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# Users Guide for Fire Image Analysis System—Version 5.0: A Tool for Measuring Fire Behavior Characteristics

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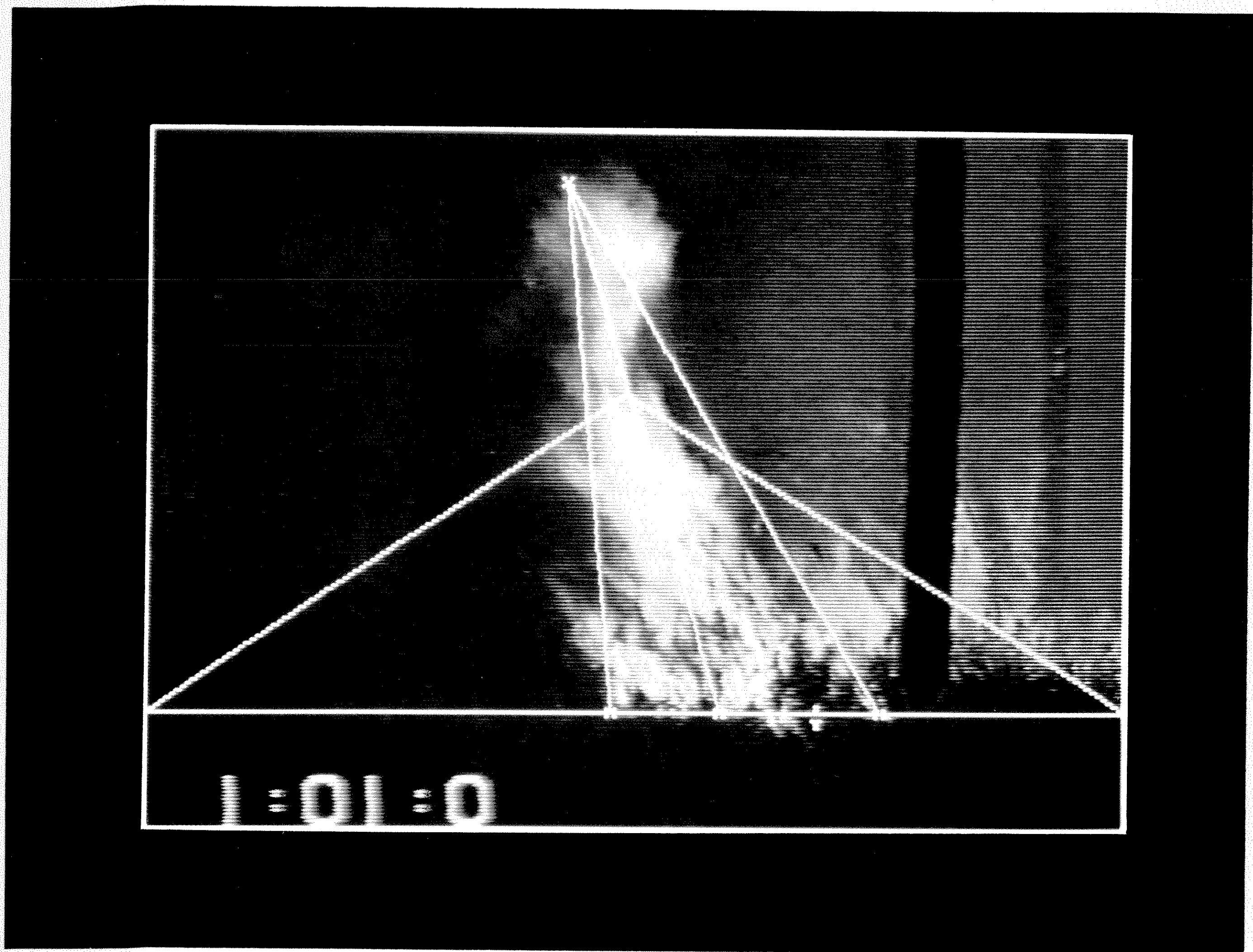

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# Contents

**Abstract**

The Fire Image Analysis System is a tool for quantifying flame geometry and relative position at selected points along a spreading line fire. At present, the system requires uniform terrain (constant slope). The system has been used in field and laboratory studies for determining flame length, depth, cross sectional area, and rate of spread.

**Keywords:** Flame length, quantifying flame geometry, rate of spread.

## Introduction

The behavior of wildland fire is recognized as important in formulating control strategies for wildfire and in using prescribed fire. Research and operational personnel use behavior characteristics, such as visually apparent flame length, flame angle, flame depth, and the rate of spread of a fire front, when they evaluate fire behavior and fire effects. The Fire Image Analysis System provides a record of these fire attributes as video image replicas that can be measured in the image analysis subsystem.

### System Overview

The system is comprised of two elements, image capture and image analysis. Images are captured with a S-VHS video camera equipped with a character generator for on-screen display of elapsed time. The image analysis subsystem is a personal computer-based system that can display video still-frame images of flames from a S-VHS video recorder and digitize selected points interactively. Values for flame height, depth, length, cross-sectional area, position, and distance from the camera position are calculated from selected point locations. Time annotation for each frame of video and the position of the flame front permits calculation of the rate of spread.

A field reference range target is used to calibrate video picture elements into English or metric units of measure. The system's unique ability to rescale objects at distances other than the calibration reference point (range target) is an important feature because the nature of spreading line fires is unpredictable. Although wind-driven line fires tend to spread with an elliptically shaped fire front, conditions at the burn site often cause the fire's leading edge to advance in a nonuniform way. Different segments of the line will often dominate and advance at a higher rate of spread than other segments, causing the measurement point to shift forward toward the camera position or away from the camera position relative to the calibration reference point. Because the distance has changed, the system must be rescaled.

System application is limited to line fires burning in even terrain (flat or uniformly sloping) where the camera's field of view is unobstructed. The camera must be positioned normal (right angle) relative to the direction of fire spread to ensure the profile of the flame is presented to the camera's field of view. System accuracy depends on careful adherence to prescribed methods for setup and calibration in the field and digitization at a workstation.

### Arrangement of the User's Guide

This user's guide is arranged to facilitate the following activities:

1. Understanding the general concept and operations of the system,
2. Selecting and setting up system hardware,
3. Loading the software,
4. Recording the fire images,
5. Quantifying the recorded images in terms of fire behavior characteristics, and
6. Performing additional analyses and operations.

## System Concept

The basic concept of the Fire Image Analysis System is illustrated in the following example:

In figure 1, a line fire is burning over a level, grass plain with a railroad track bisecting the observer's field of view. A cross section of the fire is shown because all measures of flame geometry are based on that perspective. The fire is advancing from left to right, toward the track. Because the rails of the track are parallel and the width between them is known, the observer can scale the dimensions of the fire by comparing it to the width of the rails at any given point along the track.

In the Fire Image Analysis System, a S-VHS video camera is substituted for the observer. An interactive system, where the images of the fire are overlaid with computer-generated graphic aids for measurement, is used to scale and measure the video images. In the image analysis process, the railroad track is represented as triangle A, B, C in figure 2; a single rail tie is the baseline, and the rail segments diminish into infinity. In the system, the user is able to adjust the position of the baseline (rail tie) and rescale the system to that distance. Once the system is rescaled, points on the flame are digitized using the mouse. After these points are entered (1, 2, 3, 4 in fig. 2), the system processes the measures of flame geometry and displays that information automatically.

