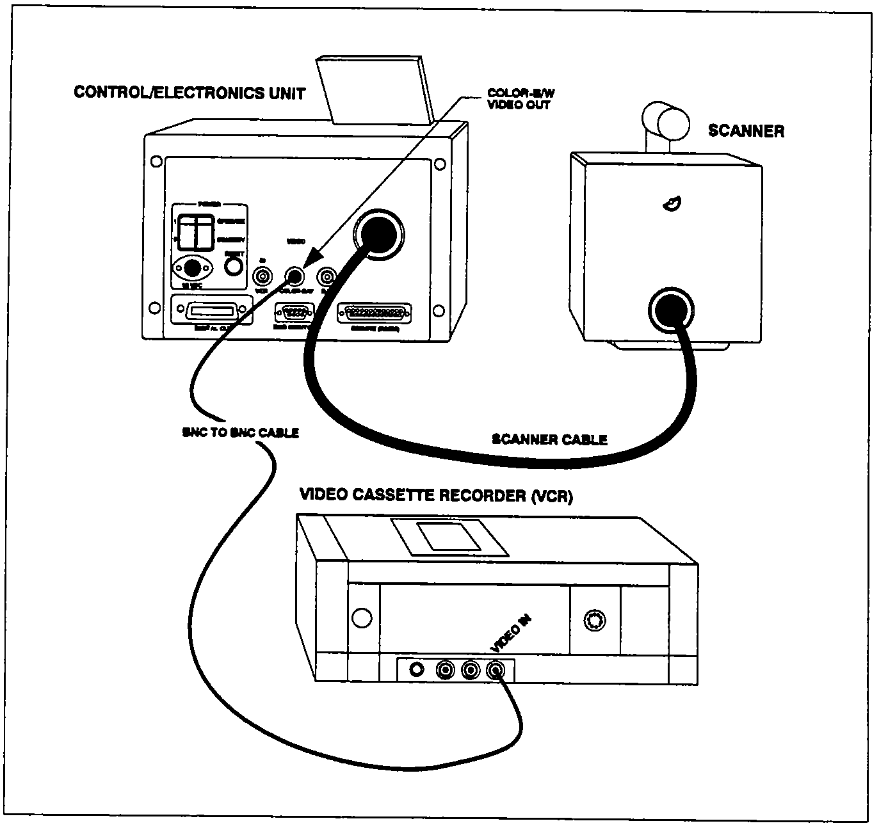


Figure 3-3
Electrical Connections for Color or B/W Recording
(power supply not shown)

3.2.3

DC Operation

For operation as a cart-portable system, the Model 760 may be connected to a 12 ampere-hour battery as shown in Figure 3-4. The batteries are part of an optional kit which also includes a Model 760 power cord, and a battery charging module. Additional batteries are available with chargers only. (Refer to the instructions furnished with the batteries.)

The "Care-Free" rechargeable battery (Inframetrics part number 05066-200) is a 12 volt, 12 ampere hour rechargeable lead-lead dioxide battery used in cart-portable applications. It will power the Model 760 continuously for a maximum period of 4.5 hours at 22° C. The battery should then be immediately charged for 18-24 hours. (Please note that lower ambient temperatures can significantly reduce total system operating time.)

For man portable applications, a lightweight 6AH Nickel Cadmium battery is offered.

Important Note!

Powering up the system repeatedly without a fully charged battery will cause irreparable damage to the battery. This type of abuse voids the warranty.

Note that the system power switches must be OFF when connecting the components. The battery voltage will be shown in the periodic status display on the monitor. When recharging the batteries, allow 18 to 24 hours for a full charge. To avoid damage, do not charge the batteries for more than 3 days.

3.2.4

Data Acquisition/Playback Analysis

The Model 760 is ideally suited to acquire thermal image data for later analysis. A special Data Acquisition Mode clears the screen of all nomenclature to allow display of the largest possible image. All instrument settings, calibration information, and the current time and date are encoded in a normally invisible region of the television frame (the vertical blanking interval). Images may be recorded continuously on a standard video cassette or disk recorder, Figure 3-5. Only black and white images should be recorded for later playback analysis. See Figures 3-5 and 3-6 for electrical connections for playback analysis and real-time analysis.

The ThermaGRAM Thermal Image Analysis System is a dynamic/static image interpreter based on an IBM PC computer (or compatible). By decoding the hidden calibration information, the system can evaluate and display temperatures of points, lines, and regions directly from video tape or from images stored on diskette by the 760. The time and date of the original recording are constantly displayed. Colorizing and readout functions are performed using color palettes and emittance values set at the time of playback.

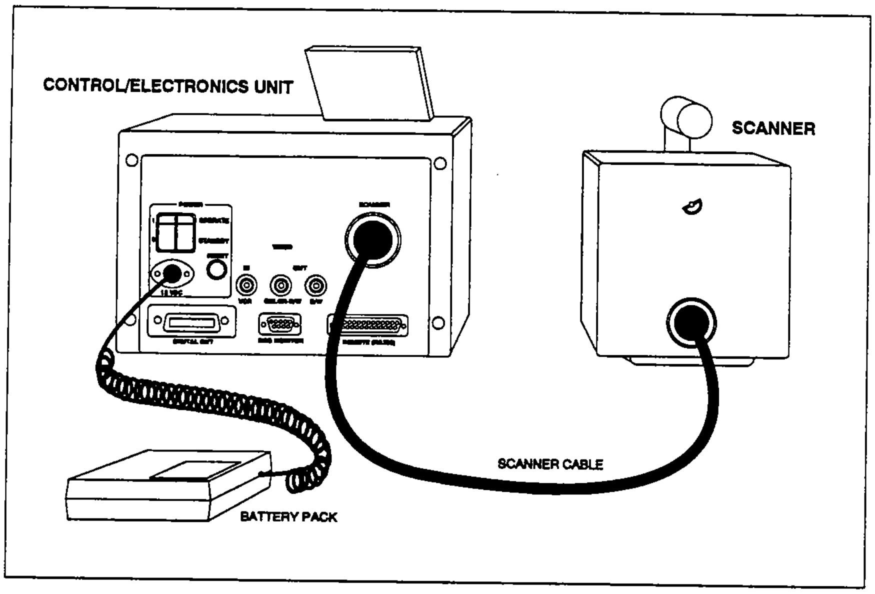


Figure 3-4
Electrical Connections, Battery Operation with Optional Battery Kit

Used in man-portable and cart portable configurations

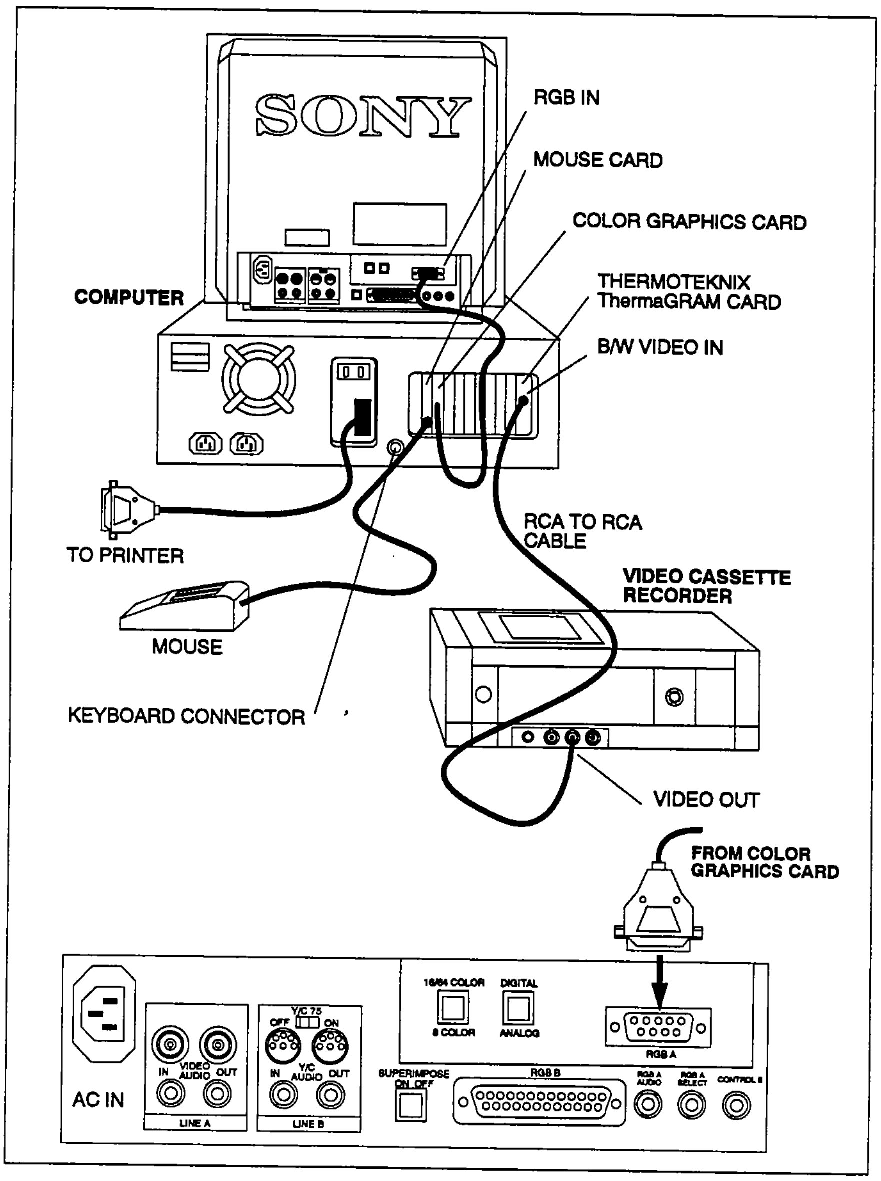


Figure 3-5
Electrical Connections, Playback Analysis

Sony GVM 1300 Monitor

Closeup of GVM 1300 Back Panel

Electrical Connections

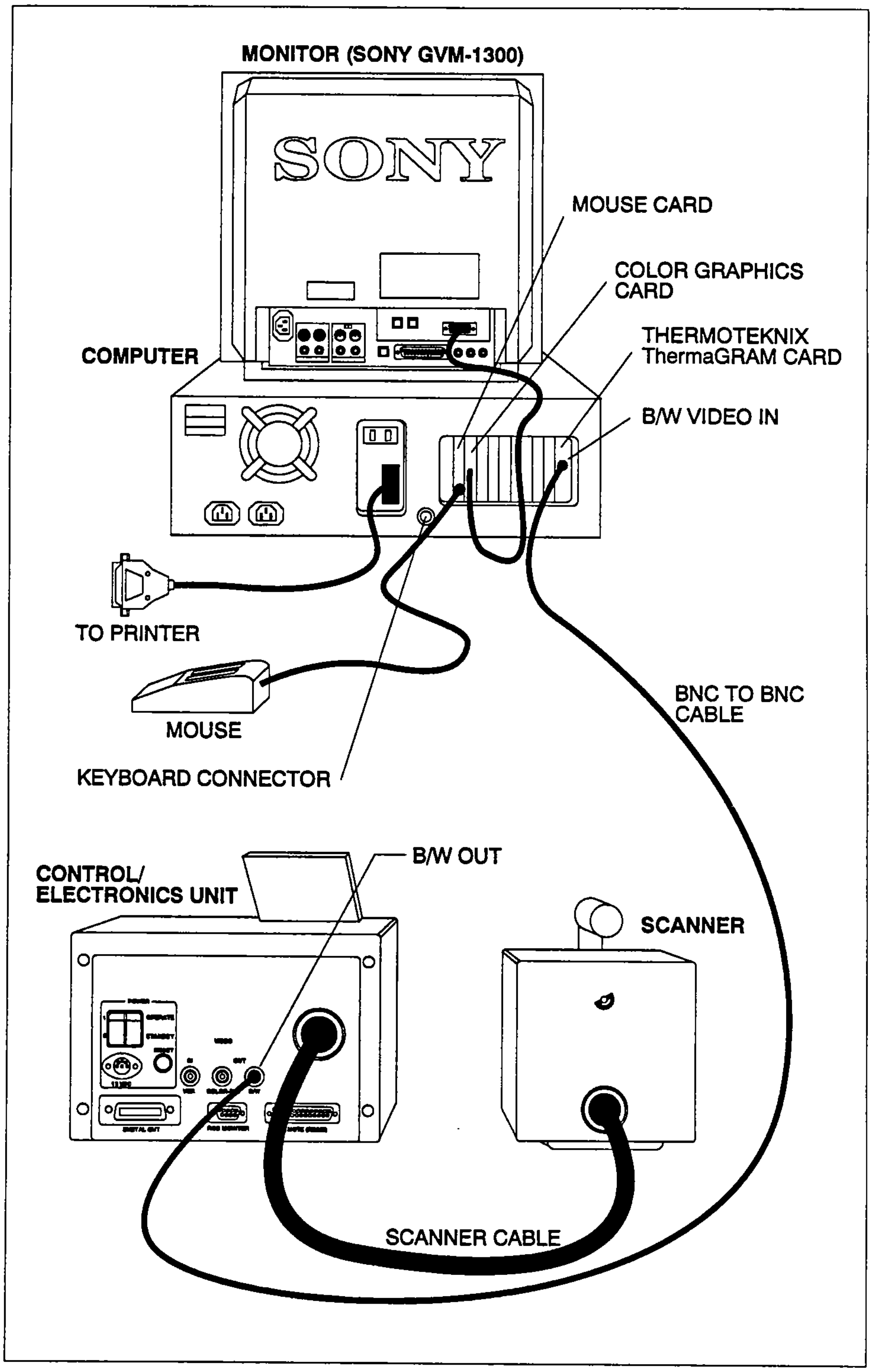


Figure 3-6
Electrical Connections, Real Time Analysis

Mounting the Scanner on a Tripod

3.3

The base of the scanner is drilled and tapped to accept a standard 1/4-20 bolt such as that found on a camera tripod, Figure 3-7. To mount the scanner, set it on the tripod pan head. Screw the bolt into the scanner base finger tight, and tighten the large lock nut. There is also a 3/8-16 thread for mounting on some heavy duty tripods.

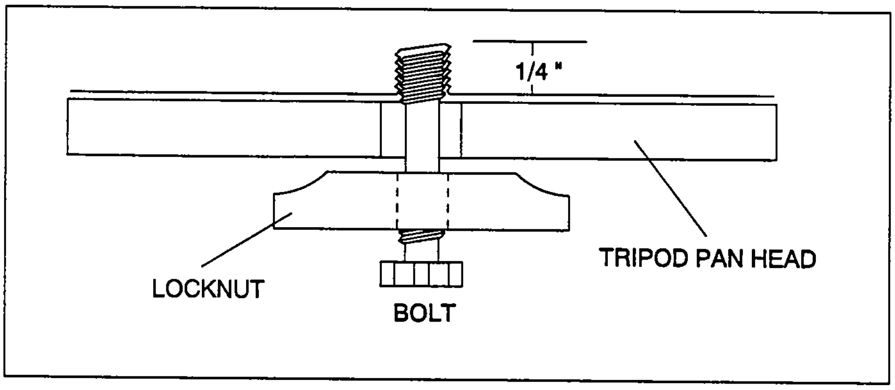


Figure 3-7
Scanner Tripod Mounting

Mounting the Optional Telescopes

3.4

To mount and focus the optional 3X and wide angle telescopes:

1. Remove the 1X telescope by moving the lock lever located on the face plate of the scanner upward to the unlock position while holding the telescope in your other hand. Pull the telescope straight out of the mount.

2. Install the 3X telescope by sliding it straight into the mount with the alignment mark (white line) on the barrel aligned with the alignment mark on the mount. Once in position, move the lever down to lock in place.

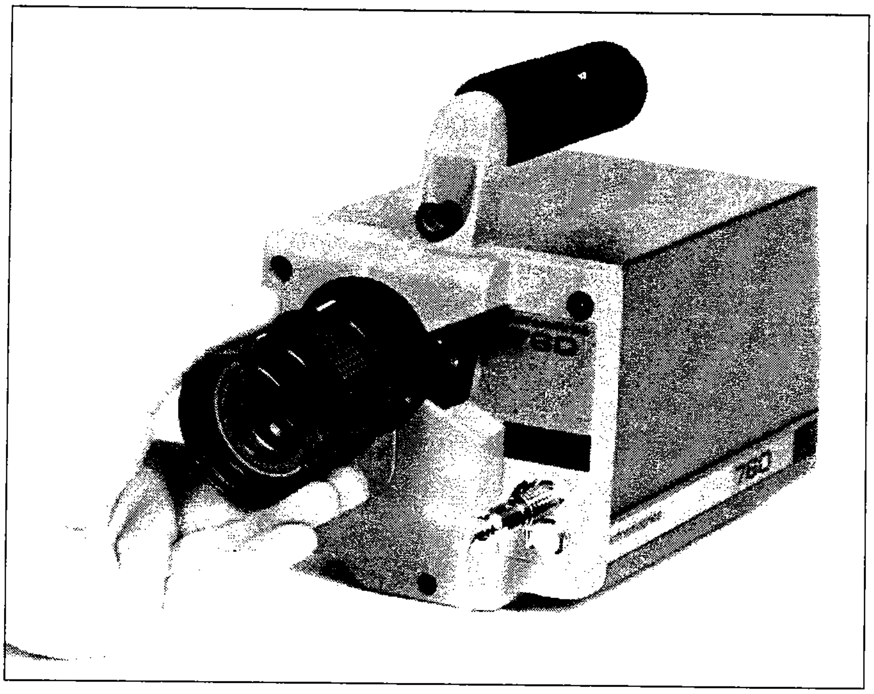


Figure 3-8
Removing and Installing Telescopes

Mounting the External Optics

3. Use the focus ring on the telescope (or the focus control on the panel if your 760 is equipped with the optional remote focus) to focus the telescope.

4. Set the telescope transmission factor to the value marked on the body of the telescope case. This factor is set in the "Measurement Configuration Setup Menu."

<u>Close-up work:</u>

1. Mount the 3X telescope as described above. Turn the knurled focusing ring on the telescope until the scribed line on the barrel is in line with the end of the sleeve it slides into. This is the infinity focus position of the telescope. Focus should be sharp at distances greater than about 30 feet. Minor adjustment of the knurled ring for sharp focus may be necessary.

2. Mount the close-up optics by carefully screwing the close-up lens onto the front of the 3X telescope. Each one of the close-up lenses is rated for a certain working distance from the end of the telescope. System focus is achieved by changing the distance from the end of the lens to the target (this should approximate the rated working distance very closely). Do not attempt to use the remote focus or the knurled ring for focus once the close-up lens is installed.

3. Enter the transmission for the close up optics under EXT OPTICS in the setup menu.

<u>To use the optional 10X or 30X telescopes</u>

1. Remove the 1X telescope by moving the lock lever located on the face plate of the scanner upward to the unlock position while holding the telescope in your hand. Pull the telescope straight out of the mount.

2. Remove the small insert from the front of the scanner unit as shown in Figure 3-9, or the remote focus mechanism if so equipped.

3. Remove the knurled locking screw from the baseplate of the 10X or 30X telescope. Install the knurled locking screw in the tripod mounting hole in the bottom of the scanner.

4. Place the scanner on the baseplate of the telescope. Install the 10X or 30X by sliding it straight into the telescope mount on the scanner, making certain that the knurled locking screw on the scanner bottom locks into the mating keyhole slot in the telescope baseplate.

5. Once the telescope is in position, move the lever down to lock into place. Install the temperature probe by screwing the threaded portion of the probe into the barrel of the telescope and placing the plug into the corresponding jack on the scanner faceplate.

6. Enter the transmission for the 10X or 30X telescope in the setup menu.

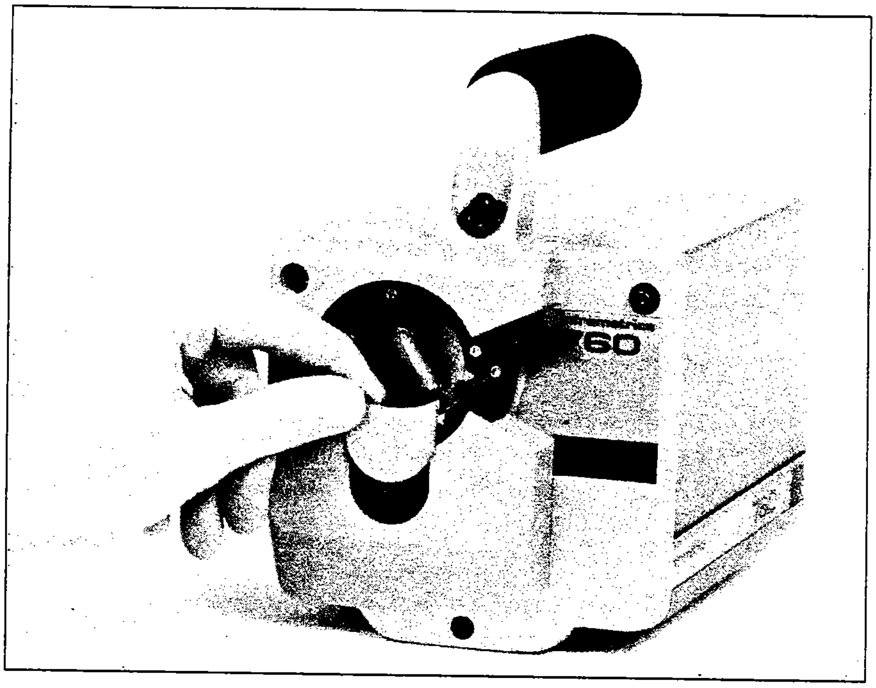


Figure 3-9
Remove Insert From Scanner

To install the remote focus mechanism, first remove the lens. Next remove the small insert from the front of the scanner unit as shown in Figure 3-9. This may take some force since it is a snug fit. Then press the motor unit into the face of the scanner, replacing the removed insert with the similarly shaped end of the motor. Once installed, the focus can be adjusted from the front panel of the control/ electronics unit.

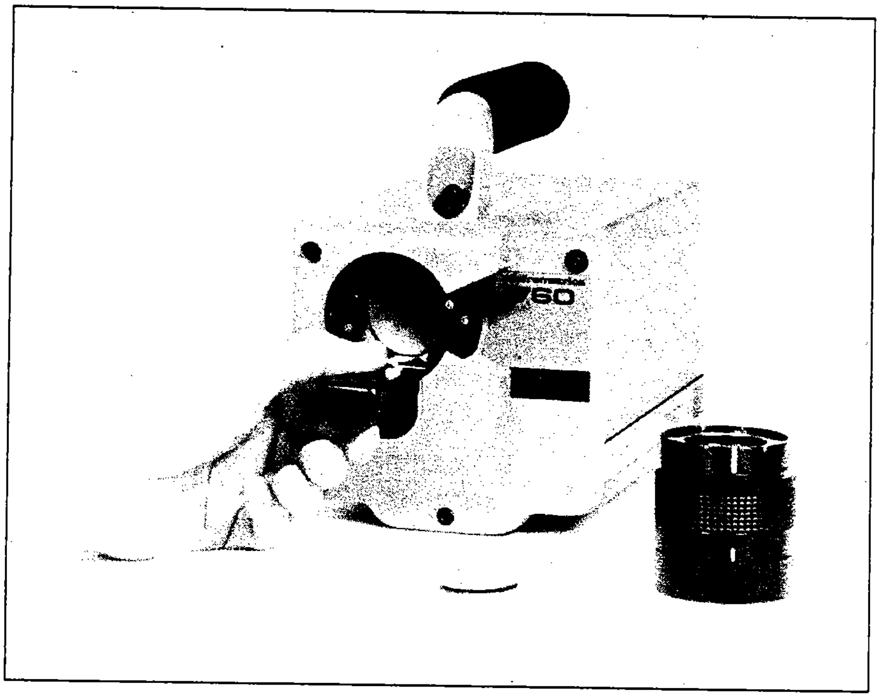


Figure 3-10
Installing the Focus Motor

3.6 Using the Optional Transporter Cart

3.6.1

Assembling the Cart

After unpacking the transporter cart, refer to Figure 3-11:

1. Lay the cart on the floor, raise the frame support vertically, and align the holes in the support and frame near the left tire. Insert the locking pin from inside the frame.

