DOT/FAA/CT-94/24

Aircraft Command in Emergency Situations Prototype Development Users Manual

June 1994

Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

1. Report No. DOT/FAA/CT-94/24	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Aircraft Command in Emergency Situations Prototype Development Users Manual		5. Report Date June 1994
		6. Performing Organization Code
		8. Performing Organization Report No.
7. Author's Gregory E. Grimstad		
9. Performing Organization Name and Address Boeing Commercial Airplane Group Technology and Product Development – Payloads P.O. Box 3707 Seattle, Washington 98124-2207		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFA03-89-C-00061
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code ACD-250

15. Supplementary Notes

The FAA TC Technical Monitor is Dr. Thor Eklund, Telephone (609) 485-5322

16. Abstract

This project involved assembly of the hardware and development of the software identified in ACES Phase I Concept Development contract study. The assembled system allows three critical stages in responding to an aircraft inflight smoke/fire event to to be examined. These stages are (1) sensing (data gathering), (2) establishing the alerting criteria to maintain quick response while reducing false alarms (data analysis), and (3) methods of providing assistance to the crew, both flight deck and cabin, in responding to an inflight event.

Four smoke/particle sensors are linked to a computer via a high speed data acquisition and control system. On the computer reside alerting logic functions and the capability to emulate the flight deck and cabin attendant displays. In addition, a thermal system that allows both location and temperature of numerous zones on a single fiber optic cable to be known was identified as a means to reduce false alarms and monitor hidden areas of an aircraft.

The primary objective of the ACES system concept is to provide the capability to reduce the time required for the flight crew to make a decision to land the aircraft during an inflight smoke/fire event.

17. Key Words Smoke detection Aircraft Fire detection Cabin safety Crew alerting Flight deck response Inflight fire		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 78	22. Price

Form DOT F 1700.7

PREFACE

This report takes the form of a users manual to assist the user in the setup and operation of a prototype aircraft smoke and fire detection system. The system is designed to provide timely and accurate detection and to assist in the management of inflight emergencies aboard commercial jet aircraft. The contract work "Aircraft Command in Emergency Situations (ACES) Phase II – Prototype System Development" was conducted by the Technology and Product Development–Payload Systems Organization, Boeing Commercial Airplane Group, under contract to the United States Department of Transportation, Federal Aviation Administration Technical Center, (FAA TC) Atlantic City International Airport, New Jersey.

Boeing personnel participating in this effort include: Tom Reynolds, Program Manager (thru December 1992); Gregory Grimstad, Principle Investigator and Program Manager (January 1993 to completion); Chuck Anderson, Gail Pier, and Brian Zabriskie all of Flight Deck Research; Cathy Rider, Payloads Documentation; Tim Regier and Mike Strand, Mechanical/Electrical lab; Robert McFarland, Material (purchasing); Patrick Riordan, Contracts; and Joe Banz, Business Management.

The contribution of technical advice from the staff of several commercial companies is gratefully acknowledged and appreciated:

Ahead Systems, Inc., Freemount California
Cerberus Guinard, Cedex, France
Dolch American Instruments, San Jose, California
Geamatic Control System AB, Frölunda, Sweden
Jamco America, Inc., Everett, Washington
Keithley Instruments, Inc., Data Acquistion and Control Division, Cleveland Ohio
Schlumberger Industries, Aerospace Transducer Division, Hampshire, United Kingdom
Walter Kidde Aerospace, Inc., Wilson, North Carolina
York, V.S.O.P., Hampshire, United Kingdom

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS *(CONTINUED)*

LIST OF TABLES

LIST OF ACRONYMS

ac	alternating current
ACES	Aircraft Command in Emergency Situations
AMM2	analog measurement module
ATIS	Automated Terminal Information System
CFM	cubic feet per minute
CPU	central processing unit
CRT	cathode ray tube
dc	direct current
DIFF	differential
Dist.	distance
DT	dual truck
DTS	distributed temperature sensor
E/E	electronic equipment
EICAS	engine indications and crew alerting system
ELEV	elevation
EMT	emergency medical technician
ETA	estimated time of arrival
ETE	estimate time enroute
FAA	Federal Aviation Administration
FAA TC	Federal Aviation Administration Technical Center
GND	ground
F	fog
FT	feet
GPIB	general purpose interface bus
HP	Hewlitt Packard
IEEE	Institute of Electrical and Electronic Engineers
IFR	instrumented flight rules
LED	light emitting diode
ma	milliamp
min	minutes
mm	millimeter
N	no
nm	nautical miles
OTDR	optical time domain reflectometry
QRH	quick reference handbook
RAM	random access memory
RCR	runway condition rating
ROM	read only memory
S-E	single-end
SGND	single-end ground
SM	statute miles
SRQ	service request
SYNO	synoptic
T/C	thermocouple
UK	United Kingdom
V	volt
Vdc	volt direct current
VIS	visibility
Y	yes
Z	Zulu time

Executive Summary

Boeing Commercial Airplane Group, Technology and Product Development, Payload Systems, performed this prototype development work for the Federal Aviation Administration Technical Center (FAA TC), Atlantic City International Airport, New Jersey, under contract No. DTFA03-89-C-00061. The work was motivated by the FAA's concern for early fire detection and timely implementation of procedures that facilitate landing an aircraft in an expedient manner.

In a Phase I study, an ACES system was identified that included improved sensor technology and enhancements to the flight deck that was made possible by advances in computer and display technologies. Costs, on a rough order of magnitude, were estimated in the initial study. The system was found not to carry a prohibitive cost and further study, in the form of prototype development, was authorized.

The second phase of the study: Phase II - Prototype Development, entailed assembling the system components identified in Phase I, integrating these components, and developing flight deck and cabin attendant display enhancements.

The hardware necessary for the prototype ACES system includes smoke sensors from four different manufacturers, a data acquisition system to collect the sensor outputs, and a computer to run the system. In addition, a continuous fiber optic cable, coupled to an operating system, allows the identification of temperature as a function of location on the cable. Because of the stand-alone architecture of the thermal monitoring system, the integration with the data acquisition and/or computer, after a great deal of effort being expended, was not achieved.

Resident on the computer are two alerting algorithms developed to take advantage of the time dependant information output of the sensors. The computer also hosts the flight crew enhancements. These include four major modules: electronic checklist, inflight diversion planner, a synoptic display, and a cabin attendant panel. The electronic checklist provides the flight deck crew with the procedures that need to be performed to configure the aircraft to respond to the situation. The inflight diversion planner ranks the nearby airports and chooses the best one based on several factors, which include: time enroute, runway length and conditions, current and forecast weather, and emergency facilities available.

This report takes the form of a users manual to guide the user in operating the system: collecting sensor data, evaluating the algorithms with the collected sensor data, and demonstrating the enhancements proposed for the flight crew - both cabin and the flight deck. The full value of the system can best be gained by using this manual while operating the system. This is especially true for the flight deck display portion of the system where color is a significant element in the transmission of information.

The code that drives ACES is written in C language a detailed explanation of which, except for that dealing with the alerting algorithms, is beyond the scope of this manual.

1. INTRODUCTION.

The ACES system has been designed to be user friendly both in the setup of the hardware elements and in the software developed for system operation. It is the intention of this document to provide a users manual to facilitate the setup and operation of the ACES system. Much of the in-depth information regarding the individual components of the system is included in the reference section of this document.

This users manual is divided into two major sections – System Setup and System Operation. In section 2, System Setup, the hardware will be introduced, briefly described, and the connections between the various components will be explained. The second of the major sections, section 3, System Operation, will walk the user through operation of the system in its three modes of operation: sensor data collection, alerting algorithm evaluation, and flight crew demonstration capabilities.

1.1 BACKGROUND.

Phase I (reference 1) of the ACES study was performed by the Boeing Commercial Airplane Group, under Contract No. DTFA03-89-C-00061, for the Federal Aviation Administration Technical Center (FAA TC), Atlantic City, New Jersey. The Phase I Concept Development study arose from the FAA's concern for the early detection and control of inflight smoke/fire events within the pressurized volume of commercial jet aircraft. The motivation for the study was the computerization of the flight deck, the advent of the two-person flight deck crew, documented times taken to locate and implement appropriate emergency procedures during past incidents, the incidence rate of false smoke/fire alarms, and the findings from two preliminary studies, references 2 and 3.

1.2 PURPOSE.

The purpose of Phase I was to define two systems that would provide timely and accurate detection of a smoke/fire event and relay that information to the flight crew in such a manner so as to speed up response time. The primary objective of an ACES type system is to provide a capability for decreasing the time needed to make a decision to land at the nearest suitable airport once an alert has been sounded.

The purpose of Phase II is to integrate the hardware elements and develop the crew alerting capabilities to address the four areas identified in Phase I as areas where improvement could be made. These areas are

Sensing – Detection of a smoke/fire event in a timely and accurate manner. This is to be accomplished by making use of sensors with improved capabilities and, where appropriate, looking for more than one fire signature – smoke and heat.

Alerting – Incorporate the improved detector capabilities into system logic for the elimination/reduction of false alarms.

Crew response – The reduction of false alarms should increase crew confidence in the system, thus insuring timely response to smoke/fire alerts. Two flight deck features, electronic checklist and inflight planner, provide the flight crew with the information needed to perform the necessary procedures and to investigate suitability of diversion airports. The cabin attendant panel is interfaced with the flight deck crew to insure a coordinated response to the situation.

Crew decision making – The system, via the electronic checklist, helps to organize and track flight crew actions and displays for the flight crew the status of all required checklist items. Prioritized information on diversion airports, with the ability to query the system on how this priority was made, aid the crew in reaching a decision in an expedient manner.

The Phase 2 system enables the user to gather, monitor, and store sensor data, use this data for the evaluation of alerting algorithms, and demonstrate the flight crew display features: electronic checklist, inflight planner, synoptic display, and a cabin attendant panel.

At the conclusion of Phase II, the ACES system was delivered to the FAA TC for further testing and evaluation.

2.   SYSTEM SETUP.

The ACES system is comprised of four major component groups: Dolch computer, Keithley data logging unit, smoke sensors, and the York thermal monitoring system. Each of these components will be described in section 2.1 through 2.4, followed by section 2.5 which will define system integration.

2.1   DOLCH COMPUTER.

The computer used to drive the ACES system is a Dolch 486 portable computer, figure 2-1. The computer, hereafter referred to as "the Dolch" has many features that made it the choice of the ACES team: portable – making it ideal for lab/field operation, powerful, color capability, and expandable. Below is a short description of the computer and the simple procedures to make the Dolch operational.

Figure 2-1. Dolch Computer.

The front of the Dolch features a keyboard that latches in front of the screen. The keyboard is accessed by pushing on the two buttons located on the top of the computer. Care should be taken so that the keyboard does not fall as it is pivoted away from the screen. The keyboard is of standard layout with 12 enhanced programmable function keys F1 through F12. The keyboard can be inclined by flipping out the two pivoted legs located at the top edge of the keyboard. A coiled cable is stored in a slot along the top edge of the keyboard and this cable plugs into the socket on the left side of the machine. Also on the left side is a cover concealing the expansion window. The cover can be removed by pressing down on the thumb tab and pivoting the cover out from the machine. Port allocation is defined in section 2.5 which deals with hardware interfaces.

Behind the keyboard is the flat panel display screen. The screen has a text capacity of 80 characters by 25 lines. Screen definition is controlled, to a degree, by the brightness knob located to the right of the screen. Next to this knob is the reset button which, when pushed, reboots the computer. A set of three indicator lights is located above the brightness knob and reset button. From left to right, these lights indicate power (green when on), hard disk (red) to indicate that the hard disk is being accessed, and CPU (yellow) to indicate fast clock speed.

The back of the Dolch is where the on/off switch is located as well as the ac power plug socket. Make sure the Dolch power switch is in the off position before plugging the computer into the power supply.

The right side of the computer is where the disk drive is located. The drive accepts 3½-inch disks.

Internal to the Dolch is a half size GPIB-PCII IEEE-488.2 (GPIB – General Purpose Interface Bus, IEEE – Institue of Electrical and Electronic Engineers) board that facilitates high speed communications between the Dolch and the Keithley data logger (section 2.2). Additional information on the Dolch can be found in reference 4. Documentation on the GPIB is contained in references 5, 6, 7, and 8.

Two video cards have been installed to facilitate the running of two additional cathode ray tube (CRT) type screens. The running of screens of differing types (flat panel and CRT) presented an unexpected problem during initial system integration. This difficulty was overcome only after several screen control cards were auditioned and a card selected that would take flat panel input instructions and translate that information and efficiently drive a CRT type screen. The three screen feature is critical to provide a more realistic showing of the flight deck and cabin attendant panel display features. The two CRT screens used during the development work were Sony Trinitron color monitors, Model No. CPD-1304. Other color monitors have also been used and no system configuration changes were required.

The mouse allows the user to move the cursor about the screen, set up the demonstration scenarios, and interact with the display functions of the flight deck and cabin attendant panel.

The programing done to run the ACES system and to provide the user friendly interface was done using Microsoft C version 6.0 (references 9, 10, and 11). A printed copy of the code has been provided to FAA TC personnel to facilitate their understanding of the system's architecture. Detailed explanation of C language programming and system software structure are outside the scope of this users manual.

2.2. KEITHLEY – HIGH SPEED DATA LOGGER.

The Keithley high speed data logger is model 576-2, figure 2-2, with data memory expanded (factory installed) from 100 to 480 kB. The 576 is a general purpose data acquisition and control instrument that serves as the interface between a GPIB controller (residing in the Dolch) and a wide range of input devices. The 576 is outfitted with an Analog Measurement Module (AMM2) which occupies option slot 1 and provides the terminal blocks (J1 and J2) into which the input devices (smoke sensors) are connected. The 576 is expandable. With the purchase of the appropriate board the Keithley can be given the capability to connect thermocouples (T/C); such a board would occupy option slot number 3 of the 576.
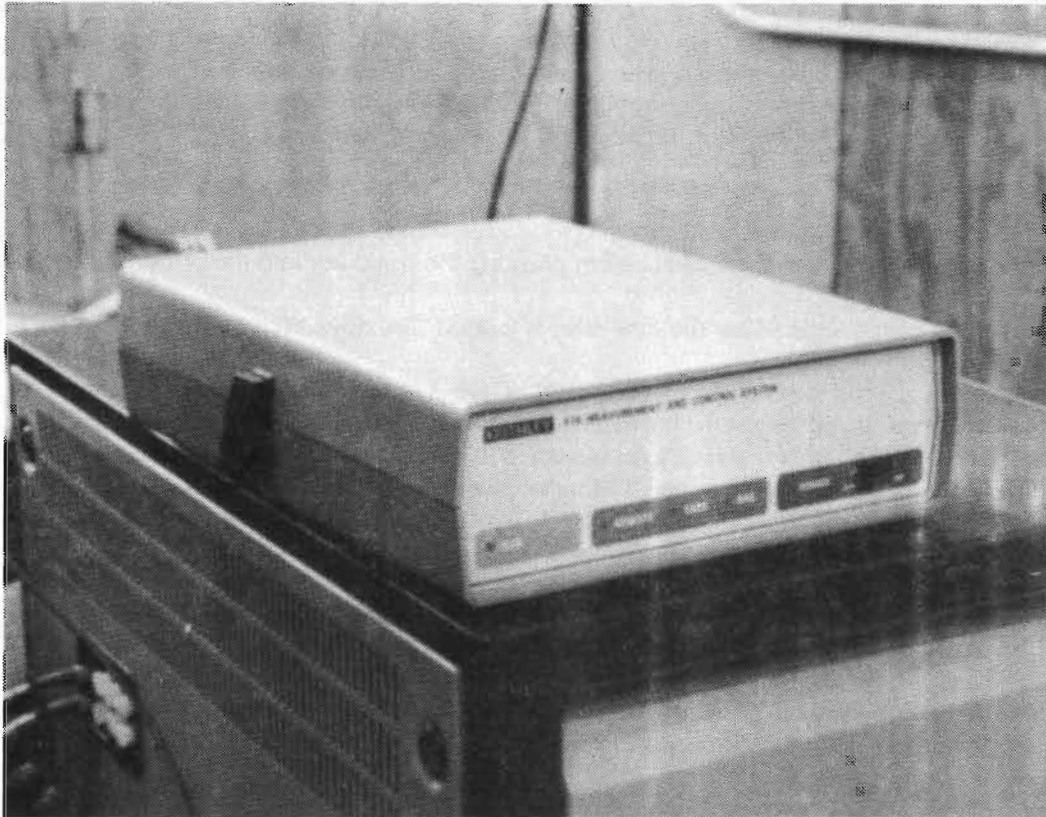
Figure 2-2. Keithley Data Logger.

A latch on the left side of the case provides access to the inside of the 576. The J1 and J2 terminal block, located on the AMM2 module, has the capacity to be configured for either eight differential channels or sixteen single-end channels. The channels are designated 0 through 7 for differential (DIFF), and 0 through 15 for single-end (S-E). The user sees 20 connector locations, sixteen single-end inputs plus four ground channels. In the single-end configuration, the SGND is used and in the differential mode the GND is used to achieve best performance.

The Keithley is configured to run in the differential mode with sensor high inputs connected to terminals 0+ to 7+, and the sensor low connected to the corresponding low input terminal (0-to7-). In this configuration the GND terminal **must** be used.

The interface of the sensors to the data logger will be discussed in section 2.5.5.

The port into which the IEEE-488 connector attaches is located on the back side of the unit. Note: the 576 will only accept a connector having metric (BLACK) threaded screws; a connector with sliver screws will damage the threads. To the outboard side of the IEEE interface is the power input port that accepts the ac line adapter.

The front panel of the 576 includes the ON/OFF power switch and five indicator lights. The POWER light is illuminated when the unit is plugged in and the power switch is turned on. Turning power on automatically causes diagnostics to be performed. If no problems are detected the RUN light will quickly flash three times, and then extinguish. However, if a problem is encountered upon start-up, the service request (SRQ) light will flash to signal error conditions. Two flashes a second indicate a problem with onboard firmware read only (ROM), 20 flashes a second is an onboard random access memory (RAM) problem. If either of these conditions should occur representatives from Keithley will need to be contacted. The TALK and RUN lamps illuminate when the 576's data acquisition circuitry is being accessed.

The 576 comes from the manufacturer with a notebook of documentation on both the 576 unit and the AMM2 card, reference 12.

2.3.   SMOKE SENSORS.

Three types of smoke (particle) detectors were used during the development of the ACES system: light scattering (Walter Kidde and Cerberus Guinard), light attenuation (Geamatic), and an ionization sensor manufactured by Jamco. Each of these sensors will be discussed in sections 2.3.1-2.3.4 and detailed specs on each sensor can be found compiled in the vendor documentation notebook, reference 13. A summary of the operating parameters for each of the four smoke sensors in the ACES system are shown in table 2-1.

Table 2-1. ACES Smoke Sensors Operating Parameters.

Sensor Manufacture (Model Number)	Power Requirement Volts	Range of Output Voltage	
		Clear Conditions	Maximum*
Walter Kidde (73055)	28	~0.125	15
Cerberus Guinard (Special Configuration for ACES)	24	2.2–2.3	24
Geamatic (SDS-300A w/ZAM12)	24	10	0
Jamco (PU90-461R3)	28	0	4.1

* The Keithley truncates all outputs at 10 volts
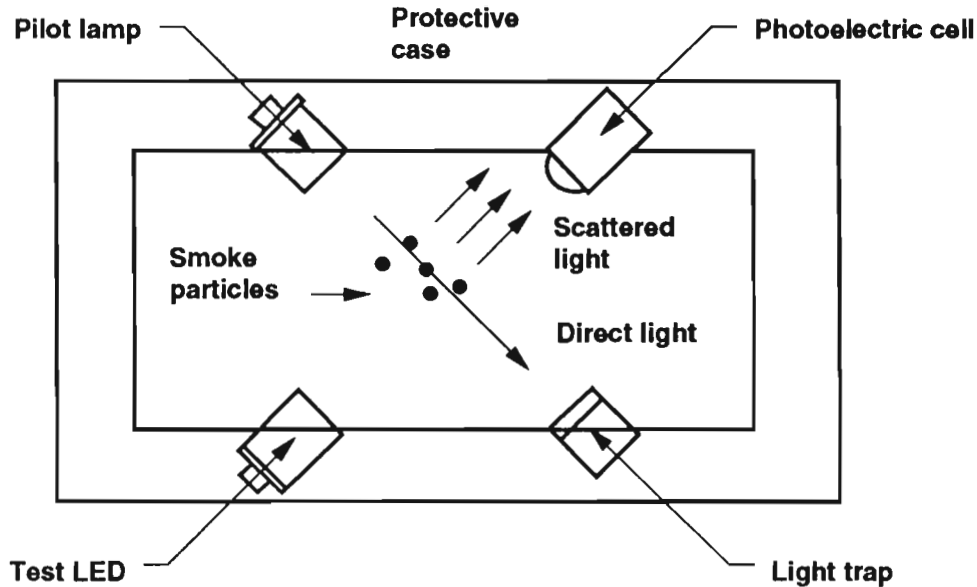
Figure 2-4. Photoelectric Smoke Detector.

The detector has a power requirement of 28 +Vdc, pin 2, and 28Vdc return, pin 4. The detector output channel, pin 8, has a quiescent value of about 0.125V. This voltage is monitored to insure that the detector is operational. As this value decreases, it is an indication that the optical surfaces require cleaning. As particles enter the optical chamber the output voltage will increase up to a maximum of 15V (Note: the Keithley's range is 0-10 volts, all voltages input to the Keithley above 10 volts are truncated at 10V, refer to section 2.5.5). It is the output signal from pin 8 that is monitored (through the Keithley to the Dolch) for determining an alert condtion.

The detector has an alarm output channel, pin 6, that is factory set to alarm in the range of 87 to 93 percent normal light transmission (13 to 7 percent obcuration measured over one foot). This channel has not been used, as the alarm level is being determined by the alerting algorithms residing on the Dolch.

2.3.2   Cerberus Guinard.

The sensor manufactured by Cerberus Guinard, figure 2-5, like the Kidde sensor, is a light scattering photoelectric detector (figure 2-4). This sensor was custom made for the ACES project by Cerberus to incorporate several features that were available from a sensor made by a subsidiary of theirs (the Gamewell sensor). To use the sensor originally identified would have required the purchase of the Gamewell's unique operating controller. Cerberus was able to rewire their detector enabling the output signal to be fed into the ACES data logger.

Figure 2-5. Cerberus Photoelectric Detector.

This ACES system sensor was linked with "and" logic and was mounted in pairs in the cargo compartment and singularly in the main deck attic area.

Particles enter the detection chamber via free convection, scattering light onto a photocell. In its quiescent (nonsmoke) state, the output voltage, pin C, is between 2.2 and 2.3V. This gives a value to monitor the health of the sensor. As particles enter the chamber the output signal rises to a maximum output value of 24V. (Note: the Keithley's range is 0-10 volts, all voltages input to the Keithley above 10 volts are truncated at 10V, refer to section 2.5.5). The alarm threshold is factory set at 3.2V which corresponds to a nominal smoke obscuration level in the chamber of 2.8 percent per foot. But as was the case with the Kidde detector, this output signal is not being used.

The Cerberus sensors require a 24Vdc power source (+/- 0.5V, at 50 ma), +24Vdc to pin A and 24Vdc return to pin B.

2.3.3   Geamatic.

The Geamatic sensor, model SDS-300A with the ZAM12 analog module, figure 2-6, is designed as a duct smoke detector and was selected for use in the air pack supply ducts. The Geamatic operates on the principle of light attenuation (figure 2-7). A beam of light shines on a photocell. As particles come between the light source and the photocell, the light is attenuated causing the photocell to see less light, and an output voltage drop results. Thus the Geamatic sensor has an output that is opposite of the Kidde and Cerberus detectors which both output a voltage rise when particles are in the light chamber.

8
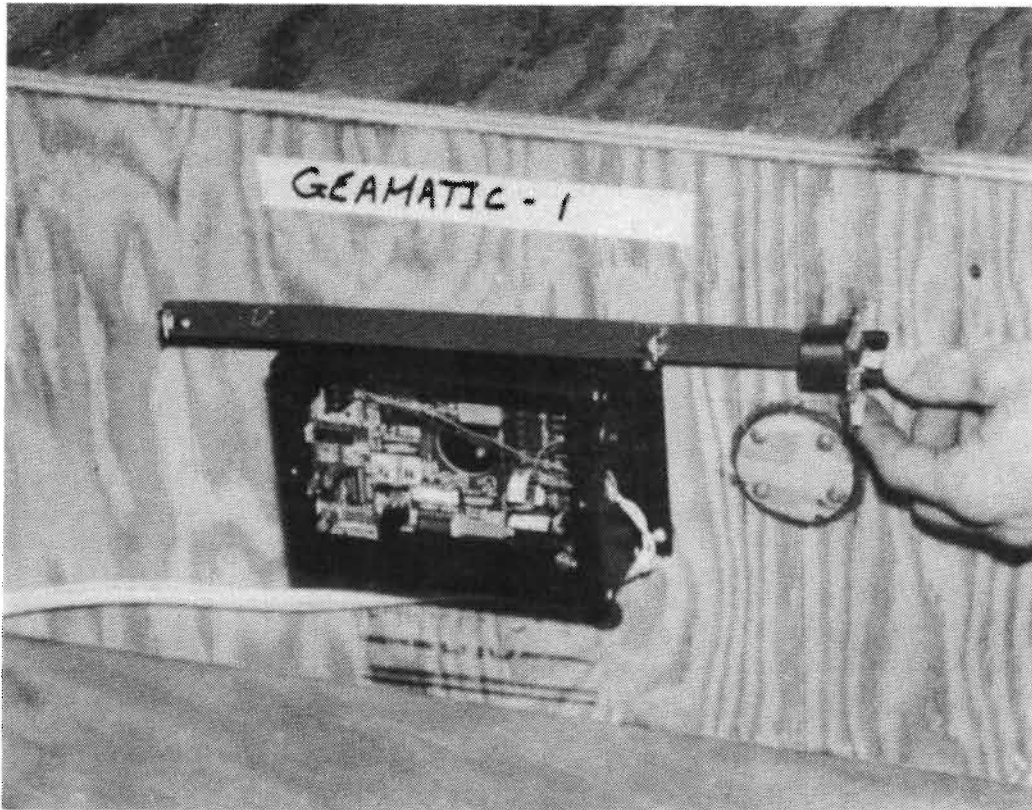
Figure 2-6. Geamatic Light Attenuation Detector.

