ADVANCED TURBOPROP INSTALLATION AERODYNAMICS

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PROBLEM DEFINITION

The expected aerodynamic effects of a propfan installed on a thick supercritical wing are summarized qualitatively on this figure.

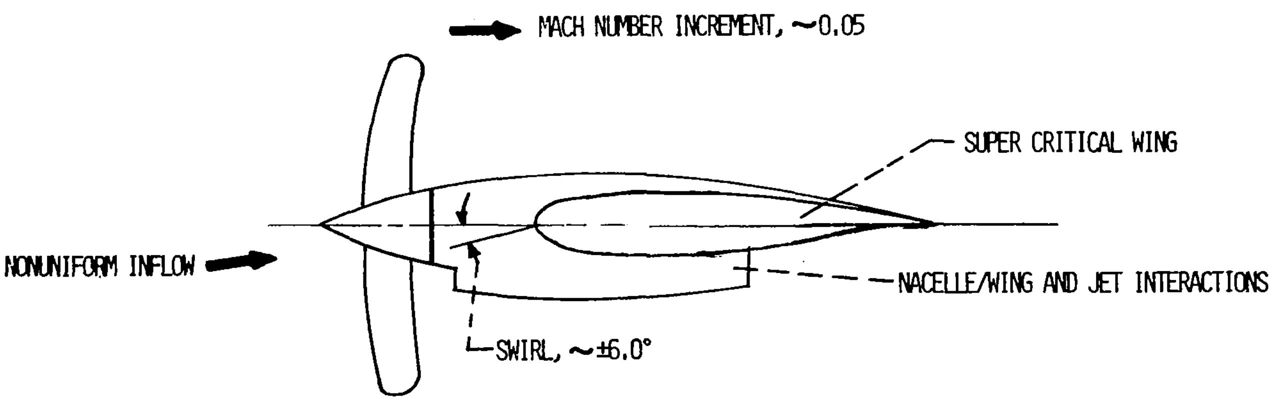
Nacelle/wing and jet interactions.- The nacelle/wing interaction affects the local profile drag and induced drag by altering the basic-wing pressure distribution in the vicinity of the nacelle. This effect can be minimized by proper contouring and filleting. The jet adds a scrubbing drag increment which may be reduced by seperating the jet from the wing surface.

Slipstream incremental velocity.- Off-design operation of the wing segment inside the slipstream could add a drag-rise increment corresponding to $M + \Delta M$ for that segment. Leading edge extensions could help this. The velocity increment also produces a friction or scrubbing drag increment.

Nonuniform inflow.- The airframe induces 2P and higher cyclic variations in the propeller onset flow which may reduce the propeller efficiency. The cyclic inflow will also impact the blade design from the standpoint of fatigue life.

Swirl loss recovery.- The presence of the wing is expected to recover some of the swirl energy wasted by the uninstalled propeller. The wing acting as exit guide vane may be contoured to maximize this benefit.

PROBLEM DEFINITION FOR WING-MOUNTED ENGINES



INSTALLATION DRAG ESTIMATE

The summary of drag increments prepared by Lockheed-Georgia Co. for NAS1-15701 (ref. 1) gives an idea of how bad the propeller installation might be. The swirl/drag divergence increment shown is from a slipstream simulator test reported in NASA CR-152138. The 18 count increment is the largest measured in the test and might therefore be considered the worst case. Examination of those test results indicates a negative 10 count increment is equally likely. This might be considered the best case, thereby bounding the total effect of installation between 7.4 percent adverse and 1.9 percent favorable.

NASA/LOCKHEED NAS1-15701 COMPROMISE A/C #1

	WORST CASE (ref.1)		BEST CASE	
$C_{D_{A/C}}$ (no props)		0.02796		0.02796
$\Delta C_{D_{INDUCED}}$	0.00030		0.00030	
$\Delta C_{D_{SCRUB}}$	0.00018		0.00018	
$\Delta C_{D_{SWIRL/DRAG\ DIVERG.}}$	0.00176		-0.0010	
$\Delta C_{D_{PROP\ EFFECTS}}$		0.00224		-0.00052
EFFECT OF INSTALLATION				
$\dfrac{\Delta C_{D_{IND}} + \Delta C_{D_{SCRUB}} + \Delta C_{D_{SW/DD}}}{C_{D_{TOT}}} =$		7.4%		(-)1.9%