2. Stand the cart upright, loosen the large monopod locknut, and raise the monopod. Tighten the locknut.

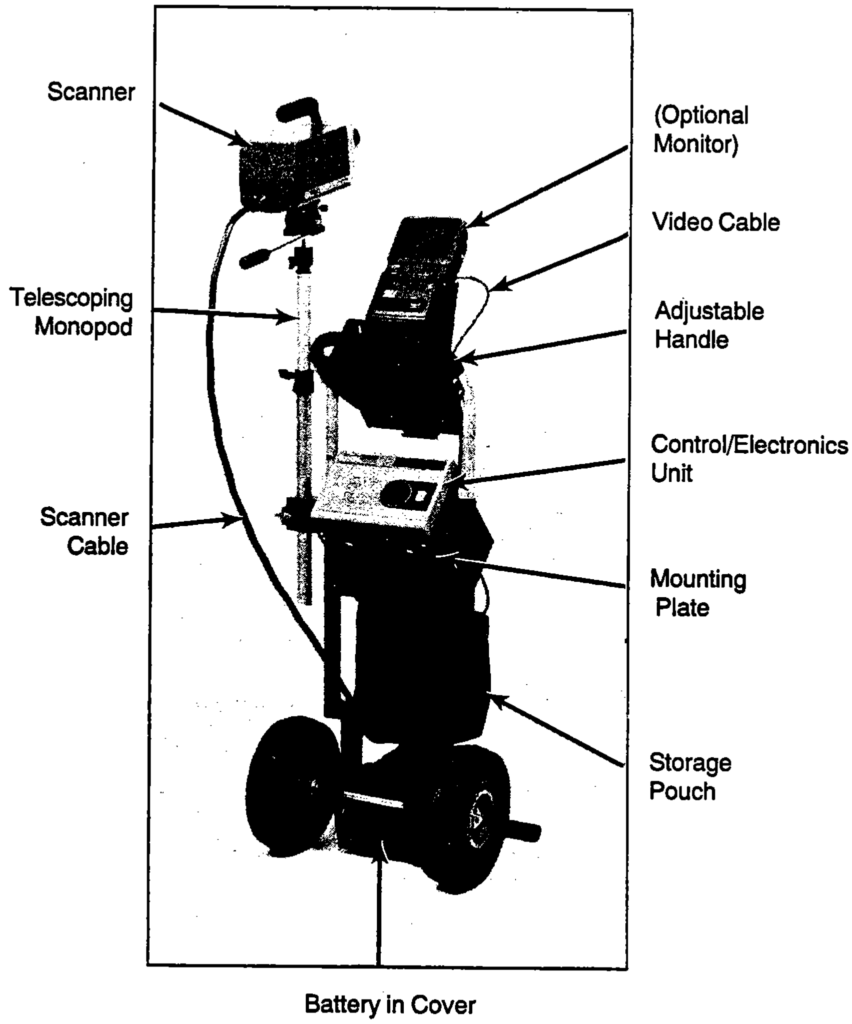


Figure 3-11
Field Transporter Cart with Model 760 and Optional Sony Series Monitor

3.6.2

Charging the Battery

Make sure that the 12-VDC battery is fully charged before transporting the system to the field. Normally, a fully charged battery will operate the system for approximately 4.5 hours. To charge the battery:

NOTE: Fully charge the battery each time to avoid battery damage

1. Insert the charger plug into the battery jack.

2. Plug the charger into a source of 120 VAC, 60 Hz power.

3. Charge the battery for 18 to 24 hours at room temperature (4°C to 30° C). The battery can be charged at temperatures to 50° C but at some loss of efficiency.

3.6.3

Mounting the Components onto Cart

1. Install the battery at the bottom of the frame support with the cable toward the front of the cart.

2. Pull the handle locking pin at the left side of the cart near the scanner monopod, and raise the handle to provide clearance for the control/electronics unit.

3. Snap-lock studs may need to be installed on the bottom of the Control/Electronics unit if not previously installed. Screw in the studs as indicated in the figure below:

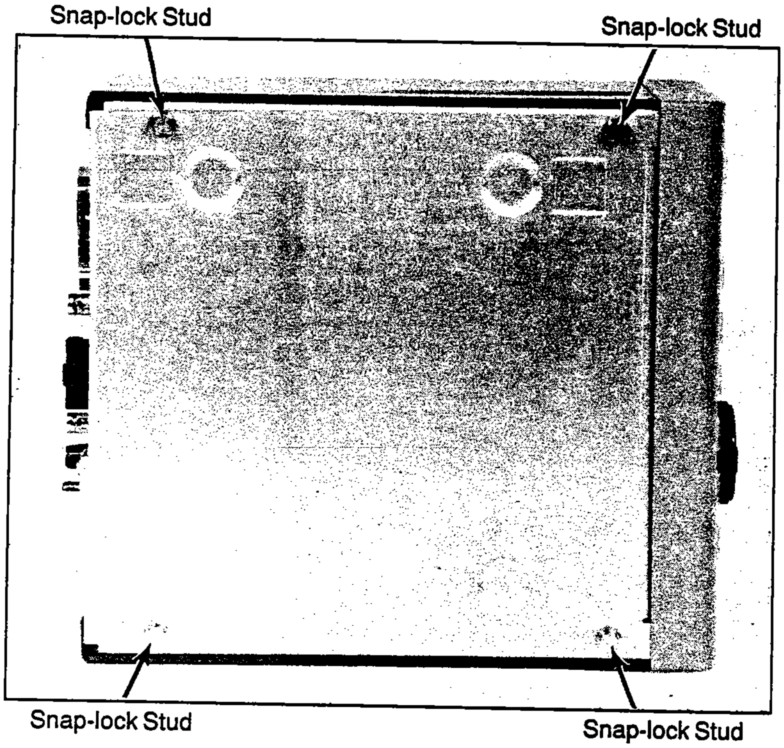


Figure 3-12
Snap-lock Studs

Install studs if not already installed

Once the studs are installed, carefully slide the control/electronics unit onto the shelf on the cart below the handle. Position the unit so that the studs protrude through the four holes in the mounting plate. Push clips to lock studs in place (see figure 3-13).

4. Position the scanner on the monopod pan head, and thread the captive screw in the pan head into the base of the scanner. Tighten the large locknut around the screw (see Figure 3-7). For carts with the new-style pan head, remove the releasable screw from the base. Install the screw in the scanner base, and position the scanner on the monopod. Be sure to pull back the pan head lever to lock the scanner securely to the monopod.

5. Connect the components as shown previously in Figure 3-4 for battery operation.

Using the Optional Transporter Cart

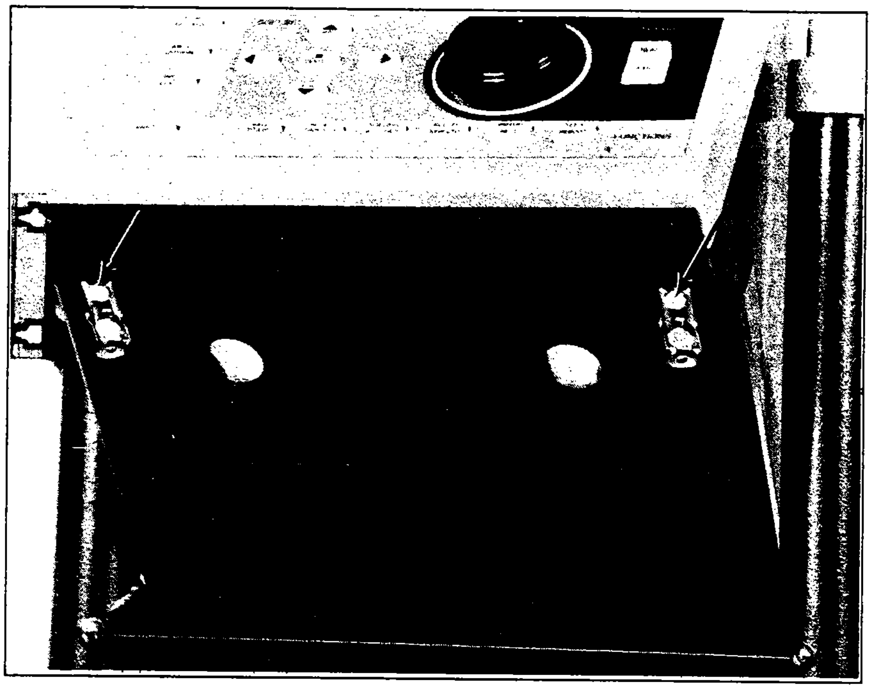


Figure 3-13
Studs Protruding Through Holes in Mounting Plate

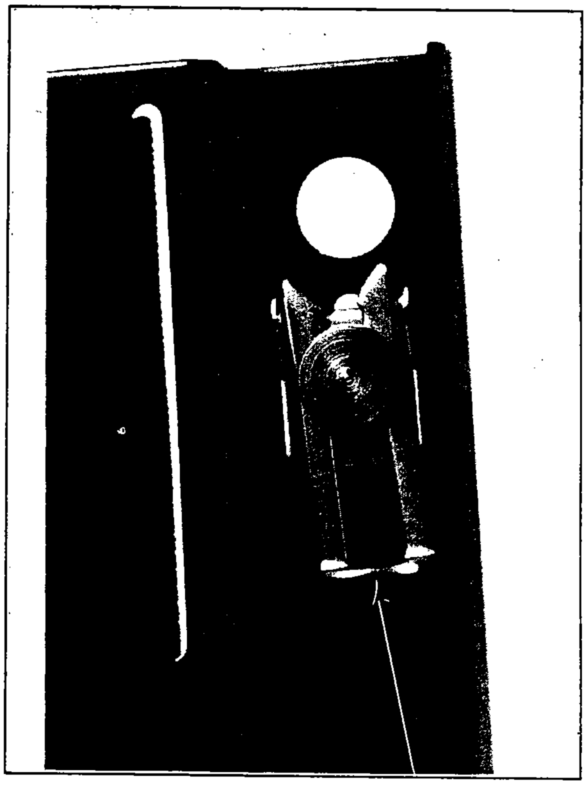


Figure 3-14
Push Clips to Lock Studs in Place

6. Raise the scanner and handle to a comfortable operating height. The handle releases by pulling out the lock pin on the left tube

7. To point the scanner up or down, rotate the monopod head handle counterclockwise to loosen. Be sure to retighten before releasing your grip to avoid the scanner tipping too far. To turn the scanner in the horizontal plane loosen the lock nut at the neck of the monopod head.

The Man-Portability Option allows one to carry the Model 760 system and all needed accessories on a vest for the ultimate in portability (see figure below).

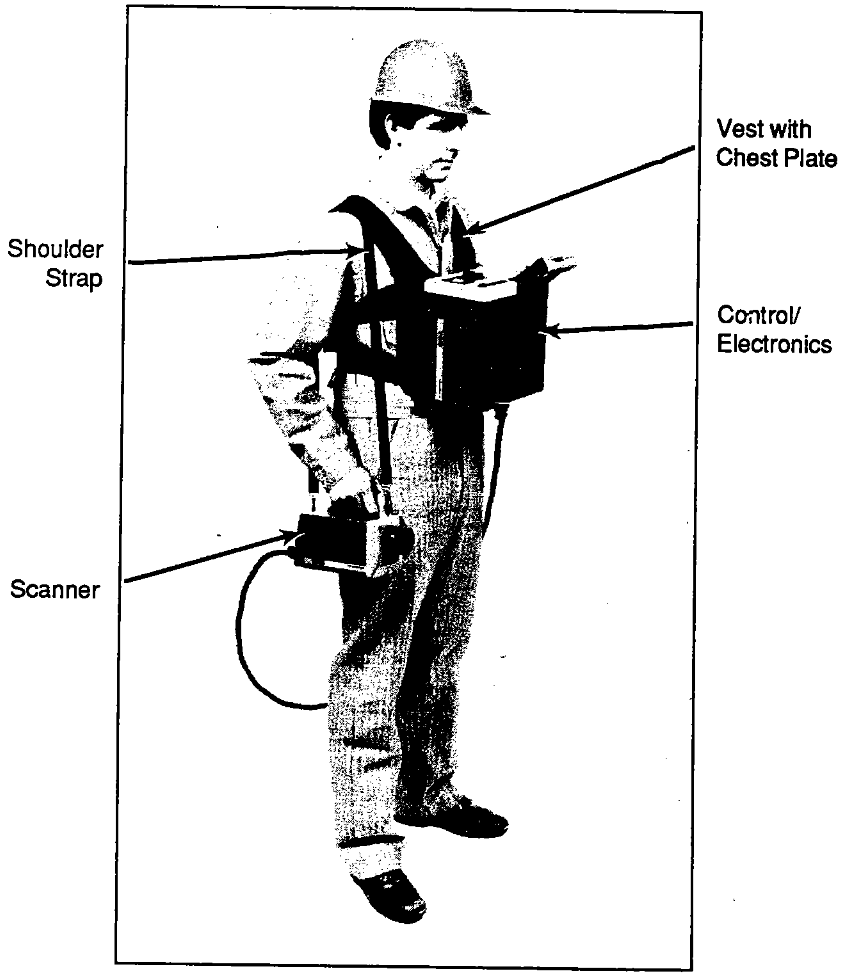


Figure 3-15
760 Man-Portability Option

Only one minor modification is required to the system—the insertion four snap-lock studs for mounting the control/electronics unit on the chest plate.

Components of the Man-Portability Option include:

- System Mounting Vest with Scanner Shoulder Strap
- Two Video Pack Batteries
- Battery Charger

Optional Accessories:

- Canon Xap Shot (still video camera)
- BA-24P Battery Charger (for Xap Shot)
- AVC-25 A/C Coupler (for Xapshot)

Man-Portability Option

The components of the Man-Portability Option fit within the Model 760's system case. The vest fits inside the lid of the case as shown in the figure below.

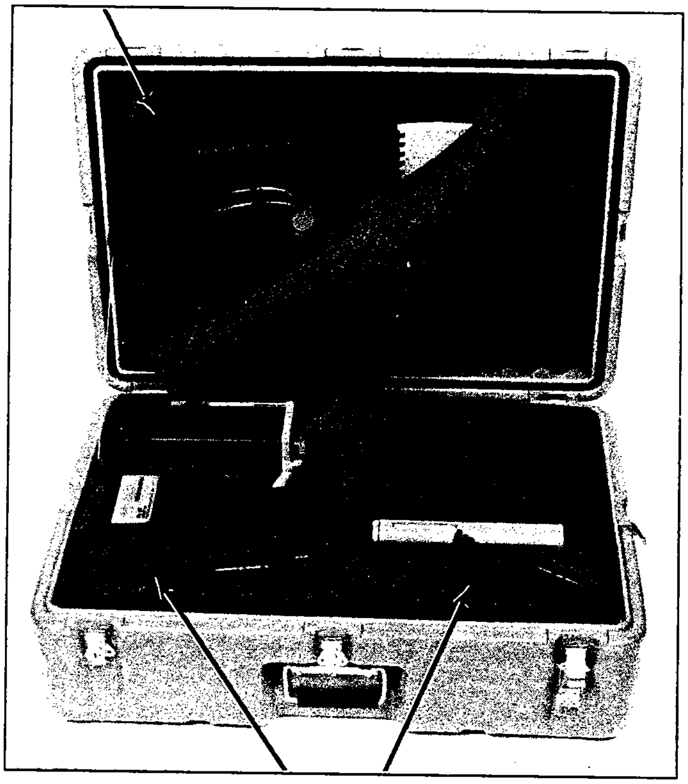


Figure 3-16
Model 760 System Case with Man-Portability Option

Procedure for Assembly of the Man-Portability Option

Use the following procedure for assembling the Man-Portability Option:

1. Make the modification to the control/electronics unit if not already done. Remove the four phillips head screws (see Figure 3-17). Replace them with the four snap-lock studs.

2. Connect one end of the scanner cable to the back of the control/electronics unit and the other to the scanner. Place both units nearyby.

3. Attach the ends of the shoulder strap to the scanner.

4. Attach the back clip of the empty battery pouch onto the back right side of the vest. It is recommended that one attach the back clip now because it can be difficult to attach the clip once the vest is on.

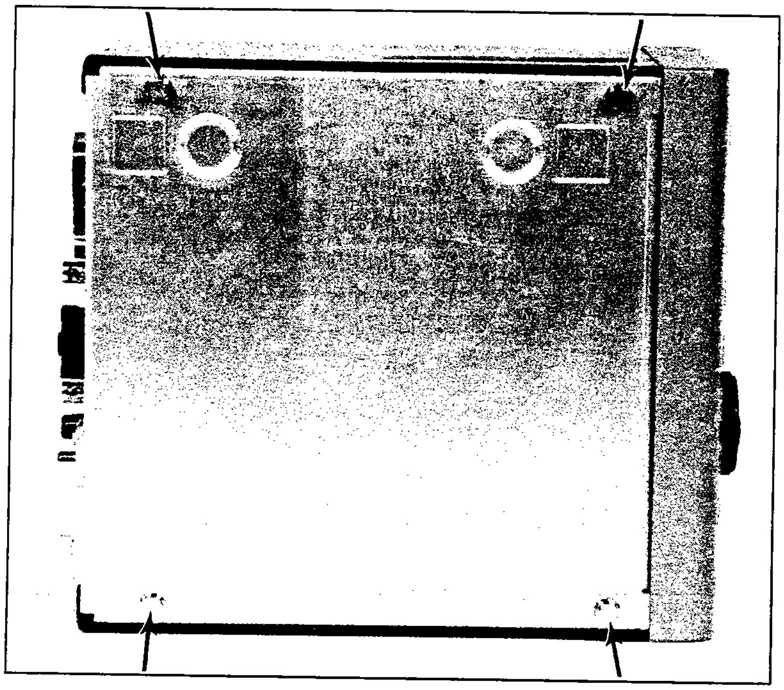


Figure 3-17
Snap-lock Studs

Install studs if not already installed

5. Slip the vest over your head (one size fits all). Then put your arms over the side straps.

Figure 3-18
Pull Vest Over Head

6. Buckle the side strap(s) as shown in Figure 3-19.

Figure 3-19
Buckle Side Straps-

7. Pull the straps on either side until the vest fits snugly (see Figure 3-20). It is important that the vest is tightened in this manner so that the system is held snugly against the chest.

Figure 3-20
Pull Ends Tight

8. Holding the free buckle, attach the video pack pouch to the vest (see Figure 3-21). Place a charged video pack battery into the pouch.

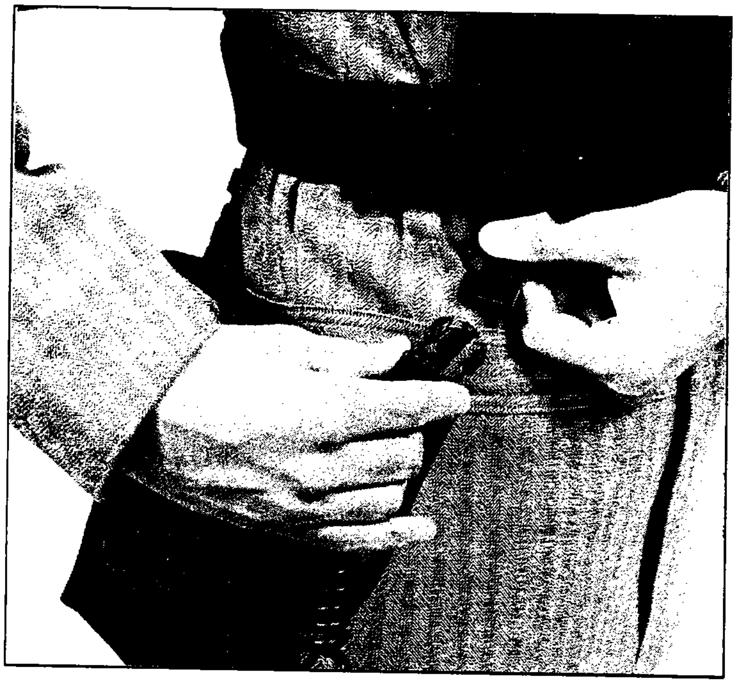


Figure 3-21
Attaching the Battery

The back clip was attached before the vest was put on

9. Attach the control/electronics unit to the chest plate on the front of the harness. The snap-lock studs fit into the four holes in the chest plate. Push the sliding fasteners over the ends of the studs protruding through the plate (see Figures 3-22 to 3-24).

Figure 3-22
Attaching the Control/ Electronics Unit to the Chest Plate

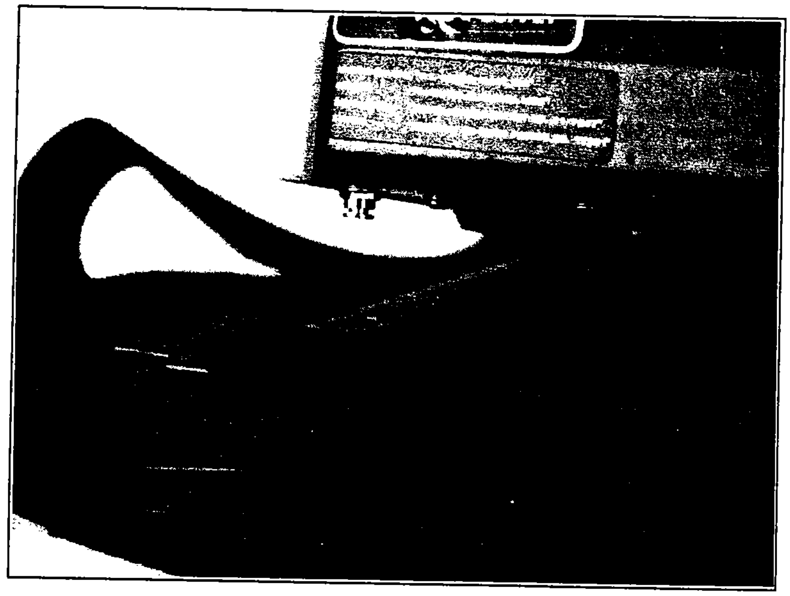
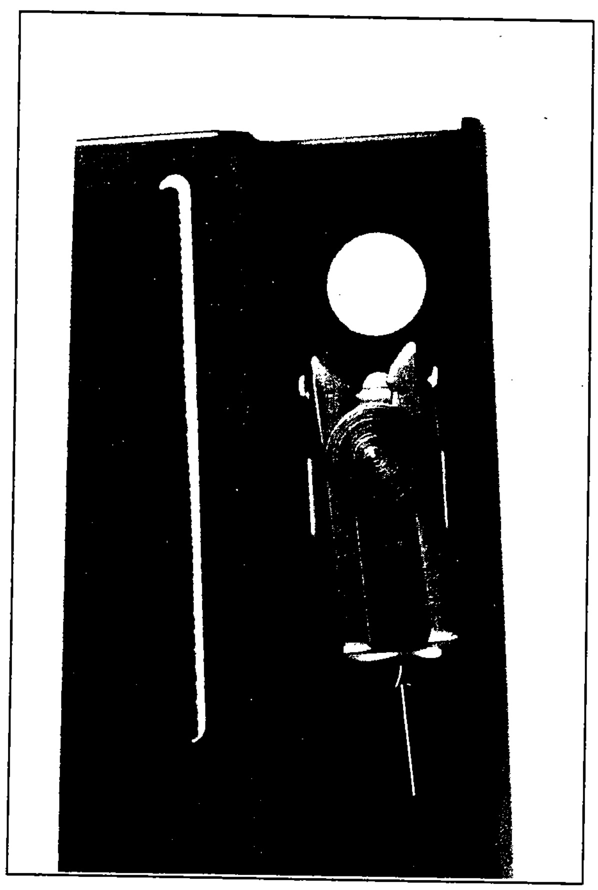


Figure 3-23
Placing the Snap-Lock Stud in Place



Push fastener up to secure

Figure 3-24
Fastener for Snap-Lock Stud

10. Once in place, the unit should be firm against the chest. If not, tighten the straps once again. For a neater look, place the loose ends of the straps into your pant pockets.

11. Pick up the scanner by the shoulder strap and place on left shoulder. Use the hook and loop fabric on the underside of the strap to secure the strap to the shoulder of the vest.

12. Connect the 12V cable from the video pack battery to the cable from the control/electronics unit.

13. Turn the system on using the power switch on the bottom of the control/ electronics unit. This completes assembly of the Man-Portability Package.

Figure 3-25
Man-Portability Option
Fully Assembled

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4.1.1

Power Switch Settings for Standby and Operate

The Model 760 has two power switches located on the rear panel, one red (on the left hand side) and the other gray (on the right hand side). The red switch is the main power switch. If it is placed in the OFF (0) position, the Model 760 will not receive power, and the position of the gray switch has no effect. Once the red power switch is turned to the ON (1) position, the mode designated by the gray switch setting will be in effect.

With the red switch ON, if the gray switch is set in the STANDBY position, power will only be applied to the cryocooler. The STANDBY mode is indicated by a red LED, illuminating the SHIFT key, over the word "STANDBY" on the front panel. If the Model 760 is powered on in this mode, it will take several minutes for the cooler to reach operating temperature. This will be transparent to the user because the rest of the system will remain off. If the Model 760 is placed in this mode from the OPERATE position, the cooler temperature will be maintained while the rest of the system will be powered down, as if it were turned completely off. This mode is used to conserve power for applications requiring battery operation that involve long interruptions during test sequences.

With the red switch ON, if the gray switch is set in the OPERATE position, power will be applied to the entire unit. If the Model 760 is powered on in this mode, it will take several minutes for the cooler to reach operating temperature. Therefore, if any of the operating modes are entered directly after initialization, the monitor will appear white until the cooler operating temperature is obtained. If the Model 760 is placed in this mode from the STANDBY position (assuming the cooler has reached operating temperature), and any of the operating modes are entered directly after initialization, the monitor will show the infrared image immediately.

4.1.2

System Initialization

Turn the gray power switch on the rear panel of the Model 760 to OPERATE and the red power switch to ON (1). When cycling power (turning the unit off, then on again), always wait a minimum of 10 seconds. A grey-scale test pattern will be displayed as shown in Figure 4-1 with a ten-increment grey scale across the bottom of the screen. Adjust the monitor's brightness and contrast controls so that each increment in the grey scale is distinguishable. The system requires approximately 15 seconds to initialize (with a disk in the disk drive), and several minutes for the cryocooler to reach operating temperature from a cold start. The message "PERFORMING SYSTEM DIAGNOSTICS AND SOFTWARE UPGRADE CHECK" will be displayed for approximately 10 seconds.

The line at the top of the screen (Figure 4-2) contains the date, the Inframetrics name, the system wavelength and the time. The internal clock is maintained by a battery for a minimum of one year. Below this line is the area in which warning messages may be displayed. Warning messages indicate that temperature measurements may not be valid. The system is not damaged under these operating conditions.