Figure 2-7. Light Attenuation Type Photoelectric Smoke Detector.

The Geamatic requires a power source of +24Vdc, terminal 1, and 24Vdc return, terminal 2. In a no smoke environment, the Geamatic has an output, terminal 14 and 15, of nearly 10V. As particles enter the light path this value drops off. The ZAM12 module allows voltage shifts to be measured directly, bypassing the built-in alarm circuitry.

The sensor can be set at one of four levels of sensitivity. With the ZAM12 module installed the sensitivity level selection only impacts the generation of the maintenance message and has no impact on the sensors capability to sense smoke. Level one, the most sensitive setting, would cause the time between maintenance messages to be much shorter than if sensitivity were set at level 4. Sensitivity is set at level 3 by the factory and this has not been changed.

9

Every second hour the Geamatic generates a calibration signal to evaluate the unit's cleanliness. The calibration signal is compared with a stored reference signal, and, if required, the strength of the light source is boosted to compensate for dust and dirt buildup on the optical surfaces. The state of cleanliness is monitored on a scale of 1 (clean) to 15. When level 12 is reached, a maintenance signal is generated. Maintenance consists of removing the cover plate exposing two internal thumb screws. Unscrewing these allows the probe to be removed from the tube. Clean the light emitting diode (LED) and the receiver at the other end.

Detailed instructions on mounting, setting sensitivity levels, and calibrating and cleaning the sensor can be found in the Geamatic section of the vendor documentation notebook, reference 13.

2.3.4   Jamco.

The Jamco detector (PU90-461R3), figure 2-8, is the same unit used by many airlines for lavatory fire warning. Mounted to the ceiling, smoke/particles reach the unit by free convection and ventilation caused by the configuration of the lavatory exhaust system. The detector uses a dual chamber configuration as a means of reducing false alarms. One of the chambers is open and sees the lavatory air; the second unit is sealed except for a small hole that allows both chambers to be at the same pressure. When the two chambers become sufficiently unbalanced the detector unit will generate an alarm. This is signaled by the alarm horn internal to the unit and the red alarm indicator lamp illuminating. The interrupt (horn silencing) switch is in the middle, located between the power lamp indicator (green) and the self-test switch. When pushed, the self-test switch exercises the alarm indicator lamp (red), horn, and internal circuitry.
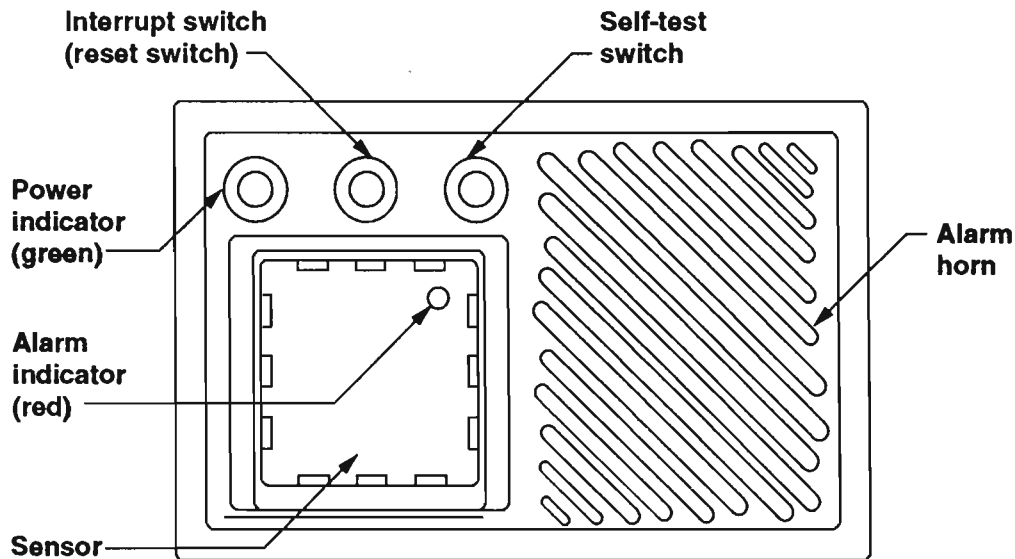
Figure 2-8. Jamco Ionization Smoke Detector.

Ionization detectors can react to the invisible particles that are given off at the very first stages of a fire and thus can provide earlier warning than a photoelectric type detector. Ionization detectors, while giving early warning, are not without their problems as air velocity and changes in altitude can make such sensors overly sensitive and thus susceptible to false alarm.

In the ACES system, ionization detectors were identified as the detector type for use in areas accessible to cabin attendants – lavatory and galley areas. The increased sensitivity provided by ionization sensors, balanced against the potential for false alarms, was considered acceptable for areas that could be readily investigated by the flight crew. This same trade was not deemed satisfactory for areas into which flight crew members do not have access to during flight.

The Jamco requires +28Vdc to pin 8; pin 7 is the 28V return connection. Detector high output is through pin 9 and the low output signal is through pin 4. Additional technical information on this detector can be found in the Jamco section of the vendor documentation notebook, reference 13. Details of sensor to Keithley connections can be found in section 2.5.5.

2.4   THERMAL MONITORING SYSTEMS.

In the Phase I study, two thermal monitoring methods were identified as having the potential to provide temperature and location information in areas throughout the aircraft. Both systems use a continuous wire. The wire is pulsed (one using sound and the other using light), and the return signal is analyzed to give temperatures along the length of the wire. Both systems allow the temperature and location, within a limiting length, to be identified. This capability may enable hidden areas within the pressurized volume to be monitored for overheat events. In addition, areas monitored by smoke sensors could be monitored for thermal conditions. The thermal information could be used as a basis, in conjunction with the smoke sensors, or singularly for generating an alert to the flight deck. Each of these systems will be detailed in sections 2.4.1 and 2.4.2.

2.4.1   York System.

The York DTS (distributed temperature sensor) System 2, figure 2-9, allows a fiber optic wire to be divided via software into zones. Each zone can be monitored for thermal conditions. Thermal monitoring of cargo compartments was identified by the ACES team as a potential method by which to reduce false alarms. If it were possible to detect small changes in temperature, two parameters (smoke and heat) might be able to be used before an alert is transmitted to the flight deck. In addition, a wire could be installed in numerous hidden areas, such as the lower lobe cheek, to enable large hidden areas of the aircraft to be monitored for overheat events.
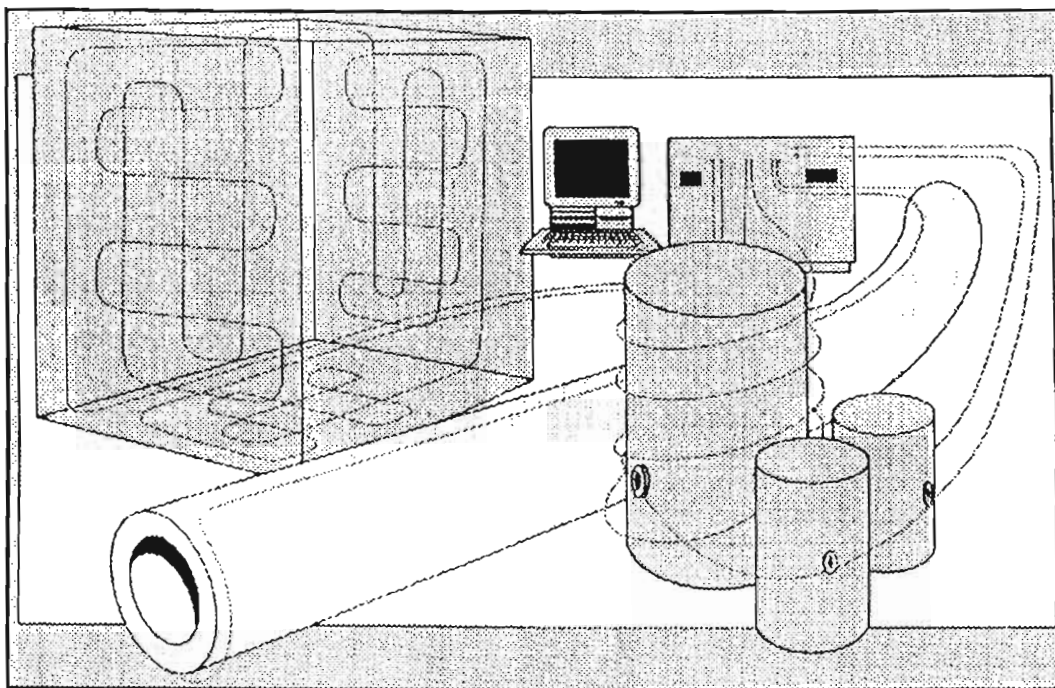

Figure 2-9. York DTS System 2

The York DTS system, in the ACES configuration, consists of one optical wire, an electro-optical unit, and a Hewlett Packard (HP) computer, disk drive and monitor. Linkage of these components is defined in section 2.5.4.

The York system is based on optical time domain reflectrometry (OTDR), a well understood measurement technique used primarily for locating the position of faults in optical fiber cables. It was found that the OTDR signal could also yield temperature information, and is the basis for the York DTS system. The York operators manual, reference 14, contains several technical articles and provides a more detailed discussion of this technique.

The electro-optical unit contains the laser source optical system for launching eye-safe light levels into the fiber, the optical detection system, and the signal processing to analyze the returning light. Light is pulsed down the fiber and scattering occurs in all directions, with some of the light directed back along the fiber to an optical coupler. Thus, some of the output light returns, via scattering, to it's source for analysis. The properties of the returning light can be examined such that the temperature of several lengths, or zones, of the fiber can be determined. The fiber is pulsed from each end, allowing fiber loses and system noise to be canceled out. Pulsing the fiber from both ends also serves to make the system insensitive to a break in the fiber, as information on either side of the break is still available. Should a break occur, the zone which contains the break can be readily identified to facilitate repair work. Splicing and/or the use of optical couplers are methods by which a break in the fiber could be repaired.

The spatial resolution of the DTS system is on the order of 7.5 meters (24.6 feet). To overcome this, the fiber optic cable is coiled so that a greater length of wire can easily be placed in each area, in effect shortening the spatial resolution to a more useful length. Additionally, the software allows zones of less than 7 meters in length to be defined by overlapping zones. The system is configured with a test section about 0.12 kilometers (690 feet) in length divided into 23 zones, about 5.2 meters (17 feet) of cable per zone. (York has made rapid progress in reducing the spatial resolution of their DTS systems, and new units have a resolution length on the order of one meter.)

The fiber optic cable is pulsed six times a minute. This number is a function of several parameters including: fiber length, fiber type, and accuracy/sensitivity required. The value of six times per minute was determined by York at their facilities in the United Kingdom (UK) when the system was being assembled for the ACES project. A York representative verified the rate of six pulses per minute when the system was setup and initially run in the Boeing test facility.

There are two key elements of an optical fiber – its core and its cladding. The core is the inner part of the fiber, through which light is guided. The cladding completely surrounds the core and confines the light within the core, thus preventing light from leaking out. The core for the fiber is an off-the-self commercial grade multimode fiber optic cable, 0.085mm in diameter. The two end sections of the cable use a 0.125mm (outside diameter) cladding of acrylate with Kevlar reinforcement and an orange polyvinyl chloride (pcv) coating. The rated maximum temperature for this section is 60°C (140°F). The test, or center, section of the cable has an 0.125mm (outside diameter) cladding of polyimide. This cladded fiber has then been drawn into a narrow-bore stainless steel tube. This combination gives the test section of the cable a maximum temperature rating of 350°C (660°F). The cable assembly has a total of four splices, at the pvc/DTS coupler interface and at the stainless/pvc interface. In the testing done to date, the orange covering has never seen temperatures above ambient, while the stainless steel section has never been subjected to temperatures above 300°F.

Detailed explanation of the principle of the York system can be found in reference 14.

2.4.2   Schlumberger System.

The Schlumberger system uses a solid wire into which a broadband ultrasonic pulse is initiated. The return signal contains information that is then processed to provide information on the wire's thermal environment. The system consists of three components: the wire, a transceiver, and a control unit. The sensor wire that was

investigated for testing in the ACES system was a 0.064 inch diameter steel alloy wire, with the capability of being up to 50 feet in length. The transceiver energizes, or pulses, the wire and receives the return signal. The return signal is relayed to the control unit where data processing and system evaluation take place.

A 50 foot wire, at the time of the study, had the capability to be divided mechanically, to create reflection points, into 8 zones. These zones could then be further divided, via software residing on the control unit, to provide a spatial resolution of about 6 inches.

At the start of the Phase 2 effort, the ACES team had a prototype system that had been tested by the Propulsion Research and Development group at Boeing. The system was returned to Schlumberger in the UK for evaluation and calibration. Unfortunately the system had been damaged in testing to such an extent that repair was not possible. It was approximately at this same time that Schlumberger made a decision to not proceed with further development of this technology. At that time, no alternative acoustic thermal sensing system was available for testing and integration into the ACES system.

2.5   HARDWARE INTERFACES.

The connections between the various hardware components are detailed in the following sections.

2.5.1   Dolch to Keithley.

The Dolch-Keithley interface is via an IEEE cable that runs from the back of the Keithley to the left side of the Dolch where the expansion port is located. The IEEE cable goes into the top, and only, port on the Dolch that will accept an IEEE cable. This can be seen in figure 2-10 and as port A in figure 2-11.

Figure 2-10. Dolch Port Allocation.

13

A – Keithley
B – Monitor
D – Monitor
H – Mouse
C, E, F, G, I – Not used
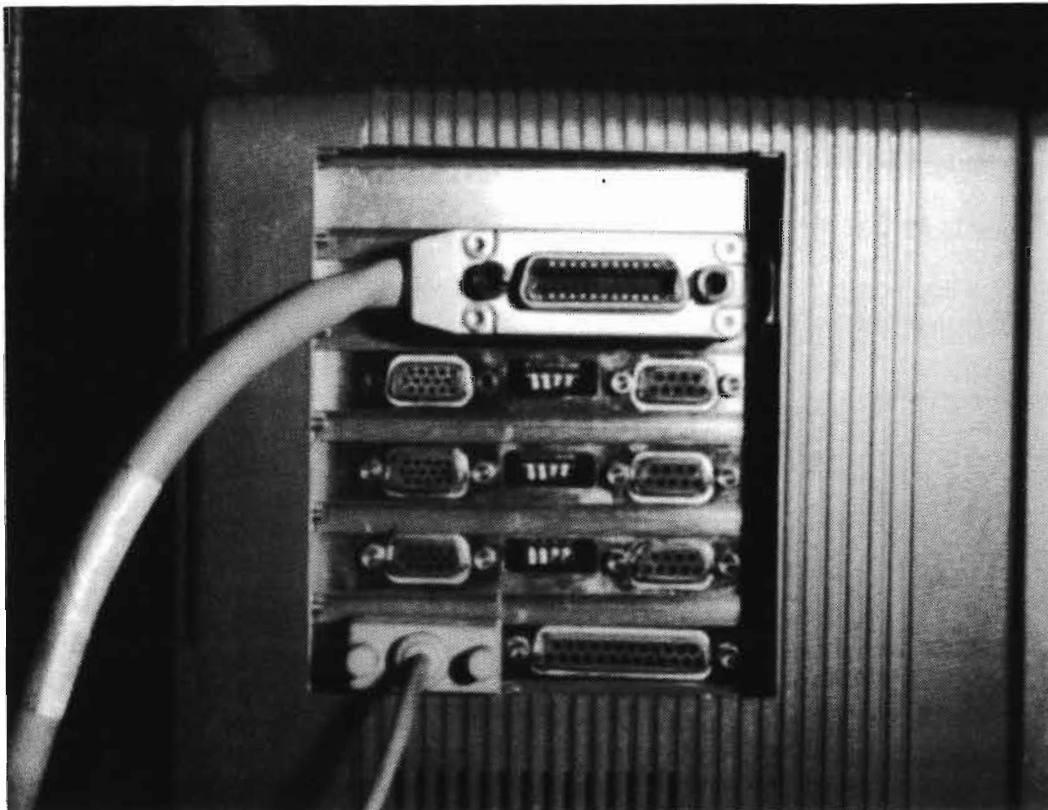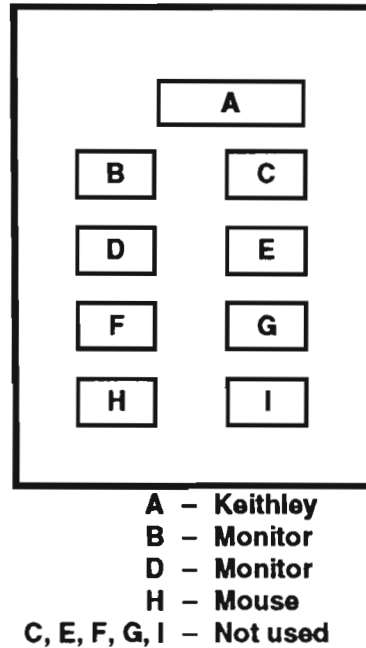
Figure 2-11. Schematic Dolch Port Allocation.

2.5.2   Monitors to Dolch.

Additional monitors can be linked to the Dolch via the ports B and D as identified in figure 2-11. The two monitors should be color capable to show the system to its best advantage. The monitors that have been used in the demonstrations are Sony Trinitron Multi Scan HG, model number CPD-1304. Other CRT monitors have been connected to the Dolch with no difficulties or system reconfiguration necessary.

2.5.3   Mouse to Dolch.

The mouse plugs into port H as identified in figure 2-11. The port is located on the left side of the Dolch. No procedures are required beyond connecting the mouse to the computer.

2.5.4   Sensor Cables.

A complete set of cables to connect the sensors to the Keithley data logger unit was fabricated. The cables were made by two different groups at Boeing: Flight Test Research Lab, and Mechanical/Electrical Lab. As a result the style and configuration of a cable for a given dectector pair may differ. Thus, while cables used for a given pair of sensors may differ in appearance, there is no difference in their functionaliity. For example, the two Kidde sensors have cables that differ in configuration, yet the cables accomplish the identical function. The cable configuration for each of the four different models of smoke sensors are described in table 2-2 through table 2-5 (Note: the cables for the Cerberus and the Geamatic sensors have shielded cables, the shield should be grounded through the Keithley).

Table 2-2. Kidde Cables.

Sensor Connection	Wire Color	Function	Connection
First of Two			
2	Red/White	+28Vdc	To power supply – red clip
5	Black/White	Common return	To power supply – black clip
6	Gray/White	Alarm out 28V	Not used
8	Brown/White	Analog out (0-15V)	To Keithley – J1
12	White	DC ground	To Keithley – J2
Pins not used	1, 3, 4, 7, 9, 10, 11		
Connector	MS24266R12B-12S Aero 9135		
Second of Two			
2	Red	+28Vdc	To power supply – red clip
4	Red		Jumpered to pin 2
5	Green	28Vdc return	To power supply – black clip
5	Black	Common return	To Keithley – J2
6	Yellow	Alarm out 28V	Not used
8	Blue	Analog out (0-15V)	To Keithley – J1
Pins not used	1 3, 7, 9, 10, 11, 12		
Connector	MS24266R12B-12S Aero 9135		
Power: 28Vdc			

Table 2-3. Cerberus Cables – Two of Two.

Sensor Connection	Wire Color	Function	Connection
A	Red	+24Vdc	To power supply – red clip
B	Blue	24Vdc return	To power supply – black clip
C	Red	Output	To Keithley – J1
D	Blue	Output	To Keithley – J2
	Black/Green	Cable ground	To Keithley ground
Pins not used	E, F		
Power: 24Vdc			

Table 2-4. Geamatic Cables – Two of Two.

Sensor Connection	Wire Color	Function	Connection
1	Red	+24Vdc	To power supply – red clip
2	Blue	24Vdc return	To power supply – black clip
14	Red	Output	To Keithley – J1
15	Blue	Output	To Keithley – J2
	Black/Green	Cable ground	To Keithley ground
Power: 24Vdc			

Table 2-5. Jamco Cable.

One of Three			
Sensor Connection	Wire Color	Function	Connection
4	Red	Output	To Keithley – J2
7	Black	28Vdc return	To power supply – black clip
8	Brown	+28Vdc	To power supply – red clip
9	Green	Output	To Keithley – J1
10	White	Output	Not used
Pins not used	1, 2, 3, 5, 6, 11, 12, 13, 14, 15		
Connector	DA-2465		
Second and Third of Three			
4	Red	Output	To Keithley – J2
7	Black	28Vdc return	To power supply – black clip
8	Blue	+28Vdc	To power supply – red clip
9	Green	Output	To Keithley – J1
10	Yellow	Output	Not used
Pins not used	1, 2, 3, 5, 6, 11, 12, 13, 14, 15		
Connector	DA-24658		
Power: 28Vdc			

2.5.5   Sensors to Keithley.

In connecting sensors to the Keithley it is imperative that the power switch, located on the front panel, is in the **off** position or damage to the AMM2 module may occur.

The Keithley has been configured, via software, (software commands as they apply to the AMM2 module can be found in reference 12, AMM2 Section, page AMM2-9), to operate in the differential mode and as such accepts signal inputs from a maximum of eight sensors. The Keithley data logger unit is shown in an open position in figure 2-12. A schematic, figure 2-13, shows the sensor connections as used in the ACES lab. Of course, any combination of sensor to channel number is acceptable. Terminal block J1 (0+ to 7+), located on the AMM2 card, accepts the sensor high output signal while the corresponding sensor low output signal goes to terminal block J2 (0- to 7-).
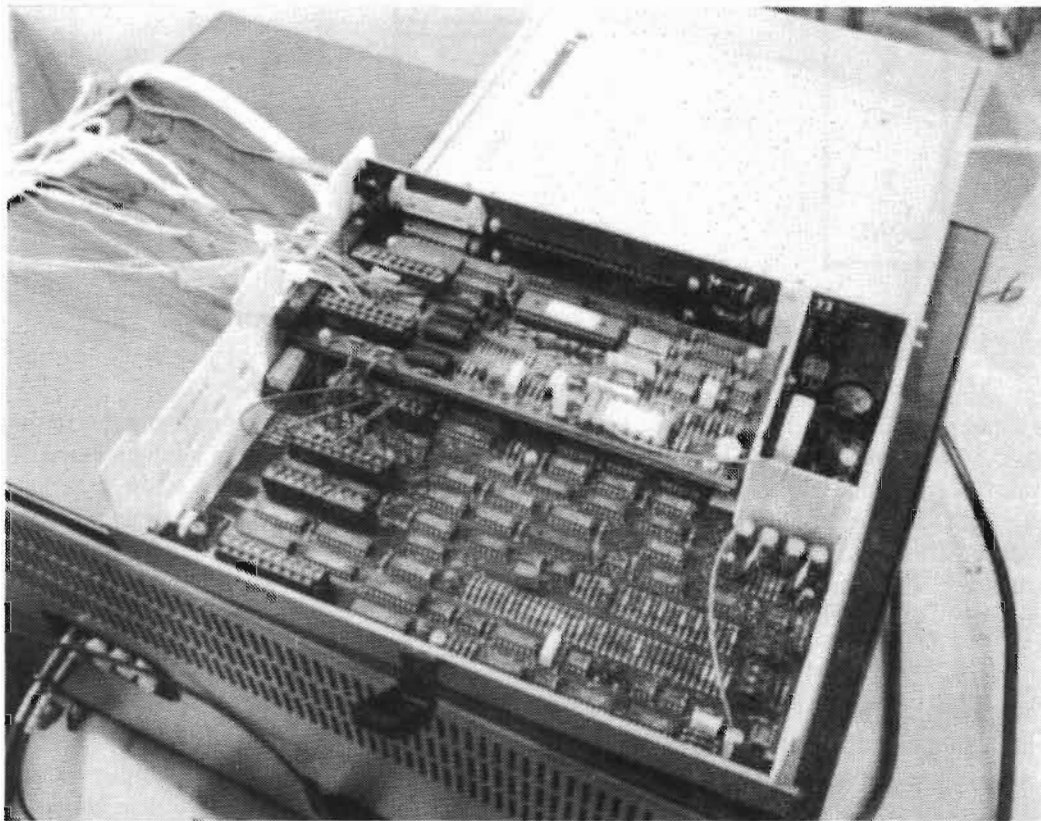
Figure 2-12. Sensor to Keithley Interface.

```
        Channel                                                      Channel
          J1                            Sensor                          J2

        GND  ──────── Ground                      Ground ────────   GND
         0   ─ Brown/White ┌──────────┐                             0
                           │ Kidde -1 │──── White ────
         1   ──── Blue ────┤ Kidde -2 │──── Black ────               1
         2   ── Green ─────┤  Jamco   │──── Red   ────               2
         3   ──── Red  ────┤Cerberus -1│──── Blue ────               3
         4   ──── Red  ────┤Cerberus -2│──── Blue ────               4
         5   ──── Red  ────┤Geamatic -1│──── Blue ────               5
         6   ──── Red  ────┤Geamatic -2│──── Blue ────               6
         7                                                           7
        SGND                                                        SGND

                        Keithley front ↓
```
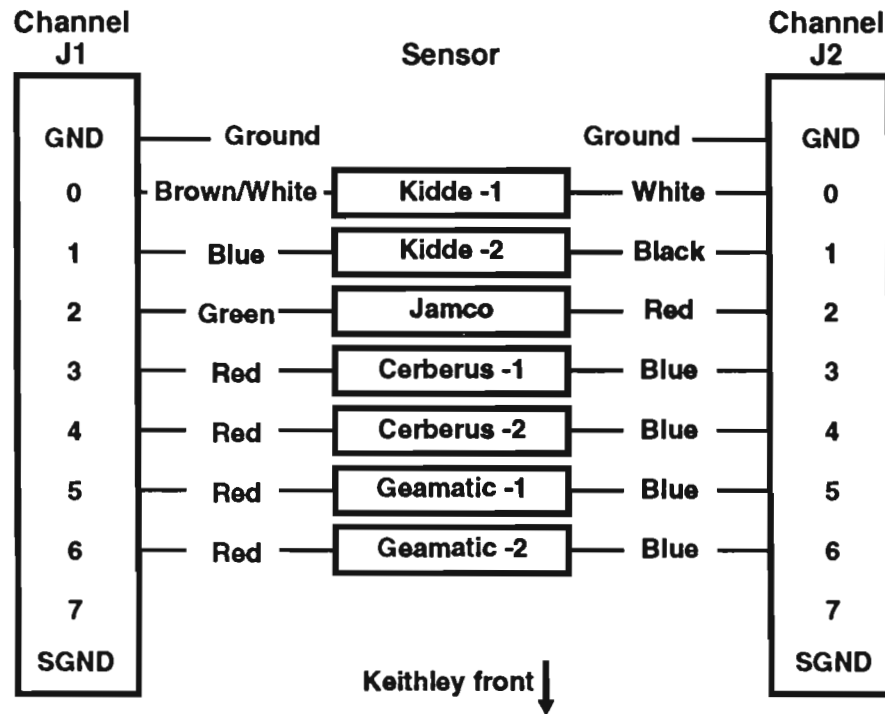
Figure 2-13. Sensor to Keithley Connections.

