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SIMULATED GROUND-LEVEL STOL RUNWAY/AIRCRAFT EVALUATION PHASE III TESTS

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16. Abstract

A De Havilland DHC-6 Series 100 Twin Otter was flown by five pilots of varied experience on 7.5° steep-gradient approaches onto a ground-level STOL runway. Forty (40) approaches and landings were accomplished using an angle-of-attack indicator (airspeed indicator blocked out) as primary speed control. Pilot performance as compared to performance with the airspeed indicator as primary speed control was slightly improved. A series of 6° steep approaches was made in simulated certification landing tests with dry and wet runways at various water depths. Runway friction, stopping, and landing distances were measured, and stopping distance ratios are shown. Maximum vertical touchdown velocities on steep approaches were also evaluated.

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INTRODUCTION

PURPOSE.

A project was conducted at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, to investigate light wing-loading factors not covered in previous tests (reference 1), associated with the approach and landing of a first-generation short takeoff and landing (STOL) aircraft operating from a simulated ground-level STOL runway. Three tests were conducted: test I, to measure pilot performance using an angle-of-attack indicator for approach guidance in comparison to previous results in reference 1 using an airspeed indicator; test II, to evaluate aircraft performance under simulated certification landing conditions (during steep approaches) on both wet and dry runways; and test III, to evaluate the vertical touchdown velocity on 7.5° glide slope using a larger sample than contained in reference 1.

BACKGROUND.

The interest in reducing congestion at conventional airports and providing the public with safe, quiet transportation for the high and/or low-density, short-haul market indicates the possible development of a STOL system. One basic part of such a system is a viable means of accomplishing instrument approaches and landings to STOLports. The STOL aircraft to be effective must be capable of making steep approaches, often in congested areas, and at low speeds in order to land on the short runways envisioned.

In phase I, the Federal Aviation Administration (FAA) conducted a cursory evaluation of approach, landing, stopping, and the departure characteristics of five different STOL-type aircraft.

Phase II of this project (reference 1) was devoted to acquiring data to establish approach, missed approach and takeoff obstacle clearance planes, touchdown dispersion, threshold crossing height, required runway length and width, decision height, etc. for the De Havilland Twin Otter (figure 1). The data was obtained under the following conditions:

1. VFR and IFR
2. Localizer offset and centered
3. Glide slope angles of 4°, 6°, and 7.5°
4. Day and night
5. Command-steering and raw data
6. FAA and commuter airline pilots as subjects

Phase II test results indicated that a De Havilland DHC-6, Series 100, Twin Otter, or similar class aircraft, could be operated onto a STOL runway 1,800 feet long and 100 feet wide, with 100-foot overruns at each end, on glide slope angles up to 7.5° with guidance colocated to the side of the runway with skew angle up to 6° to a decision height (DH) of 200 feet.

