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YO-3A Acoustics Research Aircraft Systems Manual

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YO-3A Acoustics Research Aircraft Systems Manual

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SYMBOLS

c_t	thrust coefficient
g	gravitational constant, m/sec^2 (ft/sec^2)
L	rotor lift, N (lb)
M_t	advancing tip Mach number
r	rotor radius, m (ft)
R	gas constant, $m^5/sec^2\ K$ ($ft^5/sec^2\ {}^\circ R$)
T	outside air temperature, °C (°F)
V	aircraft velocity, m/sec (ft/sec)
γ	specific heat ratio
μ	advance ratio
ρ	density, kg/m^3 ($lb\ sec^2/ft^4$)
σ	rotor solidity
Ω	rotational velocity, rad/sec (rot/min)

SUMMARY

This report documents the flight testing techniques, equipment, and procedures employed during air-to-air acoustic testing of helicopters using the NASA YO-3A Acoustic Research Aircraft.

INTRODUCTION

An air-to-air flight testing technique has been developed that measures external helicopter acoustics. This technique, developed by the Army Aeromechanics Laboratory at Ames Research Center, uses a fixed-wing aircraft as the microphone platform. It flies in close formation with the test helicopter as it records the acoustic data. The NASA YO-3A Acoustic Research Aircraft, an acoustically instrumented version of the quiet observation aircraft manufactured for the military, has become the dedicated test facility aircraft using this technique.

The use of this in-flight measurement technique enables acoustic data to be obtained without the limitations or multiple variables of ground-based flyover testing. Among the benefits of in-flight over flyby testing are the following: elimination of multiple acoustic transmission paths, reduction of atmospheric effects, elimination of Doppler effects, ability to record long steady-state data points, ability to keep microphones geometrically fixed relative to rotor. This lead to a powerful and versatile research tool in the area of helicopter acoustics.

This report documents the YO-3A aircraft, its instrumentation system, required hardware installation on the test aircraft, and the techniques used in these tests. In particular, formation flying, position locations, test matrices, and test procedures will be discussed. Five appendices are included.

AIRCRAFT DESCRIPTION

The YO-3A Acoustic Research Aircraft, shown in figure 1, is used by NASA Ames Research Center for in-flight measurement of rotorcraft noise. The aircraft, as currently configured, has had no modifications to either the airframe or engine drive train from the original military configuration. The physical characteristics of the YO-3A are given in table 1, a three-view drawing is shown in figure 2, and the flight envelope is shown in figure 3.

The very low propeller tip speed is the result of a three-to-one engine-to-propeller speed reduction. This reduction is achieved with a belt drive system which eliminates the possibility of gear-clash as a prominent noise source. Engine noise is reduced by a muffler, mounted under a prominent cowling which runs the length of the fuselage on the starboard side. These three features, low propeller tip speed, quiet belt drive, and large muffler, combine to make the YO-3A an extremely quiet

Figure 1.- YO-3A.

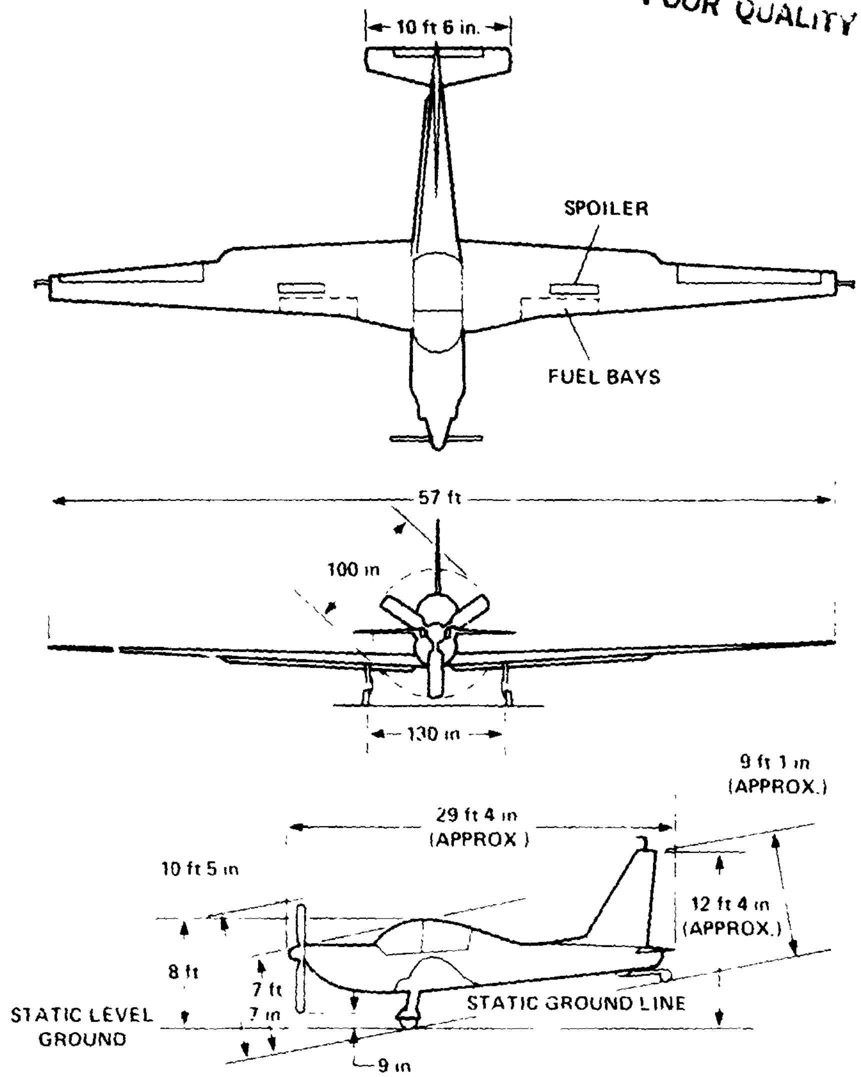

Figure 2.- YO-3A three view.

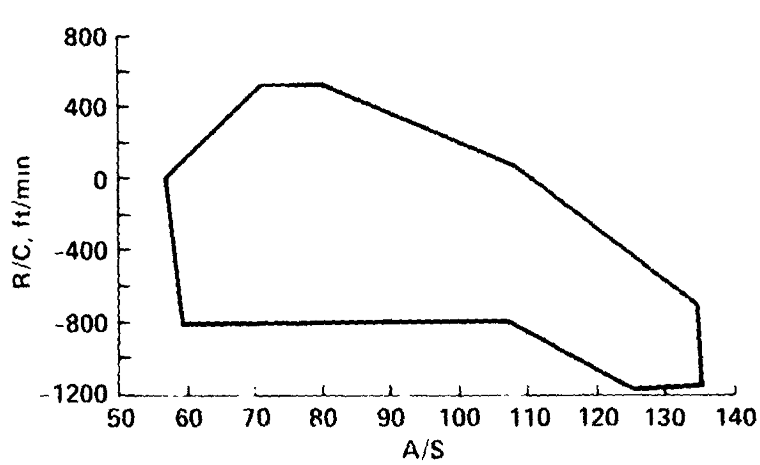

Figure 3.- Flight envelope.

TABLE 1.- YO-3A PHYSICAL CHARACTERISTICS

Wingspan	17.4 m (57 ft)
Length	8.93 m (29.3 ft)
Height	2.77 m (9.1 ft)
Maximum gross takeoff weight	1722 kg (3800 lb)
Power plant, Continental	156.6 kW (210 hp)
Propeller diameter	2.54 m (100 in.)
Stall speed	111 kmph (60 knots)
Maximum speed	204 kmph (110 knots)
Crew	2
Propeller blades	3
Landing gear	Tail-dragger
Propeller tip speed	109.7 mps (360 fps)
Flaps	Fixed

TABLE 2.- TAPE RECORDER SPECIFICATIONS

Frequency response	0-20 kHz
Tape speed	30 in./sec
Record time	30 min
Reel size	10-1/2 in.
Tape width	1 in.
Signal	2 V peak-to-peak
Carrier frequency	108 Hz

TABLE 3.- YO-3A DATA CHANNEL ASSIGNMENTS

Port microphone	1
Tail microphone	3
Starboard microphone	5
1/rev pulse	2
IRIG-B time code	4
Altimeter	9
Airspeed	10
OAT (F)	11
Angle of attack	12
Angle of sideslip	13
Voice track	14
Spare	6, 7, 8

aircraft. It is this low noise signature, along with its flight envelope, that makes it an excellent aircraft for use with air-to-air acoustic testing.

AIRCRAFT INSTRUMENTATION

The NASA YO-3A is equipped with a special instrumentation package for making acoustic measurements. This package consists of an instrumentation boom, several radio links, an acoustics package, and a recording system. In addition to the instrumentation on board the YO-3A, a separate package must be installed on the test aircraft. This package is described in detail in the following section.

The instrument boom, figure 4, mounted off the port wing, contains the following sensors: airspeed; altitude, angles of attack and side slip; and outside air temperature. The pilot instruments for airspeed, altitude, and rate of climb operate off a separate pitot-static tube mounted on the starboard wing. The radio links are an IRIG-B time code receiver used for data time correlations, a voice link, and a one-per-rotor evolution (1/rev) signal broadcast from the test helicopter. The time code receiver is set to a frequency of 171.0 MHz.

If testing is to be conducted off site (i.e., away from NASA Ames Research Center), an IRIG-B time code must be available, and NASA Ames must be informed of its frequency so that a compatible receiver can be installed. The 1/rev system, operating on a frequency of 40.95 MHz, must be cleared with local military frequency coordinator. The 1/rev system is used to correlate blade azimuth location with measured acoustic signatures.

