PART D — SPECIAL CONSIDERATIONS

CHAPTER I

INVESTIGATION EQUIPMENT

The diversity of aircraft accidents the investigator covers makes it impossible always to have available all the necessary equipment. Certain things needed during every investigation should be kept in readiness.

Proper clothing should be the first consideration; good serviceable clothing capable of rough usage is recommended. Selection should be based on the climatic conditions apt to be encountered. Give special consideration to footwear, for walking over rough terrain in dress shoes is most unpleasant.

The equipment carried should be sufficient for wreckage examination, the plotting of impact points and wreckage pattern, parts identification, and the recording of observations. Some of the items to include are:

1. Photographic equipment
2. A good magnetic compass
3. Flashlight
4. Work gloves
5. Hand tools (screwdrivers, pliers, adjustable wrench, etc.)
6. Magnifying glass (10X or stronger)
7. Marking pens and grease pencils
8. Steel tape measure
9. Knife
10. Note pad, clipboard and paper
11. Accident report forms
12. Other related forms (wreckage release, TR's, Form 44, etc.)
13. Parts tags with string or wire
14. Plastic bags
15. First aid kit

Accidents occurring in remote areas require special consideration for shelter, and for weighty items such as food and water, which increase the difficulty of transportation to the site. In the event part or all of the wreckage must be moved to another location, make arrangements for the necessary equipment and assistance before leaving for the accident site.

Remember, the investigator's kit has to be carried: Do not overload it with unnecessary or duplicate items. Many improvisations can be made in the field.

Part D — SPECIAL CONSIDERATIONS

Chapter II

PHOTOGRAPHY IN ACCIDENT INVESTIGATION

1. Photography as a Tool in Accident Investigation

Photography is a useful tool in accident investigation. A good photograph used properly can be worth a thousand words. Photographs should not be used in lieu of a written report, but should supplement it. Pictures accompanying the report should be selected with care and each should tell a definite story. There is a tendency for investigators to take pictures indiscriminately, and to enclose unnecessary photographs in the investigation report. Photographic documentation should permit the person reviewing and evaluating the report to understand the significance of the investigator's findings.

Photographs also help to refresh the memory of the investigator if there is a delay in writing the report, or if there is subsequent legal action.

1.1. Planning in Accident Photography

Random picture taking is very likely to be a waste of time, money, and effort. Photographs should be taken as soon as possible after the accident occurs and before the wreckage is moved or disturbed. Photographs may have to be obtained from the press or local authorities who were present before and during rescue operations.

In a number of instances private parties have taken pictures during the accident. These may be either still or motion pictures. There have been cases of passengers in the aircraft taking photographs of fires and other aircraft damage. All of these sources should be checked.

Identification of the significant items should show in the picture. Mark the item or write a descriptive caption on a piece of paper and position it to show in the picture. One very simple means of doing this is to use a stenographer note pad and a grease pencil.

1.2. Composition of Subject

A little care and thought in the composition of the photograph can make a tremendous difference in the final result. When the dimensions are not commonly known, some means should be used to give the viewer an idea of the size of an object. This can be done by including an object of known dimensions in the picture, or by a scale or rule.

Distracting or irrelevant items should be eliminated from the scene. Proper setting of the camera can throw unwanted items out of focus. The photographed item should fill the entire picture. Random shooting and improper distance from the subject can result in a meaningless picture.

1.3. Terrain Pictures

Pictures of the wreckage area should show the type of terrain, general wreckage pattern, and objects struck prior to impact. These, with pictures of point of first impact, gouges, scars, and the impact crater, clarify the investigation report.

1.4. Wreckage Photography

The photographer should take general wreckage pictures the same distance from the wreckage for different angle shots to keep perspective. For instance, shots from the north should be the same distance from the wreckage as those from the east, south, and west. After the general or overall pictures are taken, the major components and suspect areas should be carefully photographed.

It is good practice to have something in the picture that will prevent reverse printing of the picture. It could be very embarrassing to document a control tab position and have the picture reversed, with no way to prove which is the correct position. A caption guards against this.

Fire damage and evidence of ground and/or inflight fire usually can be documented very well with pictures. The pictures would show sagging or dripping metal, and soot patterns. This may require very careful photography to present a clear picture of the evidence available. Good color photographs can bring out the evidence of fire, particularly where there has been heat discoloration of metals.

Closeup photography can be very helpful in showing types of breaks and damage. A good closeup view of a fatigue area can show the reader exactly how the break occurred. Bending, buckling, tears, direction of rivet shear, and other damage factors, are easily explained in the report through the use of photographs.

Wreckage photographs also should show control positions, tab settings, screwjack positions, etc.; they may be significant to the investigation. It may be desirable in some cases to have an undamaged component beside the damaged items to show the extent of the damage.

1.5. Technical and Professional Assistance in Photography

The field investigator will encounter situations where he is not equipped to take the necessary photographs. In these cases, he can call upon professional sources for help, such as local or military photographers.

When using a photographer be sure to explain what it is you want the photograph to show. If you don't stay with the photographer and assure that he is doing what you want you may find that you have several artistic photographs which do not show what you wanted.

2. Photographic Equipment — Size and Weight Consideration

Many types of cameras are available for accident photography. The average field investigator usually prefers one that is light and compact. The more elaborate equipment is usually too heavy and bulky to carry to the scene of some accidents. When this type of equipment is needed, it is usually preferable to have a professional photographer.

The 35 mm single lens reflex camera with built-in light meter offers many advantages to the accident investigator. This type of camera is compact, the film is light weight, the light meter reads where the camera is pointed and the coverage of the photograph is the same as seen through the view finder. Simple snap on or screw on close up lenses are available to give the capability of on the scene close ups when needed.

A small lightweight flash unit will provide the capability of picture taking in low light conditions. A rechargeable strobe unit eliminates the need to carry extra flash bulbs.

2.1. Importance of Knowing the Equipment

It makes very little difference how good the equipment is if the operator does not understand how to use it. The best way to learn to use a piece of equipment is by practice and experimentation. While experimenting with the camera and equipment, the settings used for each exposure should be written down, and results compared after the film is processed.

By learning what the results are under varying settings the investigator will be able to make adjustments to cover the conditions which are likely to be encountered in the field.

3. Exposure

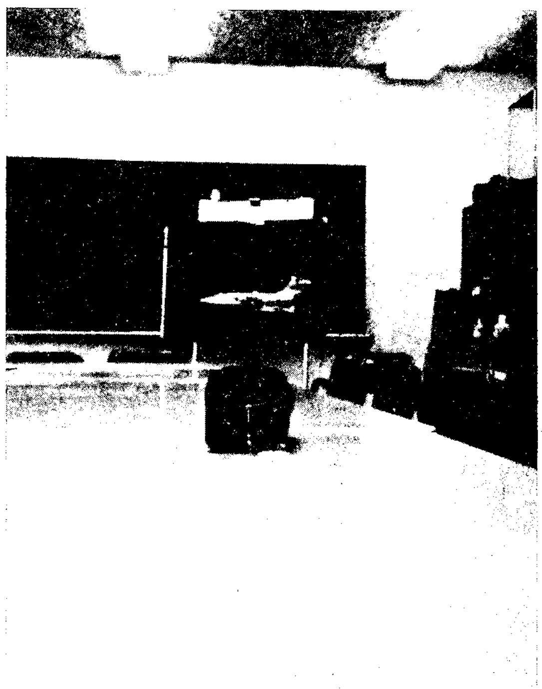
The proper exposure of the film is necessary to obtain the best results in the finished photograph. Exposure is the result of a combination of the light intensity and the time of exposure ($E=IT$). The camera has two adjustments to control exposure. The diaphragm opening controls the intensity of the light reaching the film and the shutter speed controls the length

SHUTTER SPEED AND LENS OPENING EQUIVALENTS OF EXPOSURE-VALUE NUMBERS

Exposure-Value Numbers	f/numbers 2	2.8	4	5.6	8	11	16	22
2	1							
3	1/2	1						
4	1/4	1/2	1					
5	1/8	1/4	1/2	1				
6	1/15	1/8	1/4	1/2	1			
7	1/30	1/15	1/8	1/4	1/2	1		
8	1/60	1/30	1/15	1/8	1/4	1/2	1	
9	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1
10	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2
11	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4
12		1/500	1/250	1/125	1/60	1/30	1/15	1/8
13			1/500	1/250	1/125	1/60	1/30	1/15
14				1/500	1/250	1/125	1/60	1/30
15					1/500	1/250	1/125	1/60
16						1/500	1/250	1/125
17							1/500	1/250
18								1/500

Shutter Speeds

FIGURE D II-1.



