IR FLEXCAM® S

PORTABLE INFRARED SYSTEM

USER MANUAL

infrared SOLUTIONS

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IR FlexCam S® User Manual

Preface

The IR FlexCam S® is one of the FlexCam family of handheld portable infrared cameras – IR FlexCam Pro®, IR FlexCam T® and IR FlexCam S®. The IR FlexCam family of cameras are battery (or auxiliary AC) powered; with built-in image storage via a removable CompactFlash card and varying degrees of on-screen temperature measurement and image analysis. Images can also be output from the cameras as TV-compatible video for presentation purposes.

The IR FlexCam S® has an on-camera center point temperature measurement. Images can be saved in a JPEG format and when transferred to a PC, the image center point temperature mark and value are included in the JPEG Image.

The IR FlexCam S® comes with a Microsoft Windows® compatible software program for your PC called FlexView Report™. This computer program can be used to view images, re-stored them elsewhere, and printed them. The program also provides the ability to prepare custom reports containing the infrared graphics, center point temperature, an imported visible CCD image and comments.

Scope

This Manual provides instructions for initial setup, operation and care of the Infrared Solutions' IR FlexCam S® handheld imaging radiometer. It consists of an introductory section followed by six chapters which describe 1) the operator interfaces and controls, 2) the camera hardware design features, 3) camera setup procedures, 4) camera operation, 5) image interpretation and 6) a discussion on the camera optics. In addition there are four appendices with useful information on thermography. Though the document presents troubleshooting tips, it is not a maintenance and repair manual. The theory of infrared technology is presented, where necessary, to help with target selection and image captures.

Table of Contents

Unpacking

The IR FlexCam S^{8} comes in a rugged customized carrying case packed in a heavy corrugated shipping container with foam packing.

Unpack all equipment and account for each item using the shipping papers. Inspect components for damage. If damage is noted, please notify the freight carrier and Infrared Solutions Customer Service immediately [telephone (800)760-4523].

Caution

Care should be taken in handling the IR FlexCam S^{8} camera. Although the radiometer is a rugged instrument, it should be handled like any sophisticated camera equipment.

The lens is made of Germanium, a material transparent to infrared radiation. It is coated with a multilayer antireflection coating for the 8 to 12 µm wavelength range. It should be treated with care. To clean the lens, use lukewarm water and mild detergent (Ivory Liquid or Liqui-Nox) and a soft cotton material. Rinse with clean lukewarm water and dry lightly with soft clean cotton. If wiping streaks remain, use reagent grade Acetone or reagent grade Methanol Alcohol. Soak corner of clean, soft cotton with acetone or alcohol and wipe gently. Germanium lenses and windows may also be cleaned using reading glasses cleaning tissues. Rub lightly with the cleaning tissues to avoid damage to the optical coating.

Quick Start

1) Charge battery – see procedure in paragraph 3.1 on page 8.
2) Install charged battery in camera – see procedure in paragraph 3.2 on page 9.
3) Install memory card in camera – see procedure in paragraph 3.4 on page 10.
4) Turn on camera – see location of Power switch, item 10 on page 2.
5) Set emissivity to 0.95 (factory setting) which is representative of many targets like painted surfaces – see procedure in paragraph 5.2 on page 32.
6) Set background temperature to the ambient room temperature (factory setting is 68F) – see procedure in paragraph 5.3 on page 32.
7) Remove lens cap and point camera toward target.
8) Frame the target image on the display.
9) Click the Scale Button – see location of Scale Button, item 16 on page 2.
10) Focus camera lens – see procedure in paragraph 4.2 on page 21.
11) Capture an infrared image – see procedure in paragraph 4.3 on page 22.
12) Read temperatures in the infrared image – see procedure, paragraph 5.4 on page 33.
13) Save the thermogram (infrared image) for later use – see procedure, paragraph 4.4 on page 22.

Chapter 1: Camera Interfaces and Controls

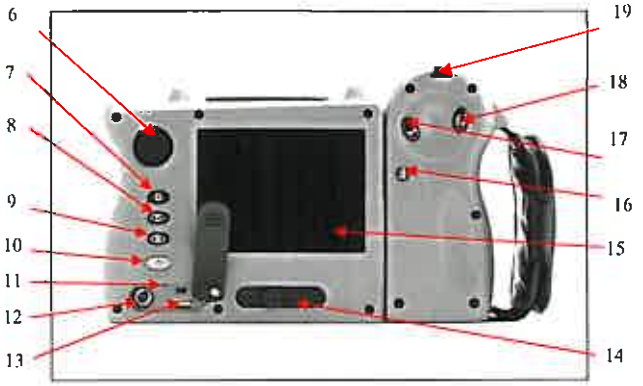
Camera functionality is described in detail in chapters 2 through 6. The purpose of this chapter is to introduce the user to the look and feel of the IR FlexCam S^{8}.

The IR FlexCam S^{8} has several direct access buttons, a menu system, image display, removable memory card and video output. The buttons and menu system are designed to be readily accessible for quick and easy operation of the camera. The IR FlexCam S^{8} has two programmable buttons that are easily programmed for direct access to menu functions that are used most often by an individual camera operator. The location of the camera interfaces and controls are shown in the following paragraphs along with a description of their function.

1.1 Interfaces and Controls Found on Camera Front and Top

1	Lens	Infrared germanium lens with manual focus.
2	Freeze Frame Button	Button used to pause and/or save an image frame, and to toggle back to the video mode. Also used to close out the menu page and return the camera to an operating mode (same as an OK click).
3	Video Port and Cover	RCA video jack used to connect camera to a TV or video monitor, plus protective cover.
4	Memory Card Slot and Cover	Slot for CompactFlash card and ejection button, plus protective cover.
5	Neck Strap Mount	Pins for attaching neck and/or shoulder strap.

1.2 Interfaces and Controls Found on Camera Back



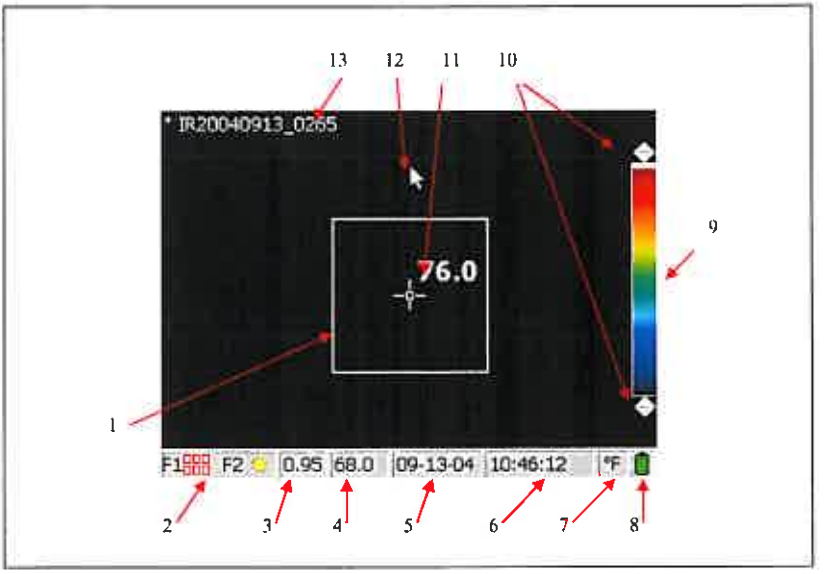
6	Mouse Controller	Used to control position of the mouse pointer in the images and text menus.
7	Crosshair Button	Used to cycle through three displays: a) no center crosshair or box, b) center crosshair with center temperature, c) center crosshair with center temperature and center box.
8	Programmable Button No. 1	Programmable to different menu functions, see paragraph 3.9 on page 14.
9	Programmable Button No. 2	Programmable to different menu functions, see paragraph 3.9 on page 14.
10	Power/Standby Switch	Used to turn camera on and off and to place the camera in a low-power standby mode to save battery power.
11	Reset Switch	Hidden switch to reset camera. Can be accessed with a paper clip.
12	Auxiliary Power Port	Connection port for AC-to-9 volt-DC power adapter.
13	Communication Ports	Standard host and client USB ports used for communications between camera and computer and peripherals.
14	Battery Latch	Used to remove battery.
15	Display	320 by 240 pixel sunlight-readable color display.
16	Scale Button	Used to re-scale the color palette to the maximum and minimum temperatures in current image.
17	Mouse Click Button	Performs mouse click ("Enter" function) for the Mouse Pointer.
18	Menu Button	Used to access the Menu mode.
19	Auxiliary Device Mount	Available for mounting auxiliary devices.

1.3 Interfaces and Controls Found on Camera Bottom

20	Tripod mount	Standard ¼ - 20 threaded hole for mounting camera on tripod.
21	Battery	7 volt lithium-ion battery for primary power.
22	Backup Battery and Breakout Connector	Coin cell battery to power camera nonvolatile memory and clock. And a connector used to interface computer with camera during manufacture. For factory use only, do not open.

1.4 Display Nomenclature

In addition to the thermal image itself each image can display a number of data items either individually or in combination. Below is a display with all the image nomenclature identified. Please note that the user has control over which nomenclature is displayed as described throughout this manual.



1	Center Box and its Temperatures	Center 50 by 50 pixel box defining a sub area of the target used to selectively control scaling of the image by eliminating the rest of the image from the scaling process
2	Programmable Buttons' icons	Icons for the two programmable buttons, F1 and F2, and location to click for changing the buttons' function
3	Emissivity	Used by camera to calculate center point temperatures and location to click for changing the emissivity value
4	Background Temperature	Used by camera to calculate center point temperatures and location to click for changing background temperature
5	Date	Current date and location to click for changing date
6	Time	Current 24 hour time and location to click for changing time
7	Temperature Units	Used to display center point temperature units and location to click for changing the temperature units
8	Power Source	Icon indicating AC power or battery level and location to click to identify remaining time left with current battery charge
9	Color Palette	Palette used in current displayed image and location to click for cycling through the different color palettes

10	Palette Temperature end points	Maximum and minimum relative temperatures of the palette and location to click to change limits of a fixed relative temperature range
11	Center point Temperature	Average temperature of the center most group of 4 pixels
12	Mouse Pointer	Mouse pointer to point out specific spot in image and for selecting menu items
13	Image Name	Name based on an assignable prefix, date image was taken and a sequencing number

Chapter 2: Camera Hardware Design Features

The IR FlexCam S^{8} is designed to be compact, flexible, rugged and easy to operate. It has a five-inch display module that can be positioned for optimal viewing by the operator while the lens/sensor module is free to be rotated into position to capture the target image. The modules can be adjusted for viewing the display comfortably while monitoring targets in difficult positions such as on the ceiling, hidden above high objects or hidden under low obstacles. Note in the pictures below how the display module and the lens/sensor module can be positioned relative to each other for optimum viewing comfort.