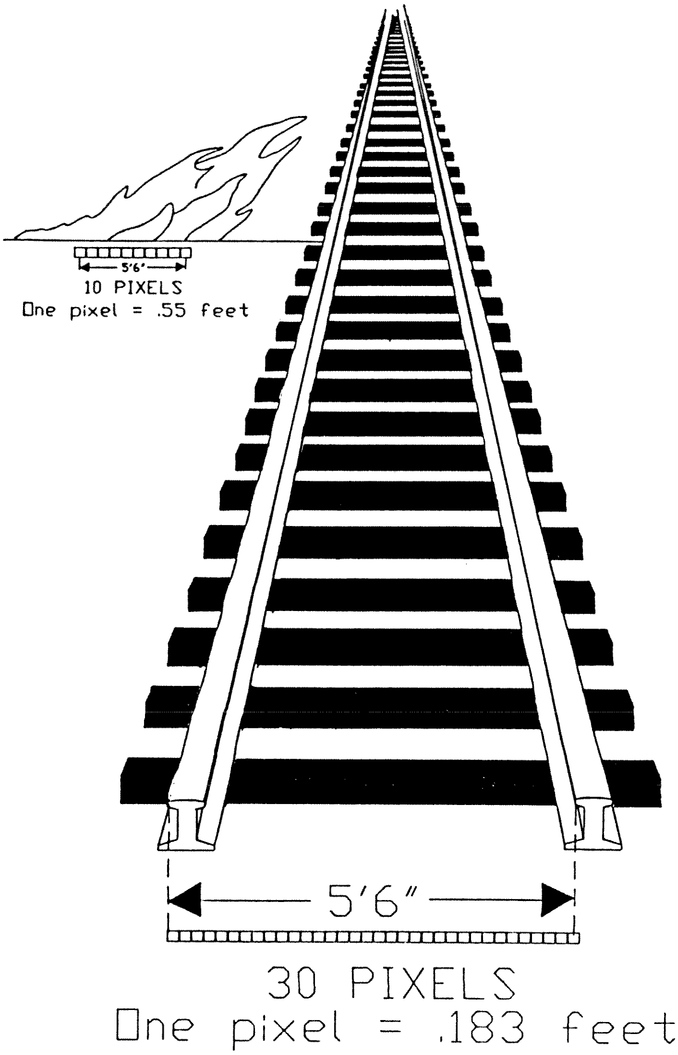


Figure 1—The system scaling concept is illustrated using the width between parallel railroad tracks. Objects can be scaled at any distance along the tracks by comparing their dimensions to the width between the rails at the same distance.

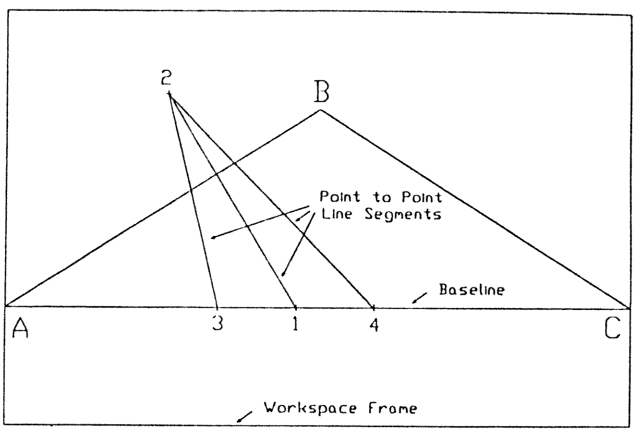


Figure 2—Elements of the computer generated video overlay workspace and graphic measurement aids using the four-point option for digitizing flame.

## System Resolution

The system resolution is a function of the horizontal and vertical resolution of the hardware and the distance of the plane of measurement to or from the calibration distance at the range target. The hardware resolution is defined by the total number of picture elements (pixels) in the horizontal (629) and vertical (189) area of the video workspace. The baseline location controls scale and determines how many pixels represent a given distance in space (fig. 1). The number of pixels decreases for the same horizontal measure of length as distance from the camera increases. The pixel sizes are exaggerated for clarity.

## Getting Started

### Hardware Requirements

#### *Image Capture*

1. Panasonic S-VHS camcorder model No. AG-450 10:1 zoom lens with standard accessories
2. Panasonic character generator for No. AG-450 camcorder, model No. VW-CG1
3. Panasonic battery pack 12 2.3 AH, model No. AG-BP212

#### *Image Analysis*

1. Computer—AT 486 or 386 with 387 math co-processor, 3-1/2-inch and 5-1/4-inch high density floppy drives, 80 MB hard drive, and mouse
2. Panasonic S-VHS 1/2-inch cassette recorder/player with digital frame memory, model No. AG-7355[1]
3. SONY Trinitron color video monitor 20-inch (RGB) super fine pitch model No. PVM-2030
4. Magitronics super VGA 1024 X 768 14-inch color monitor Luiski International part No. A-SV1448
5. Magitronics super-VGA graphics adapter with one meg RAM non-interlaced Luiski International part No. A-VGA422
6. SciMeasure color graphics interface board with S-VHS chroma decoder, P/N SCI-CGIB
7. SciMeasure color graphics generator board P/N SCI-CGGB
8. Hewlett Packard Laser Jet IV printer

[1] The Panasonic S-VHS model No. AG-7355-P has digital frame memory that improves still frame image stability and allows display of either of the two video fields that make up a video frame. This feature has a number of benefits. By digitally storing the image, the mechanics of the rotating tape head are disengaged which preserves the tape, and displaying only one field per frame improves time resolution. Time resolution is increased because a video frame (1/30 second duration) is made up of two fields (1/60 second each).

## Hardware Configuration

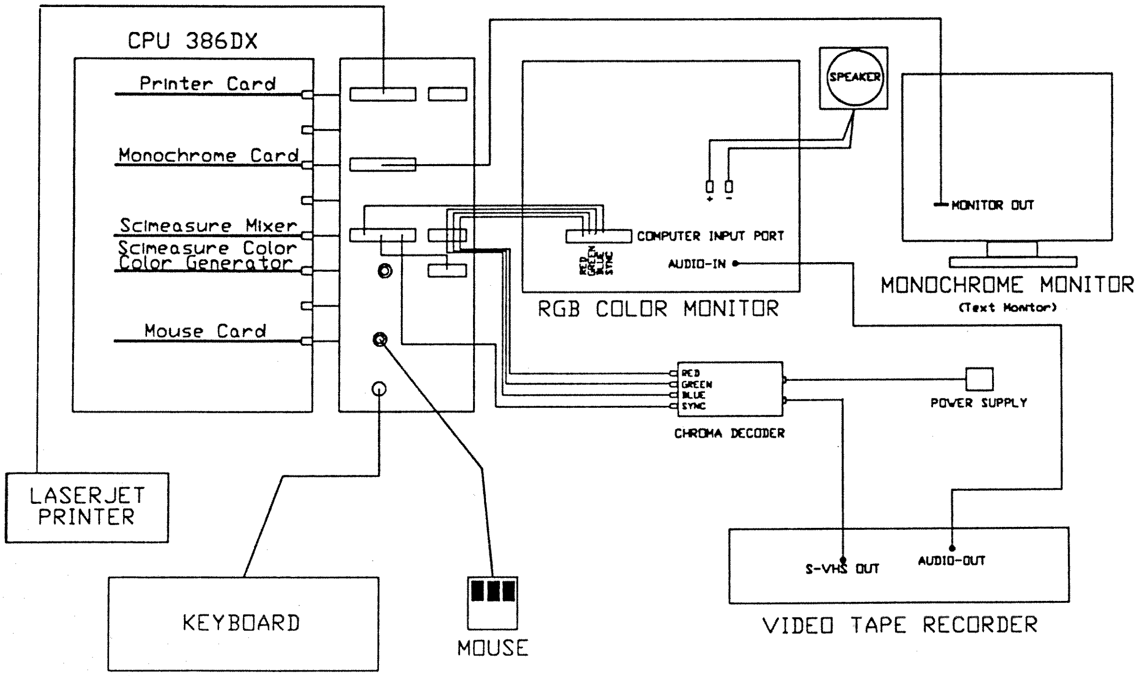


Figure 3—Schematic diagram of the Image Analysis Hardware and hardware connections.

## Loading Software

Installing the entire system from the floppy disk to the hard disk will require some familiarity with the MS-DOS operating system (the base operating system for the Fine Image Analysis System). Instructions for this procedure follow:

1. Exit any currently running software to return to the DOS prompt.

2. Change to the root directory of the desired disk.

3. If installing the system for the first time, make subdirectories to hold the FAS files and the data. An example follows:

```
[C:\]md fas
[C:\]md fas\data
[C:\]_
```

4. Copy the files on the supplied disk (if on the B: floppy drive) to the C: hard drive:

```
[C:\] copy b:*.* FAS
```

5. First-time software installation requires a few changes to the AUTOEXEC.BAT file. The line in the AUTOEXEC.BAT that begins with PATH must be modified. Using a text editor, open the file C:\AUTOEXEC.BAT. Then append the following to the last PATH command:

```
            ;C:\FAS
so that     PATH=C:\DOS
will become PATH=C:\DOS;C:\FAS
```

To print graphics, the DOS GRAPHICS utility must be installed. If the command GRAPHICS does not appear on any line in the AUTOEXEC.BAT file, it must be added:

```
PATH=C:DOS;C:\FAS
GRAPHICS
```

If the user has anything other than a standard dot matrix printer, the DOS manual on using GRAPHICS utility should be consulted. For example, if using an HP Laserjet II or higher laser printer, the following GRAPHICS command would be added:

```
PATH=C:\DOS;C:\FAS
GRAPHICS LASERJETII
```

To print a graph from within the program, simply press <Shift>-<PrintScreen>

To run the FAS software automatically when the system boots, the last line in the AUTOEXEC.BAT file must appear as follows:

RUNFAS

Once the new AUTOEXEC.BAT file has been saved, reboot the computer to load and activate the changes.