Acoustic instrumentation on the YO-3A consists of two modified dual-channel microphone power supplies, three microphones with preamplifiers, and an oscilloscope. The power supplies have been specially modified in three ways: (1) to run off the 28-volt dc aircraft power; (2) 0 and ±10, and ±20 dB gain adjustments on each output signal; and (3) potentiometers which allow fine gain adjustments to each channel during calibration. These power supplies drive the three 0.5-in. condenser microphones, leaving one channel as a spare. Figure 5 shows a typical response curve of the microphone. The three microphones and preamps are mounted on airodynamic struts located on both wingtips and atop the vertical tail, as shown in figure 6. A portable oscilloscope is used to monitor the in-flight data as it is being recorded.

The flight engineer's station, located in the front seat of the YO-3A, houses the controls on the instrument panel, shown in figure 7.

The flight engineer has the ability, through the rotary switch located in the upper right of the panel, to monitor any one of the three microphones, time code, or 1/rev signals on the centrally mounted oscilloscope.

The signals from all these sensors, plus pilot comments, are recorded on a 14-track FM wideband airborne tape recorder. Specifications for the recorder are presented in table 2.

Table 3 lists each sensor and its channel assignment. The spare channels are scheduled to be used by several system upgrades. Included in the planned upgrades are a computerized laser positioning system, multiplexing the instrument boom sensors onto one channel, recording test aircraft control inputs, and recording microphone gain settings.

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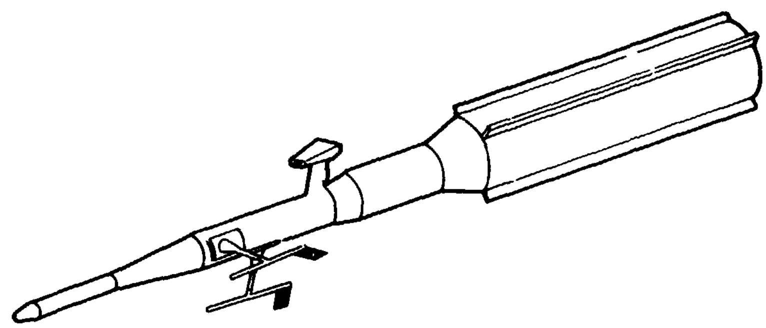


Figure 4.- YO-3A instrument boom.

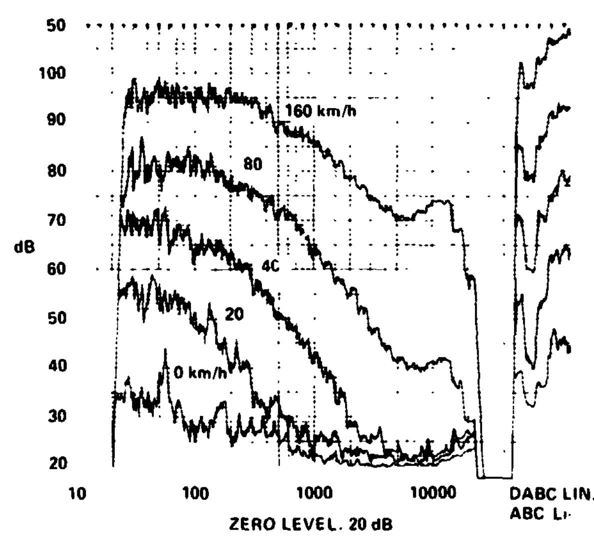


Figure 5.- Microphone response.

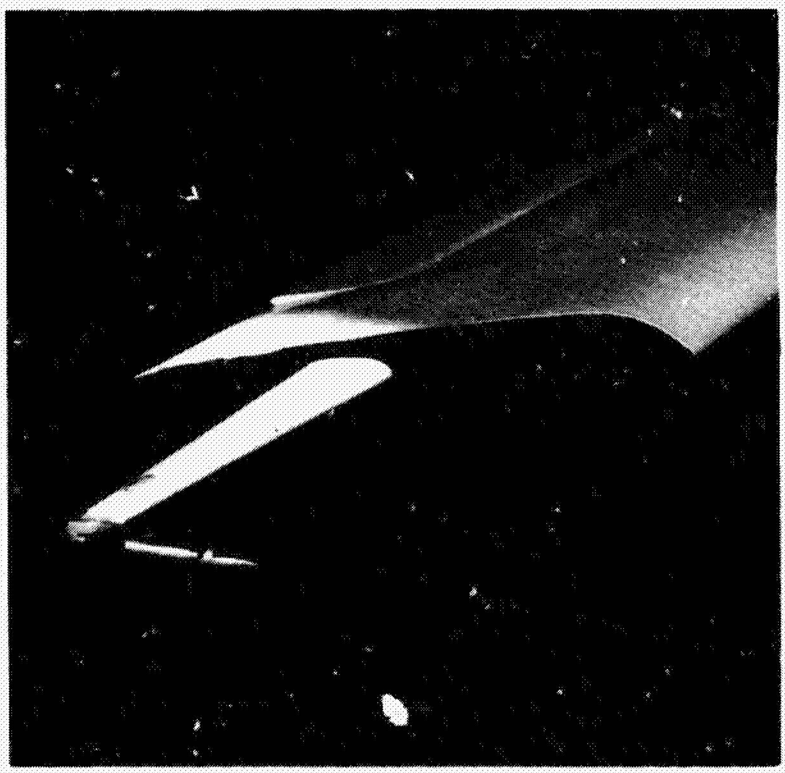
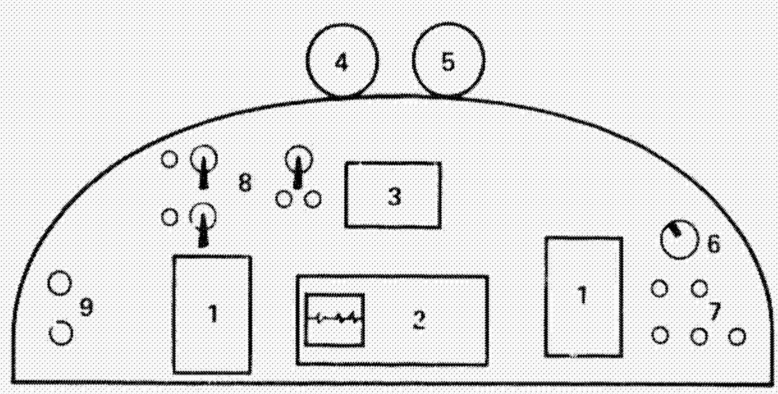


Figure 6.- Microphone mounting strut.



1. MICROPHONE POWER SUPPLIES
2. OSCILLOSCOPE
3. DIGITAL TEMPERATURE GAUGE
4. AIRSPEED GAUGE
5. ALTIMETER
6. ROTARY SWITCH CONTROLLING INPUT TO 2
7. POWER AND DATA ON/OFF SWITCHES
8. CALIBRATION SWITCHES
9. LEADS TO RECORDER

Figure 7.- Flight test engineers instrument panel.

The tape recorder, time code receiver, and 1/rev hardware are mounted in the storage bay directly behind the pilot, figure 8. A summary of the Acoustic Research Aircraft's background noise levels are presented in appendix A.

TEST AIRCRAFT INSTRUMENTATION HARDWARE

As mentioned in the preceding section, the test aircraft must provide a 1/rev signal to the YO-3A for use during data analysis. The 1/rev system used to achieve this consists of four parts, three of which must be attached to the test helicopter. Appendix B contains an itemized requirements list.

The 1/rev pickup, figure 9, must be mounted in the fixed system approximately 2 in. from a surface of the rotating system. The required mounting hardware must be supplied by the user and not by NASA. The hardware should be mounted such that a blade is at 0 azimuth when the sensor is triggered, figure 10. The pickup is an optical sensor which emits and detects an infrared beam. The sensor reacts only to a retroreflector while ignoring other reflective surfaces which pass before it. Reflective tape, acting as the retroreflector, is applied to the shaft, rotating swash plate, or pitch links, as shown in figures 11(a) and 11(b), to trigger the sensor.

The signal from the sensor is fed to the encoder/transmitter, provided by NASA. This hardware should be mounted in the test aircraft where it is easily accessible to ground crew, and easily wired to the 1/rev sensor, 28-volt dc aircraft power, cockpit on/off switch, and antenna. The encoder/transmitter package is typically assembled on a mounting plate, figure 12. If this is not a workable configuration, a custom arrangement can be devised, given reasonable advance notice. The on/off switch located in the cockpit requires only that it be connected with the encoder/transmitter, and have a flat surface for quick mounting.

The encoder/transmitter must be connected to an antenna capable of broadcasting 40.95 MHz. If a suitable antenna exists on the test aircraft, it can be used; if not, the system includes an antenna which can be modified to mount on or in the test aircraft.

TESTING TECHNIQUES

Acoustic flight testing of helicopters with the YO-3A has led to the development of specific flight testing techniques. These techniques include real-time test-point calculation, formation flying, and aircraft positioning techniques. The chase aircraft is used on all test flights for traffic identification and avoidance.

Four test positions have been identified from wind tunnel tests, theory, and flight test for use during air-to-air acoustic testing. Because of the high directivity of helicopter noise, in which the noise propagates forward, the YO-3A flies as lead aircraft in the flight formations. In order to ensure the recording of far-field acoustics, while maintaining accurate repeatable positions, a separation distance of 3.5 rotor radii is maintained.

The first position, measuring high Mach effects on the advancing blade, has the rotor hub coplanar with the tail microphone on the YO-3A. The second, measuring blade vortex interaction, has the helicopter 30° above and 45° aft of the YO-3A portside.