The modules can be adjusted so the camera display and control buttons are positioned for comfortable desktop image analysis. The camera can also be mounted on a tripod for continuous monitoring of a single location. See pictures below.

The IR FlexCam S^R is powered with a long life lithium battery that is not subject to charge capacity loss from the practice of partial charging. The camera can read the remaining charge capacity of the battery and presents that value to the operator pictorially and in terms of minutes of remaining camera run time.

Chapter 3: Camera Preparation

3.1 Battery Charging

The IR FlexCam S^{8} comes with a battery charger that works with 100 to 240 volts 50- or 60-Hertz AC input. It has a recalibration feature for maintaining correct capacity monitoring with the camera.

1) Connect the universal switching power supply to an AC wall outlet with the line cord. An adapter for the wall outlet may be needed in some non-USA countries. Connect the power supply to the dual bay battery charger -- model FLX 3002.	
2) Insert battery into one of the battery charger bays. Charging takes up to 3 hours. The LED indicator in front of each bay conveys charging status. Off: No battery detected Green Flashing: Fast charging Green Solid: Fully charged Yellow Flashing: Recalibrating Yellow/Green: Recalibrated Yellow Solid: Standby Red Flashing: Error Two batteries will charge sequentially. The second battery remains in standby mode until the first battery is charged.	
3) Generally the battery may require recalibrating once a month depending on usage. Recalibration enables IR FlexCam S^{8} to more accurately display remaining battery charge. To recalibrate a battery, use the left bay and press the recalibrate button on the front face. Recalibration can take up to 16 hours. The battery in the right bay can be charging while the left battery is being recalibrated. A warning popup window appears on the camera display when turning a camera on with a battery that needs recalibration.	

3.2 Installing and Removing Battery from Camera

1) Align the battery in the battery slot (item 21 on page 3) such that the side with terminals and latch slots face the back of the camera. Press battery into place until the latch closes. Do not use excessive force. If it does not snap into place, try reversing the battery.	
2) To remove the battery from the camera hold the camera upright and move the battery latch (item 14 on page 2) to the left. Position either hand to catch the battery as it releases from the camera.	
3) Catch battery and release the battery latch.	

When a battery powers the camera, a battery symbol will appear in the far right panel of the task bar. The remaining charge capacity is indicated graphically in green. Click on the battery icon with the mouse to obtain an estimate of the remaining camera run time available with the current battery charge.

3.3 Using AC Auxiliary Power

A universal switching power supply is supplied with the IR FlexCam S^{x} to enable powering the camera from an AC source.

1) Connect the universal switching power supply to an AC wall outlet with the line cord. An adapter for the wall outlet may be needed in some non-USA countries. This universal AC-to-DC power supply converts 100 to 240 AC-volt, 60- or 50-Hertz input to 9-volt DC output.	
2) Loosen and rotate the rubber cover for the power port (item 12 on page 2) out of the way. Attach the 9 DC-volt-power plug to the camera power port. **Caution**: The cable plug uses an outer sleeve latch to strongly secure the plug. Pull the latch back before inserting or removing the plug.	

When AC powers the camera an AC symbol will replace the battery icon in the far right panel of the task bar.

3.4 Installing and Removing the Memory Card

The IR FlexCam S* camera is supplied with a removable CompactFlash memory card. This card will hold several hundred images and is reusable.

1) Loosen and rotate the rubber cover for the memory card slot (item 4 on page 1) out of the way. Insert the CompactFlash card into the camera memory card slot. The card front label should face toward the back of the camera and the little red arrow should point down into the camera body. Push the card firmly into place to ensure good electrical connection. Do not use excessive force. Try turning the card around if it does not press into place easily. Close the cover.	

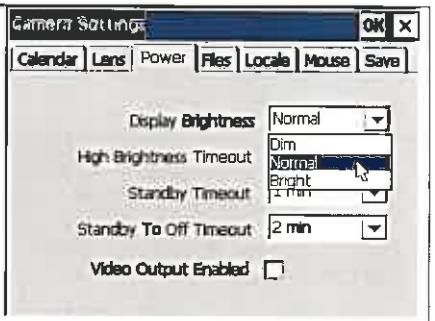
2) To remove the memory card open the cover. Press the ejection button down firmly to eject the card. Grab the card and pull it from the card slot. Close the cover.

3.5 Display Brightness

The IR FlexCam S^R display has three levels of brightness. The display can be cycled through the three levels of brightness two ways:

a) Changing the display brightness through the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" in the Menu window
3) Click on "Power" tab in the Camera Settings window
4) Select and click on the desired brightness – Dim, Normal, or Bright – in the Display Brightness pull down menu
5) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button



b) Adjust display brightness with one of the programmable buttons (see paragraph 3.9 on page 14 for details on how to program a button).

Toggle through the three levels of brightness by successively pressing the programmed Brightness button.

Note: For maximum battery life, choose the dimmest setting that provides an acceptable image.

3.6 Saving Power

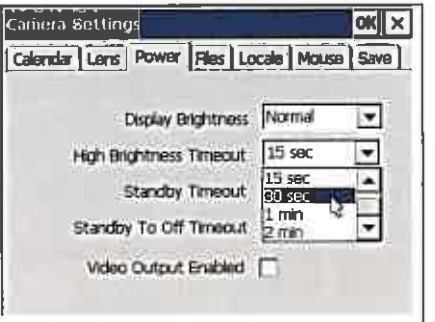
The IR FlexCam S® has a power management function to extend the life of a battery charge. One feature is to keep the intensily of the display at the appropriate level. See paragraph 3.5 above for a discussion on selecting display brightness. The camera has a means of limiting how long the display stays on high brightness before the camera automatically turns the display brightness to

normal. This occurs automatically independent of any button or mouse action. The high brightness level can also be set to stay on continuously.

Another feature of the power management function is that the camera will go into a standby mode where it automatically shuts off the display if there is no button or mouse action for a specified time interval. And, the camera can be set to automatically turn off camera power after an additional specified time interval when there is no button or mouse action. The display brightness time out, Standby Timeout and Standby to Off Timeout functions are only applicable when a battery powers the camera. When the camera is powered with AC the timeout features are disabled.

To set the power management time intervals:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu window
3) Click on "Power" tab of the Camera Setting window
4) Select and click on the desired time interval from the list in the pull down menus for a) "High Brightness Timeout", b) "Standby Timeout" and/or c) "Standby to Off Timeout" of the Power tab
5) Click OK in the Camera Settings window or press and quickly release Freeze Frame button



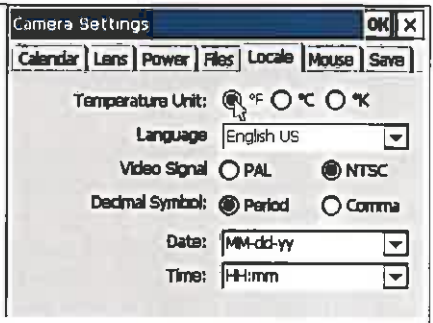
High Brightness Timeout limit is set to 30 seconds, Standby Timeout to 2 minutes and Standby to Off Timeout to 5 minutes at the factory.

When the camera goes into the Standby mode (the display shuts down but the camera remains on) the power button will begin flashing. To turn the display back on, press the power button and the camera will return to whatever Image or menu mode it was in when it was put in standby.

3.7 Setting Temperature Units

Temperature units (Celsius, Fahrenheit, or Kelvin) can be changed two ways. The easiest method is to click on the temperature unit mark found in the second panel on the right end of the task bar. This method can be used for all operating modes of the camera. The second method is to use the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" in the Menu window
3) Click on "Locale" tab in the Image Settings window
4) Check the desired temperature units button on the Locale tab
5) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button



The factory setting for temperature units is Fahrenheit (F).

3.8 Setting Date and Time

The IR FlexCam S© has an internal calendar and clock. The calendar is used in naming saved images, see paragraph 5.11 on page 41. The clock is used to record the time of day when a saved image is acquired. Both the date and time are recorded in the image file and are accessed with the FlexView software program. The Calendar tab used to set the date and time can be accessed via the menu system or by clicking on the date or time in the Task bar, panel 4 and 5 from the left, respectively.

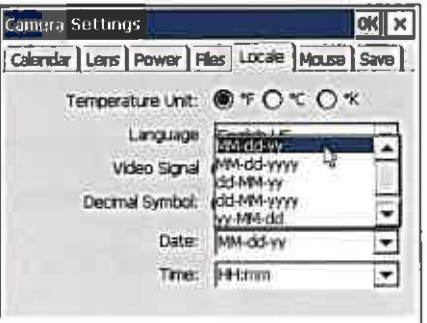
To adjust the calendar and clock via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu window
3) Click on "Calendar" tab of the Camera Setting window
4) Click on the Date button in the Calendar tab and adjust the calendar in the popup window by first selecting the month with the right/left buttons and then click on the day. The year can be changed by clicking on the year at the top of the popup window and adjusting with the up/down buttons

5) Click on the hour notation in the Time box to set the 24 hour clock hour with the up/down buttons based on a
6) Click on the minute notation in the Time box to set the minute with the up/down buttons
7) If seconds are included in the time format click on the seconds notation in the Time box to set the seconds with the up/down buttons
8) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button

The format of the date and time can be set to a number of conventions both USA and international. This is done via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu window
3) Click on "Locale" tab of the Camera Setting window
4) Select and click on the desired date format from the list in the Date pull down menu of the Locale tab
5) Select and click on the desired time format from the list in the Time pull down menu of the Locale tab
6) Click OK in the Camera Settings window or press and quickly release Freeze Frame button



The date and time formats are set to MM-dd-yy and HH:mm:ss, respectively, at the factory.

3.9 Programmable Function Buttons

Two buttons (items 8 and 9 on page 2) are programmable to several camera functions. All functions except Internal Recalibration can also be exercised through the menu system. These buttons are designed to make often-used

functions directly available by a single button push. The more frequently used functions will vary by operator and application so it is likely that different operators will want direct access to different functions.