6. To run the FAS software, type:

   [c:\FAS] RUNFAS

## Image Capture

### Recording the Fire

The process of collecting accurate data with the image analysis system begins with the proper placement, alignment, and calibration of the video camera. In documenting field fires, the first step is to locate an area of interest in the prospective burn as near a plane surface as possible. The area can be flat or uniformly sloping. Figure 4 illustrates a typical situation for flat terrain. Although some minor relief is shown for practical purposes of measurement, the surface is considered flat.

Once the area of interest is selected, camera placement depends on wind direction. The camera's line of sight should be as close to a right angle (normal) to wind direction as possible. Proper placement will show a line fire moving from left to right or right to left in the camera's viewfinder.

The right angle relationship of the camera's line of sight to the wind direction (direction of fire spread) provides two possible camera positions. For example, consider the direction of fire spread as vector 0° and the direction that the fire is spreading from as vector 180°. A camera positioned at a right angle to the fire spread would be at either 90 or 270°. Selecting a camera position between the two possibilities is based on the direction and angle of the sun. The camera should be positioned so the smoke from the fire is not back lit and direct sunlight does not strike the camera lens. In both cases, the video image will be degraded by light flare making it difficult to distinguish flames.

Back lighting of the smoke and direct sunlight striking the lens occur when a low solar angle is present. Although problems with low solar angle are most pronounced in early morning and late afternoon during the winter months, problems can also be encountered early morning and late afternoon during the summer months.

Next, the camera's line of sight is adjusted parallel to the ground-level datum by using an optical leveling device such as an Abney level or clinometer. Using a range target of known height above the ground level datum, the camera height is raised or lowered to intersect the level line sighted with the optical leveling device on the range target upper marker (fig. 4). From a slight distance behind the camera,

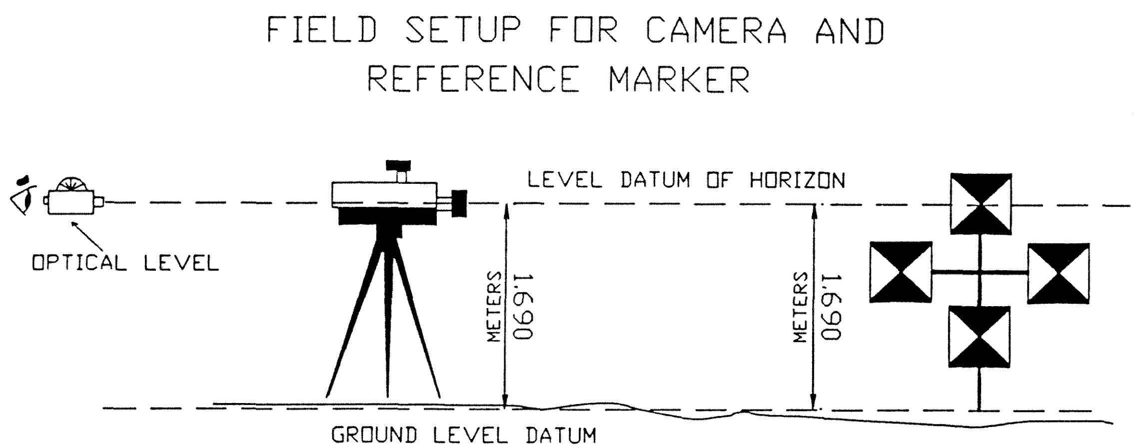


Figure 4—Using an optical leveling device, such as an Abney level or clinometer, the camera is raised or lowered so the center line axis of the lens intersects with the level datum of the virtual horizon. The height of the level datum above the ground level is measured at the reference marker; in the illustration the height is 1.69 meters.

this optical leveling device sights a level line to the center of the top marker and the lens is brought to that level. The center of the top marker is considered the virtual horizon; that is, the point where the ground level datum and the level datum at the center of the top marker converge at the horizon.

After the camera height is set, the target is centered in the viewfinder by tilting the camera upward or downward. Field tests have shown that a camera level of 5 feet above the fuel layer is adequate for flame positions 80 to 150 feet from a camera with its lens set to the maximum wide-angle focal length. For flame positions at greater distances, the camera should be raised 5 feet for every 100 feet of distance. In situations where the height of the camera or the fuel depth is greater than eye level, a ladder is used as a camera mount.

Finally, the proposed burn is named (ID). Fire ID's are limited to eight characters to conform to the MS-DOS operating system.

**Calibrating**

Figure 5 shows an example of the range target configuration. The target is also used to establish vertical and horizontal length references for calibration in the image analysis process. The target is constructed of four markers separated by fixed, measured distances. The height of the target is adjustable to suit different fuel depths and distances of points of interest along the fire line.

**Examples of Field Setup**

***Pre-Fire Field Calibration***

1. An area in a palmetto-gallberry fuel type has been designated for a prescribed burn. The burn is a headfire in flat terrain. The wind is from the west and the sun is at a low winter position to the south. In this situation, a camera

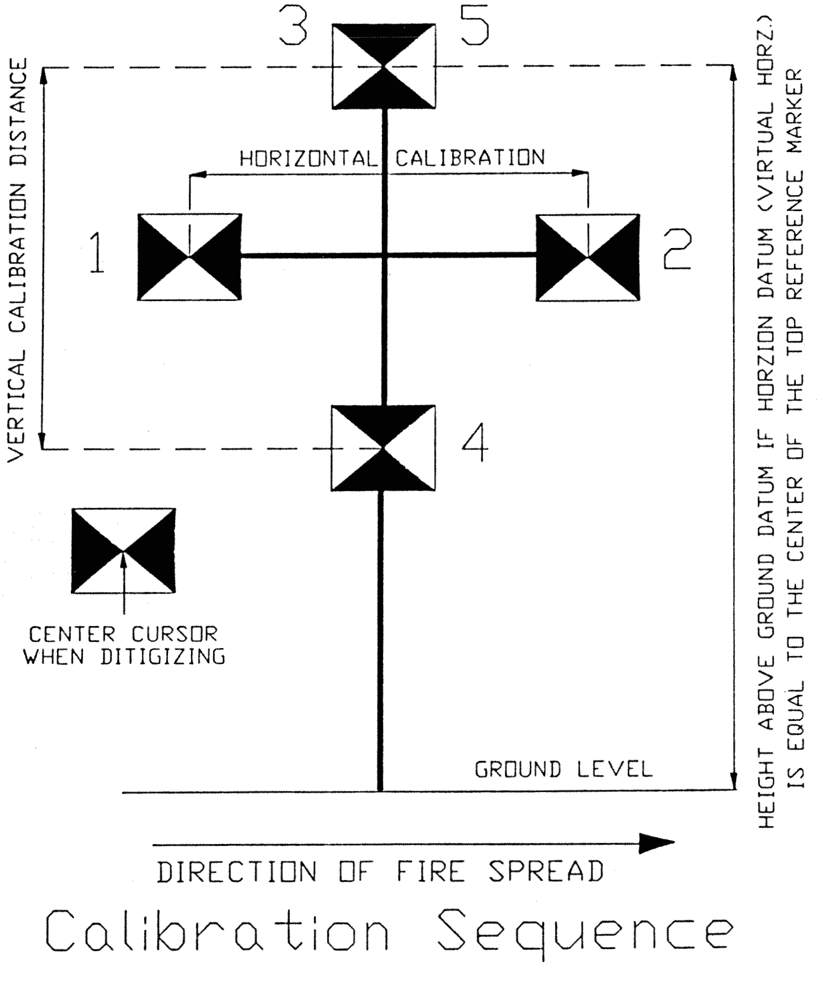


Figure 5—The range target with the markers labeled 1 through 5 shows the sequence used in system calibration when the direction of fire spread is left to right. The location for digitizing the vertical and horizontal calibration is also shown.

position south of the burn area is selected for two reasons: First, the camera's line of sight will be at a right angle (normal) to the wind direction; second, the sun to the rear of the camera will eliminate flare.