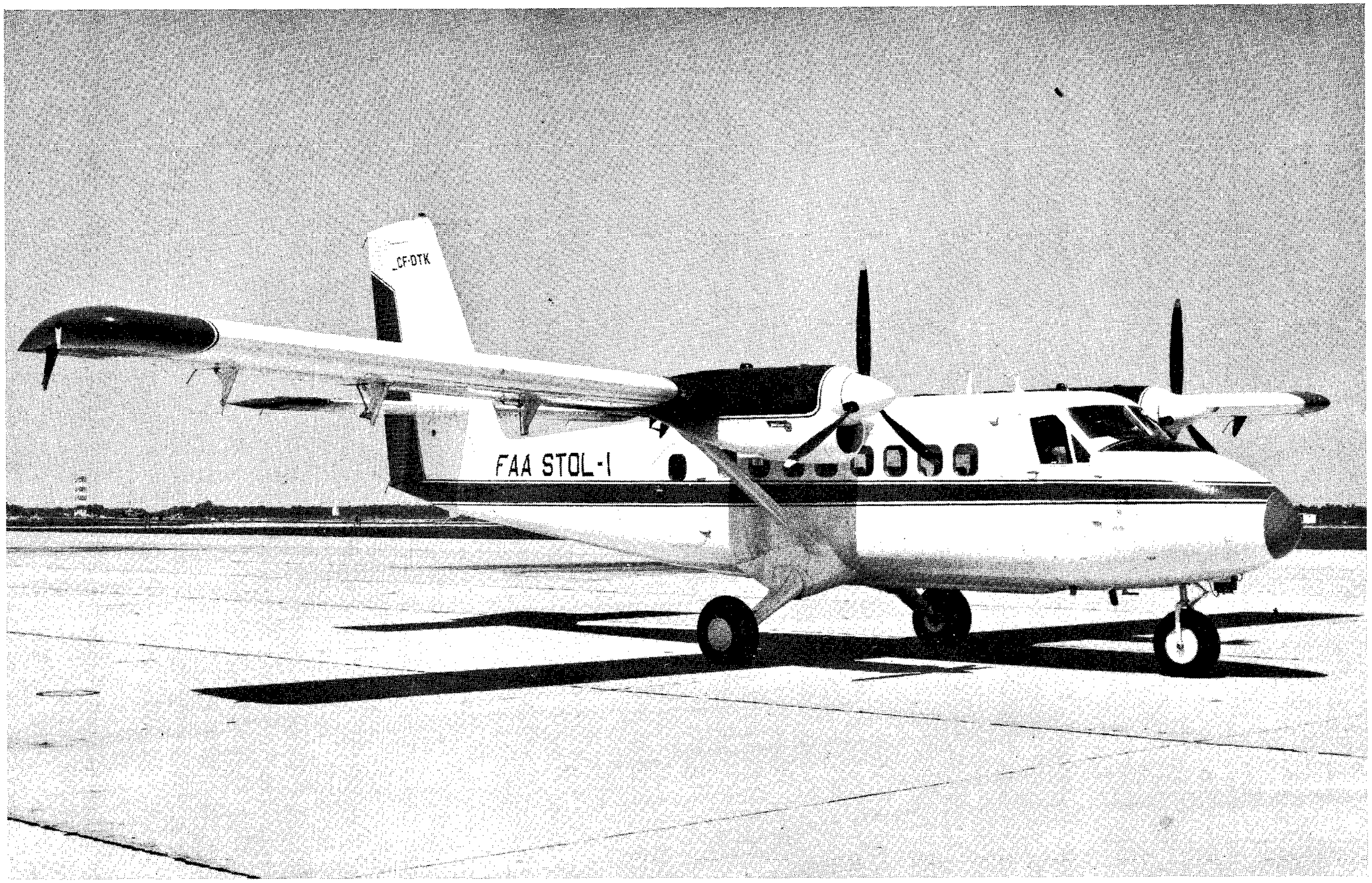


FIGURE 1. DE HAVILLAND TWIN OTTER (DHC-6) AIRCRAFT

This report (phase III) continues the effort of evaluating pilot performance using the De Havilland Twin Otter to determine the effect of wet and dry runways on landing distances, the effect on pilot performance with the use of an angle-of-attack indicator during steep approach as compared to airspeed as a primary reference, and vertical touchdown velocities.

DESCRIPTION OF EQUIPMENT AND FACILITIES.

TEST AIRCRAFT. The De Havilland Twin Otter Series 100 aircraft (figure 1) has the following general specifications:

1. WEIGHT : 11,579 lbs max takeoff; 11,000 lbs max landing.

2. ENGINE : (2) PT6A - 20 (550 ESHP) United Aircraft of Canada.

3. PROPELLERS : (2) HC - B3TN-3, three-blade Hartzel. Fully controllable through reverse pitch.

4. FLAPS : Full span, double-slotted flaps. Deflection 0° to 37.5°.

5. WING LOADING : 26.2 lb/sq ft. Area: 420 sq ft.

6. CERTIFICATED : to FAR-23 and SFAR-23.

7. CRUISE SPEED : 165 knots.

8. STALL SPEED : 57 knots (V_{SO}) (Sea Level, maximum weight).

9. APPROACH SPEED: 74 knots ($1.3V_{SO}$).

RUNWAY 17-35 (STOL RUNWAY). The ground-level test STOL runway was established on runway 17-35 at NAFEC (figures 2 and 3) in accordance with the specifications detailed in Advisory Circular, AC 150/5300-8, "Planning and Design Criteria for Metropolitan STOLports," dated November 1970. Included in this layout was a 7.5° visual approach indicator (2-box VASI) approach lighting system.

The STOL runway, as laid out, was 1,500 feet long, 100 feet wide, with 20-foot by 200-foot aiming marks, 250 feet from the threshold of each end. The overruns at each end were 150 feet.

RUNWAY 13-31 (WET/DRY TESTS). The "31" end of this runway was used for the simulated certification stopping distance tests (test II) because a survey of friction measurement on all NAFEC runways indicated that this section of runway had the most consistent friction measurements. The landing surface was of macadam and had been resurfaced within the past 12 months.

APPROACH/LANDING GUIDANCE. For the angle of attack indicator tests (test I), a modular instrument landing system (MODILS) was used to provide electronic guidance during the instrument flight rules (IFR) approaches on a 7.5° glide slope.