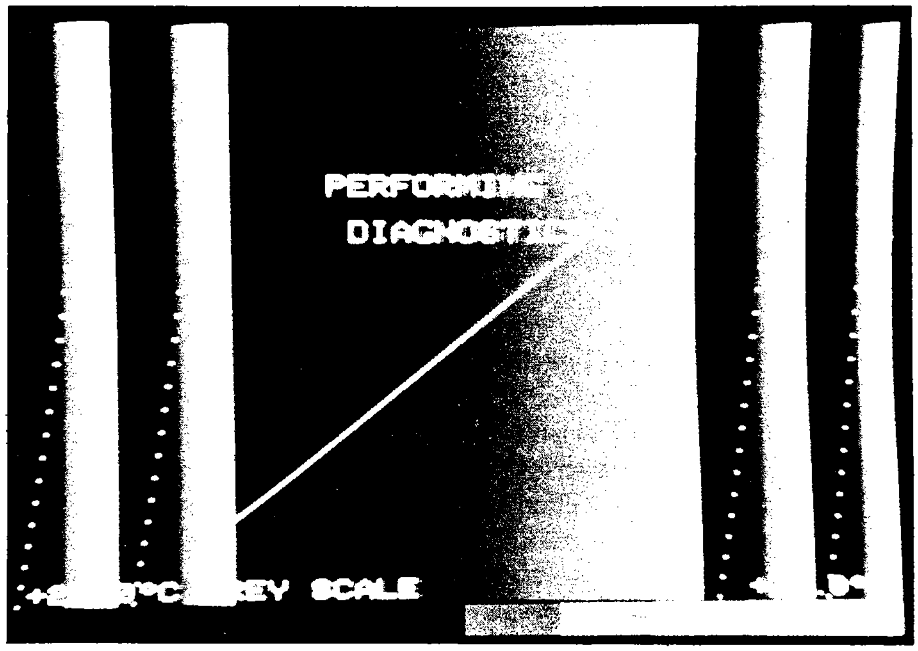


Figure 4-1
Grey Scale Test Pattern on Power-up

(Maintenance due message will appear one year from last calibration date in center of screen)

Above the grey scale is a line containing system status information such as the minimum and maximum displayed temperatures, current operating mode, and secondary system parameters which are displayed sequentially and updated every 1.5 seconds. The specific parameters displayed are listed in the table under Sequential Display.

Fixed display regions contain information about the status of the system:

mo/day/yr Name hr:min:sec

Minimum displayed temperature | Mode | Sequential status | Maximum displayed temperature

Figure 4-2
Fixed Display

A "Maintenance Due" message appears one year from last calibration date. However, if the date is inadvertently set greater than a year after calibration, the message will appear.

The current MINIMUM and MAXIMUM DISPLAYED TEMPERATURES are displayed at the lower left and right sides of the screen respectively. These are adjusted by the Temperature Span keys and Center Temperature control. Celsius, Fahrenheit, or Level units may be selected in the setup menus.

A MODE-SPECIFIC MESSAGE is shown to the right of the Minimum Temperature. This may display a cursor (CRS) or isotherm (ISO) temperature, line number, or other parameter of significance in the current operating mode.

The sequential display area, Figure 4-3, a part of the system status information line above the grey scale, is updated every 1.5 seconds and displays system parameters together with the function which sets the parameters listed in Table 4-1.

Several of these parameters are adjusted by various keys during normal system operation. Others are set only from one of the SETUP menus which will be described later.

Figure 4-3
Sequential Display

A new message is displayed each 1.5 seconds...

Table 4-1
Status Information Displays

Sequential Status Parameter	Set By
BATT = 11.7 VOLTS	N/A
EL TIME: 00:42	N/A
OPEN NORM	Measurement Configuration Setup Menu
FOV = 25H: 25V	SOFT-SET Keys
SCNR = +27.5° C	N/A
EMISSIVITY = 1.0	Measurement Configuration Setup Menu
CTR T = +31.5° C	Center Temperature Control
IMAG AVG = OFF	Processing Parameters Setup Menu
COLOR DISPLAY	N/A
1X TELESCOPE	Measurement Configuration Setup Menu
CTR LVL = 03453	N/A
BACKGROUND TEMP	Measurement Configuration Setup Menu
SPAN = 10°C	SPAN Keys
TELE = +20.5 C	Telescope temperature probe
EX OP = +12.5C	External optic temperature probe

4.2 Operating Modes

The Model 760 features seven primary operating modes and an eighth auxiliary mode selected from a menu: Image, Color, Point, Averager, Area, Isotherm, Line, and Aux. Parameters which affect the calibration of the system (emissivity, background temperature, and filter selected) together with secondary system functions are adjusted from one of four SETUP menus as described under Setup Menus.

The first operating mode selected will change the stepped grey scale (the scale used to adjust by the monitor brightness and contrast controls during startup) to a calibrated, continuous grey scale with the end points corresponding to the minimum and maximum displayed temperatures.

Note that many of the operations and key functions described for the Image Mode are identical for other operating modes.

4.2.1 Image Mode

NOTE: If the Image Mode is selected immediately upon startup, the monitor screen will remain white for several minutes, while the cryocooler reaches operating temperature.

The Image Mode, Figure 4-4, is the basic operating mode of the Model 760 and is selected by pressing the IMAGE key. In this mode, the SOFT-SET keys adjust the field-of-view (FOV) parameters. The functions of these keys can be displayed by pressing the HELP key (shift and Help). Pressing the HELP key a second time (or pressing any other key) will remove the HELP message. When FOV adjustments are made (in any operating mode), the horizontal and vertical FOVs will be displayed immediately as percentages in the sequential display area.

The MIN/MAX SOFT-SET keys decrease and increase the FOVs (horizontal and vertical simultaneously) respectively. The RIGHT/LEFT SOFT-SET keys increase and decrease the horizontal FOV without altering the vertical FOV. The center key sets the vertical FOV equal to the horizontal FOV thereby restoring the normal 3:4 aspect ratio. Pressing the shift key and the SOFT-SET keys instantly sets a minimum or maximum, horizontal or vertical FOV value depending upon the key pressed. For example, pushing shift and then the MAX key results in the maximum vertical FOV.

Rotating the CENTER TEMP control clockwise increases the temperature corresponding to the mid-grey intensity level in the image. This darkens the image (with polarity set to WHITE=HOT), and shows detail in the hotter target areas. Rotating the control counterclockwise decreases the center displayed temperatures thereby lightening the image. The focus keys (if remote focus is ordered) are used to bring the displayed object of interest into focus (in all modes except Integrated Line Scan).

The Temperature Span keys select the full-scale sensitivity of the image. Two ranges are selectable; NORMAL range allows maximum sensitivity for equivalent target temperatures to 400° C. EXTENDED range reduces the sensitivity to allow imaging of targets up to equivalent temperatures of 1500° C. Extended range is accessed in the "Measurement Configuration Setup Menu."

RANGE	CENTER TEMPERATURE	SPAN
Normal	-20 to +400° C	2, 5, 10, 20, 50, 100
Extended	20 to +1500 °C	20, 50,100, 200, 500, 1000

Table 4-2
Temperature Span Values for Normal and Extended Ranges

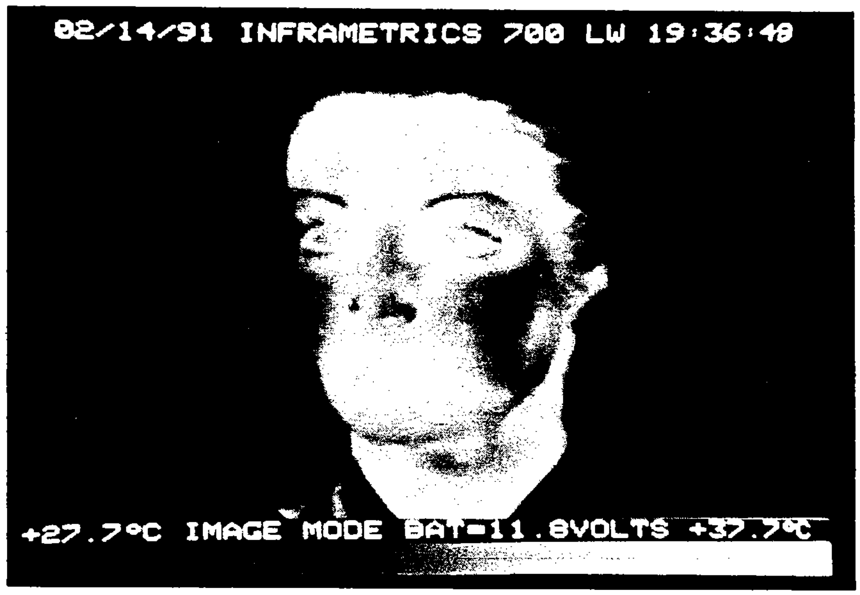
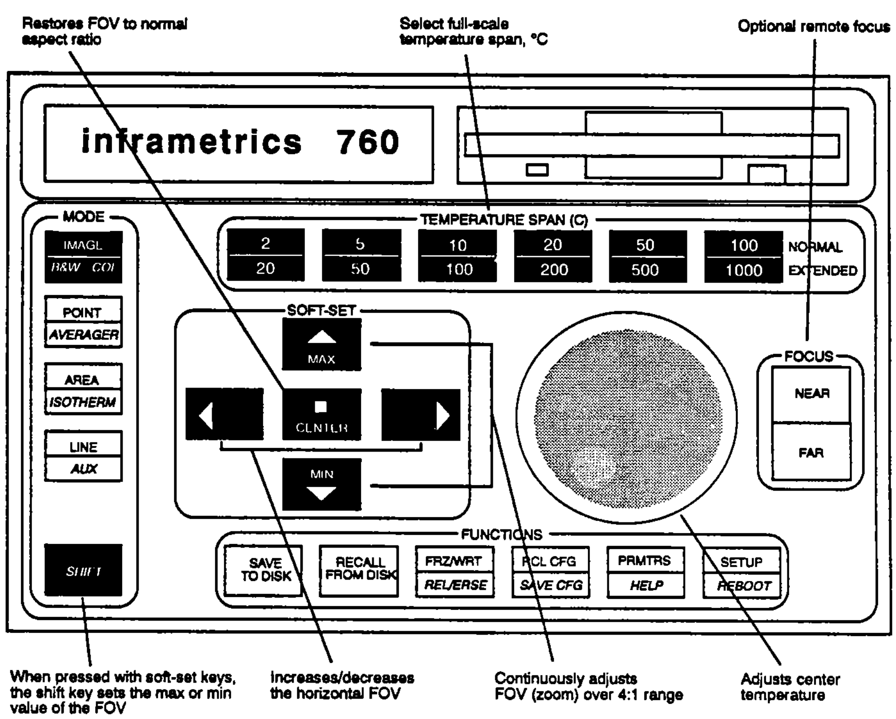


Figure 4-4
Image Mode

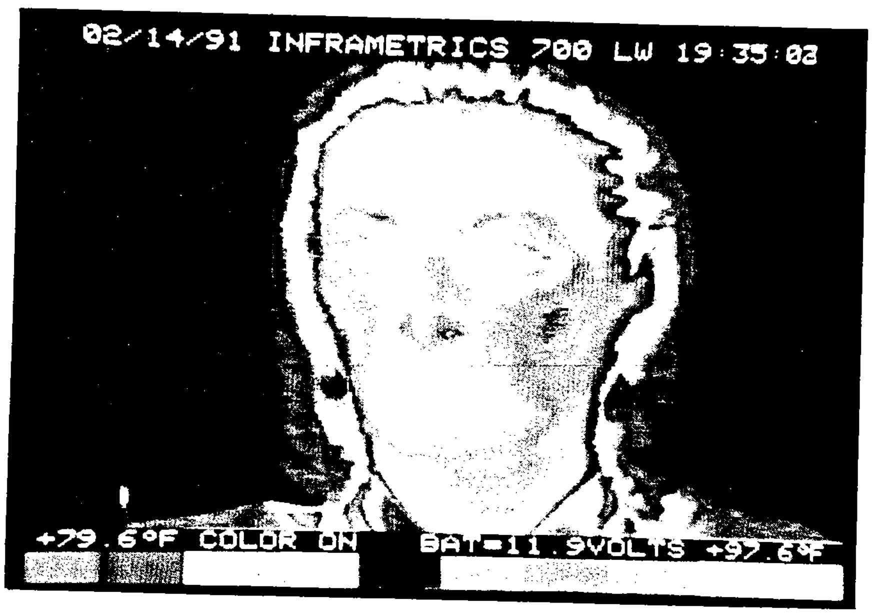


Press Image Key to activate Image Mode

4.2.2

Color Mode

Color can be enabled for any mode of operation by pressing the IMAGE/COLOR (MODE) key while the SHIFT key is depressed, Figure 4-5. Its selection sends a color image to the integral LCD display and the Color-B/W BNC video output.



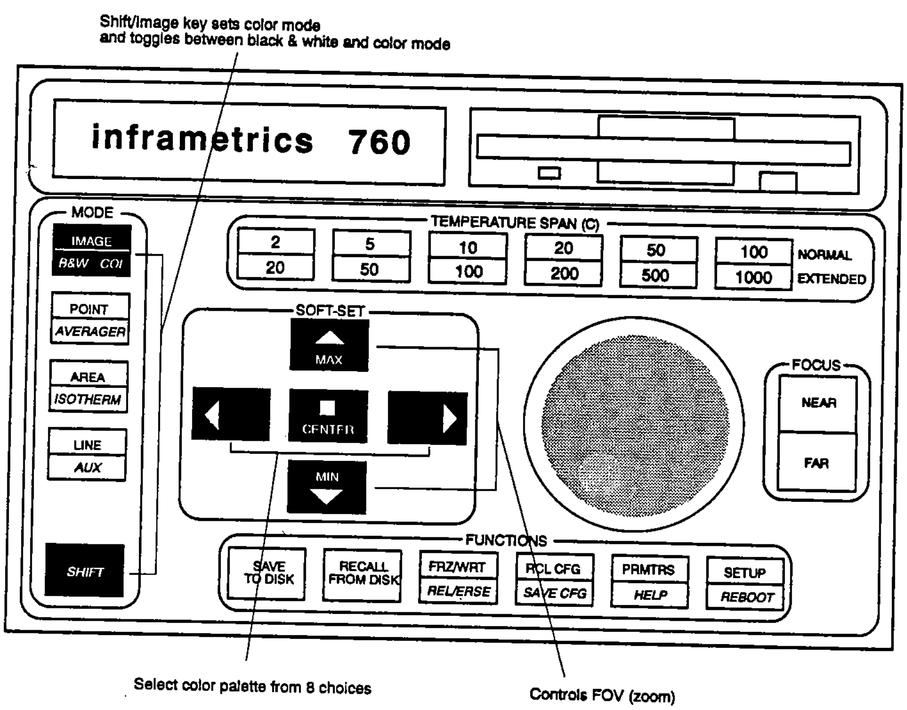


Figure 4-5
Color Mode

Select different color palettes using the left/right SOFT-SET keys

When in the color mode, the LEFT/RIGHT SOFT-SET keys select one of nine color palettes. If color has been enabled and another mode of operation is selected, the palette can be set from the second SETUP menu.

The MIN/MAX SOFT-SET keys adjust the FOVs as described for the IMAGE Mode. The other keys also function as described for the IMAGE Mode.

Eight color palettes, each containing between 6 and 20 colors, are available together with a special color plus black-and-white palette, Table 4-3. The palettes are listed below by number as selected by using either the Setup mode or the SOFT-SET keys in the Color mode.

Table 4-3
Color Palettes

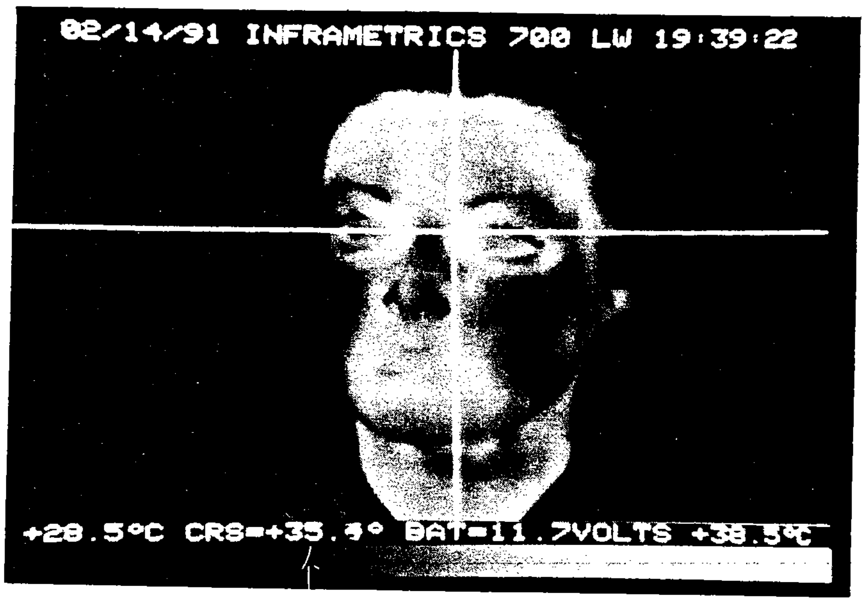
Palette Number	Display
0	10 Color Rainbow
1	20 Color Rainbow
2	256 Color Graded Rainbow
3	256 Color Modified Graded Rainbow
4	Ironbow
5	GLObow
6	10 Color Contour with Black Dividers
7	10 Color Medical
8	2 Color plus B/W; Saturation Detection (Data Acquire Mode)

4.2.3 Point Mode

In the Point Mode, Figure 4-6, vertical and horizontal cursors appear in the image. The temperature at the intersection of the cursors is displayed in the STATUS line.

The position of the vertical cursor is controlled by the LEFT/RIGHT SOFT-SET keys, and the position of the horizontal cursor by the MIN/MAX SOFT-SET keys as shown in the illustration. Note that the position of the cursors is maintained even when the mode is exited. This permits the user to adjust system parameters from the SETUP menus or to enter a mode in which the FOV can be altered and then re-enter the Point Mode without having to reposition the cursors. The SOFT-SET center key resets both cursors to the center position. The SHIFT key and an arrow key move the appropriate cursor to the edge of the screen.

Point measurements are smoothed by an exponential averaging algorithm to improve stability, and approximately 5 seconds are required for readings to stabilize after a change. The use of the Auto-Center Temperature feature is applicable for this mode (refer to SETUP menu, "Processing Parameters").



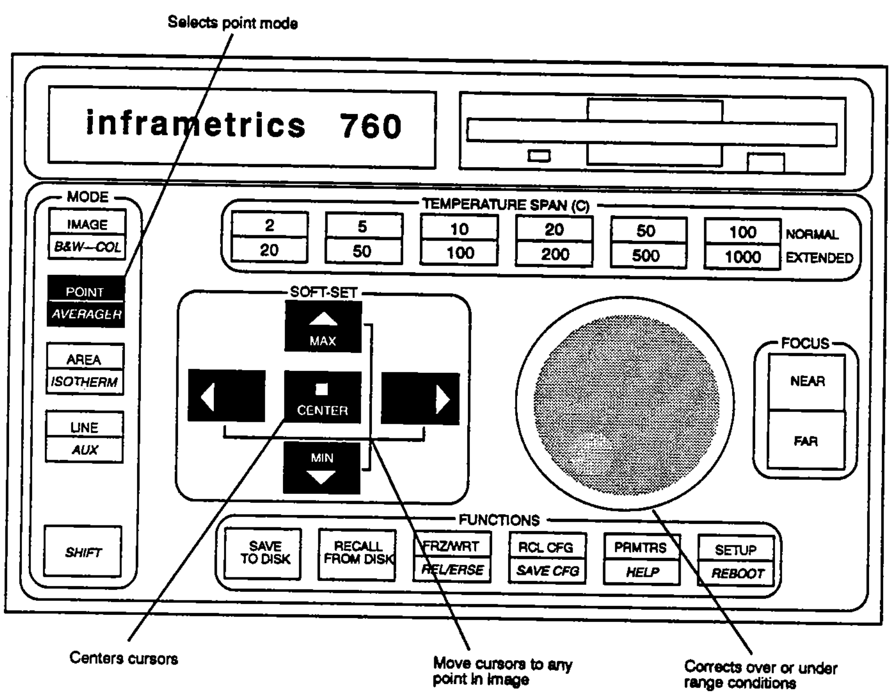


Figure 4-6
Point Mode

Temperature at the intersection of the cursors is displayed continuously

(under and over-range temperatures are indicated)

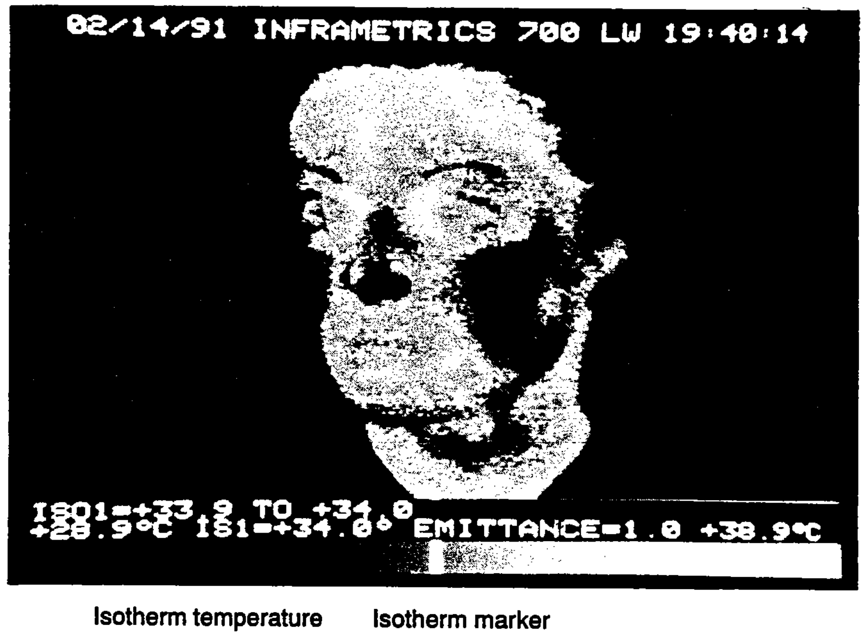
4.2.4

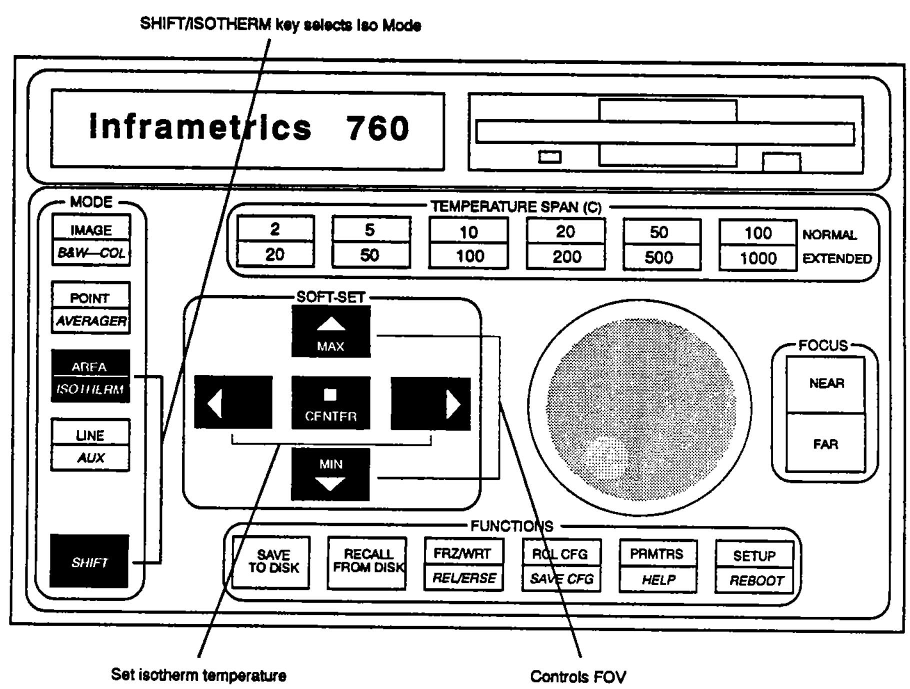
Isotherm Mode

In the Isotherm Mode, Figure 4-7, an isotherm marker appears in the grey scale.

Figure 4-7
Isotherm Mode

All objects in image at isotherm temperature are highlighted





To activate isotherm and dual isotherm mode:

1. Press the *SHIFT* and the AREA/*ISOTHERM* mode keys. The single isotherm display shown in Figure 4-7 will appear. In single isotherm mode, a single, isotherm marker appears in the grey scale. Its position is controlled by the LEFT/ RIGHT SOFT-SET keys. Each pixel in the image that is at the same grey scale level as that of the isotherm marker will be intensified. The temperature corresponding to the isotherm marker is displayed in the STATUS line. The position of the isotherm marker is maintained even when the mode is exited. The CENTER SOFT-SET key resets the marker to the center position of the grey scale.

2. Press the *SHIFT* and the AREA/*ISOTHERM* mode keys again.The dual isotherm display is shown in Figure 4-8. In dual isotherm, a second isotherm marker appears.

To vary the width of ISO1 and ISO2:

1. Press the *SHIFT* and the AREA/*ISOTHERM* mode keys again. ISO1 is activated.

2. Press the up-arrow SOFT-SET key. The marker widens.

3. Press the down-arrow SOFT-SET key. The marker narrows.

4. Press the *SHIFT* and the AREA/*ISOTHERM* mode keys again. Now the ISO2 marker is activated. The up and down arrow SOFT-SET keys work similarly.

Isotherm measurements are most accurate when the ISO cursor is near the center of the display range (grey scale)

In all of the isotherm displays, if the video level of interest is white or near-white, the intensified pixels will be difficult to see. However, they can be made readily apparent by switching the image polarity from white hot to black hot.