F 45 Diaphragm Setting; 1-/8 Second Exposure.

Figure D II-2.

F 5.6 Diaphragm Setting; 1/300 Second Exposure.

Figure D II-3.

of time that the light is allowed to reach the film.

The same exposure value (EV) can result from a large number of combinations of diaphragm opening and shutter speed. See Fig. D II-1.

Although the exposure remains the same, the content of the finished photograph will not be the same. The depth of field (those items in the photograph which are in focus) will vary as the diaphragm opening is changed. See Figs. D II-2 and D II-3. Both of these pictures were made at EV 14. Figure D II-2 was made using a combination of f 45 diaphragm setting and 1/8 second exposure, while Fig. D II-3 was made at f 5.6 and 1/300 of a second. Figure D II-2 has a much greater depth of field due to the smaller diaphragm opening.

Part D — SPECIAL CONSIDERATIONS

Chapter III

RECORDERS AND READOUTS

1. General — History

As early as 1941, the Civil Aeronautics Board and the Civil Aeronautics Administration realized the need for a device to record inflight data which could be used in accident investigation. Attempts were made to put into effect a regulation which would require flight data recorders on certain civil aircraft, particularly those with scheduled passenger flights. Finally, in July 1958, all aircraft over 12,500 lbs. gross weight, operated in air carrier service above 25,000′ altitude, were required to be equipped with a flight recorder.

1.1. Approval Basis

FAA Technical Standard Orders C51 and C51a, *Aircraft Flight Recorders,* specify design requirements for these units. Any recorder approved under TSO-C51 or C51a must measure:

– Time.

– Pressure altitude.

– Vertical acceleration.

– Indicated airspeed.

– Magnetic heading.

These five parameters must be recorded on a medium impervious to deterioration and distortion, usually aluminum, stainless steel, or inconel foil. The units must be capable of withstanding an impact shock of 1000 g's, fire of 1100°C enveloping 50% of the outside area for 30 minutes, plus immersion in sea water for 36 hours. The intelligence on the record medium must be capable of analysis after such exposure. Figure D III-1 shows a functional diagram of a typical flight recorder.

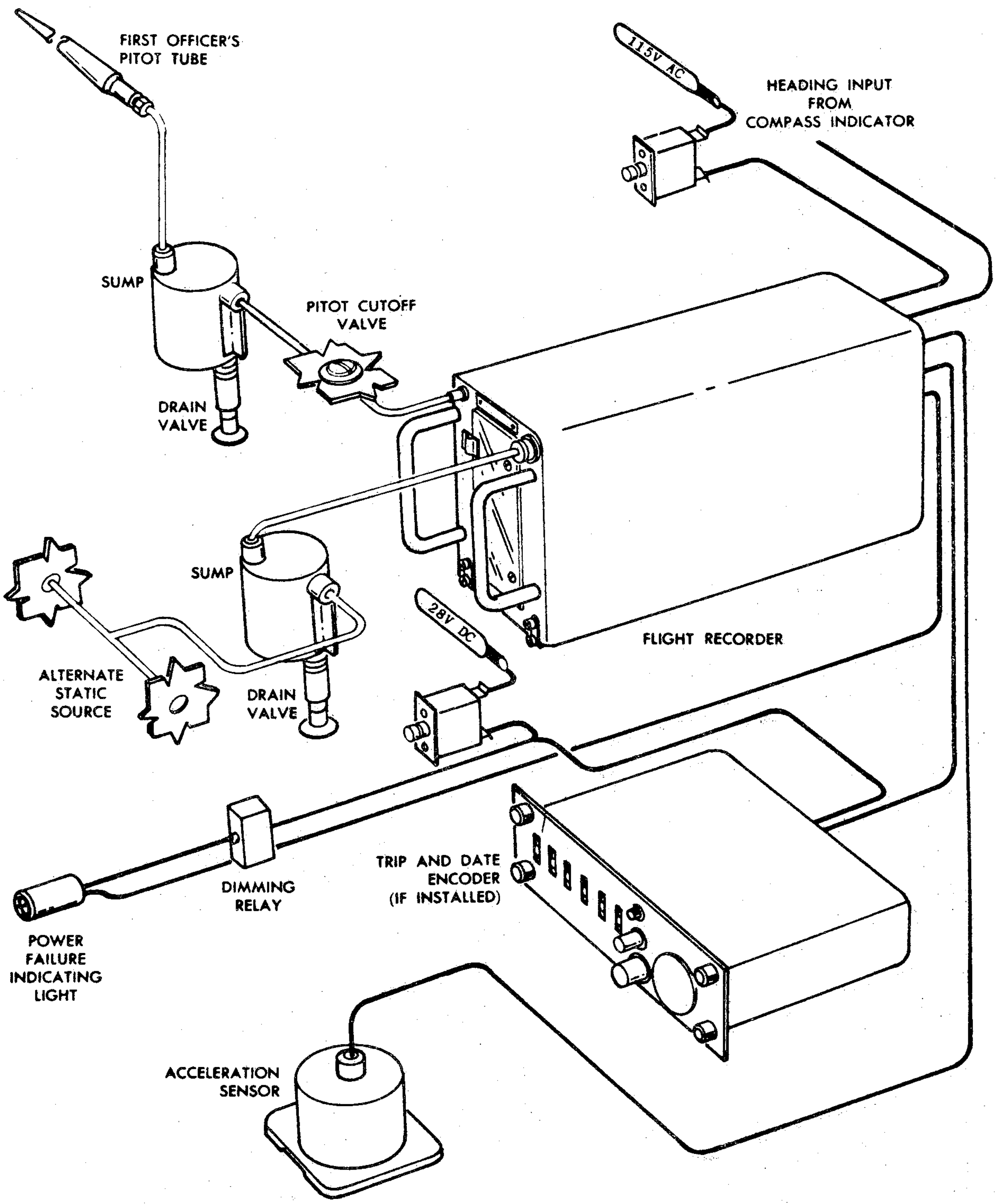
1.2. Recorders Now in Use

Lockheed Aircraft Service — The LAS model 109C/D are manufactured by Special Devices of Lockheed Aircraft Service Company, Ontario, California. The 109C Model is contained in a spherical-shaped case made of two stainless steel shells with a 1″ space between the shells filled with pearlite insulating material. The Model 109D is mounted in a 1/2 ATR size equipment case. The flight record is inscribed on aluminum foil 2¼″ wide, 1 mil thick, fed from a stainless steel spool over a teflon platen onto a takeup spool. **Figure** D III-2 shows a Lockheed Model 109C and D recorder with recovers removed.

Fairchild and United Control Data Division — The Fairchild Model 5424 and the United Control Data Division Model F542 series flight recorders are mounted in a 1/2 ATR size equipment case. The record is engraved on a high-nickel-content stainless steel strip 4.92″ wide and approximately 0.001″ thick, which is capable of sustaining the full accident environment without mechanical, thermal, or other protection. Figure D III-3 shows a Fairchild Model 5424 recorder with dust cover and cassette removed.

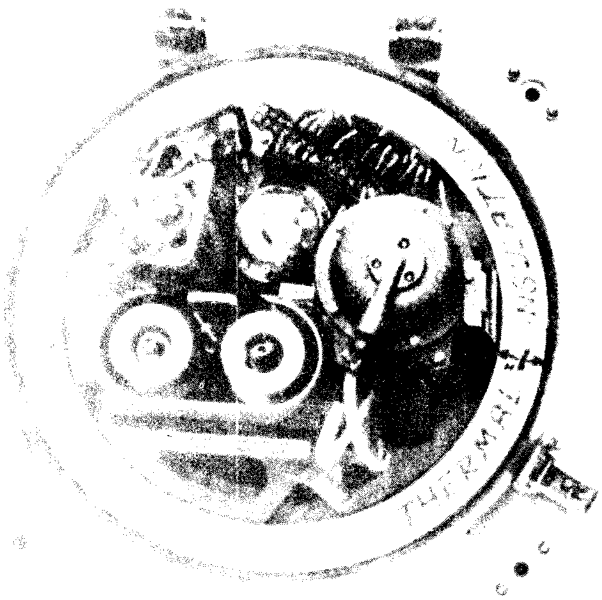
1.3. Flight Data Recorder Operation — General

