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VERIFICATION TEST OF THE AEDC HIGH ALPHA ROLL DYNAMICS SYSTEM

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ARNOLD ENGINEERING DEVELOPMENT CENTER
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A test was conducted to evaluate the new AEDC High Alpha Roll Dynamics System for large models and obtain scaling parameter information. Data were obtained at Mach numbers 0.22 thru 1.15 for a Reynolds number per ft range of 0.69×10^6 through 2.50×10^6, at angles of attack -5 to 25 deg, and spin rates up to approximately ten thousand RPM. The model configurations (L/D of 10, D = 4.5 in.) included the Basic Finner and the Modified Basic Finner. Instrumentation included a new four-component balance, tachometer, brake pad thermocouple,

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and a microprocessor-based controller for the turbine/clutch/brake sequencing and for interfacing with the PWT computer system.

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NOMENCLATURE

ALFI	Indicated pitch angle of strut support, deg
ALF-M	Model angle of attack, deg
CBAR	A reference length of the model upon which aerodynamic coefficients are based (CBAR = D), 4.50 in.
C BOX 6	Manual input number six
CLM	Pitching-moment coefficient in the body axis, pitching moment/(Q)(S)(D)
CLN	Yawing-moment coefficient in the body axis, yawing moment/(Q)(S)(D)
CLNC	Corrected yawing-moment coefficient in the body axis, corrected yawing moment/(Q)(S)(D)
CLNO	Static yawing-moment coefficient at P = 0
CLNP	Magnus-moment spin derivative coefficient, ∂CLN/∂(PD/2V), radian^{-1}
CLO	Rolling-moment coefficient at P = 0
CLP	Roll-damping coefficient from on-line data reduction program, ∂[LTOT/(Q)(S)(D)]∂(PD/2V), radian^{-1}
CLP1	Roll-damping coefficient from the final reduction of the differential correction data reduction off-line method, radian^{-1}
CN	Normal-force coefficient in the body axis, normal force/(Q)(S)
CONF	Configuration number
CY	Side-force coefficient in the body axis, side force/(Q)(S)
CYC	Corrected side-force coefficient in the body axis, corrected side force/(Q)(S)

CYO	Side-force coefficient at P = 0
CYP	Magnus-force spin derivative coefficient, $\partial CY/\partial(PD/2V)$, radian^{-1}
D	Model body diameter, 4.50 in.
DATE	Date of data acquisition
DAY	Day (of year) of data acquisition
DM	Mach number tolerance
ERCODE	Error code
FIN	Fin cant angle, deg
FN	Balance axis net normal force, lb
FNG	Balance axis gross normal force, lb
FY	Balance axis net side force, lb
FYG	Balance axis gross side force, lb
HR	Hour of data acquisition
IX	Model moment of inertia, slugs-ft^2
J	Manual input indicating number of data samples to average
L/D	Model length to diameter ratio, 10.00
LO	Static rolling moment at P = 0, ft-lb
LO_B	Bearing static rolling moment at P = 0, ft-lb
LP	Roll-damping moment, ft-lb-sec/radian
LP_B	Bearing roll-damping moment, ft-lb-sec/radian
LTOT	Total rolling moment, ft-lb
M	Mach number
MB	Set point Mach number
MM	Net pitching moment about the moment reference center, in.-lb
MN	Balance axis yawing moment transferred to the moment reference center, in.-lb, or minute of data acquisition
MODE	Data acquisition mode

P, $\dot{\text{PHI}}$	Model spin rate, radian/sec
PI	Free-stream static pressure, psfa
PART	Part number: sequential number for referencing data. One part number per ptich polar
PCA-X	Test section plume pressure-A system, psfa
PCB-X	Test section plenum pressure-B system, psfa
PD/2V	Spin parameter, radian
PE	Tunnel diffusor pressure, psfa
PHII	Initial roll position, radian or pitch sector indicated roll angle, deg
PHI	Model roll angle, deg
$\dot{\text{PHI}}$, P	Model roll rate, radian/sec
$\ddot{\text{PHI}}$	Model angular acceleration, radian/sec^2
$\dot{\text{PHII}}$	Initial roll rate, radian/sec
PM	Hygrometer mixture pressure, psfa
POINT	Point number: sequential indexing number for referencing data with a part number
POR	Average tunnel wall porosity, percent of wall area open to test section plenum
PROJECT	Project number
PROS DATE	Date of data processing
PSS	Model steady-state spin rate, radian/sec
PSSD/2V	Steady-state spin parameter, radian
PT	Free-stream stagnation pressure, psfa
PTA-X	Free-stream stagnation pressure-A system, psfa
PTB-X	Free-stream stagnation pressure-B system, psfa
Q	Free-stream dynamic pressure, psf
R x 10^{-6}	Unit Reynolds number, 1/ft

RED x 10^{-6}	Free-stream Reynolds number based on model diameter
REL x 10^{-6}	Free-stream Reynolds number based on model length
RES	Side-force residual, CY (linear fit) - CY (data)
RPM1	Model rotation rate - primary system, revolutions per minute
S	A reference area of the model upon which aerodynamic coefficients are based, 0.110
SAMPLE	Data sample identification number
SC	Second of data acquisition
SC x 100	Tunnel specific humidity
SCHED	Tunnel wall porosity schedule
SPIN	Model spin direction, 1 indicates clockwise looking upstream, 2 indicates counter-clockwise
SUMR	Sum of side-force residuals squared
TBP	Brake pad temperature, °F
TDP	Hygrometer dewpoint temperature, °F
TEST	Test number
TIME	Time (averaged) corresponding to averaged data
TIME1	Initial time, sec
TPR	Tunnel pressure ratio, PT/PE
TT	Tunnel total temperature, °F
TTA-X	Free-stream stagnation temperature-A system, °F
TTB-X	Free-stream stagnation temperature-B system, °F
V	Free-stream velocity, ft/sec

WA	Test section wall angle, deg
WIND-OFF	Wind-off part and point number
XP	Distance from the model nose to the moment reference point (see Fig. 1), calibers
XCP	Center of pressure along the X-axis referenced to model nose
YCP	Center of pressure along the Y-axis reference to model nose
Δ	Prefix indicating uncertainty in the value of a parameter (in the units of the parameter)

1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 65807F, Control Number 9 R02-05-8. The project monitor for AEDC/DOTR was Mr. A. F. Money. The results were obtained by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), operating contractor for the AEDC, AFSC, Arnold Air Force Station, Tennessee. This test was conducted in the Aerodynamic Wind Tunnel (4T) of the Propulsion Wind Tunnel Facility (PWT), August 23, 1978 under ARO Project Number P41C-20 and was in support of Technology Project V32A-R4.

The primary objectives of the wind tunnel program were to evaluate the new AEDC High Alpha Roll Dynamics System for large models and obtain scaling parameter information. Data were obtained at Mach numbers 0.22 through 1.15 for a Reynolds number per ft range of 0.69 x 10^6 through 2.50 x 10^6, at angles of attack -5 to 25 deg, and spin rates up to approximately ten thousand RPM. The model configurations (L/D of 10, D = 4.5 in.) included the Basic Finner and the Modified Basic Finner. The test data were compared with the test results obtained in the PWT Tunnel 4T (ARO Project Number P41C-A0A) and the von Kármán Gas Dynamics Facility (VKF) Tunnel A (ARO Project Number V41A-A8A) during 1976 utilizing the same configurations on a smaller scale (D = 1.8 in.).[1]

A copy of the final data is on file on microfilm at AEDC. Requests for these data should be addressed to AEDC/DOTR, Arnold Air Force Station, Tennessee 37389.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel 4T is a closed loop, continuous flow, variable-density tunnel in which the Mach number can be varied continuously from 0.1 to 1.3 and can be set at discrete Mach numbers of 1.6 and 2.0 by placing nozzle inserts over the permanent sonic nozzle. The stagnation pressure can be varied from 400 to 3,400 psfa at a majority of the Mach numbers. The test section is 4-ft square and 12.5-ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section. The model support system consists of a sector and sting attachment which has a pitch angle capability of -7.5

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[1] Jenke, Leroy M. "Experimental Roll-Damping, Magnus, and Static-Stability Characteristics of Two Slender Missile Configurations at High Angles of Attack (0 to 90 Deg) and Mach Numbers 0.2 through 2.5," AEDC-TR-76-58, July 1976.

to 28 deg with respect to the tunnel centerline and a roll capability of -180 to 180 deg about the sting centerline. A more complete description of the tunnel may be found in the Test Facilities Handbook[2].

2.2 TEST ARTICLE

2.2.1 Model

Two aluminum models (Fig. 1) were designed and fabricated by the AEDC for this test. One of them is commonly referred to as the Basic Finner. It consists of a cone-cylinder with four rectangular fins. Overall model length is ten calibers, the cone half-angle is 10 deg, and the fins are approximately one caliber in chord and have an overall span of three calibers. A set of fins with a cant angle of 2.5 deg was tested. Another configuration, the Modified Basic Finner was also tested. It utilized the same body but used an ogive nose and four fins with a trapezoidal planform and zero cant angle.

The models were dynamically balanced in roll (±1-in. gm) at the CG so that there would be no vibrational loads on the balance. The moments of inertia of the model were measured and are considered to be accurate to ±0.5 percent. Installation of the Basic Finner Configuration in 4T is sketched in Fig. 2a; a photograph of the Modified Basic Finner is presented in Fig. 2b.

