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NAVY COANDA/REFRACTION GROUND NOISE SUPPRESSOR PROGRAM PLAN.(U)

SEP 74 R E BALLARD, L L BURTON N00156-74-C-1710

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ABSTRACT

The Navy has been investigating techniques to reduce jet engine noise during ground run up testing. Boeing has conducted exploratory work under two Navy Contracts, N00156-72-C-1053 and N00156-73-C-1794, preparatory to release of this contract.

The objective of this program is to continue the development of the Coanda/Refraction concept, investigated during the exploratory contracts, to attenuate the noise generated in the exhaust of turbojet/turbofan aircraft engines during ground run-up testing.

Full scale design, fabrication and testing will be accomplished using the Coanda concept to validate the results obtained during the exploratory model studies and provide accurate noise reduction data. Concurrent with the full scale activity, additional model studies will also be conducted to evaluate the Coanda concept and its applicability to engines installed in airframes.

This document defines the detail plan that will be followed to accomplish the overall program.

RETRIEVAL REFERENCE WORDS:

Noise Suppressor
Ground Noise Suppressor
Coanda Concept
Noise Attenuation

E-3042 R1

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NOMENCLATURE

ABBREVIATIONS AND SYMBOLS

A/B	AFTERBURNING
A/F	AIR FORCE
Amb	AMBIENT
A.R.	ASPECT RATIO
Atm	ATMOSPHERIC
B.L.	BASELINE
CRES	CORROSION RESISTANT STEEL
dB	DECIBEL
Dia	DIAMETER
Dims	DIMENSIONS
DOC	DOCUMENT
EAMR	ENGINEERING ADVANDED MATERIAL REQUEST
Fab	FABRICATION
Fac	FACILITY
^{o}F	DEGREES FAHRENHEIT
Ft	FEET
GFE	GOVERNMENT FURNISHED EQUIPMENT
GNSS	GROUND NOISE SUPPRESSOR SYSTEM
gpm	GALLONS PER MINUTE
Hg	MERCURY
Hz	FREQUENCY IN HERTZ (CYCLES PER SECOND)
in.	INCHES
K	KNOTS
KHz	FREQUENCY IN 1000 HERTZ (CYCLES PER SECOND)
LBS	POUNDS
Matl	MATERIAL
Max	MAXIMUM
Mil	MILITARY

NOMENCLATURE - CONT'D.

ABBREVIATIONS AND SYMBOLS

Min	MINUTES
MPH	MILES PER HOUR
No.	NUMBER
Outbd	OUTBOARD
O.D.	ON DOCK
P	PRESSURE
ΔP	CHANGE IN PRESSURE
Prelim	PRELIMINARY
psi	POUNDS PER SQUARE INCH
psia	POUNDS PER SQUARE INCH ABSOLUTE
psig	POUNDS PER SQUARE INCH GAGE
R	RADIUS
Rad	RADIUS
Ref	REFERENCE
RPM	REVOLUTIONS PER MINUTE
Sec	SECOND
Stl	STEEL
T	TEMPERATURE
Typ	TYPICAL

1.0 INTRODUCTION

1.1 Background

One of the most serious problems associated with ground testing of jet aircraft engines is the extremely high noise level radiated from the test area. The noise endangers operating personnel hearing and disturbs nearby communities. In order to alleviate the Navy contribution to this crucial, worldwide problem, the Naval Air Systems Command has initiated a noise reduction program to attenuate noise radiated by Navy/Marine aircraft gas turbine engines during ground run-up testing. This includes noise radiated by in-airframe engines during aircraft ground run-up, preflight trim checks, and pre-/post-maintenance testing, as well as out-of-aircraft engine testing on portable test stands or in test cells.

Past equipment procurements and design studies have been limited to state-of-the-art hardware and technology which, although effective in reducing engine noise, have not yet been developed for prolonged durability against the adverse effects of engine exhaust; viz., high impact forces, excessive temperatures, and entrained contaminants. Furthermore, procurements of noise suppression equipment or test cell acoustic baffles have been diverse in origin and objectives, so that the existing equipment is not interchangeable. Many designs accommodate only one engine. Lack of commonality in design does not permit a practical, efficient logistics plan for fleet support and for replacement of deteriorating parts.

The exploratory development phase of the Coanda/Refraction suppressor development was conducted under Navy contracts N00156-72-C-1053 and N00156-73-C-1794, and is reported in References 1 and 2. The specific conclusions from the initial efforts are as follows:

(a) A technological approach applying the Coanda effect and the noise refraction principle to jet engines has been derived analytically and verified experimentally.

(b) The velocity and thermal gradients in the turned flow caused the noise to refract away from the flow. Acoustic material behind the Coanda surface can then absorb a portion of the refracted energy.

(c) Initial Coanda surface configuration parameters have been derived for radius-of-curvature and jet adapter width-to-height ratios for optimum jet efflux bending.

(d) One-sixth scale model Coanda surface parametric test results may be extrapolated for full scale model operational tests.

The results from the initial efforts will be used as technical guide lines for the work required by this contract. Specifically, the physical characteristics/properties of the one-sixth scale models will be extrapolated to full size experimental hardware with the objectives of duplicating jet-bending air-eduction characteristics, as well as resolving acoustic aspects which could not be accomplished by the models tests.

1.2 Objectives

The objective of this program is to continue the development of the Coanda/Refraction concept for attenuating the noise generated in the exhaust of turbojet/turbofan aircraft engines during ground run-up testing.

This work will expand the results from the exploratory development studies by resolving certain aspects which could not be accomplished within the scope of the initial contracts. In addition, this program will be oriented toward developing a finalized statement of the Coanda/Refraction concept with applications to specific military objectives such as test cell exhaust systems and aircraft run-up suppressor systems. The methodology to be utilized includes extrapolation of the model study results to full size experimental hardware design, extensive testing, design analyses, and documentation of results.

The long range objective of this program is to generate a "family" of aircraft engine noise suppressors. This group will be related in technological foundation to the Coanda/Refraction concept, but will be varied in equipment configuration for each type of Navy/Marine Corps engine test facility; e.g., test cell, aircraft run-up, portable muffler.

The desired operational characteristics of the equipment to be developed during this program are as follows:

(a) Improved low-frequency noise attenuation.

(b) Acoustic elements positioned out of the primary exhaust flow path to avoid deterioration due to exhaust flow forces and entrained contaminants.

(c) Elimination of turning vanes and associated structural support elements.

(d) Elimination of extensive requirements for a cooling water system to support afterburner engine testing; this includes water spray ring, piping, pumps, and associated enclosures/tanks.

Achievement of these operational characteristics will lead to improved reliability, maintainability and logistic support.

1.3 Technical Approach

During the preliminary design task, consideration will be given to the effect of J-52, J-57, J-75, J-79, TF-30, and TF-41 engine operating parameters to define the proposed suppressor capabilities for jet deflection and acoustic attenuation. In addition, model studies will be conducted to determine the applicability of the Coanda/Refraction concept to ground test engines in their airframes.

The technical approach for conducting this program is:

(a) Utilize the feasibility/initial sizing studies results to develop full size demonstrator hardware.

(b) Conduct analytic studies/calculations to design conceptual hardware for further development tests for acoustic absorptive characteristics, augmented cooling air inlets, and deflector surface film cooling air slots. The ejectors and Coanda deflector configurations resulting from the exploratory development phase will be used in the full scale demonstrator design.

(c) Fabricate a full scale demonstrator unit.

(d) Using a full size engine, conduct extensive testing for measurement of pressures, temperatures, mass air flows, and acoustic spectra.

(e) Using recorded data and observations from full scale jet deflection tests, establish realistic noise reduction criteria for material selection and operational procedures for proposed systems.

(f) Model studies will include engine/Coanda misalignment, coannular flow and twin engine exhaust evaluations to assist in determining the applicability of the Coanda concept to engines installed in airframes.

The planned program will be accomplished under six tasks described below:

TASK I will consist of the design of full scale experimental hardware including suppressor elements, enclosure structure, test site instrumentation, and the preparation of a detailed test plan.

TASK II will consist of the fabrication of the demonstrator noise suppressor and all equipment necessary for the test site and test setup.

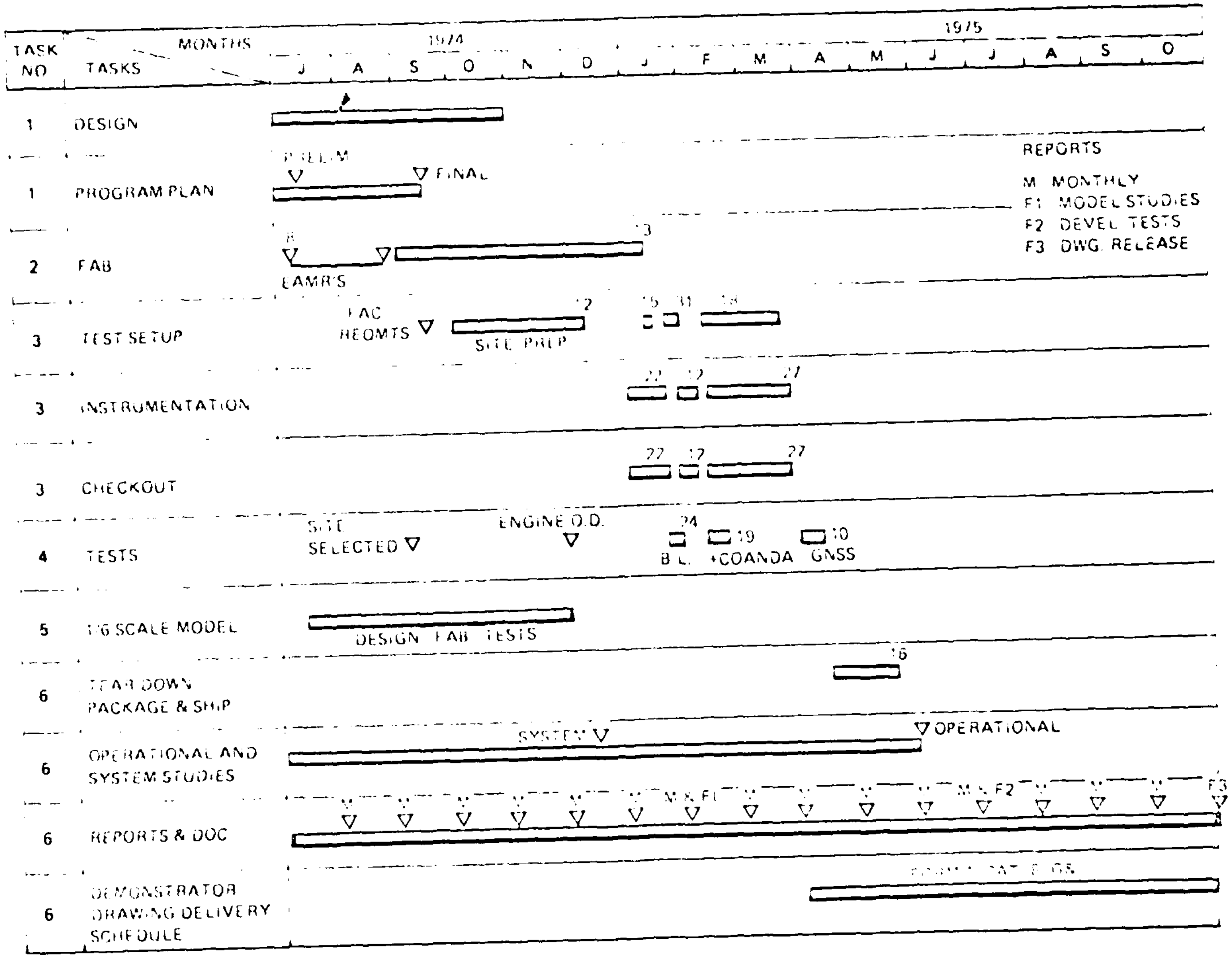
TASK III will consist of the assembly of the demonstrator noise suppressor, and installation, calibration and checkout of all required instrumentation.

TASK IV will consist of the experimental sequence of tests to evaluate the propulsion, structural, aerodynamic, and acoustic characteristics of the full scale demonstrator.

TASK V will consist of one-sixth scale model tests to obtain data that will assist in adapting the Coanda/Refraction concept to installed engine applications in various aircraft, and to support developmental changes in the full scale test program.

TASK VI will consist of the documentation of the test results including engineering analyses, design studies, and drawing preparation.

Each task is to be accomplished in accordance with the schedule shown in Figure 1. Details of these tasks are contained in Section 2.0 of this report.



PROGRAM SCHEDULE
COANDA/REFRACTION CONCEPT ADVANCED DEVELOPMENT TEST CELL SYSTEM
FIGURE 1

1.4 Government Furnished Equipment

Despite the wide range of engine performance parameters to be considered in design, testing will be accomplished with only one engine. The Navy is to provide either a TF-30-P-9 or a J-75 engine (Air Force model) as an equivalent test source. Tests will be conducted in accordance with applicable engine operation manuals and test cell capabilities.

This program plan is predicated upon use of the A/F32T-2 test cell located at McConnell AFB, Wichita, Kansas. Concurrence from the Navy for use of this facility must be received by The Boeing Company.

This program plan is also predicated upon operation of the test cell and its auxiliary systems and operation of the test engine by qualified military personnel. Logistic support of the A/F32T-2 test cell and test engine will be the responsibility of the Government.