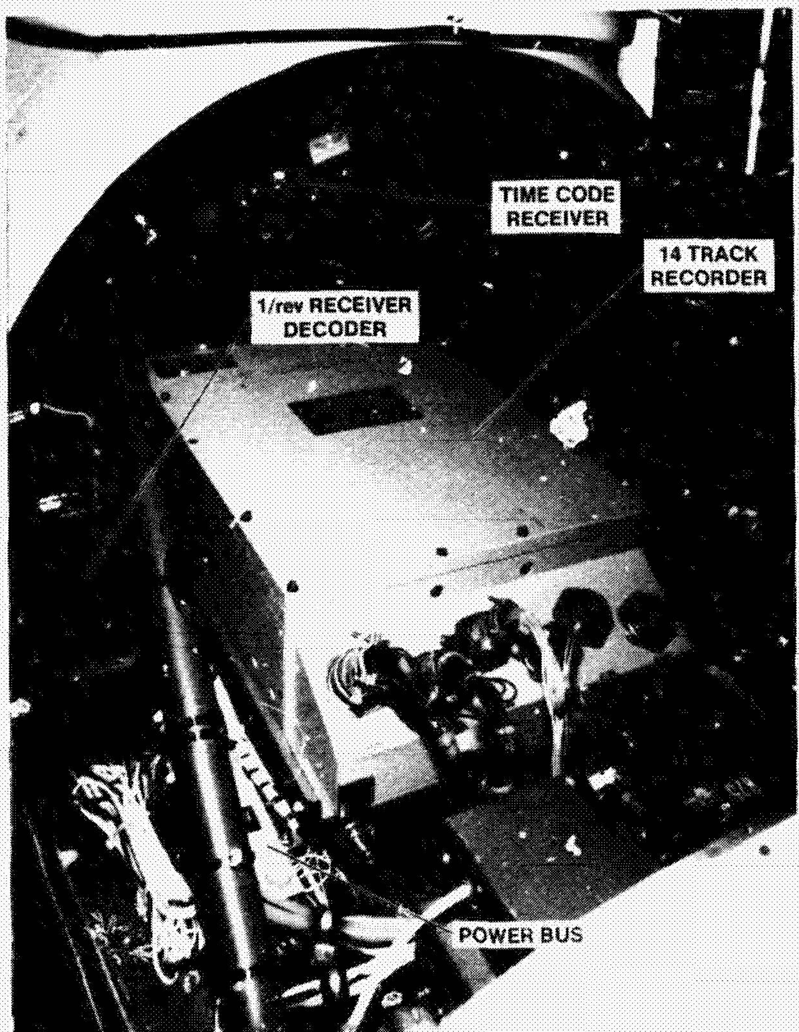


Figure 8.- Instrument bay.

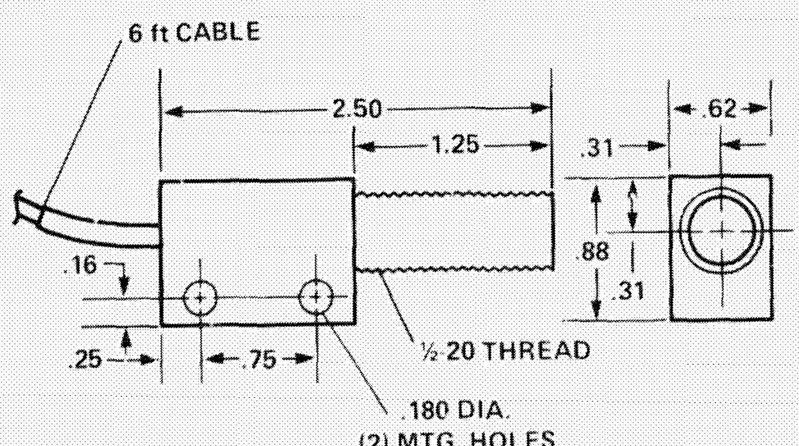


Figure 9.- 1/rev pickup.

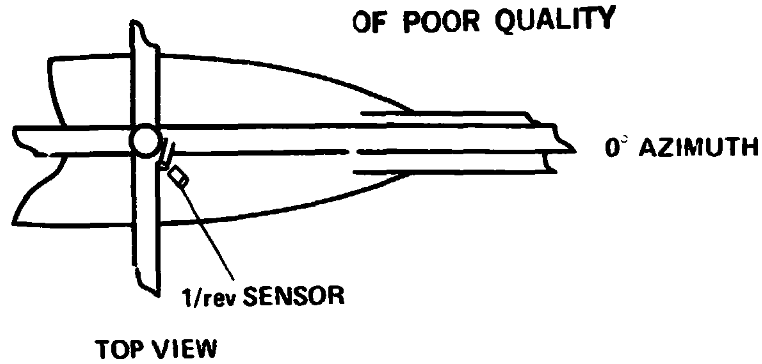
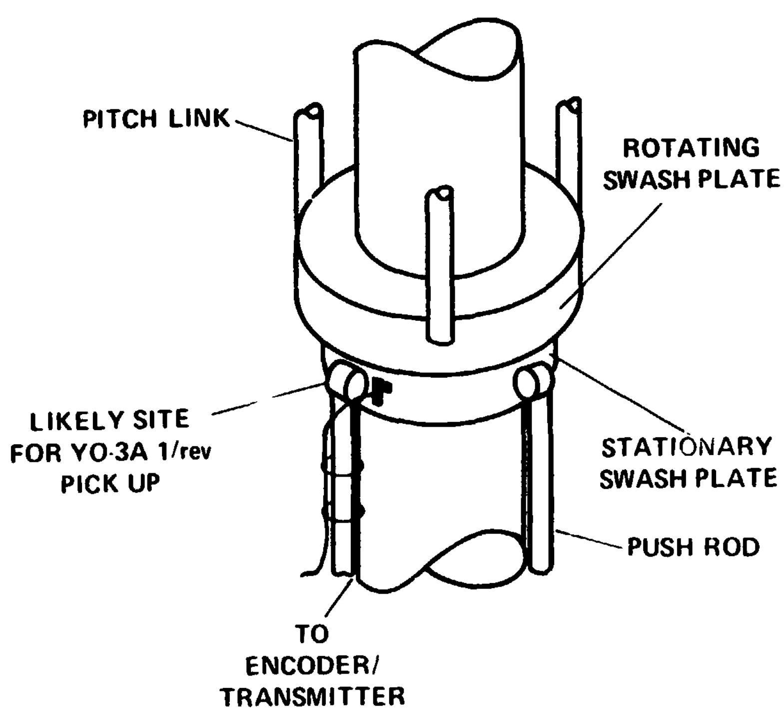


Figure 10.- 1/rev azimuthal mounting.

1/rev INSTRUMENTATION REQUIREMENTS

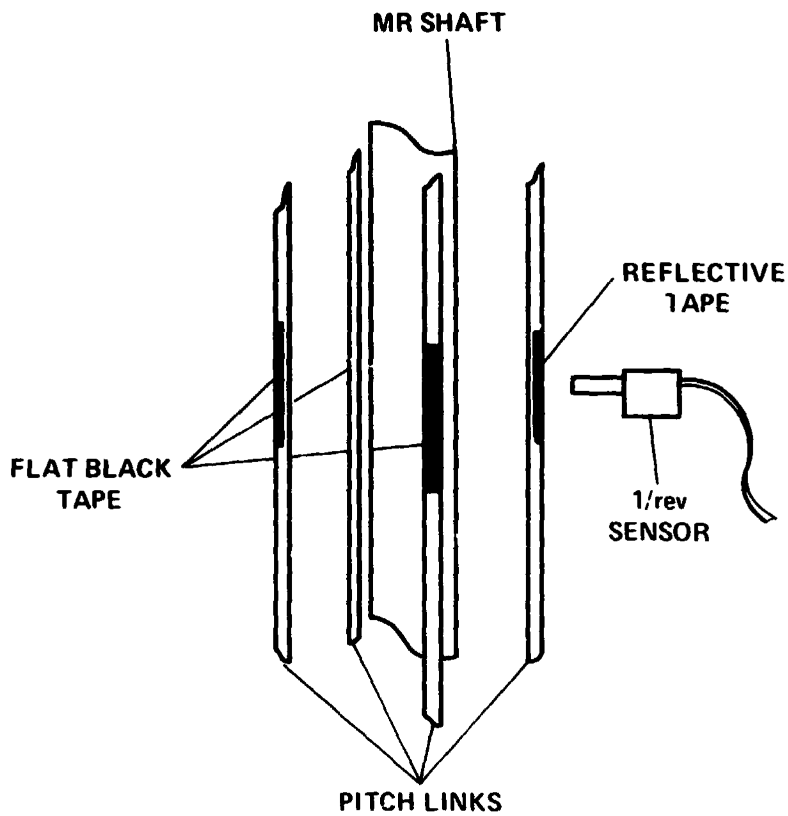


REQUIREMENTS:

- SENSOR SHOULD BE 2 in. FROM ROTATING SURFACE FOR MAXIMUM PERFORMANCE
- REFLECTIVE TAPE PLACED ON ROTATING SURFACE

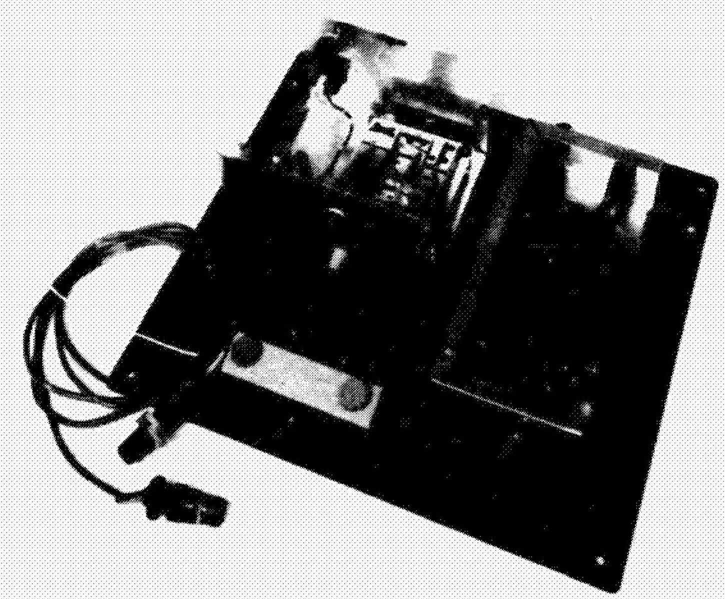
(a) Sample

Figure 11.- 1/rev mountings.