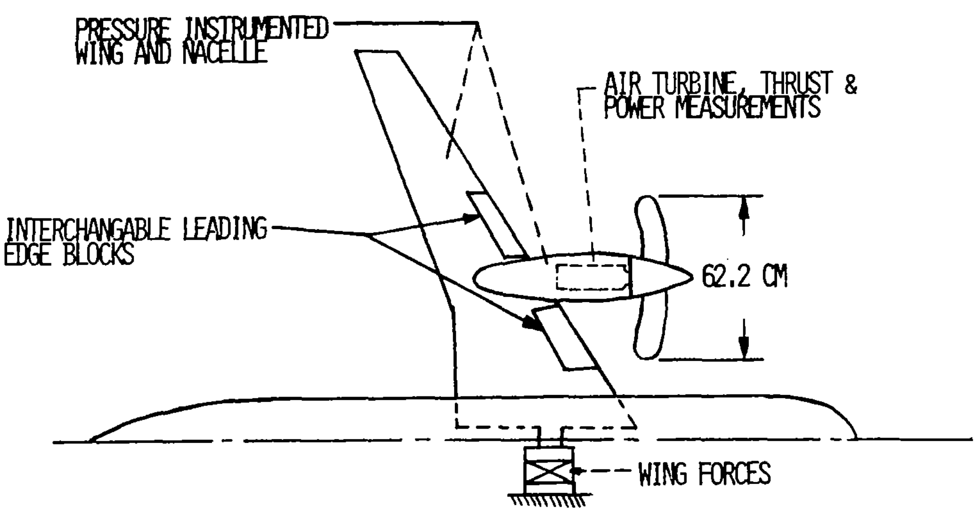
AMES APPROACH

The ejector-powered simulator test (ref.2) was intended to get an early first-order assessment of propfan installation losses. Although the results were not as accurate as expected, their magnitude should not be completely discounted. The half-model tests planned at Ames for 1980, 81 and 82 are intended to provide high-quality data on the installation losses including diagnostic measurements of normal surface pressure distributions and wake surveys. Initially, a baseline propeller/wing/nacelle model will be tested (1980) followed by a modified-leading-edge test (1981) and finally an optimized wing/nacelle configuration will be tested (1982) to assess the benefit of optimization. Later in the program a stability and control model will be tested (1985) to help assess the trade-offs between wing-mounted and fuselage-mounted engines. Efforts to develop improved analysis techniques will be continued. A inviscid small disturbance code solving the wing in the slipstream with swirl has been completed by Flow Research Corp. A new method including viscous effects will be attemped in subsequent years starting in 1981.

1. SLIPSTREAM SIMULATOR TEST - ORDER OF MAGNITUDE
2. ACTIVE PROPELLER HALF-MODEL TESTS
   - INITIAL TEST (1980)
     - -Scope the installation problem
     - -Incident noise on cabin wall
     - -Blade structural response
   - FOLLOW-ON TEST (1981)
     - -Wake diagnostics
     - -Reynolds number effects
     - -Wing-leading-edge mods
   - OPTIMIZED WING/NACELLE (1982) (CONTRACTOR)
     - -Determine optimization benefit
3. STABILITY AND CONTROL MODEL (CONTRACTOR)
   - 1ST TEST - WING-MOUNTED ENGINES (1985)
   - 2ND TEST - AFT-FUSELAGE MOUNTED ENGINES (1985)
4. ADVANCED ANALYSIS (CONTRACTOR)
   - SMALL DISTURBANCE WITH SLIPSTREAM (1979)
   - HYBRID CODE - N.S. PLUS TRANSONIC POTENTIAL (1983)

POWERED SEMI-SPAN MODEL

The powered model developed for the half-model testing consists of a pressure-instrumented supercritical wing, a non-metric half-body and the powerplant nacelle. A 62.2 cm 8-bladed propfan will be diven by a 550 kW air motor. The air motor exhaust exit area matches the exhaust exit on the transport installation so that the external nacelle contours are representative except for the faired-over inlet. The exhaust duct is instrumented and calibrated to provide accurate measurements of exhaust thrust which is to be subtracted from model forces measured by the floor balance. The propfan is the Hamilton Standard SR-2 configuration fabricated in graphite composite. The graphite blades have strain gages molded into the surfaces for measuring blade structural responses. Propeller thrust, torque and lateral forces are measured by a six-component balance mounted in the hub. In addition to the propeller model shown, a jet effects configuration with no propeller will be tested to provide the baseline data needed to get slipstream-induced increments. The fuselage and wing have been instrumented with dynamic pressure cells to measure incident acoustic pressures.