2.0 PROGRAM PLAN

2.1 Task I

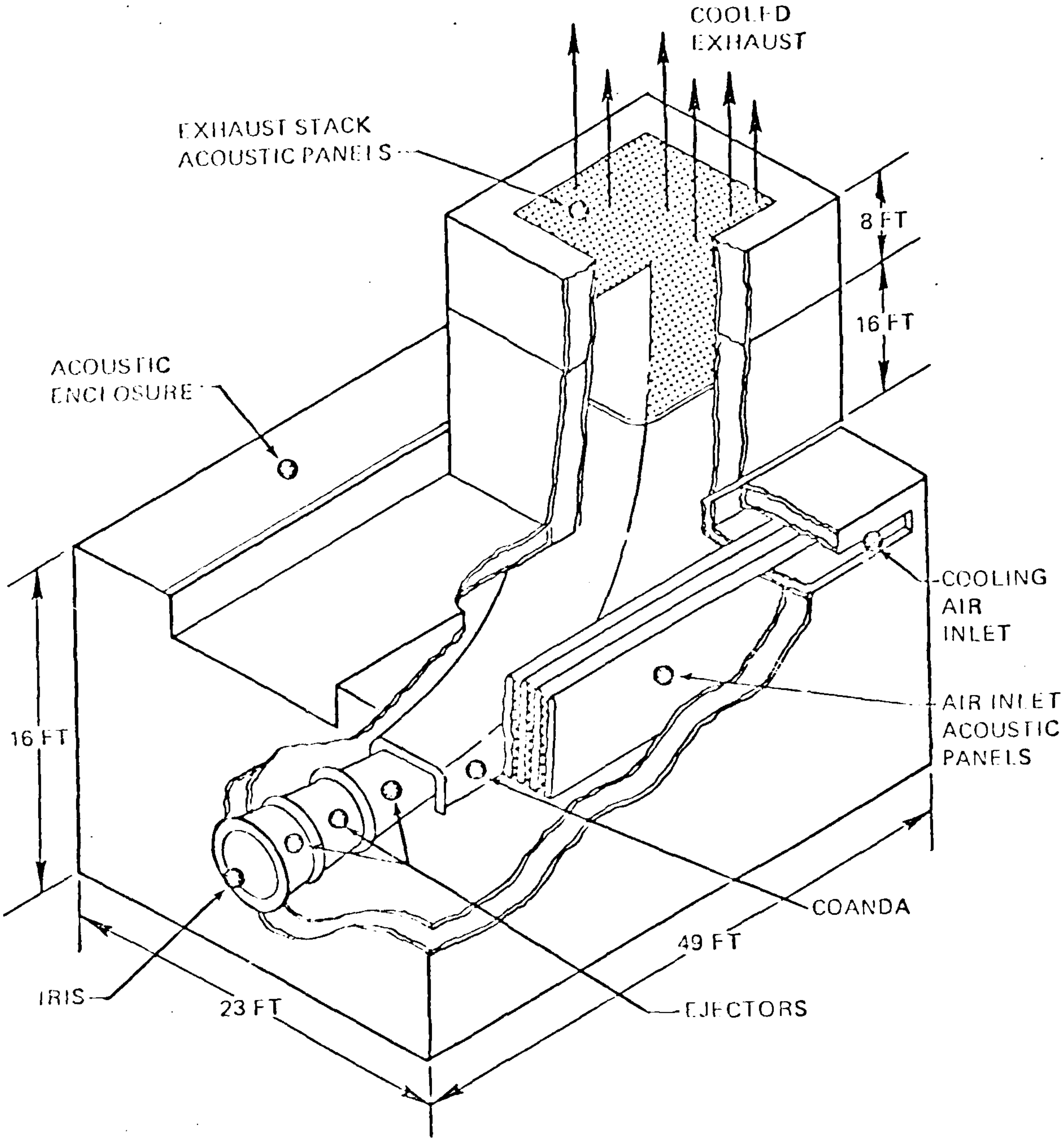
Task I consists of the design of full scale experimental hardware including suppressor elements, enclosure structure, test site, instrumentation, and the preparation of a detailed test plan.

2.1.1 Design Studies

The design studies consist of defining a configuration based on previous test results. The configuration which was defined from Reference 1 and Reference 2 model tests will be further developed by means of studies considering acoustic and fluid dynamic parameters and efficient use of manufacturing processes, materials, and other cost influencing items.

2.1.1.1 Configuration Description

The Coanda/Refraction Suppressor System suppresses jet engine exhaust noise by turning and cooling the airflow and acoustically treating the enclosure that houses the system. The Coanda effect is the turning of a jet stream due to its adherence to a curved surface. The system draws in cooling air by a series of ejectors upstream of the Coanda surface that cools the hot exhaust gases and provides a film of cooling air along the Coanda surface. The three-sided Coanda turns the flow 90° to the vertical and draws more cooling air into the open side of the flow path as the flow transitions to the vertical. The Coanda/Refraction Suppressor is illustrated in Figure 2. The enclosure is approximately 49 feet long, 23 feet wide and 40 feet high to the top of the stack, and is acoustically treated to reduce the noise coming from the ejector and cooling air flow, and the noise of the jet flow along the Coanda. Details of the construction are contained in Section 2.3.1.1.



COANDA/REFRACTION NOISE SUPPRESSOR
FIGURE 2

2.1.1.2 Criteria

The following mechanical criteria are based on previous one-sixth scale model tests. The acoustic criteria are program goals for noise suppression.

Mechanical Criteria

Environmental Conditions:
The full scale demonstrator will be designed to withstand the following conditions:

a. Wind speed of 50 MPH during testing and 120 MPH for static conditions.

b. Temperatures the range between -30°F. and 150°F.

c. Ten-inches of precipitation in the form of rain or snow.

Capability:
The suppressor design shall be capable of attaining the noise goals and withstanding the mass flows of any one of the families of engines listed in Table 1.

Cooling:
The design shall utilize only ambient air for cooling.

TABLE I

AIRCRAFT TURBOJET/FAN ENGINES

ENGINE MODEL	ENGINE EXHAUST PARAMETERS					
	IDLE		MILITARY		AFTERBURNER	
	MASS FLOW LBS/SEC	T_t °F	MASS FLOW LBS/SEC	T_t °F	MASS FLOW LBS/SEC	T_t °F
J-52-P-408	40	530	143	1400	-	-
J-57-P-20B	50	460	180	1166	180	3000-3200
J-75-P-19W	86	430	253	1166	252	3000-3200
J-79-P-17	43	613	171	1240	178	3260
TF-30-P-408	69	292	259	725	-	-
TF-30-P-412A	100	255	242	703	242	3170
TF-41-A-2	59	450	263	820	-	-

Coanda Surface:

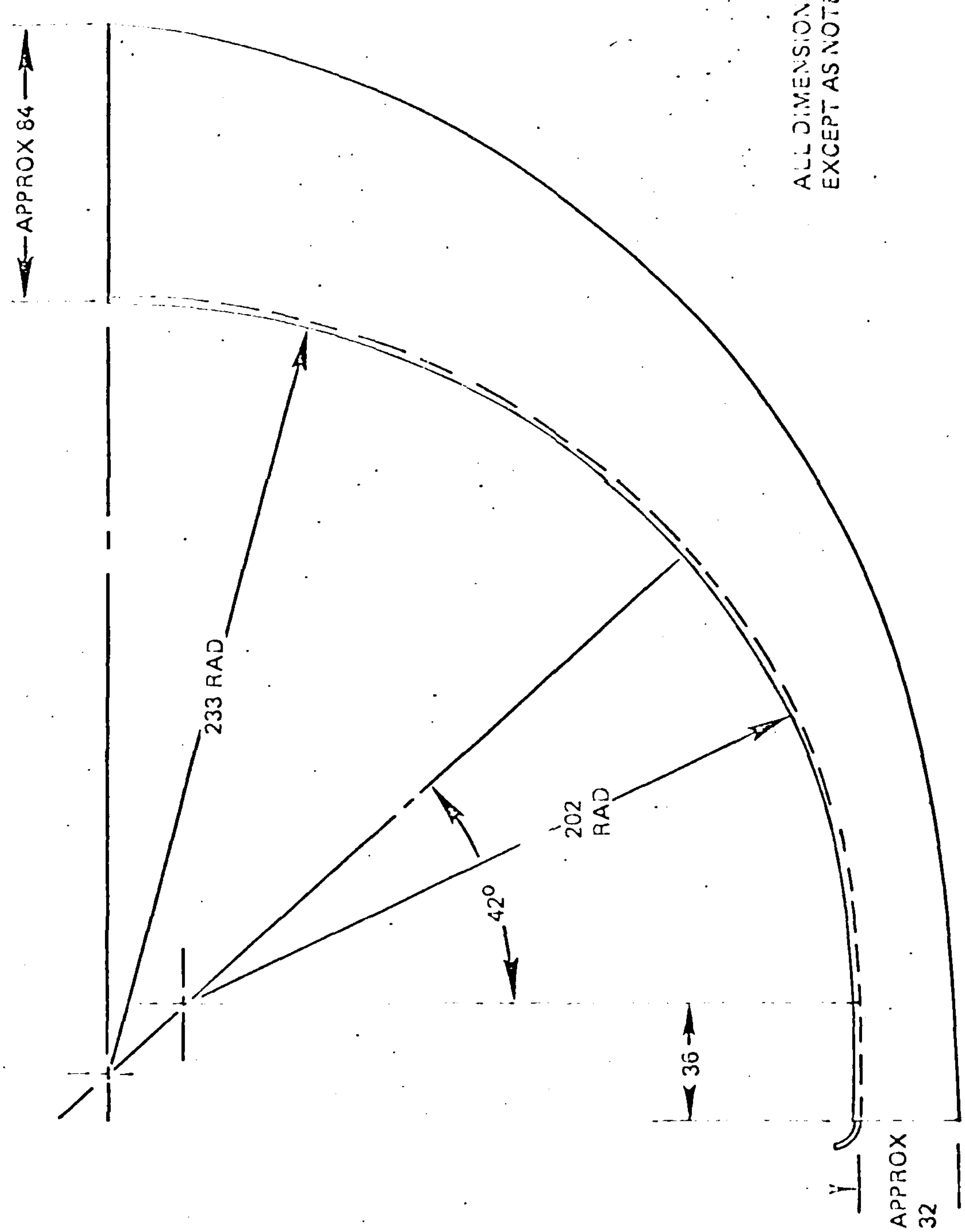
The Coanda curved surface shall form a logarithmic spiral, $R = xe^{a\theta}$, where x = 180 inches and where a = 0.20 except that the surface should be rotated such that it does not dip below the horizontal. It is acceptable to simulate the logarithmic spiral with two radii (202 inches and 233 inches) tangent to each other at the 42^{o} position as shown on Figure 3. There will be a 36-inch straight section at the Coanda surface entrance preceding the start of curvature.

The Coanda surface will be 63 inches wide between sidewalls. The sidewalls will produce a channel of approximately 32-inches deep at the Coanda entrance and approximately 84 inches deep at the exit.

The Coanda surface will be made from material that will withstand repeated temperature variations from -30^{o}F. to 1000^{o} F at flow velocities from 0 to 2800 feet/sec and will be sufficiently supported to withstand vibrations due to flow buffeting and sonic levels in the 165 dB range. Surface and structural loads due to pressure differentials are a maximum of 2 psi with the inside surfaces of the Coanda channel subjected to the lower pressure.

Transition Section:

The transition section will consist of a three ejector set that transitions from round through oval to rectangular. The ejectors are to be positioned so that the inlet highlight of one is in the plane of the exit of the preceding ejector and the exit of the last ejector is in the plane of the Coanda surface entrance.



ALL DIMENSIONS IN INCHES
EXCEPT AS NOTED

COANDA SURFACE CONTOUR CRITERIA
FIGURE 3

Mechanical Criteria - Cont'd.

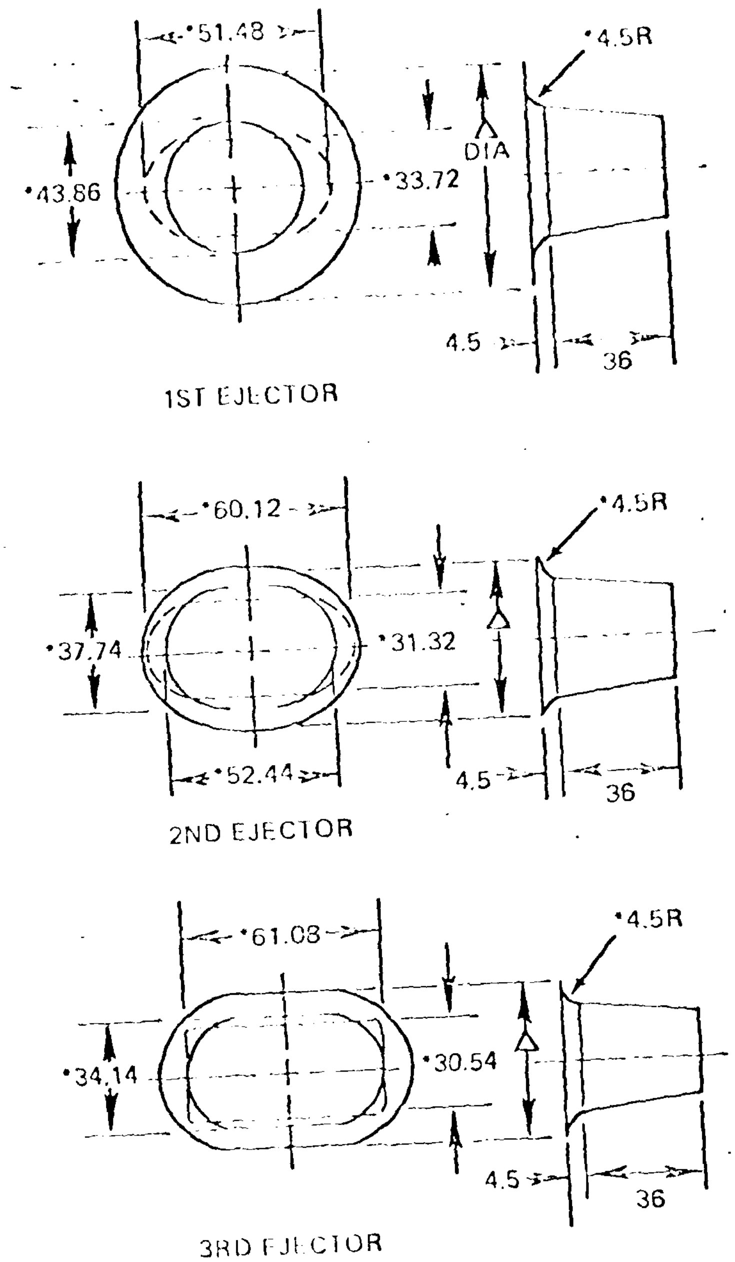
The inside dimensions for the three ejectors are shown on Figure 4. The material for these ejectors will be capable of withstanding repeated temperature rises to 1000°F and designed to a maximum internal pressure reduction of 4 psi. The ejectors will have a net force (except for their weight) in a forward direction due to augmentation of approximately 800 pounds per ejector. The inlet flanges on the ejectors may extend beyond the radius an amount required for structural or attach purposes.