3.9.1 Programmable Button Definitions

	Brightness: Used to quickly access the backlight brightness adjustment: "Dim", "Normal", and "Bright". Each time the function button is pressed the next setting will take affect.
	Browse Thumbnails: Used to quickly browse thumbnails of images stored on the compact flash card.
	Palette Visible: Used to give quick access to toggling the palette bar on and off the display.
	Lens Properties: Used to quickly access the calibration range/lens selection page.
	Recalibrate: Used to perform an immediate calibration adjustment.

3.9.2 Assigning Programmable Buttons

Assigning a new function to the programmable buttons is easy and intuitive.

1) Click on the function icon for either button that is displayed in the far left panel of the task bar. A popup menu appears listing the functions, with their icons, that are available to be assigned to that button.
2) Highlight and click on the desired new function. The function icon displayed in the task bar will change appropriately for that button.

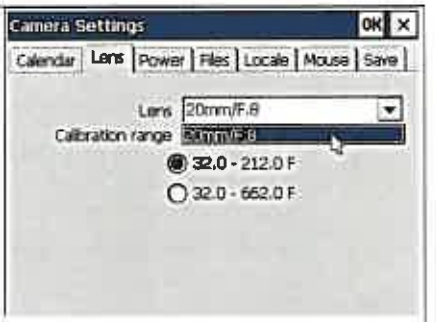
All assignable functions can be assigned to either button. Browse Thumbnails is assigned to button F1 and display Brightness to button F2 at the factory.

3.10 Selecting Calibration Range

For optimum performance, different applications will require different lenses and may require different temperature calibration ranges. A single IR FlexCam T® camera can be provided with different lenses and with alternate calibration ranges for each lens. Calibration data for each lens and alternate temperature ranges are stored in the camera memory.

To select the optimum lens type and best calibration range:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" in the menu window
3) Click on "Lens" tab in the Camera Settings window
4) Select and click on the appropriate lens from the Lens pull down menu list in the Lens tab
5) Check the appropriate calibration range button on the Lens tab
6) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button

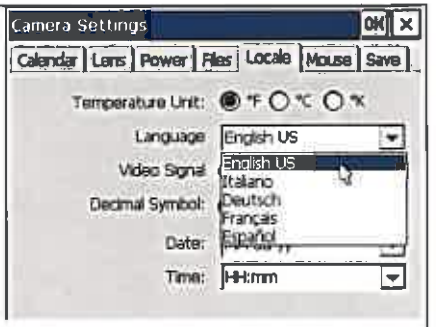


3.11 Changing Language

The IR FlexCam S® allows the user to change the menu and image display language. The camera is set to English at the factory.

To change language:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" line of the menu window
3) Click on "Locale" tab of the Camera Setting window
4) Click on the Language pull down menu on the Locale tab
5) Select and click on the desired language in the Language pull down list on the Locale tab
6) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button

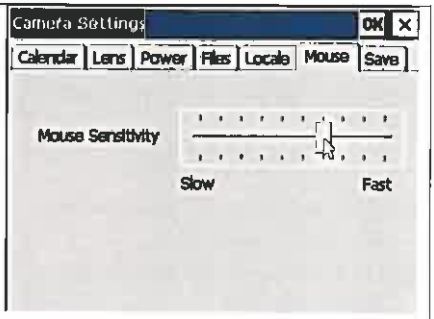


3.12 Setting Mouse Speed

The speed at which the mouse moves across the display and/or changes numerical values and the sensitivity of the mouse button to that movement can be adjusted from slow to fast.

To adjust the mouse speed:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" line of the menu window
3) Click on "Mouse" lab of the Camera Setting window
4) Highlight and drag the Mouse Sensitivity button on the Locale tab to the desired speed or click on the sensitivity bar in the desired slower or faster direction
5) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button



The mouse is set to the fastest speed at the factory.

3.13 Saving and Retrieving Camera Settings

The camera settings (like palette selection, temperature units, power management, etc.) can reside in 3 places – on the memory card, in the camera nonvolatile memory and in the camera operating memory. The camera always uses the settings stored in the operating memory. When a camera is turned-on, the setup parameters stored on the memory card are loaded into the camera operating memory replacing any settings that may have been there. If a camera is turned-on without a memory card or with a memory card that has no stored setting, the camera will load the factory settings that are stored in nonvolatile memory. These factory settings are permanent and cannot be changed except at the factory.

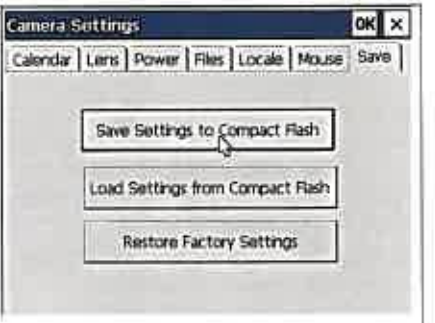
After the settings are loaded into the camera operating memory they can be changed by exercising anyone or all of the various setting functions discussed throughout this manual. The camera uses these new settings as long as the camera remains on. These changes are temporary and are not automatically added to the memory card for later use. A deliberate action in the menu system – Save Settings to Compact Flash -- must be taken to add changes to the setting stored on the memory card. If the camera is turned off before exercising the button, "Save Settings to Compact Flash", the changes will be lost.

If the camera settings have been changed and you want to revert back to the settings that are on the memory card you can reload them two ways. 1) You can turn the camera off and back on which will load the settings stored on the card. And 2) without turning the camera off you can load the settings on the card into the camera by exercising the menu function – Load Settings from Compact Flash. You can also load settings from a different card than the start-up card by

replacing the start-up card with the alternate card and exercising the menu function – Load Settings from Compact Flash.

To save current camera setting changes to the memory card:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu pop-up window
3) Click on "Save" tab of the Camera Setting window
4) Click on "Save Settings to "Compact Flash" button in the Save tab
5) Click on "OK" in Camera Settings window or press and quickly release Freeze Frame button



To reload camera settings from the start-up memory card or to load camera settings from a different card without turning the camera off:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu window
3) Click on "Save" tab of the Camera Setting window
4) Click on "Load Settings from Compact Flash" button in the Save tab
5) Click on "OK" in Camera Settings window or press and quickly release Freeze Frame button

To load factory settings start the camera without a memory card or if the camera is already on and must remain on use the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Setting" in the Menu window
3) Click on "Save" tab of the Camera Setting window
4) Click on "Restore Factory Settings" button in the Save tab
5) Click on "OK" in Camera Settings window or press and quickly release Freeze Frame button

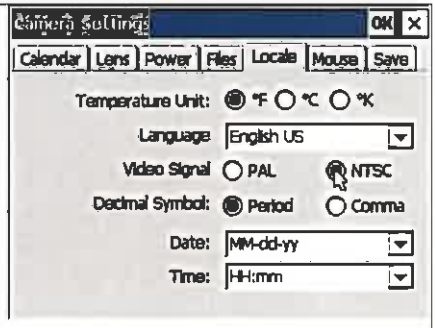
3.14 Video Output

The IR FlexCam S® can output video of the live, paused or saved images via the video port (item 3 on page 1). This video can be displayed on a TV, video projector or video display. It can also be recorded on a video recorder. The output can be set to NTSC (American TV), PAL (European TV) or turned OFF via the menu system. With the video output turned OFF the camera will use less power, saving battery charge.

Note: If a modern projector, display or TV is used that can display in either NTSC or PAL, use the PAL setting. NTSC projections cut off the top and bottom few lines losing valuable display data such as the Task bar. PAL does not.

To turn on NTSC or PAL video output:

1. Open the menu popup window by pressing the Menu button
2. Click on "Camera Settings" in the Menu window
3. Click on "Locale" tab in the Camera Settings window
4. Check the NTSC or PAL button in the Locale tab
5. Then select the Power tab and check the Video Output Enabled button
6. Click "OK" on the Camera Settings window or press and quickly release Freeze Frame button



To turn on and off the video output:

1. Open the menu popup window by pressing the Menu button
2. Click on "Camera Settings" in the Menu window
3. Click on "Power" tab in the Camera settings window
4. Check the Video Output Enabled button to turn video output on, uncheck it to turn video output off
5. Click "OK" on the Camera Settings window or press and quickly release Freeze Frame button

Video is set to NTSC and OFF at the factory.

Chapter 4: Camera Operation

The IR FlexCam S® has three image modes (live-image, pause-image and saved-image) and one menu mode.

- **Live-Image Mode --** In this mode the camera displays a (live) video image. When the camera is first turned on it starts in this mode and will continue in this mode until the operator exercises a mode change.
- **Pause-Image Mode –** In this mode a single live image frame is frozen on the camera display. By pressing the freeze frame button (item 2 page 1) for less than 1/2 second, the camera goes into this Pause-Image mode and the word "Paused" appears in the upper left corner of the display.
- **Saved-Image Mode –** In this mode images are saved on the CompactFlash card as well as frozen on the display. An image can be saved from any one of the image modes – Live-Image, Pause-Image, and even resaved from the Saved-Image mode. From any of the three modes pressing the Freeze Frame button and holding it down for more than 1/2 second puts the camera in this mode. This mode also applies when a previously saved image is retrieved and displayed on the camera display. After an image is saved, press and release the Freeze Frame button in 1/2 second or less to return to Live-Image mode.
- **Menu Mode --** In this mode, information and setup menus are displayed on the camera display. Pressing the Menu button (item 18 on page 2) starts this mode by opening a popup menu on the camera display.

4.1 Turning the Camera On, Off and to a Standby Mode

To turn the IR FlexCam S® on, install a charged battery (paragraph 3.2 on page 9) and press the Power button located to the left of the display (item 10 on page 2). The camera will start in the live-image mode. During start-up the FlexCam S® logo will appear first and then a task bar at the bottom of the display. While the task bar is showing, the camera stabilizes and performs self-calibration. This start-up process will take about 30 seconds to complete.

To save battery charge capacity while keeping the camera on, turn the display off by pressing and immediately releasing the Power button. The camera will go into a Standby mode and the power button will flash. Press the power button again to turn the display back on and the camera will return to whatever Image or menu mode it was in when it was put in standby.