2.2.2 Test Mechanism

The AEDC High Alpha Roll Dynamics test mechanism for large models (Fig. 3) is a sting mounted, four-component balance (cruciform design about the sting) with a shell mounted on ball bearings. A pneumatically driven turbine is mounted near the aft end of the sting. The turbine which can be engaged to the model mounting shell with a pneumatic clutch, spins the model to the desired speed, and then is disengaged with the clutch to allow the model to spin freely on the ball bearings. The turbine will produce a starting torque of 90 in.-lb and a developed torque of approximately 140 in.-lb. A pneumatically-operated brake is mounted immediately aft of the model mounting shell aft of the balance. The brake will provide a static braking moment of 170 in.-lb and a dynamic braking moment of 105 in.-lb. The rotational speed, roll position, and roll direction are computed from the electrical pulses produced by a ring with alternating reflective and nonreflective surfaces passing three internally mounted infrared-emitting diodes and phototransistors. The mechanism is designed to operate under normal-force loads up to 1200 lb (6000 RPM max) and axial-force loads of 150 lb and at maximum spin rates of approximately 20,000 RPM (600 lb normal-force load max). Maximum side force is 240 lb and is independent of spin rate.

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[2] Test Facilities Handbook (Tenth Edition). "Propulsion Wind Tunnel Facility, Vol. 4," Arnold Engineering Development Center, May 1974.

2.2.3 Controller

Programmable control of the model status and the data acquisition computer was accomplished by a microprocessor-based controller (Fig. 4a). This control system, as diagrammed in Fig. 4b, automatically releases the model, spins it to a specified rate, disengages and stops the turbine, initiates and stops the data acquisition computer, applies the brake, and tells the model attitude computer to move the mechanism to the next angle of attack. This makes the system more productive and is especially useful in data acquisition for models which have spin down times of a few seconds (e.g., models with large fins and small inertias). A valuable feature of this control system is the programmed monitoring of the turbine/clutch/brake to avoid mechanism damage.

2.3 TEST INSTRUMENTATION

Model forces and moments were measured with the new AEDC four-component, force-type, strain-gage balance. The small outrigger side beams of the balance were used to obtain the sensitivity required to measure small side loads while maintaining adequate balance stiffness for the larger pitch loads. A normal-force to side-force capability of five was achieved for a 1200-lb normal force loading. The transfer distance to the model moment reference was measured with a precision of ±0.005 in.

A model grounding strip was provided on the sting to detect model-sting fouling. Brake pad temperature measurement was made with an iron-constantan thermocouple.

The sting pitch and roll angles were sensed by a synchrotransmitter. Sting deflections due to loads in the normal force and side force planes were calibrated before model entry into the tunnel. During testing, the model attitude was obtained from a combination of the sting attitude and sting-balance deflections under aerodynamic loads.

All steady-state measurements were sequentially recorded by an on-line computer system in which the data were reduced to engineering units. All transient data samples were averaged over a defined interval by the on-line computer system which then reduced and tabulated a specified number of averaged samples. All balance measurements and the model attitude were paralleled to a real-time digital data acquisition system. Balance static and dynamic limits were continually monitored during testing.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS AND PROCEDURES

The test conditions are presented as follows,

M	Re x 10^{6}	PT, psia	TT, °F	PT, psia	Q, psf	V, ft/sec
0.22	0.28	415	87	401	13	250
0.22	2.00	3160	118	3030	108	265
0.60	0.70	436	90	342	86	662
0.60	1.10	689	92	540	136	660
0.60	2.50	1650	109	1292	327	679
0.90	1.10	549	91	323	185	964
0.90	2.00	1008	96	596	338	965
0.90	2.50	1286	103	757	433	975
1.15	2.00	954	96	420	388	1181

and a test summary showing all configurations tested and the variables for each is presented in Table 1.

Prior to the test period, the balance was loaded with known weights to check the balance output. Weight tares were obtained and the model attitude sensor readings were compared with the calibrations. Before the tunnel was brought on line, all high pressure gas requirements for the turbine/clutch/brake were regulated. When the test conditions were established, the controller automatically initiated the model positioning to the first desired angle of attack, the spin sequence, data acquisition, and model movement to the next programmed angle of attack.

3.2 DATA REDUCTION

The model gross forces and moments were corrected for model weight, and the indicated model attitude was corrected for balance sting deflections. Model corrected force and moment measurements were reduced to coefficient form in the body axis. The reference length, D, and the reference area, S, are given in the Nomenclature. For convenience, the moment reference center is illustrated in Fig. 1.

The one degree of freedom equation of motion in roll can be written as

$$(IX)(\ddot{PHI}) = LTOT \qquad (1)$$

where LTOT is the total rolling moment. By assuming linear aerodynamics [i.e., LTOT = LO + (LP)(P)], the equation of motion becomes

$$(IX)(\ddot{PHI}) = LO + (LP)(P)$$

with the initial conditions, PHI = PHI1 and $\dot{PHI} = \dot{PHI1}$ at TIME = TIME1, this equation can be integrated to give

$$\dot{PHI} = \left(\dot{PHI1} + \frac{LO}{LP}\right) e^{\frac{LP}{IX}(TIME - TIME1)} - \frac{LO}{LP} \qquad (2)$$

$$PHI = \frac{IX}{LP}\left(PHI1 + \frac{LO}{LP}\right)\left[e^{\frac{LP}{IX}(TIME-TIME1)} - 1\right] - \frac{LO}{LP}(TIME-TIME1) + PHI1 \qquad (3)$$

Equation (3) was fitted to approximately 200 points of roll position (PHI), time (TIME) data using a differential correction, least-squares technique to determine the constants LO, LP, PI, and PHI1. Equation (2) was then used to calculate the roll rate. Numerous tare damping-data points were obtained (PT = 2050, 1000, 400, at V = 0) to evaluate the bearing friction. The rolling-moment coefficient at P = 0, CLO, and the roll-damping coefficient CLP are defined as

$$CLO = (LO - LO_B)/QSD$$

$$CLP = (LP - LP_B)(2V)/QSD^2$$

where the subscript B denotes bearing.

The Magnus coefficients (CYP and CLNP) were determined from a linear fit of side force and yawing moment vs PD/2V for each angle of attack. The intercepts of the above data curve fits were utilized to shift the side-force and yawing-moment data through zero to obtain CYC and CLNC. Both the shifted data and nonshifted data were tabulated.

3.3 UNCERTAINTY OF MEASUREMENTS

3.3.1 General

The minimum accuracy of the basic measurements (PT and TT), based on repeat calibrations, were found to be

$$\frac{\Delta PT}{PT} = 0.0043 = 0.43\%, \quad \frac{\Delta TT}{TT} = 0.0082 = 0.82\%$$

Uncertainties in the tunnel free-stream parameters and the model aerodynamic coefficients were estimated using the Taylor series method or error propagation, Eq. (4),

$$(\Delta F)^2 = \left(\frac{\partial F}{X_1}\Delta X_1\right)^2 + \left(\frac{\partial F}{X_2}\Delta X_2\right)^2 + \left(\frac{\partial F}{X_3}\Delta X_3\right)^2 \; . \; . \; . + \left(\frac{\partial F}{X_n}\Delta X_n\right)^2 \qquad (4)$$

where ΔF is the absolute uncertainty in the dependent parameter $F = f\ (X_1, X_2, X_3 \ldots X_n)$ and X_n are the independent parameters (or basic measurements). ΔX_n are the uncertainties (errors) in the independent measurements (or variables).

3.3.2 Test Conditions

The accuracy (based on 2σ deviation) of the basic tunnel parameters, PT and TT, and the 2σ deviation in Mach number determined from test section flow calibrations were used to estimate uncertainties in the other free-stream properties using Eq. (4). The computed uncertainties in the tunnel free-stream conditions are summarized in Table 2.

3.3.3 Test Data

The balance uncertainties for the maximum calibration loads (see Table 3) given in Table 4 were combined with the tunnel parameter uncertainties using the Taylor series method of error propagation (Eq. 4) to estimate the uncertainties in the model aerodynamic coefficients (see Table 5). The accuracy in setting and maintaining a specified Mach number was ±0.005. The uncertainties in the model angle of attack and sector roll angle were ±0.1 and ±0.2 deg, respectively. The uncertainty in the model roll angle was ±20 deg and the uncertainty of model roll rate was ±2.1 radian/sec.

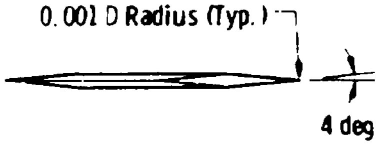
4.0 DATA PACKAGE PRESENTATION

The final data package included tabulated data, magnetic tape data, and installation and configuration documentation photographs. Comparison of the data with the reference 4T test results (AEDC-TR-76-58) are presented in Fig. 5. The data generally agree within the measurement uncertainty and therefore the comparison is considered favorable. A sample of the tabulated data is shown in Table 6.