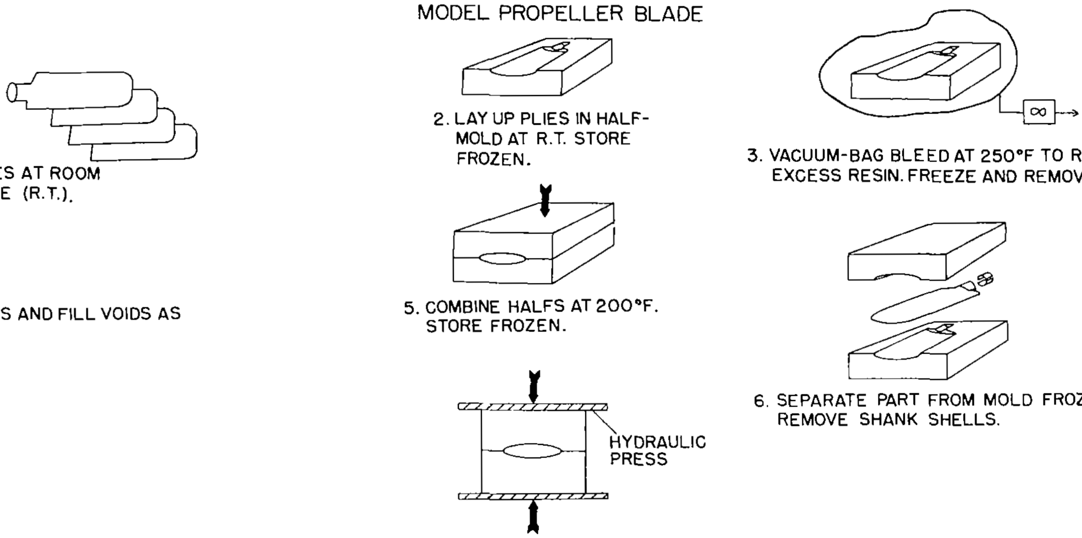


WING: $b/2 = 224$ cm
$A = 7.5$
$(t/c)_{MAX} = 0.14$
$M_{DES.} = 0.82$

GRAPHITE BLADE PROCESS

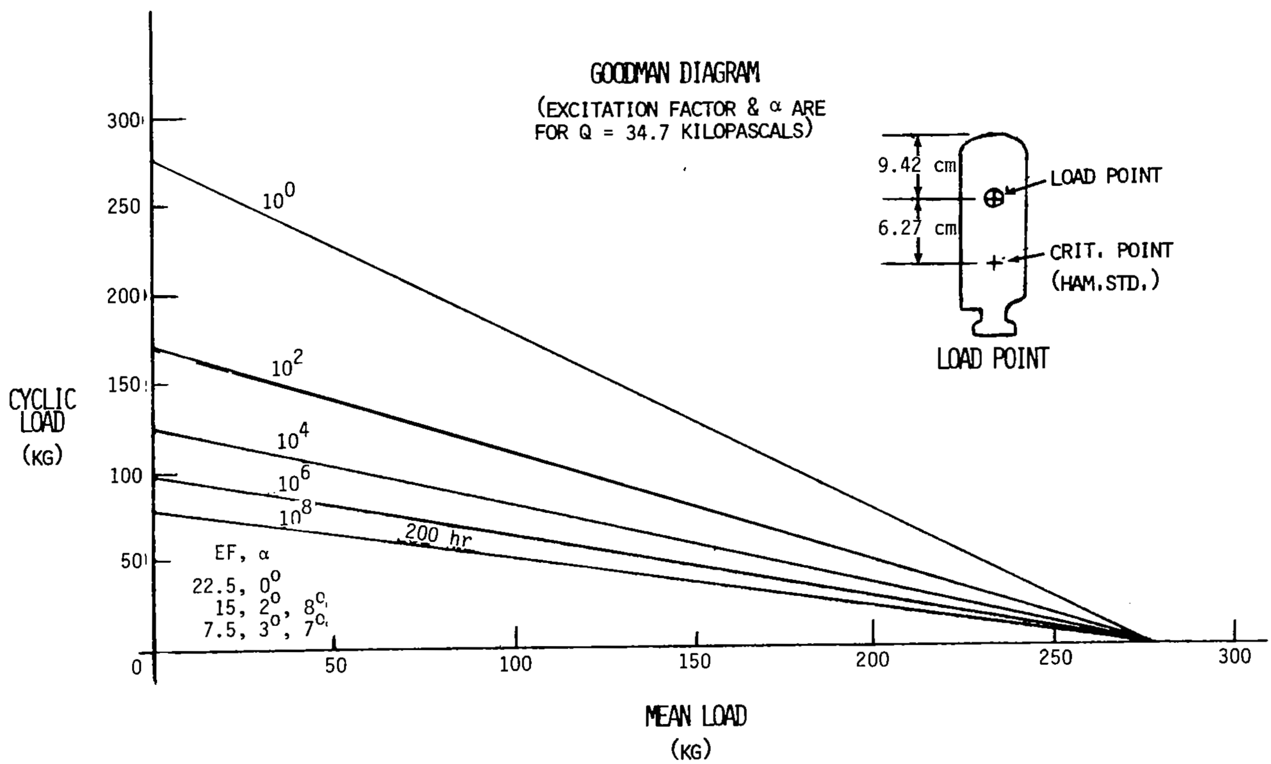
The manufacturing process developed for the graphite SR-2C blades is shown in this figure. The lay-up is composed of preimpregnated plys of unidirectional graphite tape in the ratios 1/4-bias and 3/4-longitudinal. The prebleeding is done to draw off most of the preimpregnated epoxy resin so that the lay-up will fit into the mold without excessive pressure thus avoiding fiber crushing. The technique has resulted in a blade structure with excellent mechanical properties.