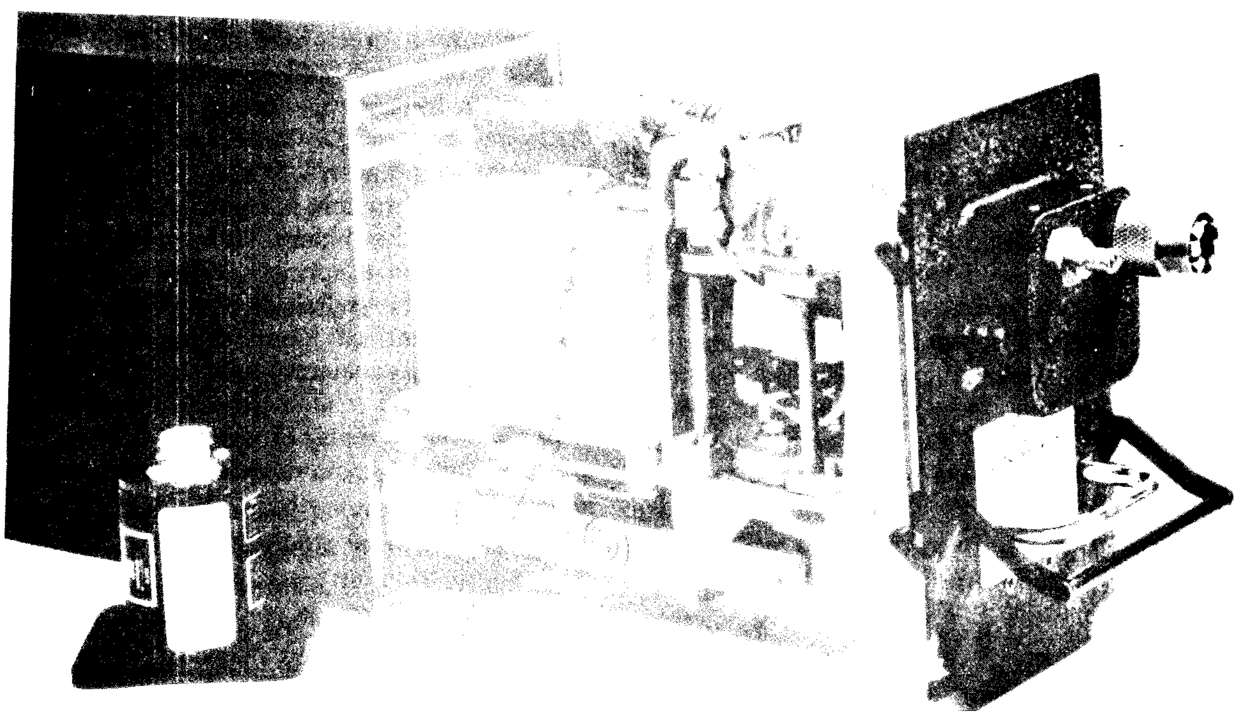
The investigator should understand the basic operation of the recorder and the source of the information provided in the various parameter traces to assist him in the analysis of this information. The flight recorder can be of significant assistance in determining the integrity or lack thereof of the aircraft systems as well as providing a basis for special studies into the aircraft performance capabilities.



Typical Flight Recorder Functional Diagram.

Figure D III-1.





Lockheed Model 109D Recorder. Recorder unit shown partially removed from case.

a. Cassette

Figure D III-2

The investigator should keep one thought in mind at all times when interpreting a flight recorder readout. **THE FLIGHT RECORDER IS NOT ACCURATE.** This is not quite as bad as it sounds, so don't throw up your hands yet. The purpose of this statement is to make the investigator question what he sees on the traces and not attempt to take it as gospel fact. The recorder was never intended to be as accurate as flight test equipment, but was intended to provide a portrayal of trends such as rates of climb or descent, and rates of heading change. The main reason why the recorder cannot be "nit-picked" is best seen by considering the reading accuracy as shown below.

— **Altitude**	±100 ft. to ±700 ft.
— **Airspeed**	±10 knots
— **Heading**	±2 degrees
— **Vertical Acceleration**	±0.2g
— **Time**	±1% in 8 hours

The above values are typical of the flight recorders in use today. The interpretation of the recorded traces will be covered in another section.

1.3.1. Parameter Input Sources

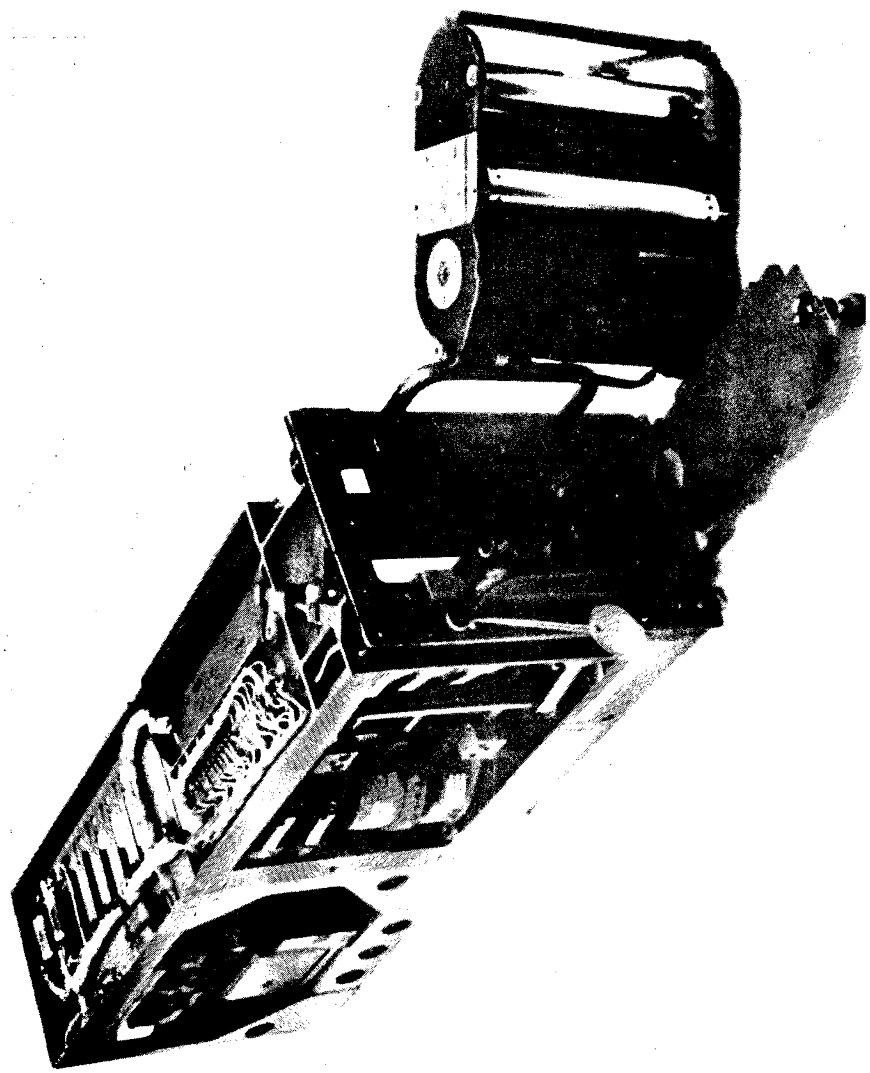
The altitude and airspeed styli are operated by pneumatics and mechanical linkages in much the same manner as the altimeter and airspeed indicators are operated, but the systems are simpler. The source of the pneumatics may be direct from the first officer's pitot head and normal static ports in simpler aircraft, or may come from a separate pitot head and an auxiliary static port in more advanced aircraft. One other method has been approved. This method utilizes the electrical signal outputs from a central air data computer which are fed into servo amplifiers in the recorder. Signals from the servo amplifiers are then utilized to drive the altitude and airspeed styli. At present, only United Air Lines employs this method; however, it may become prevalent with other carriers, and may also be put to use in the design of future flight recorders.

The magnetic heading function receives its intelligence from a synchro transmitter usually located in the first officer's radio magnetic direction indicator (RMDI), thus the source is the No. 2 compass system. Signals from the synchro transmitter are fed into a servo amplifier in the recorder and the amplifier output is used to drive the heading stylus. The heading is provided in a folded scale; i.e., the extremes of stylus movement cover 180 degrees of heading change. Separate indications are provided to permit determination of the proper heading within the extremes as follows:

The Lockheed Aircraft Services (LAS) recorder extremes are 360-180 degrees; therefore, in order to determine the values between, an auxiliary trace is provided by a cam-operated stylus near the top edge of the recording foil. The trace will be present whenever the aircraft heading is easterly between 360-180 degrees, and will be missing whenever the heading is westerly between these extremes.