(b) Alternate

Figure 11.- Concluded.



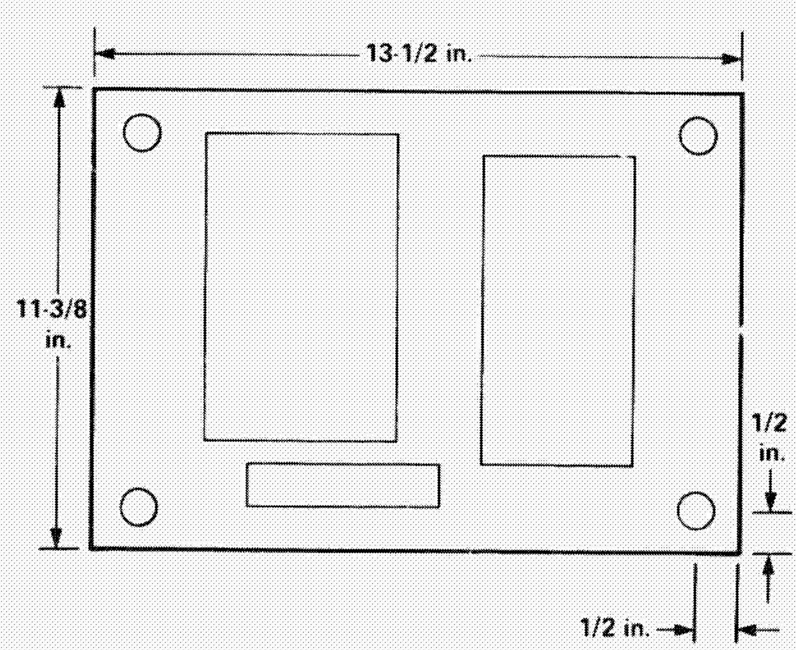


Figure 12.- Encoder/transponder package and dimensions.

The third position is a mirror image of the second. The fourth location is actually a position sweep. The test aircraft begins aft of the YO-3A in the trail position, and flies an arc to a point directly above the YO-3A. This is done to help identify the directivity pattern of the test rotor system. The four test positions are depicted in figures 13, 14, and 15, respectively.

These test locations form one leg of the three-dimensional test matrices that are used during acoustic testing. The remaining two legs are rate of descent and airspeed. Table 4 shows a typical test matrix consisting of 56 data points.

The test matrix is determined by the flight envelope of the YO-3A, and the nature of helicopter acoustics. High-speed helicopter noise, generated by high local Mach numbers on the advancing blade, propagates ahead of the aircraft, remaining essentially in the plane of the rotor. The high-speed column of a test matrix, therefore, contains the trail position in almost every row. Blade vortex interaction noise, generated by a blade intersecting the shed vortex of a preceding blade, propagates forward into the lower quadrants. The lower-speed columns of the test matrix contain the left and right position in most rows. The experimental sweeps are used to measure the directivity of the rotor acoustics from the rotor plane to directly beneath the rotor. The locations of the sweeps in the matrix are not essential; however, they are usually spaced so as to measure both thickness noise and blade vortex interaction noise.

The aircraft separation and positioning are maintained visually with the test helicopter copilot/test engineer using a hand-held rangefinder to establish and maintain the proper distance. The proper left and right positioning behind the YO-3A is judged by the pilot aligning wing markings with the vertical tail. During practice runs to familiarize the test team with these positions, the proper relative vertical separation is generally assisted by observation from the chase aircraft. Comments from the chase aircraft during the experimental sweeps are invaluable. When proficiency is obtained in holding the formations, the chase aircraft moves to a distance at which its noise will not contribute to the test data. This position is generally 2 miles behind and to the side of the YO-3A. As each test point begins, the chase goes into a slow climb, so as to further reduce possible contamination of the data. These visual techniques of formation flying have been found to be accurate to within ±1 m of the desired distances.

Test procedures call for the YO-3A pilot to set up on the specified airspeed and altitude of the test condition. When stable, the helicopter pilot maneuvers into place using the techniques discussed above. Once the proper formation is obtained in level flight, the copilot/test engineer notifies the test engineer in the YO-3A by switching on the 1/rev signal. While the test helicopter is setting up, the YO-3A test engineer adjusts the decibel gain settings on the power supplies to maximize the microphone response, while avoiding signal saturation. When the 1/rev signal is received, and the YO-3A is on condition, the test engineer begins taking data. During the data record, the test engineer continues to monitor the acoustic levels, 1/rev signal, and the time code on the oscilloscope. A detailed checklist of the procedures is presented in appendix C. At the end of each data record, the YO-3A pilot comments on the airspeed, altitude, and consistency of the run, and the helicopter pilot comments on the positioning of the aircraft and control inputs needed to maintain that position. These recorded comments prove to be invaluable during data reduction in helping select the best section of data for analysis.

These procedures work well for the level-flight test points. However, during the higher rate of sink points, where timing is critical, refinements of this