MANUFACTURING PROCESS FOR GRAPHITE MODEL PROPELLER BLADE



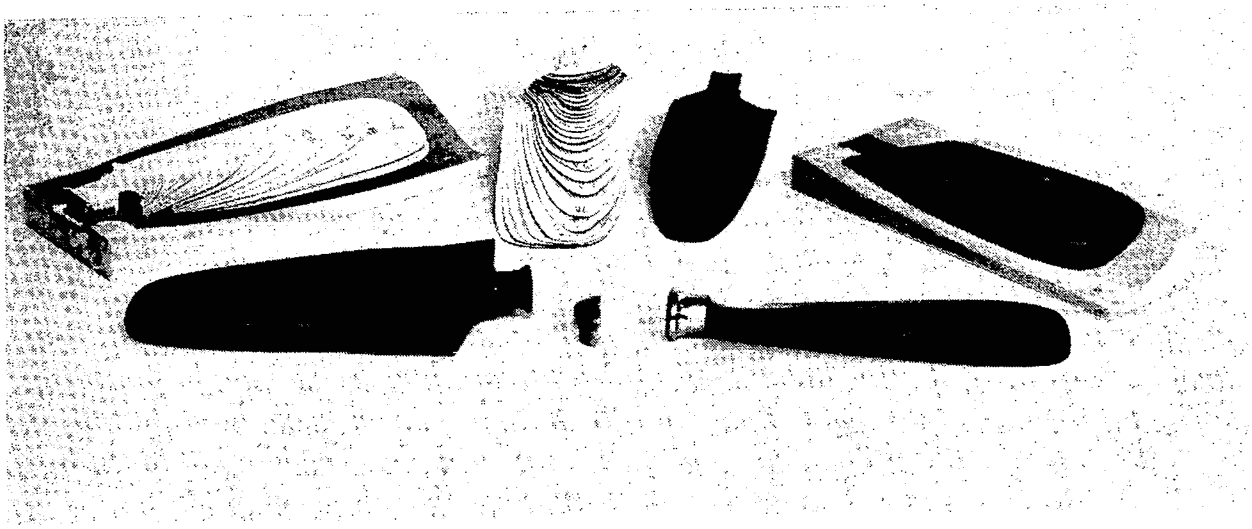
SR-2C PROPERTIES

Extensive destructive testing was done to determine the fatigue properties of production blades. This slide shows the Goodman diagram obtained from the tests. Our most severe anticipated operating condition is the point labeled excitation factor (EF) = 22.5 which occurs at zero airplane lift. Because of the large safety margin exhibited by the test results, no further attempt was made to optimize the structure.