APPENDIXES

I. ILLUSTRATIONS

Notes:
1. D = 4.5 Inches
2. All Dimensions in Calibers
3. For the Basic Finner Model, IX = 0.03671 slugs-ft^2, XP = 6.1 D
4. For the Modified Basic Finner Model, IX = 0.03328 slugs-ft^{2}x XP = 5 D



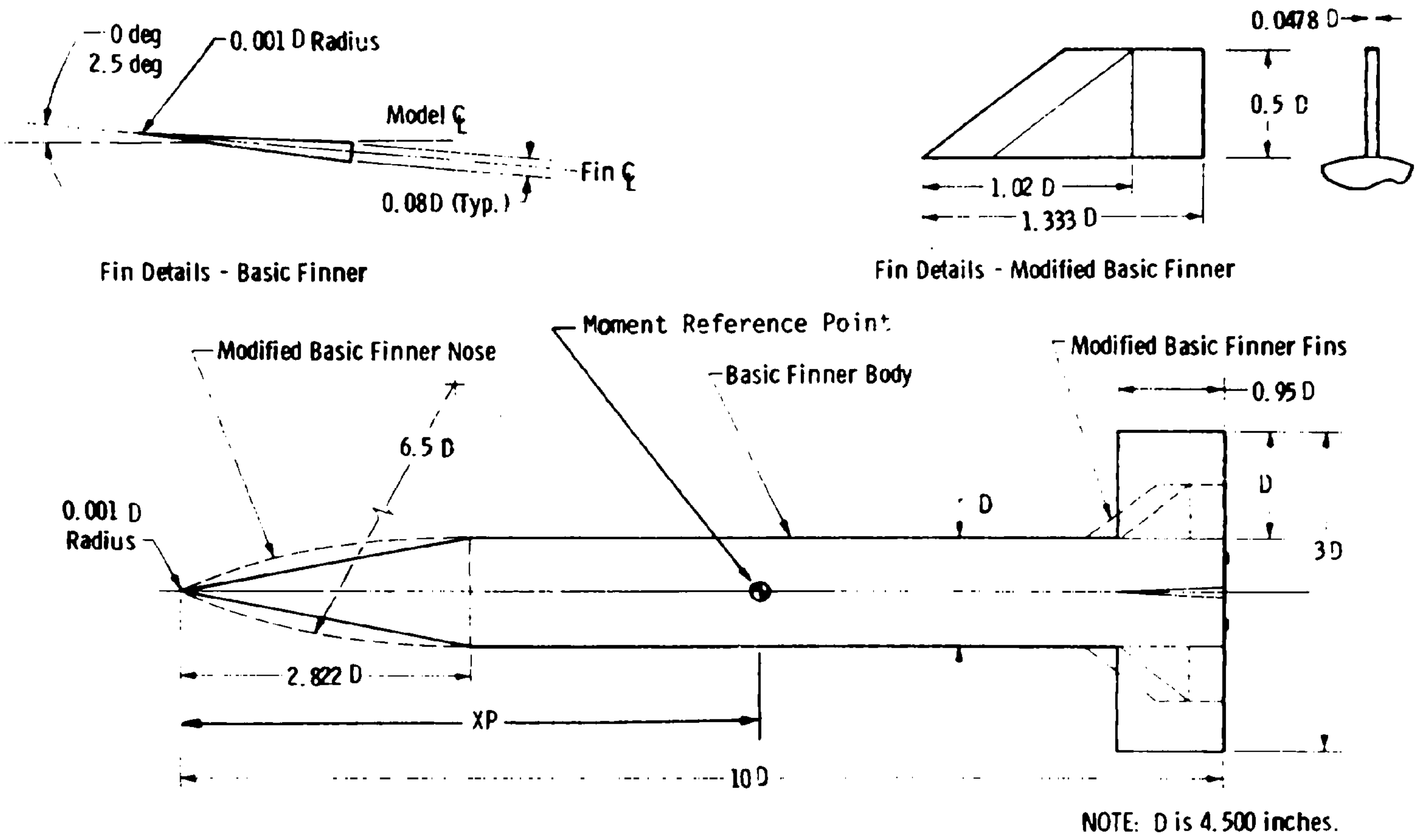
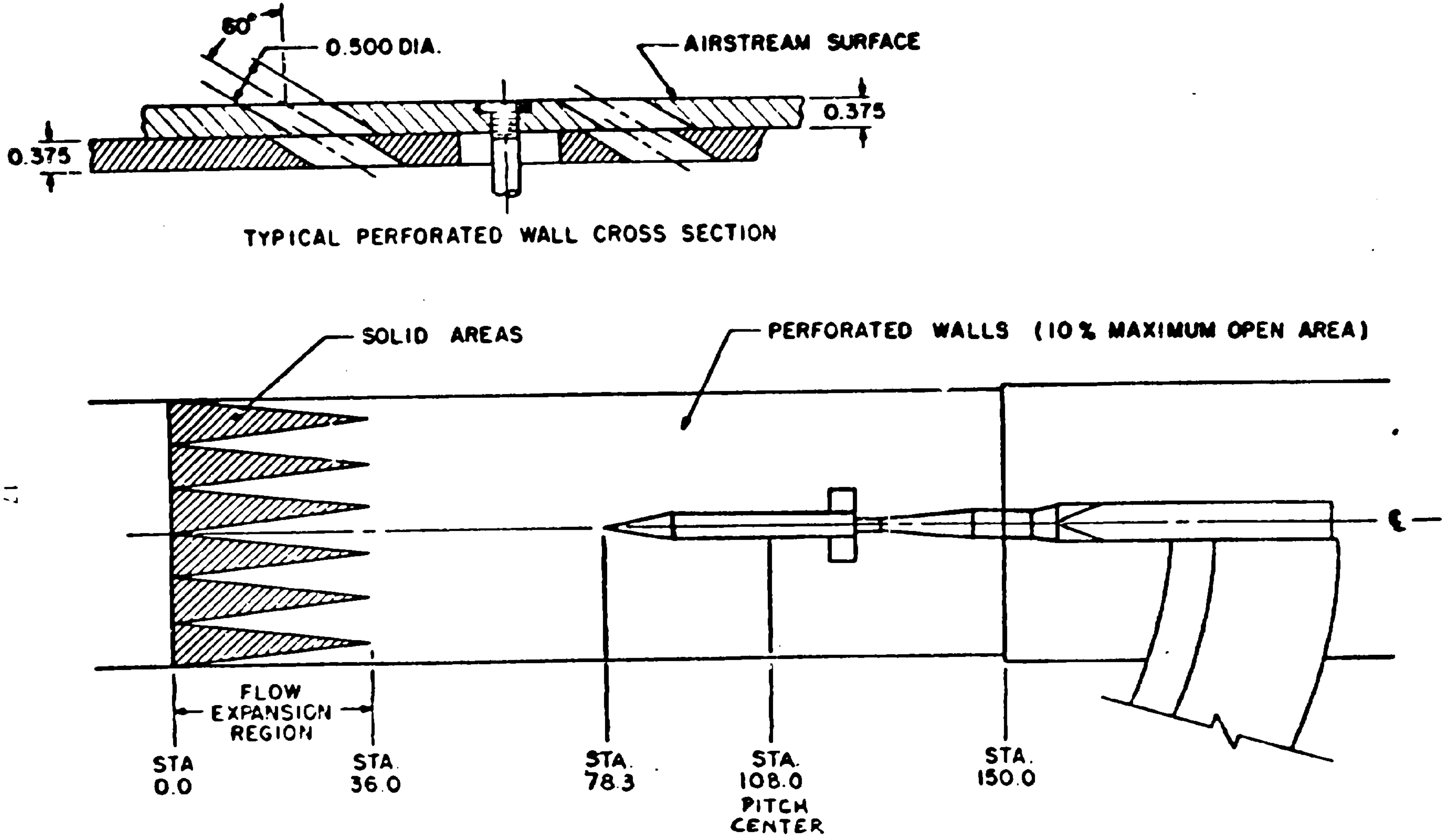
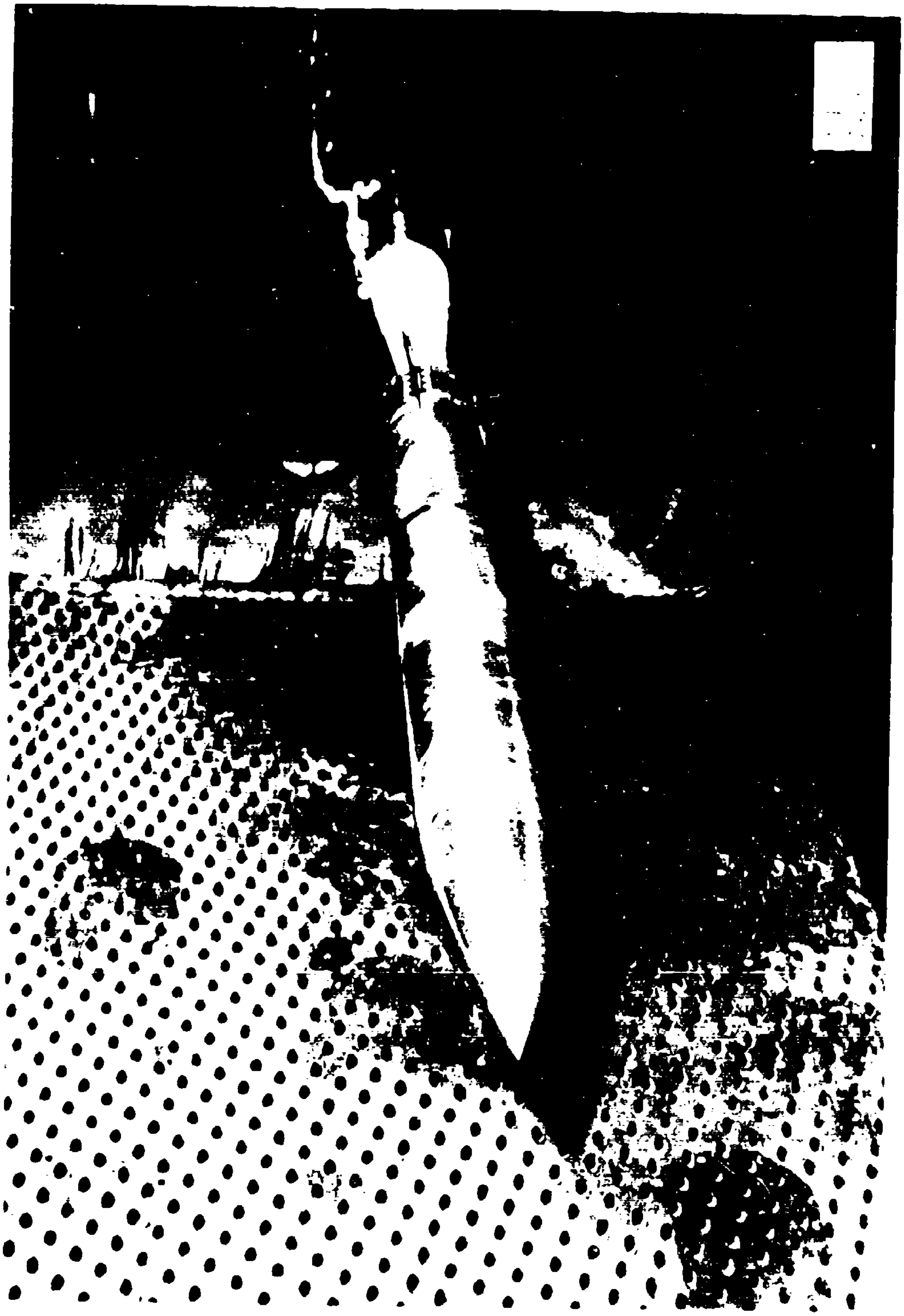