The United Control Data Division (UCDD) and Fairchild recorders are similar to the LAS recorder in that the heading stylus extremes encompass 180 degrees of heading change. However, the extremes occur at 270-090 degrees and require a north-south indicator. This is supplied by a solenoid-operated stylus which provides a binary type trace. The solenoid is controlled by an ON-OFF switch in the heading servo amplifier. When the heading is southerly, the switch is open, the solenoid is relaxed, and the binary stylus is held at its low position by a spring. When the heading is northerly, the switch is closed, the solenoid is energized, and the binary stylus is raised.

The vertical acceleration or "g" trace is provided through a remote accelerometer located near the aircraft center of gravity. The accelerometer is an induction device utilizing a spring-mounted mass moving in a coil. Initial electrical power to the accelerometer is supplied from the recorder, the up-and-down movement of the mass induces a signal which is fed back to a servo amplifier in the recorder, and its output then drives the vertical acceleration stylus.



Fairchild Model 5424 Recorder — Dust Cover and Cassette Removed.

Figure D III-3.

1.3.2. Parameter and Binary Traces

The recording styli in the LAS recorder operate with constant pressure against an aluminum foil recording medium and provide a steady trace at all times. This is referred to as embossing. The UCDD and Fairchild recorders utilize an intermittent contact operation in which a cam-operated pressure bar presses the styli against a steel foil recording medium. Each recording stylus is equipped with a knife-edged diamond scriber which scratches the foil surface lightly. This is referred to as etching. The gear-driven cam shaft has two single-lobe cams which exert even pressure on the spring-loaded pressure bar to drive it against the styli arms for altitude, airspeed, and heading. A third cam on the same shaft has ten lobes, and the cam is used to operate a second pressure bar which in turn causes the vertical acceleration stylus to contact the foil surface. The cam shaft rotation is approximately one revolution each second; therefore, the single-lobe cams cause the altitude, airspeed and heading styli to contact the foil surface once each second.

UCDD and Fairchild recorders employ four binary traces. The N-S heading binary has already been discussed as a two-position indicator, and its solenoid-type operation was explained. This binary is located just below the lower extreme of the heading trace. There are three additional solenoid-operated styli which can be used as indicators. One is used as the trip and date/reference line binary, and scribes at the bottom portion of the foil recording medium just below the sprocket holes. Normally, this binary trace serves as the zero reference for vertical or "Y" measurements. In addition, it is used to display the flight number and day of the month by setting up the proper numbers on the trip and date encoder in the cockpit. Once the encoder has started, the selected numbers are automatically registered on the reference line by a series of excursions. Counting the number of excursions when reading the flight record yields the flight number and date.

The last two binaries are auxiliary in nature, and are known as AB-1 and AB-2. AB-1 is located at the top of the foil medium just above the sprocket holes and, on UCDD recorders, provides an excursion for each minute of operation. The Fairchild recorder does not make time marks and, therefore, the trace is static. AB-2 is located between the heading trace and the vertical acceleration trace, and is normally static. United Air Lines, using the Fairchild recorder, has been using AB-1 and AB-2 to record radio transmissions. AB-1 is connected to the No. 1 VHF communication transmitter, and AB-2 is connected to the No. 2 VHF transmitter. The appropriate stylus then provides a permanent record of the transmissions, the length of which can be measured. This becomes a valuable tool for correlating the flight recorder and cockpit voice recorder to obtain real time for various inflight occurrences.

1.3.3. Recorder Times and Calibration

The aluminum LAS foil recording medium will last approximately 150 flight hours before replacement, and can be used only once. Nominal foil advance speed is 0.1 inch per minute; however, due to the design of the foil advance mechanism, this speed will vary throughout the run of the foil. This presents difficulties which will be discussed under the section on readouts. The steel foil used in UCDD and Fairchild recorders can be used for approximately 400 hours on each side because of the scribing method. The foil advance speed is held very close to 0.1 inch per minute.

Recorders are generally overhauled each 2000 flight hours. Following overhaul, the recorders are calibrated to the manufacturer's specifications. A recalibration is normally performed if the recorder is removed for repair. The current calibration must be obtained in order to proceed with a readout of the flight record since none of the recorders is ever right on the standard but should be within the specified tolerances.

1.4. Handling Recorders and Foil Mediums

The flight recorder removed from the aircraft wreckage in a major accident should be shipped to the offices of the National Trans-

NATIONAL TRANSPORTATION SAFETY BOARD

REQUEST FOR FLIGHT RECORDER READOUT

A. ACCIDENT-INCIDENT IDENTIFICATION					
1. Field Office Number	2. Aircraft Type	3. "N" Number	4. Carrier	5. Location	6. Date 7. Time

B. FLIGHT RECORDER DATA			
8. Recorder Make and Model	9. Serial No.	10. Date Last Overhauled	11. Overhauled by:

12. Carrier's Calibration Data: (Check Appropriate Box)
☐ Included with foil ☐ Requested and being sent direct

13. Recorder Condition (Describe any damage or loose connections, both external and internal)

C. METEOROLOGICAL DATA AT TIME OF ACCIDENT-INCIDENT			
14. Local Barometric Pressure (inches Hg.)	15. Temperature (Degrees F.)	16. Surface Wind Direction: Velocity:	17. Accident Site Elevation (Ft. MSL)

D. BRIEF DESCRIPTION OF ACCIDENT OR INCIDENT (INCLUDE FLIGHT NUMBER)

(Continue on back, if necessary)

E. INFORMATION DESIRED FROM READOUT

(Continue on back, if necessary)

NAME OF REQUESTOR	DATE OF REQUEST

NTSB Form 6120.20

Figure D III-4.

poration Safety Board, Bureau of Aviation Safety, in Washington, D.C. There will be many instances of minor accidents or incidents where a readout of the flight record is desirable. Most likely, in these cases, the recorder will be completely intact. In this case, it will not be necessary to ship the entire recorder, only the recording medium, preferably still contained in the cassette or magazine. This last is intended to preclude inadvertent damage to the foil recording medium by inexperienced personnel during attempts at removal. The address for shipping is shown below:

National Transportation Safety Board
Bureau of Aviation Safety
Safety Analysis and Promotion Divison, NA-87a
Washington, D.C. 20591

The investigator should obtain a copy of NTSB Form 6120.20, *Request for Flight Recorder Readout* (**Figure D III-4**), from the nearest NTSB field office, and fill it out completely. The current calibration record for the recorder should be obtained from the operator involved, and should accompany the recorder or foil. If the operator cannot furnish the calibration, it should be requested from the recorder manufacturer, with a request to send directly to the above address. Following is a list of the recorder manufacturers for contact.

LAS Special Devices Division
Lockheed Aircraft Service Company
Ontario International Airport
Ontario, California

Fairchild Industrial Products
Fairchild Camera and Instrument Corporation
5921 East Sheila Street
Los Angeles, California 90022

Sunstrand Data Division
United Control Corporation
10650 Rush Street
South El Monte, California 91733

One note of caution should be observed when shipping the Lockheed recorder. The cassette containing the foil medium should be removed and packed separately. Shipping with the cassette in place can cause considerable damage to the aluminum foil because all styli are under constant pressure. Experience has shown that handling in transit has resulted in considerable damage and interference with the readout of the traces. The following methods should be followed in removing the cassette or magazine from the recorders.

1.4.1. LAS Model 109-C (Round Ball) (Figure D III-2)

Remove the cover retaining ring by withdrawing the latch retaining pin and opening the latch. Remove the cover, and note the condition of the foil record exposed over the cassette platen and the condition of each recording stylus. Unscrew the cassette hold-down shaft by turning the knurled knob in the center of the cassette cover. The shaft cannot be removed; it can only be loosened. The cassette should now be moved or tilted gently backwards away from the recording styli to prevent more-than-necessary scratching of the foil surface. The left-hand spool in the cassette is the takeup side; therefore, turn the drive gear on the bottom of the cassette below this spool to wind on approximately twelve inches of unused foil to protect the recorded traces. Cover the exposed foil with paper or cardboard taped to the cassette to preclude further foil movement, and carefully package the cassette for shipment.