The channel marked GND serves to ground the terminal block, in differential configuration. (The terminal location marked SGND is the ground terminal if the Keithley is set up in a single wire configuration). If a number of AMM2 signal input lines are shielded, all shields should be connected to the **same** ground terminal, GND. The AMM2 inputs are non-isolated, and the signals must be referenced to power line ground, or module and/or system damage may occur. In addition, improper grounding may result in inaccuracies that effect other channels. This can result in several channels of data drifting in unison. The inputs to the Keithley **must** be within ±10V of module ground for proper operation and if any signal exceeds ±30V, module damage may result.

From conversations with Keithley personnel at the time of it's purchase, short periods of elevated voltage are not a problem. A problem could arise if the nominal input signal strength was greater than +30Vdc, that is, if the Keithley should see +30Vdc for extended periods of time. None of the ACES sensors output +30Vdc, therefore, based on input from Keithley and experience in the lab, the data acquisition system is correctly sized for the inputs it receives.

2.5.6   York.

The interfaces internal to the overall York system (fiber optic cable, DTS unit, dual disk drive HP 9122, hard drive HP 9000, keyboard, and screen) are shown in figure 2-14 and figure 2-15. All the cables are included with the system and are tagged such that setup should present no problems.

18

Figure 2-14. York Hardware Connections.
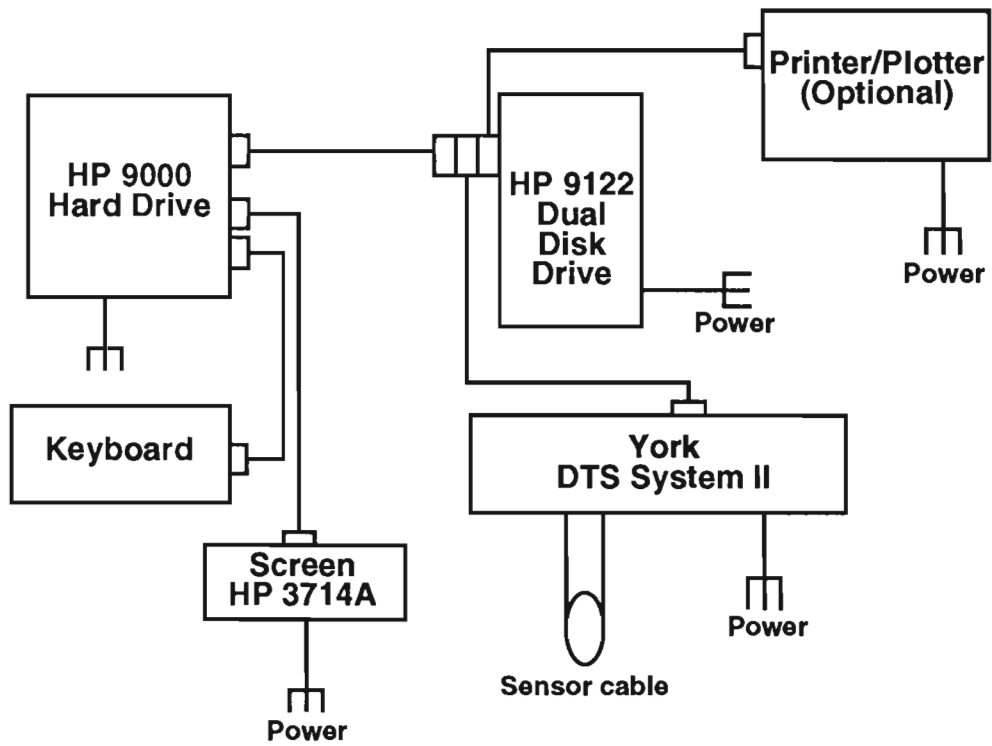
Figure 2-15. Schematic York Hardware Connections.

19

An IEEE cable port, located on the back side of the York DTS unit (figure 2-16), connects the DTS unit with the HP 9122 dual disk drive. The 9122 is also connected, via another IEEE cable to the HP 9000 hard drive unit. An option is to use an additional IEEE type cable to link the HP 9122 to a printer and/or plotter. Thus the 9122 could have four IEEE type cables stacked together to link the DTS, HP 9000, printer, and plotter.
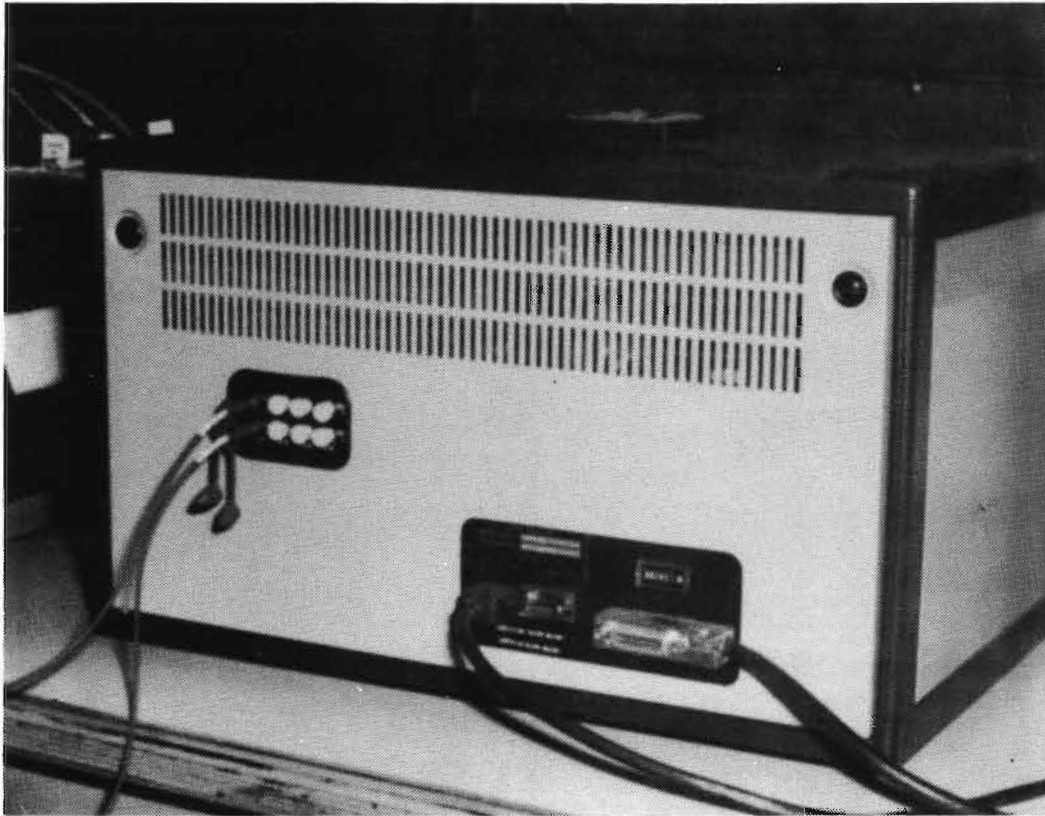
Figure 2-16. DTS System 2 Fiber Optic Cable Port.

The commands to the DTS system are via the keyboard, figure 2-17, which is connected to the HP 9000 (Note: some trouble was experienced in the lab with making a good connection between the keyboard and the hard drive unit, resulting in a message of "no link to keyboard." This problem occurs when first turning the computer on and loading the Basic System disk. This can be corrected by removing and reinserting the connector cable at both connection points and then rebooting the system). The HP 3714A screen is connected to the system via the 9000. The screen has color capability and the connector is a cable bundle, color coded to match the ports into which they connect.
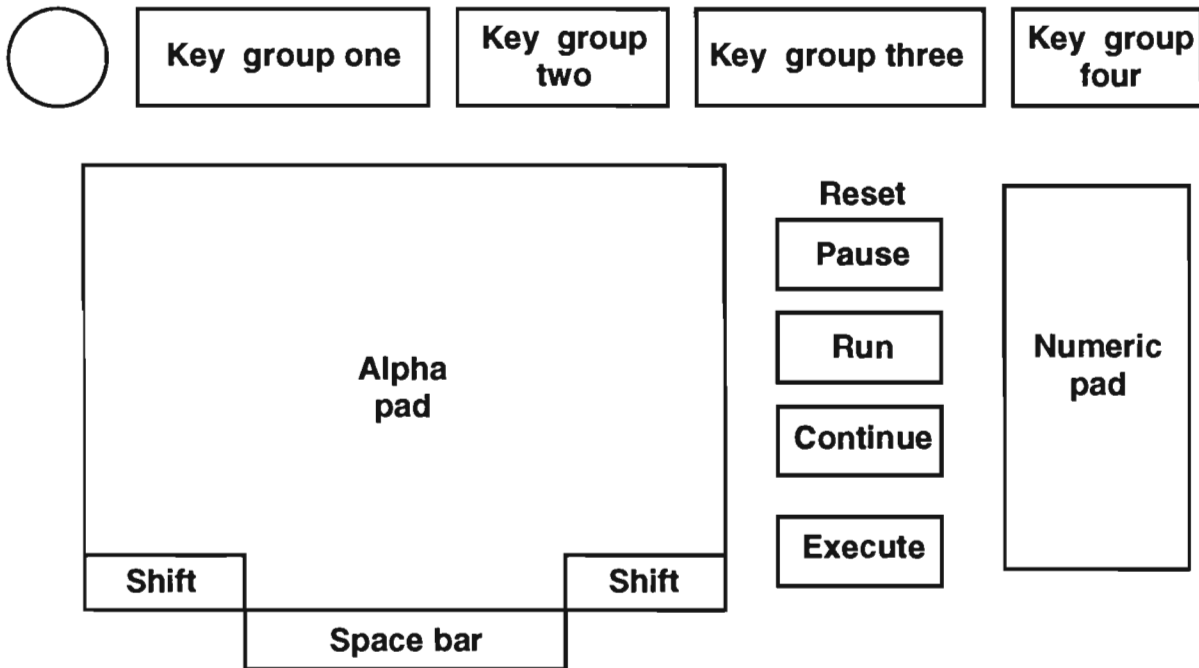
Figure 2-17. HP Keyboard Used In York System.

With the above connections made, all that remains is to mate the fiber optic cable to the DTS unit. The cable connection port is located in the back side of the DTS unit, figure 2-16. The unit has the capacity to monitor four cables. However, only one cable was used in the ACES configuration. The use of more than one cable impacts the response time of the system. With one cable, the fiber is pulsed once every six seconds. If four cables were being used, this time would increase to once every 24 seconds. When connecting the optic fiber it is good practice to clean the ends of the cable as well as the ports into which the cable connects. Cleaning can be done using a spray type electrical connection cleaner. Spray the cleaner directly into the DTS ports and onto the ends of the cable. Upon cleaning the fiber end and connection port, the fiber can be screwed into the port pair labeled L1 (loop 1). The cable end labeled 1688 mates to END1/L1 and cable end labeled 1689 mates to END2/L1.

Power up, software loading, and the procedures on system operation will be discussed in section 3.4

2.6 TEST EQUIPMENT.

The ACES sensors (Cerberus, Kidde, Jamco, Geamatic, and York wire) were installed in a test fixture in a lab area at the Boeing Plant 2 site in Seattle. The fixture was a plywood box with outside dimensions about 8.5 feet long by 7 feet high and 4.5 feet wide (about 250 cubic feet) with a plexiglass front to provide viewing. The ACES test structure and sensor configuration is shown in figures 2-18 and 2-19. An additional fixture was required for the Geamatic detector, which is designed for use in air ducts. This fixture was placed on a stand when the Geamatic was being tested, and is shown, in the testing configuration, in figure 2-20.

The smoke sensors were linked to the Keithley, and the Keithley to the Dolch. The DTS 2 system cable was coiled in a series of loops and attached to four frames in the test box with the frames attached to the ceiling. Eight thermocouples were installed to provide a check on the DTS system. The test fixture was ducted so air could be pulled through it. Air flow could be varied from zero up to 3 air changes per minute (about 700 CFM).

The testing was done with smoke and heat being generated to exercise the sensors. The testing enabled the ACES team to check system configuration, data collection and storage requirements and methods, and to verify and refine alerting logic.
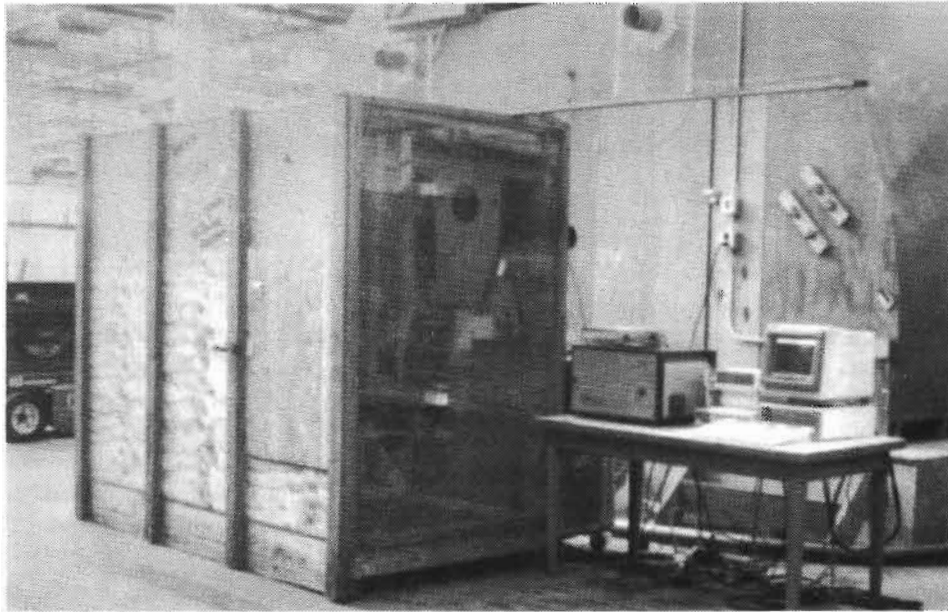
Figure 2-18. ACES Lab Configuration.

Fan

Fan contoller

Air out

Calibrated flow tube

To York DTS

K1   K2 — To Keithley and
      28V Power Supply

Baffles
(3 Locations)

C1   C2 — To Keithley and
      28V Power Supply

To Keithley and
28V Power Supply

J

J

Access
Door

To York DTS

Plexiglass
Front

Air in
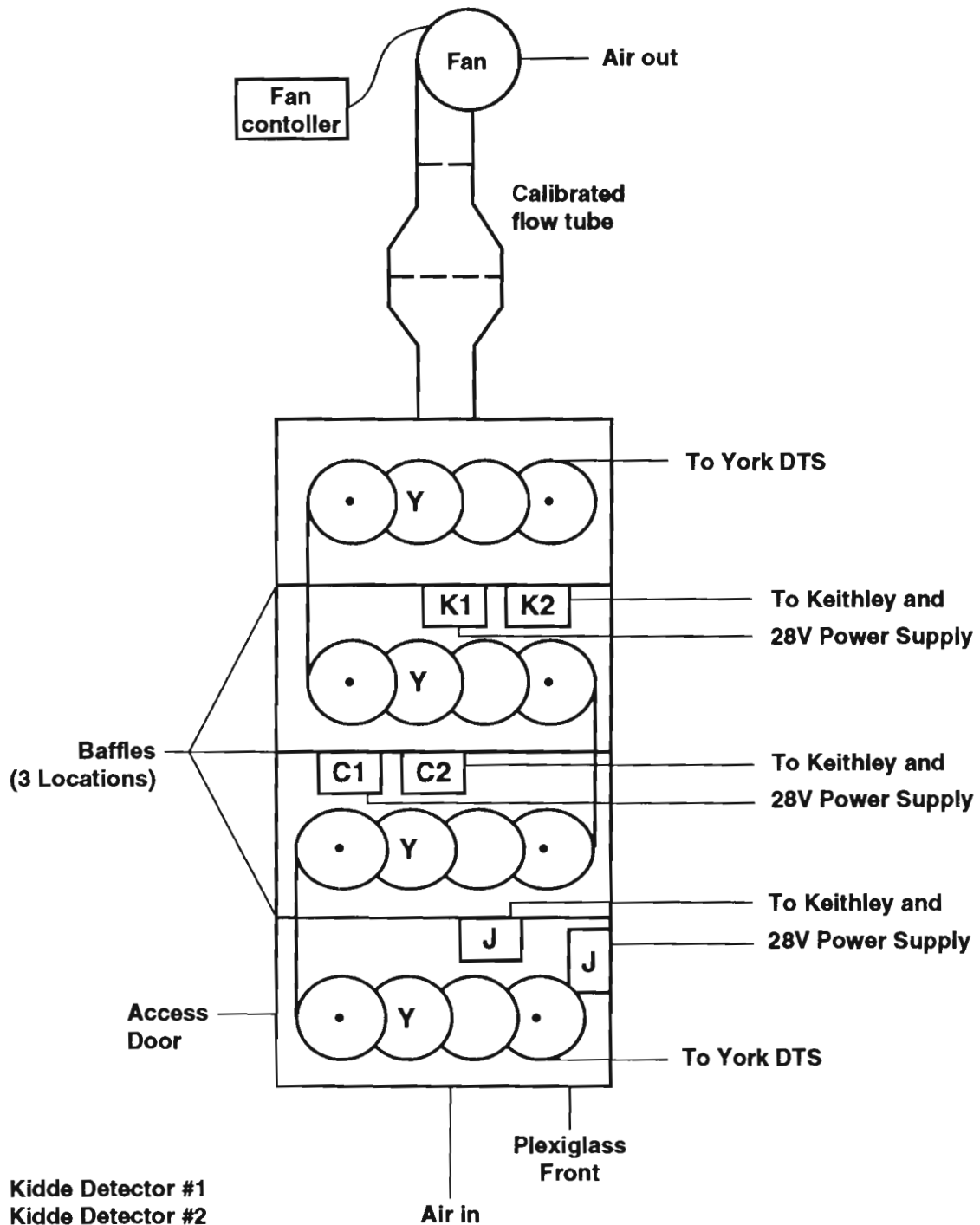
K1 - Kidde Detector #1
K2 - Kidde Detector #2
C1 - Cerberus Detector #1
C2 - Cerberus Detector #2
J - Jamco Detector
Y - York Optic Wire
• - Thermocouples (T/C)

Figure 2-19. Schematic of ACES Test Chamber Top View.

23
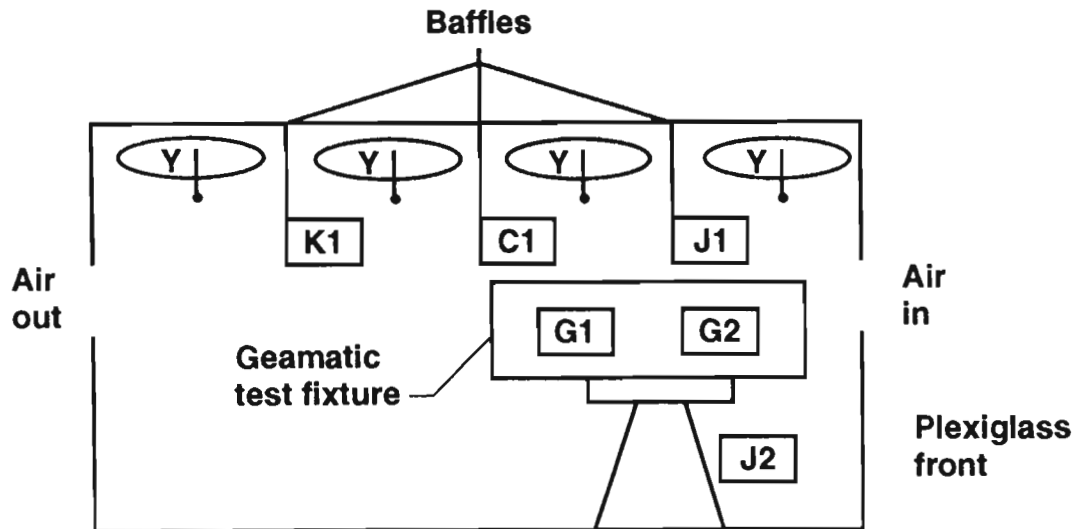
K1 - **Kidde Detector #1**
C1 - **Cerberus Detector #1**
G1 - **Geamatic Detector #1**
G2 - **Geamatic Detector #2**
J1 - **Jamco Detector #1**
J2 - **Jamco Detector #2**
Y - **York Optic Wire**
• - **Thermocouples (T/C)**

Figure 2-20. Schematic of ACES Test Chamber Side View.

2.6.1   Smoke Sources.

The sensors have been tested in the lab using several smoke sources. The most convenient was canned smoke. This product comes in a pressurized can and can be easily sprayed in the direction of the sensor(s), causing the sensor to react and allowing data to be collected. The spray worked well on both the photoelectric and ionization sensors. One product used was Smoke in a Can by Mija Industries, Plymouth, MA, model 4843 smoke-automatic fire detection accessory. A Material Safety Data Sheet is provided in the vendor documentation notebook, reference 13. (Note: product is extremely flammable).

Another smoke source used has been stick incense. Once lit, the incense provides a thin whiff of visible smoke that can be directed into a sensor. With the incense a weaker, less dense smoke can be created as compared to the canned smoke.

Means to measure smoke density were investigated. However, given the sensitive nature of the detectors, the instrumentation complications, and cost entailed, measuring this parameter at each sensor head was not deemed practical.

2.6.2   Heat Sources.

A heat gun was used as the heat source for the majority of the testing on the York system. The heat gun did not provide a great deal of control, but it did enable the wire to become active in a timely manner. A hot plate was also used as a heat source and provided a more gradual diffuse heat when compared to the heat gun. Both of these methods worked well, with the heat gun being the faster more convenient of the two.

2.6.3   Thermocouples.

A series of eight thermocouples were placed in close proximity to the York DTS wire allowing a comparison of the DTS System 2 to a calibrated source. The DTS performed well when visually compared with the T/C thermal profiles. The York lagged the T/C's as would be expected when comparing an area sensor, the York, to a point sensor, the thermocouple. The lag, if conditions were changing quickly, could be on the order of tens of seconds. Unfortunately no common data can be located with any degree of certainty of conditions under which it was collected to allow this issue to be illustrated.

2.6.4   Air Flow.

Low volumes of air, on the order of an 2-3 air changes a minute, could be flowed through the test chamber. Flow rates were measured using a calibrated flow tube. This capability was most useful in pulling clean air into the chamber following smoke testing, allowing any residual smoke to be purged from the test chamber.

In some of the testing performed with air flowing into the chamber, an air curtain would become established. The curtain would prevent smoke, rising from the floor, from reaching the ceiling and hence the ceiling mounted photoelectric and ionization sensors. Control and understanding of air flow patterns in an enclosed, ventilated volume (such as a cargo compartment) presents a design challenge to insure that smoke is able to reach the sensors in all cargo configurations and fill densities. The Geamatic sensor (photoelectric, light attenuation, section 2.3.3) is designed for use in ventilated ducts and performed well when tested at these low air flow rates.

3.   SYSTEM OPERATION.

This section will assist the user in the running of the ACES system in its three modes of operation (1) Demos, (2) Sensor Tests and (3) Alert Algorithms. To access any of these three capabilities, the Dolch must be turned on and, if sensor data is to be collected, the Keithley must be linked to the Dolch, and the Keithley and the sensors must also be powered up. Neither the sensors nor the Keithley are required to run the Alert Algorithms and Demo functions. To receive the full effect of the Demo function, it is desirable, but not necessary, for two additional monitors, preferably color, to be connected to the Dolch.

Upon configuring the system to meet the user's planned activities, all that needs to be done is to turn on the Dolch (power switch in the back). On power up, the Dolch will run through several internal diagnostic routines. This process can be accelerated by pressing the <ESC> key. Several lines of text will flash by and end with the user at a DOS prompt. Typing ACES <ENTER> will put the Setup Menu on the screen, figure 3-1.