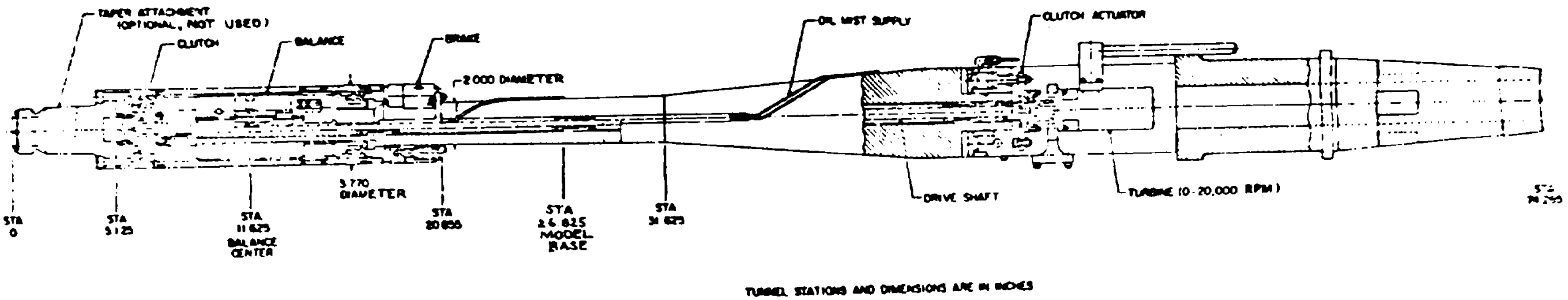
Fig. 1 Model Details



a. Profile Sketch (Basic Finner)