To turn the camera off, press and hold the Power button down for 1.5 seconds. Any paused unsaved image on the display will be lost. If the camera is in Standby mode it must first be returned to one of the Image or menu modes, before it can be turned off.

4.2 Focusing the Camera

The IR FlexCam S® uses manual focus. While holding the camera with both hands and observing the live-image on the display, rotate the lens focus ring with your right hand index finger as shown below. Rotate the lens until the image

appears sharpest. Only slight movement will typically be required to optimize focus.

4.3 Causing a Live-Image to Pause without Saving the Image

To capture and display a single frame (Pause-Image mode) while in the Live-Image mode press and immediately release the Freeze Frame button (item 2 on page 1). The current Live-Image frame is frozen on the display and the word "Paused" will appear in the upper left corner of the display. This frame will remain on the display until a) the Freeze Frame button is pressed again to put the camera back into the Live-Image mode or b) a previously saved image is retrieved form the memory card and displayed on the camera display.

When leaving the Paused-Image mode, the captured frame will be lost unless it is saved as described in the next paragraph 4.4 below. If a paused image is on the display when a saved image is being retrieved from memory a popup window will appear asking if you want to save the paused image giving you a second chance not lose the image.

4.4 Saving an Image

Images can be saved two ways. The easiest way is to press the Freeze Fame button for 1/2 second. Images from either the Live-Image mode or Paused-Image mode will be saved to the memory card. In the Live-Image mode the image is saved to the memory card as well as frozen on the display. In the Paused-Image mode the Paused-Image is saved to the memory card.

When an image is saved to the memory card it is saved in the JPEG format and the center point temperature reading, center box and cursor position showing in the image on the camera display will be captured in the saved image. While the image remains on the camera display different parameters, like emissivity, background temperature, cursor position, center box, pallet colors and pallet span can be changed. However once the image is saved none of the

parameters in that specific image can be changed to provide alternate data for a report.

The second method of saving an image is via the menu system. It can also be exercised from either the Live-Image mode or Paused-Image mode:

1) Open the menu popup window by pressing the Menu button
2) Click on "Save Image" in the Menu window

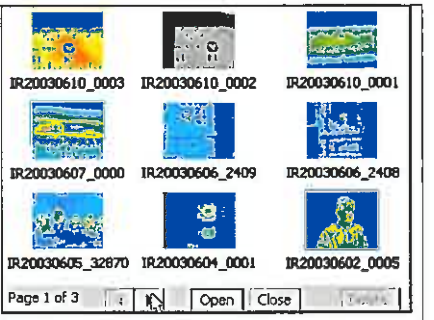
Whenever an image is saved the image name is added to the display in the upper left corner. See paragraph 5.9 on page 39 for details on the saved image name.

It is recommended that you keep no more than 300 images and preferably less than 50 on your camera's CompactFlash card. It is suggested that you periodically move the images from the CompactFlash card to your desktop or laptop PC.

4.5 Retrieving a Saved Image

All the saved images on the memory card in the camera can be seen on the camera display as thumbnail images in pages of nine at a time. For a given prefix the images will be presented in reverse order from the order in which they were taken. The first image on the first page will be the last saved image of a prefix grouping except in the case when you modify and resave an already saved image. A modified and resaved image if saved as a new image will be places next to the initially saved image. The prefix groupings are arranged in reverse alphabetical order. Any one of the thumbnails can be highlighted and opened to fill the whole display. Saved images can be retrieved in two ways:

a) With the menu system:

1) Open the menu popup window by pressing the Menu button 2) Click on "Browse Images" in the Menu window 3) Select page with the desired image by scrolling through the pages with the right/left arrows in the Task bar 4) Double click on image or highlight it and click on the "Open" button in the Task bar	

b) With one of the programmable buttons assigned to Browse images (see paragraph 3.9 on page 14 for details on how to program buttons):

1) Press the programmable Browse Images button 2) Select page with the desired image by scrolling through the pages with the right/left arrows in the Task bar 3) Double click on image or highlight it and click on the "Open" button in the Task bar	See Browse Images window above

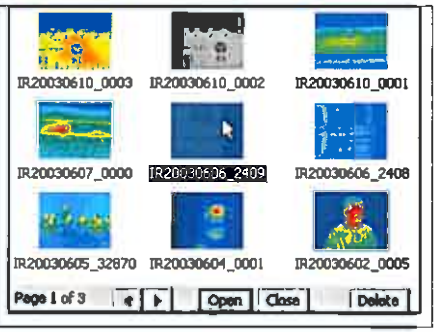
Note: With this second technique you can close the open image and return directly back to the thumbnail images by pressing the Browse Images programmable button.

4.6 Deleting Saved Images

Saved images on a memory card can be seen on the camera display as thumbnail images in pages of nine at a time. Any one of the thumbnails can be deleted two ways. Also all images can be deleted at once.

a) Delete a single image via the menu system:

1) Open the menu popup window by pressing the menu button 2) Click on "Browse Images" in the menu window 3) Select page with the desired image by scrolling through the pages with the right/left arrows in the Task bar	

4) Highlight desired image and click on the "Delete" button in the Task bar 5) Confirm the deletion by clicking on "Yes" in the popup window 6) Click on "Close" button in the Browse window or press and quickly release Freeze Frame button	

b) Delete a single image with one of the programmable buttons assigned to Browse images (see paragraph 3.9 on page 14 for details on how to program a button):

1) Press the programmed Browse Image button 2) Select page with the desired image by scrolling through the pages with the right/left arrows in the Task bar 3) Highlight the desired image and click on the "Delete" button in the Task bar 4) Confirm the deletion by clicking on "Yes" in the popup window 5) Click on "Close" button in the Browse window or press and quickly release Freeze Frame button	See Browse Images window above

All images on the memory card can be deleted at one time by:

1) Open the menu popup window by pressing the menu button 2) Click on "Camera Settings" in the menu window 3) Click on "Files" tab in the "Camera Settings" window 4) Click on the "Delete All" button in the "Files" tab	

5) Confirm the deletion by clicking on "yes" in the popup window
6) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button

4.7 Internal Recalibration

The IR FlexCam S® has an internal calibration feature where it automatically adjusts the camera electronics to produce uniformity in the infrared detector array to maintain a high quality image. When the camera senses a significant change in the temperature of the camera electronics and/or detector array or when it has seen a very high temperature target it automatically exercises this function. A shutter closes and the individual detector offsets and readout electronics are adjusted. This takes two to three seconds. During an internal calibration a weak double click will be heard in the camera and a popup window showing the word "Calibrating" will appear in the image on the display. During this process the image is frozen.

The camera operator has the option of forcing an internal calibration to occur immediately by pressing a programmed calibration button (See paragraph 3.9 on page 14 for instructions on how to program one of the programmable buttons to exercise the internal calibration).

Chapter 5: Image Interpretation

Image settings such as color palette, scaling, temperature units, center point temperature, emissivity and the like can be changed to show different information about an image. Changes can be made to these settings while the camera is in the Live-Image mode or Paused-Image mode. Setting changes made with the camera in these two modes will apply to images in those modes and to any image saved from those modes as long as the camera remains on. When the camera is turned off any setting changes not saved to the memory card will be lost. See paragraph 3.13 on page 17 on how to save setting changes to the memory card.

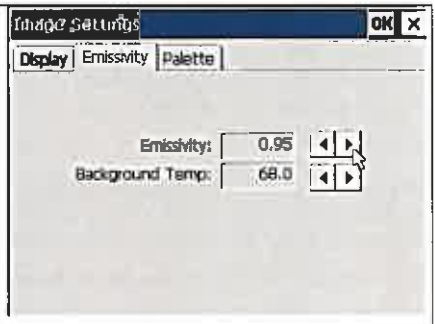
Changes made while the camera is in the Saved-Image mode will apply only to that specific image. Once the camera mode is returned to Live-Image mode or Paused-Image mode the settings in place when the camera was last in either of those modes will again apply.

If a new saved image is retrieved from the memory card, the settings of the new retrieved image and any changes to it will apply to that image only. Once an image has been modified from its previous saved state it can be re-saved replacing the previous image or saved as a new image (see paragraph 4.4 on page 21). Saved images that have been changed and not resaved will have an asterisk (*) attached to their name. The asterisk is used to warn the camera operator that the image settings have been changed and that they will be lost if the image is not resaved.

5.1 Adjusting Emissivity

Emissivity can be adjusted two ways. The easiest method is to click on the emissivity value, second panel from the left in the task bar, and raise or lower the value with up/down mouse action. Click again to close the mouse action. This method can be used for both Live-Image and Paused-Image modes. The second method is to use the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Emissivity" tab in the Image Settings wind
4) Use the right/left arrows to adjust the Emissivity or click on the value and use the up/down mouse action and click again to close the mouse action

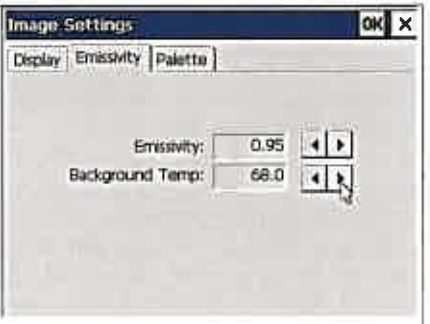


5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button	

Emissivity values are adjustable between 0.01 and 1.00 with precision of 0.01. This value along with the background temperature and target radiation measured by the camera is used for both Live-Image mode and Paused-Image mode to calculate target center point temperatures. The factory setting for emissivity is 0.95.

5.2 Adjusting Background Temperature

Background temperature can be specified two ways. The easiest method is to click on the background temperature value, third panel from the left in the task bar, and raise or lower the value with the up/down mouse action. Click on the background temperature value again to close the mouse action. This method can be used for both Live-Image and Paused-Image modes. The second method is to use the menu system:

1) Open the menu popup window by pressing the Menu button 2) Click on "Image Settings" in the Menu window 3) Click on "Emissivity" tab in the Image Settings window 4) Use the right/left arrows to adjust the Background Temp or click on the value and use up/down mouse action and click again to close the mouse action 5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button	

This background temperature along with emissivity and target radiation measured by the camera will be used to calculate target temperatures. The factory setting for background temperature is 68°F.