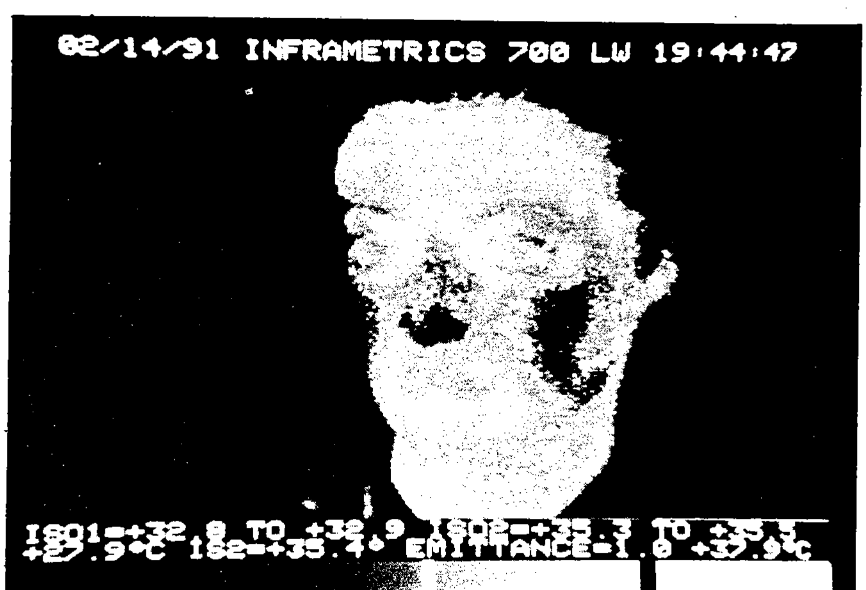


Figure 4-8
Dual Isotherm Mode

4.2.5

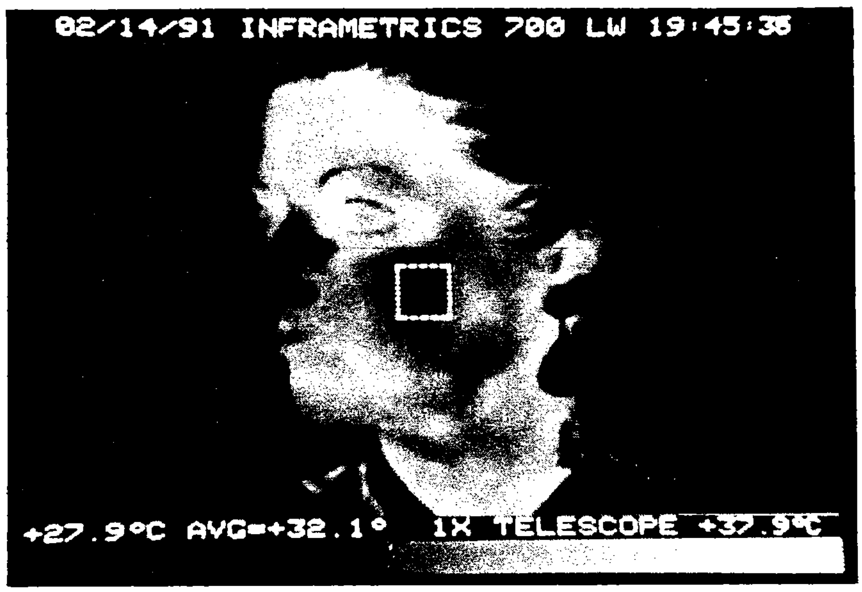
Area/Area Define Modes

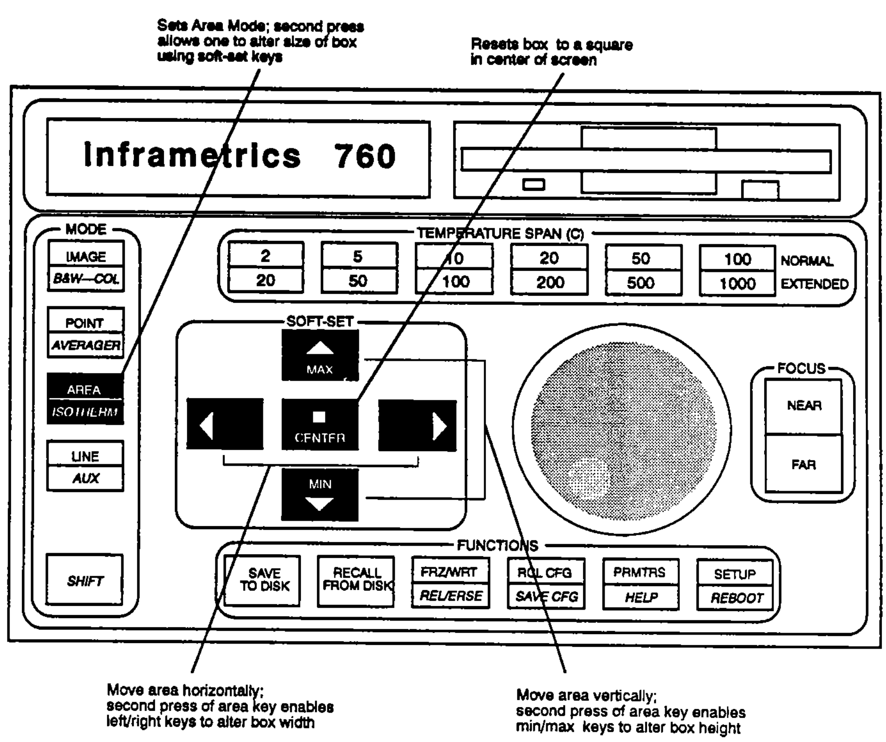
In the Area Measurement Mode, the average temperature within a rectangular box in the image may be obtained, Figure 4-9. The box is square and centered when the system is first powered up. The location of the box is controlled with the SOFT-SET keys as shown in the figure. The vertical arrows move the box up and down and the horizontal keys move it from side to side.

By pressing the AREA key again, the box size can be altered in the DEFINE AREA mode using the SOFT-SET keys. The MIN/MAX arrow keys increase or decrease the box height and the LEFT/RIGHT keys correspondingly change its width.

Figure 4-9
Area Mode

Area of user-defined height and width may be moved throughout image





Pressing the center key will return the box to the default size and position. Pressing the AREA key again will return control to the AREA mode from DEFINE AREA mode.

Whenever a system parameter (span, center temperature, rectangle location, etc.) is changed, the acquisition of temperature data from the rectangle is re-initialized as indicated by the clearing of the temperature readout area in the STATUS line.

Line Select Mode 4.2.6

The LINE key permits switching between the Line Select and Line Scan Modes of operation. In the Line Select Mode, Figure 4-10, a horizontal cursor, accessed by pressing the LINE key once, appears in the image region and represents the location of the thermal profile displayed in the Line Scan Mode. The position of the cursor is controlled by the MIN/MAX SOFT-SET keys and the FOV by the LEFT/RIGHT keys. The cursor is reset to the center by pressing the CENTER SOFT-SET key. The line number selected is displayed in the STATUS line.

Note: To increase the usable image area to the maximum size, turn blanking off in the setup menu.

Line Scan Mode 4.2.7

From the Line Select Mode, the Line Scan Mode is enabled by pressing the LINE key again. In the Line Scan Mode, Figure 4-11, the image is blanked, and a horizontal cursor representing temperature is displayed. The position of the cursor is controlled by the MIN/MAX SOFT-SET keys, and its value in degrees is displayed in the STATUS line. The intersection of the cursor and the scan line represents the temperature at that point of the scan. A labeled temperature axis may be written anywhere on the screen by pressing the FRZ/WRT key and erased by pressing the REL/ERSE key.

Once an axis has been written, the center temperature may no longer be adjusted. The axes are maintained as long as the Line Select or Line Scan Mode is not exited. The center temperature of the display may be changed in the Line Select Mode, but it must be noted that the temperature on each axis written will be changed accordingly when Line Scan is reselected. The position of the temperature cursor is not altered when the mode is exited. It is reset to the center by pressing the CENTER SOFT-SET key. The default mode of operation for Line Scan is Integration ON and may be altered from the SETUP menu (to Integration OFF). The FOCUS function operates in the Line Scan Mode only in the Integration OFF mode.

In the Line Scan Mode, the LEFT/RIGHT SOFT SET keys alter the line selected (the line will be displayed in the sequential display area as it is being altered). The new line selected will be shown when the Line Select Mode is re-entered. Moving the scanned line while viewing the graph is useful for finding the peaks of small targets.

Exponential integration of Line Scan data is performed automatically to smooth the Line scan display. Integration is disabled whenever a control adjustment is made, and is re-enabled five seconds later. The integration time constant is selected automatically to provide the appropriate amount of smoothing (noise reduction) for the temperature range in use.

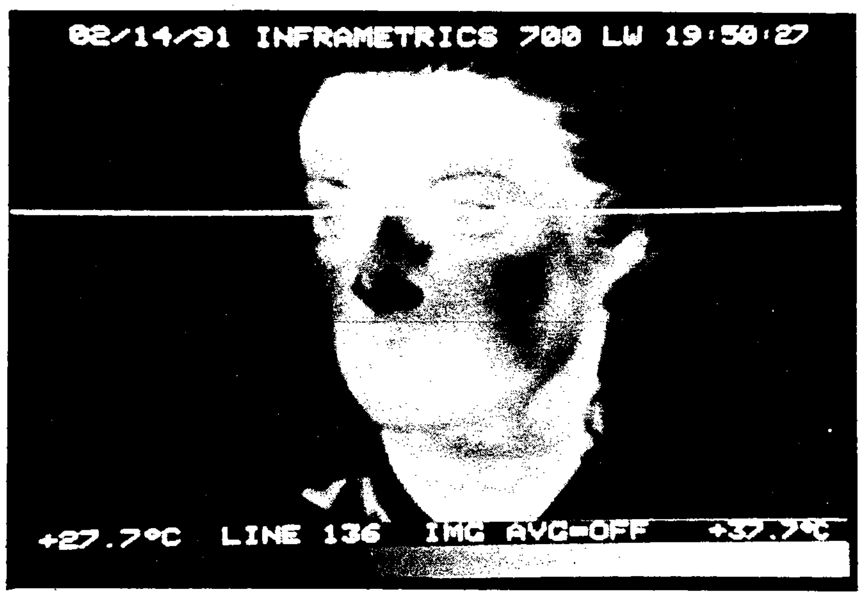
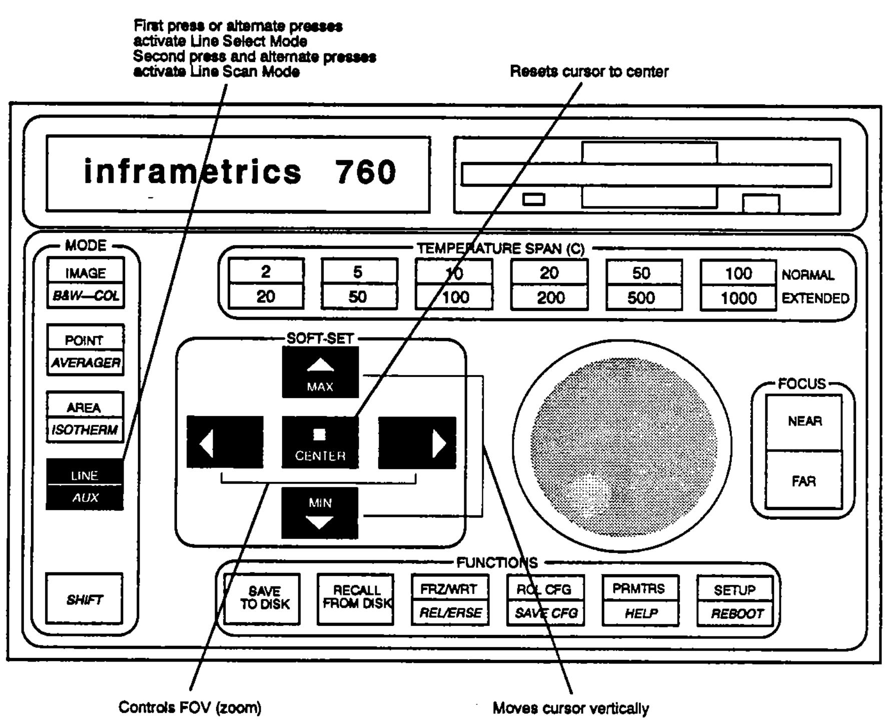
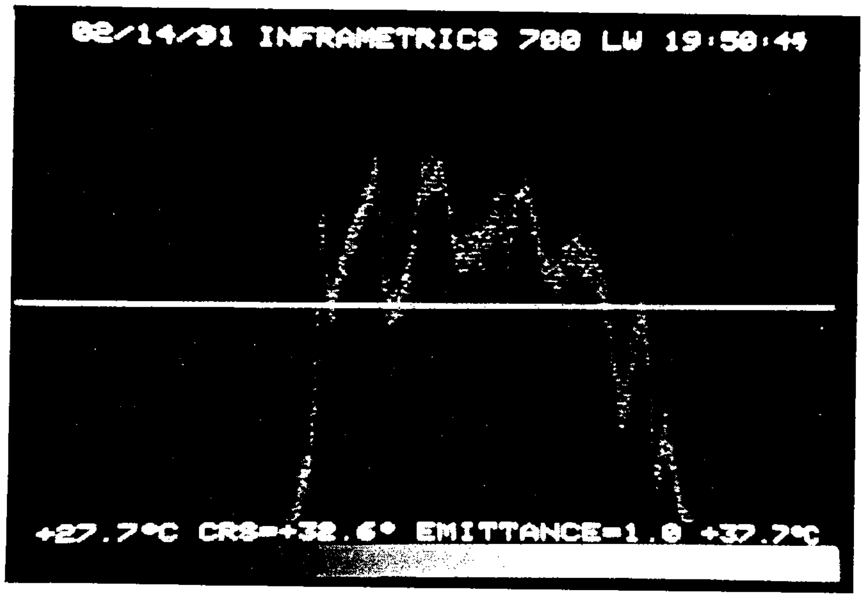


Figure 4-10
Line Select Mode

Horizontal cursor (line) represents location of thermal profile displayed in Line Scan Mode





CURSOR TEMPERATURE IS DISPLAYED CONTINUOUSLY

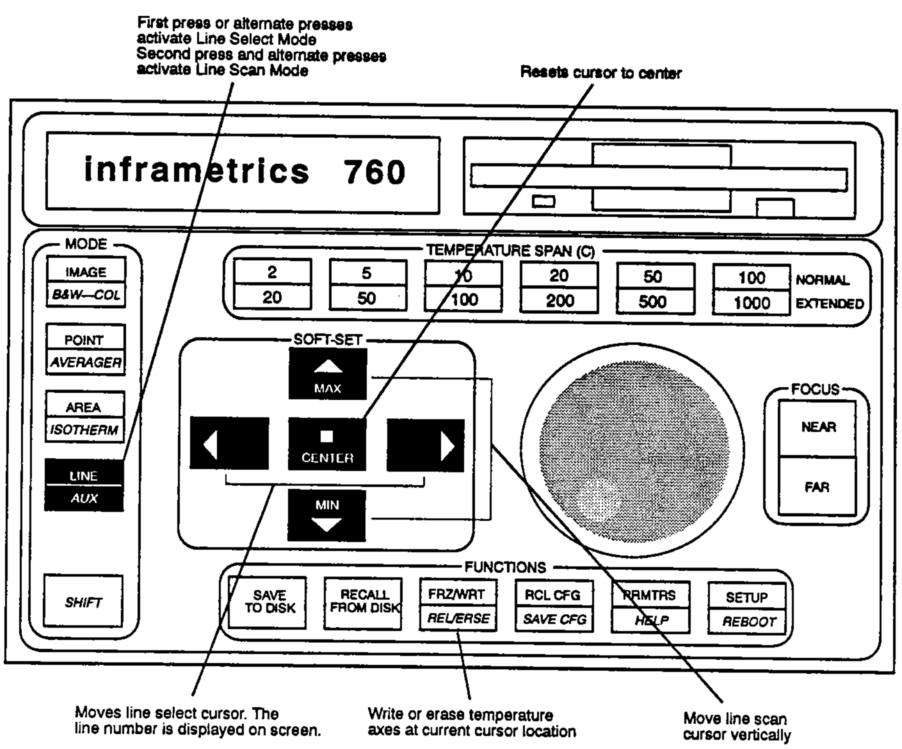


Figure 4-11
Line Scan Mode

User-defined axes can be placed on image using the FRZ/WRT key (not shown)

4.2.8 Auxiliary Modes

Auxiliary operating modes may be selected from a menu which is accessed by pressing the SETUP key four times. The MIN/MAX SOFT-SET keys are then used to move the cursor and the RIGHT/LEFT SOFT-SET keys to select the mode. The available Auxiliary Modes are described below.

4.2.8.1 *Phasing Adjustment*—The Phasing Adjustment Auxiliary Mode, Figure 4-12, permits the system phasing parameter to be adjusted to minimize distortions observed on vertical edges of objects in the scene. Here, the UP/DOWN SOFT-SET keys adjust the FOV, and the LEFT/RIGHT SOFT-SET keys adjust the value of the phasing parameter for which no value is displayed.

To adjust this parameter, aim the scanner at an object with a distinct vertical edge. Make sure that the center temperature is properly set for the object being viewed, that the focus is correct, and that the image in the area of interest is not saturated black or white. Press the LEFT or RIGHT SOFT-SET key until the edge being viewed shows no distortion.

When this mode is exited, the phasing value will be stored in nonvolatile memory for further use. This value may also be stored by pressing the CENTER SOFT-SET key.

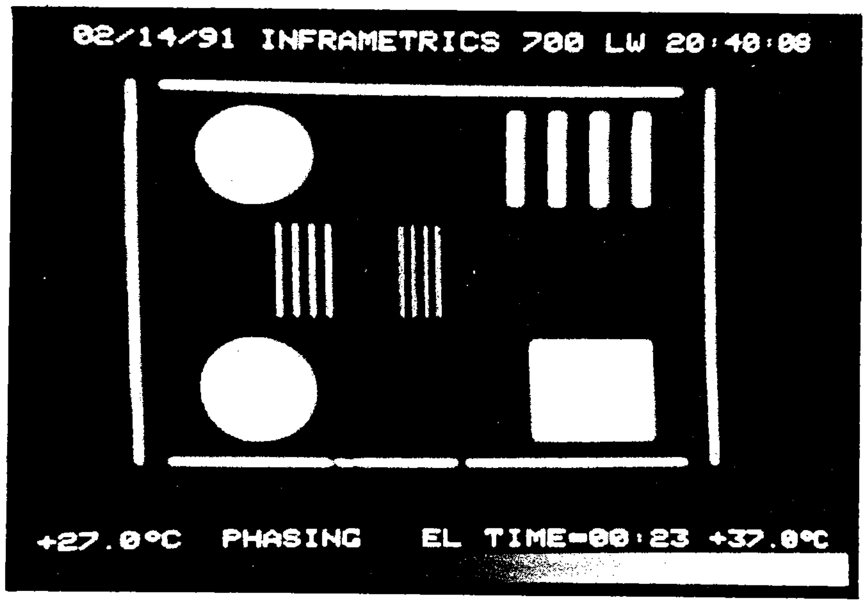


Figure 4-12a
Phasing Adjustment Auxiliary Mode

(a) Correct System Phasing

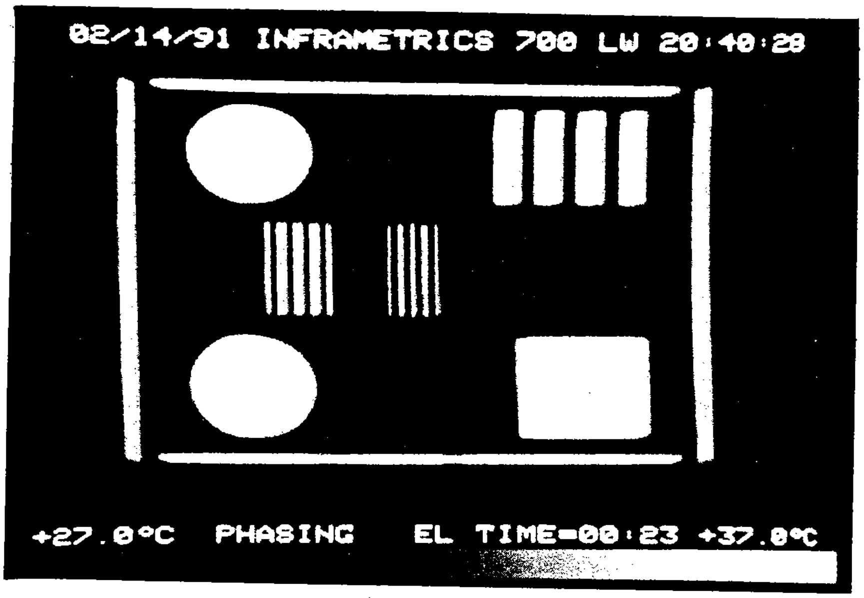


Figure 4-12b
Phasing Adjustment Auxiliary Mode

(b) Out-of-Phase Condition

Note blurred, jagged, or double image

4.2.8.2

Data Acquire—The Data Acquire auxiliary mode, Figure 4-13, is used primarily when analyzing thermal imagery with an external image processor or when recording data for later analysis.

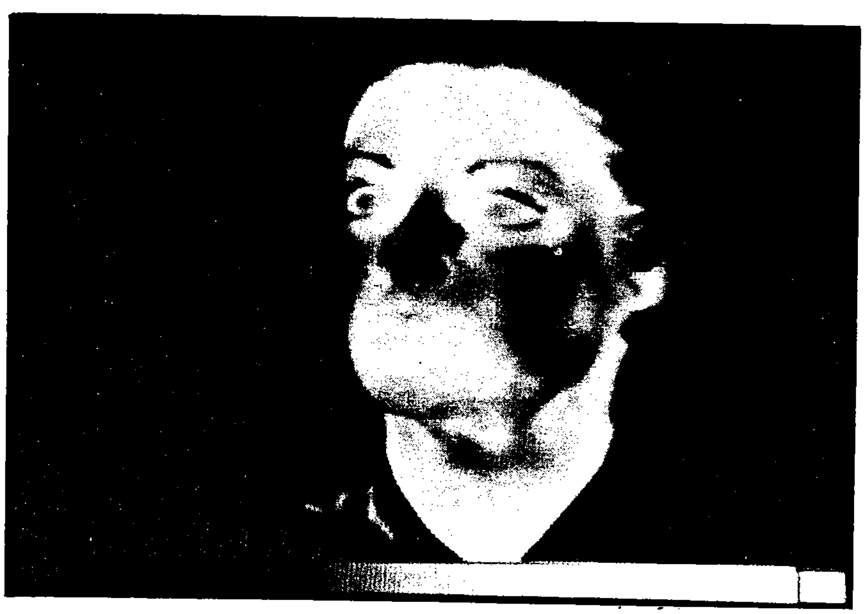


Figure 4-13
Data Acquire Mode

When this mode is selected, several functions are performed:

1. The alphanumeric display (Time/Date and Status Lines) are disabled.

2. Blanking is turned off.

3. Polarity is set to white=hot.

4. Color palette 7, labeled "BLACK/WHITE ENHANCE" is selected. This feature is used to ensure that objects in the image are within the limits of the SPAN and CENTER TEMPERATURE settings. The grey scale will contain a small blue segment at the left end and a small red segment at the right end, with a continuous grey scale in between. The blue and red segments represent underspan and overspan, respectively. The SPAN and CENTER TEMPERATURE controls should be adjusted so that no objects of interest in the scene are shaded blue or red. Video recording should be done in B/W output only. Do not attempt to analyze images recorded using color palette 7. Though the image may contain no colors, the grey scale is contaminated by the blue and red segments.

5. The emissivity is set to 1.0. The emissivity of the object(s) of interest can be set at the image processor when the data are analyzed.

In this mode the SOFT-SET keys control the field of view. The MIN/MAX SOFT-SET keys control the horizontal and vertical FOVs simultaneously, while the LEFT/RIGHT SOFT-SET keys control just the horizontal FOV.

4.2.8.3

Fast Line Scan—The Fast Line Scan Auxiliary Mode, Figure 4-14, is used to view very fast events. The vertical scan mirror is stopped at approximately the center position, and this line is displayed as shades of grey. Scans of the single line occur at approximately 125-μsec intervals and are displayed for video tape recording and playback analysis. The LEFT/RIGHT SOFT- SET keys adjust the horizontal FOV. The MIN/MAX keys are nonfunctional in this mode. Graphics can either be suppressed (FAST LINE SCAN) or enabled (FAST LINE SCAN W/ GRAPHICS). When the 760 is placed in FAST LINE SCAN, the saturation palette is automatically selected. This mode is used primarily in conjunction with the ThermaGRAM Image Processing System.

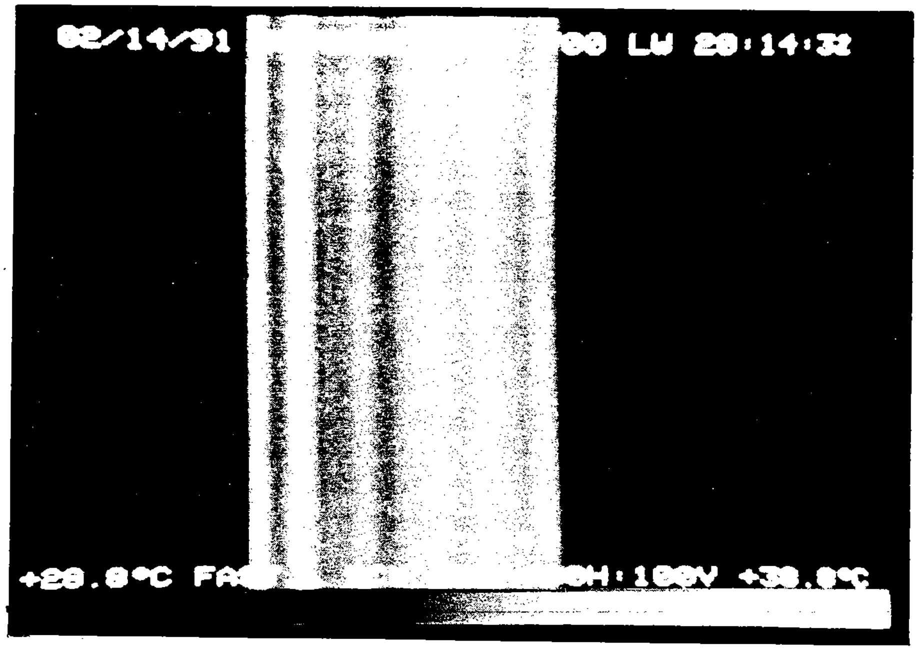


Figure 4-14
Fast Line Scan Auxiliary Mode

4.2.8.4

Grey Scale—In the black and white mode, the Grey Scale Auxiliary Mode, Figure 4-15, displays the same grey scale pattern obtained when the system is first powered up as shown. This display is useful for monitor adjustment and for checking essential video equipment. The diagonal lines indicate proper operation of the internal Isotherm and Fast Line Scan circuits. A color "greyscale" appears if the color function is selected.