2. The camera is mounted on a tripod in a line-of-sight right angle to the wind direction. A range target is moved into the burn area along the camera's line of sight and placed at the approximate center of the field of view, with the center of the top marker raised to 5 feet above the fuel surface.

3. The height of the camera is adjusted to the level datum; that is, the height of the center of the top marker of the range target (virtual horizon).

4. Once the camera is aligned, recording begins and information is fed onto the audio track. An ID for the fire and values for the distance between the horizontal and vertical markers at their center point on the range target, the distance from the range target to the camera lens, and the height of the center of the marker at the level datum on the range target aboveground level are recorded. After the calibration data is recorded, the camera is placed in standby mode or turned off until the fire is taped.

5. To record the fire, the camera power is turned on, which also powers up the character generator that displays the stopwatch timer in the camera's viewfinder. Adjustments for focus and exposure are made, and the stopwatch is displayed by pressing the display control button on the character generator. A quick check will ensure that the camera is recording and that the stopwatch is running. When the fire has traversed the field of view, the stopwatch and camera are turned off. This completes the data collection phase.

### *Post-Fire Field Calibration*

The camera may be calibrated for field setup after the fire has been recorded if the camera is leveled before taping begins. The addition of a circular bubble level to the camera body is required for aligning the focal plane vertically and horizontally. The method for attaching the level to the body follows:

1. Locate a brick or block building that has an unobstructed wall face. With the camera mounted on a tripod, position the camera 60 to 80 feet from the wall, perpendicular to the center.

2. Using an optical level, establish and mark a level position on the wall approximately 4 feet aboveground level.

3. Raise the camera lens to the level datum again using the optical level to establish a level relationship to the mark on the wall.

4. View the wall through the camera's view finder and tilt the camera up or down to center the mark on the wall to the center of the view finder. Recheck the height of the camera lens using the optical level to the point marked on the wall to assure that the lens is at the level datum. Repeat the process until you are assured that both the camera lens (at center) is at the level datum height, and the mark on the wall is centered in the view finder.

5. Using the horizontal mortar joint between the brick or block as a guide, level the camera horizontally in the view finder.

6. Locate an area on the top of the camera body to attach the bubble level. Place the level in position on the camera body and check the position of the bubble. If the bubble is centered in the level circle, a light coat of epoxy cement may be applied and the level set into place. Once the level is cemented into place, recheck to ensure the bubble is in the center of the level circle. In the event that the bubble is not centered, a deeper bed of cement will allow adjustment to the level that will center the bubble. When the bubble level is mounted and cured, the camera can be set up; and the fires recorded.

The post-burn method is similar to the pre-burn field setup and calibration; however, in this method, the range target marker that represents the level datum is raised to the level datum rather than the camera. The post-burn calibration setup procedure for the same conditions described for pre-burn field calibration follows:

1. Position the camera normal (right angle) to the wind direction, adjust the field of view to the burn area, and level the camera using the bubble level mounted on the camera body.

2. Just before the fire enters the field of view, turn on the camera and start the stopwatch timer.

3. After the fire passes the field of view, stop recording but do not turn the power off or move the camera.

4. Move the range target into the center of the camera's field of view. Using the optical level, raise or lower the range target until the center of the upper marker is level with the camera lens, which is accomplished by sighting the level from the camera at lens height.

5. Video the range target and enter the calibration information on the audio track for the distance between the horizontal and vertical markers at their center point, the distance from the camera lens to the target, and the height of the center of the level datum marker aboveground level. This step completes the procedure, and the camera can be turned off.

### *Sloped Terrain*

The only basic difference in the field setup between sloped and flat terrain is camera setup. The line of sight is across the slope. This relationship can be shown in the example of flat terrain if the area of the burn is tilted using the base of the range target pole as the axis of tilt (fig. 6).

## Image Analysis

### Starting Up

Once the hardware has been properly configured, the software loaded, and a fire captured on tape, selected image replicas of the flames can be transformed into measures of angle, position, length, height, depth, and area. If the system boots automatically, the user simply turns on the power. Otherwise, the user must boot the DOS operating system and type RUNFAS at the DOS prompt. When the system has loaded, the following menu will appear:

USDA SFFL Image Analysis Program Version 5.0

Current Units are : Feet

Select option:

1 - Digitize Fire Behavior (Contour)
2 - Digitize Fire Behavior (Point to Point)
3 - Digitize Fire Behavior (Four Point)
4 - Plot a Data Set
5 - View a Data Set
6 - Print a Data Set
7 - Change Units
8 - Quit

Enter option →

After allowing the system to warm up for approximately 10 minutes, the user must select the correct units of measure. To change the units—feet or meters—the user must press the No. 7 key. This key is a toggle and will return to the previous setting when pressed a second time. After selecting the units of measure, the user must decide which method to use in digitizing the flames and press the appropriate key. Three digitizing options are offered: contour, point to point, and four point.

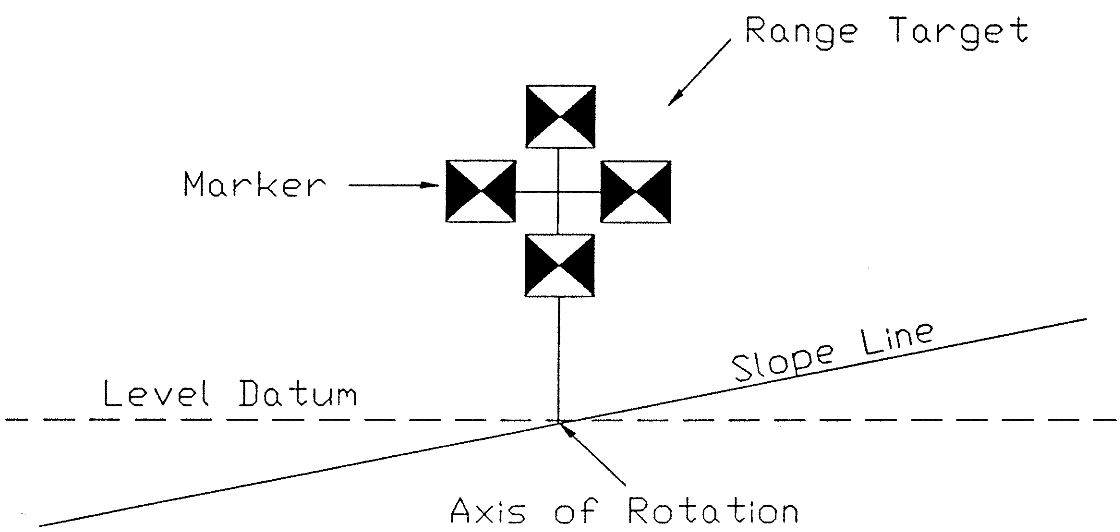


Figure 6—When using the system on sloping terrain, the base of the range target is the axis of rotation. The system establishes this point from the input of the virtual horizon.

*The Methods*

**Contour method** (fig. 7). In this method, the user defines the flame shape by tracing the outline of the flame image with the system mouse. From this input, the computer defines flame length as the distance between the midpoint of the flame base and the highest point on the flame. The angle of an interpolated line between these points is the flame angle. This method is consistent with the classic definition of flame length and angle. The contour method also provides a measure of the cross-sectional area of the flame. Additional information on relative position, height, depth, range (distance from the camera), contour length, and the slope of the terrain are given for each flame measured.

**Two-point method** (fig. 8). This method requires only two user-defined points. Using the mouse, one point is entered at the midpoint of the flame base; the other at the flame tip. This option allows the operator to follow the flame stream lines from the origin at ground level to flame tip. This method is faster than outlining the flame in the contour method but has several draw backs—no value for flame depth or cross-sectional area is given. In addition, the relative position for the flame is given for the midpoint, not the leading edge.

**Four-point method** (fig. 9). This method is similar to the contour method in parameters measured. However, in this method, an idealized shape for the flame is drawn from the input of four points, and no value for contour length is given. Using the mouse, the four user-defined points are entered: midpoint of the flame base, flame tip, and leading and trailing edges of the flame. This method is recommended based on experience with the system.