Adapter Section:

The adapter or "jet catcher" will be an adjustable type such as an iris, to allow for tailpipe diameters ranging from 19.5 to 42 inches for the engines listed in Table 1. The range of tailpipe diameters includes the J-52 engine as the smallest and the TF-30-P-412A as the largest. However, the demonstrator range of adjustment may be configured to only encompass the engine intended for the evaluation tests. The iris adjustments will be accomplished mechanically prior to each run and are dependent upon the maximum power settings to be tested during the run.

Enclosure:

The area of the secondary air inlets in the acoustic enclosure walls will be at least 30 square feet on each side and 4 square feet at the back (lower edge of stack). Acoustic baffles in the air inlet will have leading and trailing edge fairings and rounded corners to maintain effective flow areas.



• INSIDE DIMENSIONS

△ FLANGE WIDTHS TO BE THAT REQUIRED FOR STRUCTURAL AND/OR ATTACH PURPOSES

ALL DIMENSIONS IN INCHES

EJECTOR DETAILS - THREE EJECTOR TRANSITION
FIGURE 4

Mechanical Criteria-Cont'd.

The stack exit area will be at least 143 square feet and will be as narrow as reasonable for acoustic purposes (smallest duct height preferred). The dimensions for inlets and acoustic baffles are established by the acoustic criteria.

All ejectors and transition section inlets will be inside the enclosure.

Reliability:

The suppressor system shall be designed for a life cycle of 10 years.

Maintainability:

The suppressor shall be easily maintained and not require major repairs during the life of the system.

Compatibility:

The suppressor system shall be compatible with the Navy design A/F32J-15 (demountable enclosure) test cell. Interface details will be defined by the Navy.

Acoustic Criteria

The suppressor noise reduction performance will be evaluated at both the far-field (250 foot radius from the engine core) and near-field (20 foot sideline distance from the engine centerline).

The far-field and near-field noise goals are the Sound Pressure Level (SPL) spectra given in Table 2, which are the same as the Grade II criteria given in USAF Specification MIL-N-83155B.

TABLE 2

NOISE CRITERIA

FREQUENCY Hz	MIL SPEC N-83155B GRADE II (USAF)	
	FAR FIELD	NEAR FIELD
63	94	114
125	91	114
250	88	114
500	84	114
1000	83	117
2000	83	117
4000	79	117
8000	73	120
dBA	90	125

2.1.2 Test Site

The test site will include essential services for operating a turbojet engine with afterburner thrust up to 24,500 pounds. The test area terrain should be relatively flat with no more than ±1 degree angle of grade from the engine center to the acoustic recording locations.

The selected test site is an out of service "Test Cell Noise Suppressor", Model A/F 32T-2 located at McConnell Air Force Base. The cell is opposite the Contractor's facility and adjacent to an open apron that is suitable for sound pressure level measurements. The A/F 32T-2 will be modified to accommodate testing of the Coanda/Refraction Noise Suppressor.

2.1.3 Instrumentation Requirements

2.1.3.1 Engine Parameters

The engine instrumentation requirements are listed in Table 3.

2.1.3.2 Coanda Aerodynamic Parameters

The Coanda surface and ejector instrumentation are shown on Figure 5. The instrumentation includes 10 static pressure pickups and 10 surface temperature thermocouples at 10° angle increments on the Coanda centerline, 12 static pressure pickups and 12 surface thermocouples on the ejectors, four each static pressures and temperatures on the Coanda side panel, and an exit total pressure rake.

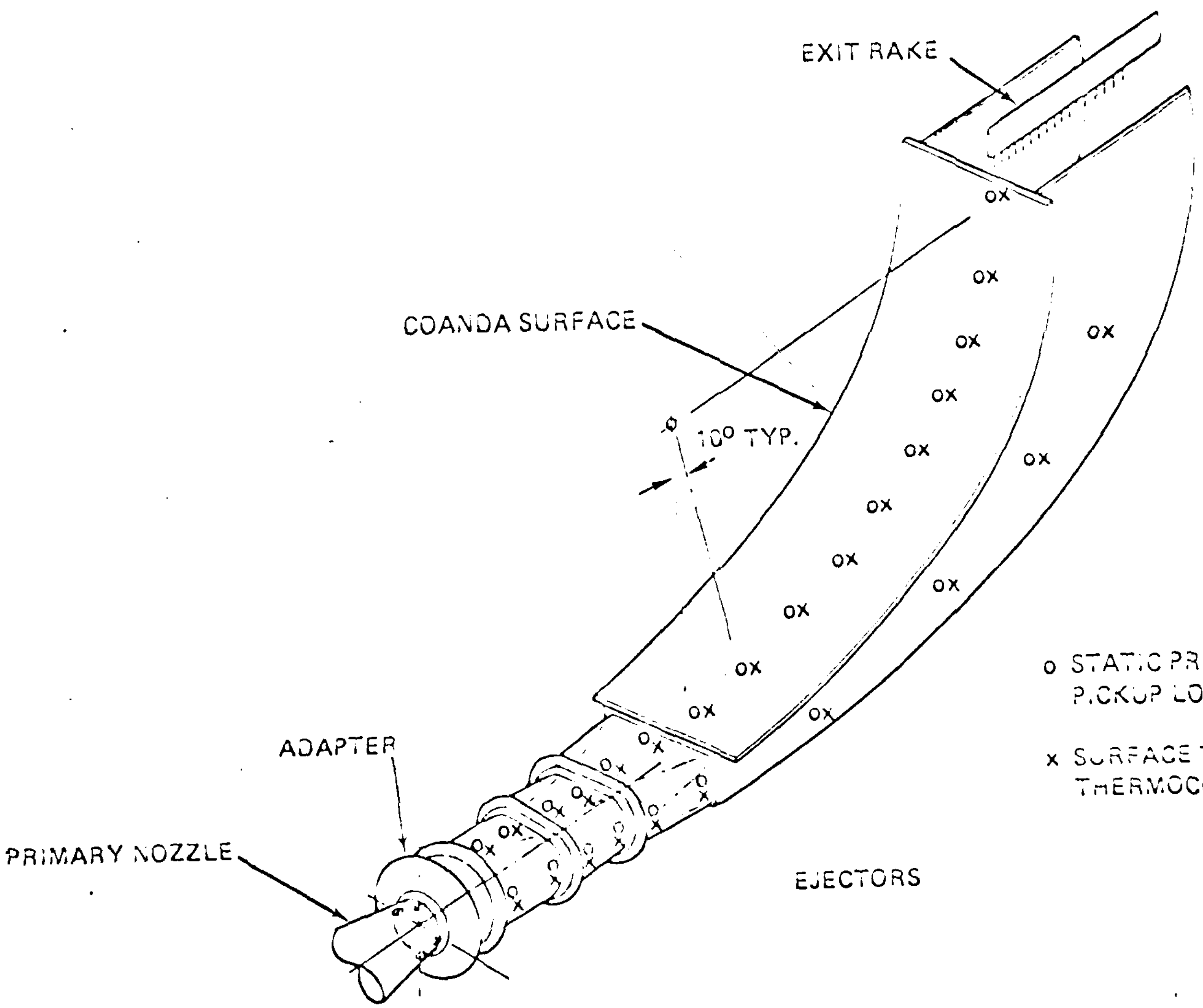
Table 4 tabulates the required instrumentation range and accuracy for these parameters.

TABLE 3

ENGINE INSTRUMENTATION

Item	Units	No.	Range	Accuracy
N_1	RPM	1	1000 - 7000	$\pm$0.5% *
N_2	RPM	1	5000 -10,000	$\pm$0.5% *
P_{T_7}	psia	1	atm - 27	$\pm$0.5% *
T_{T_7}	^oF.	1	amb - 1050	30^oF.*
W_f	lb/Min	1	0 - 1000	$\pm$1.0% *
F_g	lb.	1	0 - 25,000	$\pm$0.5% *
T_{fuel}	^oF.	1	0 - 100	$\pm 2^oF$. *
P_{T_2}	psia	1	13 - 15	$\pm$ 0.01 inch water
P_{amb}	in. Hg.	1	28 - 29	± .02 In.Hg.
T_{amb}	^{o} F.	1	0 - 110	1^o F.
P_{oil}	psig	1	0 - 60	$\pm$3% *
T_{oil}	^oF.	1	amb - 300	$\pm 5^o$ F.*
$(P_t - P_s)$ Bellmouth	in.H_2O	1	0 - 70	0.5%
Wind Velocity	MPH	1	0 - 20	±1 MPH
Wind Direction	Degrees	1	0 - 360	$\pm 10^o$ (0^o ref. to true North)
Relative Humidity	%	1	0 - 100	±5%
Engine Vibration	Mils	4	0 - 10	±1% *

* Depends on Control Cab Instrumentation



o STATIC PRESSURE PICKUP LOCATION

x SURFACE TEMPERATURE THERMOCOUPLE LOCATION

COANDA SURFACE AND EJECTOR PRESSURE
AND THERMOCOUPLE INSTRUMENTATION
FIGURE 5

TABLE 4

COANDA AND EJECTOR INSTRUMENTATION

Location and Measurement	Units	No.	Range	Accuracy
Nozzle exit static pressure	psia	4	Amb. $\pm$ 0.5	$\pm$ 1%
Ejector static pressures	psia	12	10.0 - Amb.	$\pm$ 1%
Ejector metal surface temperature	^oR	12	Amb. - 1500^o	$\pm$ 2%
Coanda surface static pressures	psia	14	10.0 - Amb.	$\pm$ 1%
Coanda metal surface temperature	^oR	14	Amb. - 1500^o	$\pm$ 2%
Exit rake total pressures	psia	14	Amb. - 17.0	$\pm$ 1/2%

2.1.3.3 Coanda Enclosure Instrumentation

The enclosure for the Coanda will be instrumented to determine the amount of secondary cooling airflow entering the Coanda and ejectors. Figure 6 depicts the static pressure instrumentation equally spaced approximately four feet apart inside the secondary air channel entrance on each side of the enclosure and aft air inlet. The average static pressure measured within the entrance will be combined with ambient pressure and secondary air entrance area to calculate secondary air mass flow. In addition, two static pressure pickups will be located inside the enclosure.

Vibration transducers will be installed on each side of one sidewall of the enclosure to monitor typical sidewall vibrations.

2.1.3.4 Acoustic Parameters

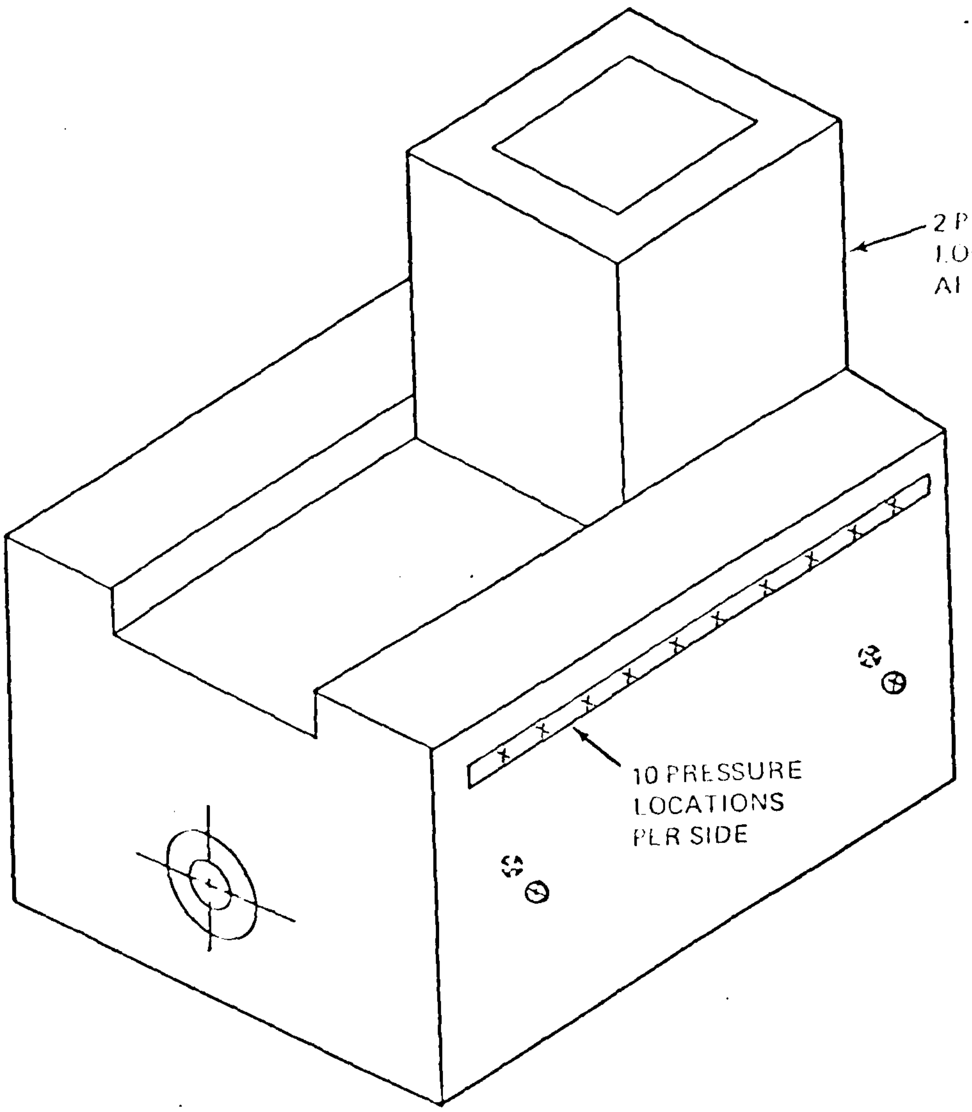
The Coanda enclosure acoustic instrumentation is illustrated on Figure 7. It includes 10 microphones paired on the sides of the enclosure wall and roof (one on the inside and one on the outside) approximately as shown. Far-field measurement microphone locations shall be as shown on Figure 8. The microphones will be mounted on two powered carts that traverse 90 degrees of the semi-circle. Each microphone will incorporate a wind screen and will be mounted such that the face will be approximately 1/2-inch above the ground level. Near-field acoustic measurements will be made on a 20 foot rectangular pattern as illustrated in Figure 9. The microphones will have a typical spacing of 20 feet from the engine centerline and between adjacent mikes. They will be mounted approximately 5-1/2 feet above engine ground level.