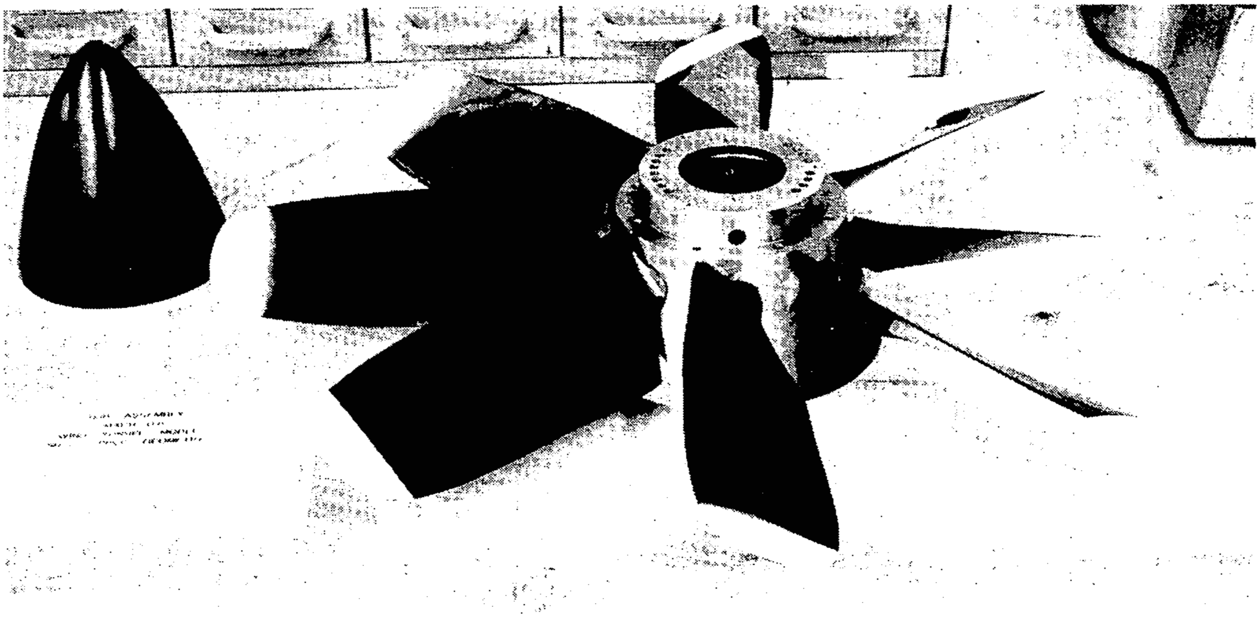


REFERENCES

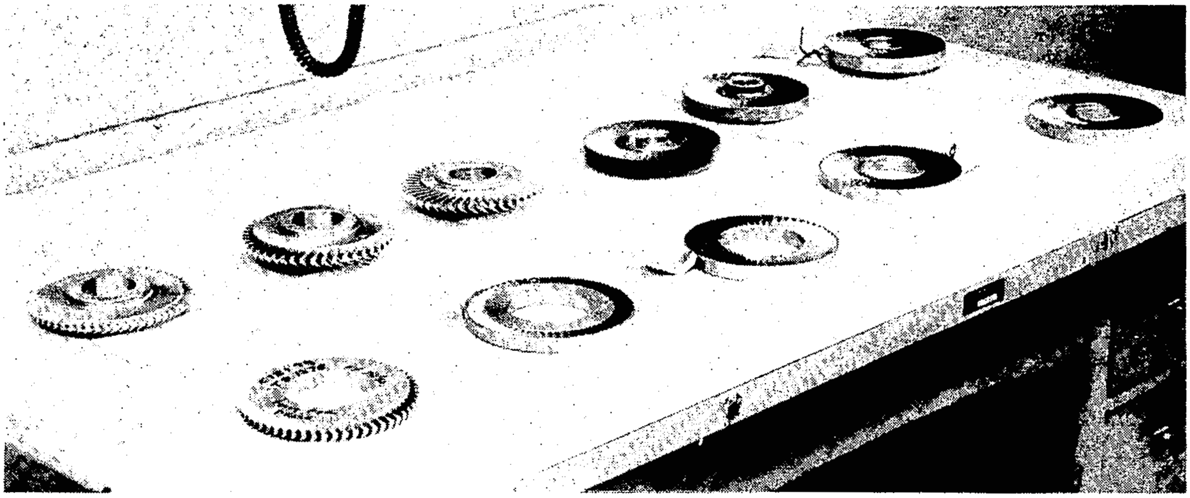
1. Final Oral Review Of Results From Lockheed-Georgia Study. "Turboprop Cargo Aircraft Systems Study". NASA Contract NAS1-15708, July 29, 1980.
2. Welge, H. Robert; and Crowder, James P.; Simulated Propeller Slipstream Effects On A Supercritical Wing. NASA CR-152138