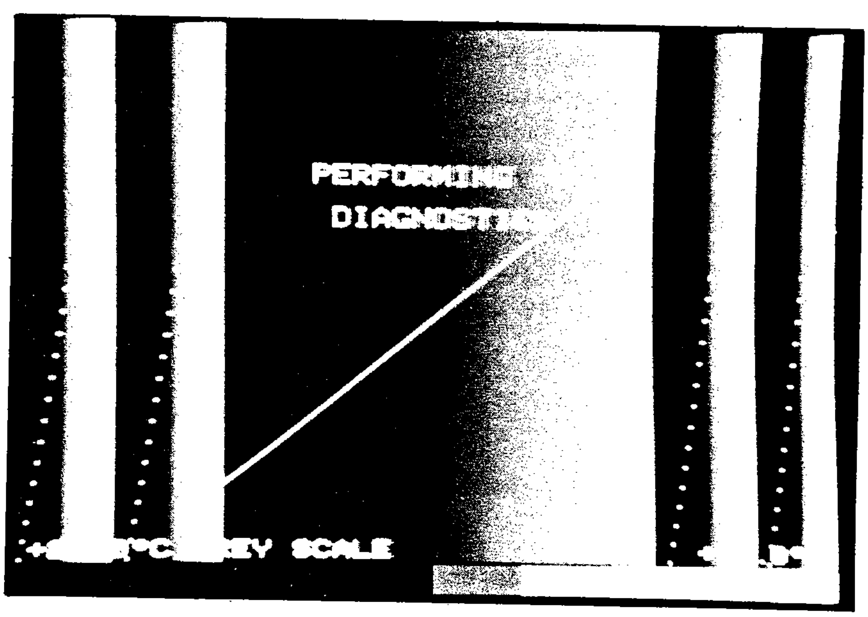


Figure 4-15
Grey Scale Auxiliary Mode

4.2.8.5 *Emissivity (Measure)* —The Emissivity (Measure) auxiliary mode is used to set the emissivity while viewing the target temperature via the area mode. This is useful when a reference material of known emissivity is attached (using a thermal bond) to a material of unknown emissivity and temperature. The temperature of the reference material will be displayed when its emissivity is entered; then the area box is placed on the unknown surface and the emissivity is adjusted until the same temperature is obtained. The emissivity obtained is the emissivity of the unknown material. To accurately use this function, the background temperature should be set in the "Measurement Configuration Setup Menu."

In this mode, the MIN/MAX SOFT-SET keys increase and decrease the emissivity, the value of which will be displayed in the scrolling display area. The LEFT/RIGHT SOFT-SET keys adjust the vertical and horizontal FOV's simultaneously.

To move the area box from the reference material to the unknown material, either move the scanner laterally or use the AREA mode to move the box, and then activate the EMISSIVITY Measure mode again. The DEFINE AREA Mode may be used to select a box of different size and shape.

This mode can be used in conjunction with a contact temperature measurement device. In this case, the user would decrease the emissivity value until the temperature displayed in the status line equals that measured with the contact device.

4.2.8.6 *Line Scan Data Transfer*—The function of this auxiliary mode is to send line scan magnitude data to an external computer via the Serial I/O Interface. When this mode is activated, a display similar to Line Select mode is displayed. The MIN/MAX SOFT-SET keys select the video line. The LEFT/RIGHT SOFT-SET keys adjust the FOVs. The CENTER SOFT-SET key dumps the line data to the Serial I/O Interface. The data consist of 256 values corresponding to the 256-pixel width of the screen. The values range from hexadecimal 0 to FF (0 to 255 decimal) which corresponding to the relative amplitude of each pixel of the line selected. The data are sent to 16 rows of 16 values each. Each row is terminated with a carriage return and line feed characters.

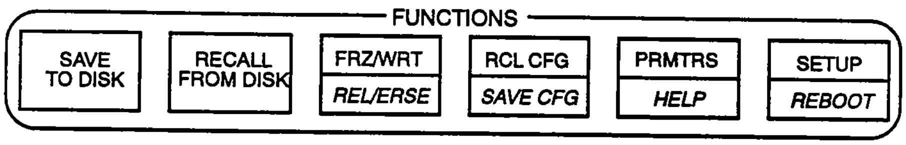
The functions that are initiated by the SOFT-SET keys may also be performed by the computer that is receiving the data (see Computer Serial I/O Interface, Section 4.8).

NOTE: Line Scan Integration must be enabled for this mode to operate.

4.2.8.7 *Calibration Data Transfer*—This mode is used in conjunction with the optional Calibration Software to send system calibration parameters to an external computer via the Serial I/O Interface.

System Functions 4.3

The system functions help to manage image files and set system parameters.



To Save an Image on Disk 4.3.1

1. While in image mode, aim and focus the scanner to produce the desired image on the monitor.

2. Push the SAVE TO DISK function key. The following message will be displayed:

STORE IMAGE NUMBER < 1 >

Enter a number from 1 to 25 for image number, or let the system increment the number automatically. Change the number by using the RIGHT/LEFT SOFT-SET keys, or using the center temperature control knob.

When the SAVE TO DISK button is pushed a second time, the image on the display is instantly frozen in memory. It takes about 25 seconds to copy the image from memory to the disk. After the message disappears, the image may be recalled to verify the save. The number displayed in the message is the number used to recall this image.

To Recall an Image From Disk: 4.3.2

1. Press the IMAGE mode key to return to image mode.

2. Press the RECALL FROM DISK function key. The following message will be displayed:

DISK RECALL SELECT < 1 >

3. Use the LEFT/RIGHT arrow keys or center temperature control knob to enter the appropriate image number. Entering 0 will retrieve the image directory.

4. Press the RECALL FROM DISK function key again to view the image in approximately 6 seconds.

The line scan, point, area, and isotherm display modes can be used to analyze the recalled image.

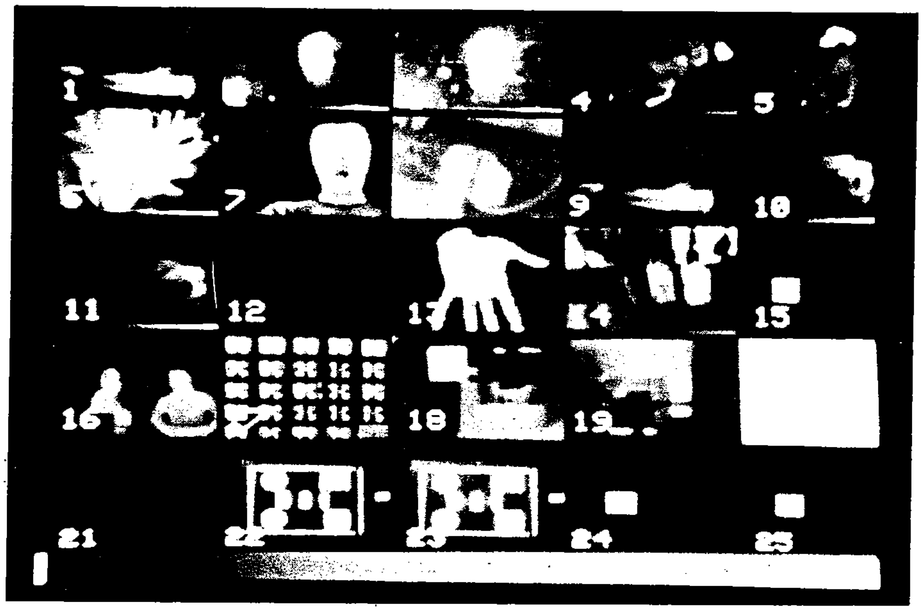


Figure 4-16
Enter 0 to Retrieve Image Directory

Exiting recalled Image Mode
To return to live image mode from a recalled image, press the IMAGE key once to exit the analysis mode (e.g. Point, Area, etc.) and a second time to enter live image mode. Pressing the Image key a *third* time will recall the same recalled image. If you wish to toggle between a recalled image and a live image while remaining in a particular analysis mode, hold down the *SHIFT* key while pressing the center SOFT-SET key.

From line scan mode, the LINE key must be pressed to return to line select mode. From there, press the IMAGE key twice to enter live image mode.

Error Messages and other Problems
If the system displays an error message or doesn't complete a save or recall within one minute, press SHIFT REBOOT and try the procedure again. If, however, the DISK FULL message is displayed, remove the diskette and replace it with one that has more available space.

4.3.3 Save CFG/Recall CFG
Saves and recalls the settings set in the setup menus. This is useful when one wants to have, for example, the temperature span, emissivity, center temperature, etc. set to the same values when resuming work at a later time.

4.3.4 FRZ/REL
Freezes and releases an image on the LCD or external monitor. To freeze an image, the image averager must be on. Note that the averager can be set to "average" one frame. Successive key presses can be used to alternately freeze and release an image in addition to the FREEZE/SHIFT RELEASE convention.

System Functions

continued

4.3.5 WRT/ERS

Used to label one or more temperature axes in the Line Scan Mode, and to remove them. See Section 4.2.7, "Line Scan Mode," for additional information.

4.3.6 PRMTRS/HELP

The PRMTRS key displays the current system status with two pages listing system parameters. See Section 4.4.1, "System Parameters," for additional information.

Pressing the HELP key (use shift key) will display a help page for the current mode.

4.3.7 SETUP/REBOOT

The SETUP function displays four setup menus. Press the key repeatedly to sequentially step through each menu. REBOOT provides the ability to execute a "soft" reset from the control panel.

4.4 System Parameter and Setup Menus

4.4.1 System Parameters

The values of system parameters are displayed on two menus, "System Parameters" pages one and two. The menus are selected by pressing the PRMTRS key once for page 1, and a second time for page 2.

SYSTEM PARAMETERS

IMAGE AVERAGER:	1 FRAME
DISK IMAGE NUMBER:	NONE
CENTER TEMPERATURE:	+33.8 °C
CENTER LEVEL:	03004
FILTER/TEMP RANGE:	OPEN NORM
TELESCOPE AND TRANS:	1X 1.0
EXT OPTICS TRANS:	1.0
SOFTWARE REVISION:	01.00

-1-

Figure 4-17
System Parameters
Page 1

Press PRMTRS key once for menu 1, a second time for menu 2

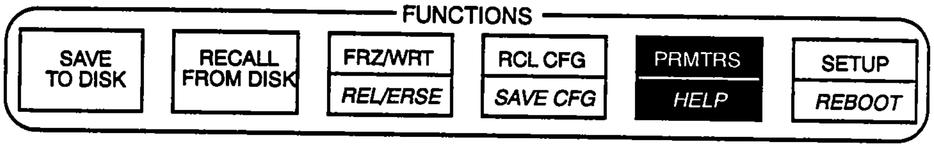


Figure 4-18
System Parameters Page 2

SYSTEM PARAMETERS

EMISSIVITY:	1.0
BACKGROUND TEMP:	+25.0°C
FIELD OF VIEW:	100H 100V
ELAPSED TIME:	01 : 47 HOURS
BATTERY VOLTAGE:	11.8 VOLTS
SCANNER TEMPERATURE:	+32.8° C
10X/30X TELE TEMP:	+24.2° C
EXT OPTICS TEMP	-5.3° C

-2-

4.4.2 Setup Menus

Menu items are selected using the MIN/MAX SOFT-SET keys. The value of the desired parameter is changed by means of the LEFT/RIGHT SOFT- SET keys. The background temperature parameter (the only exception) is changed with the CENTER TEMP control.

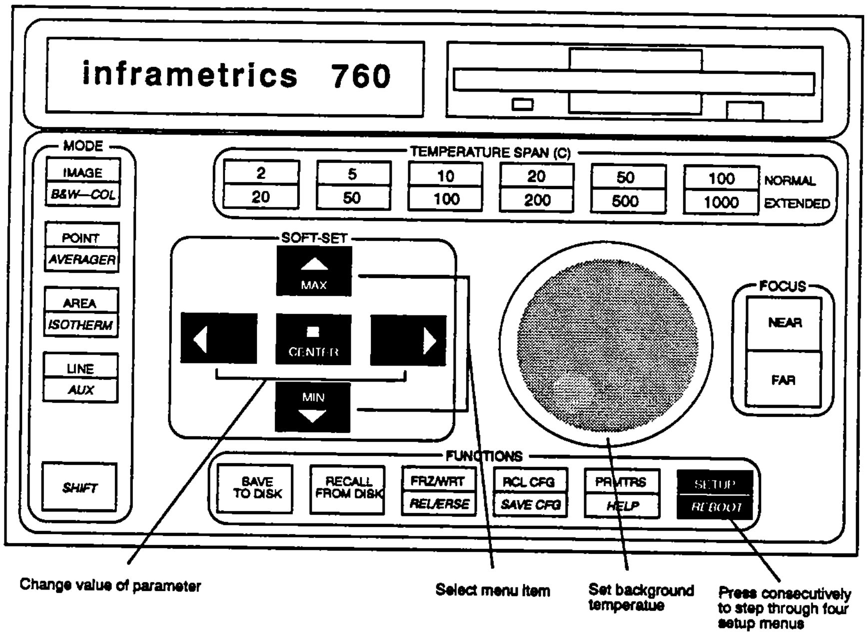
4.4.2.1 Measurement Configuration Setup Menu

Figure 4-19
Setup Menu Page 1

MEASUREMENT CONFIGURATION SETUP

➡	TARGET EMISSIVITY	<	1.0	>
	BACKGROUND TEMP	<	+25.0°C	>
	FILTER/TEMP RANGE	<	OPEN NORM	>
	EXT OPTICS TRANS	<	1.0	>
	WIDE ANGLE TELE TRANS	<	1.0	>
	3X TELESCOPE TRANS	<	1.0	>
	10X/30X TELESCOPE TRANS	<	1.0	>
	10X/30X TELESCOPE SELECT	<	10X	>

- 1 -



Select parameter and change it using the Soft-Set keys

Setup Menu Items Page 1

Emissivity

The emissivity of the target being imaged is set from this line and may range from 0.1 to 1.0. See Appendix A for a discussion on emissivity. The emissivity may be altered for frozen or recalled images. This allows the user to evaluate different objects in the captured scene using varying values of emissivity.

Background Temperature

The average temperature of the scene background may be set using the CENTER TEMP control. See Appendix A for more information on background temperature. The background temperature may be altered for frozen or recalled images, together with the emissivity.

Filter/Temp Range

This line of the menu displays the current filter being used, and may be changed to one of four possible filters or no filter in the optional filter mechanism. It is also used to access the extended range. The syntax in brackets is "OPEN-NORM" for no filter in the normal range, and "OPEN-ATT/XT" for no filter in the extended range. Some filters cause the extended temperature range feature to be enabled which is accompanied by a tenfold increase in the temperature span values. The correct calibration tables will also be selected automatically for each filter.

External Optics Transmission

This transmission factor is used continuously and must be reset to 1.0 when external optics are not installed. It is automatically reset to 1.0 when the system is powered up or reset. Any optical element, including heat shields, windows, and lenses may be corrected for by this parameter as long as the optical device is at or near scanner temperature. In cases where the external optical element does not approximate the scanner temperature, an optional "external optic temperature probe" is available. The external optics transmission factor may be altered for a frozen or recalled image. The external optics temperature obtained when the probe is connected may not be altered.

Wide Angle Telescope Transmission
Enter the transmission factor marked on the case for the wide angle telescope (either 0.5X or 0.25X) being used to ensure temperature measurement accuracy. This factor is stored in non-volatile memory and will be maintained until changed again by the user. This factor will be used whenever a wide angle telescope is installed, and may be altered for a frozen or recalled image.

3X Telescope Transmission
Enter the transmission factor marked on the case for the 3X telescope to ensure temperature measurement accuracy. This factor is stored in non-volatile memory and will be maintained until changed again by the user. This factor will be used whenever a 3X telescope is installed, and may be altered for a frozen or recalled image.

10X and 30X Telescope Transmission
Enter the transmission factor marked on the case for the 10X or 30X telescope to ensure temperature measurement accuracy. This factor is stored in non-volatile memory and will be maintained until changed again by the user. This factor will be used whenever a 10X or 30X telescope is installed, and may be altered for a frozen or recalled image. The telescope temperature obtained when the probe is connected may not be altered.

10X/30X Telescope Select
Select the particular telescope being used. The consequence of selecting the incorrect telescope will be an inverted image. If neither the 10X or 30X is in use, the setting is irrelevant. This setting may not be altered for a frozen of recalled image.

4.4.2.2 Processing Parameters Setup Menu

Figure 4-20
Setup Menu
Page 2

PROCESSING PARAMETERS SETUP

➡	IMAGE AVERAGER	<	1 FRAME	>
	LINE SCAN INTEGRATE	<	OFF	>
	CENTER TEMPERATURE	<	MANUAL	>
	THERMAL UNITS	<	CENTIGRADE	>
	TEMPERATURE OUTPUT	<	DISABLED	>
	FORMAT DISKETTE	<	NO	>

- 2 -

Image Averager

Used to select the number of image fields averaged, i.e., 1, 2, 4, or 16. Once the number has been selected, the freeze/unfreeze function is enabled (invoked using the LEFT/RIGHT SOFT-SET keys while in the Image or related mode). See Section 4.5, "Using the Image Averager," for additional information.

Line Scan Integrate (LS Integrate)

Allows operation of the line scan Mode with integration on or off. With integration on, successive scans will be averaged to reduce noise. However, the response time to changes in the scene will be slower than with integration off.

Center Temperature

Manual (MAN), locked (LOCK), or auto (AUTO) center temperature may be selected from this line. The manual mode is the default mode, and the CENTER TEMP control is used to set the center temperature. In the locked mode, the center temperature cannot be changed.

The auto center temperature mode allows the system to adjust for the optimum center temperature. When auto center temperature is enabled, the center temperature will automatically track the measured point or area temperature . Fastest response is obtained using the POINT mode. The delay caused by reading many pixels in the AREA mode makes AUTO center temperature respond more slowly. It is recommended to use the POINT mode if speed is desired. The AREA mode may then be accessed when the center temperature is close to the measured value. The best measurement accuracy is obtained with the auto center temperature enabled. Do not use auto center temperature while in the line scan mode.

Thermal Units

Used to select units of degrees Centigrade (C) or Fahrenheit (F). Also selects ":level units" (LVL) i.e., radiance levels in arbitrary units instead of temperature values (no level-to-temperature conversion is performed). These units may be changed on frozen or recalled images.

Temperature Output

The temperatures calculated in the Point and Area Modes may be sent over the Serial I/O Interface port in one of three ways:

1. ON COMMAND. The temperature will be transmitted on command from an external computer (refer to Section 4.7).

2. CONTINUOUS. The temperature will be transmitted each time a calculation has occurred.

3. 0.5 SEC. The temperature will be transmitted every half second.

These parameters may also be set by the external computer as described in the section on interfacing.

Setup Menu Items Page 2 (continued)

Format Diskette
New disks must be formatted before storing images on them.

Reformatting a disk erases all data on that disk. Do not reformat a disk that contains images that should be saved.

To format a diskette:

1. Insert the diskette into the disk drive.

2. Press the SETUP function key until the Processing Parameters Setup Menu appears (Page 2).

3. Use the vertical arrow keys to select FORMAT DISKETTE.

4. Use the horizontal arrow keys to toggle <YES>.

5. Press the center key or DISK STORAGE SAVE key.

The 760 will display the message `FORMATTING...`while the disk is being formatted.

4.4.2.3

Display Options Setup Menu
All parameters in this setup menu, except for selecting and setting the time and date, are able to be altered for a frozen or recalled image.

Figure 4-21
Setup Menu Page 3

DISPLAY OPTIONS SETUP

➡ ISOTHERM BOUNDARIES	<	ON	>
POLARITY	<	WHITE=HOT	>
BLANKING	<	OFF	>
COLOR PALETTE	<	7	>
FRONT PANEL LIGHTS	<	ON	>
VCR PLAYBACK	<	OFF	>
TIME/DATE SELECT			
TIME/DATE SET			

- 3 -

Setup Menu Items Page 3

Isotherm Boundaries
Displays isotherm ranges on the status line while in the isotherm mode.

Polarity
The polarity of the video, either black hot or white hot, is selected by this menu line. This feature is particularly useful when in the ISO Mode and the desired level is

near white. Normally, the intensified pixels would not be visible with the unit in the white hot mode, but by switching to black hot they become clearly visible.

Blanking
This feature blanks out a portion of the image (i.e., turns it black behind the on-screen alphanumerics). Blanking improves visibility of alphanumerics when displayed over high intensity shades of grey.

Color Palette
Used to select the palette number when the Color function is enabled. (Refer to Table 4-3 for palette cross reference.)

Front Panel Lights
Turns the illumination for the front panel buttons on or off.

VCR Playback
Enables data recorded on a VCR to be input to the 760 and displayed on the integral LCD. For those units equipped with RGB LCD displays, color NTSC/PAL images can be played back only in black and white. These images can be played back for viewing purposes only and cannot be analyzed by the 760.

Time/Date Select/ Set
Sets the date and time in the system. The Time Select function causes an arrow to appear in the line immediately below the Time/Date line. The arrow is used to select the digit to be changed, and the setup pointer is moved to the Time Set line. The LEFT/RIGHT SOFT-SET keys are then used to change the value of the selected digit. This procedure is repeated until the correct time and date are set. NOTE: Setting the date greater than 1 year plus 1 month from last maintenance will cause the "Maintenance Due" message to be displayed.

Auxiliary Mode Setup Menu 4.4.2.4

AUXILIARY MODE SETUP

➔ PHASING ADJUSTMENT	<	AUX	>
DATA ACQUIRE	<	OFF	>
FAST LINE SCAN	<	OFF	>
FAST LINE SCAN W/GRAPHICS	<	OFF	>
EMISSIVITY SOFT-SET	<	OFF	>
GREY SCALE	<	OFF	>
LINE SCAN DATA TRANSFER	<	OFF	>
CALIBRATION DATA TRANSFER	<	OFF	>

- 4 -

Figure 4-22
Setup Menu
Page 4

The Auxiliary Mode Setup menu is used to assign any one of the functions in figure 4-21 to the AUX key on the keyboard of the control/electronics unit. For example: with PHASING ADJUSTMENT selected as above, pressing the AUX key (shift key plus LINE/AUX key) will invoke the phasing adjustment mode.

4.5 Using the Image Averager

The Image Averager is an internal, real-time digital image processor. It is capable of storing a full frame of video information on command as well as averaging individual picture elements from 1, 2, 4, or 16 fields.

4.5.1 Image Averaging

Averaging reduces the random noise content of the thermal image by a factor equal to the square root of the number of fields averaged. On a sensitive temperature range (2, 5, or 10), in color mode, or with the target emissivity set to a low value, the noise reduction is easily noticeable as a reduction in "snow" and smoothing of color patterns. Using the averaging function is highly recommended for the two degree temperature span.

An exponential averaging algorithm is used. Each new image (field) is weighted and then added to a sum held in memory. Averaging is done in real time at the frame rate of the system. The sum becomes more like the new field, and if a series of new fields, all the same, are added, the sum will eventually equal the new image. The rate of change or adaptation is determined by the weighting of new fields. This is determined by the time constant set by the user, i.e., the number of fields selected to be averaged.

A short time constant (1 or 2 fields) will cause the image to change rapidly, but will not offer a substantial improvement in noise. This is preferred for dynamic images.

A long time constant (16 fields) will dramatically reduce the image noise, but will change slowly causing moving images to smear. This is preferred for static images where maximum sensitivity is needed.

Images may be frozen in memory with any time constant setting.

To operate the Averager, press the SETUP key twice to reach page 2 or the Processing Parameters Setup Menu. Since the Image Averager is the first item on the menu, simply press the RIGHT SOFT-SET key to choose 1, 2, 4, or 16 fields of averaging.

To freeze an image the Image Averager must be on. While in image mode, press the FRZ/WRT key to freeze the image. To return to the real-time image, press the REL/ERSE key. While in the freeze mode, the ISO, COLOR, and POINT and line scan modes may be selected in the normal manner.

Using the Image Averager

continued

To turn the averager off (and lose the stored image), go to the Processing Parameters Setup Menu, and switch IMAGE AVG to OFF, or press the shift AVERAGER key.

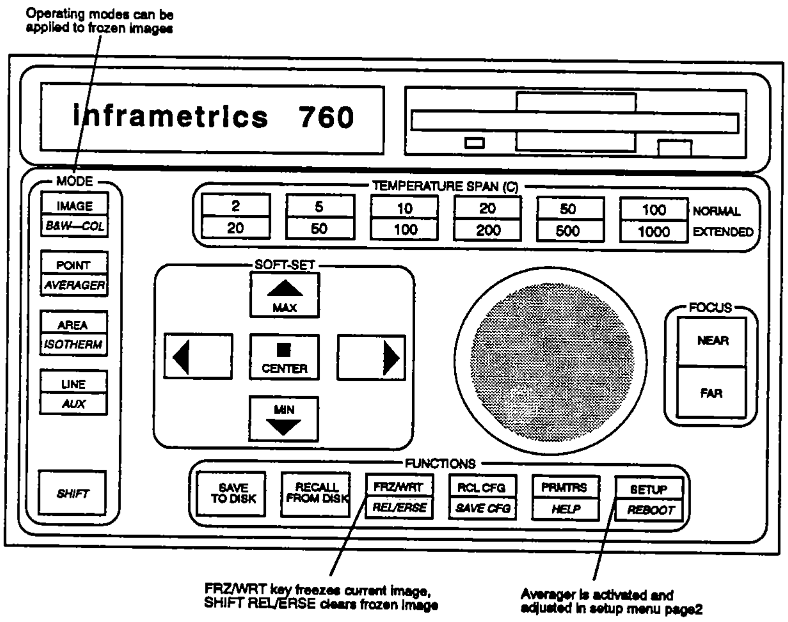


Figure 4-23
Image Averaging

Operating Notes

For Line Scan analysis, freeze the image before going into line select or scan, since FRZ/WRT and REL/ERSE keys will be reconfigured to set and erase temperature axes.