2.1.3.5 Structural Instrumentation

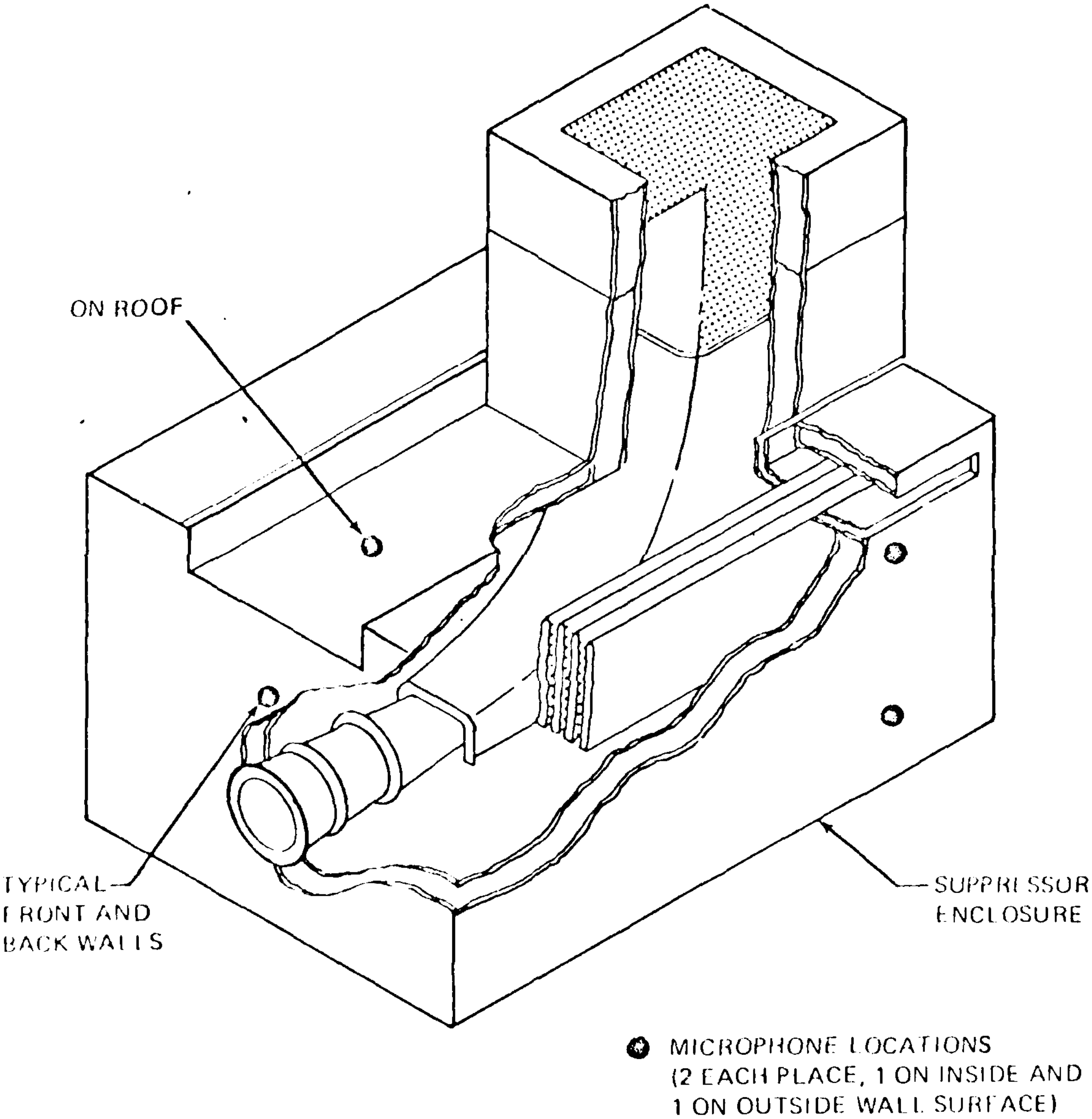
Instrumentation will be installed on the Coanda to support a brief structural analysis. Instrumentation locations are shown on Figure 10. Table 5 lists the instruments, instrument location, and an estimate of the test environment extremes. Pressure and temperature data requirements for the Coanda surface are as defined in Section 2.1.3.2.

x STATIC PRESSURE PICKUPS INSIDE SECONDARY AIR INLETS

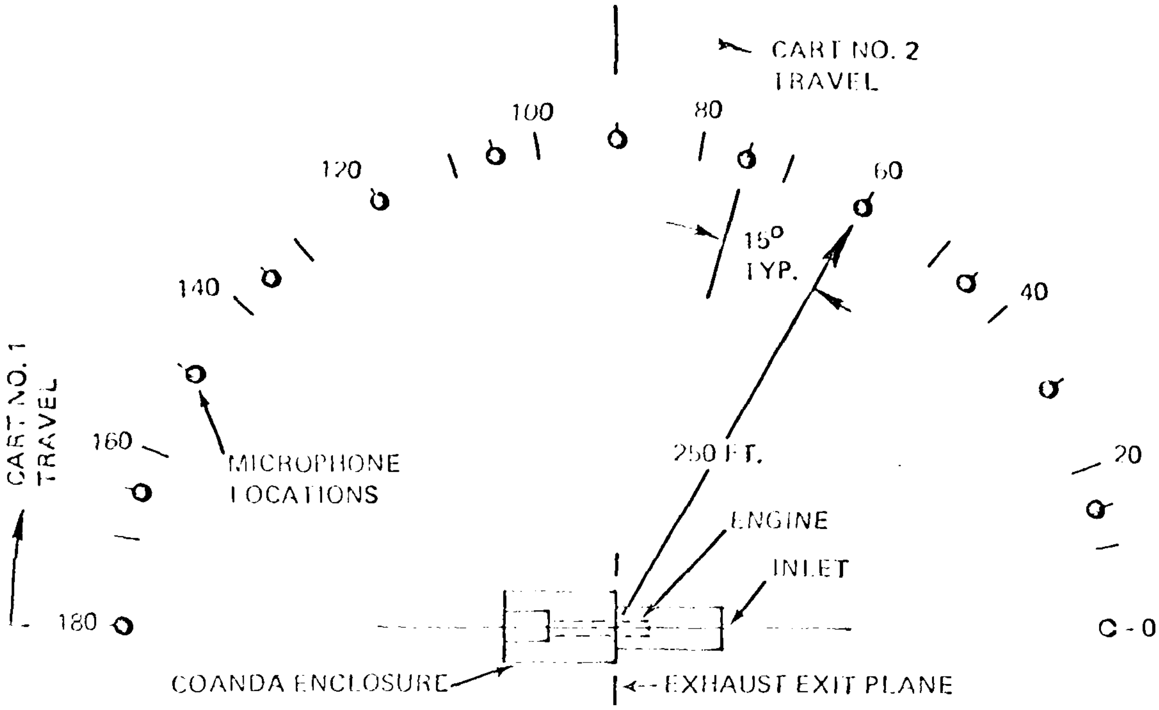
C VIBRATION PICKUP LOCATIONS INNER AND OUTER WALL



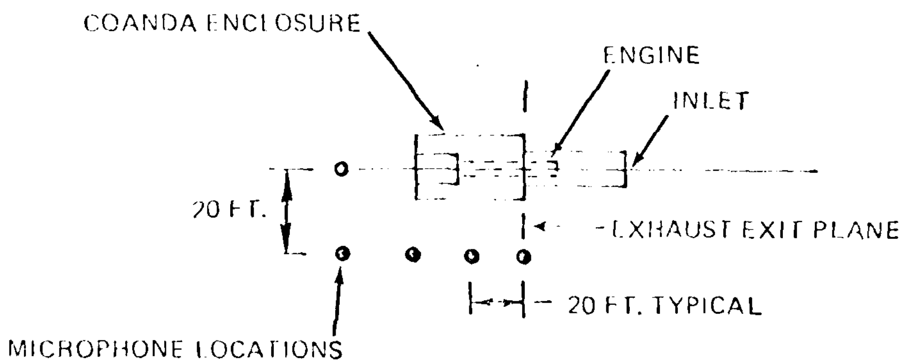
ENCLOSURE AIR INLET PRESSURE
AND WALL VIBRATION INSTRUMENTATION
FIGURE 6



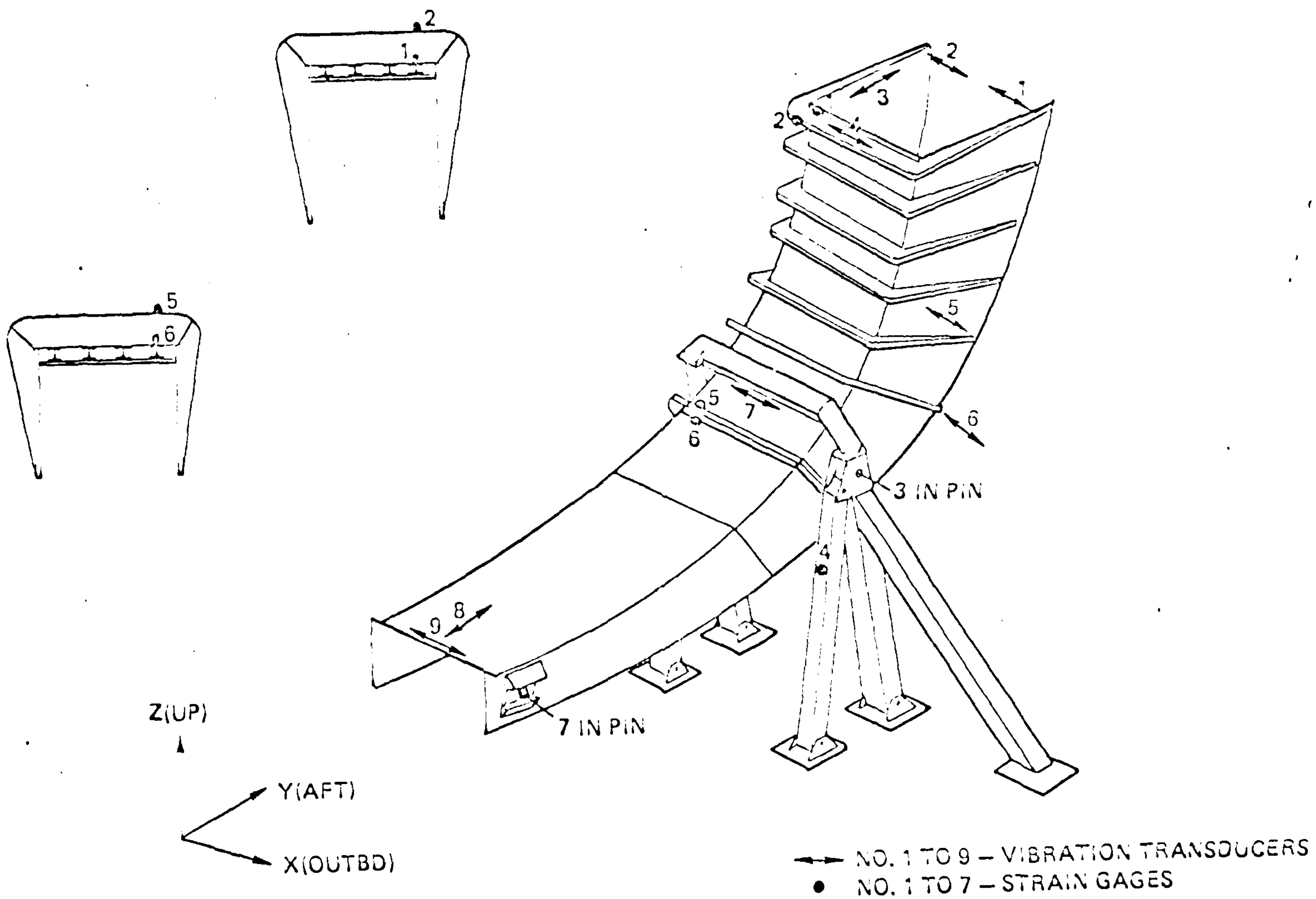
ENCLOSURE ACOUSTIC INSTRUMENTATION
FIGURE 7



FAR FIELD ACOUSTIC MICROPHONE LOCATIONS
FIGURE 8



NEAR FIELD ACOUSTIC MICROPHONE LOCATIONS
FIGURE 9



STRUCTURAL INSTRUMENTATION LOCATIONS
FIGURE 10

TABLE 5

STRUCTURAL INSTRUMENTATION

STRAIN GAGE NO.	LOCATION	MAXIMUM TEMPERATURE
1	Top Coanda I-Beam (Top Surface)	200°F
2	Top Coanda Atop Frame Surface	200°F
3	Upper Hollow Pin	250°F
4	Support Frame Leg	200°F
5	Mid-Coanda I-Beam (Top Surface)	300°F
6	Mid-Coanda Atop Frame Surface	300°F
7	Lower Pin	300°F

VIBRATION TRANSDUCERS	LOCATION	DIRECTION (REF.FIG.10)	MAXIMUM TEMPERATURE
1 & 2	Top Edge of Coanda	X	500°F
3	Top Center Side Panel of Coanda	Y	700°F
4	Top Center Surface of Coanda	X	700°F
5	Mid-Center Side Panel of Coanda	X	1000°F
6	Mid-Center Side Frame of Coanda	X	700°F
7	Mid-Center Atop Frame	X	1200°F
8	Inlet Centerline on Coanda Surface	Y	1000°F
9	Inlet Centerline on Coanda Surface	X	1000°F

2.2 TASK II

Task II consists of the fabrication of the full scale noise suppressor demonstrator and all equipment necessary for the test site and test setup.

2.2.1 Noise Suppressor Fabrication

The Coanda jet deflector system, acoustic enclosure and support structure will be fabricated at Boeing-Wichita in accordance with the design developed (and reviewed by the Navy) in Task I. The noise suppressor will be fabricated using the same techniques, wherever possible, as for a production unit. The hardware will be fabricated to endure a life cycle that includes the planned testing of this contracted effort and subsequent development phase. Materials and manufacturing processes will be selected with future hardware low production cost as a primary consideration. The hardware will have the capability of being dismantled into sections for shipping.

2.2.2 Test Equipment Fabrication or Purchase

Some test equipment and/or instrumentation will be purchased to perform the tests outlined in the following sections. Typical equipment includes additional microphones, preamplifiers, potentiometers, transducers, etc. All accountable property (less expendable material, equipment and supplies) will be delivered with the suppressor at the contract conclusion. Certain specialized, not commercially available, equipment and instrumentation will be fabricated by Boeing.