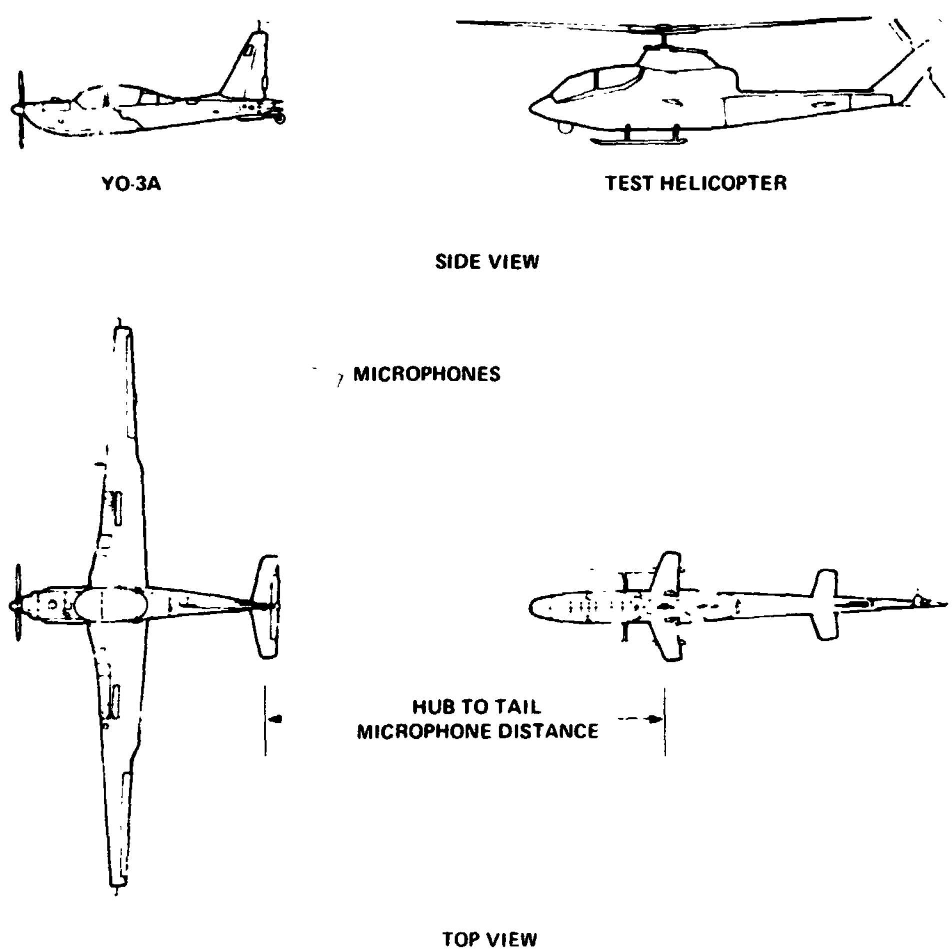
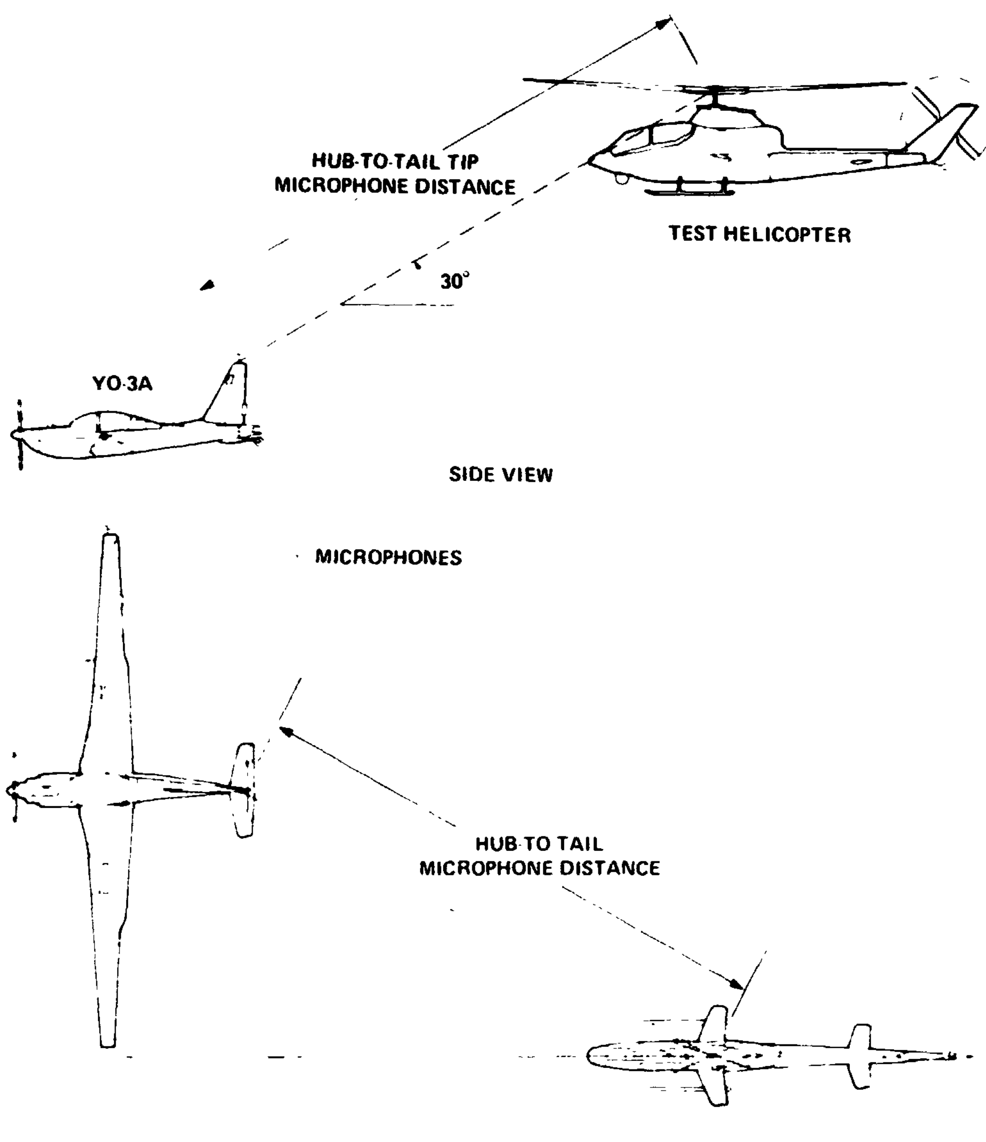
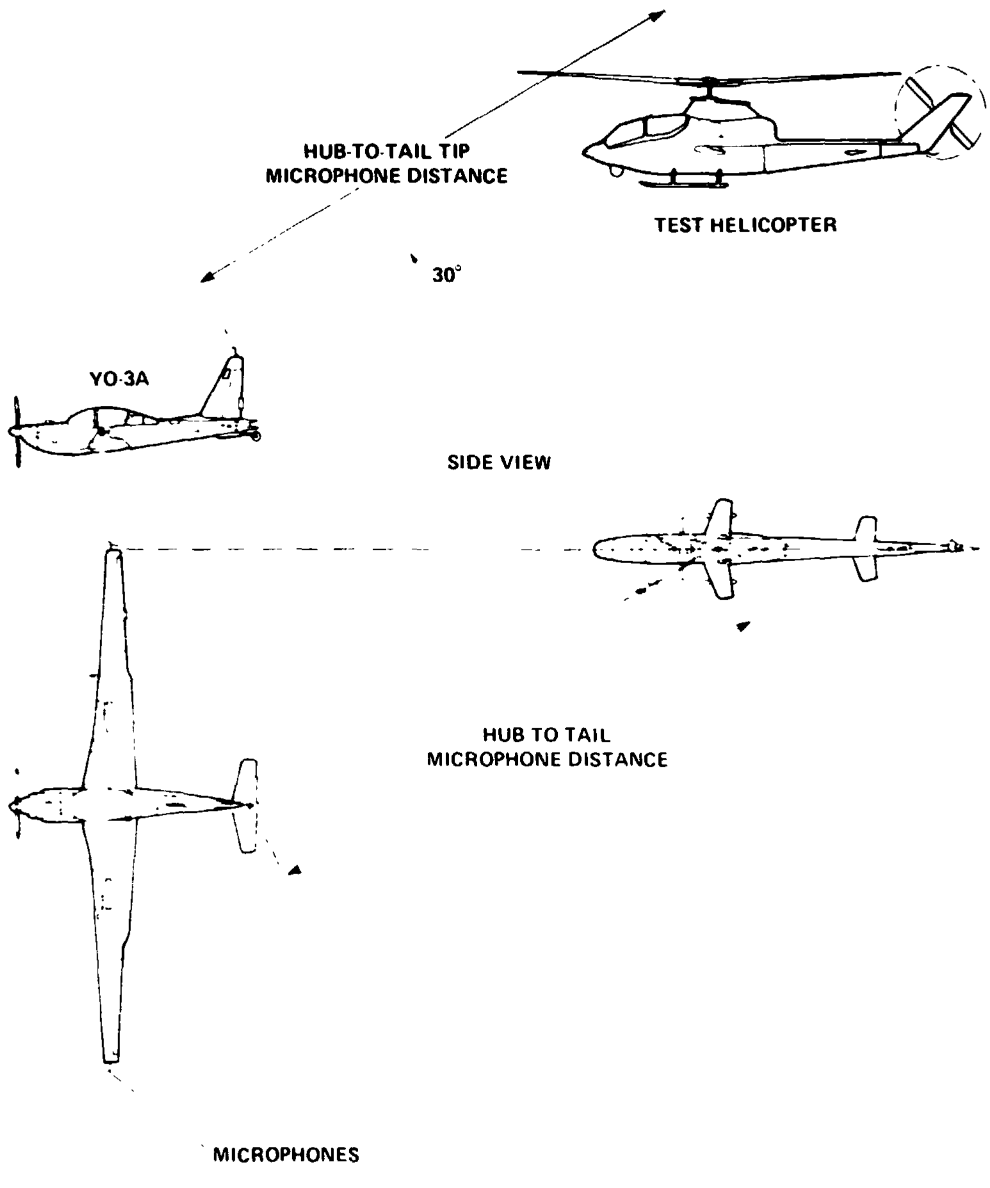


Figure 13.- Trail position.



(a) Left position

Figure 14.- Air-to-air acoustic testing.



(b) Right position

Figure 14.- Concluded.

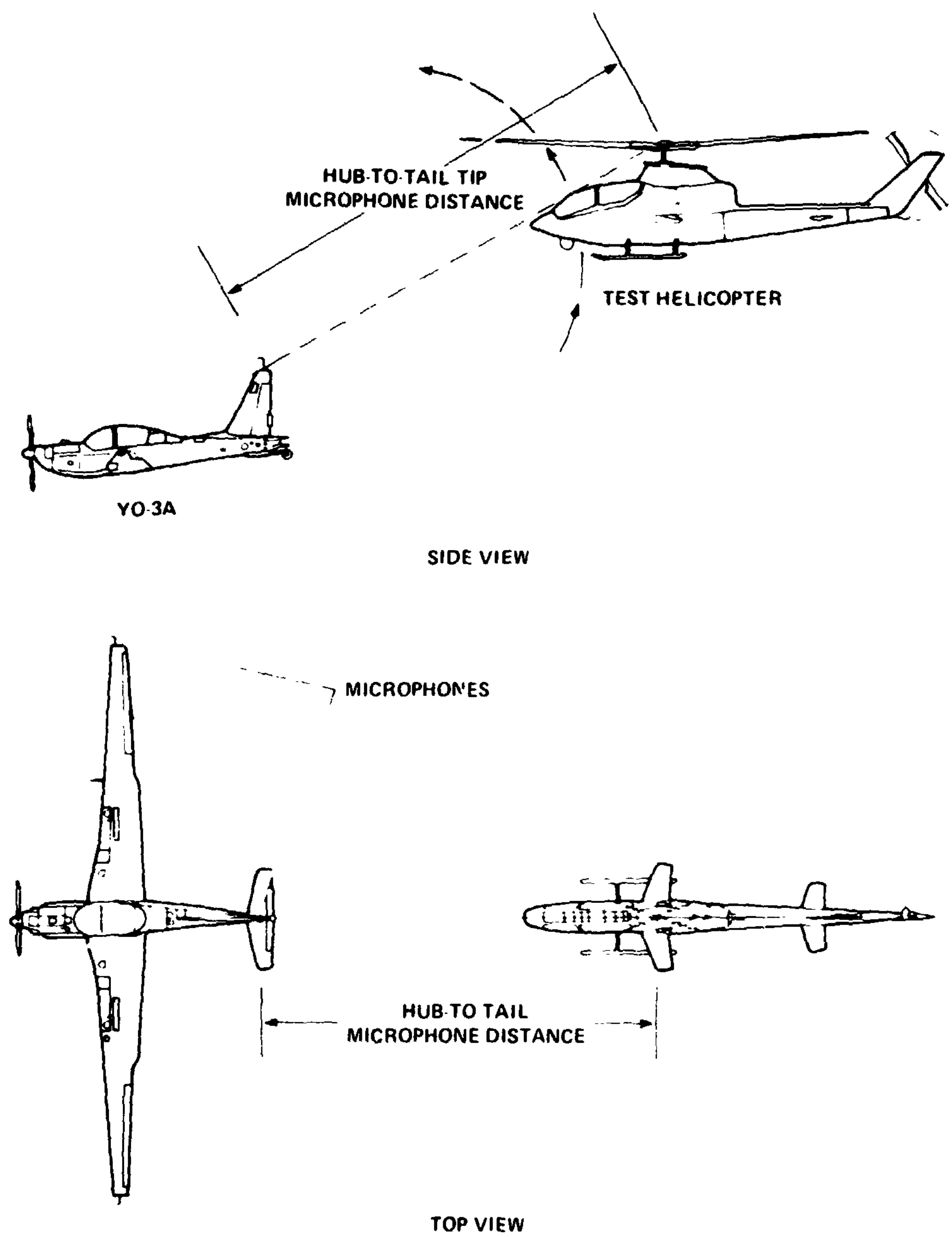


Figure 15.- Experimental sweep.

technique are required. For these points the YO-3A pilot sets up on the airspeed with the test aircraft in close formation, but not trying to hold position. Then with a radio call, the YO-3A pilot noses over to obtain and maintain the specified rate of sink while holding airspeed. The helicopter pilot simultaneously tries to get into proper position. As with level flight, the 1/rev signal is used to indicate that the helicopter is in position. When the test engineer is receiving the 1/rev signal and has been informed by the pilot that they are stable and close to but still above the calculated altitude, the data record is begun. Since each test point lasts for a minimum of 30 sec of data, significant altitude can be lost if the setup is not quickly accomplished.