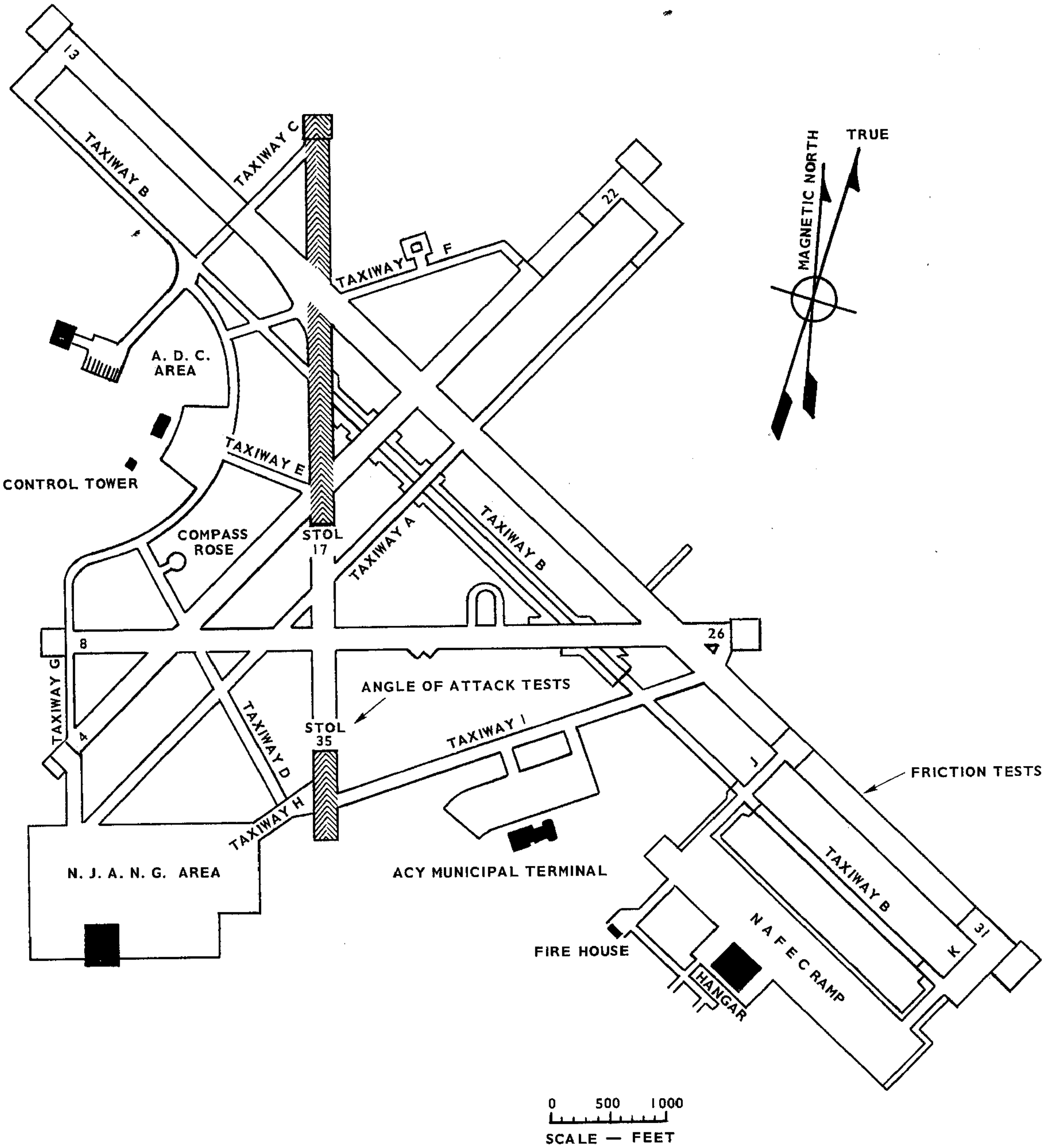


FIGURE 2. STOL RUNWAY LOCATION AT NAFEC

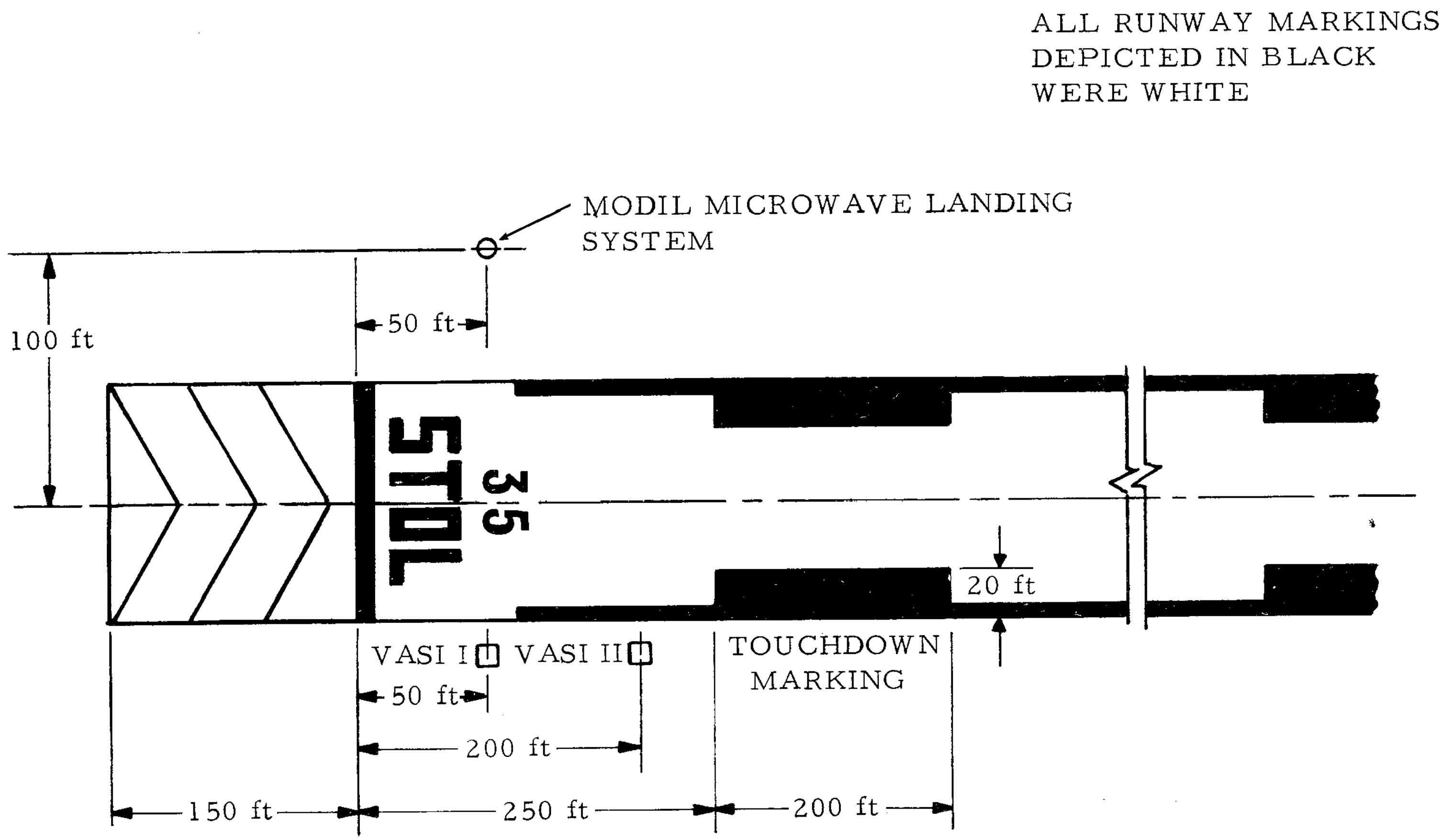


FIGURE 3. TEST STOL RUNWAY AT NAFEC

For the simulated certification landing distance tests (test II), a VASI system was used to establish a 6° approach angle desired for these approaches.

The MODILS. The MODILS (figure 4) is an integrated microwave landing system (MLS) consisting of localizer, glide slope, and distance measuring equipment (DME), operating at 5.2 GHz (C-band) designed for the FAA for V/STOL operations. The location of the MODILS can be seen in figure 3. The localizer monitor antennas are located 40 feet in front of the MODILS building.

The glide slope monitor antennas are mounted on a 25-foot pole, 100 feet in front of the transmitter. For these tests the localizer beam width was set at ±5.0°, and the glide slope at ±2.0° sensitivities.

AIRBORNE RECORDING INSTRUMENTATION. The following parameters were recorded on the airborne recorder in the aircraft:

1. Real time - coordinated with the theodolites.
2. Landing gear touchdown time.
3. Voice channel (all channels were time-correlated with real time).