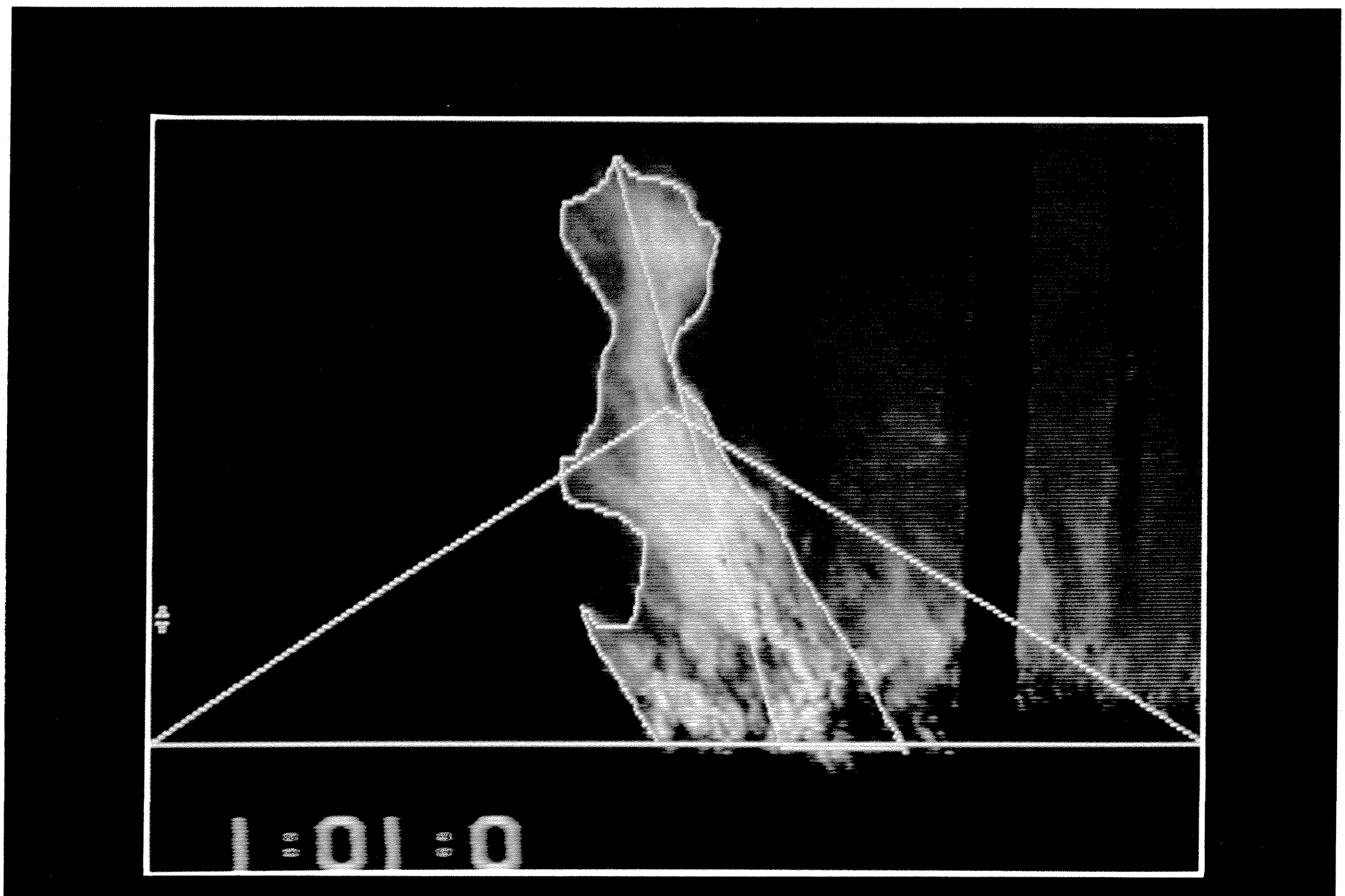


Figure 7—Example of a digitized flame in the contour mode.

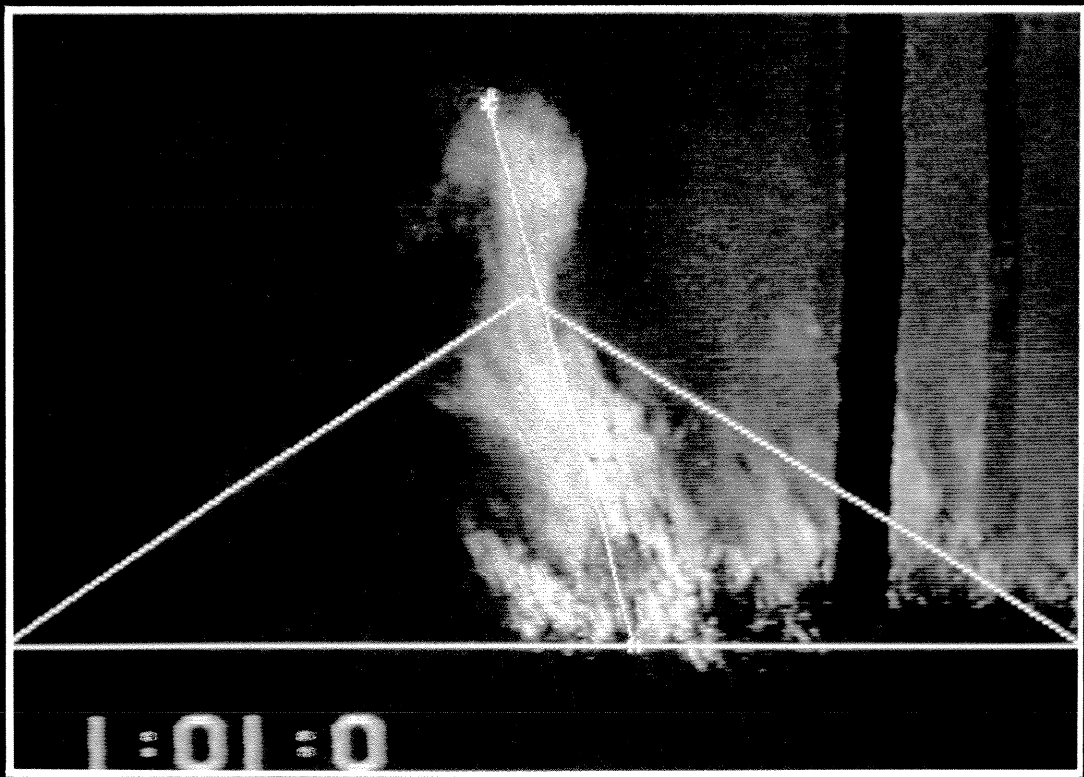

Figure 8—Example of a digitized flame in the two-point mode.

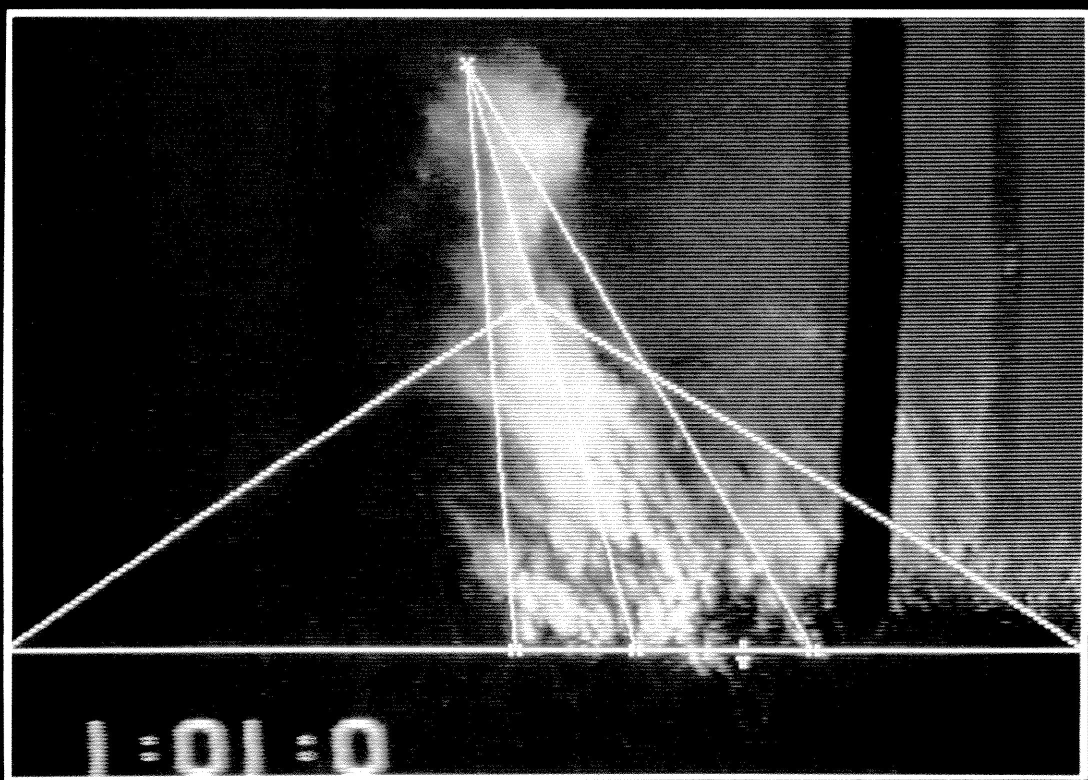

Figure 9—Example of a digitized flame in the four-point mode.