5.3 Center Point Temperature Readings

The center point temperature can be displayed on the image in any one of the three image modes, Live, Paused and Saved. In the Live-Image mode the temperature is monitored at 30 Hertz but displayed at 2 Hertz to make it more readable. It is also available in the Paused-Image mode and in images saved from the Live- or Paused-Image modes. Once an image is saved and removed from the camera display by going to another mode, the center point temperature

can not be added to or removed from the saved image nor can any other features of the saved image be changed.

The center point temperature is marked with a crosshair that represents the center of the center most 4 pixels. The temperature value is the average temperature of those four pixels.

The easiest method for turning on and off the center point crosshair and temperature value is to use the Crosshair button (item 7 on page 2). This button cycles from a) no center point and no center box, to b) center point with center point temperature, to c) center point with center point temperature and center box, and back to a).

The center box and center point with center point temperature can be turned on or off via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Display" tab in the Image Settings window
4) From the list shown check Center Point and/or Center Box if you want them appear in the image, uncheck those unwanted
5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button

Unchecking the center point removes the temperature digits and the crosshair marking the spot. The factory setting has center point temperature in the image and center box turned off.

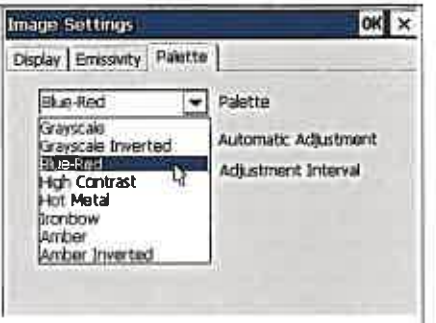
Extensions of the calibration range with approximate temperature values are provided so the camera operator can observe temperatures just beyond the calibration range. (See paragraph 3.10 on page 16 for a discussion on selecting the calibration range.) For example, the 0 to 100C calibration range has an approximate range extension from 0 to –20C and from 100 to 105C. When the approximate sign (~) appears in front of the center point temperature digits it indicates that the temperature reading is outside the selected calibration range and that the accuracy may not be within the specified accuracy of the camera.

5.4 Color Palettes

The palette colors can be changed two ways. The easiest way is to move the mouse pointer to a position over the color palette and click until the image is displayed in the desired colors.

The second way is via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Palette" tab in Image Settings window
4) Select and click on the desired palette from the list in the Palette pull down menu on the Palette tab
5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button



The factory palette setting is Blue-Red.

5.5 Scaling the Color Palette Temperatures

Scaling of the color palette to image temperatures can be divided into three categories:

a) Auto scaling where the palette temperatures are updates to the maximum and minimum temperatures in the image at a regular time interval. If the center box feature is on the image, auto scaling is done based on the temperatures in the box and not on the whole image. This feature allows the camera operator to eliminate the scaling feature from an area in the image that is very hot or very cold and of little interest.

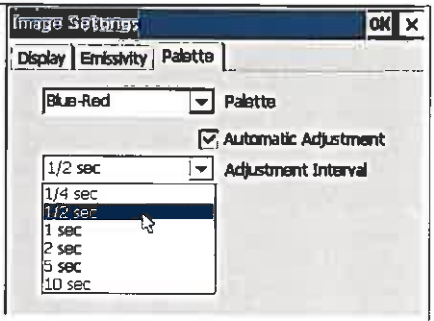
   The time between successive auto scaling is adjustable. For some operators if the target temperatures are changing fairly rapidly, fast auto scaling can be disconcerting. And for others if the time between auto scaling is long it too can be disconcerting. With the IR FlexCam S® this timing is adjustable from ¼ second to 10 seconds.

b) Manual scaling by pressing the scaling button to fix the temperature range based on the maximum and minimum temperatures in the image at the time scaling is set. If the center box feature is on the image, like in auto scaling, the scaling is done based on the temperatures in the box and not on the whole image.

c) Scaling to an arbitrary fixed temperature span.

Auto scaling is exercised via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Palette" tab in the Image Setting window
4) Check the "Automatic Adjustment" button on the Palette tab
5) Select and click on the desired time interval between auto scaling from the list in the "Adjustment Interval" pull down menu on the Palette tab
6) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button

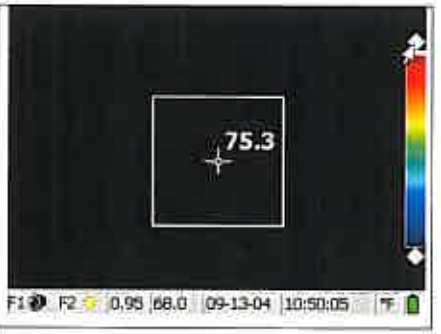


The factory setting has auto scaling turned on to ½ second.

Manual re-scaling of the color palette to the maximum and minimum temperatures in an image is accomplished by pressing the Scale Button (item16 on page 2). This can be exercised at any time in any one of the three image modes except when a saved image is retrieved. The scaling is then fixed to the temperatures in that image at the time re-scaling occurs. If the image temperatures change again and the camera is not in Auto Scale mode the button must be pressed again if the palette is to remain scaled to the maximum and minimum temperatures in the image. Again if the center box is showing the scaling occurs for the temperatures in the center box.

Setting the scaling to an arbitrary fixed temperature span can be accomplished by changing the maximum or minimum temperature values of the color palette that appears on the far right of the display.

1) Click the arrows at either end of the palette bar and raise or lower the value for that end of the palette with the up/down mouse action. The arrow turns green for the direction in which the relative temperature is being changed. When the maximum or minimum value for the camera calibration is reached the arrow for that direction disappears.



Note: Fixed temperature span widths can not be set less than 5C or 9F.

5.6 Palette Saturation Colors

Colors are linearly mapped to temperature in all three image modes and for both fixed and auto scaling of the palette temperatures to color. Scaling to the maximum and minimum temperatures, whether auto or manual, uses the full color palette to portray the temperatures in the image on the display at the time the scaling occurs.

The same scaling of temperatures with color is maintained until a re-scaling occurs. Following a re-scaling, if the camera measures a temperature greater than the palette maximum temperature and/or a temperature lower than the lowest palette temperature the pixels with these measured extreme temperature will appear in saturation colors. These colors, shown in the table below, appear on the ends of the palette color bar in the image.

Color Palette*	High Temperature Saturation Color	Low Temperature Saturation Color
Grayscale	Red	Blue
Grayscale Inverted	Red	Blue
Blue-red	White	Black
High-contrast	Blue-green	Dark Brown
Hot Metal	White	Black
Ironbow	Green	Tan
Amber	Red	Blue
Amber Inverted	Red	Blue

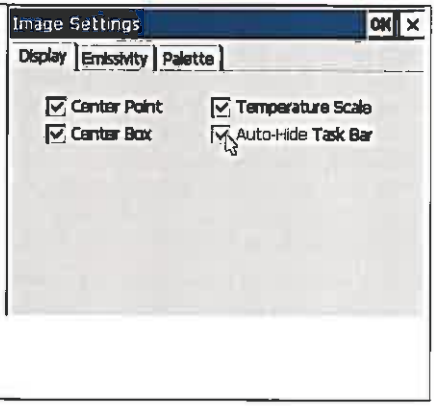
* Color palettes include grayscale palettes

If the maximum temperature of an image drops and/or the minimum temperature rises after a scaling, some palette colors or shades of color will not be used in the image until re-scaling occurs.

5.7 Hiding Color Palette and Task Bar

Both the task bar and palette can be removed from the display thus opening the entire display for viewing the image. By activating the Auto-hide Task Bar function, the task bar can be set to automatically disappear within 3 seconds if the mouse is moved off the task bar or if the mouse remains stationary on the task bar. This function is turned on via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Display" tab in the Image Settings window
4) Check the "Auto-Hide Task Bar" button to turn the function on and uncheck it to turn it off
5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button



To make the task bar reappear with the Auto-hide function turned on move the mouse to the bottom of the display.

The palette can be removed from the display two ways. The easiest way is to assign "Palette Visible" to one of the programmable buttons (items 8 and 9 on page 2) which will toggle the palette on and off the display. (See paragraph 3.9 on page 14 for details on how to program a button.)

The second way to remove the palette is via the menu system:

1) Open the menu popup window by pressing the Menu button
2) Click on "Image Settings" in the Menu window
3) Click on "Display" tab in the Image Settings window
4) Uncheck the "Temperature Scale" button in the Display tab to remove the Palette and pallet end points from the image, check it to add them to the image
5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button

The factory setting has the pallet and pallet end points showing and the Auto-Hide Task Bar function turned off.

5.8 Naming an Image

Whenever an image is saved, the image name is added to the display in the upper left corner. It consists of a prefix with zero to three alphanumeric characters followed by an eight digit date (yyyymmdd), then an underscore, and a four digit sequencing number. The prefix is found in the memory card and based on what was stored last on the card. If a new memory card with no stored prefix is used to store an image, the prefix "IR" found in the camera nonvolatile memory will be used. A prefix editor, found in the Files tab of the Camera Settings menu, provides a means for changing the prefix.

5.8.1 Changing the Image File Prefix

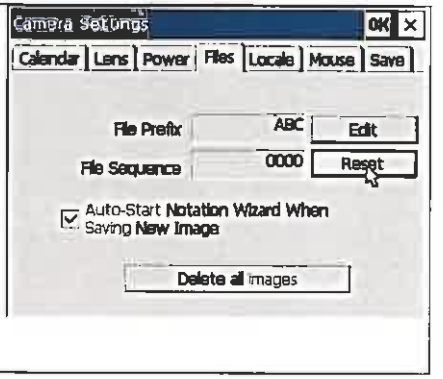
To change the prefix used in the saved image name:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" in the Menu window
3) Click on "Files" tab in the Camera Settings window
4) Open Prefix Editor by clicking on the "Edit" button of the Files Prefix line in the Files tab
5) If you want no prefix highlight the existing prefix and delete it by clicking on "Backspace", or
6) Select and click on up to three alphanumeric characters one at a time in sequence from the table
7) Click on "OK" in the Prefix Editor window"
8) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button

5.8.2 Resetting the Image File Sequence Number

To change the File Sequence Number used in the saved image name:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Settings" in the Menu window
3) Click on "Files" tab in the Camera Settings window
4) Click on the "Reset" button next to the File Sequence number.
5) Click "OK" in the Camera Settings window or press and quickly release Freeze Frame button



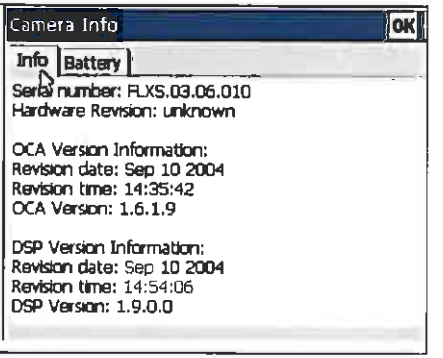
5.9 Camera Descriptive Information

Data describing the cameras are presented in two places -- the Camera Info window of the main menu and the Info tab of the Image Settings window. The Camera Info window presents data describing the current camera. The Information (Info) tab of the Image Settings window presents data describing the camera used to capture the image currently shown on the display of the current camera. The image, although shown on the current camera, may have been taken with a different camera.