2.3 Task III

Task III will consist of assembling and setting up the full scale demonstrator ground noise suppressor; and the installation, calibration and checkout of the instrumentation required to conduct the test program defined in Section 2.4.

2.3.1 Demonstrator Test Cell Set-Up

The demonstrator test will be conducted at McConnell AFB using an existing Test Cell Noise Suppressor, Model A/F32T-2, modified to include the Coanda/Refraction Suppressor system. The Model A/F32T-2 suppressor is illustrated in Figure 11. The augmentor, its enclosure, and the exhaust plenum and silencer will be replaced with the Coanda/Refraction Suppressor illustrated in Figure 2. The evaluation tests will be run using the GFP turbojet afterburning engine (TF-30-P-9 or J75-P-19W) mounted inside the test cell, with and without the suppressor system installed. A description of the Model A/F32T-2 test cell, and instructions for its operation and maintenance are contained in Reference 3. It should be noted that the A/F32T-2 test cell is designed to accommodate either of these two engines.

2.3.1.1 Coanda Test Cell Assembly and Installation

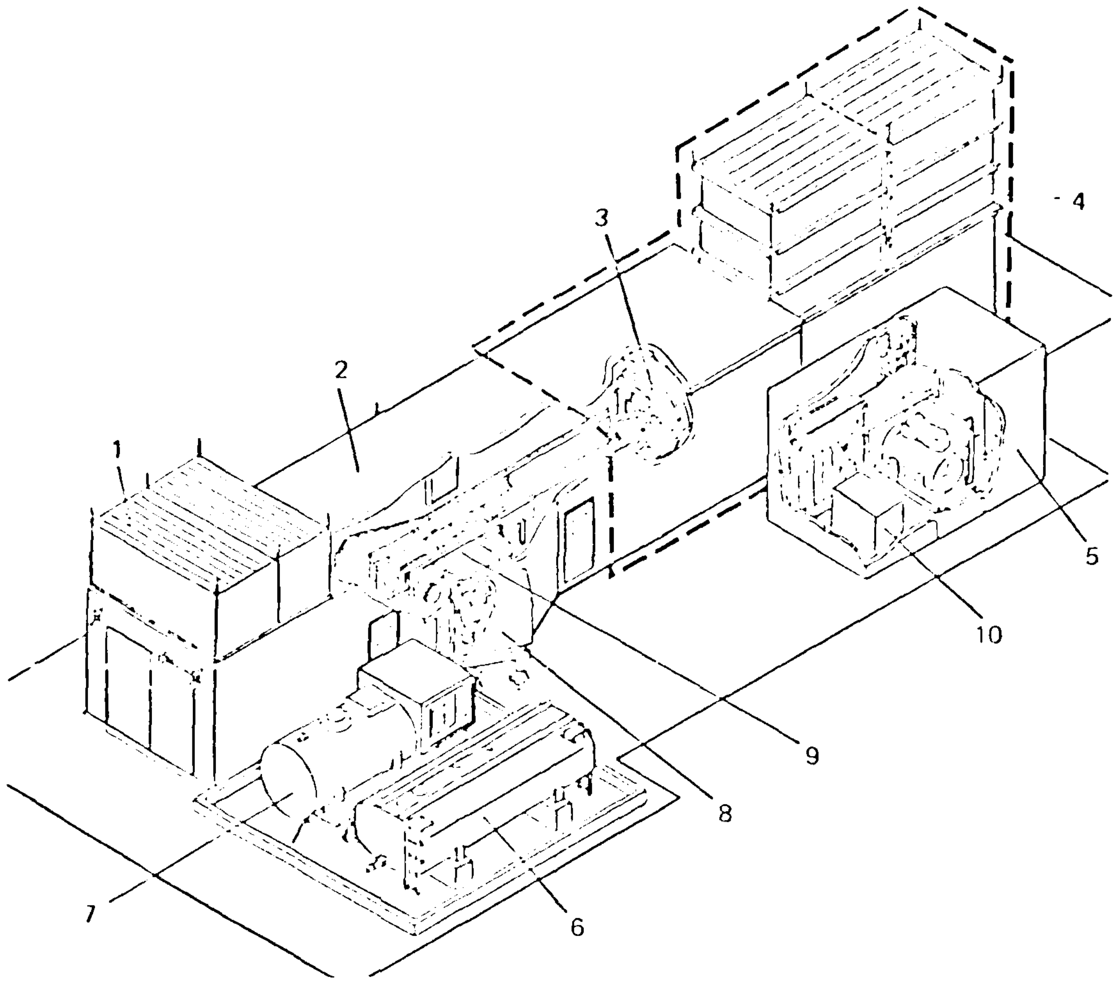
The Coanda Test Cell Assembly consists of three major subassemblies:

(1) Coanda and supports,

(2) Ejectors and supports, and

(3) The enclosure.

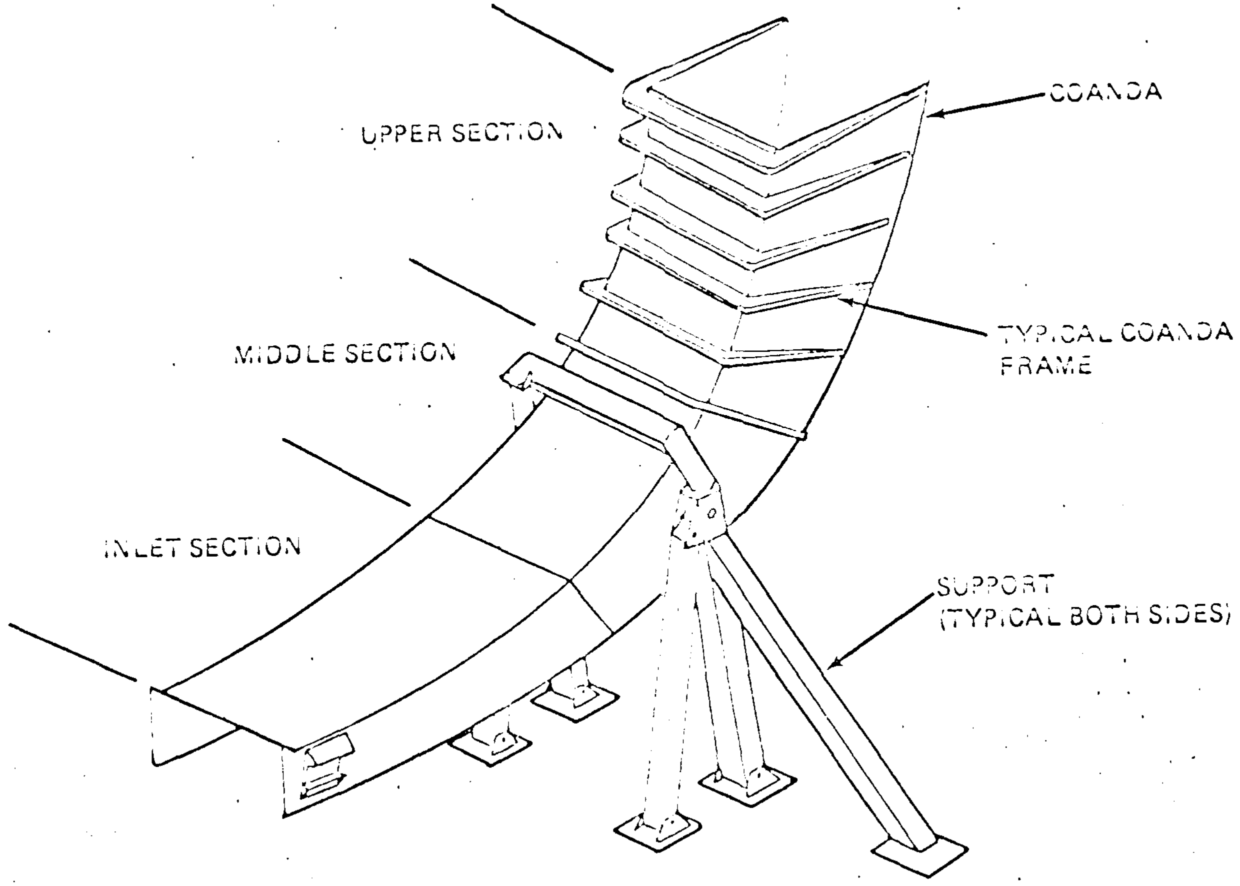
The Coanda and supports are shown on Figure 12. The unit is made of welded steel construction and disassembles into three sections for transportation and reassembly. A breakdown by approximate size and weight is shown in Table 6. The inlet section is supported at the forward end by means of the ejector assembly aft supports.



1. PRIMARY AIR INTAKE SILENCER AND ENCLOSURE
2. ENGINE TEST STAND ENCLOSURE
3. AUGMENTOR
4. EXHAUST PLENUM AND SILENCER
5. PUMPHOUSE
6. SUPPLEMENTARY FUEL TANK
7. FUEL TANK AND AUXILIARY EQUIPMENT CAB*
8. CONTROL CAB*
9. ENGINE THRUST TRAILER*
10. MOTOR GENERATOR MC 1A, OR MD 4 (GFE)

* PART OF ENGINE TEST STAND A/M37T 6 (GFE)

NOISE SUPPRESSOR SYSTEM A/F32T-2
FIGURE 11



COANDA AND SUPPORT ASSEMBLY
FIGURE 12

TABLE 6

COANDA AND SUPPORT ASSEMBLY SUBSECTIONS
(All Numbers Approximate Only)

Subsection	Length	Maximum Depth	Width	Weight-Lbs
Inlet	220	70	80	5400
Middle	130	93	80	5000
Upper	135	100	80	5000
Supports (each)	190	24	66	1500

2.3.1.1 Cont'd.

The ejector and supports are constructed of welded steel (Figure 13) and disassemble into five subsections; forward, center, and aft ejectors, and right and left hand supports. Each ejector weighs approximately 1000 lbs. and each support approximately 1500 lbs. The assembled ejectors and supports measure approximately 148" long x 168" wide x 87" high.

The double-walled enclosure is made of one-fourth inch thick steel plate of welded construction. External dimensions of the assembled enclosure are approximately 49' long x 23' wide x 40' high as shown in Figure 2.

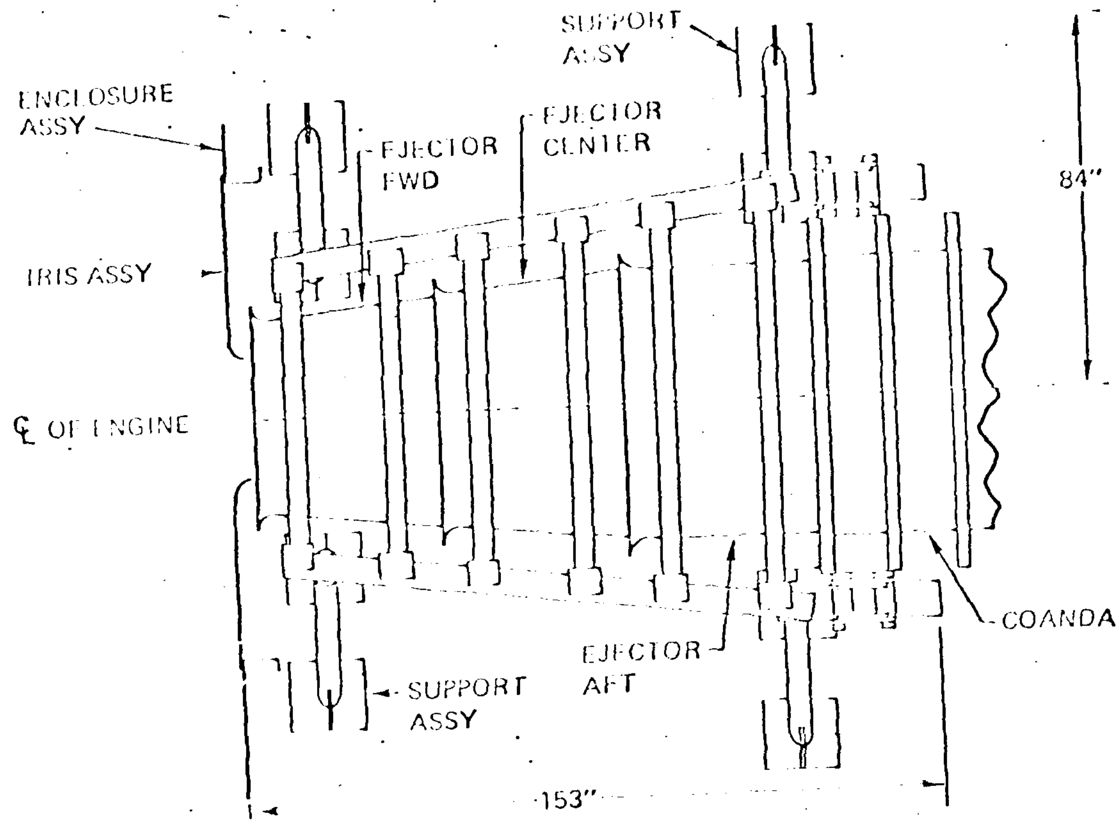
Disassembly, transportation, and reassembly of the enclosure is made practicable by designing the enclosure to break down into 58 panels in sizes from 4' x 8' to 8' x 16'. The panels are bolted together on assembly using rubber seals between inner panels and sealer between outside panels. The inside wall is designed to "float" by means of rubber support pads and by cushioned snubbers between inner and outer walls. The ceiling joint incorporates a continuous rubber strip and bulb-type isolators.