SAVE CFG stores all instrument settings including the averager time constant, but does not store an entire frozen image.

Once the image is frozen, it cannot be modified by the CENTER TEMPERATURE, SPAN, Emissivity, or other real-time controls until unfrozen.

Using an External Image Analyzer

4.6

The Model 760 is optimized for use with an Inframetrics' ThermaGRAM computer image analysis system. Features have been incorporated which allow the use of high density diskettes or video tape as low cost mass data storage medium without the loss of radiometric information.

Please note that your computer must be equipped with a high density 3.5" disk drive. Images stored by the Model 760 are recorded only on high density 3.5" disks.

A special Auxiliary Mode labeled DATA ACQUIRE MODE may be selected in the auxiliary mode menu. When recording images on videotape for later analysis, the VCR should be connected to the BLACK/WHITE ONLY output of the 760.

continued

Using an External Image Analyzer

The Image Processor will decode the hidden information to determine the current type of telescope in use and will use the transmission values set in the "Measurement Configuration Setup Menu." The correct calibration curve for any filters in use will also be selected automatically.

4.7 Video Printer

Instant color prints and color or black-and-white 35-mm slides of images on the system monitor can be made using a video image printer, Figure 4-24.

When the printer is used to record images from NTSC sources such as the system monitor (or a VCR), a built-in digital memory captures one field of the moving video image while permitting adjustment of the image's color saturation, tint, brightness, contrast, and sharpness before taking the picture.

Procedures for setting up the recorder, taking pictures, and adjusting the monitor are described in the owner's manual furnished with the unit.

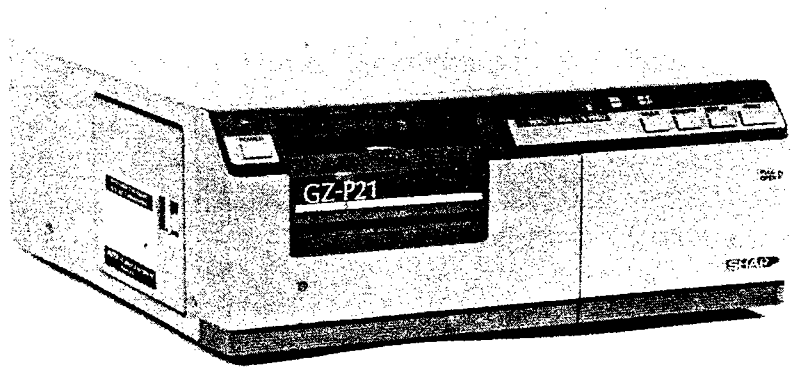


Figure 4-24
Video Image Printer

4.8 Computer Serial I/O Interface

The following information is intended to assist users of the Model 760 in configuring a computer for interfacing to the Serial Remote Control Port.

4.8.1 Hardware Interface

An RS-232 connector (25 pin female D) located on the rear panel of the control electronics may be used to receive data from and transmit data to the 760. Drive voltage levels are ±5V. The 760 interface conforms to Data Communication Equipment (DCE) standards for EIA RS-232C. The PC interface conforms to Data Terminal Equipment (DTE) EIA RS-232C standards.

4.8.2

Connections

Table 4-4 shows the pin connections and functions for the Model 760.

Pin#	760 Function	Computer Serial I/O Function	Pin# (9D)	Pin#(25D)
2	Received data	Transmitted data	3	2
7	Ground	Ground	5	7
3	Transmitted data	Received data	2	3
1	Ground	Ground	5	1

Table 4-4
Computer Serial I/O Interface Pin Connections

4.8.3

Serial Input/Output Interface Settings

To use the serial I/O interface, the RS232 handshaking control signals should be disabled before communicating with the 760. These signals are:

RS - request to send
CS - clear to send
RLSD or CD - received line signal detect or carrier detect
DS - data set ready

Refer to your computer's technical reference manual to determine whether disabling handshaking signals, setting baud rate, stop bits, data bits and parity are done in hardware or software. Note: BIOS calls can not disable these functions.

Using an IBM PC or compatible with BASIC or GWBASIC, all the proper communications settings can be set with this statement:

```
OPEN "COM 1: 4800,e,7,2,rs,ds,cd" as #1
```

where,

4800 = baud rate
e = parity (even)
7 = number of data bits
2 = number of stop bits
rs = disable request to send
ds = disable data set ready
cd = disable carrier detect

In summary, the settings for the Model 760 serial I/O interface are given in Table 4-5:

Baud Rate:	4800	Data Bits:	7
Parity:	Even	Stop Bits:	2

Table 4-5
Serial I/O Interface Settings

4.8.4 Remote Control

The remote control can duplicate all control panel input functions from over 100 feet away. This control panel is separately powered by a separate +12 V supply. It is connected to the 760's RS-232 port using a proprietary interface via a remote cable.

4.8.5 Software Interface

Commands are sent to the Model 760 as ASCII strings. An ESCAPE character (ASCII 27 DECIMAL) precedes each command to initiate the transmission. Single-letter abbreviations identify the command functions. A token specifies the intent of the command either completely or in conjunction with a string of digits. All commands must be terminated with a CARRIAGE RETURN. LINE FEED characters are ignored. If the command has been received correctly, the 760 will transmit an ACK character (ASCII 06). If the command was not interpreted correctly, the 760 will transmit a NAK character (ASCII 21). This forms the basis of a software handshaking system.

4.8.6 General Syntax

The general syntax is <ESC>Ct<CR> or <ESC>Cxnnn<CR>, and is defined below.

<ESC>	Escape Character (ASCII 27)
C	Command Character (always an alphabetic character)
t	Token < or > or =
x	inc/dec char + or - or =
nnnnn	ASCII string for parameter expressed in decimal integer format (0-99999 - not all features use this many digits)
<CR>	Carriage return

4.8.7 Normal Mode Commands

Table 4-6 lists the command structure for the serial interface. Figure 4-24 is a pictorial view of the command structure for the Control Panel functions superimposed on a diagram of the Control Panel.

4.8.8 Sample Programs

1. The following program, written in BASIC, places the system in point mode:

```
10 OPEN "COM1:4800,E,7,2,RS,DS,CD" as #1   'open rs232 port with correct settings

20 PRINT #1, CHR$(27)+"O=2"+CHR$(13)   'set 760 to point mode

30 CLOSE #1   ' close com  port #1
```

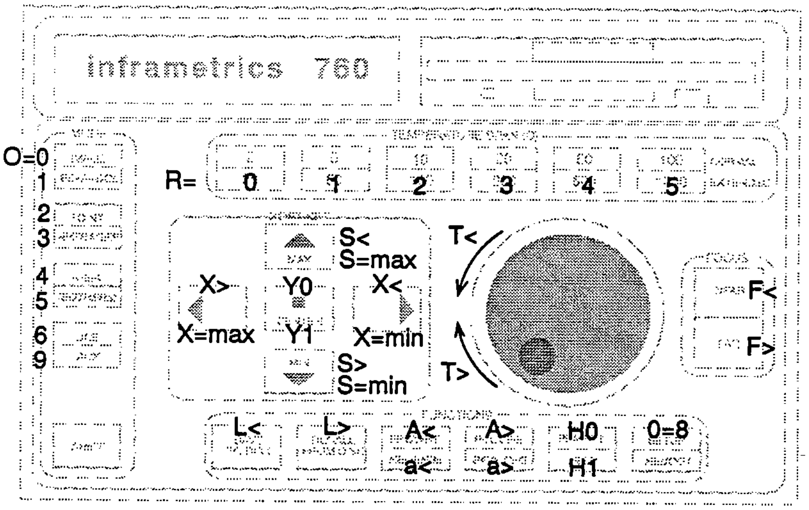


Figure 4-25
Command Structure for the Control Panel

2. The following program lets the user try out command strings directly from the keyboard of the computer:

```
10   OPEN "COM1: 4800, E, 7, 2, RS, DS, CD" AS#1
20   INPUT "INPUT THE COMMAND STRING"; MSG$
30   IF MSG$="Q" GOTO 499
40   GOSUB 500
50   GOTO 20
499  END
500  PRINT #1, CHR$(27)+MSG$+CHR$(13)
510  FOR I = 1 TO 1000: NEXT
520  RETURN
```

3. The following program takes in (point) temperature measurements on command:

```
10   OPEN "COM1: 4800, E, 7, 2, RS, DS, CD" AS #1
20   MSG$="C=1"
30   GOSUB 500
40   MSG$="O=2"
50   GOSUB 500
60   MSG$="C@"
70   GOSUB 500
80   INPUT #1,A$
90   PRINT A$
499  END
500  PRINT #1, CHR$(27)+MSG$+CHR$(13)
505  FOR I = 1 TO 1000: NEXT
510  RETURN
```

Computer Serial I/O Interface

Input from the Serial I/O Interface port varies from one computer to another. The 760 sends strings exactly as shown on the screen, i.e.:

CRS = 20.5#C   or   AVG = 53.6#C

A pound sign (#) replaces the degree symbol. In continuous mode, a transmission is made every half second. Many computers have input buffers in either the serial interface hardware or the file system. You must clear this buffer to get current data. All commands are echoed. A safe way of validating received data is to check substrings of the input. For example, verify that "CRS=" or "AVE=" was received correctly.

Table 4-6
Serial Interface Command Structure

Command Character & Syntax	Function		Bytes	Min	Max	Incr	Encoding
At or at	A<>Archive, Restore System Memory 1 a<> Archive, Restore System Memory 2						
Bxnnnnn	Set background Temp		2	-250	+400	0.5d	TEMP*
Ct[nn]	Set RS-232 output mode (Point and Area Mode use only)		1	0	3	0	C=0 or C< C=1 or C> C=2 C=3
C@	Trigger output (for C=1)						
Et[nnn]	Set target emissivity		1	10	100	1	%
Ft	F <> Set Focus						
Hn or Ht[n]	Set HELP display		1	0	-1		Arbitrary
Lt[nn]	L<(write) L.S. axis or Freeze Image						
On or Ot[nn]	Set operating Mode		1	0	31	1	Arbitrary
Rt	Set thermal range Range #		1	0	5	1	Arbitrary
St[nnn]	Set mode-specific parameter: (All single Byte)						
	IMAGE Mode	H-FOV/V-FOV		64	255	1	FOV/255
	Color Mode	Same as Image					
	Point Mode	HOR Cursor	Same as Line Select				
	ISO Mode	H-FOV		64	255	1	FOV/255
	Area Mode	Box Up/Down	0 or 255 Only				
	Define Area	Box Taller/Shorter	0 or 255 Only				
	Line Sel Mode	Cursor Line Select		9	200	1	Blanking Off
				19	198	1	Blanking On
	Line Scan Mode	Temp Cursor		48	208	1	
	Setup Mode	Setup Parameter & Aux Mode Select	Token Only				
	Fast Line Scan	No action					
	Phasing Mode	Same as Image Mode (sets FOVs)					
	Data Aquire	Same as Image Mode (sets FOVs)					
	Emissivity Set	Sets Emissivity		10	100	1	Emissivity
	Data Dump	Same as Line Select					

continued next page

continued

Serial Interface Command Structure -continued-

Command Character & Syntax	Function		Bytes	Min	Max	Incr	Encoding
Txnnnn	Set Center Temp Tctr		2	-250	+400		Range TEMP* Dependent
Xt[nn]	Set Mode-specific parameter:						
	IMAGE Mode	HOR FOV	1	64	255	1	HFOV/255
	Color Mode	Select Palette	1	0	7		
	Point Mode	Vert Cursor	1	254	1		
	ISO Mode	ISO Level	2	254	1		
	Area Mode	Box Left/Right	1	0 or 255 Only			
	Define Area	BOX Narrower/Wider		0 or 255 Only			
	Line Select Mode	HFOV	64	255	1		HFOV/255
	Line Scan Mode	Line Select	9	200	1		Blkg. Off
			19	198	1		Blkg. On
	Setup Mode	Change Parameter & Aux Mode Select		Token Only			
	Fast Line Scan	Same as Image Mode					
	Phasing Mode	Phasing Value	1	255	1		Phasing DAC
	Data Acquire	Same as Image					
	Emittance Set	Sets FOVs					
	Data Dump	Sets FOVs					
Y0	Image Mode	Set H-FOV=V-FOV					
	Area Mode	Set Standard Square					
	Define Area	Set Standard Square					
	Phasing Mode	Store Phasing Value in EEPROM					
	Point	Center Cursor					
	ISO	Center ISO Temp					
	Line Select	Center Line Select					
	Line Scan	Center Line Scan CRS					
	Data Acquire	Same as Image					
	Data Dump	Output to RS232					
Zt[nn]	Set Filter/Table#		1	0	6		Arbitrary

* TEMP encoding is (degrees C + 250) x 100; i.e., -250°=0, + 400°= 65000, + 25°= 27500
In EXTENDED RANGE, TEMP = (degrees C + 250) x 10; i.e., range is -2500° to + 4000°.

4.9 D*STAR Interface

4.9.1

Overview

The 700 series D*STAR interface is a digital output port that provides IR image, temperature range and calibration curve data for the current display image. The IR image is sent as even and odd fields that correspond to the image being displayed on the monitor. The image does not contain Isotherm data, status lines, or the reference gray scale that is present on the monitor.

4.9.2

Electrical

a. Output Buffer: 26LS31 - RS422 Differential Line Drivers

b. Signals:

1. D0 - D7: 8-Bit pixel value that represents 256 levels of gray scale (colors).
2. CLK: 5MHz pixel clock.
3. GATE: Pixel gating function
4. HSYNC: Horizontal Synchronization pulse.
5. VSYNC: Vertical Synchronization pulse.
6. GND. SHIELD: Cable shield and/or chassis ground.
7. GND. SIGNAL: Digital logic ground.

4.9.3

Mechanical

Connector:	IEEE - 488
Cable:	24 conductor, 36 AWG, Shielded
Cable length:	>100 feet
Signals:	22 signal (11 twisted pairs) 1 signal ground 1 shield ground

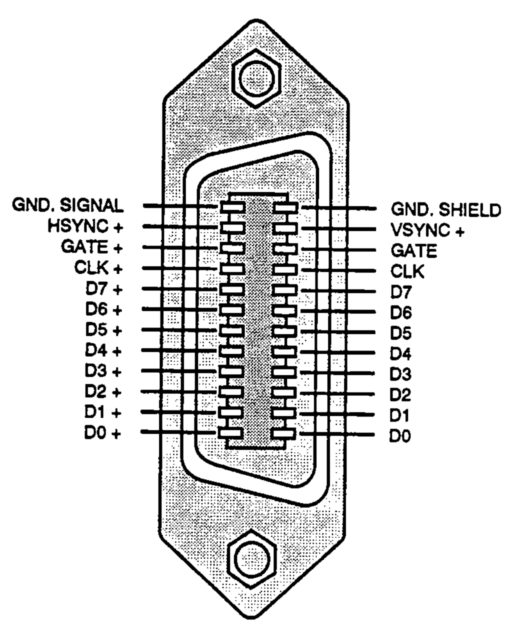


Figure 4-26
Connector Pin Assignments

The Model 760 stores images on disk in the Tiff file format. TIFF is an acronym standing for Tag Image File Format. The format is the industry standard for scanned images used on personal computers.

The image size is 207 X 256 for 60 Hz systems and 255 X 256 for 50 Hz systems with a 3:4 aspect ratio. Images contain eight bits per sample.

Thermal images stored on disk in the TIFF format can be recalled and analyzed by the Model 760, and by the ThermaGRAM system. TIFF format images can also be placed into desktop publishing programs such as Aldus PageMaker for use in reports, documentation, or other publications. The 760 does not read any files other than those it creates.

Figure 4-27 shows an example of a thermal image stored on disk in the TIFF file format, manipulated in PageMaker, and printed out on a laser printer from a Macintosh computer.

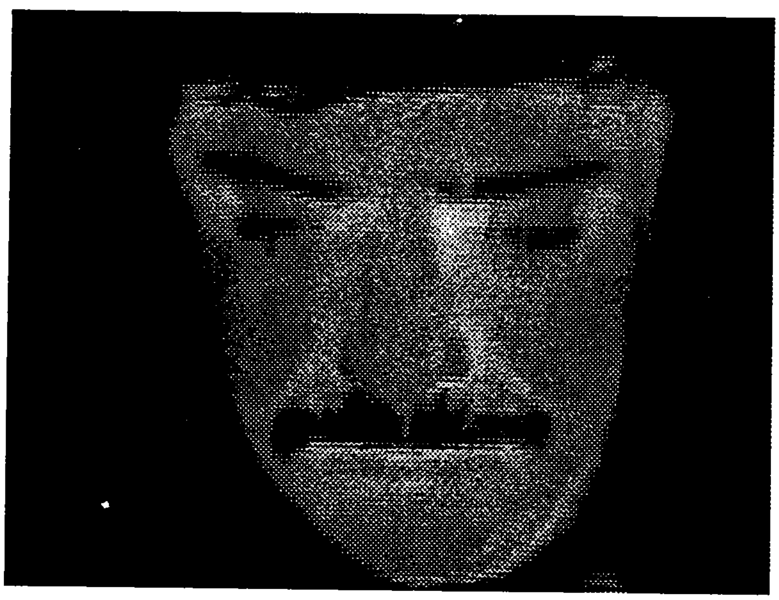


Figure 4-27
Model 760 TIFF Image Printed by a Laser Printer

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Maintenance 5.0

User Servicing 5.1

Calibration Check and Phase Adjustment 5.1.1

Periodic checkout and adjustment of system calibration and phasing may be performed by the user. Calibration checkout requires a blackbody calibration source. Phasing adjustment does not require special equipment and is described in the PHASING ADJUST MODE section.

Cleaning the Optics 5.1.2

Optical elements should be cleaned with a 50:50 mixture of reagent grade acetone and methanol. Moisten a Kleenex brand tissue with this mixture and wipe slowly with a rolling motion from the center to the edge. This will help prevent scratching by dust particles picked up by the tissue. If the optical element is very dusty, carefully blow it off with clean dry air. If the methanol/acetone mixture is not available, use isopropyl alcohol.

Lens Dessicant 5.1.3

Check the lens dessicant capsules in the lens caps occasionally to ensure that the dessicant is not saturated. If it is saturated, the dessicant will be brown colored. To dry out the dessicant simply leave it out in a dry area.

Factory Servicing 5.2

System Calibration 5.2.1

It is recommended that the calibration of the Model 760 be checked annually by Inframetrics. For a nominal fee, Inframetrics will check system calibration, clean the optics, set the horizontal and vertical fields of view, and perform a complete functional checkout of the system components.

Returning the System for Repair 5.2.2

Always contact Inframetrics Customer Service Group for Return Authorization and shipping instructions to prevent delays or loss.

Always ship the equipment in its original packaging materials. Refer to the photographs in the EQUIPMENT SETUP/UNPACKING AND INSPECTION section of this manual.

We hope that you don't experience any difficulty with your Model 760 Imaging Radiometer, but if you do, please check the following before calling us:

The Integrated Closed Cycle Cooler 5.2.3

Inframetrics' integrated closed circuit cooler requires no special maintenance other than returning the system for its annual calibration.

SYMPTOM

LACK OF HIGH PITCHED TONE DURING SYSTEM OPERATION

PROBABLE CAUSES:	ACTION:
Scanner is not connected to control/ electronics properly.	Turn off power and connect scanner.
Scanner is not receiving power.	Check power supply connections and circuit breaker.
Circuit problem or faulty galvanometers.	Call Inframetrics.

SYMPTOM

SYSTEM IS OPERATIVE (SCANNER CAN BE HEARD) BUT PRODUCES NO TEST PATTERN, TEXT, OR IMAGE

PROBABLE CAUSES:	ACTION:
Poor or improper connections.	Turn system off and make sure all connections are correct and properly secured. If using a VCR make sure it is turned on.
Monitor brightness and contrast improperly set.	Adjust monitor controls so they are on middle detent.
Faulty TV monitor.	Check system operation with another monitor.
Model 760 video port is faulty.	Attach monitor to the other video connector. Call Inframetrics.
Other video problem.	Call Inframetrics.

SYMPTOM

MONITOR DISPLAYS TEXT AND GREY SCALE, BUT NO IMAGE

PROBABLE CAUSES:	ACTION:
Lens cap is on scanner.	Remove lens cap.
The scanner is looking at a target with no thermal contrast.	Aim the scanner at a human face.
Temperature span set too high.	Use a lower setting.
Center temperature improperly set.	If image is black, turn center temp knob counterclockwise; if image is white, turn center temp knob clockwise.
Cooler needs maintenance.	Schedule factory service.

(continued)

Filter is selected or is stuck in optical path.	Set filter to OPEN - NORM and push the IMAGE mode button. If this doesn't eliminate the problem, call Inframetrics.
IR detector misaligned.	Call Inframetrics.
Chopper stuck in optical path.	Call Inframetrics.

SYMPTOM

INSTRUMENT READS KNOWN TARGET TEMPERATURES INCORRECTLY

PROBABLE CAUSES:	ACTION:
Background temperature, emittance, and/or optics transmissions are incorrectly set.	Enter proper values. See Appendix A.
Target is not being properly resolved.	Move the scanner closer to the target or use a telescopic lens. See Appendix A.
Accessory optics (3X, 10X, or close up lenses) may not be adjusted correctly.	Adjust optics correctly.
Filter is stuck in optical path.	Set filter to OPEN - NORM and push the IMAGE mode button. If this doesn't eliminate the problem call Inframetrics.
IR detector misaligned.	Call Inframetrics.
Scanner and control/electronics unit are mismatched.	Check serial numbers of components.
System calibration has not been adjusted for over one year.	Call Inframetrics for recalibration

SYMPTOM

VERTICAL LINES APPEAR IN MIDDLE OF IMAGE

PROBABLE CAUSES:	ACTION:
Scanner is too close to monitor.	Move scanner head away from monitor.

SYMPTOM

IMAGE IS CLEAR, BUT DISTORTED OR CONDENSED

PROBABLE CAUSES:	ACTION:
The monitor is near a magnetic field.	Move the monitor out of the magnetic field.
System is out of phase (saw tooth pattern on a vertical edge in image).	Check system phasing as described in Section 4, Paragraph 4.3.6.3.
Low battery voltage (look for warning indicator on screen).	Replace with a freshly charged battery.

SYMPTOM

IMAGE BREAKS UP (SEVERE PHASING PROBLEM THAT GROWS WORSE)

PROBABLE CAUSES:	ACTION:
Control/electronics is overheated.	Move control/electronics to cooler environment.

SYMPTOM

INTERMITTENT ABNORMAL OPERATION

PROBABLE CAUSES:	ACTION:
Loose interconnecting cable or cable damage.	Turn system OFF. Check all connectors for tight fit and broken, loose, or missing pins.

SYMPTOM

LOW NiCad BATTERY LIFE

PROBABLE CAUSES:	ACTION:
Battery has built up a memory from partial discharge and recharge cycles.	Completely discharge battery and recharge (see battery instructions).

SYMPTOM

SYSTEM "LOCKS UP" - TEMPERATURE SPAN AND CENTER TEMP INOPERATIVE

PROBABLE CAUSES:	ACTION:
If center temperature only, it may be in LOCK mode.	Check menu, set CTR TEMP to man or auto.
	Go to AUX MENU. Set AUX to FIELD CAL mode. Follow instructions to restore original system parameters.

Warning messages may appear on the screen indicating that temperature measurements may not be valid. The following messages may appear:

BATTERY VOL. LOW
CENTER TEMP ONLY
DETECTOR COOLING
FOCUS LIMIT
OUT OF RANGE
SERVICE COOLER

BATTERY VOL. LOW—indicates that the input voltage to the system is below specification. This condition is typically caused by an uncharged or partially charged battery.

CENTER TEMP ONLY—indicates that temperature measurements can only be made at the center temperature.

DETECTOR COOLING—indicates that the temperature of the detector has not reached operating temperature.

FOCUS LIMIT—indicates that the mechanical drive limit for focusing the lens has been reached, for the direction selected (near/far).

OUT OF RANGE—indicates that either the high end or low end of the temperature span for the selected range exceeds specification. Temperature measurements out of the selected range may not be accurate.

SERVICE COOLER—the cooler needs to be serviced by Inframetrics trained personnel. Measurements may not be accurate since the cooler may not be cooling the infrared detector to proper operating temperature.