GROUND INSTRUMENTATION. There was a temporary ground weather observation station adjacent to and 100 feet off the runway at the touchdown zone and at 6-feet elevation. Observations were made just prior to each landing run and included:

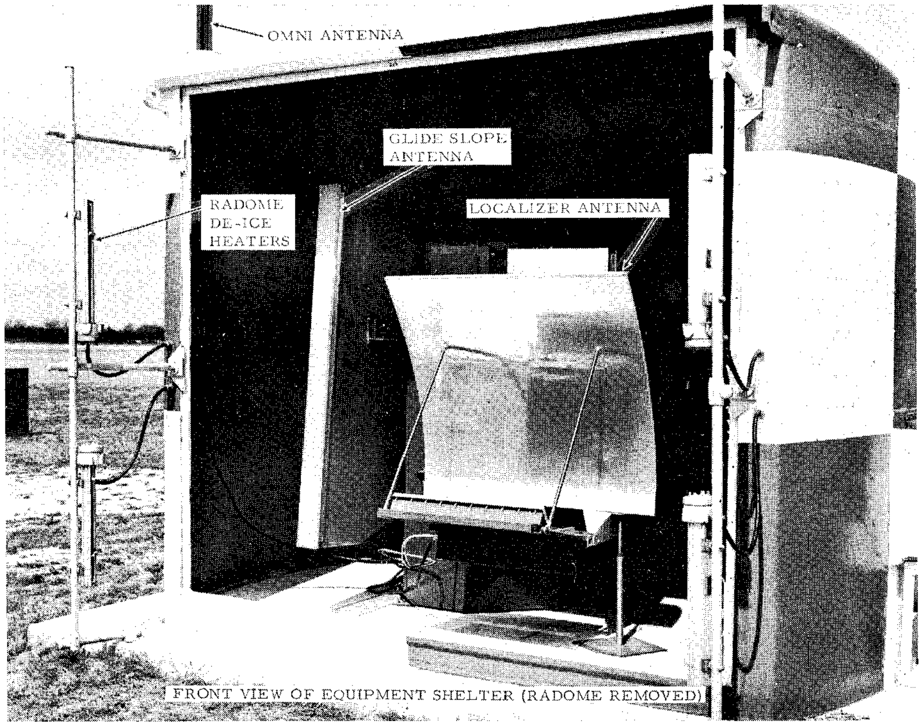
1. Ambient temperature.
2. Ambient pressure.
3. Surface wind velocity.
4. Surface wind direction.
5. Water depth on runway during wet tests.

A National Aeronautics and Space Administration (NASA) water depth gauge measured water depth from .010 inch to .100 inch. Water measurements were taken by the ground weather personnel. Measurements were taken at five locations in the touchdown and stopping area of the runway just prior to each landing. Starting at the touchdown aiming marks, water depth readings were taken down the runway every 200 feet in the stopping area of the runway.

THEODOLITES. The aircraft position in space and on the runway throughout the takeoff, and from turning base to touchdown, rollout, and stop was determined by use of the NAFEC theodolites. The theodolite accuracy was ±1 foot at touchdown in the x, y, and z axes.