### *The Basics*

When the digitizing method has been selected, the following menu will appear:

| | | | | |
|---|---|---|---|---|
| DIGITIZE FIRE BEHAVIOR - 4 POINT METHOD | | | | DATE 04/13/94<br>TIME<br>FILE |
| X Scale Factor | = ** N/A ** | m/pixel | F1 ADJUST VIDEO | F2 |
| Y Scale Factor | = ** N/A ** | m/pixel | F3 | F4 |
| Z Range | = ** N/A ** | m | F5 | F6 STILL |
| Z Correction Factor | = ** N/A ** | | F7 | F8 PLAY |
| A Angle of Slope | = ** N/A ** | Deg | F9 | F10 EXIT |
| X = 320.0000 | Y = -100.0000 | | Z = 1.0000 | MODE = CURSOR |

DIGITIZE TRAILING END OF HORIZONTAL REFERENCE

*** CALIBRATION SEQUENCE - HIT <Esc.> TO QUIT ***

At this point, the first-time user should become familiar with this interactive system. The user controls or responds to requests by pressing a key or working with the system mouse.

### *Function Keys*

Within the double-line frame of the menu are several areas of single-line framed areas. At the right of the frame, two columns are displayed. The left column is the odd sequence numbered F1 through F9; the right is the even sequence F2 thru F10. These F-numbers represent function keys on the keyboard and when labeled are active options that control system functions for adjusting the video image and hardware, handling data tasks, and exiting to the system main menu.

### *Still and Play Modes*

Before attempting to adjust, calibrate, or operate the system, the user should understand the two system modes of operation—play and still. Using the F8 function key, the play mode is set to view a tape in the standard play mode. The still mode is set with the F6 function key to view the tape in the still play mode or to use the digital frame memory on the video cassette recorder/player. If the recommended equipment described in Hardware Requirements is used, the system may be operated solely in the still mode.

## **Adjusting and Calibrating the Image Analysis System**

The proper functioning and accuracy of data from the image analysis system requires adjustment to the hardware and calibration of the software. Adjustments to the hardware primarily involve synchronizing the computer-generated workspace and attendant graphics with the still frame video images of flames. The system programming (software), which sets scaling algorithms for the display screen picture elements (pixels), must then be calibrated to the specific input.

### *Video Adjustment*

A tape is inserted into the video tape recorder, and the section of the tape containing the image of the range target is located. After locating the target, the tape is stopped and viewed in the still frame mode. Press the digital frame memory button, and the image will reappear. The selection between fields 1 and 2 should be made now. Selection is based on image stability. If the system is new and has never been adjusted, the image of the rectangular workspace frame will probably jitter and be off-center. To correct this problem, press the F6 key and then the F1 function key (adjust video).

The left and right arrow keys control the centering; the up and down arrow keys control the synchronization and are used to eliminate frame jitter. When satisfied with the adjustment, press F3 to save the settings. An additional option in the "adjust video" mode allows the user to change the color of the workspace and attendant graphic aids. Color can be used to provide contrast between the graphics in the digitization process and the image of the fire and its surroundings. The page up and page down keys control color, and the stepwise process of changing colors repeats the selections once all options have been stepped through. To exit the "adjust video" mode and access the calibration mode, press the F1 key.

***System Calibration***

The system must be calibrated for horizontal and vertical length, distance from the range target, and point placement of the virtual horizon for each digitized fire. The calibration process is the same for all three methods of flame digitization. The user is prompted by instructions for each step of the process on the text monitor. As a fail-safe feature, the calibration must be done any time the system is exited and reentered. The steps in system calibration follow:

1. Play the section where the calibration information is recorded on the audio portion of the tape and note the length of the vertical and horizontal markers, height of the virtual horizon, and distance from the camera to the range target.

2. Play the tape and determine which direction the fire is moving—left to right or vice versa.

3. Find the section of the tape with the range target using the search feature on the recorder and press the digital frame memory button to freeze the frame in digital mode.

4. Horizontal length will be calibrated first. The instruction "DIGITIZE TRAILING END OF HORIZONTAL REFERENCE" is now displayed on the lower half of the text monitor screen, below the system menu. The trailing end of the reference is the center of the horizontal marker (on the range target) that is closest to the fire's origin. For example, in figure 5 the fire is spreading from left to right; therefore, horizontal marker 1 is closest to the fire's origin. To digitize the center of the target, move the mouse to center the cursor over the image of the trailing end marker and press the right mouse button. If properly entered, a white dot will appear in the dead center of the marker.

5. The screen instruction changes and now reads "DIGITIZE LEADING EDGE OF HORIZONTAL REFERENCE." The leading edge of the horizontal reference is the horizontal marker (on the range target) farthest from the fire's origin; therefore, opposite the trailing marker (fig. 5, No. 2). To digitize this point, center the cursor on the marker and press the right mouse button.

6. The screen instruction should now read "ENTER THE LENGTH OF THE HORIZONTAL REFERENCE." The length of the horizontal reference is distance (in feet or meters) between the points entered in steps 4 and 5. After this value is typed and the enter key is pressed, the system is calibrated for horizontal measurement.

7. Verticle length will be calibrated next, and the screen instruction on the text monitor should read "DIGITIZE TOP END OF VERTICAL REFERENCE." The procedure is the same as that used for horizontal calibration, except that the upper and lower markers on the range target are used. Locate the mouse cursor at the center of the upper marker (fig. 5, No. 3); press the right mouse key.

8. The screen instruction changes to read "DIGITIZE BOTTOM END OF VERTICAL REFERENCE." Using the mouse, enter a point at the center of the lower marker (fig. 5, No. 4).

9. The screen instruction now reads "ENTER THE LENGTH OF VERTICAL REFERENCE." The length of the vertical reference is the distance between the center point digitized on the upper marker and the center point digitized on the lower marker. To calibrate for vertical measurement, type the value (in feet or meters) and press enter.

10. "DIGITIZE A POINT ON THE VIRTUAL HORIZON" now appears on the text monitor screen. This point coincides with the level datum that was established in the field calibration of the camera. The center of the upper vertical reference represents this point (fig. 5, No. 5). Using the mouse, center the cursor in the marker and press the right mouse button. A mark will appear to the left and right of the workspace frame at the same height as the point entered.

11. "ENTER HEIGHT OF THE VIRTUAL HORIZON ABOVEGROUND LEVEL DATUM." Enter the height aboveground level to the point on the reference entered in step 10.

12. "ENTER THE CAMERA TO CALIBRATION REFERENCE DISTANCE." Enter the distance from the front lens element to the range target, and the basic calibration is complete.

**Operating the System**

***Digitizing Flames (Three Methods)***

Before flames can be measured, the baseline must be moved to the leading edge of the flame at ground level. This adjustment to the baseline location sets the system scaling to that distance from the camera. As a system fail-safe feature, the baseline must be calibrated before any flame measurements can be made. The baseline location is controlled by the mouse, and the position is fixed by pressing the F9 function key. After the initial baseline adjustment, F9 must be pressed again to move the baseline to another position and again to fix the position.

In the case of sloping terrain, the baseline must be adjusted to coincide with the slope. To adjust the slope of the baseline, press the F9 key, then the F7 key, and adjust the baseline with the mouse. Working from the left or right end of the baseline, move the cursor up or down and that end of the baseline will follow the cursor. Once the baseline is at the proper slope, press F9 to fix the angle of slope. To move the baseline location on the slope press F9; move the baseline with the mouse; press F9 again to fix the position.

Setting the baseline and, if necessary, the slope are the same for all three methods of flame digitization. Once the baseline is set, the flames can be digitized, using one of the three following methods:

**Contour**.
1. Using the mouse, position the cursor on the leading edge of the flame at the baseline (ground level) and press the right key on the mouse to begin.