The Camera Info window has two tabs, Info and Battery. The Info tab lists the camera serial number, software versions, lens description, number of image files on the memory card and the used and free space on the memory card. The second tab, entitled Battery, shows the power source, battery or AC, remaining battery charge, battery manufacturer, serial number and number of discharge cycles.

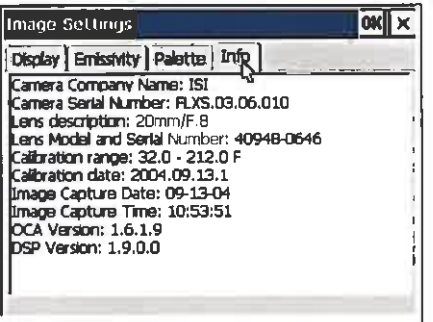
Acquire the Camera Info data by:

1) Open the menu popup window by pressing the Menu button
2) Click on "Camera Info" in the Menu window
3) Click on the "Info" or "Battery" tab in the Camera Info window
4) Click "OK" in the Camera Info window or press and quickly release Freeze Frame button to close the window



The Info tab of the Image Settings window presents the name of the camera manufacturer, camera serial number, lens focal length and f-number, lens model and serial number, camera calibration date and capture date and time for the image showing on the display. It also presents the version of software used for managing the camera operation (OCA) and the version for performing image data processing (DSP). This data and therefore the Info tab in the Image Settings window is not available if the image on the display is live or a paused image. But once the image is saved, the Info tab is available and this data is permanently attached to the file containing the image. Acquire this data by:

1) Retrieve or save an image to the camera display
2) Open the menu popup window by pressing the Menu button
3) Click on "Image Settings" in the Menu window
4) Click on "Info" tab in the Image Settings window
5) Click "OK" in the Image Settings window or press and quickly release Freeze Frame button to close the window



Chapter 6: Camera Optics

The camera has a 160 by 120 focal plane array. It uses microbolometer detectors that require no cryogenic cooling and responds to long wave infrared radiation in the 8 to 12-micron wavelength band. The detector elements are square and located in a rectangular grid with 51-micron pitch. The optical path of the camera includes a band pass filter to restrict the camera response to the 8 to 12 microns wavelength band. This wave band is selected to help the IR FlexCam S^{R} see low temperatures, limit its response to sun glints and limit the influence of humidity.

IR FlexCam S^{R} is provided standard with an f0.8 20mm focal length lens. The lens is made of germanium and is antireflection coated for high transmission in the 8 to 12 micron wavelength band. Two additional lenses are available, a wide angle, 10.5 mm focal length f0.8 lens to capture larger targets at short distances and narrow angle, 54 mm focal length f1.0 lens to capture small targets at long distances. The FOV (Field of View) and IFOV (Instantaneous Field of View) for the three lenses are listed in the following table.

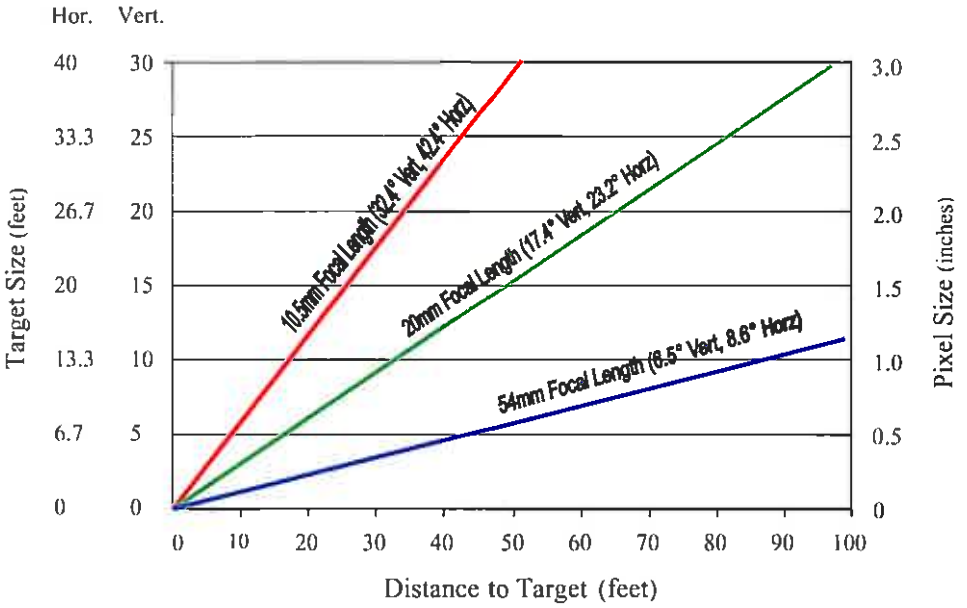
Lens Focal Length (mm)	Horizontal FOV (degrees)	Vertical FOV (degrees)	IFOV (degrees)
10.5	42.4	32.4	0.278
20	23.2	17.4	0.146
54	8.6	6.5	0.054

When alternate lenses are used, the camera requires alternate calibration data. This alternate calibration data is stored in the camera memory at the factory and is selected via the menu system. See Paragraph 3.10 on page 15.

Spot size, expressed as a ratio, is another way of describing radiometer optics. It is the ratio of the distance to the target to the size of the measurement area seen by a single detector. It is commonly used to describe point radiometers. For example, a point radiometer with a 60:1 spot size will measure the average temperature of a 1-inch diameter area on a target at 60 inches from the radiometer or 1 foot in diameter at 60 feet. The spot size for an individual detector on the IR FlexCam S^{R} with the standard lens is 333:1. For the wide-angle lens it is 206:1 and for the narrow angle lens it is 1059:1. There are 19,200 spot size measurements made in a single image with the IR FlexCam S^{R}.

The chart below shows how the pixel sizes (or spot sizes) and total target sizes vary with distance to the target for the three lens options.

6.1 Target and Pixel Sizes versus Distance to Target
(Shown for three lens options)



Appendix A – Measurement Basics

A.1 Heat, Temperature and IR Measurement Basics

Temperature is a measure of the thermal energy contained by an object; the degree of hotness or coldness of an object is measurable by a number of means and is defined by temperature scales. Temperature, in turn, determines the direction of net heat flow between two objects.

There are three (3) modes of heat transfer, *conduction*, *convection* and *radiation.* All heat is transferred by means of one or another of these three modes—usually by two or three modes in combination. Of these three modes, infrared thermography is most closely associated with radiative heat transfer, but it is essential to understand all three in order to comprehend the significance of IR thermograms.

Temperature is expressed in either absolute or relative terms. There are two absolute scales called "Rankine" (English system) and "Kelvin" (metric system). There are two corresponding relative scales called "Fahrenheit" (English system) and "Celsius" or "centigrade" (metric system). Absolute zero is the temperature at which no molecular action takes place. This is expressed as "zero Kelvins" or "zero Rankines" (0 K or 0 R). Relative temperature is expressed as "degrees Celsius" or "degrees Fahrenheit" (°C. or °F.). The numerical relationships among the four scales are as follows:

$$T_{Celsius} = 5/9\ (T_{Fahrenheit} - 32)$$
$$T_{Fahrenheit} = 9/5\ T_{Celsius} + 32$$
$$T_{Rankine} = T_{Fahrenheit} + 459.7$$
$$T_{Kelvin} = T_{Celsius} + 273.16$$

Absolute zero is equal to -273.1°C and also equal to -459.7°F. To convert a change in temperature or "delta T"(ΔT) between the English and metric systems, the simple 9/5 (1.8-to-1) relationship is used:

$$\Delta T_{Fahrenheit\ (or\ Rankine)} = 1.8\ \Delta T_{Celsius\ (or\ Kelvin)}$$

A.2 Conductive Heat Transfer

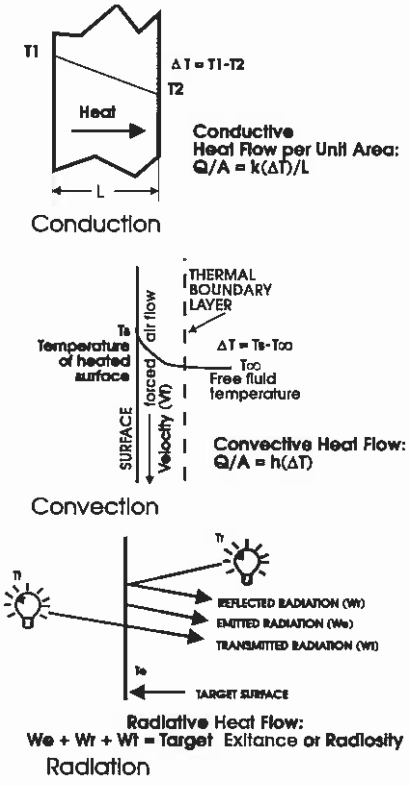
Conductive heat transfer is the transfer of heat in stationary media. It is the only mode of heat flow in solids, but can also take place in liquids and gases. It occurs as the result of atomic vibrations (in solids) and molecular collisions (in liquids) whereby energy is moved, one molecule at a time, from higher temperature sites to lower temperature sites. An illustration of conductive heat transfer is what happens when a transformer is mounted to a heat sink. The thermal energy resulting from the I^2R loss in the transformer windings is conducted into the heat sink, warming the heat sink and cooling the transformer.