COMM/NAV AVIONICS. The aircraft was equipped with normal communications, very high frequency omnirange (VOR), ILS, automatic direction finder (ADF), and 4096 transponder (figures 5, 6, and 7).

A switching arrangement was provided to substitute one MODILS receiver for the aircraft's conventional ILS equipment. This meant that the test receiver in the cockpit could drive the pilot's instruments, including the flight director, for an instrument approach to a runway equipped with a standard ILS System or MODILS/MLS transmitter.



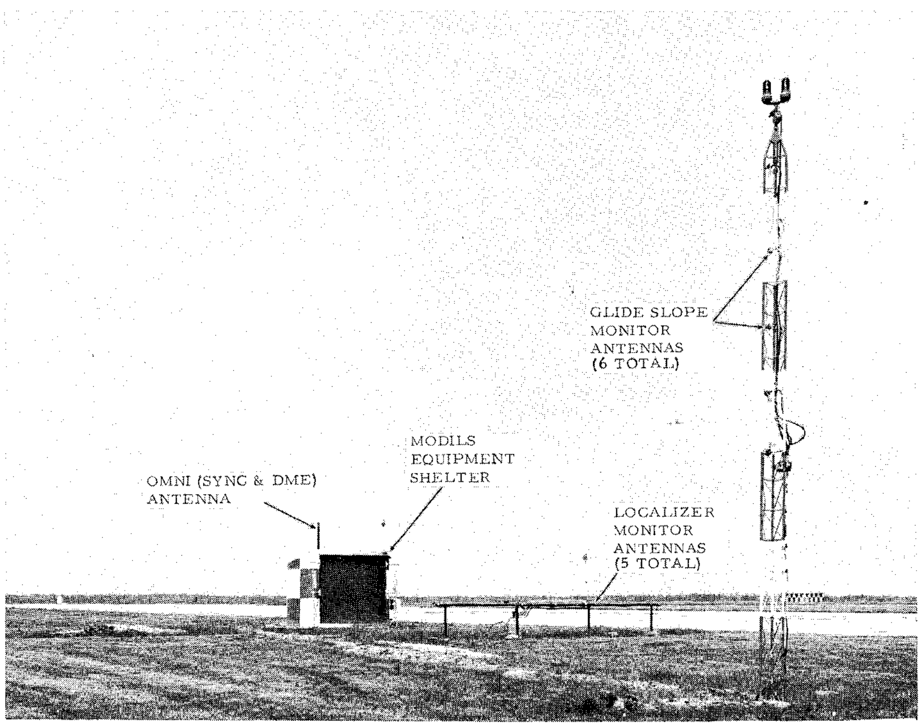


FIGURE 4. MODILS GROUND STATION

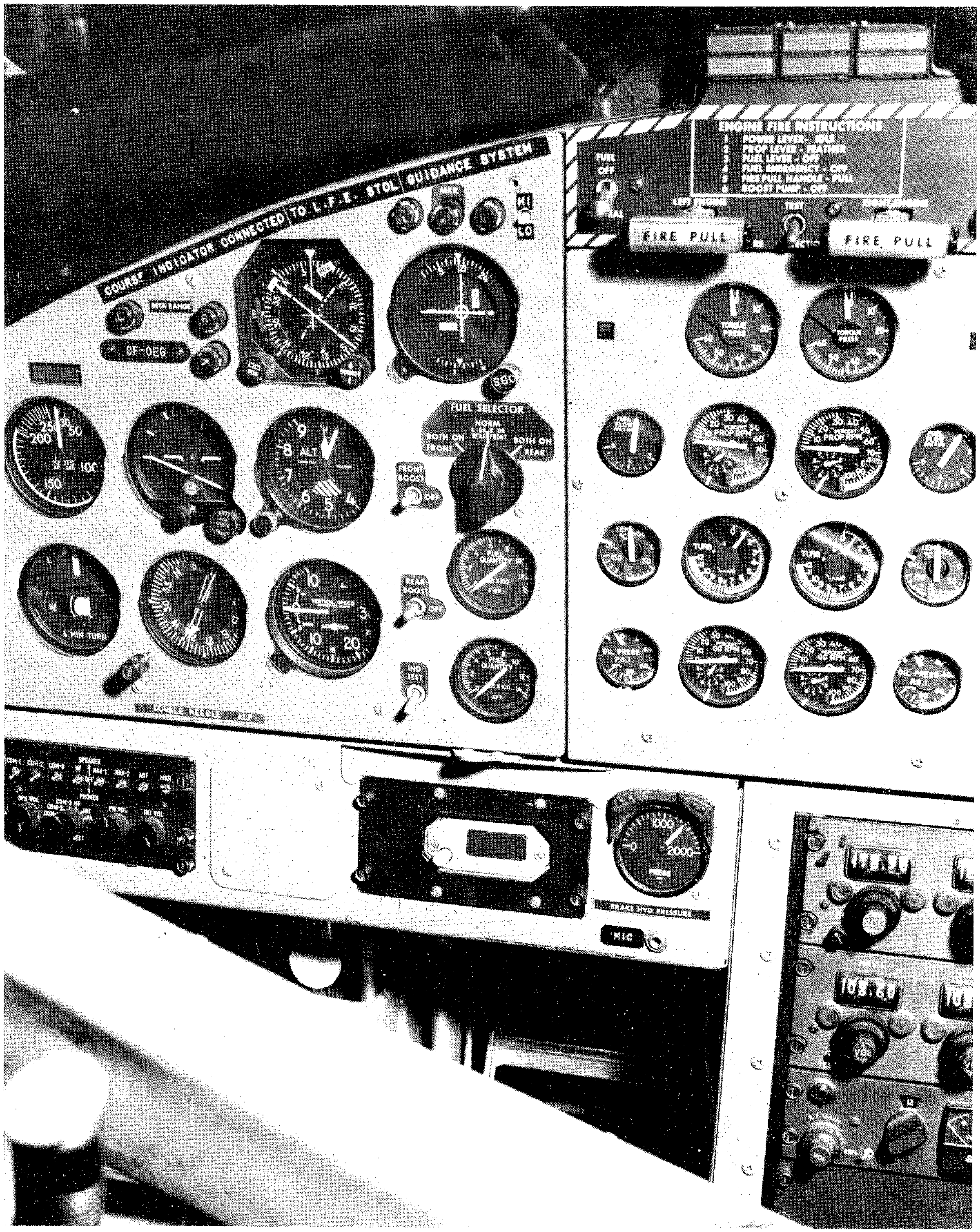


FIGURE 5. TWIN OTTER - STANDARD INSTRUMENT PANEL - PILOT SIDE

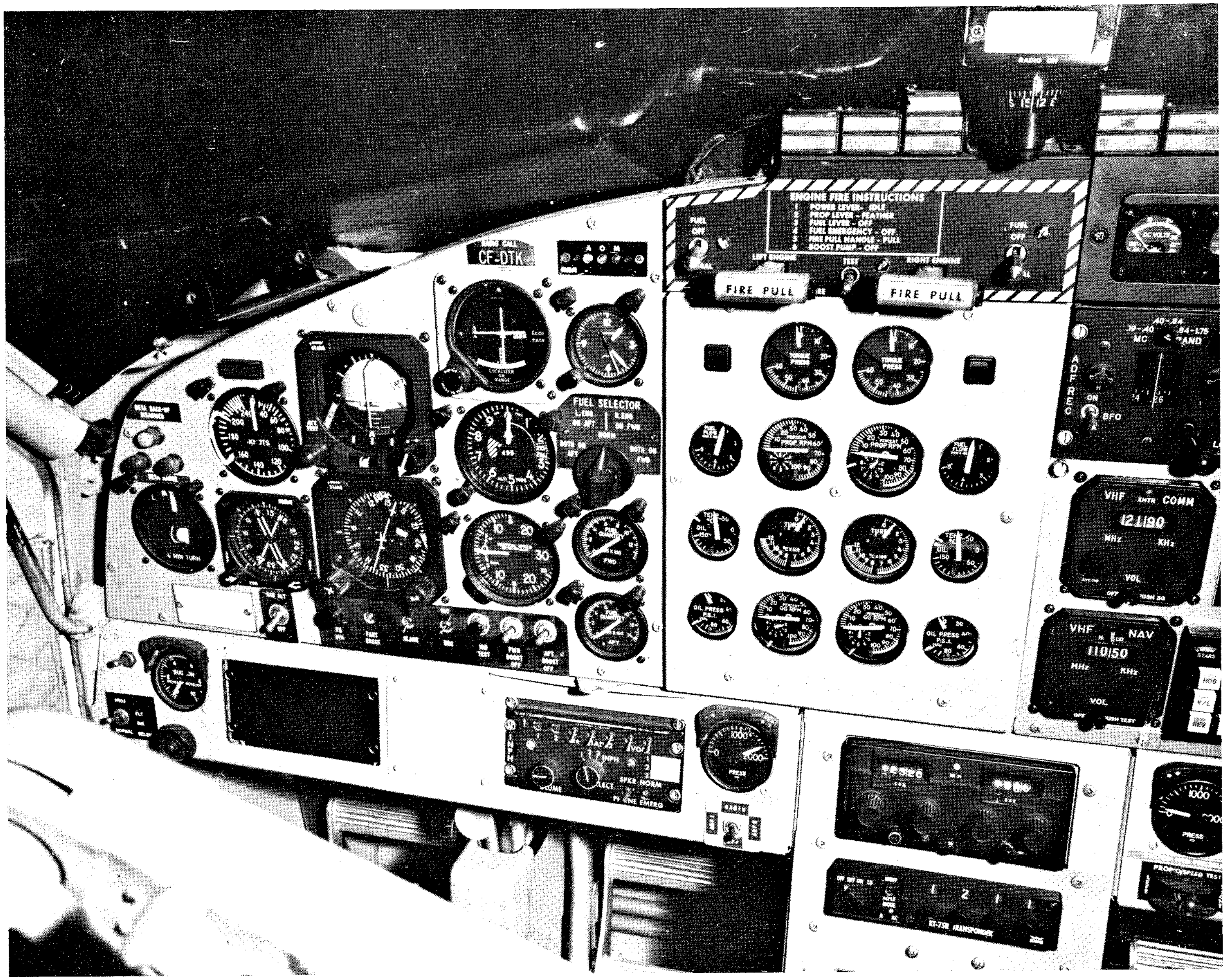


FIGURE 6. TWIN OTTER WITH FLIGHT DIRECTOR PANEL - PILOT SIDE