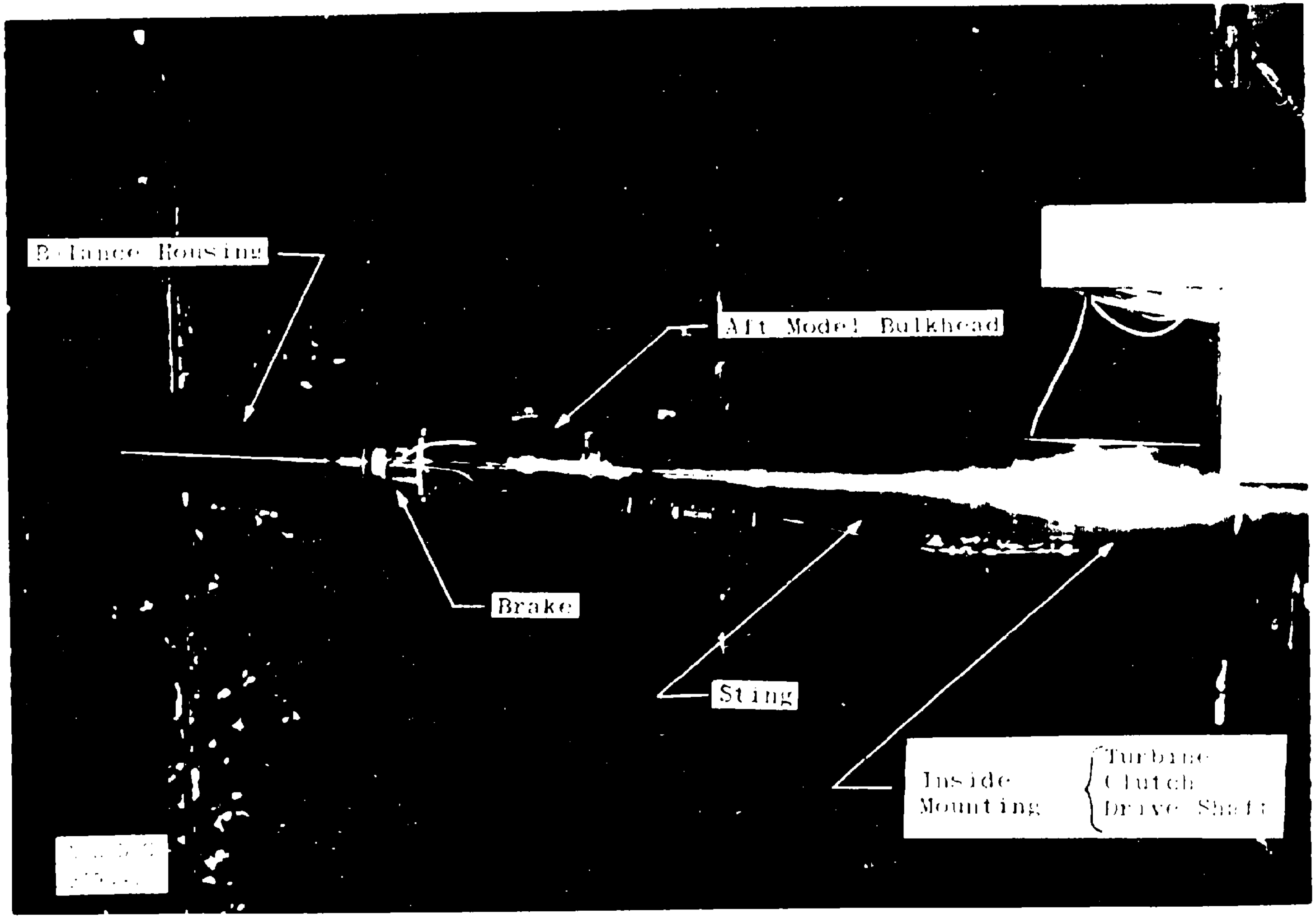
Fig. 2 Model Installation in 4T



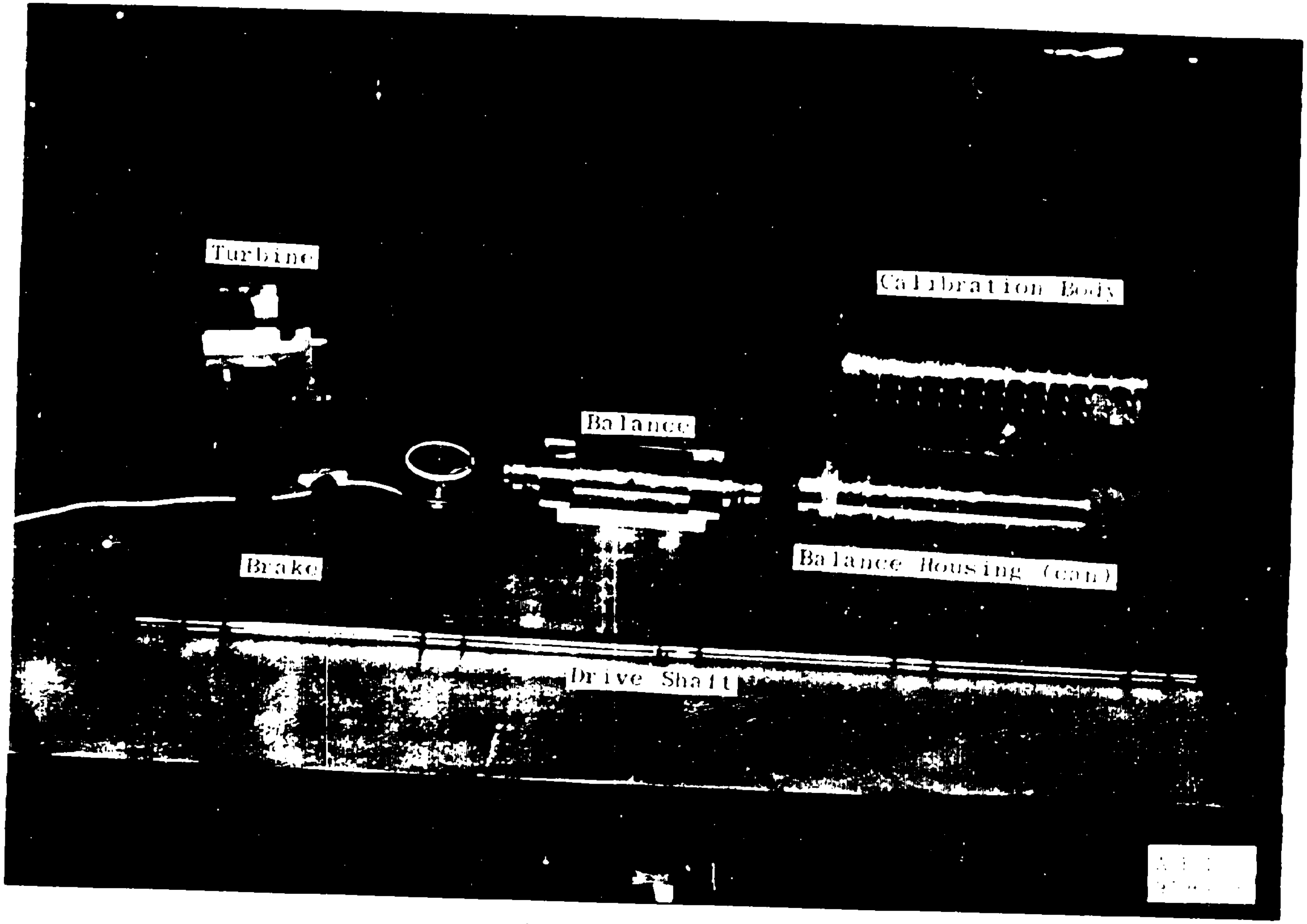


a. Profile Sketch

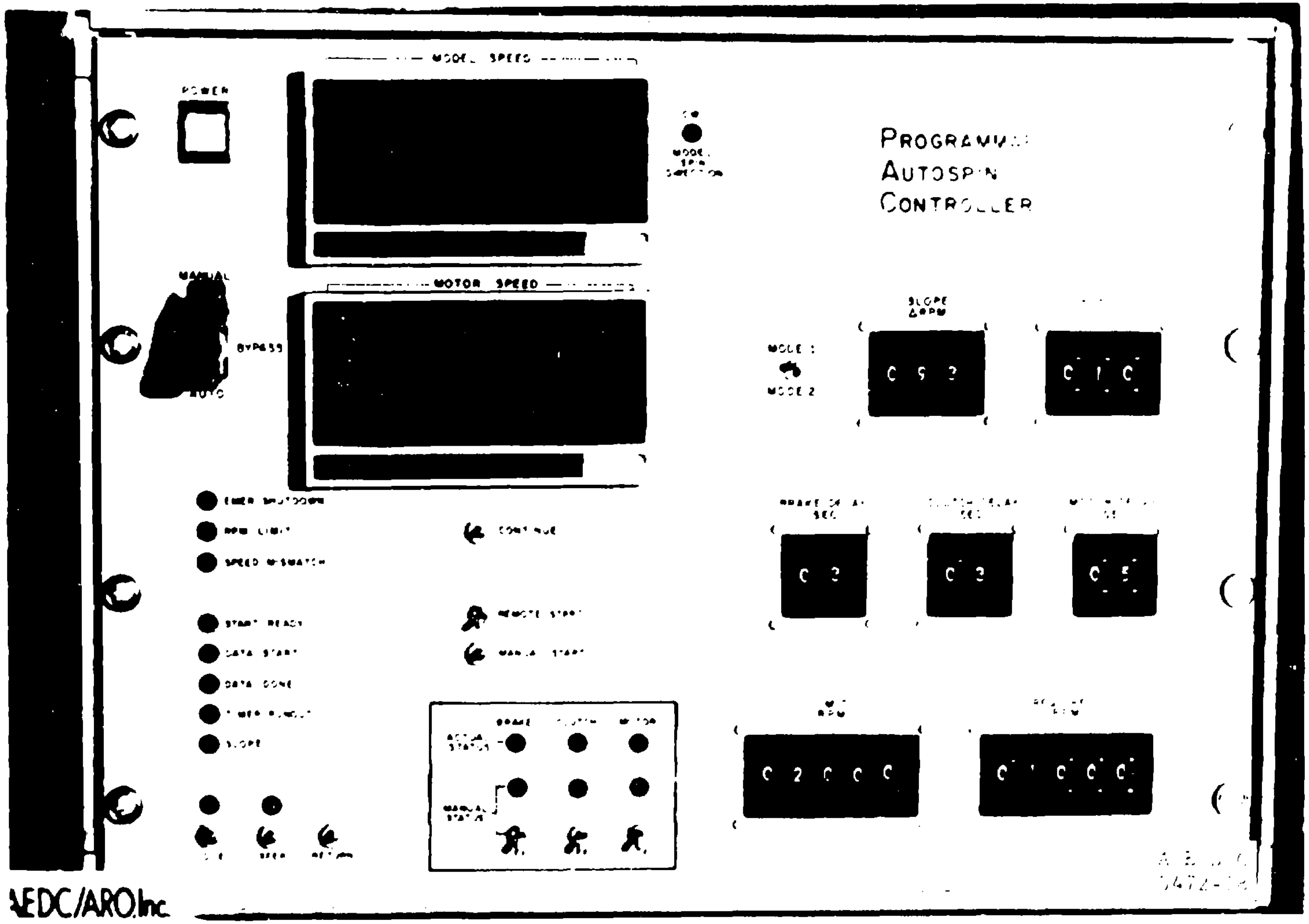
Fig. 3 High Alpha Roll Dynamics Test Mechanism



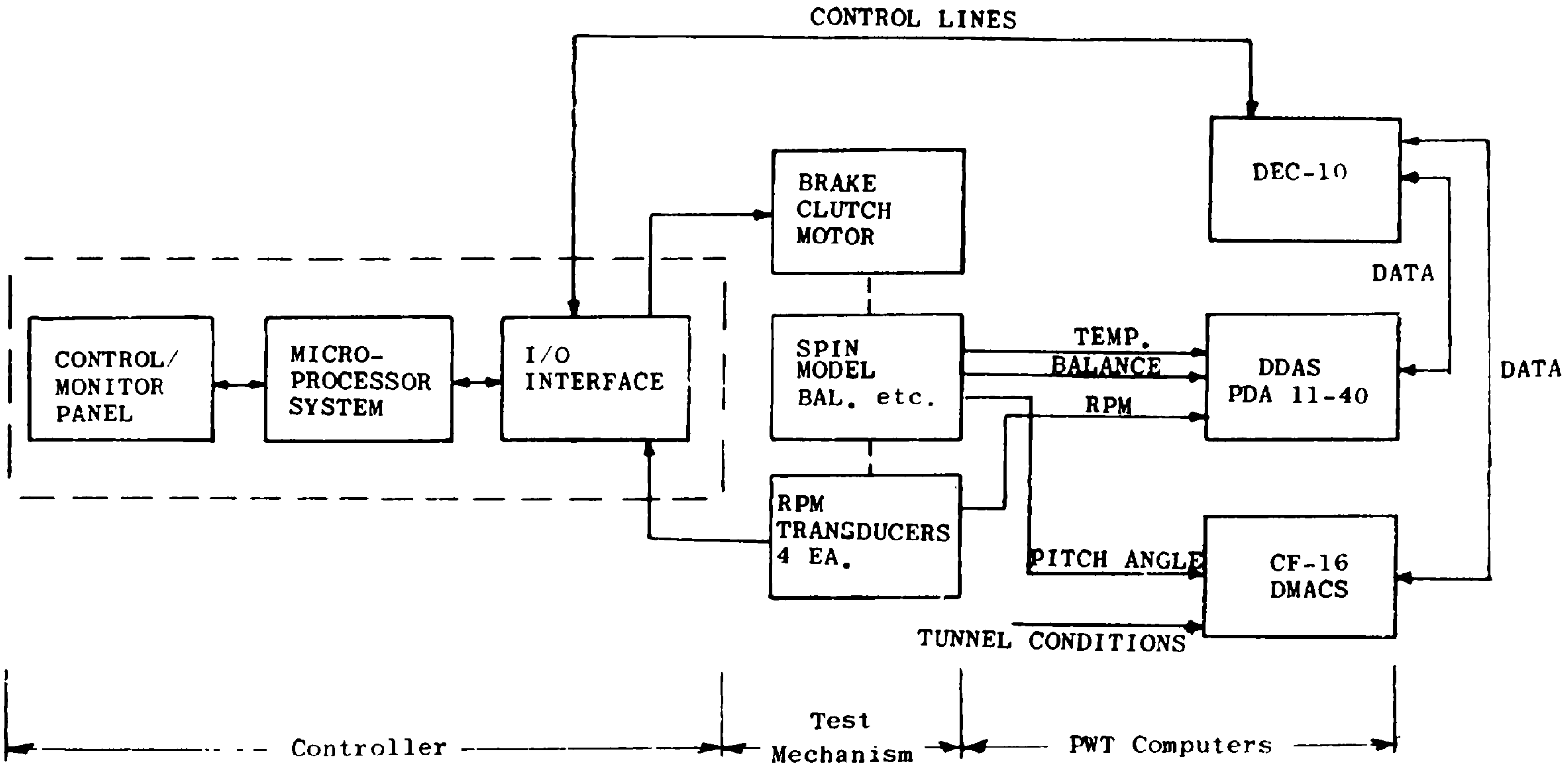
b. Profile Photograph (Model Removed)
Fig. 3 Continued