The test matrix discussed above is flown in such a way as to maintain several nondimensicnal engineering parameters constant: coefficient of thrust, advancing tip Mach number, and advance ratio. By keeping these parameters constant, any acoustic differences between test points must be due to the remaining variables (e.g., rate of descent). Thrust coefficient, defined in equation 1, is kept constant by varying altitude, by keeping track of fuel used, and by assuming rotor thrust equals aircraft gross weight.

$$C_T/\sigma = L/(\rho\pi r^2\Omega^2\sigma) \qquad (1)$$

At each data point, a test altitude must be calculated and held, but during a rate-of-sink test point the data are begun such that the desired altitude is approximately the mean of that run. The advancing tip Mach number and the advance ratio, equations 2 and 3 respectively, are obtained by varying airspeed and main rotor rotational speed.

$$M_t = V/\sqrt{\gamma gRT} \qquad (2)$$

$$\mu = V/\Omega r \qquad (3)$$

These computations cannot be done a priori as neither the fuel use profile nor outside air temperature can be adequately forecast. A routine has been written (appendix D) and programmed into a portable programmable calculator which computes these flight parameters in real time by an observer on the chase aircraft. This minimizes the number of people involved in the test, does not restrict the test area, and maintains a safe number of "eyes" outside the cabins for air traffic identification and avoidance.

The chase engineer, in addition to computing the test points, also performs the bookkeeping duties of the flight card and keeps notes of pilot comments as a supplement to the recorded comments.

CALIBRATION PROCEDURES

A complete calibration of the instrumentation package must be conducted for each new data tape recorded. This is required to convert the data to engineering units during past flight analysis. A calibration checklist is presented in appendix E. Certain instrumentation hardware is needed to calibrate the system, as shown in figure 16.

TABLE 4.- SAMPIE ACOUSTIC TEST MATRIX
AIRSPEED, KNOTS

Rate of sink, fpm	60	80	90	100	110	120	130
0	LTR	LTE	TR	LTE	T	---	---
200	LT	LT	LT	LR	LT	---	---
400	LR	LR	LTR	LTE	LR	TR	---
600	L	LR	L	TR	LT	LT	---
800	LR	LR	LR	L	LT	T	T
1000	---	---	---	---	---	---	T

L = left position
T = Trail position
R = Right position
E = Experimental sweep

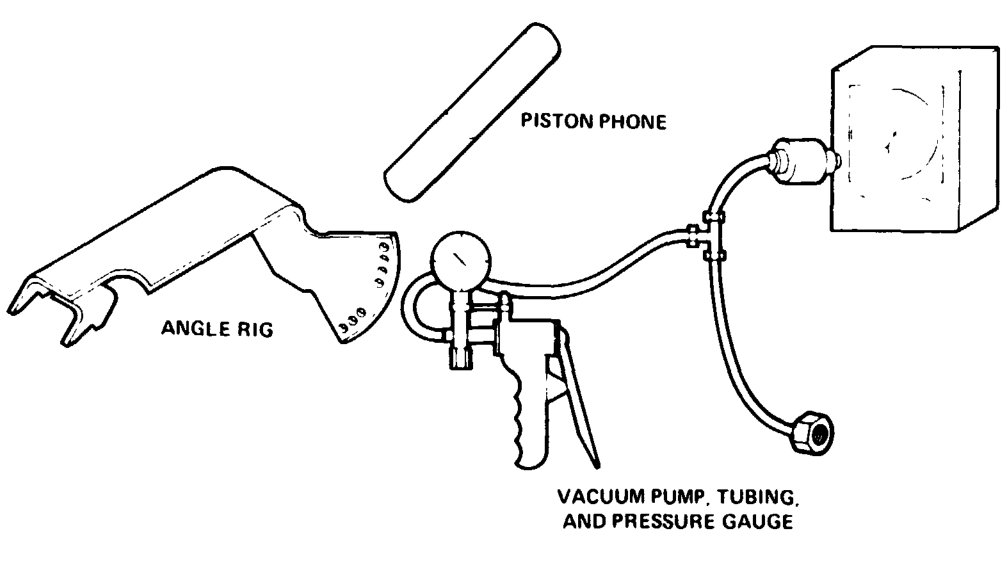


Figure 16.- Calibration Equipment.

CONCLUDING REMARKS

The YO-3A aircraft is used by NASA and Army personnel at Ames Research Center to conduct in-flight acoustic testing of helicopters. This testing technique, proposed and pioneered by the U.S. Army Research and Technology Laboratories Aeromechanics Laboratory, has proven itself to be an extremely valuable research tool in the understanding of helicopter-related acoustic phenomenon. The in-flight testing technique eliminates most of the contaminating factors encountered in other types of external acoustic testing.

This manual documents the instrumentation system, the calibration and test procedures, and the flight testing techniques used when testing with the Acoustic Research Aircraft, and includes a description of the hardware to be installed on the test helicopter.

This in-flight acoustic testing technique requires precision formation flight in order that accurate, repeatable data are obtained. The development and refinement of these formation flight techniques have been a collective effort by the many test pilots who have participated in these tests. Their contributions have been vital to the success of this testing method, and are gratefully acknowledged.

APPENDIX A

YO-3A BACKGROUND NOISE DATA SUMMARY

Background noise data from the YO-3A Acoustic Research Aircraft is presented here, in the form of third octave plots. These sample data are provided as a means of illustrating the facility's capabilities, not rigorously documenting its acoustic characteristics.

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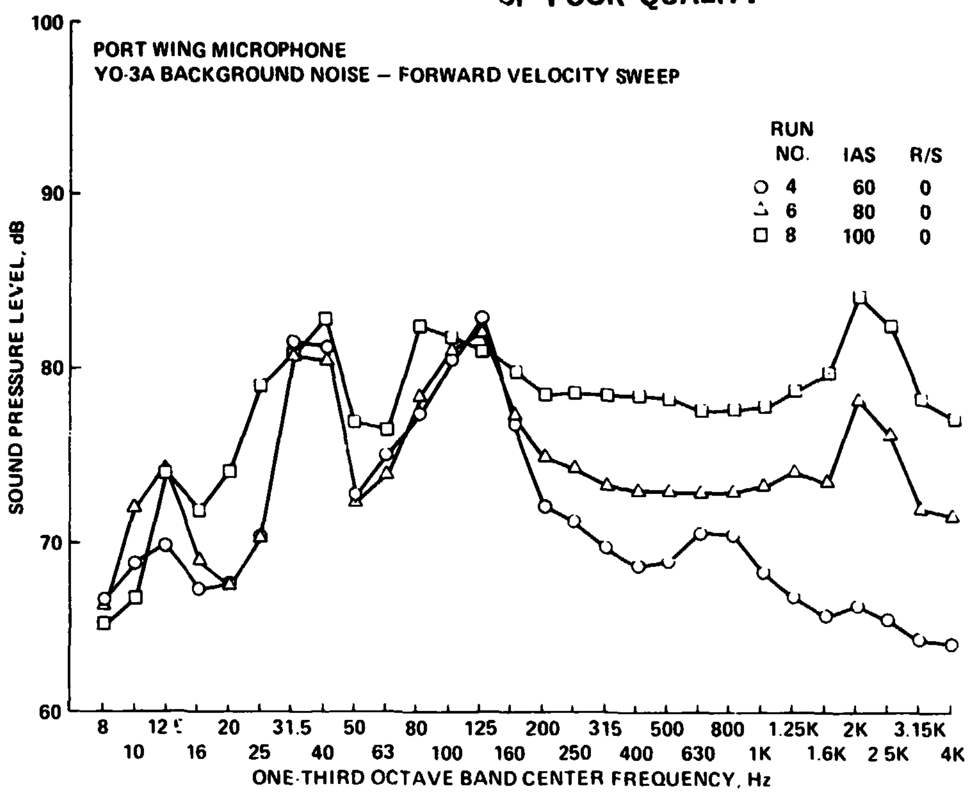

Figure A1.- Port microphone noise levels in level flight.

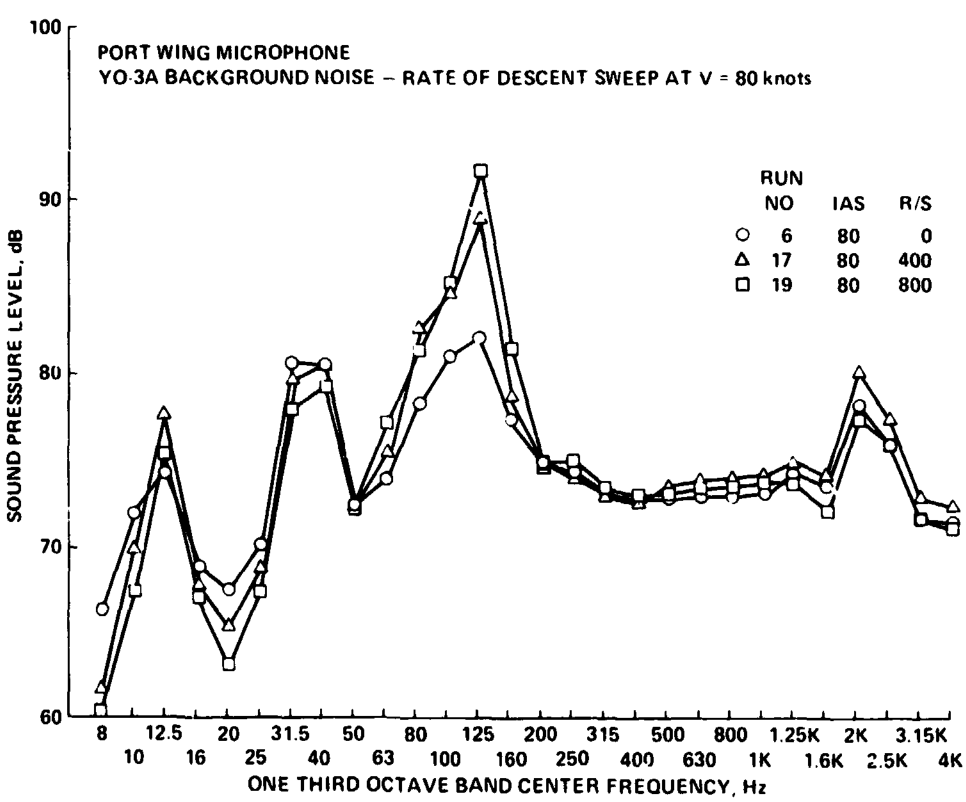

Figure A2.- Port microphone noise levels in descent.