The Fourier conduction law:

$$\mathbf{Q/A=k(\Delta T)/L}$$

expresses the conductive heat flow, Q per unit area, A, through a slab of solid material of thickness, L, and a thermal conductivity, k, with a temperature drop of ΔT=T1-T2 across it, as shown in Figure A.1(top). In real terms this expression means that the rate of heat flow increases with increasing temperature difference, increases with increasing thermal conductivity and decreases with increasing slab thickness. Thermal conductivity is, generally, highest for metals, and lower for nonmetals and porous materials such as brick.

Figure A.2.1 Three Modes of Heat Transfer



A.3 Convective Heat Transfer

Convective heat flow takes place in a moving medium and is almost always associated with transfer between a solid and a moving fluid (such as air). Free convection takes place when the temperature differences necessary for heat transfer produce density changes in the fluid and the warmer fluid rises as a result of increased buoyancy. Forced convection takes place when an external driving force, such as a cooling fan, moves the fluid. An illustration of convective heat transfer is what happens at the interface between the surface of a heat exchanger and air moved by an exhaust fan. The thermal energy stored in the heat exchanger is convected into the surrounding air, warming the air and cooling the surface of the heat exchanger.

Figure A.1(center) demonstrates the forced convective heat transfer between a flat heated plate and a moving fluid. In convective heat flow, heat transfer takes effect by means of two mechanisms; the direct conduction through the fluid and the motion of the fluid itself. Newton's cooling law defines the convective heat transfer coefficient, h, which expresses the combined effect of these two mechanisms:

$$h = (Q/A)/(T_S - T_\infty)$$

The presence of the plate causes the free fluid velocity, Vf, of the fluid, to decrease to zero at the surface and influences its velocity throughout a variable distance called the boundary layer. The thickness of the boundary layer depends inversely on the free fluid velocity, and is greater for free

convection and smaller for forced convection. The rate of heat flow depends, in turn on the thickness of the convection boundary layer and the temperature difference, ΔT, between Ts and $T\infty$ (Ts is the surface temperature, $T\infty$ the free fluid temperature outside the boundary layer).

Convective heat transfer per unit area is expressed as a rearrangement of Newton's cooling law:

$$Q/A = h\,(\Delta T)$$

In real terms this expression means that the rate of heat flow increases with increasing temperature difference and with increasing fluid heat transfer coefficient. Increasing fluid velocity increases the heat transfer coefficient.

A.4 Radiative Heat Transfer

Radiative heat transfer is unlike the other two modes in several respects:

- It can propagate through a vacuum.
- It occurs by electromagnetic emission and absorption.
- It occurs at the speed of light and behaves in a manner similar to light.

While conductive and convective heat transferred between points is linearly proportional to the temperature difference between them, the energy radiated from

a surface is proportional to the *fourth power* of its absolute temperature. The radiant thermal energy transferred between two surfaces is proportional to the *third power* of the temperature difference between the surfaces.
An illustration of radiative heat transfer is what happens when a power resistor is mounted adjacent to a diode on a circuit card. Much of the thermal energy resulting from the I^2R loss in the resistor radiates from the surface of the resistor and some of it is absorbed by the surface of the diode, warming the diode and cooling the resistor.

Thermal infrared radiation leaving a surface is called radiant exitance or radiosity. It can be emitted from the surface, reflected off the surface, or transmitted through the surface, as illustrated in Figure A.1(bottom). The total exitance is equal to the sum of the emitted component, (We), the reflected component, (Wr), and the transmitted component, (Wt). The surface temperature, however, is related only to We, the emitted component.

The measurement of thermal infrared radiation is the basis for noncontact temperature measurement and infrared (IR) thermography. The location of the infrared region in the electromagnetic spectrum is illustrated in Figure A.2.

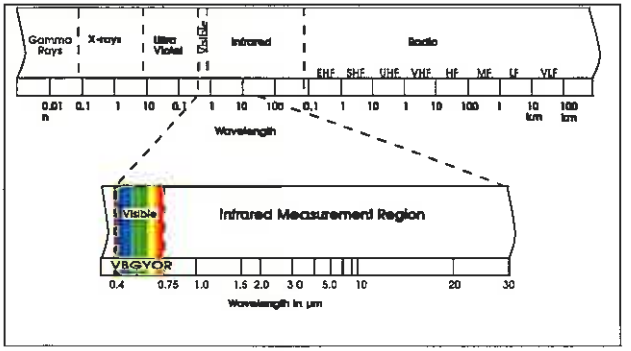


Figure A.4.1 Light and infrared in the electromagnetic spectrum.

Like light energy, thermal radiation is a photonic phenomenon that occurs in the electromagnetic spectrum. While light energy transfer takes place in the visible portion of the spectrum, from 0.4µm to 0.75µm, radiative heat transfer takes place in the infrared portion of the spectrum, between 0.75µm and about 1000µm, although most practical measurements are made out to only about 20µm. (***µm** stands for micrometers or "microns". A micron is one-millionth of a meter and the measurement unit for radiant energy wavelength.*)

All target surfaces warmer than absolute zero radiate energy in the infrared spectrum. Very hot targets radiate in the visible as well. The heating element of an electric stove at 800 K glows a cherry red, for example, and, as it cools, it loses its visible glow but continues to radiate. This radiant energy can be felt with a hand placed near the surface but the glow is invisible because the energy has shifted from red to infrared. IR thermal imagers measure and display images of this infrared radiated energy.

There are two key physical laws regarding infrared energy emitted from surfaces.

The heat radiated from the surface is expressed by the Stephan-Boltzmann law:

$$W = \varepsilon\sigma T^4$$

where:

W = Radiant flux emitted per unit area (watts/cm^2),
ε = Emissivity (unity for a blackbody target),
σ = Stephan-Boltzmann constant = 5.673x10^{-12} watts cm^{-2} K^{-4},
T = Absolute temperature of target (K),

and the peak wavelength , λ_m, (in µm) at which a surface radiates is determined by Wien's displacement law:

$$\lambda_m = b/T$$

where:

λ_m = Wavelength of maximum radiation (µm)
b = Wien's displacement constant = 2897 (µm K)

From the point of view of IR radiation characteristics, there are three types of target surfaces; blackbodies, graybodies and non-graybodies (also called real bodies or spectral bodies). A blackbody radiator is defined as "a theoretical surface having unity emissivity at all wave-lengths and absorbing all of the radiant energy impinging upon it." Emissivity is defined as "the ratio of the radiant energy emitted from a surface to the energy emitted from a blackbody surface at the same temperature." Although blackbody radiators are theoretical and do not exist in practice, the surface of most solids are graybodies, that is, surfaces with emissivities that are fairly constant with wavelength. Figure A.3 shows the comparative spectral distribution of energy emitted by a blackbody, a graybody and a non-graybody, all at the same temperature (300 K).

As shown in Figure A.1(bottom), the total exitance available to a measuring instrument form a target surface has three components: emitted energy (*We*), reflected energy (*Wr*) from the environment and other reflecting sources, and energy transmitted through the target surface (*Wt*) from sources behind the target. If the target is a blackbody emitter, it has an emissivity of 1.00, and it will reflect and transmit no energy. If the target is a graybody emitter, it will resemble a blackbody in spectral distribution but, since its emissivity is less than unity, it may also reflect and/or transmit energy. If the target is a non-graybody emitter, it also may emit, reflect and transmit energy. Since only the emitted component,

We, is related to the temperature of the target surface, it becomes apparent that a significant step in making IR temperature measurements is eliminating or compensating for the other two components.

Infrared radiation from the target passes through some transmitting medium on its way to the infrared instrument. If the medium is a vacuum there is no loss of energy, but most infrared measurements are made through air. The effect of most atmospheric gases can be ignored for short distances, such as a few meters. As the path length increases, however, atmospheric absorption can be a source of error. There are two spectral intervals that are relatively free from absorption losses. These are known as the 3-5µm and the 8-14µm atmospheric "windows". Almost all infrared sensing and imaging instruments are designed to operate in one of these two windows. The IR FlexCam S® operates in the 8-14µm window.

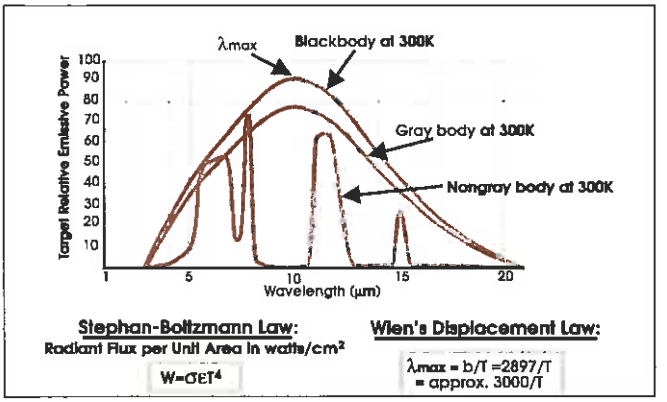


Figure A.4.2 Spectral Distribution of 3 Types of Emitters at 300K

Since most measurements using the IR FlexCam S® are made through a relatively short atmospheric path (less than 10 meters), errors due to atmospheric losses can generally be ignored. Solid media, however, such as a glass or quartz viewing port used in some manufacturing processes, can seriously attenuate infrared energy if situated between the target and the infrared instrument, and can make temperature measurement difficult. In those cases, the spectral transmission and absorption characteristics of the medium must be taken into consideration in calibrating the instrument.

A.5 How the IR FlexCam S® Converts Radiance to Temperature

The IR FlexCam S® corrects the infrared radiance from any single point on the target surface (where the cursor is placed), so as to approach a true temperature measurement at that location. To do this, it first assumes that the IR absorption of the air path between the target and the instrument is negligible. It also assumes that there is no IR energy transmitted through the target from sources behind the target. In order to correct for reflection of the ambient instrument background, it requires an operator input called background temperature. This setting allows the software to correct for the reflected component of the radiance. It also requires an operator input called target emissivity. This setting allows the software to correct the emitted component or the radiance for the effective emissivity of the target surface. Simple procedures for using the IR FlexCam S® to determine the correct settings for these operator inputs can be found in Appendix B.

Appendix B - Determining Background Temperature and Emissivity

B.1 Procedure for Determining Background Temperature Setting

The radiant energy due to the ambient temperature behind the instrument reflects off the target surface and, unless the target is a blackbody emitter, this energy contributes to the exitance reaching the instrument and may result in an error in temperature measurement. The background temperature setting allows the software on board the IR FlexCam S® to correct the temperature reading at the cursor for the reflected component.