c. Mechanism Disassembled
Fig. 3 Concluded



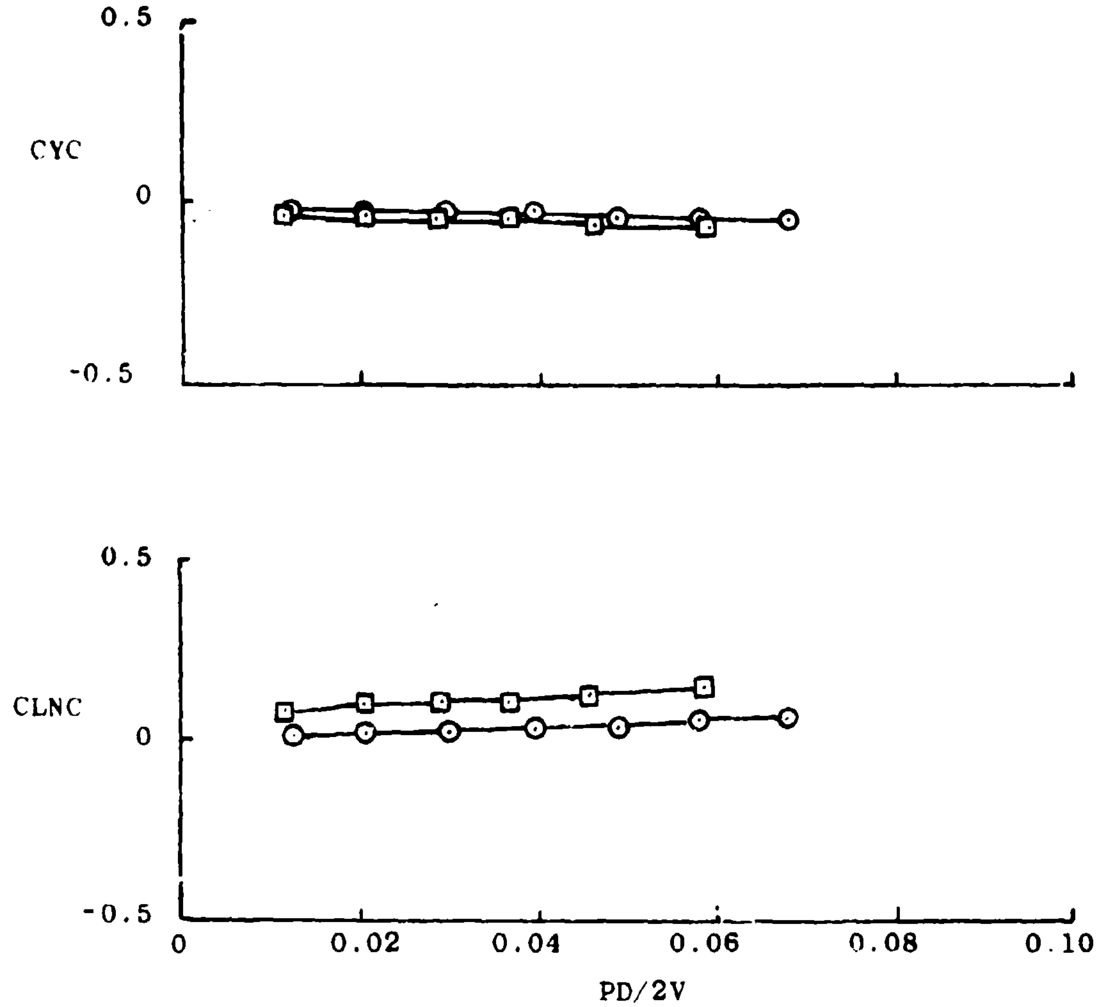
a. Control Panel
Fig. 4 Controller



b. Interface Diagram

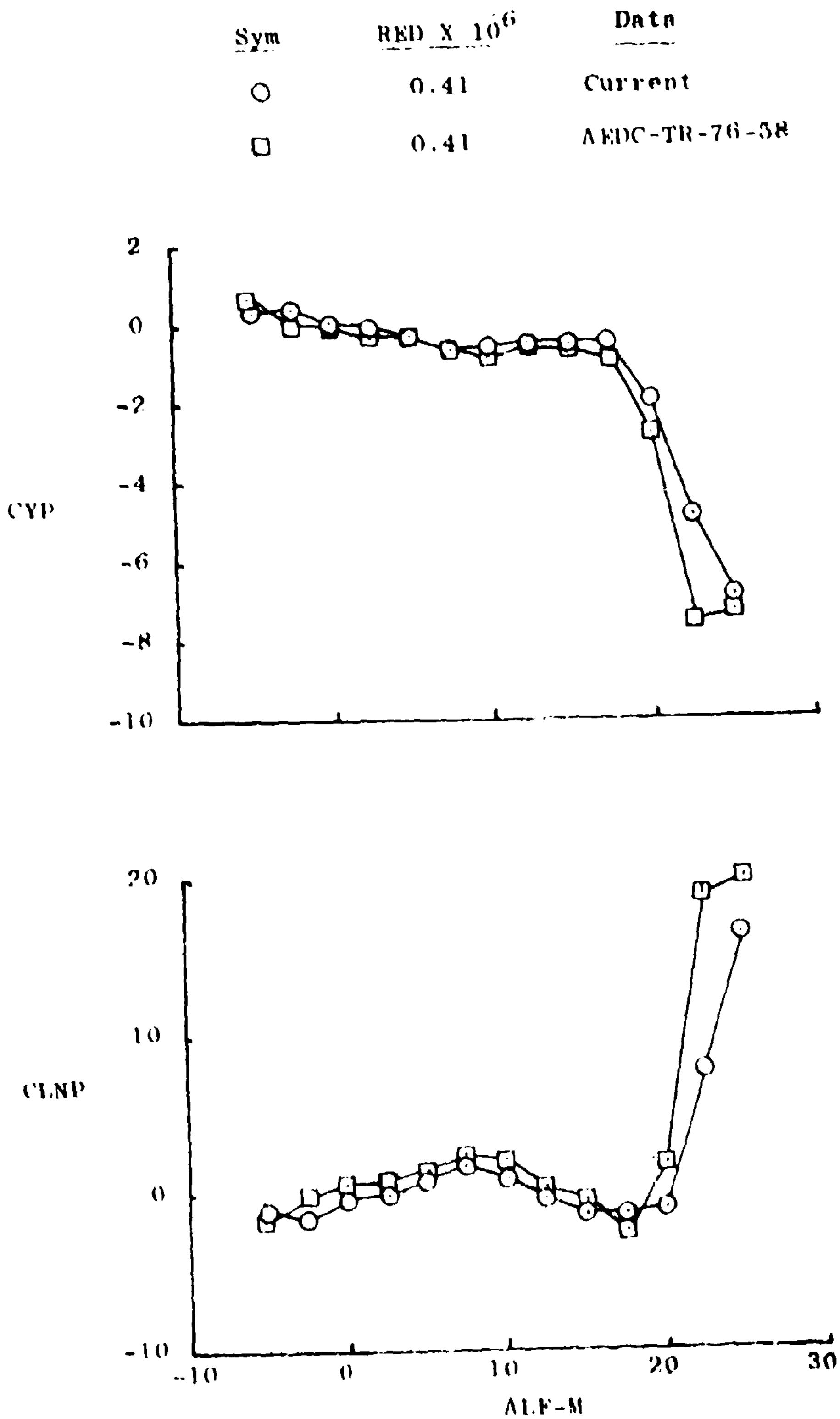
Fig. 4 Concluded

Symbol	ALF-M	RED X 10^{-6}	Data
○	10.02	0.41	Current
□	9.97	0.41	AEDC-TR-76-58



a. Modified Basic Finner, CYC and CLNC Versus PD/2V, M =0.90

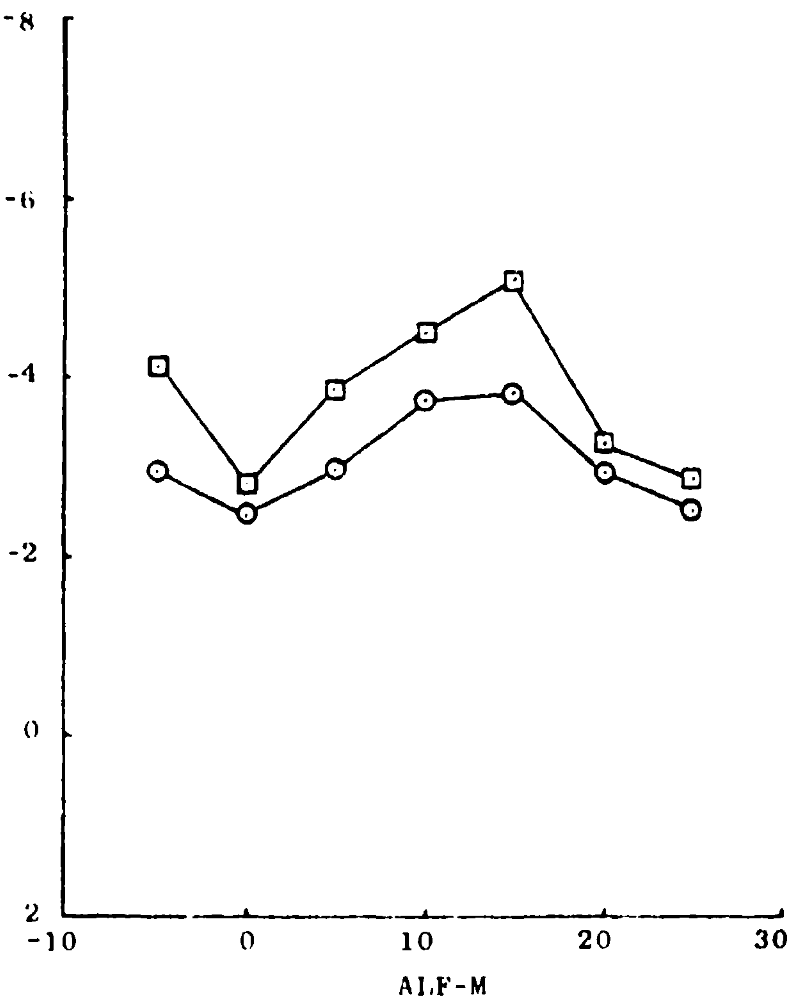
Fig. 5 Data Comparison



b. Modified Basic Finner, CYP and CLNP Versus ALF M, M = 0.90

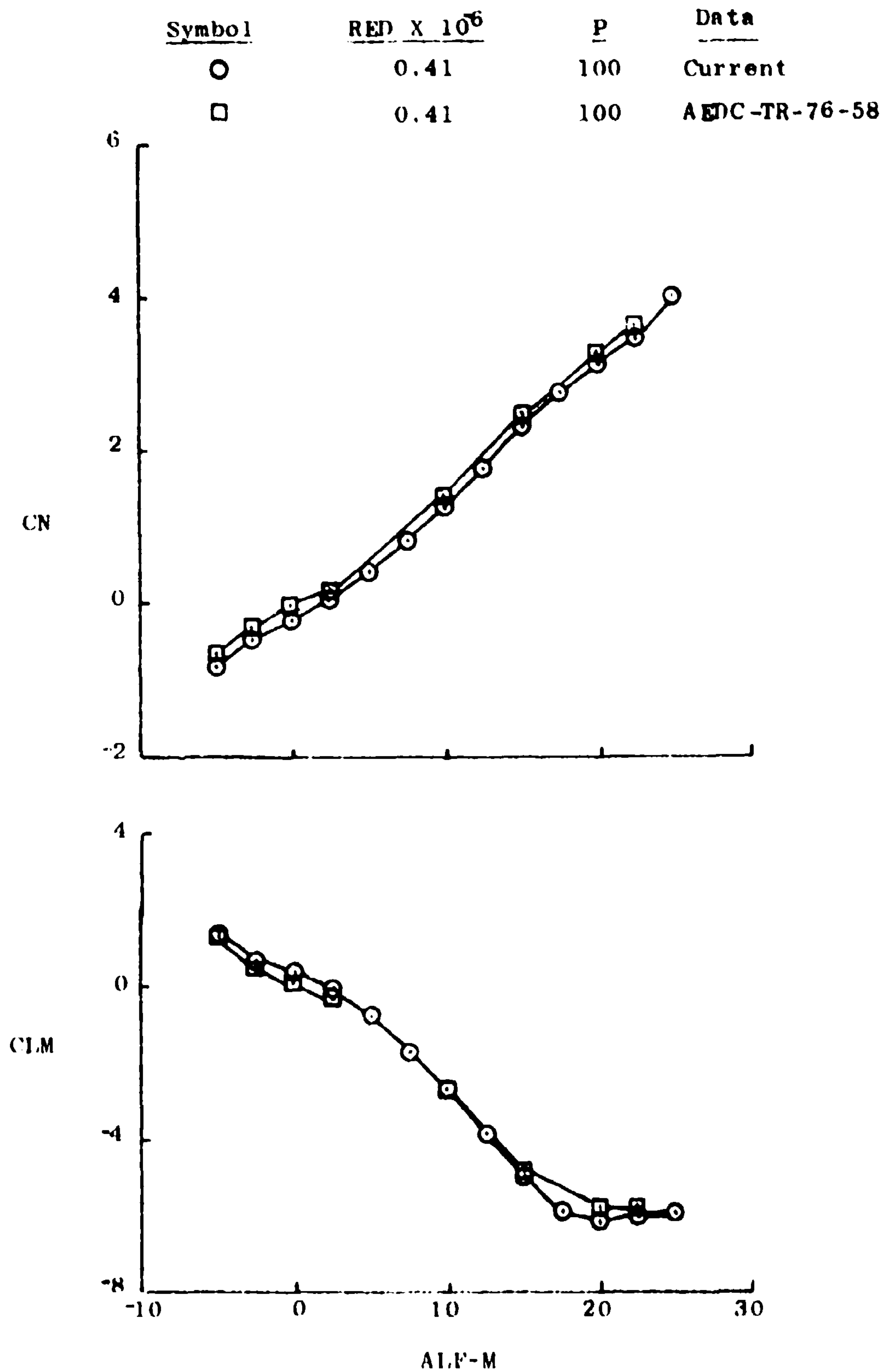
Fig. 5 Continued

Symbol	RED X 10^6	Data
O	0.41	Current
□	0.26	AEDC-TR-76-58



c. Modified Basic Finner, CLP1 Versus ALF-M, M = 0.90

Fig. 5 Continued



d. Modified Basic Finner, CN and CLM Versus ALF-M, M = 0.90
Fig. 5 Concluded

II. TABLES

TABLE 1. TEST MATRIX SUMMARY

MODIFIED BASIC FINNER MODEL						
CONF	FIN CANT	RED X 10^{-6}	R X 10^{-6}	MACH NUMBER		
				0.00 (1)	0.60 (2)	0.90 (3)
2	0.0	0.00	0.00	118-121*		
		0.26	0.70		124,127	
		0.41	1.10		131,132	134
		0.95	2.50			137,138

BASIC FINNER MODEL							
CONF	FIN CANT	RED X 10^{-6}	R X 10^{-6}	MACH NUMBER			
				0.22 (4)	0.60 (5)	0.90 (6)	1.15 (7)
4	2.5	0.10	0.28	148,149			
		0.41	1.10		168,169		
		0.75	2.00	156,157		163,164	166
		0.95	2.50		159,161		

*Part number

Notes:
(1) RPM max = 6408, (V = 0, tare)
(2) RPM max = 4966
(3) RPM max = 4364
(4) RPM max = 353
(5) RPM max = 986
(6) RPM max = 980
(7) RPM max = 1108

TABLE 2

(±) ESTIMATED UNCERTAINTY IN TUNNEL TEST CONDITIONS

For R 1.1 X 10^6(M=0.6 and 0.9), and R=2 X 10^6(M=0.22 and 1.15)

Uncertainty*	MACH NUMBER			
	0.22	0.60	0.90	1.15
ΔM	0.006	0.007	0.007	0.005
ΔQ	5.95	2.93	1.99	1.87
ΔPT	4.30	2.61	2.34	3.10
ΔPl	4.33	2.39	1.99	2.16
ΔTT	0.75	0.75	0.75	0.75
ΔV	7.3	7.7	6.4	4.0