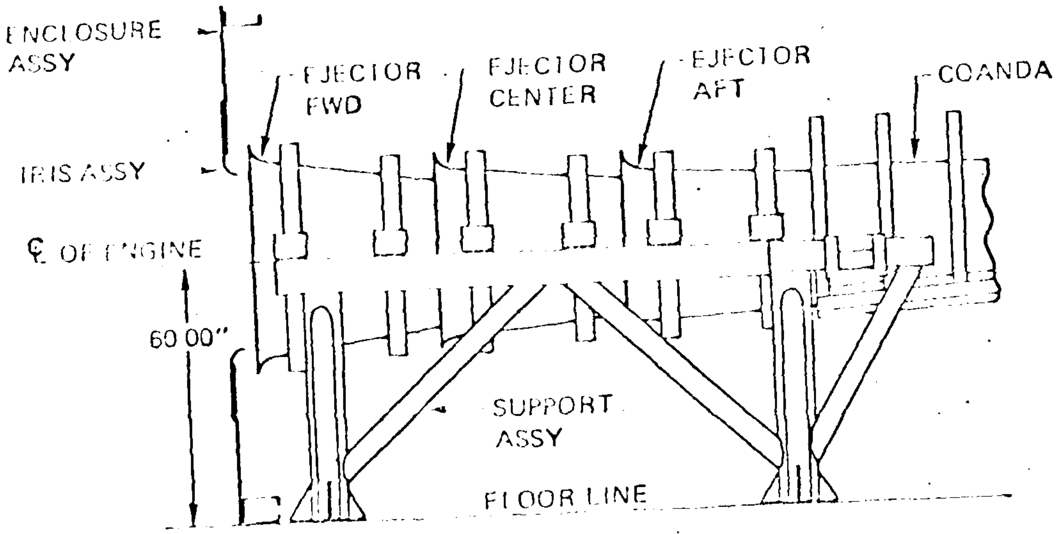
The forward wall of the enclosure adapts to the A/F32T-2 test cell at the engine exit plane. The wall will be attached to the test cell to serve as an acoustically treated partition for baseline tests. Three basic configurations will be tested as summarized in Table 7.

2.3.1.2 Engine and Test System

The Navy has indicated that a P&WA Model J75-P-19W should be assumed as the test engine. The tests will be conducted with a calibrated bellmouth. A description of the engine and its operation is contained in Reference 4. The performance ratings of the engine are shown in Table 8.

The test system, previously shown on Figure 11, includes all systems necessary for safe and efficient engine operation as described in Reference 3.





EJECTOR AND SUPPORT ASSEMBLY
FIGURE 13

TABLE 7

TEST CONFIGURATIONS

Configuration	Description
I (Baseline)	J75 Engine, A/F 32T-2 Test Cell No suppressor, and with the front wall of noise suppressor at engine exit plane
II	Same as Configuration I plus Coanda only
III	Same as Configuration II plus Noise Suppressor Enclosure Installation

TABLE 8

J75-P-19W PERFORMANCE RATINGS

RATINGS AT STANDARD SEA LEVEL STATIC CONDITIONS

Thrust	Jet Thrust in Pounds (Min.)	Maximum N_1 rpm	Maximum N_2 rpm	Specific Fuel Consumption lb/hr/lb thrust	Rated Measured Gas Temp (Max.) °F
Maximum (1)	24500	6400	8990	2.15	1175
Military (2)	16100	6440	9000	.82	1166
Normal	14300	6080	8750	.79	----
90% Normal	12900	5830	8575	.77	----
75% Normal	10700	5470	8300	.76	----
Idle (Nozzle Open)	1150 (max)	2750(min)	5950 (min)	1710 lb/hr max	----

NOTES: N_1 - Speed of low pressure compressor-turbine unit.

N_2 - Speed of high pressure compressor-turbine unit.

(1) This rating is obtained with afterburning and is limited to five minutes.

(2) Operation at this power is limited to 30 minutes.

2.3.2 Data Acquisition System

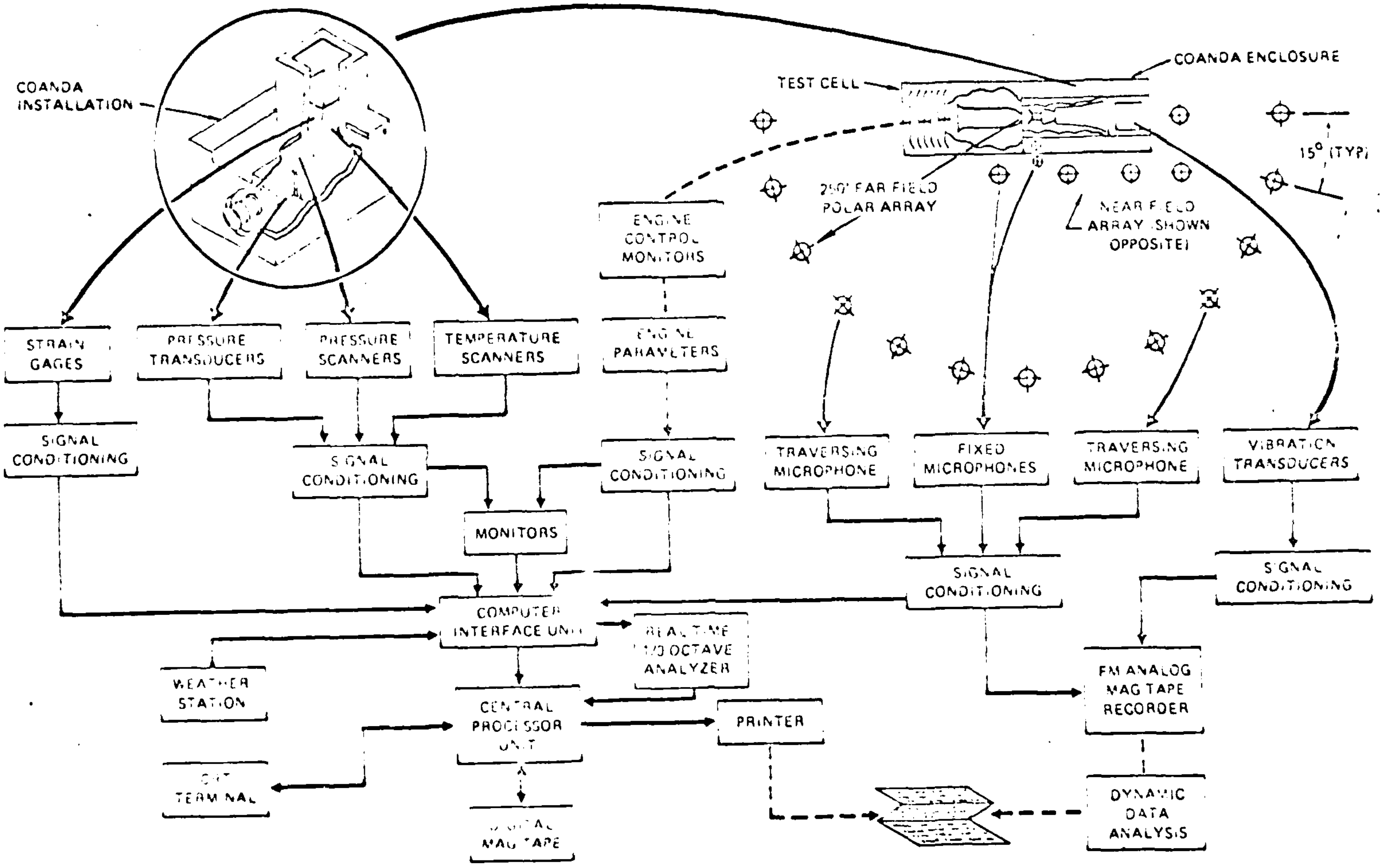
The test instrumentation will be designed and installed to provide specific data pertaining to engine operating parameters, suppressor acoustic performance, environmental weather conditions, Coanda enclosure vibration levels, suppressor pressures, temperatures, stress and vibration response levels.

The block diagram of Figure 14 depicts the basic operational functions of the planned test data system. Data signals will be rapidly scanned and processed through a real time analyzer, a mini-computer, digital tape recorder, and on-line printer for corrected and normalized data printouts. Raw data recorded on digital magnetic tape will be retained for additional analysis, if required. Acoustic and vibration data signals will be simultaneously recorded on the FM analog magnetic tape system for subsequent analysis.

2.3.2.1 Engine Performance Data Acquisition

Basic engine performance data parameters listed in Table 3 will be recorded during all testing utilizing existing test cell instrumentation where practical. Additional data parameters will be instrumented with industry standard data sensors. Engine performance data will be recorded for each steady state condition in conjunction with the test specimen data parameters.

Output signals of selected transducers will be scaled in engineering units for on-line monitoring during test condition setup.



BLOCK DIAGRAM OF DATA ACQUISITION AND PROCESSING CONCEPT
FIGURE 14

2.3.2.2 Temperature and Pressure Data Acquisition

Static pressure probe, pressure rake and surface temperature thermocouple instrumentation will be installed as outlined in Paragraph 2.1.3.2. Pressure and temperature transducer signals will be sampled rapidly by data system scanners interfaced to the computer through a multiplexer and analog/digital converter. During set up and recording of each test condition, individual pressures and temperatures will be displayed on a cathode ray tube (CRT) monitor which can be periodically updated by operator command.

2.3.2.3 Vibration and Strain Data Acquisition

The Coanda will be instrumented with high temperature vibration transducers at nine proposed locations as shown in Figure 10. Final pickup locations will be adjusted to be compatible with the test configuration. Seven strain gages will be installed to provide mean strain data at the locations shown in Figure 10. The strain gage signal conditioning output signals will be interfaced to the computer through a multiplexer and analog/digital converter. Four additional transducers will be installed on the noise suppressor enclosure to monitor the vibratory response of the structure wall as shown in Figure 6. Output response signals of the vibration transducers will be channeled through their respective signal conditioning systems and the dynamic response data will be recorded on a FM magnetic tape system.

2.3.2.4 Acoustic Data Acquisition

Far field acoustic array measurements will be sensed at 13 points on a 250 foot polar array by two traversing, wind screened microphones, positioned with their sensing elements 1/2 inch above the ground plane. Near field acoustic measurements will be sensed at five locations on a rectangular array by fixed, wind screened microphones with their sensing elements 5.5 feet above and parallel to the ground plane. Fixed microphones will also be located at ten locations, paired inside and outside the suppressor enclosure walls, for wall transmission loss studies. Microphone signals will be channeled through signal conditioning modules, a General Radio 1921 Real Time Analyzer, a Varian Mini-computer, digital tape recorder and on-line printer. The data will also be recorded on a FM magnetic tape system for subsequent additional analysis.

2.3.2.4 Cont'd.

Microphone positions and the basic acoustic data systems are included in the block diagram of Figure 14. All acoustic data will be corrected during acquisition to acoustic standard day values with respect to temperature and relative humidity.

Data will be analyzed on-line using the real time analysis system set for an 8-second integration time. Computed and tabulated data listings will consist of 1/3 octave band, octave band, overall, and dBA levels at the respective measurement location. The print out will be available following completion of each test sequence.

2.3.2.5 Environmental Data Acquisition

Wind velocity and direction, barometric pressure, ambient air temperature and relative humidity will be recorded automatically or manually for each test condition. Wind direction and velocity will be referenced to the engine centerline and monitored continuously during acoustic data acquisition periods.

2.3.2.6 Calibrations

All instrumentation equipment will be calibrated in accordance with standard laboratory procedures maintaining traceability to the National Bureau of Standards. System calibration will be performed before and after each test period to insure data reliability.

2.4 Task IV - Full Scale Demonstrator Tests

Task IV will consist of accomplishing the test program to evaluate the full scale demonstrator configuration with respect to propulsion, acoustic, aerodynamic and structural considerations.

2.4.1 Full Scale Hardware Test Program

The full scale hardware test program is to be performed in compliance with Reference (5). The engine, jet engine test cell and adapter kits are to be furnished by the Government. The Coanda/Refraction Suppressor and enclosure are to be designed and fabricated by The Boeing Company-Wichita Division. The crew for operating and maintaining the engine and GFE test cell Model A/F 32T-2, as well as spare parts, will be furnished by the Government.

The objective of the test is to prove the Coanda/Refraction noise suppression concept by full scale demonstration tests and experimental investigations using a jet engine with afterburner. The test is intended to:

(1) Measure the sound pressure levels in near- and far-field for all frequency bands.

(2) Determine the capability to educt required cooling air

(3) Evaluate the Coanda surface film cooling

(4) Measure the deflection surface operating temperatures.

(5) Provide experimental data to substantiate the structural analyses.

Preliminary engine runs will be made at the beginning of tests of each configuration to check out the hardware and systems.

The acoustic tests are the prime objective of the test program and are intended to measure sound pressure levels and hardware dynamic response to the sound pressure environment. Details of the acoustic evaluations are contained in Section 2.4.2.

2.4.1 Cont'd.

Propulsion tests will be performed to assure that the engine fuel and oil supply, mechanical, pneumatic and instrumentation systems are functioning properly. Checks will be made to assure that the engine responds properly to engine controls and that the power settings fall within prescribed limits. Necessary engine trimming operations should be performed during propulsion system tests.

Aerodynamic testing referred to herein generally refers to the flow of the jet exhaust through the Coanda, the ejector cooling air flow evaluation, the airflow induced by the Coanda and the resulting forces on the Coanda and its enclosure.

Structural testing refers to the recording of strain gage and accelerometer data and related pressures and temperatures that are supportive to the brief structural analysis of the Coanda structure. Structural test data will be recorded during the acoustic testing.

Three basic configurations are to be tested as defined in Table 7. Each configuration will be tested at three power settings; idle, military, and maximum afterburning (without water injection).