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Temperature, Emissivity, Reflectance and Transmittance Measurement

Introduction

A thermal imaging radiometer responds to the sum of the emitted, reflected and transmitted energies coming from the object of interest (the target). This combination of energies is called target exitance or target radiosity (Figure A-1). To obtain the target temperature, the emitted energy must be extracted by subtracting the reflected and transmitted energies from the incoming radiosity. The result then must be scaled up by the emissivity to obtain a blackbody equivalent value. This value can then be converted to temperature by querying the calibration lookup table within the software of the Model 760. The resultant temperature is displayed on the monitor. *A.1*

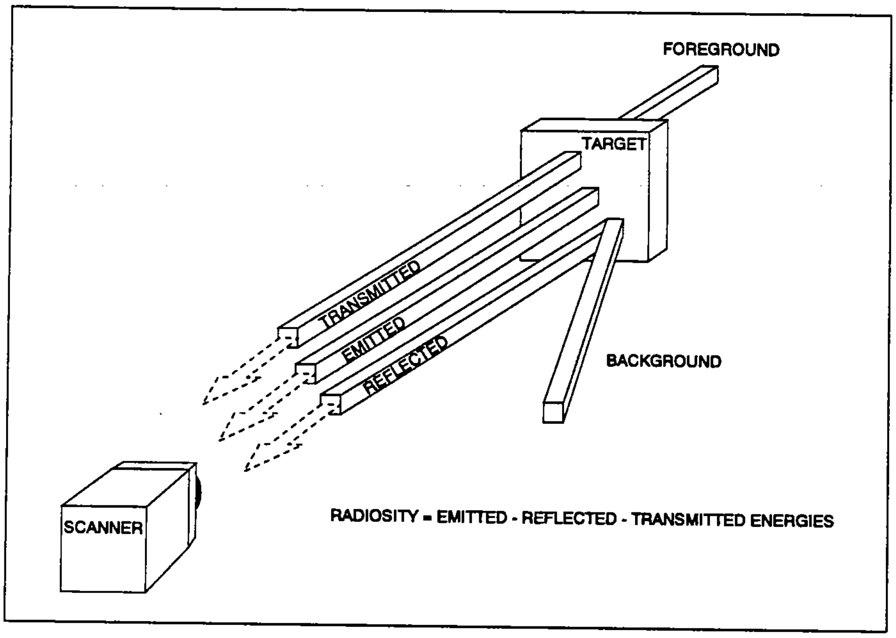


Figure A-1
Target Radiosity

In all Model 760 internal calculations, the greybody approximation is assumed. For a graybody, the emissivity, reflectance and transmittance are constant for all wavelengths within the waveband over which the instrument measures. The techniques described below also assume the graybody approximation.

The Model 760 temperature extraction algorithm is written for opaque targets since they comprise the majority of cases. For transmissive targets (non-opaque), the special case where the foreground radiance equals the background radiance is admissible.

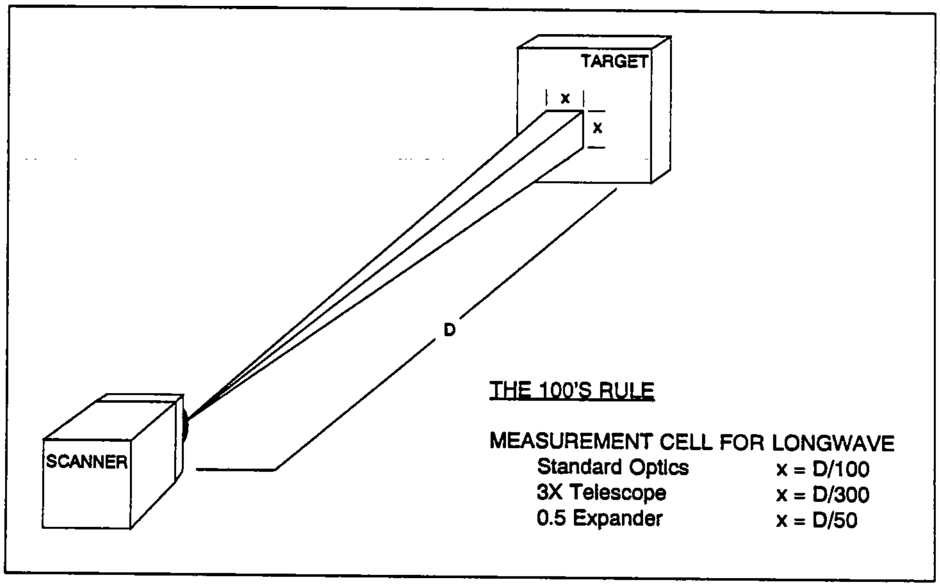
Temperature Measurement—Opaque Targets *A.2*

Using the Model 760 for temperature measurement of opaque objects requires knowledge of:

a. Background Temperature
b. Target Emissivity
c. External Optics Transmittance

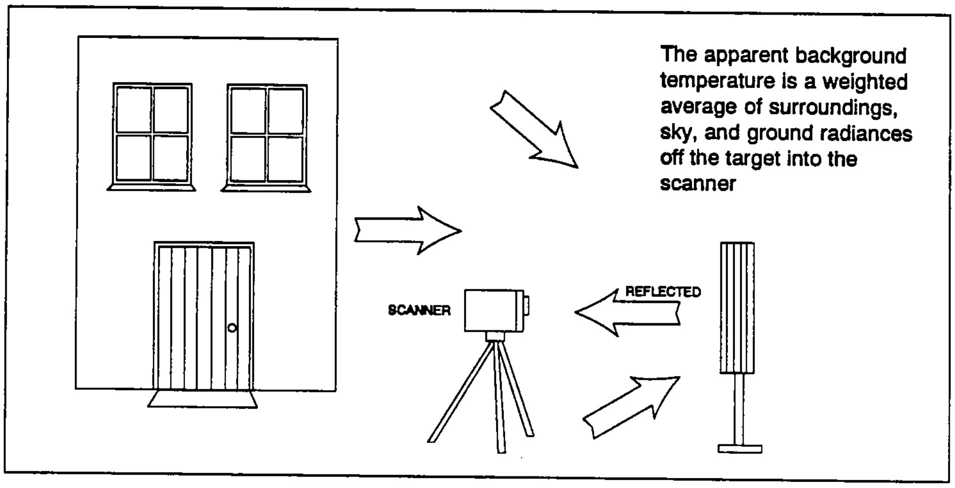
All these parameters can be obtained using the Model 760. Emissivity, reflectance and transmittance measurements follow this discussion. For measurement of any of these values, an extended source is assumed. An extended source is one which is large enough to provide at least one measurement cell. Thus, signal modulation due to system resolution will not affect the measurements. For the Model 760 long waveband (8-12μm) system with standard optics, a measurement cell is 1/100 times the distance between the target and the internal focusing lens (Figure A-2). Note that the optical path internal to the scanner is about 9" between the center of the lens and the detector. A measurement cell can be thought of as the area over which the instrument averages to obtain a single point reading. Thus for a point temperature measurement of a target at 100", the readout is the average over an area of about 1" x 1".

Figure A-2
Measurement Cell



"Background" is defined for the purposes of this discussion, as the energy which will be reflected off the target into the scanner (Figure A-3). "Foreground" is defined as the energy which will be transmitted through a target into the scanner. The following steps outline the procedure for measuring the temperature of an opaque target:

Figure A-3
Background Temperature



The following steps outline the procedure for measuring the temperature of an opaque target:

Procedure for measuring the temperature of an opaque target

1. In the setup menu, set the EMISSIVITY to 1.00.
2. In the setup menu, set the EXT OPTICS transmission to the appropriate value (1.00 if no external optics).
3. Place a piece of aluminum foil in front of the target at the same orientation. For reasonably flat targets, foil pasted to a piece of cardboard works well. For convoluted targets, forming the foil over the surface can be advantageous.
4. In image mode, observe the thermal pattern of the foil. This image represents the background. If it is uniform, use the AREA mode to obtain an average temperature. If it is not uniform, make it uniform, if possible, by placing shields appropriately. Shielding can be any good emitter which will remain constant in temperature during the measurement period. If the background cannot be made uniform, measure and note the areas of variation.
5. Remove the foil.
6. In the setup menus, enter the background temperature measured in step 4 using the center temperature adjust knob. Also, in the setup menus, enter the appropriate target EMISSIVITY value.
7. Use any of the Model 760 measurement modes to measure the target temperature.

Note:
This procedure applies for both long and short wavebands

NOTE

The Model 760 is designed to provide the most accurate temperature measurement at the middle grey level of the display brightness range. This is most easily achieved if the AUTO CENTER TEMP function is used with the POINT or AREA modes with a small temperature span (eg. 10° C). Also, best accuracy will be achieved for high emissivity targets since emissivity uncertainty magnifies measurement error considerably for low emissivity targets.

A.3

Temperature Measurement — Non-opaque Targets

The temperature measurement algorithm in the Model 760 will work for non-opaque targets only in the special case where foreground radiance equals background radiance. Foreground radiance is inferred by removing the target and measuring foreground temperature with the emissivity set to 1.00 and the external optics transmission set appropriately. If this measurement equals the background temperature as measured above, use the above procedure to measure target temperature.

A.4

Emissivity Measurement

There are two basic techniques for measuring the target emissivity using the Model 760: directly by comparison with a known emitter at the same temperature and indirectly by calculation using measured values of reflectance (and transmittance if necessary). The first works well when a reference emitter can be applied to an opaque target; the target must be at a temperature different from the background. The reference emitter must be at the same temperature as the target. The second technique works well for smooth surfaces since reflected energy is measured. The second technique places no restriction on target temperature.

Also, the target need not be opaque with the second technique. However, the transmittance must be considered in addition to the reflectance when calculating the emissivity. The following procedures give the steps for the two measurements:

A.4.1 Reference Emissivity Technique

The target must be opaque. The target must be hotter or cooler than the background. Normally, the greater the temperature difference, the better the measurement. Bear in mind, though, that the target and/or the reference emitter could be damaged by too great a temperature. Also, temperatures below the dew point may cause condensation on the surface resulting in a spurious measurement. A ten to twenty degree Celsius temperature difference is usually adequate. Refer to Figure A-4 and follow this procedure to measure the emissivity:

1. Afix the reference emitter to the target.

2. Allow the Model 760 to stabilize by operating for 15 minutes. Make the following settings:
   a. CTR TEMP to AUTO
   b. EMISSIVITY to 1.00
   c. TEMP UNITS to LVL
   d. EXT OPTICS to 1.00 (or appropriate value)
   e. TEMPERATURE SPAN to 5 or 10

3. Measure the background level. Place a piece of aluminum foil in front of the target at the same orientation. For reasonably flat targets, foil pasted to a piece of cardboard works well. For convoluted targets, forming the foil over the surface can be advantageous. In image mode, observe the thermal pattern of the foil. This image represents the background. If it is uniform, use the area mode to obtain an average level reading. If it is not uniform, make it uniform in the region of the reference emitter by shielding, moving the reference or other adjustments. The background must be the same for the reference as for the target where measurements are made. Note the background level.

4. Measure the target level. Remove the aluminum foil and focus on the target. Note the target level.

5. Measure and note the reference level.

6. Calculate the target emissivity using the equation:

$$\text{Emissivity} = \frac{[\text{Target Level} - \text{Background Level}]}{[\text{Reference Level} - \text{Background Level}]} \times \text{Reference Emissivity}$$

Measure the emissivity several times. Use the average value for temperature measurements.

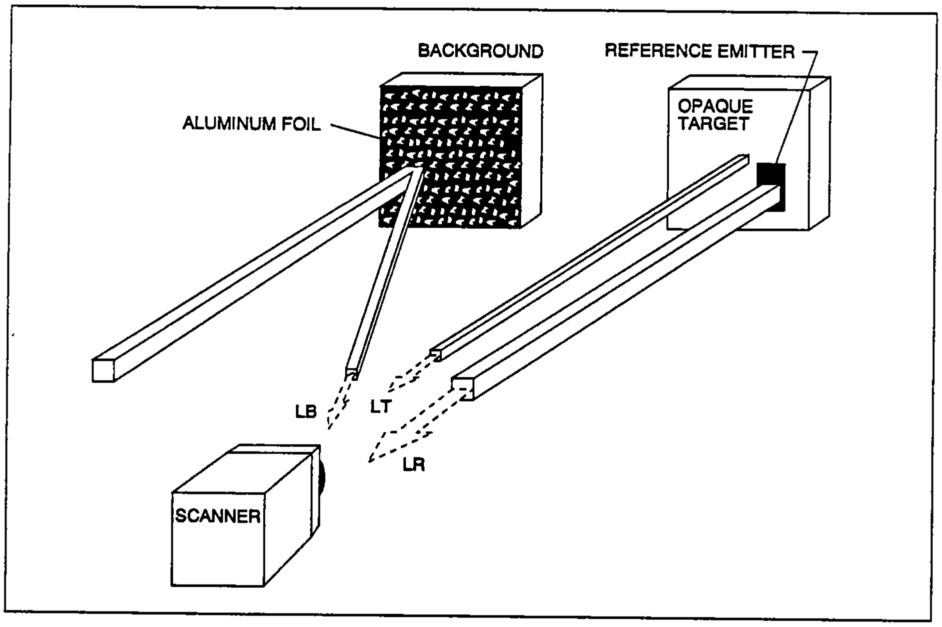


Figure A-4
Reference Emissivity Technique

Emissivity Calculated from Reflectance — Opaque Targets A.4.2

To calculate the emissivity of opaque targets with this technique, first measure the reflectance as outlined in A.5, below. Then calcu late the target emissivity using:

Target Emissivity = 1 - Target Reflectance (opaque target)

Emissivity Calculated from Reflectance and Transmittance — Non-Opaque Targets A.4.3

Measure the target reflectance using the procedure in A.5. Measure the target transmittance using the procedure in A.6. Calculate the emissivity using :

Target Emissivity = 1 - Target Reflectance - Target Transmittance

Reflectance Measurement A.5

This technique may be used for either waveband and works best with smooth surfaced targets which provide a crisp mirror reflection (specular reflector). The target need not be coated or touched; it can be at the same or different temperature from the background. The only restriction on target temperature is that it remain constant and uniform during the measurement of the reflected levels. The target need not be opaque. If it is transmissive be sure that the radiance level coming through the target is uniform over the area of measurement and constant for the measurement period.

The following procedure requires two energy sources with different radiances. They need not be blackbodies, but should be reasonably good emitters. Their radiances must remain constant throughout the measurement. They should be different enough in temperature to provide good radiance contrast. The ratio of the thermal level difference reflected off the target to that of the thermal level difference measured directly yields the target reflectance. Using the difference of two reflecting sources causes the emitted and transmitted target energies to cancel.

Typical sources include a piece of cardboard at ambient and a blackbody source at, say, 50°C; ambient cardboard and a person's hand (recommended only when nothing else is available); or two blackbodies, one at, say, 30°C and one at 50°C. For small targets one may need to reduce the size of the source. Two electrical resistors of different values wired in parallel with a constant voltage across them can work well as small sources. The procedure is (see also Fig. A-5):

Procedure for reflectance measurement

1. Position the two temperature sources near the target, power them up if necessary, and let them stabilize.

2. Allow the Model 760 to stabilize by operating for 15 minutes. Make the following settings :

    a. CTR TEMP to AUTO
    b. EMISSIVITY to 1.00
    c. TEMP UNITS to LVL
    d. EXT OPTICS to 1.00 (or appropriate value)
    e. TEMPERATURE SPAN to 5 or 10

3. With the Model 760 camera aiming directly at the sources, focus on and measure their respective levels using point or area mode.

4. Reposition the Model 760 scanner, the sources and the target so the reflections of the sources are visible on the display screen. If necessary, one source reflection at a time may be measured. Using point or area mode measure the target where the reflection(s) is (are) visible. Adjust the focus to provide crisp image of the sources.

5. Calculate the target reflectance using:

$$\text{Target Reflectance} = \frac{[\text{Source A Refl Level - Source B Refl Level}]}{[\text{Source A Dir Level - Source B Dir Level}]}$$

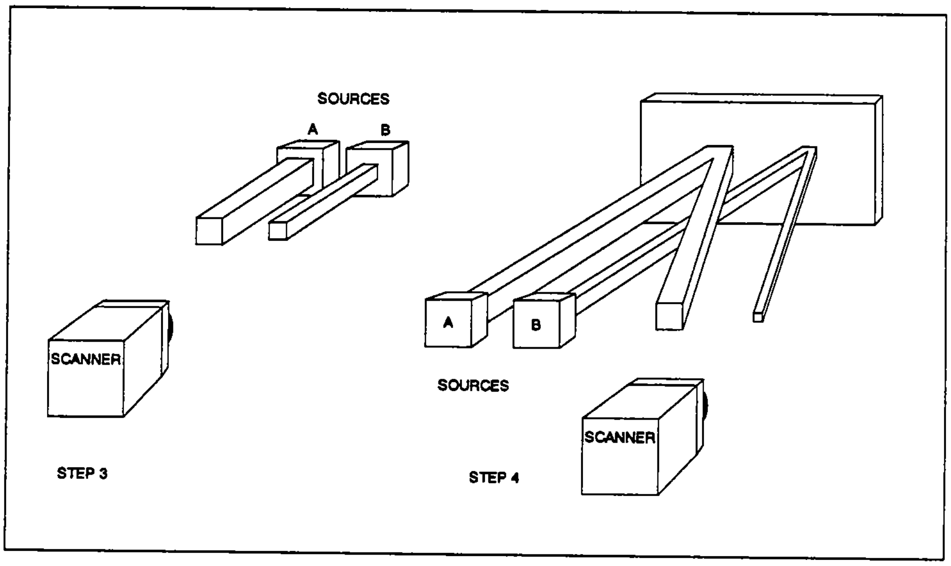


Figure A-5
Reflectance Measurement

A.6

Transmittance Measurement

The transmittance of a non-opaque target is measured similarly to the above reflectance measurement. Two sources of different radiance are used. Their respective levels are measured directly. Then the target is placed between them and measurements are taken where the sources are seen through the target. The ratio of the difference of the source levels with the target interposed to the difference of the source levels directly gives the target transmittance. Difference measurements are used to negate the effect of the target and background radiance. Thus, no restriction is placed on target and background temperatures except that they must remain constant in time and uniform over the measurement area when the target is placed in front of the sources.

The following procedure requires two energy sources with different radiances. They need not be blackbodies, but should be reasonably good emitters. Their radiances must remain constant throughout the measurement. They should be different enough in temperature to provide good radiance contrast. See A.5 for more details. The procedure is:

Procedure for transmittance measurement

1. Position the two temperature sources near the scanner, power them up if necessary, and let them stabilize.
2. Allow the Model 760 to stabilize by operating for 15 minutes. Make the following settings:

    a. CTR TEMP to AUTO
    b. EMISSIVITY to 1.00
    c. TEMP UNITS to LVL
    d. EXT OPTICS to 1.00 (or appropriate value)
    e. TEMPERATURE SPAN to 5 or 10

3. With the Model 760 camera aiming directly at the sources, focus on and measure their respective levels using POINT or AREA mode.

4. Place the target between the Model 760 scanner and the sources. Adjust the focus to provide a crisp image of the sources. Using POINT or AREA mode, measure the target levels where the images of the transmitted sources are visible.

5. Calculate the target transmittance using:

Target Transmittance Calculation

$$\text{Target Transmittance} = \frac{[\text{Source A Trans Level} - \text{Source B Trans Level}]}{[\text{Source A Dir Level} - \text{Source B Dir Level}]}$$

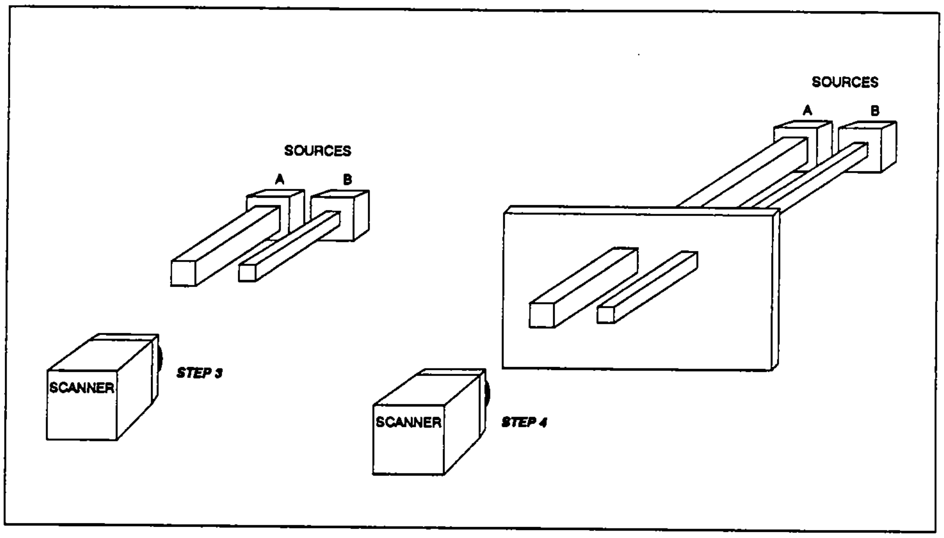


Figure A-6
Transmittance Measurement

A.7 Emissivity Values of Common Materials

Emissivity values obtained using the above procedures are averaged over the response of either wavebands of the Model 760. Though the procedures may not produce as high an accuracy as other methods, the fact that the same instrument can be used to find emissivity as to subsequently determine temperature for the same target can be tremendously advantageous. Spectral emitters (non-greybodies) will be properly averaged if their emissivity is measured at about the same temperature as they will be utilized. That is, for spectral emitters, it will appear that their emissivity changes with temperature since the blackbody radiance curve is weighted non-uniformly by them.

Do not assume an emissivity value in the 3-5μm waveband will be the same in the 8-12μm waveband. Many materials, especially plastics and polymers exhibit spectrally emissive behavior. Other materials may also be different. Spectrally these two wavebands are far apart. The emissivity values in the following table are total normal emissivitys. The measurements were made perpendicular to the target surface with a broadband instrument. Where two values are given the first corresponds to the first temperature and the second to the second temperature.

Since Table A-1 lists total emissivity measured with a broadband instrument, there could be significant differences in specific wavebands. Use these values as a guide. Measurement with the Model 760 will provide better values for your specific target.

Table A-1
Total Normal Emissivity of Common Materials

	Temperature (°F)		Emissivity*	
Aluminum				
Highly polished plate. 98.3% pure	440	1070	0.039	0.057
Polished Plate	73		0.040	
Rough Plate	78		0.055	
Oxidized at 1110° F	390	1110	0.11	0.19
Al-surfaced roofing	100		0.216	
Calorized surfaces, heated at 1110° F				
Copper	390	1110	0.18	0.19
Steel	390	1110	0.52	0.57
Brass				
Highly polished:				
73.2% Cu. 26.7% Zu	476	674	0.028	0.031
62.4% Cu. 36.8% Zn. 0.4% Pb. 0.3% Al	494	710	0.033	0.037
82.9% Cu. 17.0% An	530		0.030	
Hard rolled, polished, but direction of polishing visible	70		0.038	
but somewhat attacked	73		0.043	
but traces of stearin from polish left on	75		0.053	
Polished	100	600	0.096	
Rolled plate, natural surface rubbed with coarse emery	72		0.20	
Dull plate	120	660	0.22	
Oxidized by heating at 1110° F	390	1110	0.61	0.59
Chromium: see Nickel Alloys for Ni-Cr steels	100	1000	0.08	0.26
Copper				
Carefully polished electrolytic copper	176		0.018	
Comm'l ., emeried, polished but pits remaining	66		0.030	
Comm'l. scraped shiny but not mirror like	72		0.072	
Polished	242		0.023	
Plate, heated long time, covered with thick oxide layer	77		0.78	
Plate heated at 1110° F	390	1110	0.57	
Cuprous oxide	1470	2010	0.66	0.54
Molten copper	1970	2330	0.16	0.13
Gold				
Pure, highly-polished	440	1160	0.018	0.035
Iron and Steel				
Metallic surfaces (or very thin oxide layer):				
Electrolytic iron, high polished	350	440	0.052	0.064
Polished iron	800	1880	0.144	0.377

* Two emissivities are shown for the two given temperatures

Table A-1
Total Normal Emissivity of Common Materials (continued)

	Temperature (°F)		Emissivity	
Iron freshly emeried	68		0.242	
Cast iron, polished	392		0.21	
Wrought iron, highly polished	100	480	0.28	
Cast iron, newly turned	72		0.435	
Polished steel casting	1420	1900	0.52	0.56
Ground Sheet steel	1720	2010	0.55	0.61
Smooth sheet iron	1650	1900	0.55	0.60
Cast iron, turned on lathe	1620	1810	0.60	0.70
Oxidized surfaces:				
Iron plate, pickled, then rusted red	68		0.612	
completely rusted	67		0.685	
Rolled sheet steel	70		0.657	
Oxidized iron	212		0.736	
Cast iron, oxidized at 1100° F	390	1110	0.64	0.78
Steel oxidized at 1100° F	390	1110	0.79	
Smooth oxidized electrolytic iron	260	980	0.78	0.82
Iron oxide	930	2190	0.85	0.89
Rough ingot iron	1700	2040	0.87	0.95
Sheet steel, strong rough oxide layer	75		0.80	
dense shiny oxide layer	75		0.82	
Cast plate, smooth	73		0.80	
rough	73		0.82	
Cast iron, rough, strongly oxidized	100	480	0.95	
Wrought iron, dull oxidized	70	680	0.94	
Steel plate, rough	100	700	0.94	0.97
High temp. alloy steels (see Nickel Alloys)				
Molten Metal				
cast iron	2370	2550	0.29	
mild steel	2910	3270	0.28	
Lead				
Pure (99.96%), unoxidized	260	440	0.057	0.075
Gray oxidized	75		0.281	
Oxidized at 390° F	390		0.63	
Mercury	32	212	0.09	0.12
Molybdenum filament	1340	4700	0.096	0.292
Monel metal, oxidized at 1110° F	390	1110	0.41	0.46
Nickel				
Electroplated on polished iron, then polished	74		0.045	
Technically pure (98.9% Ni. + Mn). polished	440	710	0.07	0.087
Electroplated on pickled iron, not polished	68		0.11	
Wire	368	1844	0.096	0.186
Plate, oxidized by heating at 1110° F	390	1110	0.37	0.48
Nickel oxide	1200	2290	0.59	0.86

Table A-1
Total Normal Emissivity of Common Materials (continued)

	Temperature (°F)		Emissivity	
Nickel Alloys				
Chromnickel	125	1894	0.64	0.76
Nickelin (18-32 Ni: 55-68 Cu: 20 Zn). gray oxidized	70		0.262	
KA-2S alloy sttel (8% Ni: 18% Cr). light silvery, rough, brown after heating	420	914	0.44	0.36
after 42 hr. heating at 980° F	420	980	0.62	0.73
NCT-3 alloy (20% Ni: 25% Cr). Brown splotched, oxidized from service	420	980	0.90	0.97
NCT-6 alloy (60% Ni: 12% Cr). Smooth black, firm adhesive oxide coat from service	520	1045	0.89	0.82
Platinum				
Pure, polished plate	440	1160	0.054	0.104
Strip	1700	2960	0.12	0.17
Filament	80	2240	0.036	0.192
Wire	440	2510	0.073	0.182
Silver				
Polished, pure	440	1160	0.0198	0.0324
Polished	100	700	0.0221	0.0312
Steel, see iron				
Tantalum filament	2420	5430	0.194	0.31
Tin-Bright tinned iron sheet	76		0.043	0.064
Tungsten				
Filament, aged	80	6000	0.032	0.35
Filament	6000		0.39	
Zinc				
Comm'l. 99.1% pure, polished	400	620	0.045	0.053
Oxidized by heating at 750° F	750		0.11	
Galvanized sheet iron, fairly bright	82		0.228	
Galvanized sheet iron, gray oxidized	75		0.276	
MISCELLANEOUS				
Asbestos				
Board	74		0.96	
Paper	100	700	0.93	0.945
Brick				
Red, rough, but no gross irregularities	70		0.93	
Silica, unglazed, rough	1832		0.80	
Silica, glazed, rough	2012		0.85	
Grog brick, glazed	2012		0.75	
See refractory Materials below.				
Carbon				
T-carbon (Gebr. Siemens) 0.9% ash	260	1160	0.81	0.79
This started with emissivity at 260° F of 0.72, but on heating changed to values given				

Table A-1
Total Normal Emissivity of Common Materials (continued)

	Temperature (°F)		Emissivity	
Carbon filament	1900	2560	0.526	
Candle soot	206	520	0.952	
Lampblack-waterglass coating	209	362	0.959	0.947
Same	260	440	0.947	0.952
thin layer on iron plate	69		0.927	
thick coat	68		0.967	
Lampblack, 0.003 in. or thicker	100	700	0.945	
Enamel, white fused, on iron	66		0.897	
Glass, smooth	72		0.937	
Gypsum, 0.02 in. thick on smooth or blackened plate	70		0.903	
Marble, light gray, polished	72		0.931	
Oak, planed	70		0.895	
Oil layers on polished nickel (lub. oil)	68		——	
Polished surface, alone	—		0.045	
+0.001 in. oil	—		0.27	
+0.002 in. oil	—		0.46	
+0.005 in. oil	—		0.72	
thick oil layer	—		0.82	
Oil layers on aluminum foil (linseed oil)				
Al foil	212		0.087	
+1 coat oil	212		0.561	
+2 coats oil	212		0.574	

Basic Infrared Theory for Imaging Radiometers

Introduction *B.1*

Thermography is the process of generating a thermogram by using an infrared imaging system, usually with some means of temperature calibration. A thermogram is a photograph or two dimensional record of an image which maps the apparent temperature of the scene as sensed by an infrared imaging system. A thermal imaging radiometer is a device which produces thermograms and measures quantitatively the thermal radiation within a definite waveband incident upon it.