1.4.2. LAS Model 109-D (ATR Case) (Figure D III-2)

Unlock the front of the recorder and slide the chassis out of the unit. Again, note the condition of the styli and the exposed foil, then proceed with the cassette removal and packaging as described for the Model 109-C recorder.

1.4.3. Fairchild Model F-5424 (ATR Case) (Figure D III-3)

Open the front of the recorder by unscrewing the knob at the top of the sliding trap door, pressing on the spring-loaded button immediately below the door, and sliding the door downward to clear the cleats. The door will now swing downward, exposing the magazine containing the foil medium. Grasp the handle on the magazine and raise it all the way to unlock the magazine. The magazine may then be pulled straight back out of the recorder. Package the magazine carefully for shipment.

1.4.4. United Control Data Division Models F-542 and FA-542 (ATR Case)

Open the front of the recorder by unlocking the knob at the top of the hinged trap door. The door will drop down, exposing the magazine. Removal of the magazine is the same as in the Fairchild recorder.

NOTE: Be sure to obtain the flight recorder make, model, and serial number (manufacturer's serial number), and the barometric pressure at the time of the occurrence. The barometric pressure is necessary to convert pressure altitude to mean sea level altitude.

1.5. Readout Methods

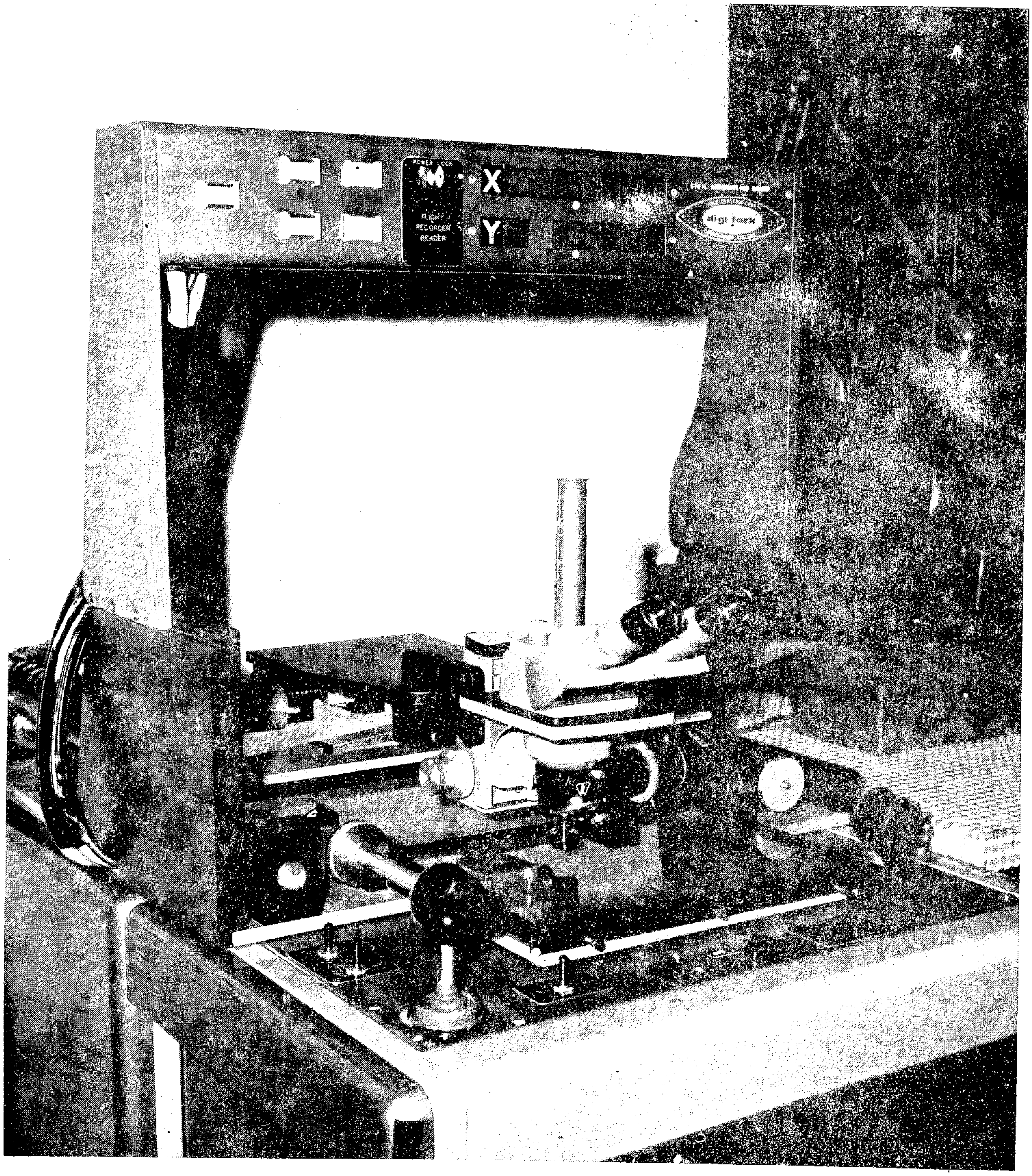
Remember, the entire foil record should be submitted in order to provide an accurate readout. There have been cases where only that portion of the foil containing the flight of interest have been received for a readout and, for reasons to be described in the following paragraphs, an accurate readout could not be accomplished.

Another point of importance is to supply information as to where to find the occurrence on the foil record. If the foil was removed immediately following the occurrence and no further flights were made, then it should be noted on the readout request. If subsequent flights were conducted following the occurrence, then some indication should be provided as to how many flights back the occurrence may be located. The length of the flight in question is also helpful in determining that the proper flight has been selected.

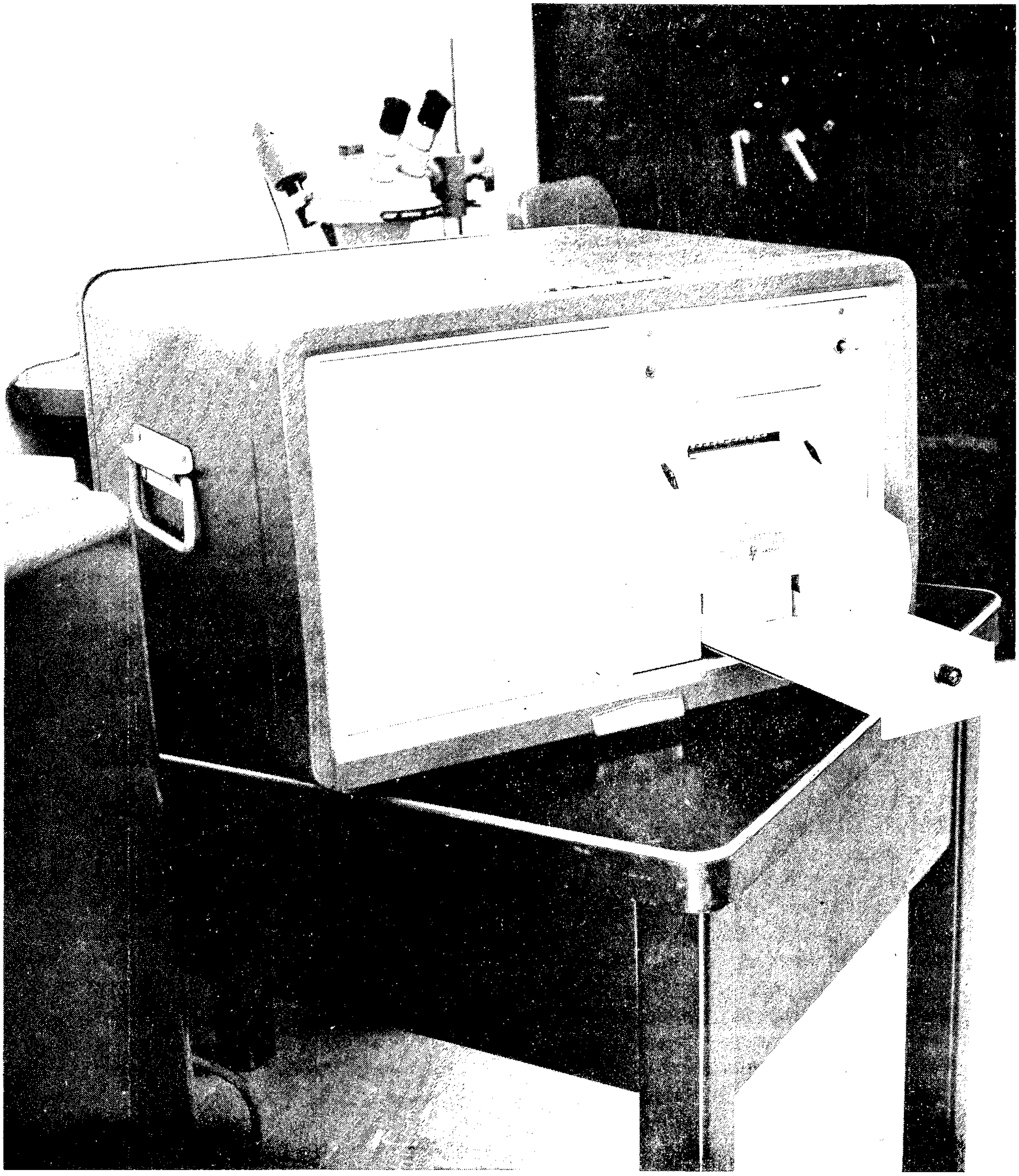
To begin the readout, the foil is placed on a precision measuring machine (**Fig. D III-5**). This machine utilizes a moving microscope with integral lighting as well as externally controlled fiber lights to highlight the traces. The microscope moves horizontally for the "X" or time measurement, and in or out for the "Y" or vertical measurement. All measurements are in inches from a zero reference, and are recorded to the nearest one-thousandth of an inch. All vertical measurements are made using the previously described reference binary as the zero reference. The horizontal or time measurements begin at an arbitrarily determined zero point, dependent on where during a flight the measurement should begin. Each trace is read separately, with readings being taken at random. The object is to duplicate the parameter traces within reason by taking readings at sufficient intervals to duplicate significant changes in the traces. The readings are not taken at the same point of time on each trace, since changes may occur in one trace which may not be reflected in others. As each reading is taken, its values of "X" and "Y" are recorded on a paper strip in a digital recorder by pressing a button on the machine console (**Fig. D III-6**). Following completion of the readout of each trace, the microscope is returned to the initial reading to insure repeatability and accuracy.