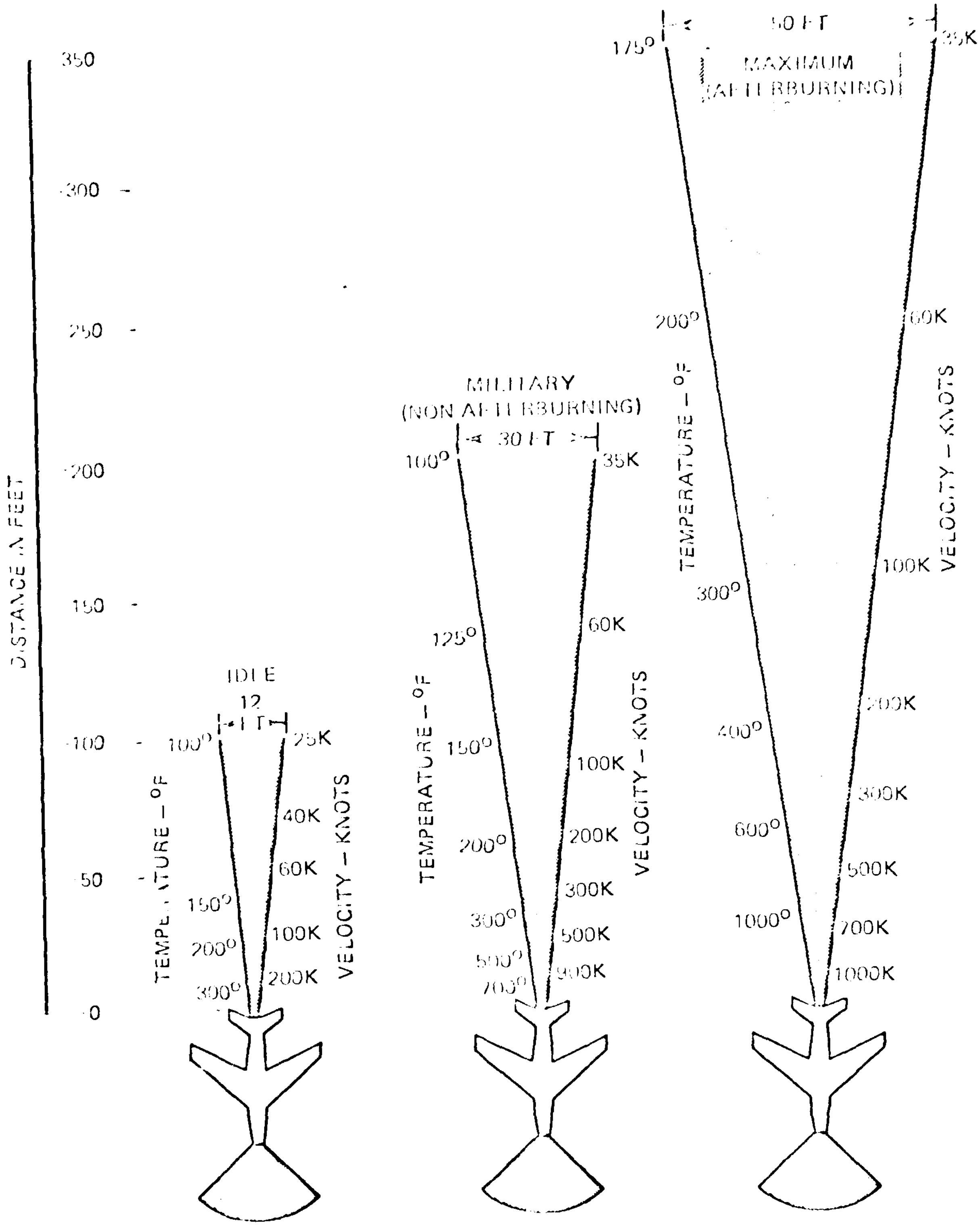
An estimate of the planned test sequence is summarized in Table 9.

It should be noted that the Configuration I testing will be performed without the use of jet exhaust deflectors or sound suppressors. The jet wake temperature and velocity diagram for the test power settings are shown on Figure 15. Special precautions will be taken because of the noise and exhaust blast hazard to personnel, equipment and potential fire of vegetation in the jet wake area.

TABLE 9

FULL SCALE TEST PROGRAM SUMMARY ESTIMATE

CONFIGURATION	NO. OF TESTS (ESTIMATED)	TEST DESCRIPTION	PURPOSE OF TEST: PRO-PULSION	ACOUSTIC	AERO-DYNAMIC	STRUC-TURAL
I	2	Preliminary-Cycle all systems, repair leaks & instrumentation and trim engine.	X			
	1	Pressure survey of test cell and engine parameters	X			
	1	Final checkout	X			
	2	Baseline tests	X	X		
II	2	Preliminary operational checks	X			
	2	Preliminary Temp & Press Survey	X		X	
	2	Adapter adjustments	X		X	
	2	Baseline Acoustic & Structural	X	X	X	X
III	2	Preliminary Operational Checks	X			
	2	Prelim Cooling Airflow Checks	X		X	
	2	Adapter & Cooling Air Adjustments	X		X	
	2	Complete Sys Performance Eval	X	X	X	X



APPROXIMATE JET WAKE VELOCITIES AND TEMPERATURES
FOR THE J 75 AFTERBURNING ENGINE
FIGURE 15

2.4.2 Acoustic Evaluation

The acoustical performance of the noise suppressor system will be evaluated by measuring the Sound Pressure Level (SPL) at the locations and under the conditions described below.

2.4.2.1 Meteorological and Extraneous Noise Limits

Acoustical measurements will be made within the following limits:

Meteorological:

(1) Surface wind 5 knot maximum

(2) Ambient temperature 30° to 35°F

(3) Relative humidity 25 to 90%

Extraneous Noise Limits:

(1) Signal-To-Noise ratio 10dB at 250 ft. radius.

2.4.2.2 Far Field Acoustic Measurements

Far field acoustic measurements will be made on a 250 ft. radius semicircle at 15° increments as shown on Figure 8. These measurements will be made at ground level on a hard surface (either concrete or asphalt). The data will be corrected for atmospheric absorption. Measurements will be made for military rated thrust and afterburning power settings.

2.4.2.3 Near Field Acoustic Measurements

Near field acoustic measurements will be made approximately 20 feet from the suppressor centerline or 10 feet from the suppressor walls at a height of 5.5 feet for the locations shown in Figure 9. Measurements on opposite sides of the walls and at the inlet and exit of the air ducts will be made at the locations shown in Figure 7. Measurements will be made for idle, military rated thrust and afterburning power settings.

2.4.2.4 Suppressor Acoustic Performance

Acceptable performance of the suppressor system will be determined by comparing the 250 foot far-field and 20 foot near-field measurements to the values listed in Table 2 of Section 2.1.1.2.

2.4.2.5 Instrumentation

A calibration and frequency response of the entire measurement system, including microphone, will be used to correct the measured data. The range of frequency response of the system will be from 45 to 11,300 Hz and the response stated within ± 2dB. An acoustic calibrator will be used for a system calibration from the microphone to the analyzer. The sound pressure level (dB Re .002 DYNE/CM^2) produced by the calibrator will be known within ± .5dB. The noise suppressor interior microphones will be capable of measuring 170 dB and the exterior microphones capable of measuring 140 dB.

2.4.2.6 Jet/Coanda Baseline Test

The A/F32T-2 test cell located at McConnell AFB will be used to suppress the inlet and engine case radiated noise. The test cell exhaust plenum and silencer section will be removed and the front double wall of the Coanda enclosure will be installed to prevent noise radiation from the interior of the cell. Noise measurements will be made in the near-field and far-field for this configuration at engine power settings of military and full afterburner power power settings and will serve as the jet exhaust noise baseline. The Coanda surface baseline will be obtained by adding the Coanda surface and repeating the measurements and power settings used in the Jet Exhaust Noise Baseline test.

2.4.2.7 Full Scale Demonstrator Coanda Test Cell System Test

The Full Scale Demonstrator Test Cell System will be made ready by adding the acoustic enclosure to the Coanda baseline configuration described in Paragraph 2.4.2.6 above, and by repeating the measurements and power settings used in the baseline tests. The resulting measurements will be compared to the criteria of Paragraph 2.1.1.2, to evaluate the Demonstrator System.

2.4.2.8 Data Reduction

General Data:

Tabulations of the recorded data will be printed from the on-line data acquisition system. Identification information such as run number, nozzle pressure ratio, exhaust gas temperature, configuration, date, meteorological information, and measured and calculated performance results will be provided similar to that presented on Figure 16.

A run log will be maintained including any information that might be pertinent to the test results. All adjustments and changes to the equipment and instrumentation will be recorded.

Acoustic Data:

Acoustic data will be obtained from the microphone arrays previously described using the General Radio 1921 real time analyzer, magnetic tape recorder, mini-computer and printout. This provides for printing out selected acoustic data on-line. However, most data will be recorded on digital magnetic tape and analyzed later. This is done to speed up data acquisition. The far-field microphones will be traversed on a 250 foot radius with data recorded at 15 degree intervals. Each position for the far-field and the near-field microphones will be identified on the data listing for positive identification of test data.

Sound pressure level (SPL) will be tabulated for both one-third and full octave band frequencies from 50 to 10,000 Hz. Overall sound pressure level (OASPL) and "A" weighted (dBA) measurements will be computed and tabulated for each microphone location for each test condition. Plots will be provided of the full scale one-third octave SPL similar to that shown in Figure 17.

FULL SCALE DEMONSTRATOR DATA
NAVY COANDA/REFRACTION NOISE SUPPRESSOR

Configuration ____ Run ____ Date ____

Wind Angle ____ Velocity ____ Rel Humidity ____

Ambient Temperature ____ Ambient Pressure ____

Engine: Throst ____ RPM: N_1 ____ N_2 ____

Pressure Ratio ____ Temp Ratio ____

Bellmouth: P_T ____ Delta P ____

Coanda: P_S 1 PSIA ____ T_S 1 °F ____
2 ____ 2 ____
-
10 ____ 10 ____

Side Panel: P_S 1 PSIA ____ T_S 1 °F ____
2 ____ 2 ____
3 ____ 3 ____
4 ____ 4 ____

Ejectors: P_S 1 PSIA ____ T_S 1 °F ____
2 ____ 2 ____
- ____ - ____
- ____ - ____
12 ____ 12 ____

Enclosure: P_S 1 PSIA ____ P_S 13 PSIA ____
Secondary Air Inlet 2 ____ 14 ____
- ____ - ____
- ____ - ____
12 ____ 24 ____

Coanda Rake: P_T 1 PSIA ____ T_T 1 °F ____
- ____ - ____
- ____ - ____
14 ____ 14 ____

Engine Airflow, W_{AP} = ____

Engine Fuel Flow, Primary W_{FP} = ____

Afterburner $W_{FA/B}$ = ____

Secondary Airflow: W_{AS} = ____

Subscripts: A = Air; S = Static or Secondary
A/B = Afterburner; T = Total
P = Primary

FIGURE 16
NAVY COANDA/REFRACTION NOISE SUPPRESSOR
TEST RESULTS PRINTOUT - TYPICAL

```
RUN 208              POS  1        MIKE #  1

DATA RECORDED 3AUG73   AT   80   DEG F      45 PCT RH

                  70         80         90         100        110        120
FREQ    SPL
  50   101.3   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  63    99.0   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  80    99.3   XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 100   101.3   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 125   106.3   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 160   101.3   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 200    97.5   XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 250    96.8   XXXXXXXXXXXXXXXXXXXXXXXXXXXX
 315    95.8   XXXXXXXXXXXXXXXXXXXXXXXXXXX
 400    95.3   XXXXXXXXXXXXXXXXXXXXXXXXXX
 500    93.8   XXXXXXXXXXXXXXXXXXXXXXXXX
 630    88.7   XXXXXXXXXXXXXXXXXXXX
 800    87.7   XXXXXXXXXXXXXXXXXXX
1.0K    90.0   XXXXXXXXXXXXXXXXXXXXX
1.2K    83.7   XXXXXXXXXXXXXXX
1.6K    92.2   XXXXXXXXXXXXXXXXXXXXXXX
2.0K    83.0   XXXXXXXXXXXXXX
2.5K    77.0   XXXXXXXX
3.1K    75.4   XXXXXX
4.0K    73.2   XXXX
5.0K    77.8   XXXXXXXXX
6.3K    76.1   XXXXXXX
8.0K    74.8   XXXXXX
10.K    72.7   XXXX

OA     110.9
dBA    115.3

 104.5     108.4     101.5      98.1
  92.7      92.8      88.7      79.6
```

FIGURE 17
FULL SCALE COANDA BASELINE NOISE (EXAMPLE)

2.4.2.8 Acoustic Data - Cont'd.

Summary plots of OASPL and dBA for the far-field microphone (level versus microphone angle) will also be provided.

Pressure and Temperature Survey Data:

All static pressure pickups and metal temperature thermocouples will be given identification coding and the data recorded in tabular form for each test condition.

The individual probes on the traversing total pressure and total temperature rakes will be identified and the data recorded on digital magnetic tape and listed in tabular form. These data will be used in a computer program to compute the total mass flow at the exit of the transition section and the exit of the Coanda surface.

Strain Gage Data:

The strain gage data will be presented as mean stresses for each of the test runs and strain gage locations.

Vibration Environment:

The vibration data will be presented in displacement versus frequency plots from 10 to 1000 Hz.

Photographs:

Photographs will be taken of all hardware and instrumentation.

2.5 Task V - One-Sixth Scale MODEL Tests

Task V will consist of one-sixth scale model tests with the one-sixth scale model burner to obtain data that will assist in adapting the Coanda/Refraction concept to in-aircraft applications, and to support unexpected changes in the full-size model test program.

2.5.1 One-Sixth Scale Model Test Program

The objective of the one-sixth scale test program is to perform preliminary investigations into adapting the Coanda/Refraction exhaust noise suppressor concept to engines-in-airframe ground run-up applications. This involves allowance for motion of the aircraft engine tailpipe during operation, adaptation to twin engine aircraft (such as F-4 and F-14) and size extrapolation of current suppressors to accommodate coannular airflows simulating the scaled engine airflow range of 470 to 600 Lbs./Sec. The current configuration is designed to handle airflows to 300 Lbs./Sec in full scale. An outline of the method of investigating these areas by scale model testing is given below. The testing will be accomplished in the Boeing-Wichita Acoustic Arena Facility. The same program rationale will be maintained that was utilized for the previous scale model programs, References 1 and 2; i.e., the tests will be primarily aerodynamic in nature, with limited acoustic evaluation. These tests will be run independently, but concurrently with the full scale test program. Three test configurations will be evaluated.

The first configuration to be evaluated will allow for airplane tailpipe movement and will require a new transition section ejector system with an enlarged inlet. The inlet will be just large enough to capture the flow allowing for simulation of 6-inch (full scale) movement of the tailpipe. Tests will be run with the engine tailpipe displaced one-inch (model scale) in the vertical and horizontal planes with and without the adapter section installed. Metal surface temperature, internal static pressure and flow attachment data will be recorded for each test. Acoustic data will be recorded near the inlet for each typical configuration with and without the adapter plate. Ambient conditions and exhaust nozzle flow parameters will also be recorded.

A second model test series will be run to determine the effects on attachment of the coannular flow produced in fan engines such as the TF41 and TF30-P-408 (non-A/B). These tests will evaluate the effects on jet deflection of exhaust flow with a high velocity annulus of cooler gas surrounding the hot exhaust primary core flow. Since the full scale program involves only testing with engines with afterburners (which allows coannular flow to mix at non-A/B power settings), these scale model tests will provide data and operational trends that may be extrapolated to full scale operation of long duct turbofan engines. The method used will be to provide a dual flow system with a hot inner core, sized to one-sixth scale of a TF41 or TF30-P-408 engine. Model hardware from the previous pure turbojet flow simulation tests will be used if possible.