2. Outline the flame with the mouse ending at the baseline on the trailing end of the flame. Do not digitize the base of the flame at ground level. Press the right key on the mouse to end.

**Two-Point**.
1. Position the mouse cursor at midpoint of the flame base (the baseline) and press the right mouse key.

2. Position the cursor at the flame tip and press the right mouse key.

**Four-Point**.
1. Position the cursor at midpoint of the flame base (the baseline) and press the right mouse button.

2. Position the cursor at the flame tip and press the right mouse button.

3. Position the cursor at the leading edge of the flame at ground level and press the right mouse button.

4. Position the cursor at the trailing edge of the flame at ground level and press the right mouse button.

***Point Input Considerations***

Point placement during digitizing is straightforward for the leading edge at ground level and the tip of the flame. However, point placements for the midpoint of the flame base and the trailing edge at ground level rely on the judgment of the user. The trailing edge of the flame is often obscured because the shape of the fire front is elliptical. To solve this problem, the user can interpolate the line down the trailing edge of the flame. This procedure may require digitizing the flame a number of times until the line represents a best fit of the trailing edge of the flame.

***Creating and Saving Data***

When a flame is completely digitized, the computer will calculate the geometry for that observation and display the results on the text monitor. Each observation may be saved in a file. Instructions are displayed on the text monitor for each step in creating files and saving or deleting observations in these files.

The step-by-step procedure for creating and saving data to a file follows:

1. After the system is calibrated and the baseline is set, but before the flame is digitized, press the F4 key and the following screen instruction will appear on the text monitor: "Do you wish to 1. Append to OR 2. Create a data file." Enter 2 to create a data file.

2. The instruction changes on the text monitor to "Enter Name of recording file :." Enter a name of no more than eight characters plus three characters for file extension.

3. After the file name is entered, the instruction on the text monitor changes to "Enter a short description for data set :." The file must be described in 40 characters or less. This information is printed as a header in the internal plot program.

4. After a flame is digitized, press F3 to save data.

5. The instruction "Enter Time Tag MM:SS:CC:" is displayed on the text monitor. This is the time taken from the

screen display on the video monitor of the camera timer where MM equals minutes; SS, seconds; and CC, hundredths of a second. The character generator only displays to a tenth of a second; thus, enter tenths followed by a zero. For example 1 minute, 29 seconds, and one-tenth of a second will be entered 01:29:10. Enter a colon between minutes, seconds, and tenths or hundredths of seconds.

6. The process for digitizing and saving data continues until the entire fire has been digitized or complete digitization has been postponed. Exiting the digitizing mode closes the file. An append file feature has been incorporated into the system, which allows the user to reopen a closed file at a later time. This feature is also used to reopen a file to delete an observation.

### *Deleting Data*

The F5 key, labeled "DELETE RECORD" on the text monitor menu, controls the delete function in the system. However, the system does not allow complete file deletion, which must be done at the operating system level. The steps for deleting observations within files follow:

1. Press the F5 key and the following instruction appears: "Do you wish to delete data by 1. Sample No. or 2. Time :." Select the option by entering either 1 or 2 and pressing return.

2. If option 1 is selected, enter the sample number (numbers consecutively assigned to the observations). If the observation is deleted by the time tag, reenter the time tag assigned during the save data process.

### *Viewing and Printing Data*

During the digitization process, recorded data may be reviewed without exiting the program by pressing the F3 key. After viewing the data, press any key and the system reverts to the digitization mode. If you have exited the fire image analysis system, view data (No. 5) or print data (No. 6) can be selected from the fire image analysis main menu. In both View and Print, the data are presented in the same format with the time given in minutes, seconds, and tenths and hundredths of a second (fig. 10). In both View and Print, a list of the files are displayed on the screen. If you have accumulated more files than one screen can display, the remainder will scroll down the screen until it reaches the end. You may stop the scroll at any point by pressing the control key and the "s" key simultaneously. To continue, press enter and the file list will continue to scroll.

### *Plotting Data*

It is often helpful in the analysis process to evaluate the data in graphic form. A simple quick plot feature in the system provides for cursory examination of the data in cartesian coordinate form. The step-by-step procedure for using the plot program follows:

1. At the main menu, enter option 4, and a list of the current files is shown. At the bottom of the list, this instruction appears: "Enter Name of File to be plotted from →." Type the file name and press return.

2. Once the file name is entered, the screen displays file information and parameters.

| Rec # | Time Secs | F_Posn Ft | F_Hite Ft | F_Len Ft | F_Ang Deg | FtoCam Ft | Fslope Deg | F_Area SqFt | F_D Ft |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 00:57:05 | -1.92 | 8.81 | 9.69 | 24.64 | 65.48 | 0.00 | 13.96 | 3.17 |
| 2 | 00:58:70 | -1.16 | 6.67 | 7.18 | 21.86 | 65.48 | 0.00 | 12.31 | 3.69 |
| 3 | 00:59:70 | -0.58 | 9.29 | 10.01 | 21.99 | 65.48 | 0.00 | 19.44 | 4.19 |
| 4 | 01:00:70 | 0.20 | 6.83 | 7.56 | 25.50 | 65.48 | 0.00 | 11.91 | 3.49 |
| 5 | 01:01:70 | 0.17 | 7.94 | 8.75 | 24.95 | 65.48 | 0.00 | 13.61 | 3.43 |
| 6 | 01:02:70 | 0.36 | 5.76 | 7.24 | 37.29 | 62.50 | 0.00 | 9.83 | 3.41 |
| 7 | 01:03:70 | 0.78 | 5.30 | 8.09 | 49.02 | 62.50 | 0.00 | 10.01 | 3.77 |
| 8 | 01:04:70 | 1.26 | 6.79 | 7.89 | 30.61 | 61.57 | 0.00 | 10.58 | 3.12 |
| 9 | 01:05:70 | 1.78 | 4.40 | 5.71 | 39.55 | 61.57 | 0.00 | 8.55 | 3.88 |
| 10 | 01:06:80 | 3.28 | 7.63 | 9.42 | 35.91 | 72.37 | 0.00 | 15.69 | 4.11 |
| 11 | 01:07:80 | 3.00 | 6.64 | 8.08 | 34.75 | 64.45 | 0.00 | 14.16 | 4.26 |
| 12 | 01:08:80 | 4.42 | 6.96 | 8.73 | 37.09 | 73.66 | 0.00 | 21.07 | 6.05 |
| 13 | 01:09:70 | 4.58 | 7.24 | 9.19 | 37.97 | 71.12 | 0.00 | 22.18 | 6.13 |
| 14 | 01:10:70 | 4.33 | 6.83 | 8.35 | 35.04 | 68.75 | 0.00 | 19.19 | 5.62 |
| 15 | 01:11:70 | 4.12 | 7.25 | 7.89 | 23.24 | 68.75 | 0.00 | 17.37 | 4.79 |

Figure 10—Example of the data format for the View and Print utilities from the system main menu. Note that the time annotation is in minutes, seconds, and tenths and hundredths of seconds.

| | | |
|---|---|---|
| Data File Type is | : | FOUR POINT METHOD |
| File Description | : | HEADFIRE BIANNUAL |
| Date File Created | : | 01/04/91 |
| No of Parameters | : | 9 |

| | | |
|---|---|---|
| 1 Time | Secs | Elapsed Time |
| 2 F_Posn | Ft | Rel Position of Flame Base |
| 3 F_Hite | Ft | Flame Height |
| 4 F_Len | Ft | Flame Length |
| 5 F_ang | Deg | Flame Angle from Vert. |
| 6 FtoCam | Ft | Camera to flame distance |
| 7 Fslope | Deg | Baseline slope |
| 8 F_Area | SqFt | Projected Flaming Cross Section |
| 9 F_D | Ft | Flame Depth |

Enter Number of X-axis Variable to be plotted →2
Enter Number of Y-axis Variable to be plotted →4

At the bottom of the display is the instruction "Enter Number of X-axis Variable to be plotted→." The X-axis variable is selected by a number from the list on the display and is the horizontal axis on the graph. Enter the number of the parameter and press return.

3. The instruction, "Enter Number of Y-axis Variable to be plotted→," is displayed next. Again, the Y-axis variable is selected from the list on the display for the Y-axis and is the vertical axis on the graph. Type the number of the parameter and press return.

4. After the X and Y parameters are selected, the screen changes, and the data for the axis is displayed. Press return again and the plot is displayed (fig. 11).