The Setup Menu is the starting point for the ACES system. It is here that one of the three modes of operation is chosen. As an overview of the construction of the menu system it will be helpful to refer to figure 3-2, the ACES Screen Map. At the bottom third of the screen are the commands that allow the user access to select options and menus within the system; these commands are detailed in table 3-1, ACES Menu Control Functions.

```
┌─────────────────────────────────────────────────────────────┐
│  ┌───────────────────────────────────────────────────────┐  │
│  │                                                       │  │
│  │   Aircraft Command in Emergency Situations (ACES)     │  │
│  │                                                       │  │
│  └───────────────────────────────────────────────────────┘  │
│                                                             │
│   This system provides the capability to run three types of ACES │
│   system functions:                                         │
│   1)  Capability to TEST and collect data from a number of different │
│       heat/smoke detectors and store data in files for future use; │
│   2)  Selection from a number of signal functions (or the ability │
│       to build new ones) to exercise and experiment with the ALERT │
│       ALGORITHM parameters;                                 │
│   3)  DEMONSTRATION of various fire/smoke scenarios with associated │
│       flight deck and cabin attendant procedures.           │
│   The following menus provide the capability to select the desired │
│   configuration and modify various parameters within the scenario. │
│                                                             │
│                        Setup Menu                           │
│   Select Function:  Sensor Tests    Alert Algorithms    Demos │
│                                                             │
│  ─────────────────────────────────────────────────────────  │
│   <space>:          next choice                             │
│   <enter>:          select current choice                   │
│   <up/down arrow>:  line up/line down                       │
│   <ctrl A>:         advance to next menu                    │
│   <ctrl F>:         save current settings, resume           │
│   <ctrl B>:         back to previous menu                   │
│   <ctrl G>:         skip to EICAS display                   │
│   <ctrl Q>:         exit                                    │
└─────────────────────────────────────────────────────────────┘
```
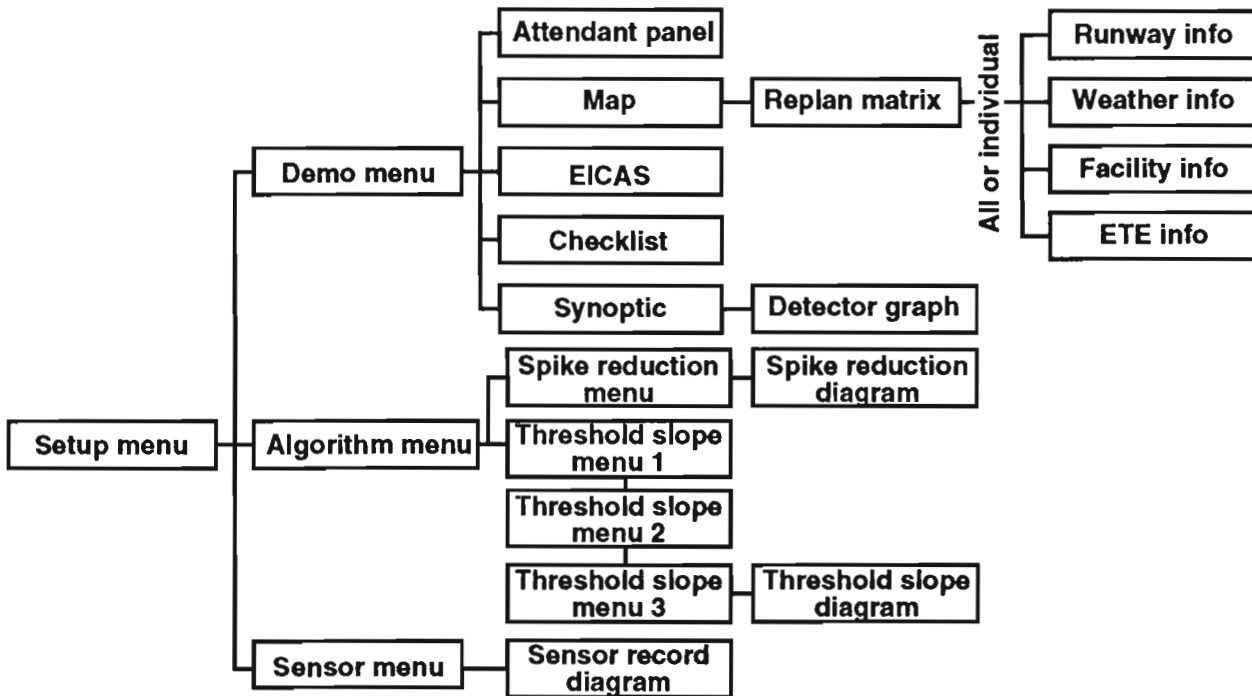
Figure 3-1. ACES Setup Menu.

Figure 3-2. ACES Screen Map .

Table 3-1. Menus Control Functions.

<space>	next choice	Moves the user through the choices that are on the SAME line, the choice that is highlighted is the choice that will become active.
<enter>	select current choices	Activates the choice selected from above and moves the user to the next line of the menu.
<up/down arrow>	line up/line down	Moves the user up and down between lines on the menu.
<crtl A>	advance to next menu	Takes the user forward to the next menu. This has the effect of activating all the highlighted parameters (choices) on the menu. The user may change one parameter then advance to the next menu, which leaves the other highlighted parameters active.
<crtl F>	save current settings; resume	This function serves to make the highlighted parameters the new default values, therefore the next time through the menu the values saved will be highlighted.
<crtl B>	back to previous menu	Useful for backing up and changing previous selections and/or parameter values.
<crtl G>	skip to EICAS	During system development this allowed the programmer to quickly skip forward to the flight deck upper EICAS screen and from there acess all display functions. Is now of limited value and has been known to lock up the system.
<crtl Q>	exit	Exits the ACES program returning the user to a DOS prompt. Typing ACES will return the user to the Setup Menu.

To select one of the three modes of system configuration, the user taps the space bar; the function ready to be activated is shown highlighted in yellow, while the modes not chosen are shown in white. The user can only access one mode at a time. Upon spacing to the desired choice, pushing <ENTER> activates the selection.

3.1 DEMOS.

This path enables the user to become familiar with the various display options that have been developed for the ACES flight deck and cabin attendant panel. Scenarios have been constructed to show all the sensor types and locations and the flight deck display components: master warning/caution light/switch, engine indication and crew alerting system (EICAS) both upper and lower screens, electronic checklist, inflight diversion planner, overview and condition of the sensor array (the synoptic display), and the cabin attendant panel, as well as the interaction between the flight deck and cabin attendant panels.

The master warning/caution and EICAS are the systems used on Boeing aircraft to alert the flight deck crew of a smoke/fire event. Figure 3-3 shows these components as arranged on a 757-200 flight deck.
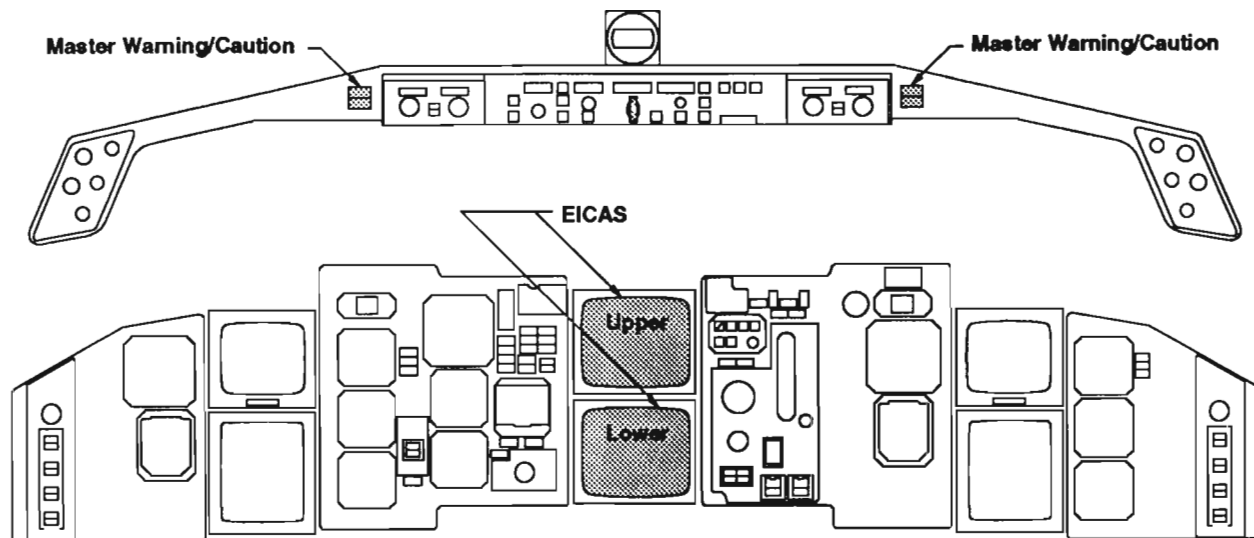
Figure 3-3. 757-200 Flight Deck EICAS Displays.

With the user at the Setup Menu, tap the space bar, selecting "Demos" so indicated by the text appearing yellow. Push <ENTER> to activate the selection, this will present the user with the ACES Scenario Menu screen, figure 3-4.
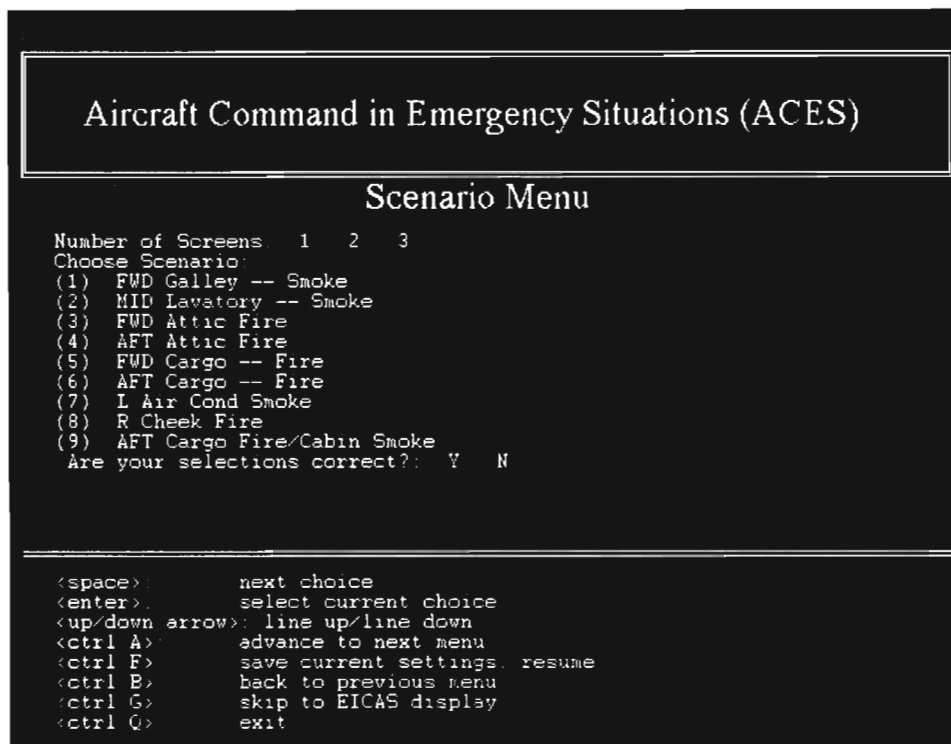
Figure 3-4. ACES Scenario Menu.

3.1.1   Scenario Menu.

The first choice pertains to the selection of a number of active display screens. The default value is one screen – that of the Dolch. Two additional screens may be added to the system via the ports located on the left side of

the computer. The ports to be used in connecting additional monitors are detailed in section 2.5.2. In the one screen configuration, much of the interaction between the upper and lower EICAS screens and the cabin attendant panel is lost. The two screen configuration is not much better; it is only when three screens are being used that the full interplay of the system can be displayed. The remainder of this discussion will assume the user is in the three screen configuration.

Select the number of screens to be used by tapping the space bar, and push <ENTER> to activate the selection and advance to the next section, Choose Scenario. (Note: if no additional screens are connected to the Dolch and more than one screen is chosen, the system will go through several function checks and screen changes before locking-up. Holding down <Ctrl><Alt><Del> at the same time will return the user to the DOS prompt, and typing ACES<ENTER> will return the user to the Setup Menu). Here the user has the choice of nine scenarios, one for each location and sensor type proposed for the ACES system. Use the Up/Down arrows to move between the nine scenarios. Again, the yellow box indicates the scenario to be activated and pressing <ENTER> activates the highlighted scenario and moves the cursor to the next line. This line asks "Are your selections correct?" N<ENTER> takes the user back to the first line – "Number of Screens," Y<ENTER> continues the demo, and the selected scenario is activated.

3.1.2   Sensor Profile.

The Sensor Menu screen clears with the display of a sensor signature. This feature is for discussion only and would **NOT** be an element seen on the flight deck. In the upper right hand corner of the screen is a continue box within which the cursor arrow is automatically positioned. Pressing the left button on the mouse continues the demonstration of the scenario.

3.1.3   Master Warning/Caution and Upper EICAS.

The user is presented with an emulation of the master warning/caution indicator-switch and the upper EICAS screen, figure 3-5.
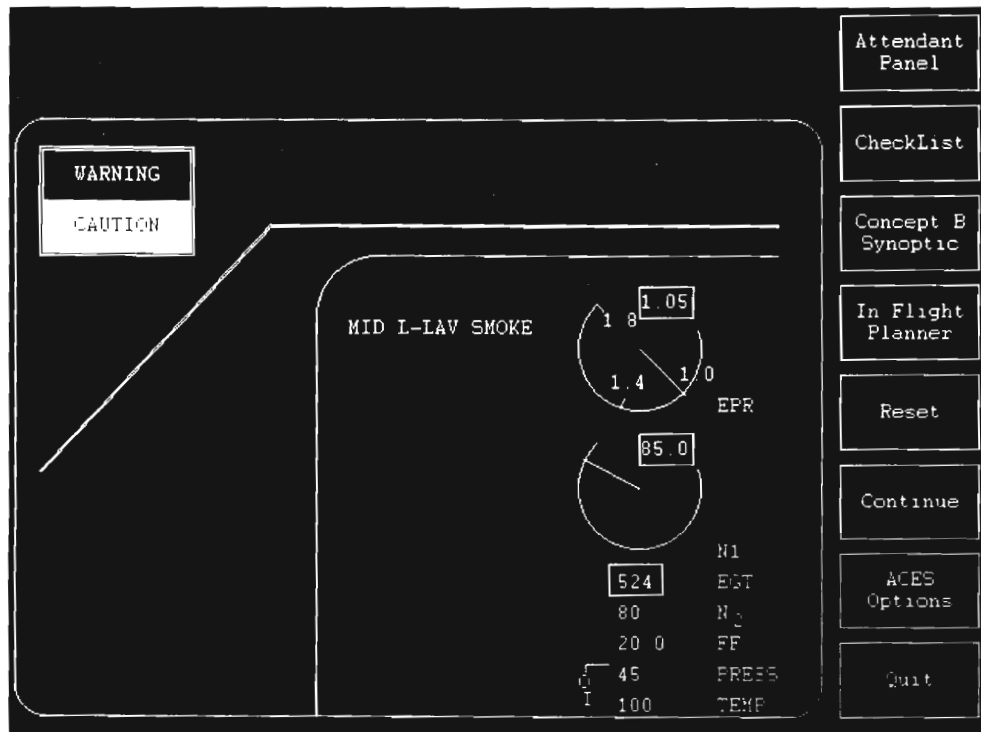

Figure 3-5. ACES Master Caution/Warning and Upper EICAS Screen.

The format displayed is that which will appear on all the ACES flight deck and cabin attendant demo screens. The majority of the screen is used to emulate the proposed features. In figure 3-5, this is a portion of the upper EICAS screen (where the words "MID L-LAV SMOKE" appear) and the master warning/caution indicator-switch. The right hand column of eight buttons are for moving between various locations within the Demo elements. These eight buttons would **NOT** appear on a functioning flight deck. The eight buttons are explained in table 3-2.

Table 3-2. Demonstration Screen Control

Attendant Panel	This moves the cursor to the attendant panel, making that the active screen.
Checklist	This moves the cursor to the checklist panel on the lower EICAS screen, making that the active screen.
Concept B Synoptic	This moves the cursor to the synoptic display feature located on the lower EICAS, making that the active screen.
Inflight Planner	This moves the cursor to the in-flight planner, located on the lower EICAS screen, making that the active screen.
EICAS	This moves the cursor to the upper EICAS screen, making that the active screen. Note: depending on which display feature is active, four of the above five buttons will appear. The four buttons listed below will appear on all DEMO SCREENS.
Reset	This is a function used during development work. Resets the active screen to the start of the process; for example, if the CHECKLIST was the active screen and several procedures had been exercised, clicking on RESET would clear the CHECKLIST enabling the user to redo the checklist without returing to the start of the scenario.
Continue	Removes the user from the ACES program to the DOS prompt C:\ACES\DEMO> typing ACES returns the user to the Setup Menu.
ACES Options	This function returns the user to the Scenario Menu.
Quit	Same as Continue, see above.

The flight deck crew is first made aware of a smoke/fire event via the master warning/caution switch-indicator. The indicator illuminates, red for warnings (top half of the switch), and amber for caution level alerts (bottom half). The switch-indicator is located on the glare shield in the pilot's field of view. This light is emulated in the ACES system by the double box located in the upper left quadrant of the screen.

The ACES flight deck procedure in responding to a fire alert is to move the cursor arrow to the yellow caution box in the upper left hand corner of the screen and clicking the left button on the mouse. This action serves to bring up the message on the upper EICAS screen: "MID L-LAV SMOKE" (middle left lavatory).

The left hand side of the upper EICAS screen is where all warnings and cautions messages are displayed. The message identifies the subsystem and source of the problem, e.g., "MID L-LAV SMOKE" and is color coded to reflect the level of the alert, red for warning and amber for cautionary. The flight deck crew has now been alerted to the fact that the smoke sensor in the left side mid cabin lavatory has gone into alert. Moving the cursor to the EICAS screen and clicking on the message brings the lower EICAS screen into play.

It is at this stage that the benefits of having three monitors will be seen as two of the monitors will be emulating an EICAS screen.

3.1.4   Lower EICAS Screen.

The lower EICAS screen is where the remainder of the flight deck display functions are presented: electronic checklist, inflight planner, and synoptic display. Each will be explained in the next three sections.

3.1.4.1   Electronic Checklist.

The Electronic Checklist, figure 3-6, presents the flight deck crew with an electronic version of the Quick Reference Handbook (QRH). The QRH is a manual, giving the crew the specific procedures developed by the airline that are to be followed in a given situation. Time spent locating the procedure within the QRH is time not spent directly dealing with the emergency. Thus, without having to retrieve a paper document, the flight deck crew are given the procedures, via the electronic checklist, to be followed in responding to the situation.
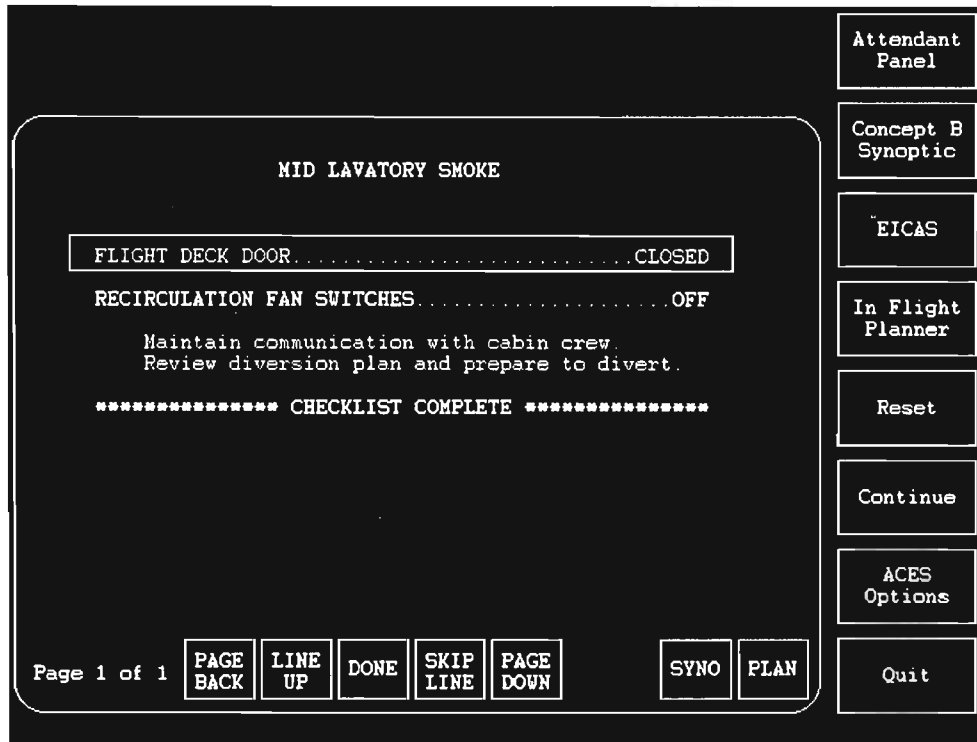
Figure 3-6. ACES Electronic Checklist.

The basic design of the checklist is similar for all alerts. This format provides for the differentiation of the current, completed, incomplete or skipped, and intransit (an item that has been initiated but whose action has yet to reach completion) action items or procedures. An item is declared completed when feedback is received to verify that system reconfiguration has been successfully accomplished. In the lavatory procedure shown in figure 3-6, the second line of that procedure, "RERCIRCULATION FAN SWITCHES—OFF," would be the active line of instruction if it were surrounded by a magenta box with text also in magenta. Upon turning the switch off, the magenta box would move to the next line of the procedure (in this example there is no additional procedure) and the color of the text would change from magenta to green and a open green box would appear to the left of the test. The open green box denotes that an item has been initiated and the system is in transition, but no positive feedback on system reconfiguration has been received. Upon receiving confirmation that the recirculation fans have shut down the open green box would become a solid green box. These differences are outlined in table 3-3.

Table 3-3. Electronic Checklist Status.

Current	Shown in magenta, surrounded by a magenta box.
Completed	Shown in green, with a solid green box in the left hand margin.
Incomplete or Skipped	Shown in white, when other items in the checklist have been completed. The system automatically returns to the OPEN item.
Intransit	Shown in green with an open green box in the left hand margin.

The checklist for a lavatory smoke event is shown in figure 3-6, above. The location ("MID LAVATORY") and nature of the event ("SMOKE") is displayed at the top of the page, in amber to reflect the cautionary level. Below this are the checklist items, with the first action item indicated in magenta surrounded by a magenta box. The user clicks on this box to indicate that this action has been completed. This causes the item to be displayed in green, with a solid green box in the left hand margin. The system has automatically moved to the next procedure on the list (Recirc Fans), which is displayed in magenta, surrounded by a magenta box. Clicking on this item completes the checklist and both items are now displayed in green, with two solid green boxes in the left margin. The last line on the checklist ("**CHECKLIST COMPLETE**") has also turned green, indicating that all checklist procedures have been acted on.

In addition to the procedures, the checklist instructs the flight deck crew to maintain communications with the cabin crew. This is purposely done to foster a full team environment in reacting to a potential emergency situation. The flight deck crew is further reminded to begin reviewing their diversion options. This flight deck diversion feature will be discussed in section 3.1.4.2.

The electronic checklist prioritizes the procedures that should be taken in response to a given alert. It is, however, up to the flight deck crew to carry out the procedures. This was a conscious design decision based on discussions with members of the Boeing Flight community. In contrast, one can easily envision an ACES system that, once a sensor went into an alert condition, would initiate many of the checklist items without any input from the flight deck crew. Pilots have the responsibility for the fate of the aircraft and, from our discussions, pilots feel strongly that actions should be initiated from the flight deck with the flight crew active participants in the decision loop.

The seven boxes located at the bottom of the checklist page, figure 3-6, are defined in table 3-4.

Table 3-4. EICAS Control Functions.

Page Back	If the checklist has multiple pages (screens) of procedures, this allows the user to go back a page.
Line Up	Moves up one line at a time. Should an item be skipped, this function enables the return to that line.
Done	Clicking this function causes the checklist to be checked off in its entirety.
Skip Line	Advances user to the next line. The skipped line remains active – magenta. This allows checklist to be done in the order the flight deck deems most appropriate.
Page Down	If the checklist has multiple pages (screens) of procedures, this allows the user to move to the next page.
Syno	This function replaces the electronic checklist with the SYNOPTIC display feature.
Plan	This function replaces the electronic checklist with the DIVERSION PLANNING map.

3.1.4.2   Inflight Planner.

At this stage of the alert the flight crew has responded to the alert and completed the items on the checklist. In all situations characterized by smoke and/or fire, landing at the nearest suitable airport is always required, with the caveat that it is the "responsibility of the captain to asses the situation and execute sound judgement to determine the safest course of action," – Boeing Operations Manual. This manual further states: "It should be stressed that for persistent smoke or a fire that cannot be positively confirmed to be completely extinguished the earliest possible descent, landing, and passenger evacuation should be accomplished." Thus, in an inflight smoke/fire emergency, it is imperative that the captain be able to reach a decision as to the nearest suitable airport, obtain clearance for a new route, and execute the diversion in a timely manner.

To assist the flight deck crew with these tasks, an Inflight Planner has been developed for the ACES system. The Planner recommends, in a priority listing, possible alternative airports and allows the pilot to assess the factors that have been used by the system to reach its (the system's) conclusions.

Much of the flight planner information makes extensive use of terms and abbreviations that appear cryptic to those outside the pilot community. However, all the terms and abbreviations used are those that would be recognized by an individual with the training required of a commercial jet aircraft pilot. A goal of this section is to provide the reader with a basic understanding of the language in which the information is displayed.

The user can access the Planner by clicking on "PLAN AID" in the lower right corner of the EICAS screen. The user will be presented with the ACES Inflight Planner Map, figure 3-7.
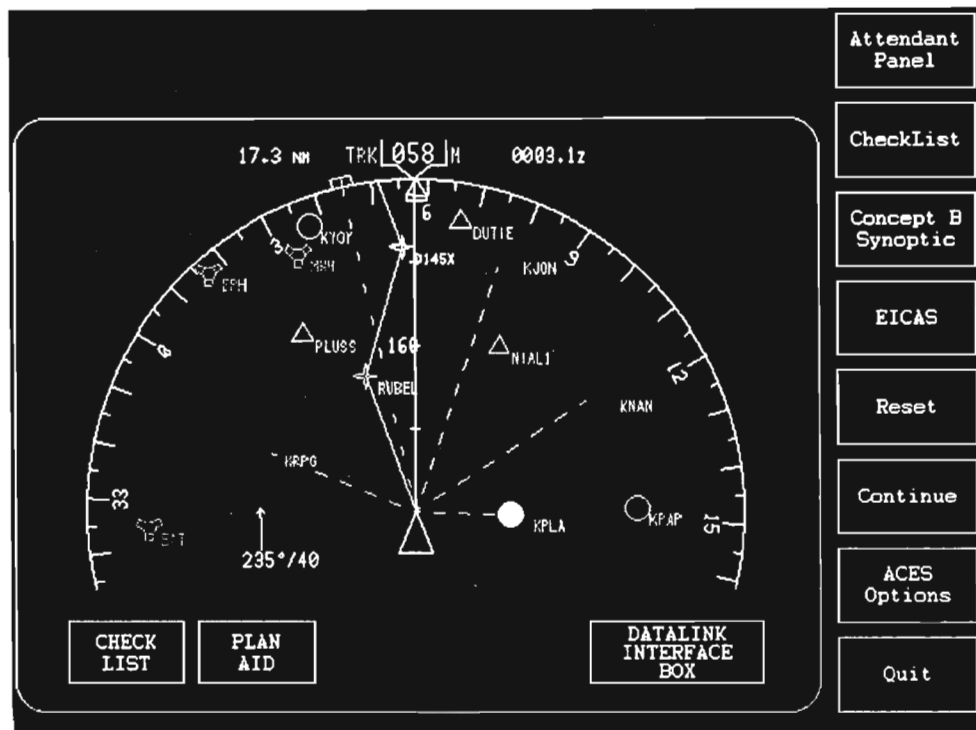

Figure 3-7. ACES Inflight Planner Map.