*in the units of the parameter

TABLE 3

BALANCE LIMITS

Balance Component	Design Limit*	Calibration Limit
Forward, Aft FNG, lb	1200	500
Forward, Aft FYG, lb	240	100

* 6000 RPM max for this loading.

TABLE 4

(±) ESTIMATED UNCERTAINTY IN BALANCE CALIBRATION

Balance Component, lb	Type Gage Loading*	
	FNG	FYG
ΔFN	2.50	0.46
ΔFY	0.44	0.29
ΔMM	6.43	2.03
ΔMN	2.14	1.01

* Maximum calibration loading

TABLE 5

(±) ESTIMATED UNCERTAINTY IN AERODYNAMIC COEFFICIENTS

Parameter	ALF-M, deg	Mach Number			
		0.22	0.60	0.90	1.15
ΔCN	0	0.375	0.296	0.220	0.105
	20	0.410	0.295	0.216	0.106
ΔCY	0	0.078	0.06[illegible]	0.045	0.022
	20	0.080	0.062	0.045	0.022
ΔCLM	0	0.289	0.680	0.505	0.081
	20	0.447	0.667	0.489	0.091
ΔCLN	0	0.089	0.116	0.086	0.025
	20	0.094	0.117	0.086	0.025
ΔCYP	0	0.820	0.066	0.282	0.207
	20	0.275	0.372	0.696	1.074
ΔCLNP	0	0.188	0.165	0.122	0.043
	20	0.139	0.185	0.123	0.820
ΔCLPI	0	1.229	0.353	0.308	0.342
	20	1.111	0.327	0.297	0.406
ΔPD/2V	0	0.0007	0.0011	0.0006	0.0003

ARO, INC.
AEDC DIVISION
A SV[illegible]DRUP CORPORATION COMPANY
PRO[illegible] [illegible]ION WIND TUNNEL
ARNO[illegible] AIR FORCE STATION, TENNESSEE

Table 6. Typical Tabulated Data

PART	POINT	PROJECT	TEST	DATE	DAY	HR MN SC	PB	DN	SCHED	MODE	ERCODE	PROB DATE	WIND-OFF	AEDC PROPULSION WIND TUNNEL
134	4	P41C-20	TC538	8/23/78	235	17:39:52	0.900	0.005	8		0	0 21-OCT-78	1224 2	TRANSONIC 4T

M	PT	Q	PL	RX10-6	ALFI	PHII	TTA-1	TTA-2	PTA-1	PTA-2	PCA-1	PCA-2	PE	TPR	MA	POR	SCX100	PN	TOP
0.904	554.9	186.9	326.6	1.114	-4.91	0.0	91.0	91.2	554.9	554.5	330.2	330.5	454.3	1.221	-0.00	5.02	0.804	476.	16.3

CONF	REDX10-6	RELX10-6	V	FIN	J	TSP	SPIN	C BOX6	L/D	D	XP	IX	CRAP
2	0.418	4.179	964.2	0.0	.50	82.8	1	0	10.00	4.50	22.500	0.03320	4.500