Thermograms can be portrayed in black and white (B&W) or color. Color thermograms delineate temperature variations quite well at the expense of spatial detail. Black and white thermograms delineate spatial variations quite well at the expense of temperature detail. Modern thermal imaging radiometers display both color and B&W as well as providing absolute temperatures.

The purpose of this appendix is to use basics of infrared theory to identify performance criteria for selection of a thermal imaging radiometer.

Thermal Imaging Radiometers *B.2*

Thermal imaging radiometers not only display an image of the heat patterns radiating from surfaces, they are designed to produce temperature information as well. This is a big step since none of these instruments measures temperature directly, but must infer temperature from the measured radiant energy. The great advantage of thermal imaging radiometers over non-contact thermometers is they allow rapid assessment of a situation via thermal patterns and show the operator exactly what is being measured. They also have a much faster response time (nanoseconds vs. milliseconds) than non-contact thermometers. A thermal imaging radiometer performs over 1 million measurements per second. Pattern recognition by the operator facilitates real time or post processing analysis of the right area at the right time. With video recording and computer processing, tremendous amounts of thermal data can be archived, accessed and analysed. The major disadvantage of thermal imaging radiometers compared to non-contact thermometers is their cost which is typically 20 to 30 times higher.

Many types of non-contact temperature measurement instruments are available today. Nearly all rely on the same basic physical phenomenon: All real-world objects radiate energy; the amount of energy radiated increases with increasing temperature. The radiated energy is distributed over a band of wavelengths in the electromagnetic spectrum (Fig. B.1).

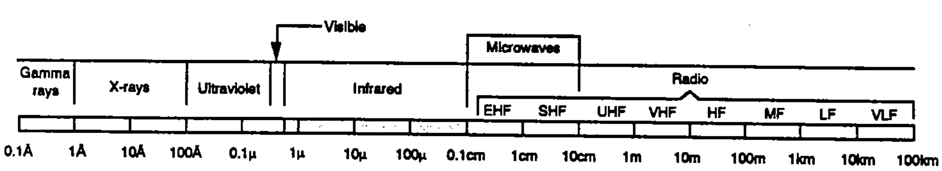


Figure B-1
The Electromagnetic Spectrum

The spectrum spans from low frequency radio waves to microwaves, then to the infrared, visible light and X-Ray wavelengths. The distribution for a specific object temperature is the Planck function. The peak of this curve moves toward shorter wavelengths as the object temperature increases (Fig. B-2). The Planck distribution is modulated by the efficiency of the object as a radiator. This efficiency, called emissivity, is 100% for a perfect radiator, called a blackbody. Real objects have emissivities less than one which can vary with wavelength.

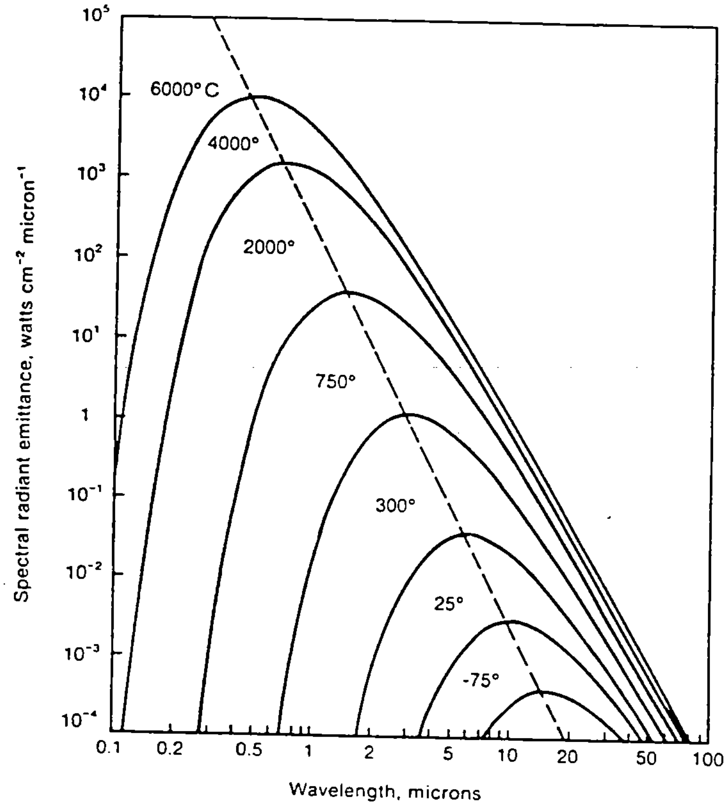


Figure B-2
Blackbody Radiation Curves

Objects at or near room temperature have spectral energy distributions that peak in the middle infrared region, near 10μm (micrometers). A sufficient amount of energy is radiated to allow detection at great distances by a sensitive instrument. The consistency of the relationship between object temperature and radiated energy allows a calibrated instrument to make highly accurate non-contact temperature measurements.

High performance thermal imaging radiometers differ from conventional television cameras in several ways. One class of system operates with one or a few individual detector signals scanned mechanically across the screen rather than with the large photosensitive surface typical of a TV camera. These detectors must be cooled to cryogenic temperatures. Another class of system, the pyroelectric vidicon, is similar to a television camera, employing a large, uncooled, thermally sensitive surface. However, due to the nature of the pyroelectric effect, these systems are difficult to quantify. The Schottky barrier is also a large surface obviating mechanical scanners. It has not yet been developed into a viable thermal imaging radiometer. Consequently, the discussion will be limited to mechanical scanning systems.

To perform accurate temperature measurements, thermal imaging radiometers incorporate a blackbody reference source that is viewed periodically by the detector for calibration. They use lenses and windows that transmit infrared wavelengths of electromagnetic energy; materials such as germanium, zinc sulfide, and silicon are typical. Optical filters can tailor the spectral response of thermal imaging radiometers to optimize measurement of (or transmission through) specific materials including gases, plastics, and flames. Low pass, high pass, band pass, reject and attenuating optical filters are available.

While thermal imaging radiometers employ many types of scanners, the specific type is generally not apparent to the operator. Nearly all systems incorporate scan conversion circuitry to create a TV compatible output. The referencing technique may also be obscure since electronic circuits perform recalibration during the invisible blanking portion of the TV image.

B.3

System Performance

The performance of a thermal imaging system is measured in a way that shows the total quantity of useful output information in a unit of time. This includes a combination of the thermal sensitivity or equivalent random noise level, the scan speed or update rate of the scanner, and the image resolution or number of independent measurement data points within the image. Other considerations include system dynamic range, spectral band sensitivity, calibration and accuracy. Features such as weight, power consumption, display and user friendliness follow these parameters and can be readily evaluated by the user.

An imaging system intended for night vision use, without measurement capability, will generally be specified by a comprehensive parameter known as MRTD (Minimum Resolvable Temperature Difference). MRTD is measured by determining the minimum thermal contrast needed for a human observer to identify a series of vertical bars using the system under test. The bars get smaller and closer together, thereby testing the system's image resolution. The thermal contrast (temperature difference between the bars and background) is small, testing the system's thermal sensitivity. The observer's eye performs temporal integration, offering a sensitivity improvement that is a function of the system's scan speed. A low MRTD indicates a system with a high performance figure of merit, and one with greater effectiveness in aiding the user to locate and identify small, low-contrast thermal targets.

A thermal imaging radiometer is a measurement system in addition to a viewer, and the performance is generally specified in a manner that is more useful in measurement applications. Three independent parameters— thermal sensitivity, scan speed and spatial resolution— replace the combined MRTD for thermal imaging radiometer specification. Thermal sensitivity is specified by noise equivalent temperature difference (NETD) defining the equivalent system noise level. Scan speed is the frame update rate of the scanner. Spatial resolution is most usefully specified by a continuous slit response function (SRF) curve.

The combination of the three yields an indication of the overall performance of a system. Tradeoffs among the three parameters may be made by a system designer for optimization, but it is the total that is most difficult to increase. Finally, these parameters must be incorporated into a quantitative system whose accuracy should be specified.

B.3.1 Thermal Sensitivity

Thermal energy is given off by objects in individual bursts known as photons, much the same as visible light. The timing between these burst is random. When very small samples of an object's radiation are made, the random emission of photons is visible as a variation in intensity, or thermal noise. Noise in the thermal image looks the same as the "snow" that is seen when a television camera operates in extremely low light. Both are caused by random noise of photons from either the scene or the light sensitive element in the camera.

A thermal imaging system is characterized by a noise equivalent temperature difference, the temperature difference between two objects that results in a signal equal to the random background noise of the camera. Averaging of multiple image data points reduces this noise level by the square root of the number of samples averaged. Well- designed instruments will average measurement points to reduce this noise. Noise is only significant when operating on the most sensitive ranges, viewing low thermal contrast targets.

B.3.2 Scan Speed

The rate at which complete thermal images are updated by a particular mechanical scanner is the scan speed of the system. The rate at which television images are updated on the monitor is the frame rate and is defined by television industry standards.

Low scan speeds offer low acoustic noise and low cost as advantages, but result in an image that distorts severely when the scanner or scene moves. In addition, low frame rates (below about 50 Hz) on non- T.V. compatible systems cause an annoying flicker in the display. Extremely low frame rate (slow scan) systems offer high thermal and spatial sensitivity but are very difficult to focus and point.

B.3.3 Spatial Resolution-Slit Response Function and IFOV

Spatial resolution is the ability of the thermal imaging system to detect and accurately measure the temperature of small objects, where "small" is defined relative to the size of the total image.

Resolution in the thermal image is seen as the ability to present a highly detailed picture versus one which appears unfocused, much the same as the difference between a low resolution computer graphics image and a high resolution CAD system. However, resolution is much more important for a measurement system since the accuracy of the temperature measurement at each point in the image depends on the degree of resolution, even beyond that which appears sharp to the eye.

Resolution is normally determined by characteristics not of the electronics, but of the scanner with it's optics scanning mechanism and detector. Typically, an infrared system will detect radiation at the scanner using a detector of finite size, thereby limiting the resolution. The electronics subsequently digitizes the image into picture elements, pixels, smaller than the detector samples. In this way, the pixel digitization does not reduce the system performance. One must be careful to realize that a 256 by 256 pixel image does not usually contain nearly as many true spatial resolution elements (detector samples).

The three-dimensional plot (Fig. B-3) shows the response of a typical electro-optical imaging system to a point source of illumination. As an example, this might show the relative response of a thermal imaging radiometer to a small, very hot object at a great distance. The vertical axis represents temperature and the X and Y axes represent horizontal and vertical dimensions on the television monitor.

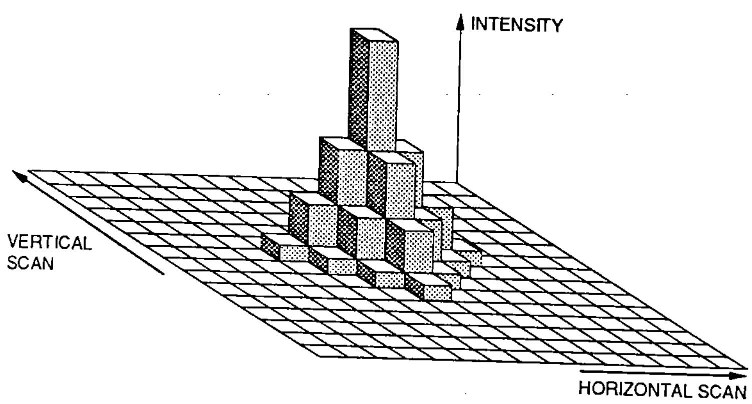


Figure B-3
Response to a Point Source

Notice that, due to the small object size, the response of the system to the object is less than 100%. As the object becomes larger, the response gradually approaches 100% and the measurement becomes more accurate. There is no particular point where the object measurement is 100% accurate, but rather there is a continuous curve of response versus object size.

It is convenient to characterize a thermal imaging system by the relative response to a vertical slit target of various widths. The curve of this response is called a slit response function (SRF), and is useful in determining the amount of error or required correction factor for a target that can be approximated by one or more slit shapes. Figure B-4 shows typical SRF curve.

The measured radiance of an object whose approximate SRF is known is a function of the object radiosity and average surroundings radiosity. An approximate equation in temperature form is:

$$T_{apparent} = (SRF)\ T_{object} + (1\text{-}SRF)\ T_{surround}$$

The error between apparent and true temperatures is greater when a large difference exists between the object and surroundings temperatures.

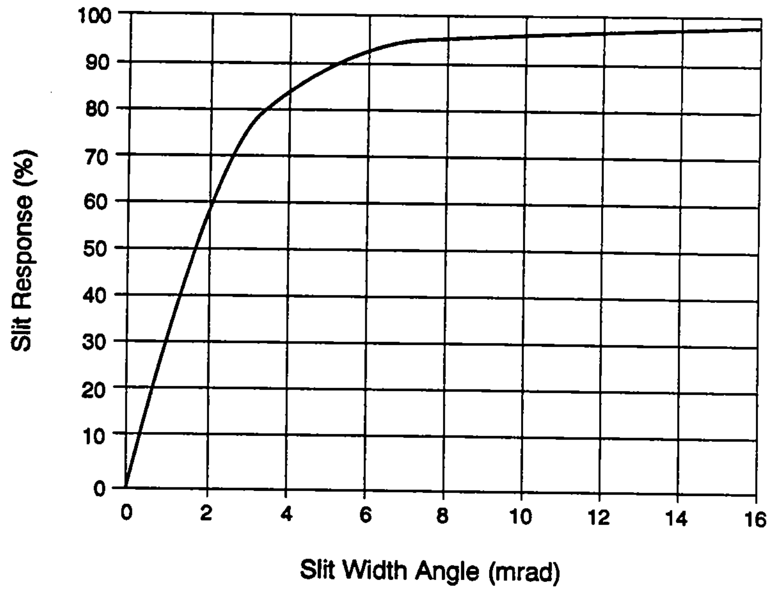


Figure B-4
Typical Slit Response Function

The instantaneous field of view (IFOV) is defined as the ratio of the detector size to the effective system focal length. Thus, a 0.001" by 0.001" (0.0254mm by 0.0254mm) detector with 0.5" (12.7mm) focal length would have a 1.8mr (milliradian) IFOV. The system 50% SRF and IFOV should be about the same, with the IFOV being somewhat larger.

B.3.4 Resolution Elements Per Image

Regardless of how one specifies resolution, it should be considered in context of the total image as well. A wide field of view (FOV) with good resolution is much more desirable than a narrow FOV with the same resolution. A measure of this is the total number of resolution elements per image. To find the total, divide the horizontal FOV by the resolution element size and multiply the result by the number of infrared (IR) lines per image. For example, a scanner which has a 1.8mr 50% SRF, 20 degree horizontal FOV and 200 IR lines per image generates almost 39,000 resolution elements per image. Note that the scanning mechanism determines the number of IR lines per image. The number of TV lines displayed per image, though important, is not the critical specification.

B.3.5 Dynamic Range

Dynamic range specifies the ability of a thermal imaging system to resolve fine temperature differences while simultaneously imaging large temperature spans. Dynamic range can be expressed as the number of grey shades, or digital levels of intensity, used to encode the thermal image, much like the number of gradations on a thermometer.

Since many measurements are made after an image has been stored either on videotape, computer disk, or the internal image memory, it is important to be able to accurately measure every object in the image without adjusting the controls. A greater number of levels of encoding allows both goals of fine resolution and wide span to be met simultaneously.

B.3.6

Calibration and Accuracy

Thermal imaging systems measure radiation within a certain spectral band and must convert radiant intensity to temperature by the use of a measured calibration curve. Due to variations in system spectral response, every system has a unique calibration curve. Any modifications to the spectral response, such as the use of optical filters, will create a new curve. Also, any add-on optical elements such as telescopes and windows will reduce the transmission of radiation and change the slope of the curve.

The basic calibration curves for modern thermal imaging radiometers are measured at the factory and stored in a read-only memory along with any special curves for installed optical filters. Older instruments generally have printed calibration curves which the operator must access to infer temperatures. When additional optics are used, the spectral response is generally flat enough to be insignificant, so that only a transmission factor is required. Some instruments can sense when a particular optic is attached and automatically correct for it's inherent transmission loss.

The error in measurement of any system can be divided into a random error (precision) and a fixed error (bias). The purpose of instrument calibration is to remove the bias and define the precision. The NETD of a thermal imaging radiometer a measure of it's precision. Should manufacturers be able to totally remove bias through calibration, thermal imaging radiometers would be very accurate given typical NETDs of 0.18°F (0.1°C). However, most instruments are calibrated over a wide range of target temperatures, typically several hundred degrees Fahrenheit. Bias is difficult to remove over this broad range. The calibration curve fit to the data points will be imperfect. The quality of the fit depends on the number of calibration data points taken and on the algorithm used.

Thermal imaging radiometers must also endure wide variations in environmental temperatures. Since these instruments are AC coupled devices, they really measure differences. To get absolute temperatures, there must be a reference to provide DC restoration. In many instruments the reference is the internal scanner temperature. Thus, if the scanner temperature varies from it's value at calibration, the DC restoration level will shift. To provide a versatile instrument, this shift is compensated for electronically. The internal reference is usually measured with a thermistor or other electronic temperature sensor. System accuracy is intimately related to the accuracy of this sensor and the quality of electronic controls to compensate for instrument temperature changes.

Detector sensitivity changes rapidly with detector temperature. Thus, good stability in detector temperature is mandatory. For years, liquid nitrogen has been used as a detector coolant. As a liquid evaporating under its own vapor pressure, it's temperature stability is excellent. Joule-Thompson (J-T) cooling is the expansion of a high pressure gas through a small orifice. Thermoelectric (TE) cooling employs the Peltier effect. Its advantage is that only electricity, no gas or liquid, is used. TE cooling can be used only to cool detectors responsive in the 3-5μ region. Another all-electric cooling mechanism is the Stirling engine. The

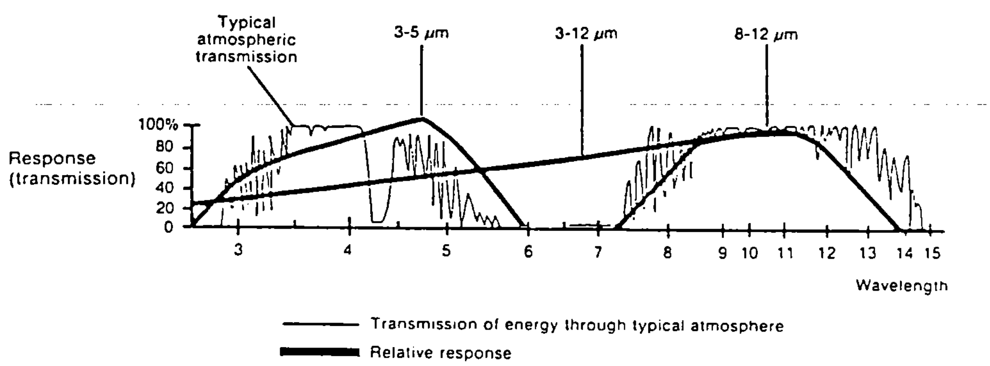
Stirling engine or closed cycle cooling system maintains an absolute cryogenic temperature and may be used with shortwave, longwave or broadband detectors.

Finally, changes in detector sensitivity, optics transmission and electronic drift will cause the instrument to go out of calibration over a period of time. Every instrument must periodically be recalibrated according to manufacturers' recommendations.

Spectral Band Selection

The earth's atmosphere absorbs radiated energy in the infrared except for two wavelength regions called the atmospheric windows (Figure B-5). Typically, it is the water vapor in the atmosphere that absorbs the majority of the infrared energy over much of the spectral band. Many gases absorb as well, but generally at only one or a few narrow spectral lines.

Figure B-5
Atmospheric Transmission



The atmospheric windows allow radiometric measurements with minimal losses. The 8-14μm (longwave) region is exceptionally free of absorbtion except with very high atmospheric water content. The 3-5μm (shortwave) region has relatively high transmission, but usually requires compensation when high accuracy measurements are to be made at path lengths greater than one meter.

Modern thermal imaging radiometers are available with 8-14μm (longwave), 3-5μm (shortwave), or 3-14μm (broadband) spectral response. Instruments are also available which detect and image short and long wavebands independently and simultaneously. These are often called "two color" systems.

Due to a higher thermal contrast at "earth" temperatures (-4° F to about 120° F or -20° C to 50° C) in the longwave region, greater overall system performance can be achieved. At higher temperatures, the 3-5μm wave band exhibits higher thermal contrast. However, there is always more energy at higher temperatures in a given waveband. So, if the 8-14μm waveband is adequate at earth temperatures, it will certainly be adequate at higher temperatures. In fact, filters must often be used to limit the amount of radiant energy impinging on the detector at higher temperatures in both wavebands.

Most common material surfaces have higher emissivities in the 8-14μm waveband. Some surfaces have higher emissivity in the shortwave region. Often one waveband will be preferred due to the spectral emissivity characteristics of the target to be measured.

Sun glint is a far more serious problem in the 3-5μm waveband than in the 8-14μm waveband. There is several hundred times more energy from the sun in the 3-5μm waveband than in the 8-14μm waveband. Thus even a minor reflection of the sun's energy from a surface into the detector can saturate a 3-5μm system while the 8-14μm system remains relatively unaffected. For outdoor work this requires users of 3-5μm waveband systems to be extremely cautious in their viewing and interpretation of their thermal imagery.

Lower cost detectors, and thermoelectrically cooled detectors are available for the 3-5 μm band. The need to correct for atmospheric transmission generally results in less accurate temperature measurements. Broadband systems have the highest sensitivity, but are most susceptible to atmospheric losses and variations in atmospheric transmission due to weather conditions.

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blackbody — an ideal thermal radiator (emissivity 1.0) which emits and absorbs the maximum theoretically available amount of thermal radiation at a given temperature.

BNC — a video connector with interlocking male and female components

electromagnetic spectrum — the entire range of radiation extending in frequency approximately from 10^{23} cycles per second to 0 cycles per second.

emissivity — a normalized ratio indicating the ability of a surface to emit radiant energy compared to that of a blackbody. The emissivity of human skin is about 0.98.

FOV — an abbreviation for field of view.

galvanometer — a motor-like device which drives each of the scanning mirrors in a back and forth motion.

IFOV — an abbreviation used for instantaneous field of view— the angular field which the infrared detector element detects or senses; measured in mRad, or milliRadians.

isotherm — a line of equal temperature.

MDT — an abbreviation for minimum detectable temperature.

NTSC — National Television Standards Committee. U.S. television color encoding standard.

radiometer — an instrument for detecting and measuring radiant energy.

RGB — an abbreviation standing for red, green, blue — a video format where each primary color is transmitted separately via a separate cable.

scanner — an electro-optical mechanical system using mirrors and a sensor for creating an image.

spectral response — that part of the electromagnetic spectrum over which a sensor system responds.

SRF — an abbreviation used for slit response function.

µm — the unit symbol for microns or micrometers; 1×10^{-6} meters.

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INDEX

INDEX

T

U

V

W

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