33

The map displays the location of the aircraft (the large white triangle) and the four nearest airports: KPPG (Pago-Pago), green circle; KJON (Jonsville), blue/green circle; KNAN (Nanoon), blue circle; and KPLA (Plamyra), yellow circle. Each color reflects the system's prioritization of which airport is the best. Definition of the color code is given in table 3-5. Clicking on one of the airports causes the selected airport to be displayed with a white circle around it and have the flight path recalculated for flight to that airport.

Table 3-5. ACES Inflight Planner Color Code.

Color	Priority
Green	Highest-the system's first choice
Green/Blue	Second
Blue	Third
Blue/Yellow	Not used
Yellow	Not recommended – unacceptable conditions exist

This screen displays a "DATALINK INTERFACE BOX" which has no active function in this emulation of the flight deck, other than to show that a future system may have this capability. Such a capability will allow updated weather information to be received by the aircraft inflight, and this may impact the order in which the system ranks the diversion options.

In the lower left hand corner of the EICAS screen are two boxes that enable the user to (1) return to the Checklist (section 3.1.4.1), or (2) query the system as to how the airport priority was arrived at.

Clicking on "PLAN AID" will present the user with the lower EICAS screen configured as in figure 3-8, ACES Diversion Planning Aid. This display shows the categories used by the system in prioritizing the four potential diversion airports: ETE (estimated time enroute), runway, weather, and facility. The ETE is the calculated time requied to put the aircraft on the ground. This time is shown in white for each airport, e.g., KPPG has an ETE of 29 minutes. The four candidate airports for diversion are shown color coded as defined in table 3-5. This screen identifies the reason for KPLA's low (yellow) ranking; the runway is not capable of accommodating the aircraft and the weather is unfavorable. This information is clearly and concisely conveyed to the flight deck crew by use of the color coded display. (Note: areas appearing blank in figure 3-8, are locations of blue boxes.)

The screen shown in figure 3-8 will be referred to frequently as this is the entry screen for the retrieval of diversionary information available to the flight deck crew. Behind each of the 24 boxes shown in figure 3-8 is a page that provides the flight deck crew with pertinent information on the selected subject.

Clicking on "ETE" in the top row will provide the user with a summary of the travel time to each of the four airports, figure 3-9, ACES ETE Information. The information is provided as "ETE (min)" – estimated time enroute in minutes, "ETA (Z)" – estimated time of arrival in Zulu time, "DIST.(NM)" – distance to the airport in nautical miles, and "COURSE" – the required heading. The user then may investigate the other three categories (weather, runway, and facility) by clicking on the appropriate box at the bottom of the screen. By clicking on "PLAN AID" the user is returned to the top level planning aid menu, figure 3-8.
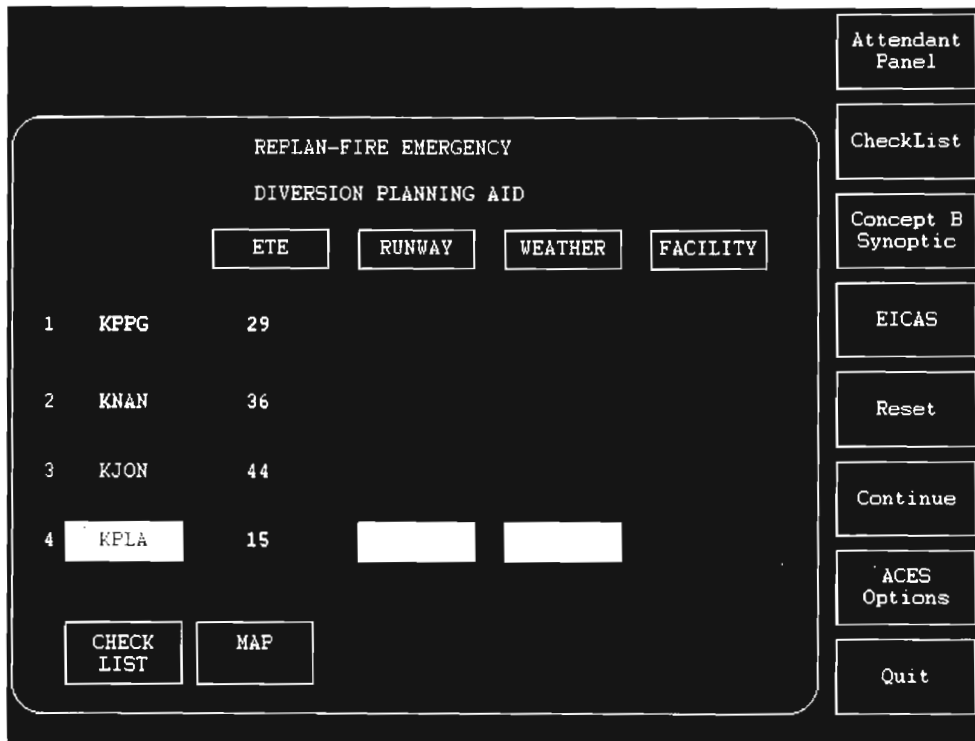
Figure 3-8. ACES Diversion Planning Aid.

Figure 3-9 ACES ETE Information.

Clicking on "RUNWAY" presents the user the information shown in figure 3-10, ACES Runway Analysis. The runway information is presented graphically to quickly convey the facts regarding runway length, runway number (05 for KPPG), and required aircraft braking distance. Braking distance is based on the calculated weight of the aircraft at start of approach. Thus, fuel burn enroute is accounted for in the graphics displayed in figure 3-10. Aircraft with fuel jettison capability (a system not available on the study aircraft) would require development of procedures to take into account the advantages such a system may offer. From this information it is clearly seen why airport KPLA has been rejected as a potential diversion. The combination of aircraft landing requirements and available runway length, plus overrun (shown in blue), will not accommodate the aircraft.
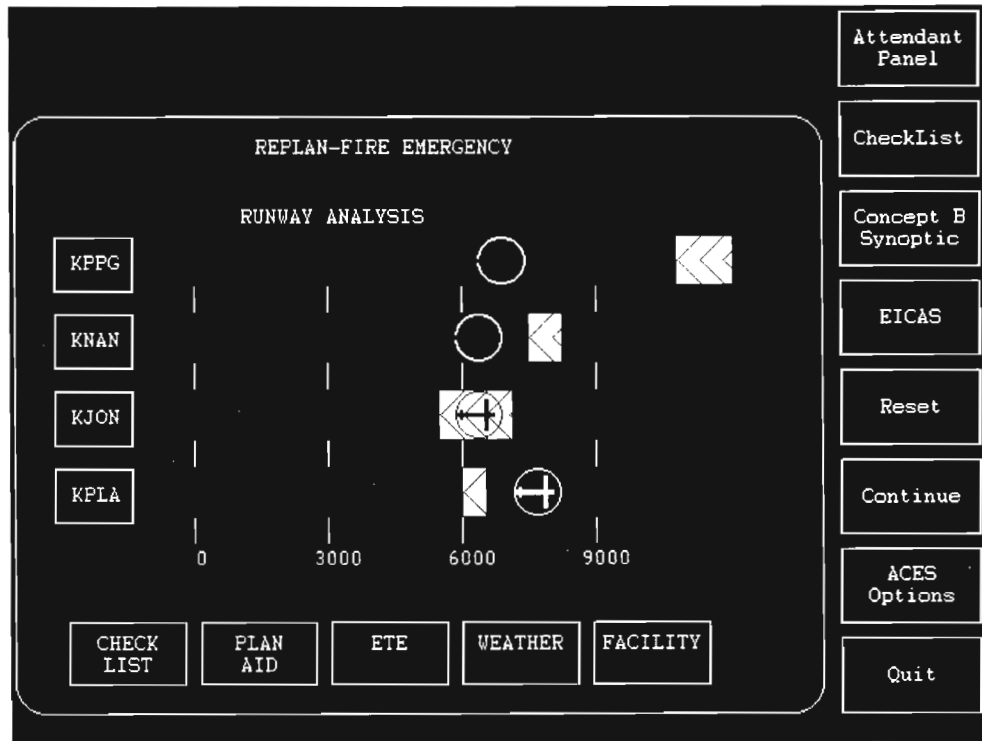
Figure 3-10. ACES Runway Analysis.

The third category that the flight deck crew may choose to look at is weather. See figure 3-11 for this screen display. The weather information available to the flight deck crew is "REPORTED" and "FORECAST." Both categories provide "CEIL (FT)," ceiling conditions in feet, "VIS (SM)," visibility in statute miles, and "ISSUED (Z)," time report was issued in Zulu time. The forecast report duplicates these categories with the addition of the time (Zulu) for which the forecast will be in effect, "FOR (Z)." In the example shown, KPPG conditions are forecasted to improve from a ceiling of 2000 ft and visibility of 3 SM to 2500 ft and 5 SM, whereas the conditions at KNAN are forecast to deteriorate from a ceiling of 1000 ft and visibility of 2 SM to 800 ft and 1 SM.

The final category that the flight deck crew can access for information is the Facilities Information screen, figure 3-12. This screen summarizes the emergency capabilities available both at the airport and in surrounding communities. The airport resources are "APPRCH AIDS" (approach aids), "FIRE SUPPR" (fire suppression) capabilities graded as A, B, or C, and number of "RESCUE UNITS." The local resources reported are "HOSPTLS" (hospitals), "BURN CENTR" (burn center), and the number of "EMT UNT" (Emergency Medical Technician Units), i.e., ambulance services.
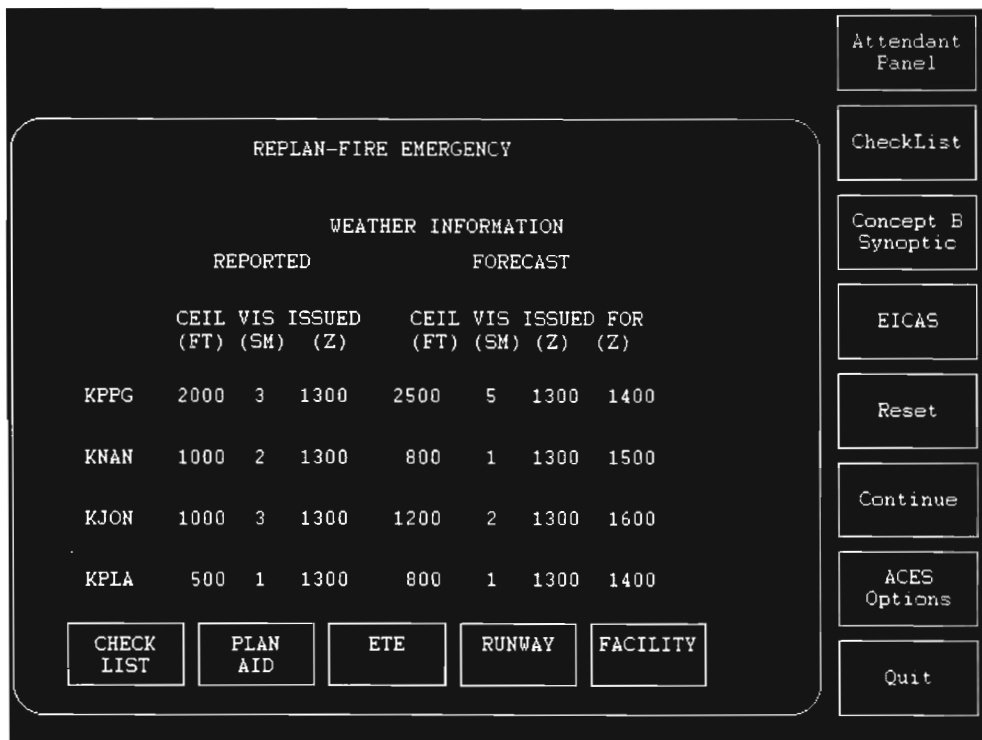
Figure 3-11. ACES Weather Information.

Figure 3-12. ACES Facilities Information.

In addition to viewing the airport information as a comparison of the four available airports, the user can access ETE, runway, weather, and facilities information on each individual airport. The individual format allows for more information to be displayed to the flight deck. Each of these four screens will be detailed in the following paragraphs.

When the Diversion Planning Aid screen (figure 3-8) is active, information on an individual airport is available by clicking on the box that is the intersection of the airport/category for which information is sought. Thus by clicking on the intersection of "RUNWAY" and "KNAN," detailed information on runway conditions for KNAN will be presented on the lower EICAS screen, this is shown in figure 3-13.
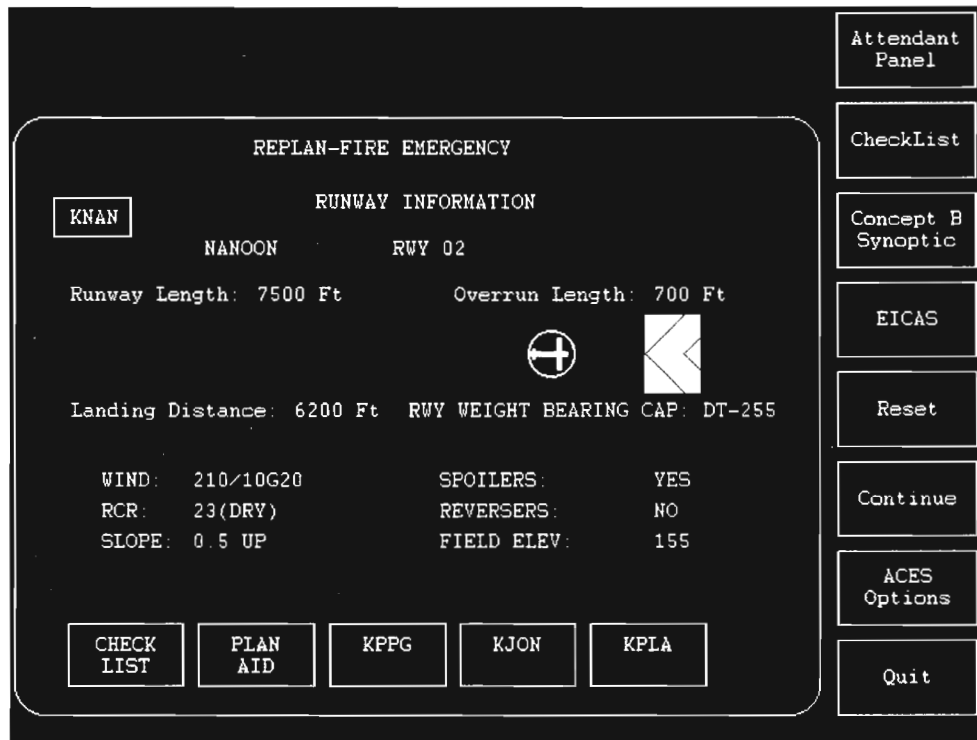
Figure 3-13. ACES Airport Runway Information.

The ACES airport runway information screen displays the airport that has been called up (KNAN), the ranking given to this runway (blue/green), airport name (Nanoon), runway number (RWY 02). In this example, runway length is 7500 feet (the green or dark area) with an additional 700 feet of overrun length (the blue or lighter shade area). The calculated landing distance for the aircraft is 6200 feet. This number is based on many parameters including aircraft weight, wind conditions, and runway surface conditions. The runway weight bearing capacity for a dual truck configuration is given as 255,000 pounds (DT-255). The wind is shown to be from a heading of 210°, steady at 10 knots with gusts to 20 knots. Runway condition rating (RCR) is a measure of braking conditions and is a component used in the calculation of the aircraft's landing distance. The RCR scale ranges from a high of 25 for a well maintained runway with dry conditions, and down to 0 for no traction or ice conditions. Slope shows the runway to be sloped uphill at 0.5°. The aircraft is certified to brake without either spoilers or reversers, however, the planner calls for use of spoilers, while deployment of thrust reversers are not deemed necessary. The final piece of information is field elevation, which is given as 155 feet.

When the user selects the intersection of "ETE" and "KNAN" for the diversion plan aid (figure 3-8), the information displayed on the lower EICAS screen will appear as shown in figure 3-14, ACES Airport ETE Information. The airport selected is shown in the upper left hand corner and the ranking given this parameter is displayed in the upper right corner. Next are given the times (ETE and ETA), distance and course heading. Following that information is the "FD REPORT" – winds and temperature aloft forecast, for each of the four airports. The top line of the report 3000, 9000, 18000, and 30000 is altitude in feet. The data given for KNAN at 18000 ft, 2330+8, will be used to decode the information. The first two digits give wind direction in tens of degrees, the second two wind speed in knots, followed by the temperature in degrees celsius. Thus, 2330+8 is read as wind from 230° at 30 knots, temperature +8°C. Temperature information is not given for altitudes below 3000 ft or for an altitude within 2500 feet of the reporting airport. Temperatures above 24000 feet are always negative, and the minus sign is omitted. The forecast for KNAN at 30000 feet, 234037, reads as wind from 230° at 40 knots with a temperature of -37°C.
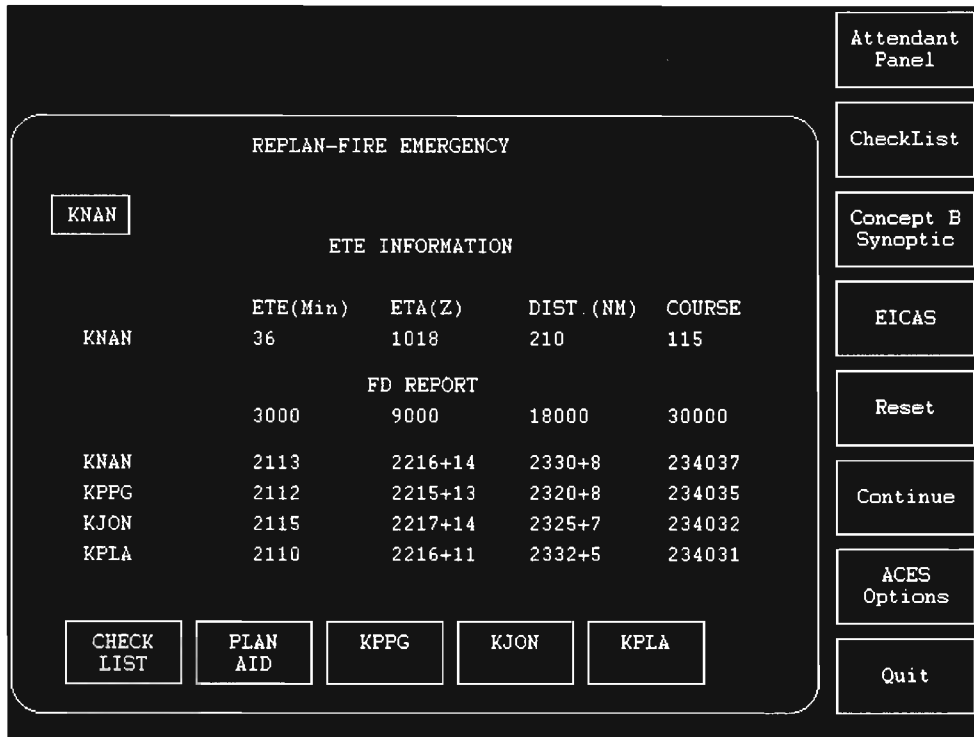
Figure 3-14. ACES Airport ETE Information

Weather for each airport may be viewed by the flight deck crew using the same procedure as for the runway and ETE information. The user must first return to the diversion planning aid screen and select the weather/airport box. Selecting the intersection of "WEATHER" and "KNAN" will give the information as shown in figure 3-15, ACES Airport Weather Information.
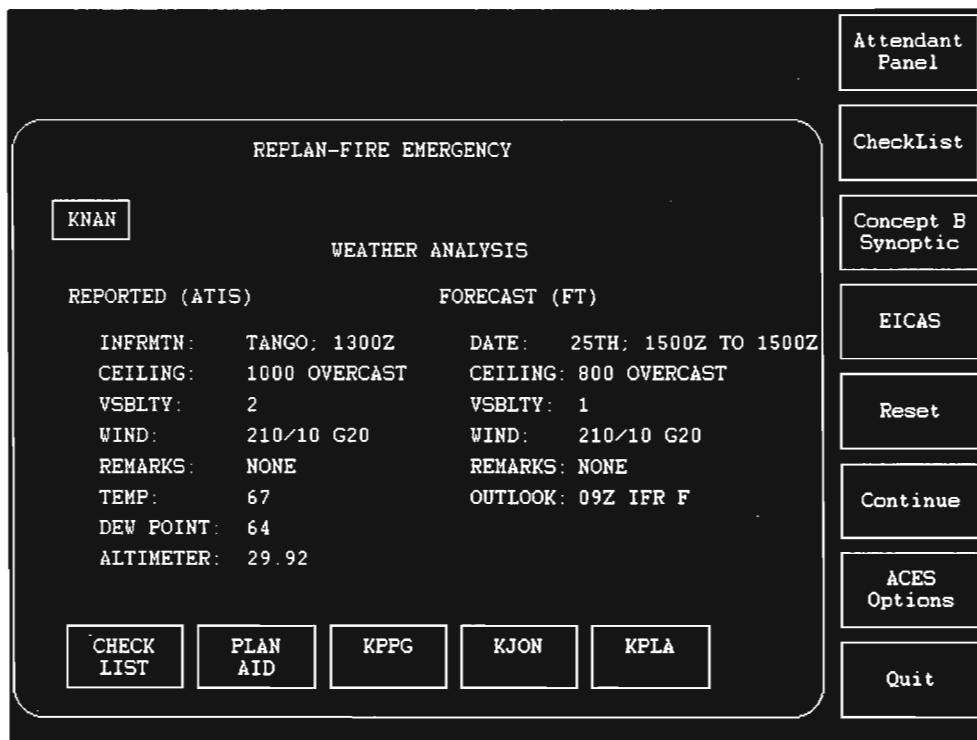
Figure 3-15. ACES Airport Weather Information.

The weather analysis page provides both reported and forecast information. The data under the heading "REPORTED (ATIS)" are from the automated terminal information system (ATIS). This is a continuous broadcast of weather conditions at the broadcasting airport. The report is given a title, in this case "TANGO," and the time at which it was released, 1300Z. (the title moves up the alphabet as the report is updated; Tango to Uniform to Victor). The conditions being reported in the Tango report are: ceiling at 1000 ft with overcast conditions, visibility ("VSBLTY") 2 miles, wind heading 210 degrees steady at 10 gusting to 20 knots, temperature 67°F, dewpoint 64°F, and pressure altimeter setting of 29.92 inches of mercury. "FORCAST (FT)" is the terminal forecast information which is shown to have been issued at 1300Z projected out through 1500Z for the day of the 25th. The rest of the information is same as the reported, with the addition of the outlook which reads "09Z IFR F." This translates as: at 0900Z, instrumented flight rules (IFR) are forecasted to be in effect due to fog (F).

Conditions at Nanoon are shown to be deteriorating from a 1000 ft ceiling to 800 ft. This is reflected in its green/blue color as a second order ranking.

The last column in the Diversion Planning Aid, figure 3-8 supplies the flight deck crew with information on emergency facilities at the airport and in the surrounding community. When the intersection of "KNAN" and "FACILITIES" is selected the user is presented with the information as shown in figure 3-16, ACES Airport Facilities Information. The information is divided into two sections, "AIRPORT RESOURCES" and "LOCAL RESOURCES." The airport section reports on three parameters: (1) "APPROACH AIDS" – none for KNAN, this airport operates using visual flight rules (VFR), (2) "FIRE SUPPR" – fire suppression capabilities of three fire engines and a hazardous material response team, and (3) "RESCUE UNITS" – of which there are three. There are also three parameters reported for the local resources: (1) "HOSPTLS" – 3 hospitals with a total of 425 beds and the capacity to handle mass casualty situations, (2) "BURN CENTR" – a local burn center with a 30 bed capacity, and (3) "EMT UNIT" – of which there are four. These facilities are rated as a green – the best rating; this is reflected by the green box at the top of the screen.

```
                         REPLAN-FIRE EMERGENCY

   ┌──────┐
   │ KNAN │
   └──────┘                FACILITY INFORMATION
                                KNAN
        AIRPORT RESOURCES
           APPROACH AIDS      NONE
           FIRE SUPPR         (3) ENGINES, HAZ. MAT. RESPONSE
           RESCUE UNITS       (3)

        LOCAL RESOURCES
           HOSPTLS            (3) 425 BEDS TOTAL, MASS CASUALTY
           BURN CENTR         (Y) 30 BEDS
           EMT UNIT           (4)


   ┌───────┐ ┌──────┐ ┌──────┐ ┌──────┐ ┌──────┐
   │ CHECK │ │ PLAN │ │ KPPG │ │ KJON │ │ KPLA │
   │ LIST  │ │ AID  │ │      │ │      │ │      │
   └───────┘ └──────┘ └──────┘ └──────┘ └──────┘
```

Figure 3-16. ACES Airport Facilities Information.