SAMPLE	ALF-M	PD/2V	P	RPM1	CN	CLM	CY	CLN	TIME	XCP	YCP	PHI	LJCT
1	-4.99	0.0844	433.8	4143.	-0.9243	1.9571	0.03770	-0.16952	0.1280	-2.1175	-4.8288	503.7	-2.6546
2	-4.99	0.0805	413.9	3952.	-0.9184	1.9215	0.03835	-0.17173	0.3780	-2.0924	-4.6788	609.4	-2.5289
3	-4.99	0.0768	395.0	3772.	-0.9133	1.8848	0.03761	-0.17420	0.6280	-2.0639	-4.9345	710.2	-2.3979
4	-4.99	0.0733	377.0	3600.	-0.9029	1.8494	0.03575	-0.17071	0.8780	-2.0485	-5.1249	806.3	-2.2788
5	-4.99	0.0700	359.9	3437.	-0.8896	1.8050	0.03541	-0.16839	1.1280	-2.0293	-5.1174	898.1	-2.1712
6	-4.99	0.0668	343.6	3281.	-0.8821	1.7651	0.03755	-0.17049	1.3780	-2.0026	-4.8131	985.7	-2.0622
7	-4.99	0.0638	328.0	3133.	-0.8753	1.7346	0.03531	-0.17019	1.6280	-1.9844	-5.6412	1069.5	-1.9708
8	-4.99	0.0609	313.2	2991.	-0.8678	1.7102	0.03446	-0.16806	1.8780	-1.9711	-5.7545	1149.3	-1.8779
9	-4.99	0.0582	299.1	2856.	-0.8639	1.6994	0.03495	-0.16731	2.1280	-1.9560	-6.5005	1225.6	-1.7738
10	-4.99	0.0556	285.8	2729.	-0.8534	1.6599	0.03282	-0.16790	2.3780	-1.9348	-7.7469	1298.5	-1.7152
11	-4.99	0.0531	272.9	2606.	-0.8649	1.6583	0.03147	-0.16641	2.6280	-1.9180	-7.1073	1368.0	-1.6461
12	-4.99	0.0507	260.6	2489.	-0.8551	1.6480	0.03300	-0.16176	2.8780	-1.9037	-8.0407	1434.5	-1.5562
13	-4.99	0.0484	248.8	2376.	-0.8592	1.6222	0.03056	-0.15895	3.1280	-1.8898	-5.8984	1497.9	-1.4916
14	-4.99	0.0462	237.6	2269.	-0.8525	1.6022	0.02781	-0.15573	3.3780	-1.8804	-6.0214	1558.5	-1.4165
15	-4.99	0.044	226.9	2167.	-0.8456	1.5806	0.03011	-0.15693	3.6280	-1.8693	-5.5574	1616.4	-1.3559
16	-4.99	0.0421	216.7	2070.	-0.8439	1.5712	0.02905	-0.15348	3.8780	-1.8630	-5.6668	1671.8	-1.3000
17	-4.99	0.0402	207.0	1977.	-0.8413	1.5552	0.02431	-0.15207	4.1280	-1.8497	-5.7446	1724.6	-1.2310
18	-4.99	0.0385	197.[illegible]	1888.	-0.8360	1.5403	0.02300	-0.15103	4.3780	-1.8438	-7.7028	1775.0	-1.1724
19	-4.99	0.03[illegible]	188.[illegible]	1804.	-0.8314	1.5239	0.02627	-0.14770	4.6280	-1.8344	-8.1678	1823.2	-1.1367
20	-4.99	0.03[illegible]	[illegible].4	1723.	-0.8292	1.5192	0.02424	-0.14153	4.8780	-1.9252	-21.1852	1869.2	-1.0676
21	-4.99	0.033	[illegible]	1646.	-0.8239	1.4969	0.02434	-0.14096	5.1280	-1.8196	-6.7438	1913.1	-1.0356
22	-4.99	0.0322	[illegible]	1572.	-0.8265	1.4935	0.02536	-0.13995	5.3780	-1.8090	-6.4979	1955.2	-0.9599
23	-4.99	0.0306	[illegible]	1502.	-0.8232	1.4840	0.02276	-0.13750	5.6280	-1.8047	-5.5848	1995.2	-0.9713
24	-4.99	0.0292	[illegible].0	1433.	-0.8228	1.4755	0.02271	-0.13570	5.8780	-1.7957	-12.6969	2033.5	-0.9215
25	-4.99	0.0280	[illegible].8	1374.	-0.8210	1.4742	0.02164	-0.13170	6.1280	-1.7986	-11.0592	2070.1	-0.8488
26	-4.99	0.0267	137.5	1313.	-0.8219	1.4693	0.01970	-0.12586	6.3780	-1.7892	-16.7221	2105.1	-0.8099
27	-4.99	0.0254	130.8	1249.	-0.8201	1.4630	0.02030	-0.12506	6.6280	-1.7873	-7.5126	2138.5	-0.7923
28	-4.99	0.0243	124.8	1192.	-0.8214	1.4601	0.01959	-0.12259	6.8779	-1.7815	-7.2016	2170.3	-0.7133
29	-4.99	0.0232	119.5	1141.	-0.8249	1.4590	0.01934	-0.12165	7.1279	-1.7726	-7.3568	2200.8	-0.7450
30	-4.99	0.0221	113.9	1087.	-0.8148	1.4494	0.01989	-0.12044	7.3779	-1.7820	5.0155	2229.8	-0.6803
31	-4.99	0.0211	108.8	1039.	-0.8181	1.4427	0.01722	-0.11742	7.6279	-1.7686	-6.2025	2257.6	-0.6429
32	-4.99	0.0202	103.9	992.	-0.8151	1.4422	0.01763	-0.11592	7.8779	-1.7755	5.9191	2284.1	-0.6153
33	-4.99	0.0193	99.3	948.	-0.8123	1.4348	0.01714	-0.11280	8.1279	-1.7731	0.0919	2309.4	-0.6119
34	-4.99	0.0184	94.7	904.	-0.8083	1.4286	0.01669	-0.11162	8.3779	-1.7741	-10.2939	2333.5	-0.5796
35	-4.99	0.0176	90.4	863.	-0.8058	1.4232	0.01589	-0.10987	8.6279	-1.7736	5.2390	2356.6	-0.5248
36	-4.99	0.0168	86.4	825.	-0.8147	1.4298	0.01835	-0.11092	8.8779	-1.7614	2.3024	2379.6	-0.5466
37	-4.99	0.0160	82.3	786.	-0.8123	1.4263	0.01334	-0.10639	9.1279	-1.7643	-5.7563	2399.6	-0.4894
38	-4.99	0.0153	78.6	751.	-0.8049	1.4178	0.01429	-0.10297	9.3779	-1.7714	0.8946	2419.7	

CTP	CLNP	CYO	CLNO	CLP	LP	IG	CLD	PSS	PSSD/2V	SUMR	CLP1
0.36864	-1.06401	0.01132	-0.09972	-4.0282	-0.0061	0.0115	0.0015	1.90	0.0044	4.78467E-08	-4.080E+00

DATE 21-OCT-78 PROJECT NO P41C-20

Table 6. Concluded

ARO, INC.
AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
PROPULSION WIND TUNNEL
ARNOLD AIR FORCE STATION, TENNESSEE

PART	POINT	M	RX10-6	ALFI	CONF
134	4	0.904	1.114	-4.91	2

CYP	CLNP	CYO	CLNO	SUMR
0.35864	-1.06491	0.01132	-0.09972	4.785E-08

SAMPLE	ALF-M	P	PD/2V	CYC	CLNC	RES
1	-4.99	433.8	0.0844	0.0264	-0.0698	4.72E-03
2	-4.99	413.9	0.0805	0.0270	-0.0720	2.64E-03
3	-4.99	395.0	0.0768	0.0261	-0.0745	2.02E-03
4	-4.99	377.0	0.0733	0.0244	-0.0710	2.60E-03
5	-4.99	359.9	0.0700	0.0241	-0.0687	1.71E-03
6	-4.99	343.6	0.0669	0.0263	-0.0708	-1.70E-03
7	-4.99	328.0	0.0638	0.0240	-0.0705	-4.79E-04
8	-4.99	313.2	0.0609	0.0231	-0.0683	-6.88E-04
9	-4.99	299.1	0.0582	0.0235	-0.0576	-2.18E-03
10	-4.99	285.8	0.0556	0.0219	-0.0682	-1.01E-03
11	-4.99	272.9	0.0531	0.0222	-0.0667	-2.59E-03
12	-4.99	260.6	0.0507	0.0217	-0.0620	-3.00E-03
13	-4.99	248.8	0.0484	0.0192	-0.0592	-1.41E-03
14	-4.99	237.6	0.0462	0.0185	-0.0560	-1.46E-03
15	-4.99	226.9	0.0441	0.0188	-0.0572	-2.52E-03
16	-4.99	216.7	0.0421	0.0177	-0.0536	-2.19E-03
17	-4.99	207.0	0.0403	0.0170	-0.0523	-2.15E-03
18	-4.99	197.7	0.0385	0.0177	-0.0513	-3.50E-03
19	-4.99	188.9	0.0367	0.0150	-0.0450	-1.41E-03
20	-4.99	180.4	0.0351	0.0129	-0.0418	6.51E-06
21	-4.99	172.4	0.0335	0.0 10	-0.0412	-6.66E-04
22	-4.99	164.6	0.0320	0.0140	-0.0432	-2.24E-03
23	-4.99	157.3	0.0306	0.0114	-0.0373	-1.60E-04
24	-4.99	150.0	0.0292	0.0114	-0.0360	-6.60E-04
25	-4.99	143.9	0.0280	0.0103	-0.0320	-9.17E-06
26	-4.99	137.5	0.0267	0.0084	-0.0261	1.44E-03
27	-4.99	130.8	0.0254	0.008	-0.0253	6.94E-04
28	-4.99	124.8	0.0243	0.008	-0.0229	6.84E-04
29	-4.99	119.5	0.0232	0.008	-0.0219	5.38E-04
30	-4.99	113.9	0.0221	0.008	-0.0207	-4.07E-04
31	-4.99	108.8	0.0211	0.0	-0.0177	1.90E-03
32	-4.99	103.9	0.0202	0.00	-0.0162	1.14E-03
33	-4.99	99.1	0.0193	0.0055	-0.0131	1.27E-03
34	-4.99	94.7	0.0184	0.0054	-0.0119	1.41E-03
35	-4.99	90.4	0.0176	0.0046	-0.0101	1.90E-03
36	-4.99	86.4	0.0168	0.0070	-0.0112	-8.37E-04
37	-4.99	82.3	0.0160	0.0020	-0.0057	3.88E-03
38	-4.99	78.6	0.0153	0.0030	-0.0033	2.67E-03