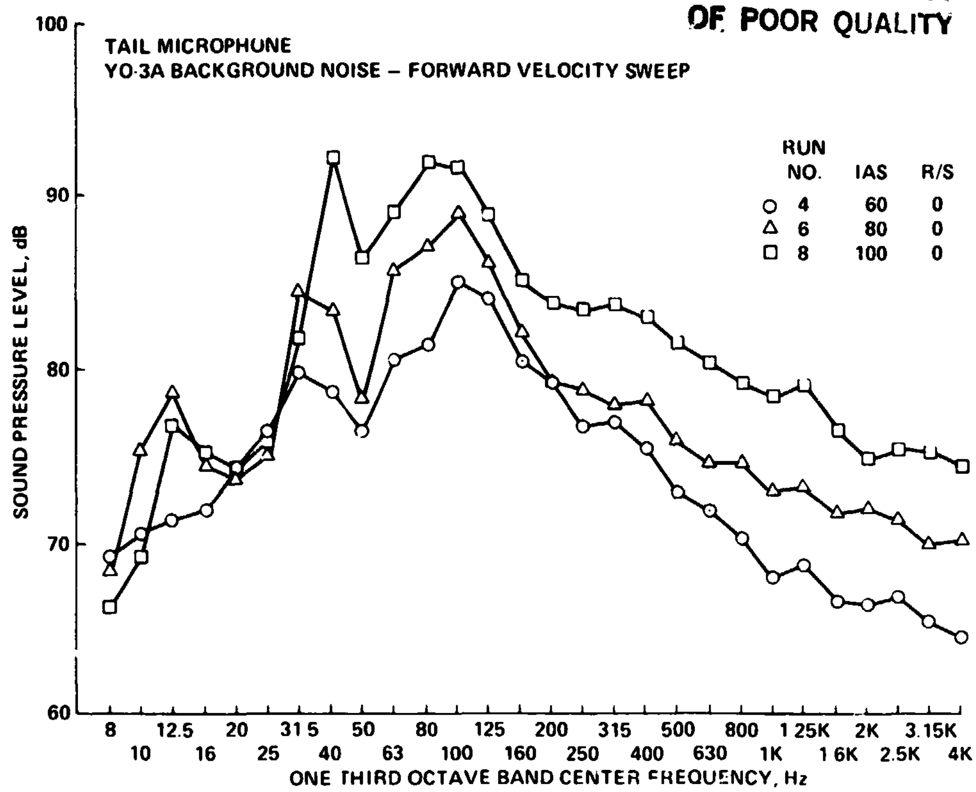

Figure A3.- Tail microphone noise levels in level flight.

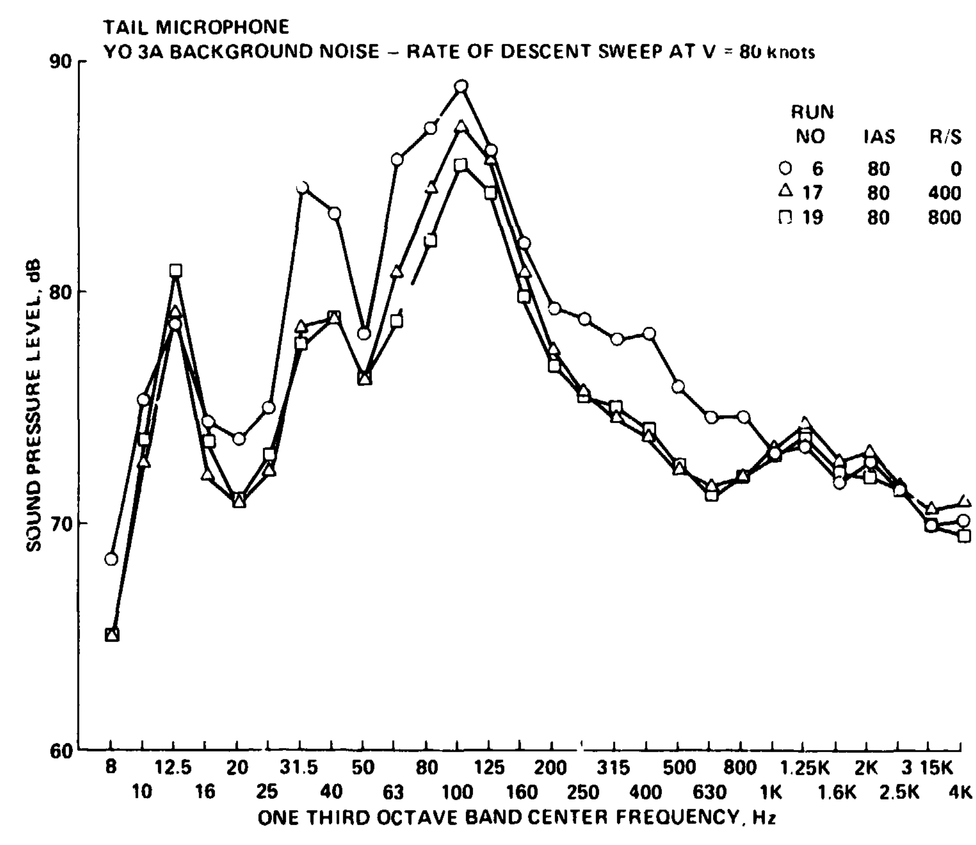

Figure A4.- Port microphone noise levels in descent.

APPENDIX B

REQUIREMENTS LIST FOR TEST AIRCRAFT FLOWN WITH THE ACOUSTIC RESEARCH AIRCRAFT

1. Installation of 1/rev pickup in the hub area.

2. Installation of encoder/transmitter package, including connection to power source, 1/rev sensor, and on/off switch.

3. Installation of antenna, including hookup with encoder/transmitter.

4. VHF and UHF communication radios.

5. Means of obtaining accurate fuel usage data in real time.

In order to obtain quality research acoustic data, it is desirable to maintain certain nondimensional coefficients constant. To this end, the test aircraft gross weight must be accurately known. The test aircraft should be measured for weight and balance prior to the test. Accurate fuel use information is essential. The fuel gage should be accurately readable to 1 gal of fuel per 300 lb of aircraft gross weight. If the fuel gage is not adequate, it is possible to use performance charts of engine torque as fuel rate to improve the accuracy of the gage reading.

APPENDIX C

FLIGHT TEST ENGINEER'S CHECKLIST

The flight test engineer aboard the YO-3A has many responsibilities during a test. The following checklist is provided to ensure that each action is done correctly and in the proper order.

Preflight

0. Install new tape in recorder
1. Ensure that bullet nose cones are securely mounted on all microphones
2. Ensure that all power switches at the engineer station are off
3. Ensure that static ports on instrument boom are clear

4. After the YO-3A has cranked up, pilot switches on instrument power.

5. Power up all instruments at flight test engineer station.

6. Have test aircraft turn on 1/rev; check reception of signal on channel 4 with scope.

7. With test aircraft practicing formation flying, check microphone gain settings with scope levels.

8. When in test area, check time code reception on channel 5.

9. When ready to begin testing, radio outside air temperatures (OAT) reading to chase engineer for computation of test point. Enter the calculated test condition on flight card.

10. Check gain setting and signal levels as test aircraft gets in position. Have YO-3A pilot give verbal signal when "on condition." Check 1/rev channel 4, for signal from test aircraft that they are in position.

11. When test point is obtained, start tape and timer. Announce "Tape is running for flight number 10, run number 15, 100 knots, 600 down, tail position" as an example.

12. Constantly check the signal levels on the microphone channels, adjust the gain settings if signals reach saturation levels. Record any gain setting changes on flight card.

13. After 30 sec of data announce, "End of data, ready for pilot comments, . . ., end run ____." Stop tape and timer.

14. Repeat the procedure from step 9 for the remaining test points.

15. After the last test point, shut off all equipment at test engineer's station

16. Pilot shuts off instrument power.

APPENDIX D

PROGRAM LISTING OF TEST POINT COMPUTER PROGRAM

Altitude calculation

Step	Operation
24	Label A
25	Recall 05
26	÷
27	Recall 10
28	×
29	(
30	Recall 21
31	-
32	Recall 03
33	)
34	÷
35	Recall 07
36	=
37	Store 13
38	Y^x
39	0.19
40	-
41	1
42	=
43	Change sign
44	÷
45	6.876EE-06
46	=
47	Stop

RPM calculation

Step	Operation
48	Label B
49	((
50	Recall 02
51	+
52	Recall 12
53	)
54	÷
55	Recall 11
56	)
57	Store 14
58	$\sqrt{x}$
59	÷
60	((
61	Recall 06
62	+
63	Recall 12
64	)
65	:
66	Recall 11
67	)
68	$\sqrt{x}$
69	×
70	Recall 09
71	=
72	Stop

Velocity calculation

Step	Operation
73	Label C
74	Recall 13
75	$\sqrt{x}$
76	÷
77	(
78	Recall 14
79	×
80	Recall 01
81	)
82	$\sqrt{x}$
83	×
84	Recall 04
85	=
86	Stop

Temperature conversion

F to C

Step	Operation
1	Label 0
2	-
3	32
4	=
5	×
6	5
7	÷
8	9
9	=
10	Store 02
11	Stop

Storage addresses

Storage	1	Density ratio, reference
	2*	Outside air temperature
	3*	Pounds fuel used since takeoff
	4*	Desired true airspeed
	5	Reference pressure
	6	Reference temperature
	7	Reference A/C weight
	9	Reference RPM of main rotor
	10	Pressure, sea level standard
	11	Temperature, sea level standard
	12	Degrees Kelvin conversion
	13	Calculated scaling ratio
	14	Calculated temperature ratio

*Updated inputs for each new test point

APPENDIX E

CALIBRATION CHECKLIST

1. Install microphones with flat screen covers on amplifiers located on aerodynamic struts on wing tips and vertical tail. Serial numbers of microphones and the location of installation must be noted. Subsequent installations of the microphones must match this record.