Another option, when viewing the Diversion Planning Aid screen figure 3-8, is to click on one of the four airport boxes. This action will present the flight deck crew with an overview of the available ETE, runway, weather, and facility information for the selected airport. ACES Airport Summary Information, figure 3-17 shows how this looks when "KNAN" is clicked on.


```
                         REPLAN-FIRE EMERGENCY

   ┌──────┐
   │ KNAN │                    NANOON
   └──────┘
   ETE: 36 Min          Course: 115        Lat:  15:10.3S
   ETA: 1018            Dist:   210 NM      Long: 169:42.6W

   Runway: 02          Length: 7500 Ft     Ovrn: 700 Ft
   Required Landing Distance: 6200 Ft

   APPROACH: VFR Rwy 02                     Mins: 1000/3

   WX:  Rpt: (at 1300 Z)         Fcst (at 1300 for 1500)
        Ceil: 1000  Ft                Ceil: 800  Ft
        Vis:  2 SM                    Vis: 1 SM

   FACILITIES:  Medical: 1               Fire/Rescue: A

   ┌───────┐ ┌──────┐ ┌──────┐ ┌──────┐ ┌──────┐
   │ CHECK │ │ PLAN │ │ KPPG │ │ KJON │ │ KPLA │
   │ LIST  │ │ AID  │ │      │ │      │ │      │
   └───────┘ └──────┘ └──────┘ └──────┘ └──────┘
```
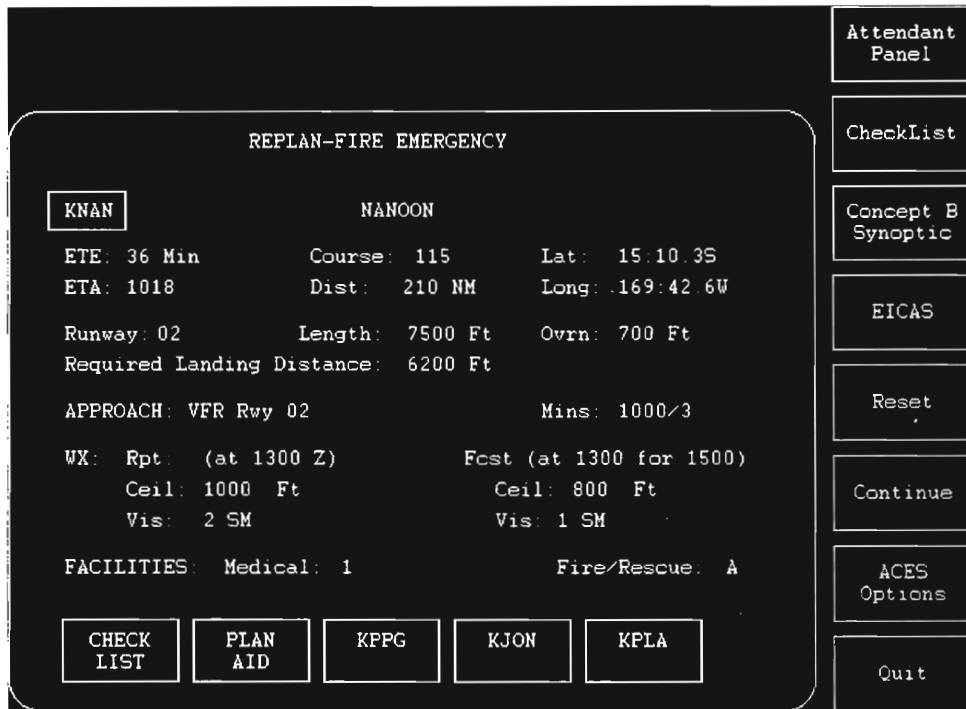
Figure 3-17. ACES Airport Summary Information.

This screen is divided into four sections to reflect the parameters used in prioritizing a diversion airport: ETE, runway, weather, and facilities. New terminology used on this screen is "Mins" for airport minimums, 1000 foot ceiling, and 3 SM visibility and "WX" for weather. For an airport that has unacceptable conditions, (KPLA for example), those areas that are rated unacceptable would be highlighted in yellow to bring these facts to the attention of the flight deck crew.

The flight deck crew thus has the ability to query the system as to how airport prioritization has been reached. The crew can, of course, choose any of the suggested airports or choose not to divert at all. The flying of the aircraft is the responsibility of the captain and the tools developed for the crew are just that; tools to help the crew make an informed decision based on the available facts. The captain remains in command of the aircraft.

The planner is a dynamic tool. As information is updated, the airport prioritization could change. If data link capability were available, updated information on winds, runway conditions (wet or dry), visibility, etc., could influence the system to rank the airports in a different manner. This situation is probably not applicable to the scenario provided in the demonstration, as the ETE for all the airports is fairly short. However, if two airports were closely located and the ETE great enough, a lower ranked airport could become over time more desirable than the airport initially ranked first.

3.1.4.3   Synoptic Display.

It is the synoptic display feature of the ACES system that has generated the most controversy within the various disciplines that makeup the flight deck alerting, information, and procedure community. There are, to summarize, two schools of thought regarding alerting information on the flight deck. One is, the more information that can be efficiently and clearly given to the flight crew, the better. The other is, if a procedure cannot be given to assist the crew in responding to the information, then that information is not relevant.

The sensors used in the ACES system, especially a thermal monitoring capability, would allow meaningful time histories to be collected and displayed in a coherent, organized manner. Given this capability the ACES prototype includes a function that allows the flight deck crew to view the status, including sensor output, of the smoke/fire system in the pressurized volume of the aircraft.

The synoptic display feature included in the ACES system shows a potential format that such a feature might take. The goal of the synoptic feature is to provide the flight deck crew a means to monitor an area. It is **NOT** intended to require the crew to be fire experts and analyze the information presented to determine if a diversion is warranted. The paramount procedure for the flight deck crew remains the same – when an emergency has been declared, land the aircraft in the most expedient manner possible.

At this stage in the emergency procedure the flight deck crew has responded to the alert, completed the items on the checklist, and made a decision on a diversion airport. The time enroute to a suitable airport could be up to three hours away with some aircraft models in flight over water. It is at this stage, when flight deck work load has returned to something resembling normal, that the flight crew may wish to access the synoptic display feature of the ACES system. From the inflight planner, the Synoptic feature can be accessed by clicking on "CHECK LIST," which returns the user to the checklist menu, figure 3-6. From this menu, clicking on "SYNO" takes the user to a screen as shown in figure 3-18.

42
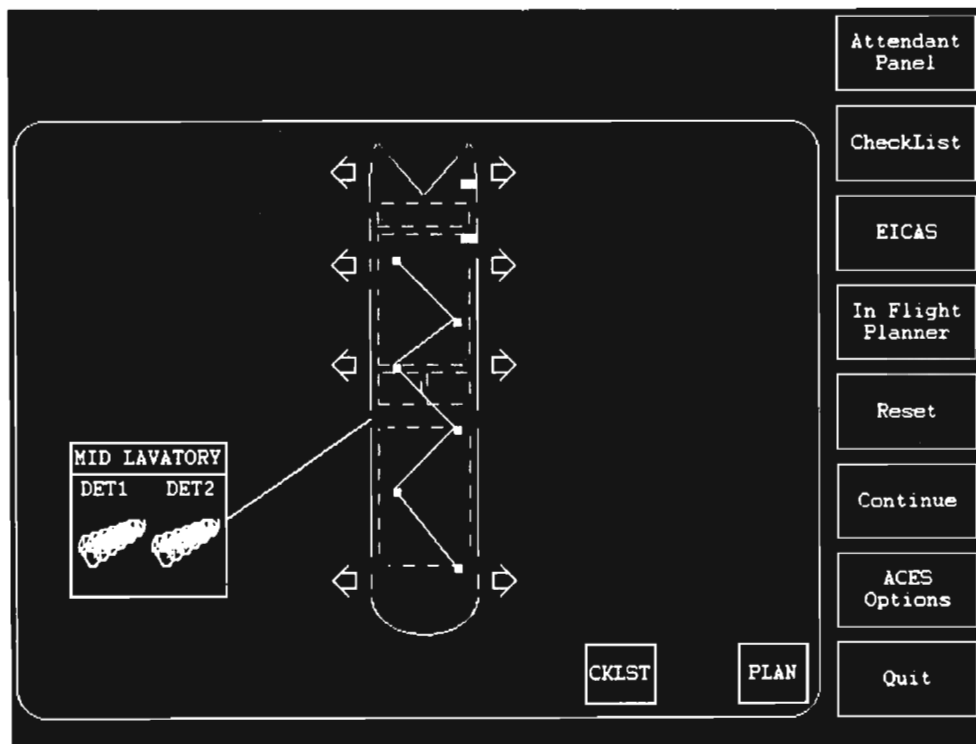
Figure 3-18. ACES Synoptic Display.

This display gives a schematic of the pressurized volume in light blue. The white arrows indicate emergency exit locations. The colored squares along the side of the aircraft are main deck smoke/fire sensors; lav in green, galleys in blue and misc. spaces (coat closet) in pink. Main deck ceiling sensors are shown in yellow, with the squares representing smoke sensors and the connecting yellow line a thermal monitoring fiber. The areas monitored below the main deck are shown outlined with a light blue dashed line. These lower deck areas, from nose to tail, are the forward electronic equipment (E/E) bay, the forward cargo compartment, the two air-conditioning packs located between the cargo compartments, and the aft cargo compartment.

In the example shown in figure 3-18, the left mid lavatory is the location for which an alert has been sounded. This is indicated by the sensor square changing in color from green (no alert) to red (alert) and the sensor profile box being displayed. Taking the mouse and clicking on the title of the sensor profile box will display, on the lower EICAS screen, a time history of both sensors located in the mid lavatory. One sensor is located in the ceiling of the lav and the second is mounted inside the vanity volume where paper products are stored. The profiles of the individual detectors can be viewed by clicking on one of the red squares located within the profile box.

The condition of any of the sensors can be viewed from the synoptic display by clicking the mouse on any sensor location. The profile for that sensor(s) will be shown. For display purposes the profiles have been hard coded in the alert condition.

43

3.1.4.4   Cabin Attendant Panel.

While the flight deck crew has responded to the alert and completed their checklist tasks, the cabin crew has also been responding to the mid lav smoke alert, for which they have primary responsibility. The cabin crew is made aware of the alert in three ways: (1) via the alarm horn built into the sensor, which may also be linked into the cabin audio system; (2) by the warning light located on the ceiling outside each lav, which identifies right/left lav; and (3) by the cabin attendant panel, figure 3-19.
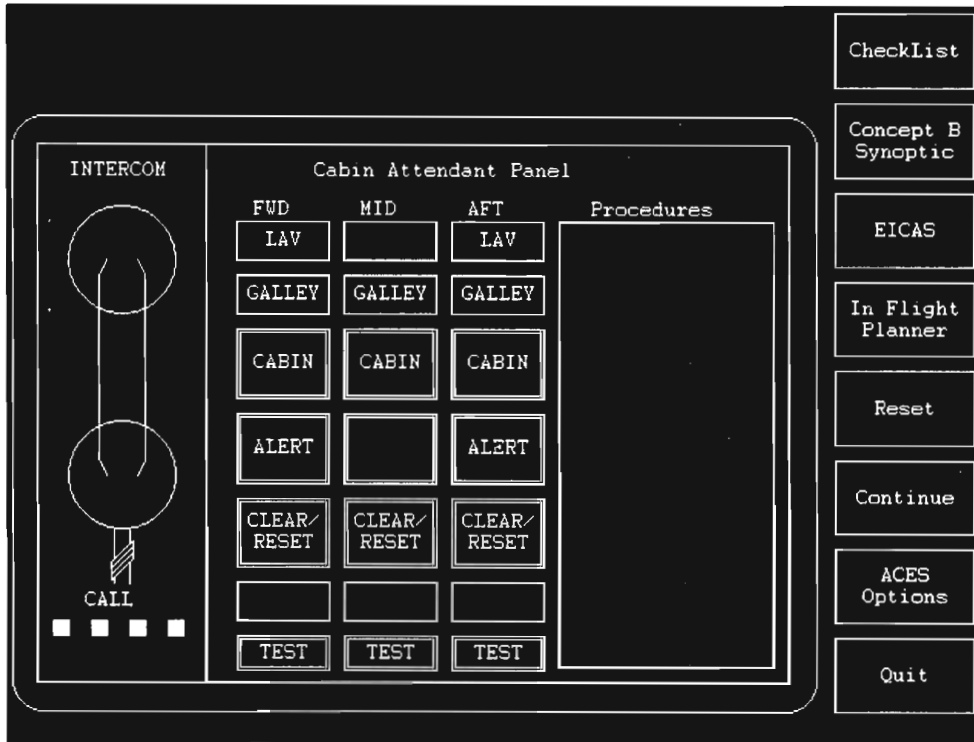
Figure 3-19. ACES Cabin Attendant Panel.

The ACES system proposes a panel of this, or similar design, be located at three locations in the aircraft: forward, mid-cabin, and aft. The panel features an array of buttons/switches that allow the identification of lavatory, galley and cabin smoke/fire events for each zone of the aircraft. In the case of a Mid Lav incident, all three panels would display the same information by having the top row ("LAV"), center column ("MID" – mid station location) button, and the fourth row middle column ("ALERT") button both illuminate red. The cabin attendant response would be to push the alert button which silences the alarm, turns the alert button from red to white, and causes a message to be sent to the upper EICAS screen on the flight deck. The message informs the flight deck crew that the cabin crew is aware of the situation and is investigating. Upon determining the nature of the situation a cabin attendant then pushes the "CLEAR/RESET" button. This action is transmitted to the flight deck crew and returns the cabin attendant panel to its normal state. At this point verbal communications can be established with the flight deck, via the handset co-located with the panel, and a full verbal report can be made.

The attendant panel allows non-verbal communication between the flight deck and the cabin crew at a time when both crews may be experiencing high workloads. Thus, via the quick action of pressing a button, effective communications can take place without either crew interrupting the other's response to the situation.

The panel allows a cabin attendant to originate a smoke event message to the flight deck by pressing the button/switch on the panel marked "CABIN." Such action will alert the flight deck crew of smoke in the main passenger cabin, and the appropriate checklist will be available for access by the crew.

44

The bottom row of buttons marked "TEST" allows the panel lights in each column to be illuminated as a check against bulb failure, as well as any internal circuitry tests that may be required. The Procedures box, located to the right of the buttons, is envisioned in one of two configurations. One, to contain a set of cards on which emergency procedures would be printed or two, an electronic checklist similar to that proposed for the flight deck.

3.2   SENSOR TESTS.

The goal of this section is to provide the methods by which the user can define the sensor array, collect sensor data, name and store data as required, and finally to normalize sensor data as appropriate.

The sensors, at this stage, have been connected to the Keithley and the Keithley has been linked to the Dolch and all components have been connected to their respective power supplies. Instructions on how to make these connections are detailed in section 2.5, Hardware Interfaces.

Turning on the power supplies, the Dolch, and the Keithley is all that remains to be done to begin the data collection process. Upon power up, push the <ESC> key on the Dolch to skip over the Dolch diagnostics. When the DOS prompt comes up type ACES <ENTER> and the user will be presented with the Setup Menu (figure 3-3). From this menu the user has three options: Demo (discussed in section 3.1), Alert Algorithms (to be discussed in section 3.4), and Sensor Tests to be discussed in this section.

3.2.1   Definition of Sensor Array.

From the Setup Menu, figure 3-1, the user is given three options: Sensor Tests, Alert Algorithms, and Demos. Tapping the space bar moves the user between these three choices. Activate the Sensor Tests branch of the system by highlighting "Sensor Tests" and pushing <ENTER>. The screen will clear and the Sensor Menu will be displayed, figure 3-20.
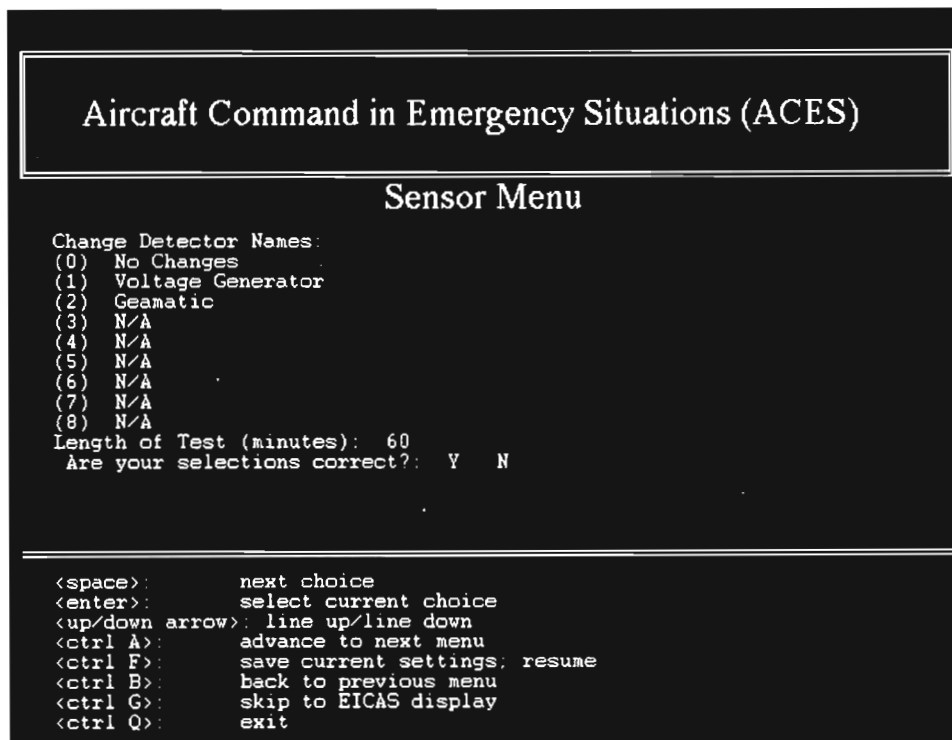

Figure 3-20. ACES Sensor Menu.

45

To give an example of how the two data collection limitations work two examples are given: (1) if a test time of 3 minutes is input, the sampling interval will be once ever 0.25 seconds, as this test will be limited by the rate of sampling constraint, and (2) if a test interval of 20 minutes is input, a sampling interval of 1.20 seconds will be used as this test is constrained by the limit of 1000 data points.

The final question for the user is if the selections (or inputs) are correct. By selecting Y (yes), the user will be presented with the screen as shown in figure 3-21, Sensor Data Display.
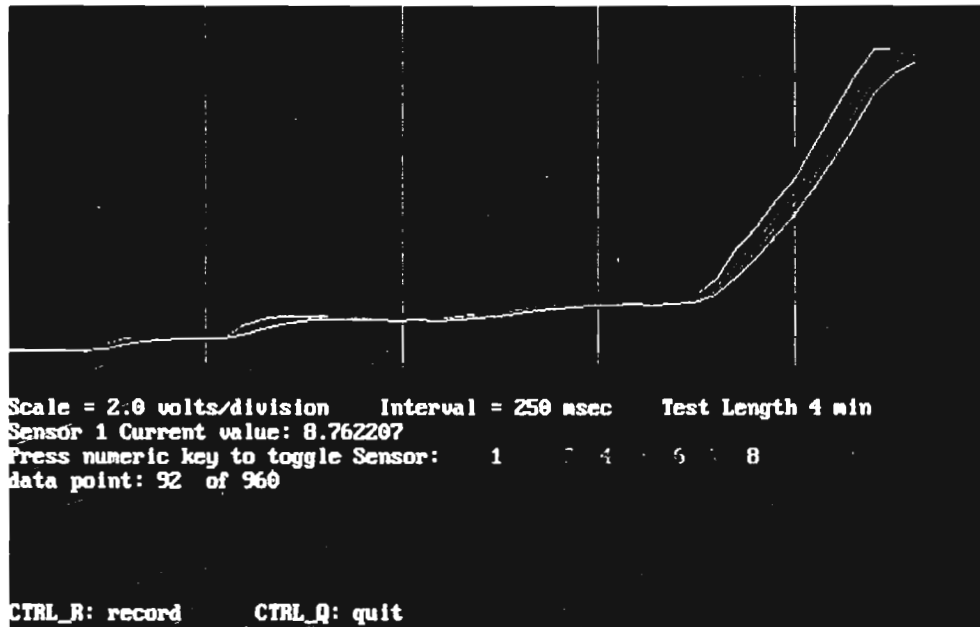

Scale = 2.0 volts/division   Interval = 250 msec   Test Length 4 min
Sensor 1 Current value: 8.762207
Press numeric key to toggle Sensor: 1   ? 4 · 6 · 8
data point: 92 of 960

CTRL_R: record   CTRL_Q: quit

Figure 3-21. ACES Sensor Data Display.

The first line of the sensor data display screen informs the user of the scale of the graph, 2.0V/division, the calculated sampling interval 250 msec (four times a second), and the length of the test, in the example 4 min (minutes). The second line shows the sensor number (as defined in Sensor Array Menu) and its value in real time. The sensor shown on this line is the one highlighted when the user exited the Sensor Menu, figure 3-20. The choice of which sensor to monitor in real time is a function of the test configuration and the sensor which is of most interest to the user for that particular test. The third line on the screen provides information on which sensors have been selected for display. The numeric keys, located on the top row of the Dolch keyboard (not the function keys), allow the user to turn on and off the sensor channels to be displayed. Each channel is color coded to provide visual clarity. However, when all eight channels are displayed, telling which channel is which can be difficult, especially if all the signals are at about the same output level. The fourth line shows the data points that have been collected (shown in figure 3-21 as 92) and the total number of data points to be collected (960) over the length of the test run.

At the bottom of the screen are the commands that control the start and termination of a test/data collection run. The sensor data can be observed on the screen. However, data recording does **not** begin until the CTRL_R command is given (CTRL_R: hold down the CTRL key and the R key at the same time). This command will begin data collection and cause a red "Recording" message to be displayed in the bottom right hand corner of the screen. Data recording can be terminated at any time by doing a CTRL_Q (CTRL_Q: hold down the CTRL key and the Q key at the same time). This action halts the recording and exits the user to the data save function. If the test is allowed to run to its conclusion, the Recording message disappears and line four will read data point: 960 of 960. Yet even when recording has stopped, the sensor signals can continue to be viewed on the screen. To save and store the data the user must do a CTRL_Q to leave the data display screen and exit to the data saving function. This function will be detailed in the next section.

47

3.2.3   Data Storage.

The data saving prompt given the user upon exiting the data collection or recording function asks the user to input the Dolch channel number, comments, and a file name. For example, typing "4 forward cargo baggage fire, Fire4.dat" <ENTER>, will save the data from channel 4 (Cerberus-1 sensor), add the comment forward cargo baggage fire to the file header, and name the file Fire4.dat. The user will again be prompted for a file to save, and this procedure is repeated until either all eight channels are saved or until <ENTER> on a blank line is input. This latter action exits the user from the data naming/saving function.

Each data file has a eight line header block that contains the following information:

> @File Name: (user input)
> @Sensor No.: (user input)
> @Comment: (user input)
> @Sampling Interval:
> @Sampling Unit:
> @Date/Time:
> @Data Points:
> @

If a mistake or oversight is made and the user decides **before** running the next test that additional channels of data should have been saved, there is recourse to keep the data files needed. All the test data is placed in files named Temp1.dat through Temp8.dat for each of the eight channels of data. To rename a Temp*.dat file, the user must exit to the DOS prompt. Using the rename command, the needed file(s) can be renamed. For example typing "rename Temp1.dat, Fire1.dat" <ENTER>, will rename Temp1.dat to Fire1.dat. All eight Temp*.dat files will be written over at the next recorded test run.

3.2.4   Normalization.

A simple normalization function has been provided to allow the user to standardize the data. In the lab the function has been used exclusively on the data generated by the Geamatic sensor, section 2.3.3. To review, the Geamatic is a light attenuation sensor and in normal conditions its output is a high value of about 10V. When particles come between the light source and the photocell, a voltage decrease occurs. This is the opposite of both the photoelectric light scattering and ionization smoke detectors. Therefore, to allow all the signals to be analyzed for similar trends and thresholds, the Geamatic signal is inverted via the normalization function.

To access the function the user must leave the ACES menus and return to DOS. This can be done by pushing <ENTER> twice. When given the DOS prompt, type "NORMAL" <ENTER> (command is not case sensitive). The user will be prompted for the following:

> File name,Scale,Offset,Newfile name

An example of an input would be:

> Fire6.dat,-1,10,Fire6N.dat

This command will take file Fire6.dat (data from sensor Geamatic-1, which based on the configuration defined in table 3-6 is Dolch channel 6), multiply the sensor data by -1.0, then add 10 to each data point, and name the new file Fire6N.dat. During testing, the procedure that was established was to add a capital N to the end of the old file name to indicate that the file had been normalized.

The new file Fire6N.dat will have the same header information as the Fire6.dat with the addition of a new top line giving the new file name, Scale, Offset, and the Time and Date the file was normalized. Thus the header block will be nine lines long rather than the eight line header for a regular file.

3.3 ALERTING ALGORITHMS.

A primary goal of the ACES system is the reduction of false alarms. This goal might be achieved with a combination of enhanced sensor technology and system logic; sensors that provide analog output and algorithms to interpret what the sensors are "saying." The majority of the sensors used in commercial jet transports today provide only on/off type information. That is, the sensor is either in a normal, no alarm, state or in alarm mode, with but a single criteria used to distinguish between the two. The criteria for most photoelectric systems is that the amount of light incident on the sensor photocell exceeds a threshold value. Sensors currently in use are set to alarm at light obscuration on the order of 10 percent over one foot.

The sensors selected for the ACES system (other than the Jamco ionization sensor) provide analog output. Such output allows rate of change as well as threshold information to be incorporated into alerting schemes. Such a system should have the effect of reducing false alarms without affecting system sensitivity. Of the many schemes investigated, two algorithms, Spike Reduction and Threshold/Slope were found to provide a good mix of sensitivity **and** a capability to protect against false alarms.

A method to achieve this goal was the development of the spike reduction algorithm. This algorithm applies to but a single sensor and seeks to minimize false alarms that can result from elevated sensor voltages of short duration (spikes). The spike reduction code can be thought of as a filter that does not allow short duration high sensor values (spikes) to pass through. If however, the high values persist the alarm criteria will be satisfied and an alert signal generated. This algorithm will be explained in detail in section 3.3.1

The development of the threshold/slope algorithm provides a second method of false alarm protection. Multiple sensors, up to a maximum of three, are monitored for sensor voltage level (threshold) and the signal increase or decrease over time (slope). These two parameters are compared to limits established by the user. A criteria has been established such that an alert is only triggered when sensors are at given levels either in combination or singularly. The parameters that control this algorithm will be explained in section 3.3.2.