The paper tapes are pasted onto work sheets to begin the data reduction. The calibration data provided by the investigator are used to plot curves with inches of "Y" versus units of feet, knots, degrees, and 'g' units. These curves are then used to reduce the raw "Y" readings to usable actual values. The raw "X" readings are applied to a time constant to obtain minutes and seconds of elapsed time from the zero reference. Since the recorder knows only pressure altitude, the QNH barometric pressure (altimeter setting) provided by the investigator is used to convert pressure altitude to mean sea level altitude. THIS IS THE ONLY CORRECTION MADE TO THE READOUT DATA UNLESS OTHERWISE SPECIFIED.

A data graph is plotted following reduction of the raw data into actual values of time, altitude, airspeed, etc. This data graph becomes part of the public file when attached to the factual report, and is used as another tool in reconstructing the sequence of events leading to the accident or incident.



N.T.S.B. Recorder Readout Machine
Figure D III-5



N.T.S.B. Readout Digital Recorder.

Figure D III-6.

1.5.1. Analysis of Recorder Readouts

In analysis, the flight recorder data provides trends in each parameter which can be analyzed along with the voice recorder output and integrated with all of the other known facts developed during the investigation to determine the probable cause. Inaccurate as this data may be when compared to more exacting flight test equipment, it will nevertheless provide the basis for aircraft performance studies when the need arises.

Flight recorders provide other benefits in that certain air carriers, both United States and foreign, are utilizing the recorder to conduct post-flight analysis of the landing approaches on recorded flights to detect deviations from standard practices which may be corrected immediately. Also, one United States air carrier utilized flight recorder readouts (provided by NTSB on a confidential basis) in its continuing study of inflight turbulence, to develop ways and means of avoiding exposure to such atmospheric conditions. These studies will benefit the air carrier industry. Since landing accidents and inflight turbulence account for 63% of the total readout cases, it may be appreciated that the flight data recorder can serve as a useful tool in the prevention of accidents and incidents, as well as in the investigation of these occurrences.

1.6. Accident/Incident Readout Statistics

Fiscal year 1969 completed nine years of flight data recorder operation. During this time a total of 303 flight data recorder cases of record were received from accidents/incidents investigated by CAB/NTSB and foreign governments. Only a small percentage of these cases resulted in no readout. The causes were destruction of the recorder or foil recording medium, recorder malfunction or failure to operate, and inability to recover the recorder due to local conditions such as deep water. Readouts in a greater percentage of these cases were made difficult as the result of damage to the foil recording medium. This damage was caused by fire or heat, mechanical damage to the recorder and, in some instances, inadvertent damage from mishandling of the foil medium during recovery. Flight recorder readouts have been performed by CAB/NTSB to assist the accident investigators from 13 foreign countries. Also, five readouts were performed to assist investigators of the U.S. Air Force.

The following table lists flight data recorder cases of record as of June 30, 1969, with a breakdown as to types of accidents and incidents.

TYPE	NUMBER	PER CENT
*Landing Regime	127	42
Inflight Turbulence	63	21
Aircraft Malfunction	25	8
*Takeoff Regime	19	6
*En Route	17	6
Near Miss (Evasive Action)	10	3
*Midair Collisions	9	3
*Explosion (Bomb)	2	1
Taxi Accidents/Incidents	2	1
Miscellaneous (Tests, etc.)	29	9
TOTAL	303	100

* Includes accidents of a catastrophic nature.

As a matter of interest, 39% of the above cases were received during fiscal years 1968 and 1969. In addition to the above, a total of 28 cases have been received in the first half of fiscal year 1970.

1.7. Proposed New Flight Recorders

Acting on a recommendation of the Civil Aeronautics Board, the Federal Aviation Agency on February 24, 1967, proposed a regulation requiring 14 additional flight recorder parameters for large turbine-powered planes.

The additional parameters relate to the aircraft's attitude, response to aerodynamic forces, control and control surface positions, and engine performance. They are:

a. Pitch attitude.

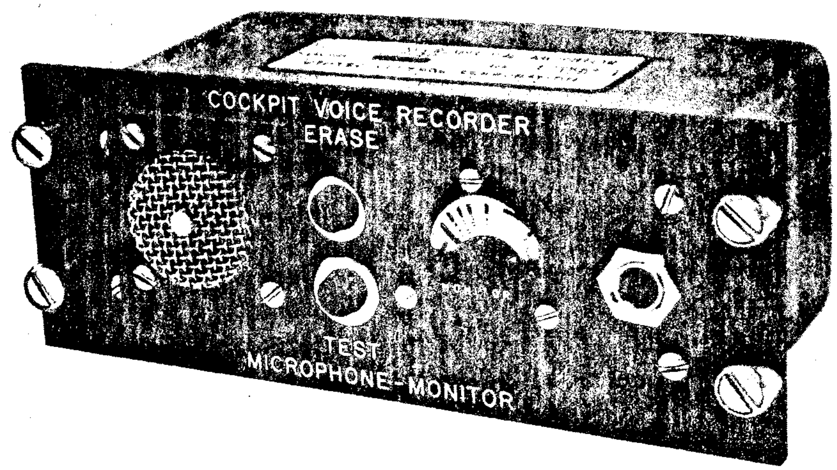
b. Angle of attack.

c. Angle of bank.

d. Pitch rate.

e. Yaw rate.

f. Roll rate.



United Control Data Division Microphone Monitor with Test and Erase Buttons.
Figure D III-7.

g. Position of the control column.

h. Position of the control wheel.

i. Position of the rudder pedals.

j. Position of the pitch trim mechanism.

k. Position of the wing flaps.

l. Ambient air temperature.

m. Two of the following parameters for each engine:

– torque

– pressure ratio

– gas temperature

– r.p.m.

These new recorders may be designed to utilize magnetic tape which will lend itself to computerized data reduction. In the interest of retrofit, it may be possible to cover most or all of the additional parameters on the present cockpit voice recorder.

Minimum airworthiness standards concerning flight recording systems in SST aircraft require telemetering of many channels of flight data to ground-based computers. This would continuously and rapidly analyze the data and alert the flight crew to any unusual situations involving such items as fuel reserves, navigation equipment, or any malfunction.

A less desirable alternative to telemetering data means should be a jettisonable flight recorder. It should include flotation and radio crash locator devices to facilitate recovery of the recorder, in event of an accident during transoceanic flight.

Two economic advantages of flight recorder data telemetry systems are (a) reduction of accident and incident losses, and (b) rapid servicing at arrival terminals, since maintenance personnel will have advance information relative to replacement parts needed.