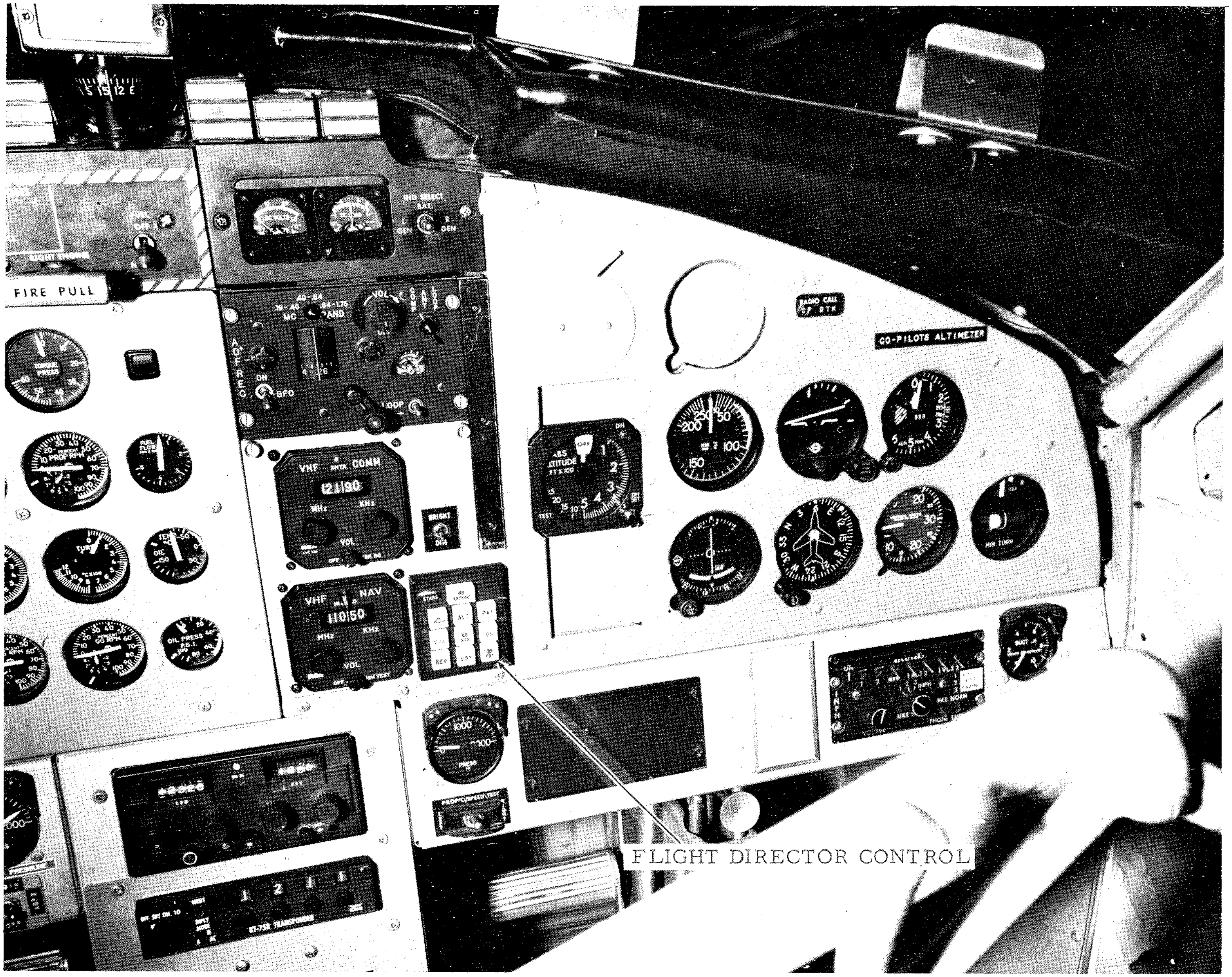


FIGURE 7. COPILOT PANEL SHOWING FLIGHT DIRECTOR CONTROL

ANGLE-OF-ATTACK INDICATOR. The angle-of-attack indicator used for these tests was a Teledyne Avionics, Specialties Division, instrument (figure 8). The installation had a 50° probe (50° travel, stop to stop) and was used with a 30-unit indicator (1.67 units/degree). The readout was a round panel-mounted instrument. The system consisted of a transmitter, a panel-mounted indicator, an indexer, and an interface unit. The indicator was calibrated to indicate the approach angle-of-attack when pointing to the 3 o'clock position, which was equivalent to a speed of 1.3 V_{SO}.

It was not intended to evaluate the Teledyne Angle-of-Attack Indicator, per se, but only to evaluate pilot performance with the use of this type of angle-of-attack indicator versus use of an airspeed indicator for speed control.

FLIGHT DIRECTOR. The Sperry "STARS" flight director used is a three-axis reference system that utilizes the VOR localizer and glide slope data furnished by standard navigation receivers. Altitude data are received from an altitude control sensor, heading data from the directional gyro, and attitude data from the vertical gyro. Using this information, the system computed steering commands which were displayed on the pitch and roll flight director command bars (on the instrument display) to guide the aircraft along a selected flight path.

WET/DRY INSTRUMENTATION. During simulated certification landing tests on runway 31, a friction measurement was made with the FAA Diagonal Brake Vehicle (DBV) just prior to aircraft landing on each run.