The following procedure is one method of determining what the background temperature setting should be:

1. Set target emissivity to 1.00.
2. Crush a large sheet of aluminum foil (about 1ft square) and then spread it back into a sheet, so that it simulates a diffuse reflector.
3. Place the reflector between the IR FlexCam S® and the planned target and allow the reflector to come to thermal equilibrium. Check to be certain that no point sources (including the operator's body) are in the image.
4. Place the cursor in the center of the image and read the apparent temperature. Repeat for two other points away from the center of the image. Average the three readings.
5. Set the average of the three readings as the value for background temperature.

B.2 Procedure for Measuring the Effective Emissivity of an Unknown Emitter Using the IR FlexCam S® Camera

The effective emissivity is the value necessary to enter into the target emissivity parameter in order for the software on board the IR FlexCam S® to correct the temperature reading at the cursor. Setting the correct effective emissivity is critical in making temperature measurements. The table of normal emissivities provided in Appendix C can be used as a guide. When high measurement accuracy is important, it may be better to determine the effective emissivity of the surface directly using the camera under similar operating conditions. This is because emissivity can vary with temperature, surface characteristics and measurement spectral band, and may even vary among samples of the same material. One method, known as the "reference emitter" method can be used to determine the emissivity setting needed for a particular target material, by using the same instrument that will be used for the actual measurement. The procedure is illustrated in Figure B.1 and is described as follows:
Prepare a sample of the material large enough to contain several "spot sizes" or "IFOVs" of the instrument. (A 4 in. x 4 in. sample is a good choice.)
Spray one quarter of the target sample with flat black (light absorbing) paint (emissivity is about 0.96 in the 8-12μm region) or cover it with black electrician's tape (emissivity is about 0.95 in the 8-12μm region) or use some other substance of known high emissivity.

Heat the sample to a uniform temperature as close as possible to the temperature at which actual measurements will be made.
Making certain that the value for background temperature has been properly entered (see B1). Adjust the emissivity to the known emissivity of the coating and measure the temperature of the coated area by placing the center point crosshairs of the IR FlexCam S^{2} in the center of the coated area. Repeat for two other locations on the coated area. Average the three readings.
Move the center point crosshairs to the uncoated area of the image and adjust the emissivity value until the temperature reading obtained in (4) above is repeated. This new emissivity value should be used for this and similar target materials.

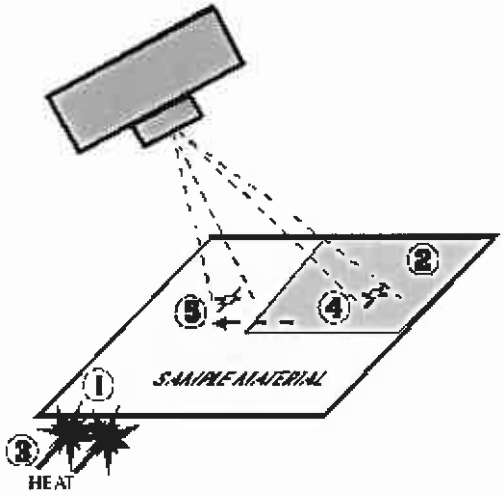


Figure B.2.1 Measuring Effective Emissivity of a Material Sample Using the Reference Emitter Method

Appendix C – Emmisivity Values
Tables of Normal Emissivity (8-14µm Region)

Material	Temperature °C	Emissivity (ε)
Aluminum, polished	0	0.05
Aluminum, rough surface	0	0.07
Aluminum, strongly oxidized	0	0.25
Asbestos board	0	0.96
Asbestos fabric	0	0.78
Asbestos paper	0	0.94
Asbestos slate	0	0.96
Brass, dull, tarnished	0	0.22
Brass, polished	0	0.03
Brick, common	0	0.85
Brick, glazed, rough	0	0.85
Brick, refractory, rough	0	0.94
Bronze, porous, rough	0	0.55
Bronze, polished	0	0.10
Carbon, purified	0	0.80
Cast iron, rough casting	0	0.81
Cast iron, polished	0	0.21
Cement	0	0.54
Charcoal, powdered	0	0.96

Material	Temperature °C	Emissivity (ε)
Chromium, polished	0	0.10
Clay, fired	0	0.91
Copper, polished, annealed	0-17	0.01-0.02
Copper, commercial burnished	0	0.07
Copper, oxidized	0	0.65
Copper, oxidized to black	0	0.88
Enamel	0	0.90
Formica	27	0.93
Frozen soil	0	0.93
Glass	0	0.92
Glass, frosted	0	0.96
Gold, polished	0	0.02
Ice	0	0.97
Iron, hot rolled	0	0.77
Iron, oxidized	0	0.74
Iron, sheet, galvanized, burnished	0	0.23
Iron, sheet, galvanized, oxidized	0	0.28
Iron, Shiny, etched	0	0.16
Iron, wrought, polished	0	0.28

Material	Temperature °C	Emissivity (ε)
Lacquer, bakelite	0	0.93
Lacquer, black, dull	0	0.97
Lacquer, black, shiny	0	0.87
Lacquer, white	0	0.87
Lampblack	0	0.96
Lead, gray	0	0.28
Lead, oxidized	0	0.63
Lead, red, powdered	0	0.93
Lead, Shiny	0	0.08
Mercury, pure	0	0.10
Nickel, on cast iron	0	0.05
Nickel, pure polished	0	0.05
Paint, silver finish	25	0.31
Paint, oil, average	0	0.94
Paper, black, shiny	0	0.90
Paper, black, dull	0	0.94
Paper, white	0	0.90
Platinum, pure, polished	0	0.08
Porcelain, glazed	0	0.92
Quartz	0	0.93
Rubber	0	0.95

Material	Temperature °C	Emissivity (ε)
Shellac, black, dull	0	0.91
Shellac, black, shiny	0	0.82
Snow	0	0.80
Steel, galvanized	0	0.28
Steel, oxidized strongly	0	0.88
Steel, rolled freshly	0	0.24
Steel, rough surface	0	0.96
Steel, rusty red	0	0.69
Steel, sheet, nickel-plated	0	0.11
Steel, sheet, rolled	0	0.56
Tar paper	0	0.92
Tin, burnished	0	0.05
Tungsten	0	0.05
Water	0	0.98
Zinc, sheet	0	0.20

Appendix D – Technical Specifications
IR FlexCam S® Portable Infrared System Specification

Imaging Performance	
Detector	Focal Plane Array (FPA), Uncooled Microbolometer
Spectral Band	8μm to 14μm
Thermal Sensitivity @ 30Hz	< 0.09°C at 30°C
Focusing	Manual
Digital Image Enhancement	Automatic Full-time Enhanced
Display and Image Storage	
Digital Display	5 inch high-resolution, 320 x 240, sunlight readable color LCD
On-screen Indicators	Battery status, target emissivity, background temperature and real-time clock
Palettes	Up to eight unique palettes available
Storage Medium	16MB Compact Flash Card (stores 350 images). Larger capacity cards available.
File Formats	JPEG. 14 bit center point temperature measurement.
Temperature Measurement	
Temperature Ranges	0°C to 100°C (32°F to 212°F). 0°C to 350°C (32°F to 662°F).
Accuracy	±2°C or ±2%
Measurement Modes	Center point, center box/full-image area min/max, average, movable spot, color alarm above and below
Emissivity Correction	Based on user input. Variable from 0.1 to 1.0
Measurement Corrections	Automatic, based on user input for ambient temperature, emissivity and optics
Standard Optics	
20mm f/0.8 Germanium	Field of view: 23° Horizontal x 17° Vertical
Spatial Resolution (IFOV)	2.6 mrad
Power	
Battery Type	Li-Ion Smart Battery, rechargeable, field-replaceable
Battery Operating Time	2+ hours continuous operation
Battery Charging	2-bay intelligent charger powered via AC outlet or 12v from car (optional)
AC Operation	AC adapter 110/220 VAC, 50/60Hz
Power Saving	Automatic shutdown and sleep mode (user specified)
Interfaces	
Video Output	RS170 EIA/NTSC or CCIR/PAL composite video
USB	Future (image and measurement data transfer)
Physical Characteristics	
Weight	1.95kg (4.3 lbs) including battery
Size	69mm x 262mm x 162mm (2.75" x 10.5" x 6.5") camera only
Tripod Mounting	¼" – 20 UNC
Environmental	
Operating Temperature	-10°C to +50°C (14°F to 122°F)
Storage Temperature	-40°C to +70°C (-40°F to 158°F)
Humidity	10% to 95%, non-condensing
Shock	25G, IEC 68-2-29
Vibration	3G, IEC 68-2-6
Transit Drop	MIL-STD-810F, Method 516.5, Procedure IV
Encapsulation	IP54

Appendix D

infrared SOLUTIONS
SHARPER • SIMPLER • SMARTER

FlexView Software Installation Guide

Included with your FlexCam camera is FlexView image analysis software that runs on any computer running Microsoft® Windows™ 98/ME/2000/XP, or NT 4.0. This software is provided on the included CD-ROM disk. To install the software on your computer, perform the following steps:

1. Start your computer and close any open applications.
2. If you have a previous version of the FlexView software installed, uninstall it as follows:
   Open My Computer->Control Panel->Add/Remove Programs, highlight the old version of software by clicking on its name, and click the "Add/Remove..." button.
3. Put the CD-ROM disk containing the FlexView software in your CD-ROM drive.
4. After a moment, the installation program should start automatically. If it doesn't, use Windows explorer to find the file, "setup.exe" on the CD-ROM disk, and start the installation by double clicking on this file.
5. Follow the on-screen instructions to complete the installation.

A help file for the FlexView software is installed on your computer as part of the installation. You will need a web browser to view the help file. You can obtain Internet Explorer free of charge from www.microsoft.com. You can obtain Netscape Navigator free of charge from www.netscape.com. Some CD-ROMs may provide a version of Internet Explorer for you to install.

To start the FlexView software, simply double click on the FlexView icon on your desktop, or use the start menu. The help file and release notes can be viewed using the start menu.

If you encounter any difficulties installing this software, or have any other questions, you may contact us at:

Infrared Solutions, Inc.
3550 Annapolis Lane N.
Suite 70
Plymouth, MN 55447
Tel: (763) 551-0003
Fax: (763) 551-0038
Email: software@infraredsolutions.com
Website: www.infraredsolutions.com