5. A hard copy can be printed by pressing and holding the Shift key and pressing the Print Screen key. Note that the print screen process takes 5 minutes or longer and should not be considered as a primary source of plots for fire data.

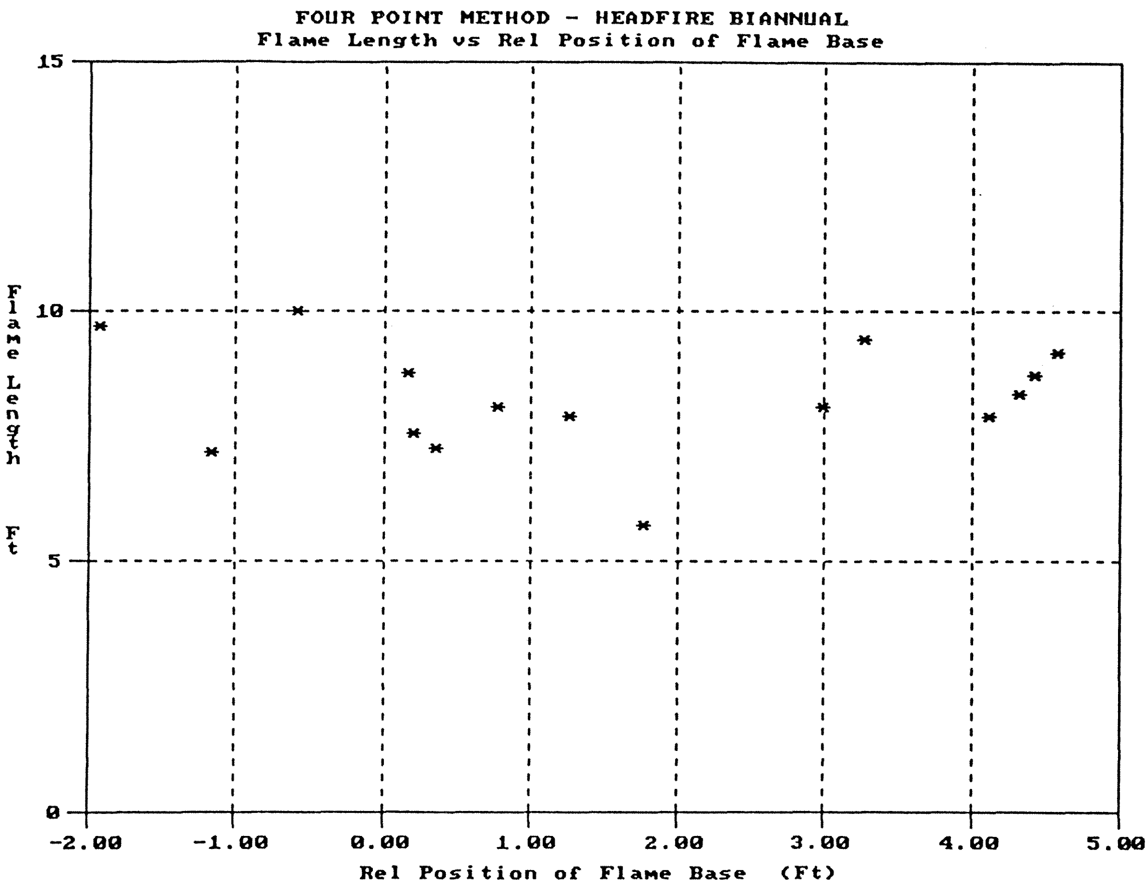


Figure 11—The relationship between relative position of the fire and flame length is shown in a two-dimensional plot created by the Plot utility from the main menu.

6. To exit from the plot, press the return key to return to the plot menu.

7. To exit plot, press the return key to access the main menu.

## Sampling Flame Images

Once the mechanics of operating the system are mastered, the user should concentrate on how to sample flame images. Typically, a number of flames are sampled from the many frames of video shot as the fire traverses the camera's field of view. Sample frequency is determined by the user, based on the desired information and the objectives of the study.

However, the difference between human visual perception of flame and instantaneous video images (one-sixtieth of a second per field) should be understood before attempting to gather a representative sample of flame images. This understanding is crucial to representative sampling of flame height and length. The conventions set forth in the literature cite a relationship between visual estimates of flame length and Byram's fireline intensity for determining fire intensity (Rothermel and Deeming 1980). In video analysis of flames, flame length varies from frame-to-frame and field-to-field and depends on the stage of development of the flame pulse; that is, flame length is not a constant but, in fact, a rapidly pulsating phenomenon. Experience has shown that the pulsation frequency varies with the intensity of the fire from a very high frequency for low-intensity fires to a much lower frequency for high-intensity fires. To an observer, the flames of lower intensity fires appear to flicker. In higher intensity fires, the pulsation frequency is low enough for an observer to view the flame building to a maximum length. To match the video data to the visually perceived flame length or height, only the field of video where the flame is at its maximum extension should be considered representative of flame length or height.

## Additional Operations

### Rate of Fire Spread

Rate of spread can be calculated from the output of elapsed time and relative position of the fire front at two different positions along the direction of spread. Rate of spread is the traverse distance divided by the elapsed time in seconds.

### Exporting Data Into Other Programs

The data are saved in ASCII Text format and may be exported to other software programs. These files are located in the Files subdirectory under the directory FAS. The file extension for all data files is .DAT (fig. 12).

## Literature Cited


**Rothermel, Richard C.; Deeming, John E.** 1980. Measuring and interpreting fire behavior for correlation with fire effects. Gen. Tech. Rep. INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 4 p.


| Time Secs | F_Posn Ft | F_Hite Ft | F_Len Ft | F_Ang Deg | FtoCam Ft | Fslope Deg | F_Area SqFt | F_D Ft |
|---|---|---|---|---|---|---|---|---|
| 57.05 | -1.92 | 8.81 | 9.69 | 24.64 | 65.48 | 0.00 | 13.96 | 3.17 |
| 58.70 | -1.16 | 6.67 | 7.18 | 21.86 | 65.48 | 0.00 | 12.31 | 3.69 |
| 59.70 | -0.58 | 9.29 | 10.01 | 21.99 | 65.48 | 0.00 | 19.44 | 4.19 |
| 60.70 | 0.20 | 6.83 | 7.56 | 25.50 | 65.48 | 0.00 | 11.91 | 3.49 |
| 61.70 | 0.17 | 7.94 | 8.75 | 24.95 | 65.48 | 0.00 | 13.61 | 3.43 |
| 62.70 | 0.36 | 5.76 | 7.24 | 37.29 | 62.50 | 0.00 | 9.83 | 3.41 |
| 63.70 | 0.78 | 5.30 | 8.09 | 49.02 | 62.50 | 0.00 | 10.01 | 3.77 |
| 64.70 | 1.26 | 6.79 | 7.89 | 30.61 | 61.57 | 0.00 | 10.58 | 3.12 |
| 65.70 | 1.78 | 4.40 | 5.71 | 39.55 | 61.57 | 0.00 | 8.55 | 3.88 |
| 66.80 | 3.28 | 7.63 | 9.42 | 35.91 | 72.37 | 0.00 | 15.69 | 4.11 |
| 67.80 | 3.00 | 6.64 | 8.08 | 34.75 | 64.45 | 0.00 | 14.16 | 4.26 |
| 68.80 | 4.42 | 6.96 | 8.73 | 37.09 | 73.66 | 0.00 | 21.07 | 6.05 |
| 69.70 | 4.58 | 7.24 | 9.19 | 37.97 | 71.12 | 0.00 | 22.18 | 6.13 |
| 70.70 | 4.33 | 6.83 | 8.35 | 35.04 | 68.75 | 0.00 | 19.19 | 5.62 |
| 71.70 | 4.12 | 7.25 | 7.89 | 23.24 | 68.75 | 0.00 | 17.37 | 4.79 |

**Figure 12**—Example of the .dat file format found in the data subdirectory of FAS. In this format, time is expressed in seconds and fractions of second that accommodate import into database software packages.

**Adkins, Carl W**. 1995. Users guide for fire image analysis system—version 5.0: a tool for measuring fire behavior characteristics. Gen. Tech. Rep. SE-93. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 15 p.

The Fire Image Analysis System is a tool for quantifying flame geometry and relative position at selected points along a spreading line fire. At present, the system requires uniform terrain (constant slope). The system has been used in field and laboratory studies for determining flame length, depth, cross sectional area, and rate of spread.

**Keywords**: Flame length, quantifying flame geometry, rate of spread.

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