2. Install ground power plug into aircraft. Check that pilot's power switches are off before turning ground power on.

3. Tape over the static ports on the instrument booms pilot-static tube. Install headsets at both crew stations. Failure to install both headsets results in no voice recording. Set radio selector to intercom position.

4. Remove the "T" plug, and attach vacuum hose to "T' joint in plumbing in instrumentation bay behind pilot's seat. Attach the remaining end of the vacuum hose to the suction port on the pressure gage. Location of "T" fitting shown in figure E1.

5. Turn on the pilot's power switch, figure E2 (upper left hand corner of bottom panel) and power up all instrumentation.

6. Remove lid on recorder and install tape reel. Consult instructions on lid for detailed direction. Replace lid and secure.

7. Pump down the pressure transducers several times to warm up hoses and flex the transducers to eliminate any hysteresis. Do not exceed 0.7 psia during this step.

8. Pump down both total and static pressure transducers to the proper pressure (0.1, 0.3, 0.55 psia). When at the correct value, clamp the hose section attached to the hand pump. After checking that pressure setting is holding, proceed as follows from test engineer's seat in cockpit.

   a. Turn on tape; watch for "lock-on" light, timer should keep track of elapsed time.

   b. Using headset and microphone switch, note the pressure value, transducers, and digital temperature reading.

   c. Allow 5 sec of data, then stop recorder.

   d. Proceed to next pressure value and repeat steps a through d.

9. Remove top hose from "T" joint and attach vacuum hose to that leg of "T." Replace "T" cap on the side "T" leg. Install single pot clip into temperature calibration plug and engage calibration mode. The OAT gage should now display a reading of approximately 30° F. The total pressure transducer has now been disconnected, leaving just static pressure.

10. Repeat step 8 with pressure settings of 0.55, 1.0, and 2.0 psia. Never exceed a pressure of 2 psia on this transducer.

19. Perform the following checks to ensure readiness to test.

  a. Static ports on instrument boom clear of tape.

  b. "T" joint plumbing proper, secure, and tight.

  c. Bullet cones on all three microphones.

  d. OAT display switched to test position.

  e. Scope shut off.

  f. Microphone power supplies shut off.

  g. Recorder power shut off.

  h. Pilot's power switch shut off.

  i. Switch scope to external trigger.

  j. If calibration is performed at end of flight, the microphones should be removed and stored in their proper boxes, and plastic protective caps put over amplifiers.

  k. Disconnect power plug from aircraft.

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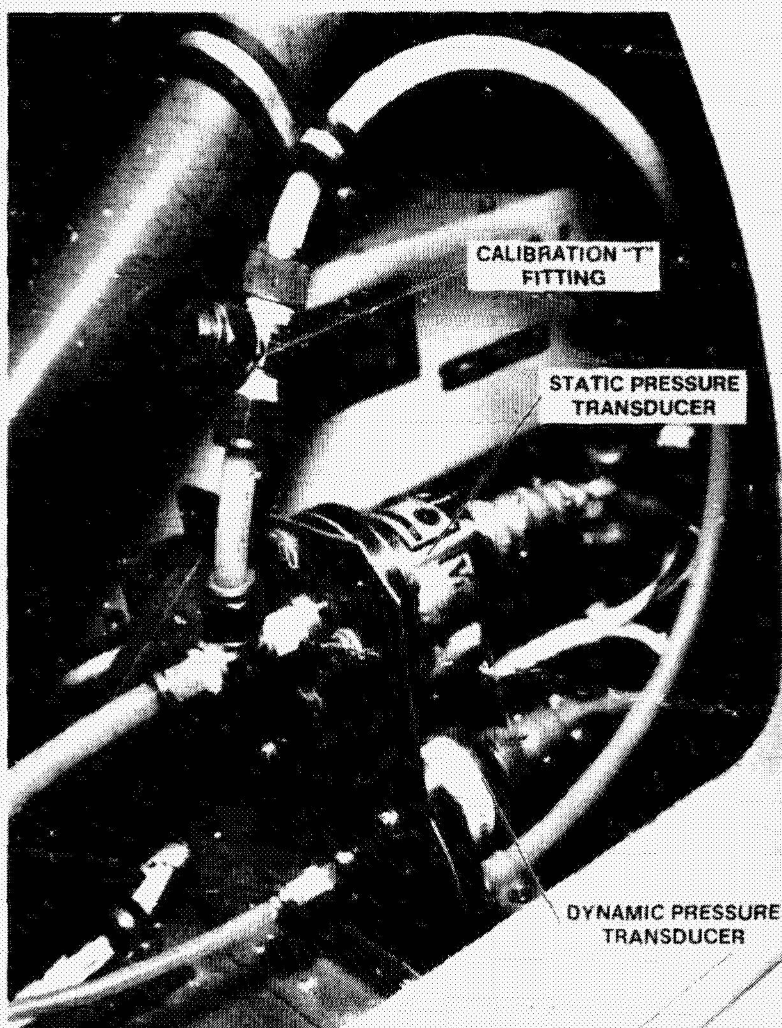

Figure E1.- Calibration "T" fitting location.

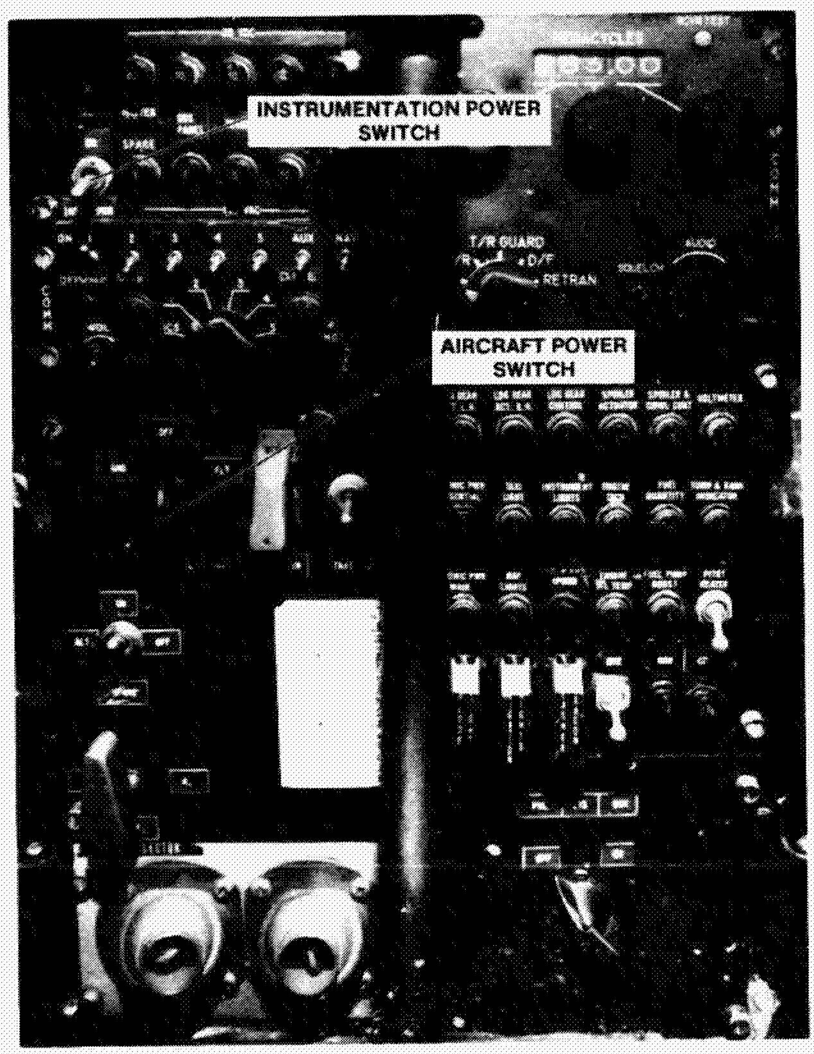

Figure E2.- Pilots instrument panel.

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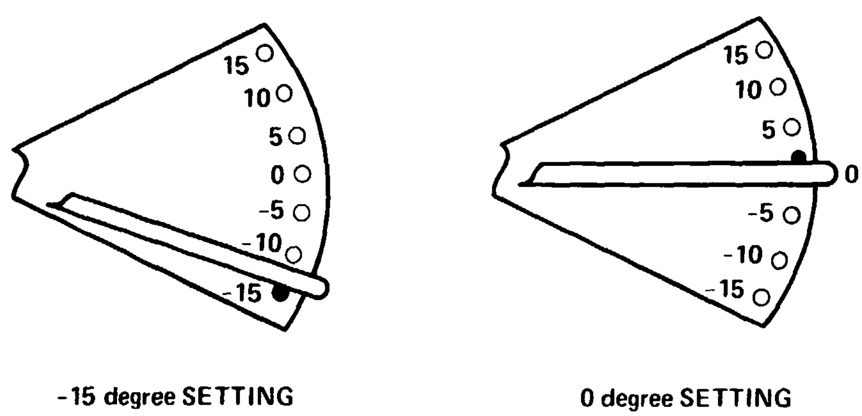

Figure E3.- Angle rig use.

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