The NAFEC DBV is a 1968 Chrysler Station Wagon (figure 9) equipped with a high-performance engine for fast acceleration, power steering, power brakes, and dual fifth-wheel systems to provide two sets of speed and stopping distance information. The braking system was modified to permit diagonally opposite wheels to be braked while the other diagonal pair remained unbraked. This diagonal braking technique enables the DBV to perform locked-wheel skids at high speeds on very slippery surfaces and maintain good directional control while being braked to a complete stop. The braked wheels of the test vehicle are equipped with American Society for Testing Materials (ASTM) tires, specification E-249, size 7.50 X 14, smooth tread (bald tire) configuration, inflated to 24 pounds per square inch (lb/in^2) pressure. The use of ASTM tires on the braking wheels of the DBV eliminates effects caused by tread wear and tread design. The unbraked wheels are equipped with production tires having good tread design to insure directional control.

Stopping distance of the test vehicle is measured by electronic digital readout meters which are actuated by the brake application switch. The meters record the stopping distance in feet from brake application to vehicle stop.

During the test runs, the vehicle was accelerated to a speed slightly above 60 mi/h whereupon the driver shifted the transmission to the neutral position, and diagonal wheels were locked at 60 mi/h. In evaluating pavement surface friction, DBV tests were conducted for both dry and wet surface conditions.

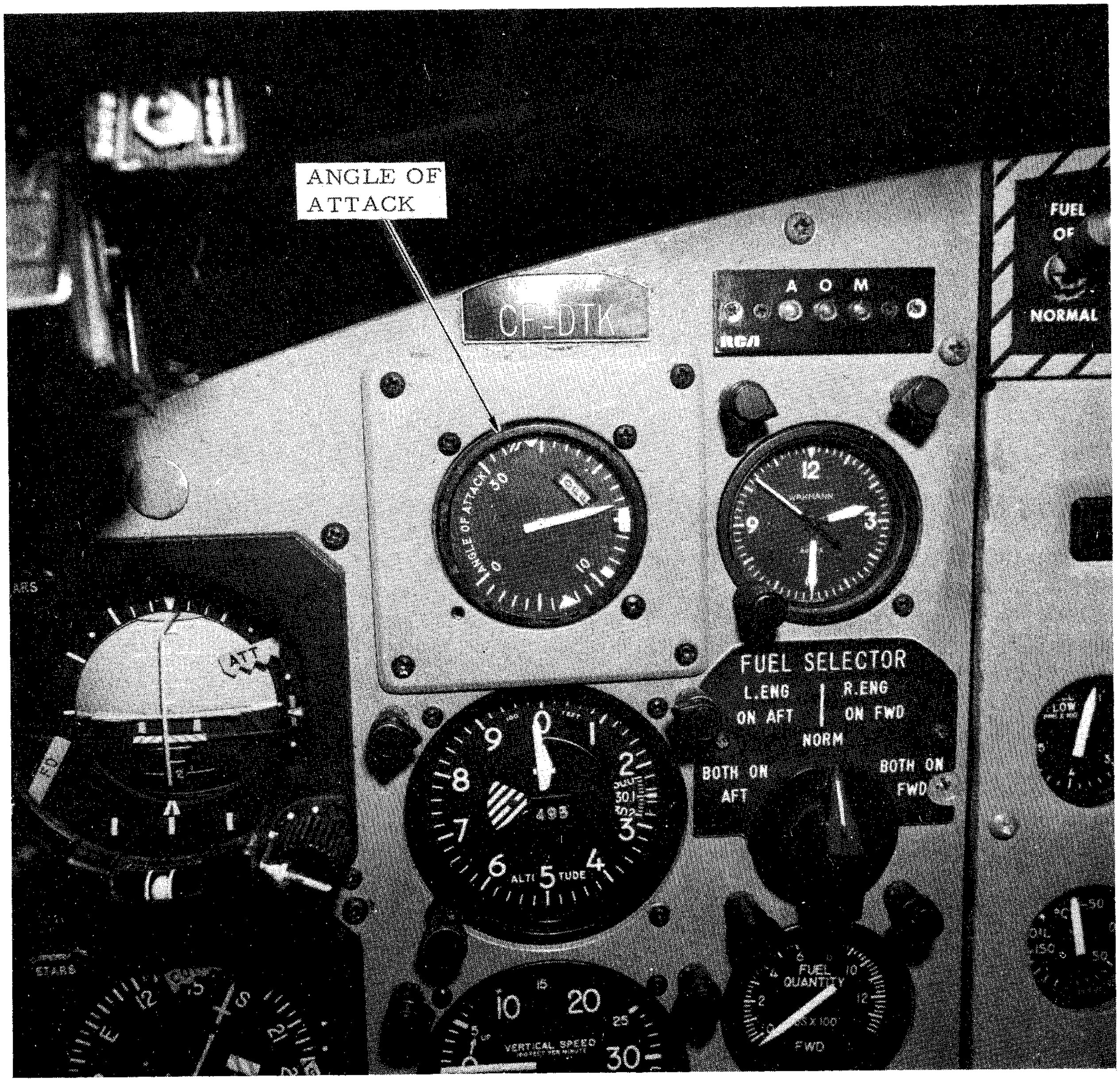


FIGURE 8. ANGLE-OF-ATTACK INDICATOR

FIGURE 9. THE DIAGONAL BRAKING VEHICLE