To access the alert algorithm section of the system the user begins at the ACES Setup Menu, figure 3-1, selects "Alert Algorithms" and pushes <ENTER>. This action brings up the ACES Algorithm Menu, figure 3-22.
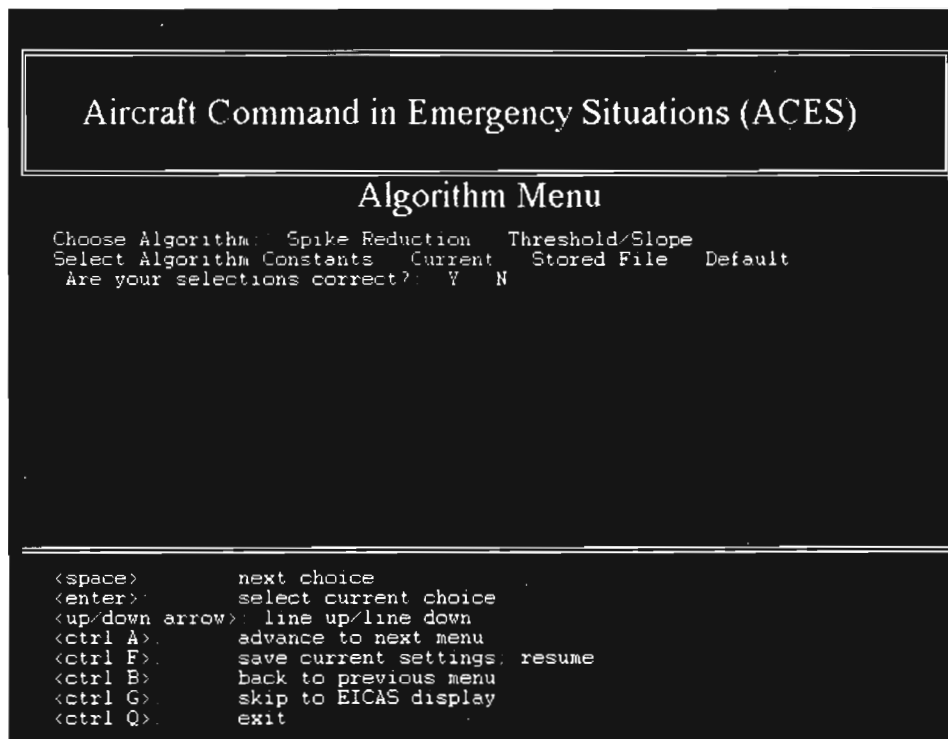
```
┌──────────────────────────────────────────────────────────┐
│ Aircraft Command in Emergency Situations (ACES)          │
└──────────────────────────────────────────────────────────┘

                    Algorithm Menu

  Choose Algorithm:  Spike Reduction   Threshold/Slope
  Select Algorithm Constants   Current   Stored File   Default
   Are your selections correct?   Y   N




  <space>          next choice
  <enter>          select current choice
  <up/down arrow>  line up/line down
  <ctrl A>.        advance to next menu
  <ctrl F>.        save current settings, resume
  <ctrl B>         back to previous menu
  <ctrl G>.        skip to EICAS display
  <ctrl Q>.        exit
```

Figure 3-22. ACES Algorithm Menu.

The Algorithm menu allows the user to choose which of the two algorithms; Spike Reduction or Threshold/Slope, the user would like to investigate. The algorithms have been constructed so that the user is easily able to change algorithm controlling parameters. This control is achieved by the selection of algorithm constants. The user is given three options (Current, Stored File, and Default) on what values will be designated to the various parameters. If data has been run through the algorithm without the Dolch being turned off, the selection of Current provides the user with the same set of constant values as used on the previous run of the algorithm. Selecting the "Stored File" option invokes a prompt for a file name. This file will contain values the user has saved from a previous session. The user is able to name a file after the data has been plotted or by exercising <ctrl F>. Upon initiating <ctrl F> the user is prompted for a file name. The Default selection accesses a file that is hard coded into the program, as will be seen in the next section this is the file with the data set v1.dat.

<ctrl F> is one of eight functions that are displayed at the bottom of the screen. These functions operate in the same manner as described in table 3-1, Menu Control Functions. The function <ctrl G> is not a viable function in the algorithm menu and if exercised can result in the system locking-up.

3.3.1   Spike Reduction.

The function of this algorithm is to reduce false alarms by filtering-out conditions that may result in an alert occurring due to transient, short term, elevated sensor output. Such an output could result from many factors, the most likely being a system voltage spike. The parameters that control the manipulation of the sensor output data will be explained in this section.

From the ACES Algorithm Menu, figure 3-22, the user selects "Spike Reduction," "Default," and "Y" (yes) to bring the user to the Spike Reduction Menu, figure 3-23.

```
┌─────────────────────────────────────────────────────────────────┐
│  ┌───────────────────────────────────────────────────────────┐  │
│  │                                                           │  │
│  │   Aircraft Command in Emergency Situations (ACES)         │  │
│  │                                                           │  │
│  └───────────────────────────────────────────────────────────┘  │
│                                                                 │
│                     Spike Reduction Menu                        │
│                                                                 │
│     Sensor Data File:  v1.dat                                   │
│     Noise Amp:  0.10                                            │
│     Initial Range Constant:  1.00                               │
│     Lag Constant:  5                                            │
│     Confidence Interval Constant    3.00                        │
│     Average Smoothing Constant:  5                              │
│     Number of Data Points:  50    100    200                    │
│     Data:  Sensor Data Only    Sensor Data w/ Detection Algorithm│
│     Display Detection Bands    Y    N                           │
│     Graphing Delay (data points/second)    5                    │
│      Are your selections correct?    Y    N                     │
│                                                                 │
│  ─────────────────────────────────────────────────────────────  │
│                                                                 │
│     <space>:          next choice                               │
│     <enter>           select current choice                     │
│     <up/down arrow>:  line up/line down                         │
│     <ctrl A>          advance to next menu                      │
│     <ctrl F>          save current settings: resume             │
│     <ctrl B>          back to previous menu                     │
│     <ctrl G>          skip to EICAS display                     │
│     <ctrl Q>          exit                                      │
└─────────────────────────────────────────────────────────────────┘
```

Figure 3-23. ACES Spike Reduction Menu.

This is the menu that allows the user to define the parameters that control the Spike Reduction alerting function. The selection of Default gives the user the screen as configured in figure 3-23. This is also the configuration the screen would have if Current is selected upon first booting up the Dolch. The user is able to change any of the parameters using the up/down arrow to move to various lines in the menu. The function of these parameters will be discussed below.

The Spike Reduction algorithm accomplishes several functions: smooth the signal data; create a confidence interval or a zone of acceptible variation around the smoothed curve; monitor the smoothed data; and if the smoothed data exceeds the confidence interval, signal an alert. How this is accomplished and how the variables control the process are explained below. The ACES computer code that defines these functions can be found in the section of code titled ALERT.C – Spike Reduction, reference 15.

The first step is to import a data point from the designated file. From the menu in figure 3-23 we know this to be v1.dat. In the code this takes the form Data[v1][j]. Data[v1] is the file and [j] is a data point contained in the file. To this data point a random noise value is added (±). The amplitude of the noise is controlled by the user via the Noise Amp input. The noise is used to provide a wiggle to the data, as flat data makes the alerting function overly sensitive. This is the blue line seen in the ACES Spike Reduction Plot, figure 3-24.
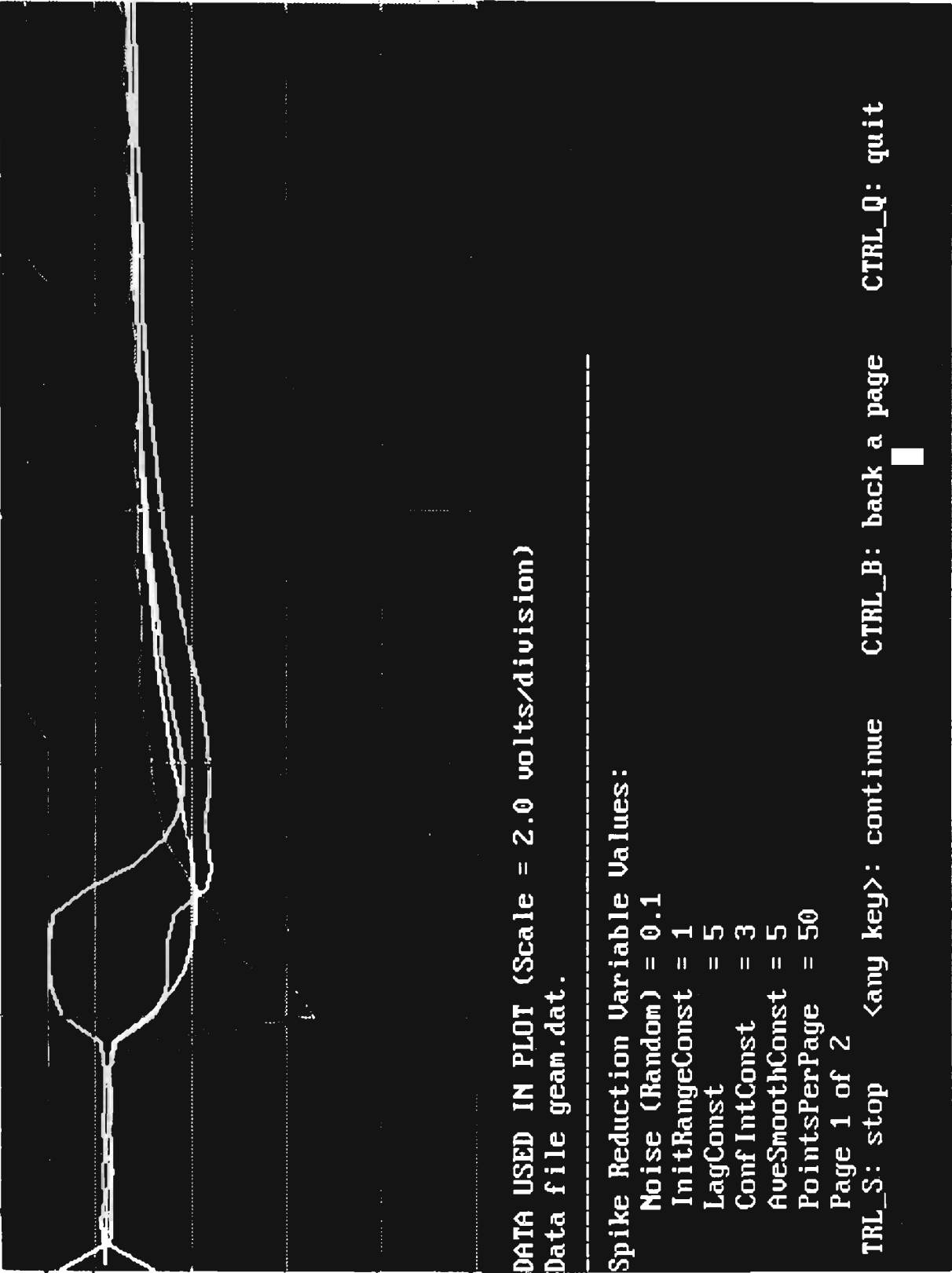
```
DATA USED IN PLOT (Scale = 2.0 volts/division)
Data file geam.dat.

Spike Reduction Variable Values:
   Noise (Random) = 0.1
   InitRangeConst = 1
   LagConst       = 5
   ConfIntConst   = 3
   AveSmoothConst = 5
   PointsPerPage  = 50
   Page 1 of 2
CTRL_S: stop   <any key>: continue   CTRL_B: back a page   CTRL_Q: quit
```

Figure 3-24. ACES Spike Reduction Plot.

A value of 0.1 has been successfully used to add enough variation without introducing unwanted variation. This line of code takes the basic form of:

Data[v1][j] = Data[0][j] ± [rand( )/32767] * NoiseAmp

Where rand( ) is a pseudo-random number generator function that is included in the standard C library. The rand( ) function inputs a number between 0 and 32767, if the rand value is less than 16884 (midpoint between 0 and 32767) the resulting calculated value (rand( )/32767*NoiseAmp) is added to the value of the data point. If the rand factor is greater than or equal to 16884 the resulting factor is subtracted from the data point. This has the effect that about 50 percent of the data has a small factor added to it while the remainder of the data has a small factor subtracted.

The next step in the process is to average or smooth the data. It is this function that creates the white line, seen in figure 3-24. The data is averaged to weed-out the effects of short duration fluctuations in sensor output. The user has input on how the averaging is weighted via the "AveSmoothConst" (ASC). The new average (ave[j]) is a function of the previous average (ave[j-1]) times the ASC plus the new data point (Data[v1][j]) all divided by the ASC plus one. This line of code has this basic appearance:

ave[j] = (ASC * ave[j-1] + Data[v1][j]) / (ASC + 1.0)

Next, the confidence intervals are generated, this is the acceptable range within which the detector signal should be found when an alerting condition is **not** present. The confidence interval is defined by the two yellow lines seen in figure 3-24. The confidence interval is created using several of the user defined inputs and a weighted average as defined above. The difference between two consecutive averages is taken and the result squared. The squared factors are then summed over the range specified by the user via the "LagConst" (LC) variable. This result has been identified in the code as SumSquares, and is shown below:

SumSquares = SumSquares + (ave[k-1] - ave[k])**2

Where k is a counter that counts from LagConst points in the past to the current point, one point at a time. SumSquares is set to zero at the start of the loop. The result of this loop is then divided by the LagConst factor and the square root taken. This result has been defined in the code as RMS, (this factor is not a true root mean square (RMS) and it should have been identify using a more appropriate name) and is shown below:

RMS = sqrt(SumSquares / LagConst)

The upper confidence interval is based on the average of LagConst points in the past plus the RMS times the user input confidence interval constant shown on the screen as "Conf IntConst" (CIC):

upper = ave[j-LC] + (CIC * RMS)

When the sensor data, plus the noise, is greater than the **upper** confidence band for **FIVE** consecutive data points, the alarm criteria is satisfied. An alarm is indicated by the red line ramping up from 9.0 volts to 9.4 volts. This is the top most dotted line seen in figure 3-24. If, for example, the upper band is exceeded 3 times and on the fourth time the data falls below the criteria, the counter is reset to zero and no alert is signaled to the flight deck. In practice the lower band, while displayed, is never used to generate an alarm.

The choice of five consecutive data points was selected based on the fastest sampling speed of four samples per channel per second, it seemed reasonable that a sampling window of 1.25 seconds was adequate to give false alarm protection while retaining system sensitivity. The criteria of counting data points when the sampling rate decreases (say to 1 data point every second) may impact the system response time to an unacceptable level. The definition of an acceptable level, while certainly considered, was not specifically addressed for sampling rates less than the four samples per channel per second.

The remaining inputs to be made on the Spike Reduction Menu, figure 3-23, determine how the data will be displayed in figure 3-24. "Number of Data Points" controls the density of data points displayed on the screen: 50, 100, or 200 data points before the screen must reset. The "Data" option allows the user to choose what will be displayed on the plot: "Sensor Data Only" (no smoothed data curve, no confidence band, no alert line), "Sensor Data w/Detection Algorithm" shows the sensor data plus the detection algorithm, the red alert line. With "Display Detection Bands," choosing "Y" (yes) displays the smoothed curve and the confidence interval.

With the choice of both "Sensor Data w/Detection Algorithm" and "Display Detection Bands," the user is presented with a Spike Reduction Plot as configured in figure 3-24. The sensor data is shown in blue, the smoothed data in white, the confidence bands in yellow, and the alert line in red. The data file the user selected is also shown; in figure 3-24 this is happens to be geam.dat. The algorithm variable values are displayed on the lower half of the screen. The commands on the bottom line of figure 3-24 are defined in table 3-7.

Table 3-7. Data Plot Key Functions.

Key Stroke	Function	Explanation
CTRL_S	stop	Halts graphing of the data
<any key>	continue	Restarts the graphing
CTRL_B	back a page	Moves back to the previous page e.g., from page 2 move to page 1
CTRL_Q	quit	Exits the user out of the Spike Reduction plot and promts for saving of current settings

<CTRL_Q> quits the graphing, without the option of restarting. Upon quitting the user is prompted: "Do you want to save the current settings? (Y or N)?" If the answer is yes an additional prompt "Enter file name:" is displayed. The algorithm variables can now be saved and recalled by selecting the Stored File option available in the ACES Algorithm Menu, figure 3-22.

3.3.2 Threshold/Slope.

The function of the threshold/slope algorithm is to reduce false alarms by looking at a maximum of three sensor signals, then generating an alert to the flight deck based on the condition of these signals. Such a scheme allows a voting methodology to be constructed with the user defining the parameters of sensor signal slope and the absolute level of sensor output. These parameters will be explained in this section. The computer code, reference 15, that defines these functions can be found in the section of code titled THSLOPE.C – Threshold/Slope.

From the ACES Algorithm Menu, figure 3-22, the user selects "Threshold/Slope," "Default" and "Y" (yes) to bring the user to the Threshold/Slope Menu #1, figure 3-25.

Figure 3-25. ACES Threshold/Slope Menu #1

This is the first of three menus that allows the user to define the alerting parameters for the three sensors. The first task requires that the user have a file of sensor data to run through the algorithm. This file is input on the first line of the menu. In the example shown in figure 3-25 this file name is v1.dat. The next four lines of this menu allow the user to input maximum and minimum values for both the threshold and slope parameters. The relationship of these values is shown in figure 3-26, ACES Alert Parameters, and explained in the following paragraphs.
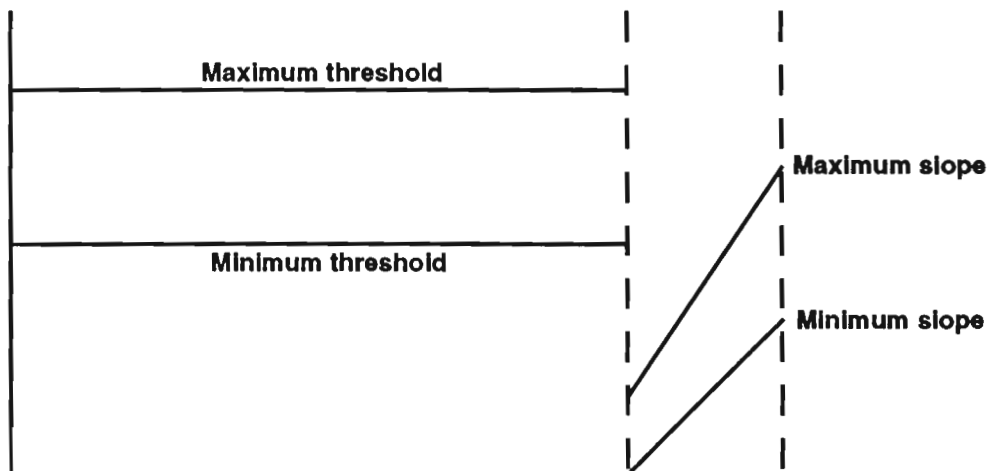

Figure 3-26. ACES Alert Parameters.

The second line of the menu prompts the user to input a "Maximum Threshold" (designated Alert in the code). In figure 3-25 this value is 7.90. A sensor voltage output above 7.90 will place that sensor, but not necessarily the system, in alarm condition. The maximum threshold value needs to be appropriate for the sensor being evaluated, as the output characteristics for each sensor type are different. The third line in the menu prompts for "Minimum Threshold" (AlertMin in the code). A value of 7.25 is shown in figure 3-25. Above this value, coupled with other criteria being met, the system can be declared in alarm mode and a alert message be sent to the flight deck.

Slope definition is initially somewhat cumbersome, but after using the system for a short period this becomes easy. The slope value is equal to the tangent of the angle divided by ten (slope value = Tan Ø/10). This relationship is shown in figure 3-27. When the sensor slope exceeds the input for the maximum slope (designated SlopeAlert in the code), the sensor, but not necessarily the system, will be declared in alert mode. When **both** the minimum slope parameter (SlopeAlertMin in the code) and the minimum threshold is exceeded, the system is placed in the alarm mode.
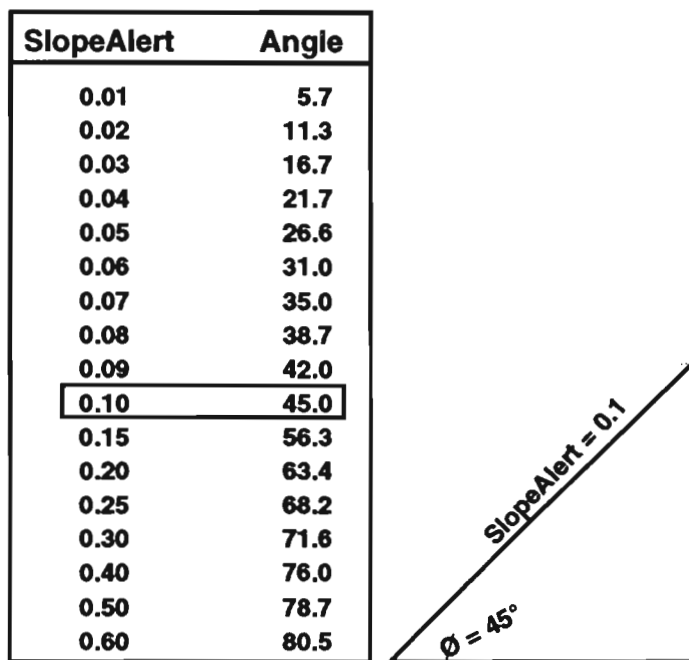
SlopeAlert	Angle
0.01	5.7
0.02	11.3
0.03	16.7
0.04	21.7
0.05	26.6
0.06	31.0
0.07	35.0
0.08	38.7
0.09	42.0
0.10	45.0
0.15	56.3
0.20	63.4
0.25	68.2
0.30	71.6
0.40	76.0
0.50	78.7
0.60	80.5

Figure 3-27. SlopeAlert Definition.

The final two inputs to Menu #1 allow the user to control the density and speed at which the data is displayed. "Number of Data Points: 50, 100, 200" allows the user to spread the data at 50 points per page or compact it to 200 points per page. "Graphing Delay" sets the speed at which data is placed on the screen, in data points per second. Note: these values can only be set in Menu #1 and will control the rate and density at which the data defined in Menu #2 and #3 are displayed.

The procedure of inputting a file name and the four alerting parameters is repeated for Threshold/Sensor Menu #2 (figure 3-28) and Threshold/Sensor Menu #3 (figure 3-29). In this manner three data files and three sets of algorithm parameters can be identified. It is not required to identify three files. The algorithm can be run using one or two data sets. (Note: the algorithms were developed with the assumption that data set number three, as defined by Threshold/Sensor Menu #3, would be thermal data, and as such the algorithm looks at this data set differently. These differences will be identified below.)

```
┌─────────────────────────────────────────────────┐
│  Aircraft Command in Emergency Situations (ACES) │
└─────────────────────────────────────────────────┘

                Threshold/Slope Menu #2

Sensor Data File 2    v2.dat
Maximum Threshold:   6.80
Minimum Threshold:   6.45
Maximum Slope    0.18
Minimum Slope    0.12
 Are your selections correct?    Y    N




<space>.           next choice
<enter>            select current choice
<up/down arrow>    line up/line down
<ctrl A>           advance to next menu
<ctrl F>           save current settings, resume
<ctrl B>           back to previous menu
<ctrl G>           skip to EICAS display
<ctrl Q>           exit
```

Figure 3-28. ACES Threshold/Slope Menu #2.

```
┌─────────────────────────────────────────────────┐
│  Aircraft Command in Emergency Situations (ACES) │
└─────────────────────────────────────────────────┘

                Threshold/Slope Menu #3

Sensor Data File 3:   v3.dat
Maximum Threshold:   7.00
Minimum Threshold:   5.50
Maximum Slope:   0.16
Minimum Slope    0.10
 Are your selections correct?    Y    N




<space>.           next choice
<enter>            select current choice
<up/down arrow>:   line up/line down
<ctrl A>:          advance to next menu
<ctrl F>.          save current settings; resume
<ctrl B>.          back to previous menu
<ctrl G>:          skip to EICAS display
<ctrl Q>:          exit
```

Figure 3-29. ACES Threshold/Slope Menu #3.

The logic making use of these inputs is shown below, [j] counts data points and [jrep] tracks the data files. As such, [jrep] can have a value of between one and three, one being the data from Menu #1, two one being the data from Menu #2, and three being the data from Menu #3. The data from each file (sensor) are evaluated to determine if any of several alerting criteia, for the individual sensor, has been met. The sensor alerting criteria is shown below:

(Data[jrep][j] > Alert[jrep]) Data value is greater than the maximum threshold;

OR

(Slope[jrep] > SlopeAlert[jrep]) Slope of sensor curve is greater than the maximum slope;

OR

(Data[jrep][j] > AlertMin[jrep] Data value is greater than minimum threshold;

AND

Slope[jrep] > SlopeAlertMin[jrep]) Slope of sensor output is greater than minimum slope;

OR

(Data[jrep] > 1.1*Alert[jrep]) Data value is 10 percent greater than maximum threshold.

Thus an individual sensor can be declared in alert one of three ways. This is shown below for sensor one, as defined in Menu #1, figure 3-25.

(1) Sensor data is above the maximum threshold value (Data[v1][j] > 7.90). This condition is defined as VALUE;

OR

(2) Slope of sensor data is grater than maximum slope (Slope[v1] > 0.20). This condition is defined as SLOPE;

OR

(3) Minimum threshold value is exceeded (Data[v1][j] > 7.25),

AND

Minimum slope value is exceeded (Slope[v1] > 0.11). This combined condition is defined as SLOPE_VALUE.