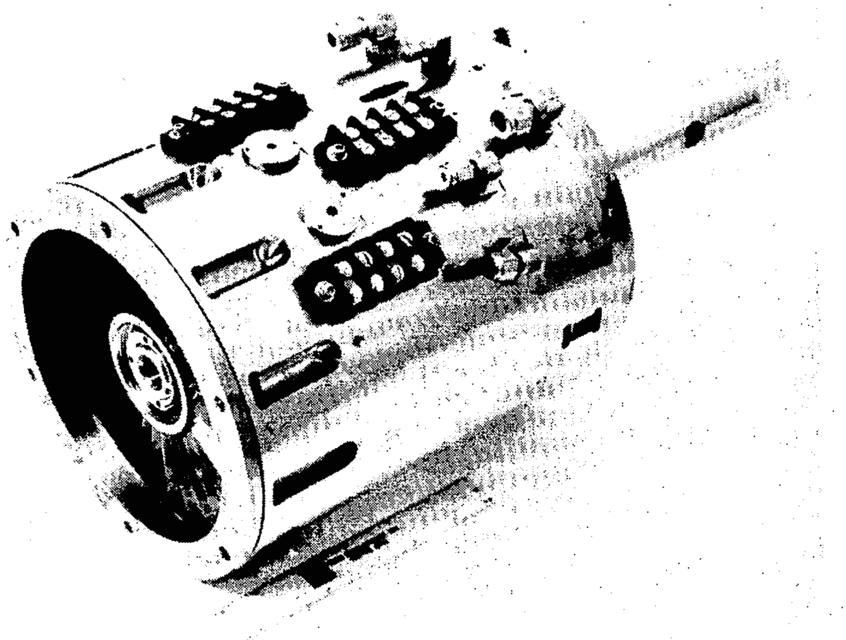
Blade fabrication stages.



Model hub/propfan assembly.



TDI turbine motor components.