1.8. Cockpit Voice Recorders Background Information

On the basis of CAB and FAA recommendations to enhance safety in the operation of aircraft, the FAA in 1960 conducted a study of the feasibility of recording crew conversations in the cockpit. It was determined that such a voice recorder could be developed, capable of doing the job under the high noise level of the area.

FAA TSO C-84, *Cockpit Voice Recorders,* was issued September 2, 1964, establishing minimum performance standards for cockpit voice recorders.

Federal Aviation Regulations, Parts 25, 91, and 121, were amended to require the installation of cockpit voice recorders in transport-category aircraft operated in air carrier service. The compliance dates set were July 1, 1966, for all turbine-powered aircraft, and January 1, 1967, for all pressurized reciprocating four-engine aircraft.

Voice recorders approved in accordance with FAA TSO C-84 are:

Collins Radio Corporation

Fairchild Camera & Instrument Corporation

Lockheed Aircraft Service, Inc.

Microdot, Inc.

United Control Data Division

Figure D III-6 is a United Control Data Division Cockpit Voice Recorder with thermal cover removed showing random loop storage tape magazine. **Figure D III-7** shows a United Control Data Division Microphone Monitor with test and erase buttons.

1.9. Voice Recorder Capabilities

Initially it was proposed that the voice recorder equipment have the following capabilities:

a. Record each crew member's conversation (transmitted and received) with ground facilities or with the intercommunication system. Other cockpit conversation should be recorded; sufficient channels should be provided so no more than one crew member records on a channel at one time.

b. Retain only the last 30 minutes of the crews conversations.

c. Contain provision for stopping the recorder in the case of a crash, so that the last 30 minutes of conversation would not be erased.

d. Record should withstand crash conditions as required in TSO-C51.

e. Record should be intelligible over the ambient noise of the cockpit, or it should be possible to filter out the unwanted noise with appropriate ground equipment.

f. Recorder should be capable of recording crew voices other than on the communication and intercommunication systems, without the use of lip or throat microphones.

g. Recorder should provide indication of proper operation.

The foregoing objectives were met by the use of a four-track recording system (all tracks being recorded in the same direction) assigning functions as follows: One track to the cockpit area microphone (**Fig. D III-7**), one to the captain's audio circuit, recording all input to his headset or speaker as well as output from his microphone, another identical arrangement for the first officer, and the fourth track employed in the same manner for the flight engineer's position. In the case of aircraft with a two-man flight crew, the fourth track is assigned to the passenger cabin public address system, thereby recording cabin attendant's announcements.

Provision was made for the crew, upon completion of a flight segment without reportable incident, to erase all recorded material on the tape. This function may only be accomplished after two series switches are actuated. One of these is the "squat" switch, thrown by the application of weight on the landing gear. The second function varies among aircraft and airlines, and is one of the following: Activation of parking brake, application of external electrical power, use of the shaft brake on #1 engine (Fairchild turboprop aircraft only). Note that the combination of functions indicates arrival at the gate area.

The applicable FAR (121.359) governing the operation of the CVR prescribes that it shall be operated continuously from the inception of the first cockpit checklist prior to starting engines until the secure aircraft checklist is completed. It is for this reason that there is no ON-OFF switch provided for the CVR. Its operation may be halted, however, by pulling a circuit breaker, and since there is a continuous erasing and recording process underway as long as the recorder is operating, the investigator as well as the operator must be alert to the requirement for pulling the circuit breaker before re-applying electrical power to an aircraft wherein it is desired to preserve the CVR recording.

Considerable use is made of the data available on the CVR apart from the intra-cockpit conversations. For example, it is possible to derive information from aircraft with wing (pod) mounted turbojet engines or other than Allison turboprop engines relative to engine/shaft r.p.m., from which data a determination of thrust or shaft horsepower may be made. This requires specialized techniques and equipment which are applied by the Bureau's Washington-based CVR specialists.

Much useful information is obtained by the correlation of the flight data recorder readout with the CVR transcription. This activity is probably most fruitful in those cases where the flight crewmembers do not survive the accident.

Part D — SPECIAL CONSIDERATIONS

Chapter IV

ACCIDENT PREVENTION RECOMMENDATIONS

1. Purpose of Accident Prevention Recommendations

The main purpose of accident investigation is **accident prevention.** In this regard all conditions found during the investigation which *could* cause accidents are potential for prevention efforts. Unfortunately, however, those factors not directly connected with the accident cause often are ignored until they eventually become the primary cause in a later accident.

1.1. Preparation of Accident Prevention Recommendations

In preparing recommendations, furnish sufficient information to allow for proper evaluation of the safety hazard. Good recommendations may be rejected from lack of supporting data. Determine whether or not similar accidents have been caused by the unsafe condition, discuss the safety hazard and cite how it can be eliminated. Make corrective action recommendation complete, but stick to the subject, and avoid including extraneous material. Do not try to include several recommendations in one report.

1.2. Submission

Timely submission of the recommendation is important if accidents are to be prevented. In cases where serious deficiencies are revealed, submit a concise report immediately without delaying to collect additional data. Supplemental data can be submitted at a later date. In less serious situations the initial presentation should be as complete as possible. Before submitting the recommendation, be sure that the corrective action is practical and possible.

Part D — SPECIAL CONSIDERATIONS

Chapter V

CAUSAL FACTORS CHECKLIST

CAUSAL FACTORS

PERSONNEL FACTORS

Pilot —

Attempted operation with known deficiencies in equipment.

Attempted operation beyond experience/ability level.

Became lost/disorientated on VFR flight.

Continued VFR flight into adverse weather conditions.

Continued flight into area of severe turbulence.

Delayed action in aborting takeoff.

Delayed in initiating go-around.

Diverted attention from operation of aircraft.

Exceeded designed stress limits of aircraft.

Failed to extend or assure landing gear down, locked.

Failed to retract landing gear.

Retracted gear prematurely on takeoff.

Inadvertently retracted gear on ground.

Failed to observe other aircraft.

Failed to observe objects or obstructions.

Failed to maintain flying speed.

Misjudged distance, speed, altitude, or clearance.

Failed to maintain adequate rotor rpm (helicopters).

Failed to use, or incorrectly used miscellaneous equipment.

Failed to follow approved procedures, directives, instructions.

Improperly operated powerplant and powerplant controls. (Includes propeller controls.)

Improperly operated brakes and/or flight controls on ground.

Improperly operated flight controls in air.

Prematurely lifted off.

Improperly leveled off.

Improper IFR operation

Improper inflight decisions or planning

Inadequate or incorrect compensation for wind conditions

Inadequate or improper preflight preparation and/or planning

Inadequate supervision of flight (Pilot)

Lack of familiarity with aircraft involved

Mismanaged fuel system.

Operated recklessly (related to poor judgment).

Operated carelessly (neglect, forgetfulness).

Selected unsuitable terrain.

Started engine without proper assistance and/or equipment.

Taxied/parked without proper assistance.

Copilot —

Misunderstood orders or instructions.

Unauthorized action of the copilot

Dual Student —

Failed to relinquish control.

Control interference

Spontaneous, improper action

Flight Instructor —

Inadequately supervised flight.