In addition the sensor can be placed in a High mode of alert. This criteria is met when Data[v1] are greater than 1.1 times 7.90. A sensor in this condition is defined as HIGH. In the lab an increase 1.1 times (or 10 percent) above the value defined by maximum threshold was not uncommon. Therefore based on engineering judgement as well as experience gained in the lab a factor of 1.1 times the maximum threshold level was deemed appropiate.

In addition to each sensor being evaluated for it's alert condition, the three sensors together are evaluated before the criteria for alerting the flight deck is satisfied.

It is at this stage that the assumption that the sensor defined in Menu #3 is a thermal sensor comes into play. This distinction will be identified below in defining the six sensor configurations that can result in an alert signal being sent to the flight deck.

(1) All three sensors are greater than or equal to their maximum threshold value (sensor condition is defined as VALUE).

(2) One sensor is greater than or equal to it s maximum threshold (VALUE) and one sensor is greater than or equal to it's maximum slope (sensor condition is defined as SLOPE).

(3) One of the smoke sensors (defined in Menus #1 or #2) must be greater than or equal to maximum threshold (VALUE) and the thermal sensor (defined in Menu #3) is greater than or equal to minimum threshold and minimum slope (SLOPE_VALUE).

(4) All three sensors have exceeded both their minimum threshold and their minimum slope (SLOPE_VALUE).

(5) The thermal sensor (defined in Menu #3) is greater than or equal to maximum threshold times 1.1 (condition defined as HIGH).

(6) Both sensors defined in MENU #1 and #2 (smoke sensors) are both greater than or equal to Maximum Threshold times 1.1 (HIGH).

ACES Threshold/Slope Plot (figure 3-30), shows how an alert event is displayed. The various lines will be explained starting at the top and working down. The top line (green) is the top of the grid and represents 10V. The next three lines (red) indicated if the sensors defined in Menus #3, #2, and #1 respectfully, are in a condition of alert. If the line has ramped up by an amount equivalent to 0.2V, that indicates an alert condition. Next comes the lines that define the maximum (cyan) and minimum (green) thresholds. On the right fifth of the plot is the area showing the maximum (cyan) and minimum (green) slopes. The curved lines are the three sets of sensor data from the files v1, v2 and v3.dat. The yellow line indicates the status of the three sensors as a group. The ramping up of this line indicates that the criteria to initiate an alert being sent to the flight deck has been met.

Below the graph is the status of each of the three sensors. If the sensor is in a normal condition the status would read "OK." Otherwise the status displayed corresponds to the four conditions - "VALUE," "SLOPE," "SLOPE_VALUE," and "HIGH," as defined previously in this section.

The next line on the graph gives the number of data points to be displayed per page, as defined in Menu #1. This is followed by the number of pages required to display the data. In this example two page are necessary. The last line shown in figure 3-30 has the same function as defined in table 3-7.

In the example shown the criterion that initiated the alarm is the sensor defined in Menu #3 (the thermal sensor) which has a status of HIGH. This means that the sensor's output value has exceed its maximum threshold times a factor of 1.1. In this example that is 7.0*1.1, or 7.7V.

Status 1 = VALUE
Status 2 = HIGH
Status 3 = HIGH

Solid line is file 'v1.dat'
Medium dotted line is file 'v2.dat'
Fine dotted line is file 'v3.dat'

200 Points Per Page
Page 1 of 2
CTRL_S: stop   <any key>: continue   CTRL_B: back a page   CTRL_Q: quit
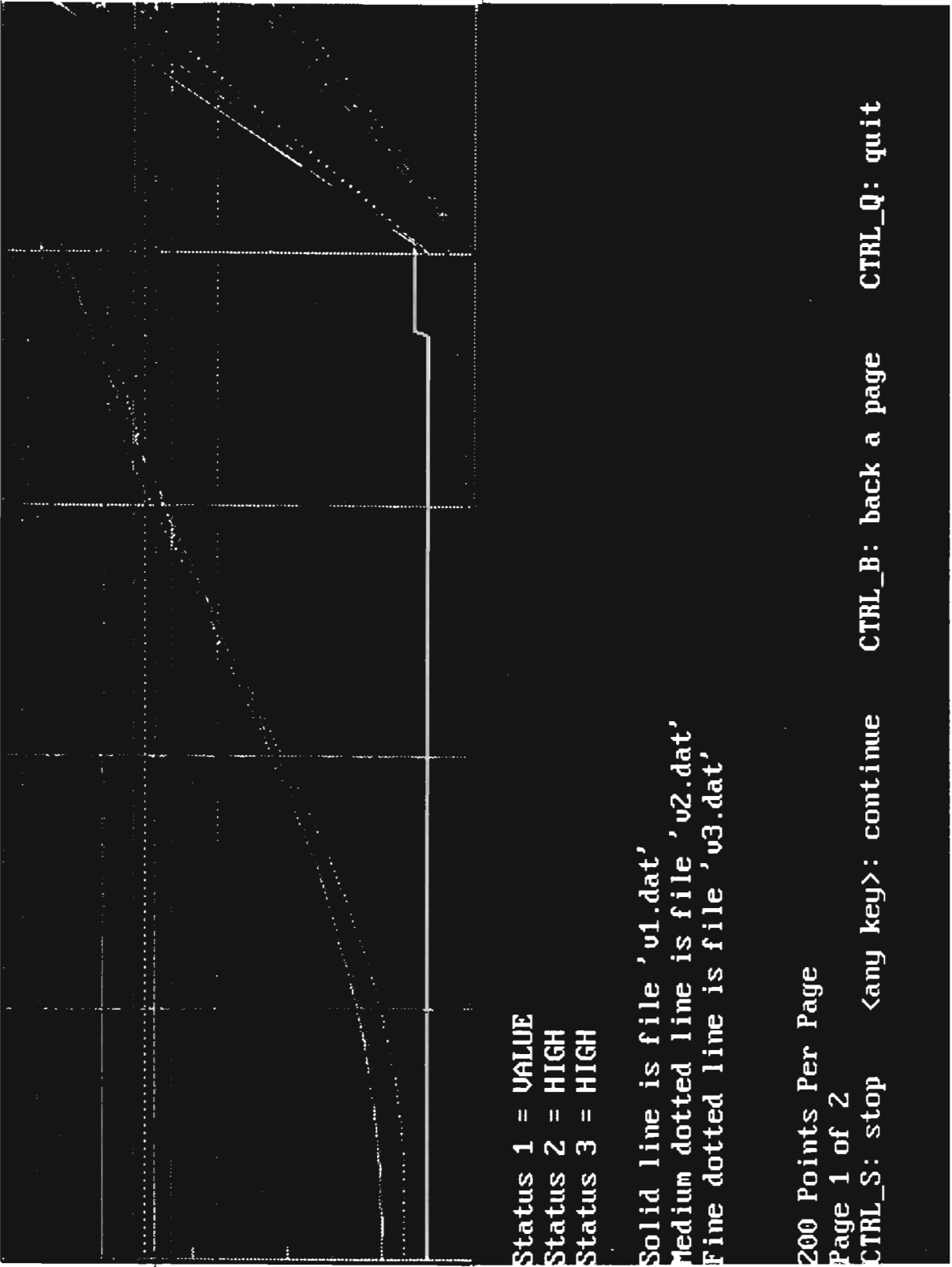
Figure 3-30. ACES Threshold/Slope Plot.

3.4 YORK DATA SYSTEM OPERATION.

A major disappointment in the ACES program was an inability to link the York DTS2 system into the Dolch/ Keithley system. As a result, thermal data can not be routed from the DTS to the Dolch for data storage and retrieval for use in the Alert Algorithm (section 3.3). Two major avenues were explored to find a means to accomplish this link, and both are discussed below.

The ACES team had hoped to divorce the DTS2 from it's HP operating system and run the DTS output directly to the Keithley or the Dolch. The York DTS unit is connected to the HP operating system via a IEEE type cable (see figure 2-15 for York hardware connections). It was hoped that this cable would enable the DTS output to be routed directly to the Dolch, and the necessary data processing could be performed internal to the Dolch. Upon discussions with York this option was found **not** to be possible, as significant data processing takes place within the HP and the task to transfer this capability to the Dolch, even if possible, would require resources beyond the scope of this project.

The second option explored was to link the HP control system into the Dolch/Keithley. Such a configuration would allow the processing to be done by the HP and then feed the post-processor data to the Dolch. This was envisioned to be possible by routing the HP output, via IEEE cable, to the Dolch. This method may be a viable option. However, differences in sampling rate (4 times per second (maximum) versus once every 6 seconds for the York), starting and ending data collection at the same time, and language difficulties between the HP and the Dolch introduced difficulties of a magnitude that the ACES team was unable to surmount.

Due to the lack of a link with the York system, ACES consists of two major component groups – the Keithley/ Dolch and the York DTS2. The following sections of 3.4 will detail the operation of the York system.

3.4.1   York System Software Configuration.

From the discussion in section 2.5.6 the York hardware components should be correctly connected and the DTS box ready to be powered up. Before turning the unit on however, open the front panel of the DTS box, accessible by turning the keyed latch located on the left-hand side of the front panel. Upon power up four LED lamps, located on the forward upper quadrant of the two left most cards internal to the DTS box, will illuminate. The LEDs will extinguish when the system has warmed up. Experience has shown that the system will continue to stabilize even after the lamps have gone off. A warm up period of about an hour is suggested before thermal testing is begun. When testing was being done on an every day basis in the ACES lab the DTS was powered up and left that way for days at a time so testing could commence when the user was ready, rather than wait for system warm-up and stabilization.

With the unit warmed up the next procedure is to load the software that drives this system. To do this it is necessary to load four disks: Basic System, DTS_1, DTS_2, and 23 Zone Parameter File. The steps involved in this process are outlined below.

Insert the disk titled; "BASIC SYSTEM" into Drive 1 of the HP9122 dual disk drive. Switch on (power up) the HP9122, the HP300, and the screen. When soft keys appear at the bottom of the HP screen, the disk will have stopped being addressed and the basic system disk can be ejected from the drive.

Next insert the disk labeled "DTS_1" into Drive 1 and the disk labeled "DTS_2" into Drive 0 of the HP 9122. This will be the users introduction to the system's less than user friendly command structure. The commands must be input as shown; with all the colons, comas, and quotes. Using the HP keyboard type the following:

> LOAD"DTS_1:,700,1" <ENTER>
> LOADSUB ALL FROM "DTS_2:,700,0" <ENTER>
> SET TIME TIME ("10:30:00") <ENTER>
> SET TIMEDATE DATE ("day:month:year") <ENTER> [e.g., ("18:Feb:1994")]
> INITIALIZE":MEMORY,0,0",1000 <ENTER>

To verify that a memory location has been allocated type:

> CAT":MEMORY,0,0" <ENTER>

This command will cause the header created for this address to be displayed on the screen. This serves to confirm that a memory location has been allocated.

Remove the two disks from the drives and insert the disk labeled "23 Zone Parameter File" into Drive 1. It is this disk that contains the software to divide the test, stainless steel clad, portion of the fiber optic cable into 23 measurement zones. Upon inserting this disk press:

> RUN (Refer to figure 2-17 for key location)

Several messages will be momentarily displayed indicating that the parameter files are being loaded. When loading is complete, the user will be in the DTS2 designed operating system. The blue rectangles at the bottom of the screen refer to the keys in the upper left corner of the HP keyboard (Key Group One in figure 2-17). These are referred to as the "softkeys."

At this stage the softkeys present the user with three options: CHECK, DEFINE, and MEASURE. CHECK allows the user to insure that the optic fiber has been connected in an optimum manner, DEFINE enables the user to define parameter elements, and MEASURE initiates the system to begin temperature data recording. Each of these three options will be dealt with below under a separate heading .

3.4.1.1   Check Mode.

This mode of operation is detailed in reference 14, section 6.2.1. An outline of this function is given in this section.

The CHECK mode is used primarily to determine if the connection between the two ends of the fiber optic cable and the DTS2 unit is a good one. With "CHECK" selected, the signal trace from the cable is displayed. FIBER 1 is the **only** display option that will show a screen trace. A good connection is evident by the screen trace looking similar to that shown in figure 3-31.
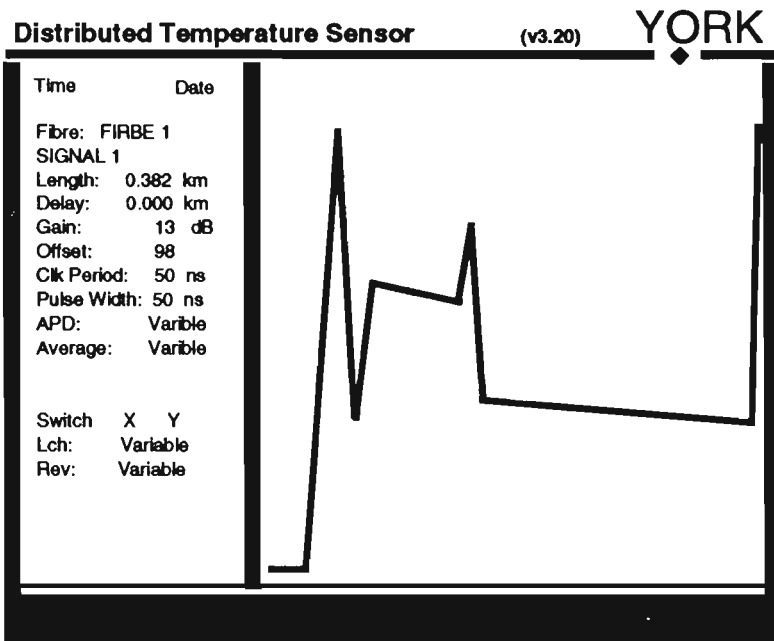
Figure 3-31. York Screen Trace.

If the trace does not look similar to that shown in the above figure, "playing" with the DTS/cable connection should enable the user to improve the connection, so that the trace takes the form as shown.

Selecting <RETURN> softkey k4 moves the user back up a menu level to CHECK/DEFINE/MEASURE.

3.4.1.2   Define Mode.

The DEFINE mode is detailed in section 6.2.3 of reference 14. An outline of this mode is given below.

The "23 Zone Parameter File" that has been loaded on to the HP (section 3.4.1) can be redefined by using the following key strokes, starting at the CHECK/DEFINE/MEASURE menu:

> <DEFINE> (k1)

This places the user in the first level of the DEFINE mode menus. The next three keystrokes brings the user to the zone definition menu.

> <SELECT FIBER> (k5)
> <FIBER 1> (k5)
> <DEFINE ZONES> (k5)

At this stage the user has the option of making changes to certain of the elements listed in the parameter file. These elements are shown below, using Zone_1 as the example.

Zone Name	Zone_1	
Start	.133	(for Zone_1)
End	.139	(for Zone_1)
Nom	70.0	Nominal temperature
Max	80.0	Maximum Temperature Alarm Point
Min	60.0	Minimum Temperature Alarm Point
Log	(this line is intentionally blank)	
Int'vl	0.1	Data Sampling Rate, Minutes
Dur'n	0.5	Sampling Duration, Hour

The Start and End parameters for each zone **should not** be changed as these values define the fiber length for the zone. These values were defined by York to optimize the DTS unit and the type of cable being used. Again, these values should not be altered.

The three temperatures – Nom, Max, Min, – can be configured to reflect the environment in which the cable is installed. The temperature of greatest interest is Max, which sets the Maximum temperature alarm point. This feature allows different zones of the cable to be set to alarm at different temperature threshold points. This allows multiple areas with widely varying thermal environments to be monitored by a single cable.

The sampling rate and duration can be set for all 23 zones at once, rather than inputing these two values for each individual zone. This method is detailed below.

At this point the documentation provided in reference 14, York DTS II Operators Manual, and the actual operation of the system diverges. The user should select:

<KEY SET #2> (k2)

Followed by:

<LOG ALL ON> (k2)

and

<FILL & QUIT> (k9)

These keystrokes will prompt for two inputs. These prompts will appear in the red region of the screen. The first prompt will read as follows:

Enter time interval, minute: (e.g., 0.1) <ENTER>

This is the interval at which the fiber will be pulsed. Given the fiber length and system characteristics the interval of once every 0.1 minutes (6 seconds) was found by York to be optimum.

Enter duration, up to 1 hr, hour: (e.g., 0.5) <ENTER>

This instructs the system that the test is to run for 0.5 hours. Note: maximum allowable entry is 1.0, that is the maximum test duration is one hour.

With the above keystrokes and inputs the user has defined the test interval and duration for all 23 zones. To return to an upper level menu, the user must "step" up through the layers. This is done by pressing <RETURN> (k4). On the way up through the menu layers the user must input the location to which the data will be stored. This is reflected by the use of the <OTHER> selection and typing MEMORY,0,0; this is reflected by the following keystrokes:

> <RETURN> (k4)
> <RETURN> (k4)
> <OTHER> (k7) Type: MEMORY,0,0 <ENTER>

This last line refers to the memory location first initialized and verified in section 3.4.1. Following this input, press:

> <RETURN> (k4)
> <RETURN> (k4)

And finally:

> <EXIT> (k4)

This last keystroke brings the user out of the DEFINE mode to the top level CHECK/DEFINE/MEASURE menu.

The systems health has been confirmed (CHECK), the alarm and run time parameters have been set (DEFINE). Testing can now be initiated. This is the MEASURE mode, will be explained in the next section.

3.4.1.3   Measure Mode.

With the user at the top level CHECK/DEFINE/MEASURE menu, pushing <MEASURE> softkey k5 results in the beginning of the temperature measurement cycle. This mode of operation is detailed in reference 14, section 6.2.2. An outline of this function is given below.

When k5 is pushed, the system begins data collection, display, and storage. Data, in numerical form, for each of the 23 zones are displayed in the column to the left of the graph. The graph displays cable length, X axis, versus temperature Y axis. The section of cable to be viewed is controlled by the user, through functions detailed in the paragraphs below.

The user has access to a cursor function that enables the user to bound a section of the trace for enhanced display. A box construction function is accessed through the selection of <WINDOW> softkey k0. The section of fiber of most interest is from 0.133 to 0.250, the stainless steel portion of the cable. Using the cursor function, place the cursor at location 0.133 and move to the <WINDOW> menu. Use the position of the cursor to construct the left margin of the box by pushing the left/bottom key (k5). Push <RETURN> (k4) to move up to the previous softkey set which includes the cursor function. Reposition the cursor at 0.250 and again select <WINDOW> (k0). Now use the cursor to establish the right margin of the box by pushing the right/top key (k6). The user can now build the top and bottom of the box in a similar manner. Select the <WINDOW> menu (k0), press the appropriate margin menu key (bottom = k5, top = k6), and while holding down the shift key, move the cursor to the appropriate location/value. After completing top and bottom margins, the section of trace to be examined is bounded; exercising <DISPLAY BOX> (k9) will cause the box to occupy the entire graphic portion of the screen. The softkeys k3 and k8, <FULL WINDOW> and <DEFAULT WINDOW> respectively, enable the user to move quickly between these two display options.

Moving back up a "menu," <RETURN> (k4), allows the user to silence the buzzer. The buzzer sounds each time an alarm point, as set in Section 3.4.1.2, is exceeded. The buzzer can be toggled off with the <BUZZER OFF> (k3) feature.

Located in the same key set group as <BUZZER OFF> is <KEY SET #2> (k6). Activating this function and the <VIEW LOG ZONE> (k6) function on the next level allows the user to view any one of the 23 zones of data. The data when viewed in this manner is presented with time as the X axis and temperature as the Y axis. Viewing the data in this manner smooths out the "jumpiness" that is evident when viewing all 23 zones at once.

While still at the <VIEW LOG ZONE> level, the user can determine if data is still being logged or if the run is complete. The following message will appear in red in the lower section of the screen:

> "Number of zones currently logging from this fiber loop=X"
> If X=0 the run has been completed.
> If X=23 data is still being collected.

Assuming that the run has been completed, then with the user at the <VIEW LOG ZONE> level, the following key strokes will bring the user back up to the top level MEASURE menu:

> <RETURN> (k4)
> <RETURN> (k4)

If the measurement cycle has not been completed the user can terminate the test run by:

> <ABORT> (k4)

The user will then be asked to confirm this decision

> <YES> (k5)

Selecting <YES> will halt the test run. A short wait may occur as the final measurement cycle is concluded.

With the test run terminated, either by Abort or end of test duration, the data is stored in memory and should be moved to disk for safe keeping. This can be done by placing a disk in Drive 0 and typing:

> COPY"MEMORY,0,0" TO ":,700,0" <ENTER>

The data has now been transferred to disk. This disk should be marked to reflect the test parameters and to facilitate retrieval of the data at a future date.

At a later date if the test data needs to be reviewed the user can do so via the READ_DATA function. This function will be explained in the next section.

3.4.1.4   Viewing the Collected Data.

The collected data can be displayed as Distance vs Temperature vs Time using the display program titled READ_DATA. To use the program READ_DATA, first press:

> PAUSE located in the middle column of button directly above the RUN button, see figure 2-17.

Insert the disk READ_DATA into Drive 0 and load the program by typing the following:

> LOAD"READ_DATA:,700,0" <ENTER>

At this point, if the computer has not been turned off the test data will be stored in the HP's internal memory and the program can be run to display the data. The program is run by pressing the RUN key, see figure 2-17.

If the data is not in memory then the READ_DATA program must be edited to read the data from disk. To edit the program the user will make use of the function keys designated Key group four in figure 2-17. To access the program for editing, the program must first be run. This is done by pressing the RUN key. Pressing the ALPHA key will clear the screen of any graphics that may be on the screen. Pressing the Edit key, located in Key group four will place the user in the edit mode. Move to the line of code to be changed and edit that line and press the EXECUTE key located in the same key block as the RUN key. Continue this process of moving to a line, editing the line, and pressing EXECUTE. When all the changes have been made, pressing RUN will cause the edited READ_DATA program to be run and the data displayed. Note: The EXECUTE key must be pushed for **each** line of code changed.

Place the disk containing the data set in Drive 1, and edit the program to reflect the data location. To do this, edit line 110 which reads, by default, as follows:

        110   Msus$=":MEMORY,0,0"

To reflect that the data is in memory.

If the data is to be read from Drive 1, this line must be changed to read:

        110   Msus$=":,700,1"

This change will cause the program to look to Drive 1 for the data file.

Regardless of where the data is located the program may need to be edited to customize it to the measured data. The number of measurements made for each zone needs to be entered into line 180. The line reads as follows:

        180   N_pts=36 !Number of measurements made on each Zone

This number should reflect the length of the test, in minutes, times six (each zone is sampled six times a minute). Therefore the value to input for a 30 minute test would be N_pts=180.

The READ_DATA program can now be run, the result of which will be displayed on the screen. In the lab a pin plotter was available to plot the results. To enable the plotter, function line 800 of the program must be edited. The line reads as follows:

        800 ! Plotter is 705, "HPGL"

Removal of the comment flag (!) will allow the data to be routed to the plotter.

3.4.1.5   Making Another Data Run.

When wanting to make a second run of measurements **AND** the computer has not been turned off, the procedure is as follows:

        Insert DTS_1 into Drive 1
        Insert DTS_2 into Drive 0

Type:

        LOAD"DTS_1:,700,1" <ENTER>
        LOADSUB ALL FROM "DTS_2:,700,0" <ENTER>

Re-initialize the memory, by typing:

INITIALIZE":MEMORY,0,0" <ENTER>

This action will cause the data residing in memory to be written over. It is imperative that the user is aware of this and if the data in memory is wanted for future use it **MUST** be copied to disk.

Inset the disk marked "23 Zone Parameter File" into Drive 1 and press:

RUN (Refer to figure 2-17 for key location)

The measurement cycle can now be initiated by pressing <MEASURE>, softkey (k5).

If the computer has been turned off between data runs then the procedures outlined in this entire section need to be followed. This entails booting the system with the Basic System disk, setting time and date, as well as loading the 23 Zone Parameter File.

4.   SUMMATION.

This users guide is intended to escort the user through both System Setup and the three functions of System Operation: flight deck demonstration, alerting algorithms and data collection. This manual cannot begin to answer all the questions nor provide complete instruction on every keystroke encompassed in operating the ACES system. It is, however, hoped that with this manual along with time spent using the system, the reader will quickly feel comfortably operating ACES in all its configurations.

5.   REFERENCES.

1   Reynolds, T.L., et al. "Aircraft Command in Emergency Situations (ACES) Phase 1: Concept Development," DOT/FAA/CT-90/21. April 1991.

2   Blomberg R.D., et al. (Dunlap and Associates), Technology Assessment for Aircraft Command in Emergency Situations," DOT/FAA/CT-87/20. October 1988.

3   Hughes Associates, "Integrated Fuselage Fire Detection and Monitoring System," DTRS 57-87-C-00093, September 3, 1988.

4   Dolch Operators Manual - delivered to FAATC September 23, 1993.

5   Getting Started with Your GPIB-PCII/IIA and the NI-4882 MS-DOC Handler, February 1991 Edition, Part Number 320320-01, delivered to FAATC March 7, 1994.

6   Universal Language Interface Using HP-Stype Calls, July 1991 Edition, Part Number 32-135-90, delivered to FAATC March 7, 1994.

7   Using Your GPIB Software with Microsoft Windows, February 1991 Edition, Part Number 320319-01, delivered to FAATC March 7, 1994.

8   NI-488.2 MS-DOS Software Reference Manual, August 1991 Edition, Part Number 320282-01, delivered to FAATC March 7, 1994.

9   Reference, Microsoft C, Version 6.0 for MS OS/2 and MS-DOS Operation Systems, 1990, delivered to FAATC February 22, 1994.

10   Installing and Using the Professional Development Sytstem, Microsoft C, Version 6.0 for MS OS/2 and MS-DOS Operation Systems, 1990, delivered to FAATC February 22, 1994

11   Advanced Programming Techniques Microsoft C, Version 6.0 for MS OS/2 and MS-DOS Operating Systems, 1990, delivered to FAATC February 22, 1994.

12   Keithley Model 576 High Speed Data Logging System , Document Number 576-901-01 Rev B, October 1990, delivered to FAATC September 23, 1993

13   Sensor Vendor Documentation, delivered to FAATC September 23, 1993.

14   York V.S.O.P. (Ventures and Special Optical Products) DTS II Operators Manual, Issue 3, September 29, 1989, System Manual - delivered to FAATC September 23,1993.