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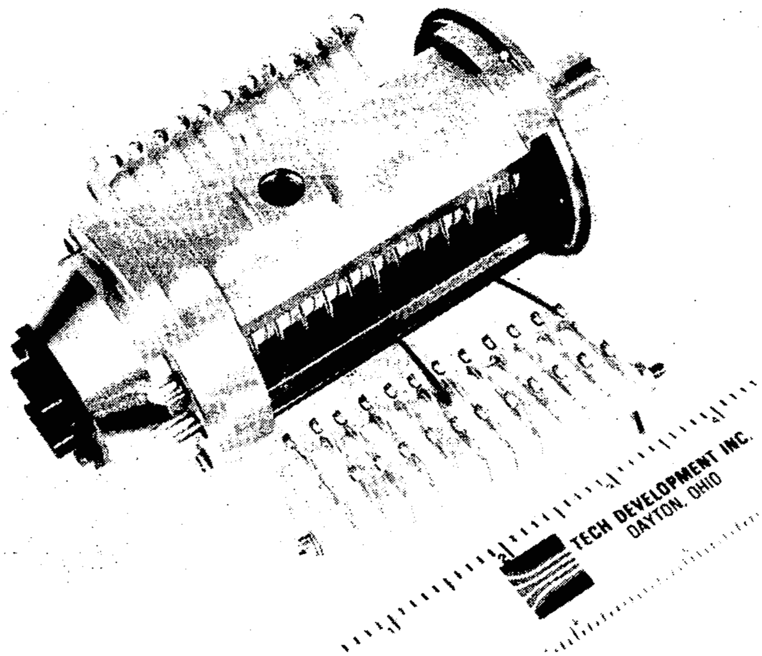
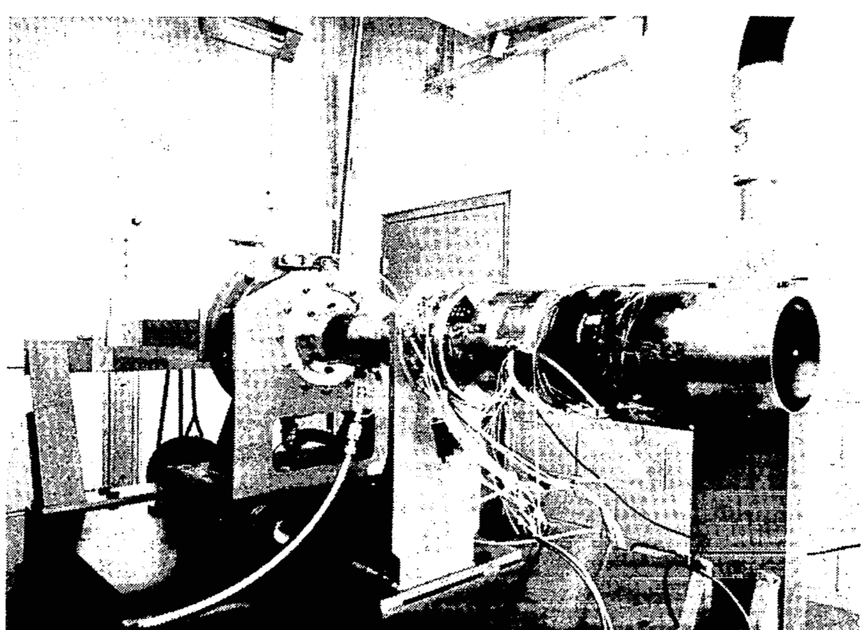
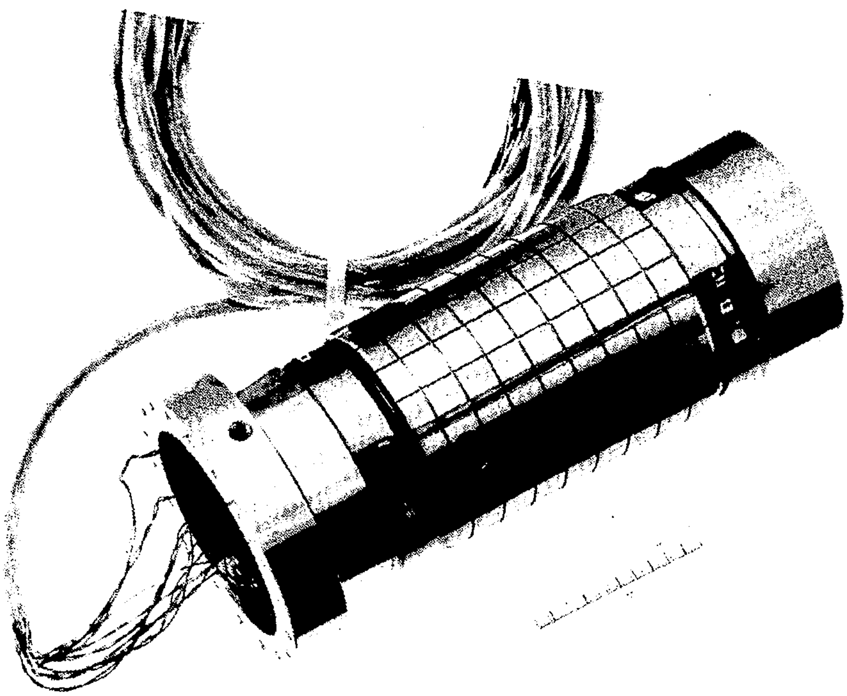


TDI motor slipring assembly.



Motor and prop balance on dynamometer test stand.



Component propeller balance.