Maintenance, Servicing, Inspection (Personnel)

Improper maintenance — maintenance personnel
Improper maintenance — owner personnel
Improperly serviced aircraft — ground crew
Improperly serviced aircraft — owner-pilot
Inadequate inspection of aircraft — maintenance personnel
Inadequate inspection of aircraft — owner-pilot personnel

Operational Supervisory Personnel (Company, Owner, Operator)

Inadequate flight training — procedures
Inadequate ground training — procedures
Inadequate supervision of flight crew
Inadequate supervision/training of ramp crews (signal men, etc.)
Failure to provide adequate directives, manuals, equipment
Deficiency, company-maintained equipment, services, regulations
Other

Weather Personnel

Incorrect weather forecast
Inadequate weather observation
Incomplete weather report
Inadequately maintained facilities
Training deficiency
Excessive workload
Inadequate/incorrect weather briefing
Other

Traffic Control Personnel

Failed or delayed in initiating emergency procedures.
Failed to advise of unsafe weather condition.
Failed to advise of unsafe airport condition.
Failed to advise of other traffic.
Cleared aircraft to wrong runway under existing conditions.
Issued improper or conflicting instructions.
Inadequately spaced aircraft.
Failed to properly identify aircraft on radar.
Other

Airport Supervisory Personnel (Airport Management)

Improper maintenance — airport facilities
Failed to notify of unsafe condition and/or failed to mark obstruction.
Improper/inadequate snow removal
Improper operation of facilities
Improper inspection of facilities
Other

Airways Facilities Personnel

Inadequately maintained airways facilities.
Inadequately maintained approach facilities.
Failed to issue NOTAM.
Other

Production, Design Personnel

Substandard quality control
Incorrect factory installation
Poor/inadequate design
Other

Miscellaneous — Personnel

Pilot of other aircraft
Ground signalman
Spectator
Ground crewman (propeller accident)
Passenger
Driver of vehicle
Other

AIRFRAME

Wings

Spars
Ribs, stringers, cap strips

Wing attachment fittings, bolts
Bracing wires, struts
Skin and attachments
Fairings
Wingtips
Wheel well doors
Nacelles, pods, pylons (structural components)
Inspection door
Other

Fuselage

Bulkheads
Floor structure
Longerons
Skin and attachments
Stringers
Doors, door frames (excluding wheel well doors)
Fairings
Windshields, windows, canopies
Seats (including tiedowns)
Wheel well doors (including actuating mechanism)
Other

Landing Gear

Main gear shock-absorbing assembly, struts, attachments, etc.
Normal retraction/extension assembly
Emergency/extension assembly
Tail wheel assemblies (includes tail skids)
Nosewheel assemblies
Wheels, tires, axles
Ski assemblies
Float assemblies (pontoons)
Skid assembly
Braking system (normal)
Braking system (emergency)
Landing gear warning and indicating components
Gear locking mechanism (includes drag linkage)
Switches, levers, cranking mechanism, etc.
Nosewheel steering
Other

Flight Control Surfaces

Elevator assembly, attachments
Rudder surfaces, attachments
Aileron surfaces, attachments
Horizontal stabilizer, attachments
Flap assemblies
Spoilers and slots — leading edge flaps, speed brakes
Other

POWERPLANTS

Engine Structure

Reciprocating Engine

Crankcase
Crankshaft
Master and connecting rods
Cylinder assembly
Piston, piston rings
Valve assemblies
Blower, impeller assembly
Mount and vibration isolators
Other

Turbine Engine

Compressor rotors
Compressor stators
Compressor discs
Compressor spacers
Compressor blades
Compressor case
Burners
Transition liners
Turbine nozzles
Turbine discs
Turbine spacers
Turbine buckets
Turbine case
Exhaust nozzle
Reverser mechanisms

Ignition System

Magnetos
Distributor (not integral with magneto)
Spark plugs
Igniters
Coils
Low tension wiring
High tension wiring
Ignition harness, shielding
Switches (ignition)
Leads
Other

Fuel System

Tanks
Lines and fittings
Selector valves
Crossfeed valves
Filters, strainers, screens
Priming systems
Carburetor
Fuel control
Pumps
Fuel injection system
Fuel nozzles
Vents, drains, tank caps
Dump valves
Ram air assembly
Oil dilution system
Other

Lubricating System

Tanks
Lines, hoses, fittings
Valves
Filters, screens
Pump pressure
Pumps scavenger
Oil coolers
Magnetic plugs
Seal and gaskets
Regulators
Cowling
Other

Cooling System

Baffles
Fins
Radiators
Pumps
Jackets
Other

Propeller and Accessories

Blades
Hubs
Electric pitch control mechanism
Hydraulic pitch control mechanism
Counterweights
Spinners, domes
Governors
Synchronization mechanism
Blade retention mechanism
Metal cap, blade leading edge (wood propeller)
Safety clip
Planetary gear
Slip ring
Other

Exhaust System

Manifolds
Mufflers
Augmentor tubes
Gaskets
Clamps
Stacks
Baffles
End plates
Other

Engine Accessories

Vacuum pumps
Generators
Hydraulic pumps (engine driven)

Electric pumps
Cowl flaps actuating assembly
Oil cooler actuating assembly
Feathering motors, pumps
Starters
Other

Engine Controls — Cockpit

Throttle-power lever assemblies
Mixture control assemblies
Fuel injection control
Induction air, preheat controls
Oil cooler controls
Propeller governor controls
Cowl flap controls
Other

Powerplant — Instruments

Power indicators
Fuel pressure gauge
Fuel quantity gauge
Fuel flow indicator
Oil temperature gauge
Oil pressure gauge
Oil quantity gauge
Other

Miscellaneous Powerplant

Powerplant failure for undetermined reason
Ingestion (birds)
Foreign object damage (other than birds)
Compressor stalls
Other

SYSTEMS

Electrical
Hydraulic
Flight controls
Anti-icing, de-icing systems — ice and rain protection
Air conditioning, heating-pressurization
Autopilot
Fire warning/detection
Fire extinguishing
Oxygen system
Other systems

Instrument, Equipment, Accessories

Flight and navigation instruments
Communications and navigation equipment (aircraft)
Miscellaneous equipment/accessories

ROTORCRAFT

Rotor Assemblies

Main rotor blades
Tail rotor blades
Main rotor head assemblies
Balancers
Stop cables
Droop stops
Universal joints, couplings
Bearings
Jet tip boosts
Blade trim tabs
Main rotor brake assembly
Other

Transmission Rotor Drive System (Rotorcraft)

Engine drive shaft
Main rotor drive shaft
Free wheel unit (when not in engine)
Main rotor brake assembly
Main rotor gear box
Main rotor pulleys, belts
Tail rotor drive shaft assembly
Tail rotor gear box
Main rotor intermediate gears (dual main rotors)
Clutch assembly
Gear box oil cooler, blower
Sprag system
Other

Flight Control Systems (Rotorcraft)

Cyclic pitch control system
Collective pitch control system
Tail rotor pitch control system
Stabilizing surface-dampers
Mixing unit (collective pitch control system)
Other

Miscellaneous Units and Assemblies (Rotorcraft)

Automatic stabilization equipment (ASE)
Transmission oil pressure indicator
Transmission warning test indicator
Transmission temperature indicator
Dual tachometer (engine and main rotor)
Emergency flotation gear
Tail booms/pylons/cones
Other

AIRPORTS/AIRWAYS FACILITIES

Airport Facilities

Instrument landing system
TVOR
Approach lighting
Runway lighting
Ramp facilities
Taxiway lighting and marking
Obstruction lighting
Other

Airport Conditions

Wet runway
Ice/slush on runway
Snow on runway
Snow windrows
Unmarked obstructions
Soft shoulders (runway)
Glassy water (seaplane landing areas)
Rough water (seaplane landing areas)
High vegetation
Hidden hazard
Poorly maintained runway surface
Soft runway
Wet ramp/taxiway
Ice/slush on ramp/taxiway
Snow on ramp/taxiway
Soft shoulders ramp/taxiway
Poorly maintained ramp/taxiway surface
Other

WEATHER

Low ceiling
Rain
Fog
Snow
Hail
Icing conditions; includes sleet, freezing, rain, etc.
Conditions conducive to carburetor (induction) ice
Unfavorable wind conditions; parked, holding on ground, taxiing
Unfavorable wind conditions; takeoff and landing (includes crosswind conditions)
Sudden windshift (takeoff or landing accidents)
Turbulence in flight, clear air
Turbulence in flight; in clouds, including thunderstorms, etc.
Downdrafts, updrafts — (includes mountain wave)
Local whirlwind
Tornado
Lightning strike
Hurricane, cyclone
Line squall
Adverse winds aloft (unrecognized and/or unpredicted)
High temperature
Obstructions to vision (smoke, haze, sand, dust)
High density altitude
Other

TERRAIN — OTHER THAN AIRPORTS

Wet, soft
Snow covered
Icy
High vegetation
Hidden obstructions
Rough/uneven
Rough water
Glassy water
High obstructions (approach-takeoff)
Other

MISCELLANEOUS

Bird strike
Wake turbulence/wingtip vortices (in-flight)
Prop/jet blast (on ground)
Pilot intoxication
Physical impairment of pilot
Pilot incapacitation
Static discharge
Evasive maneuver to avoid collision
Unqualified person operated aircraft without authority.
Sabotage
Suicide
Whiteout
Sunglare
Foreign object damage (other than powerplant)
Smoke in cockpit
Vertigo/disorientation
Other
Undetermined

Note: Those factors under rotorcraft includ items peculiar to rotorcraft only. Item common to both fixed-wing and rotor craft are included in the appropriat sections.