The last series of model tests will be conducted to develop a system for twin engine aircraft. These tests will require a new model with either two sets of transition ejectors or one set with internal splitters. A new "double wide" Coanda surface will be required with a removable splitter. Test simulation will be conducted alternately with one engine at A/B and the other at idle; with both engines at full military; with one engine at idle and the other at full military; and with both engines at idle power settings. These tests will be repeated with and without a center surface boundary (splitter) installed on the Coanda surface. The object is to observe; (1) the effects of concurrent jet deflection by two distinct power jet sheets in the same deflection chamber, (2) any adverse boundary conditions between two distinct energy levels of dynamic gases which might prevent deflection, and (3) to determine if a divider wall is required between the two chambers.

Test data measurements and calculations during the last two test series will include metal surface temperatures, internal static pressures, flow attachment parameters, nozzle exhaust flow and ambient conditions.

2.5.1.1 Design

2.5.1.1.1 Requirements

Design drawings will be prepared for the new model hardware and facility changes required to accomplish the model testing outlined above. The drawing quality will be sufficient to expedite fabrication by the Shop with liaison support from the design engineer.

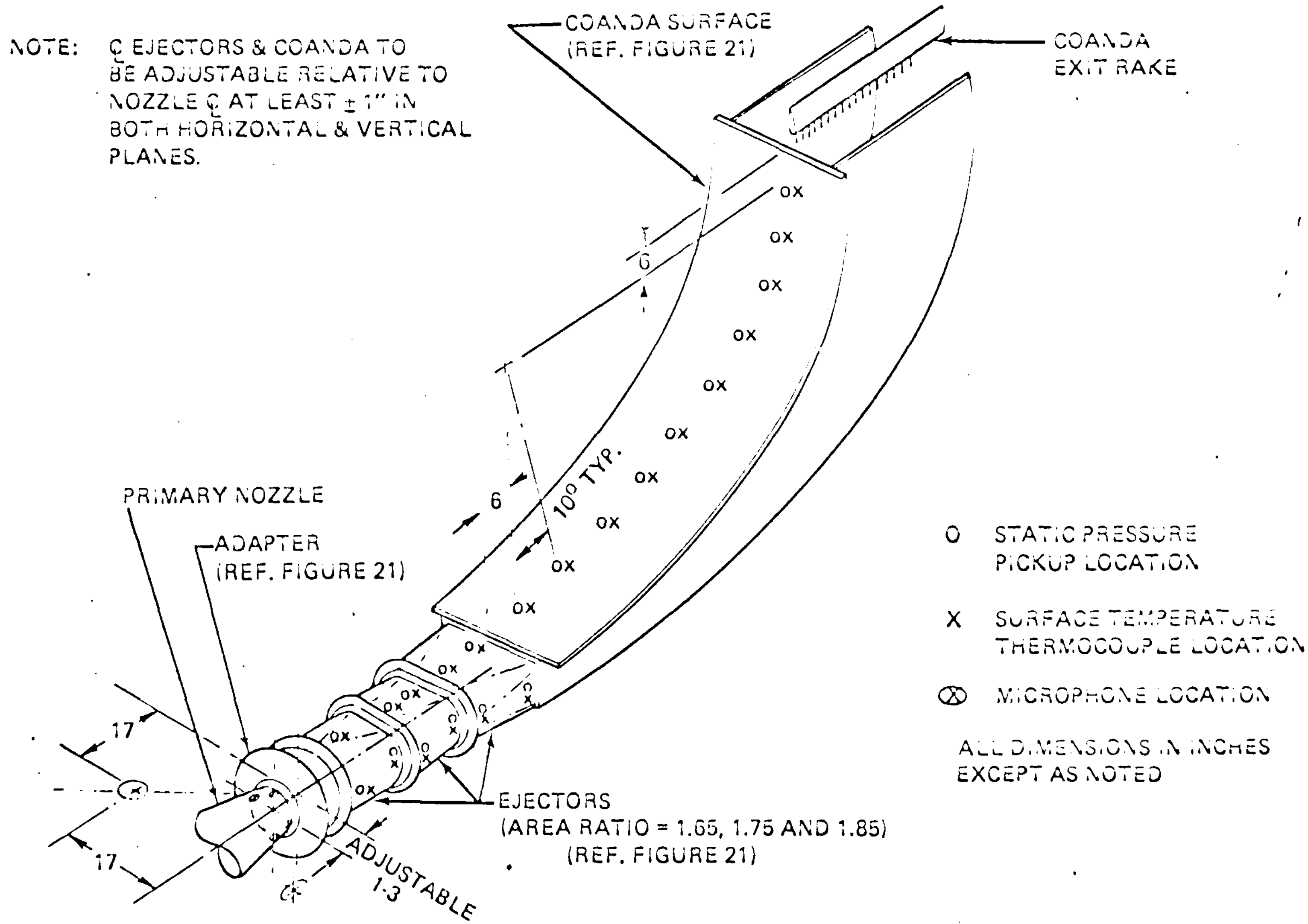
2.5.1.1.2 Configurations

The configuration of the Coanda surface and transition ejectors for the first series of model tests to allow for engine tailpipe excursions is shown in Figure 18. The models are similar to those developed in previous model tests (References 1 and 2) except that the first ejector inlet will be enlarged to capture the engine exhaust with up to six inches (full scale) misalignment. The design for misalignment makes it necessary to increase all of the ejector area ratios, but only the last ejector aspect ratio.

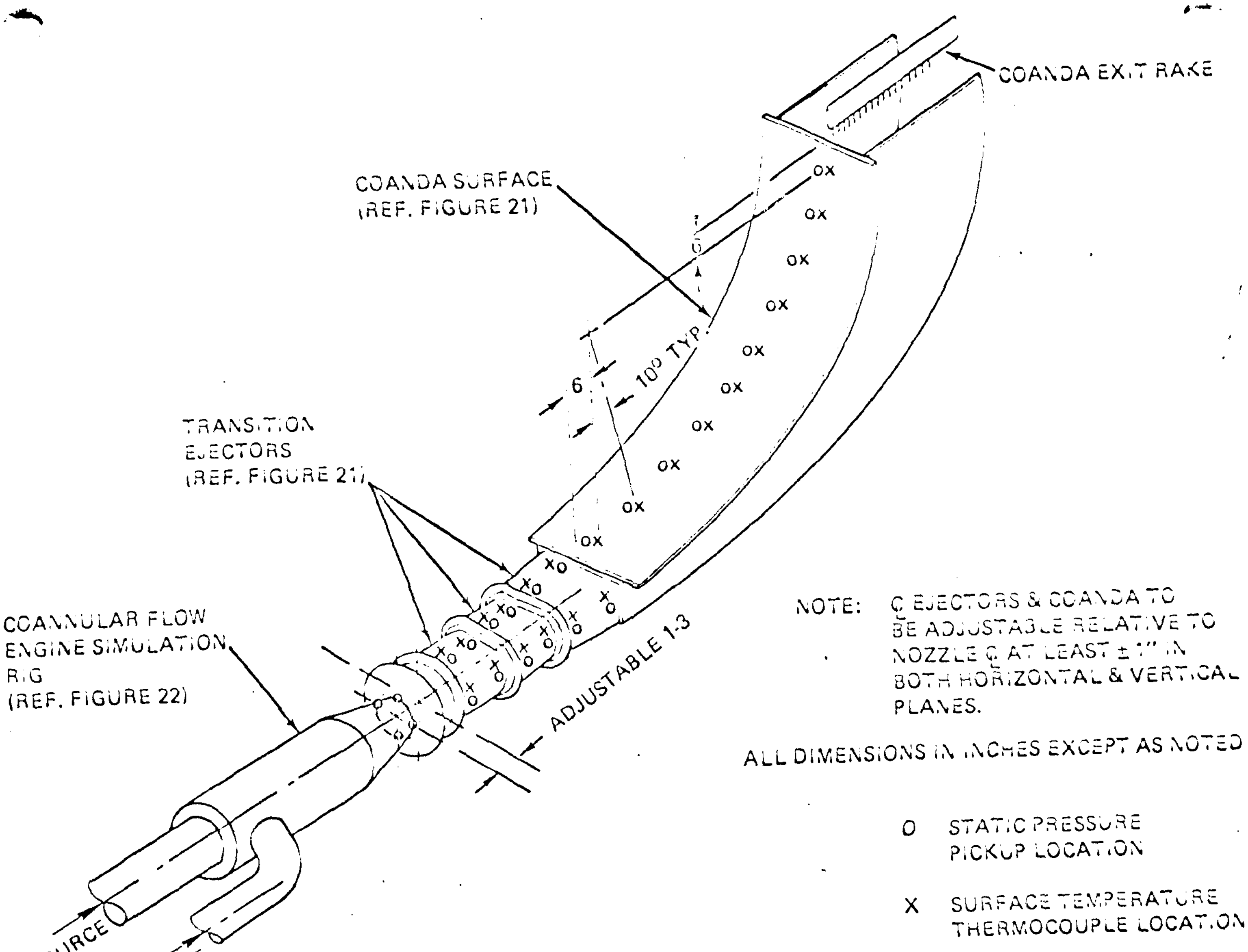
Figure 19 depicts the configuration of the test setup for testing coannular flows with a hot center jet and a colder surrounding flow at flow rates simulating 470 to 600 Lbs./Sec. (full scale). The existing suppressor model hardware transition ejectors and Coanda surface will be used with this nozzle arrangement.

The model configuration for the twin engine, in-airframe adaptation testing is shown in Figure 20. The transition section ejectors have a dual inlet that simulates the engine exhaust centerline distances for the F-4, F-111, and F-15 aircraft. The F-14 engine exhaust centerlines are wide enough apart to easily adapt to two separate single engine ejector Coanda sections housed in one acoustic enclosure. Facility changes will be required to provide two nozzles with centerlines simulating the distance between the engines as shown in Figure 20.

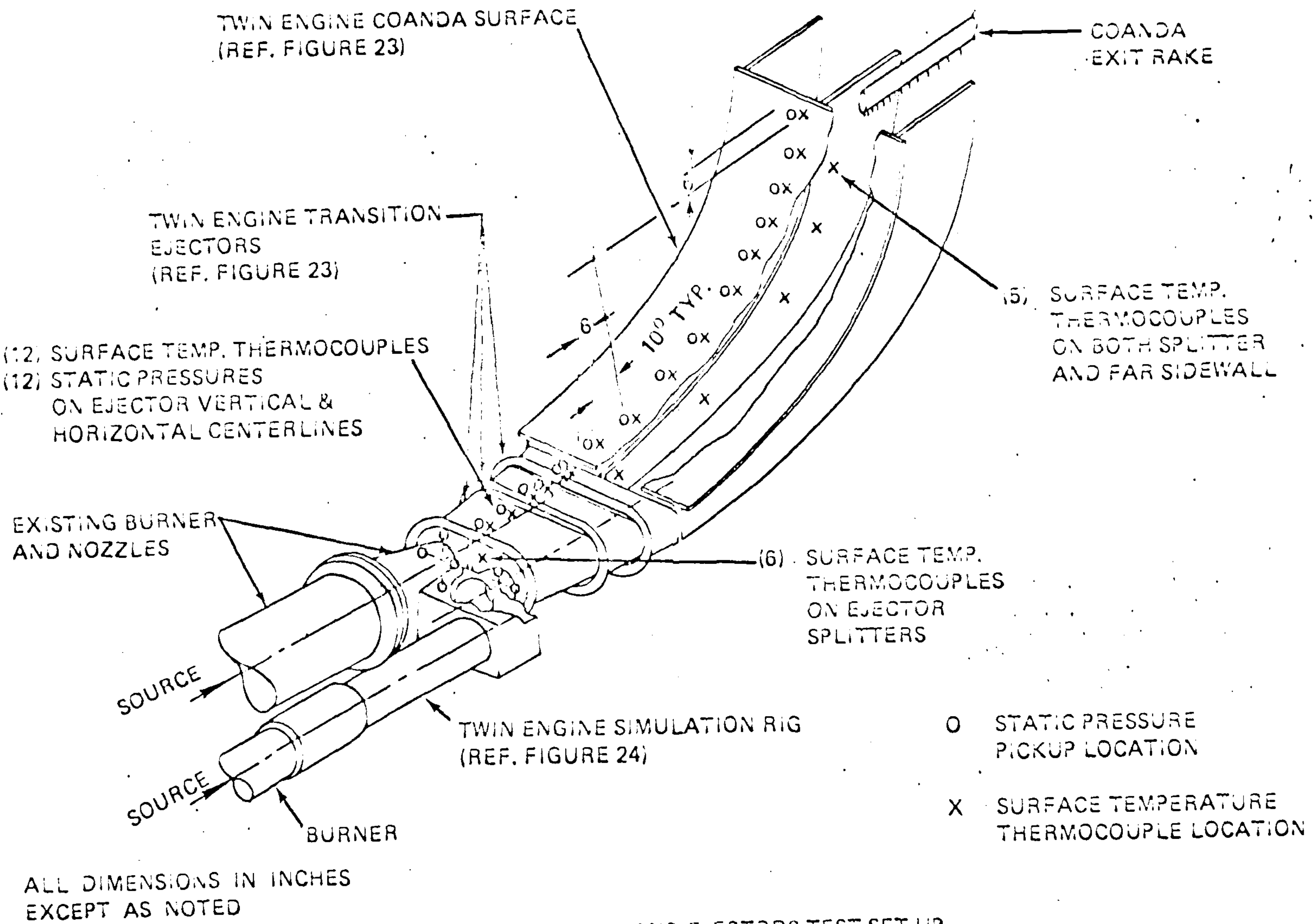
The twin engine and coannular flow model test hardware design will be based on the tailpipe misalignment test results.



COANDA AND EJECTOR TEST SET-UP
FIGURE 18



COANNULAR FLOW TEST SETUP
FIGURE 19



TWIN ENGINE COANDA AND EJECTORS TEST SET-UP
FIGURE 20

2.5.1.2 Fabrication

The hardware required for evaluating tailpipe misalignment, Figure 21, will be fabricated first.

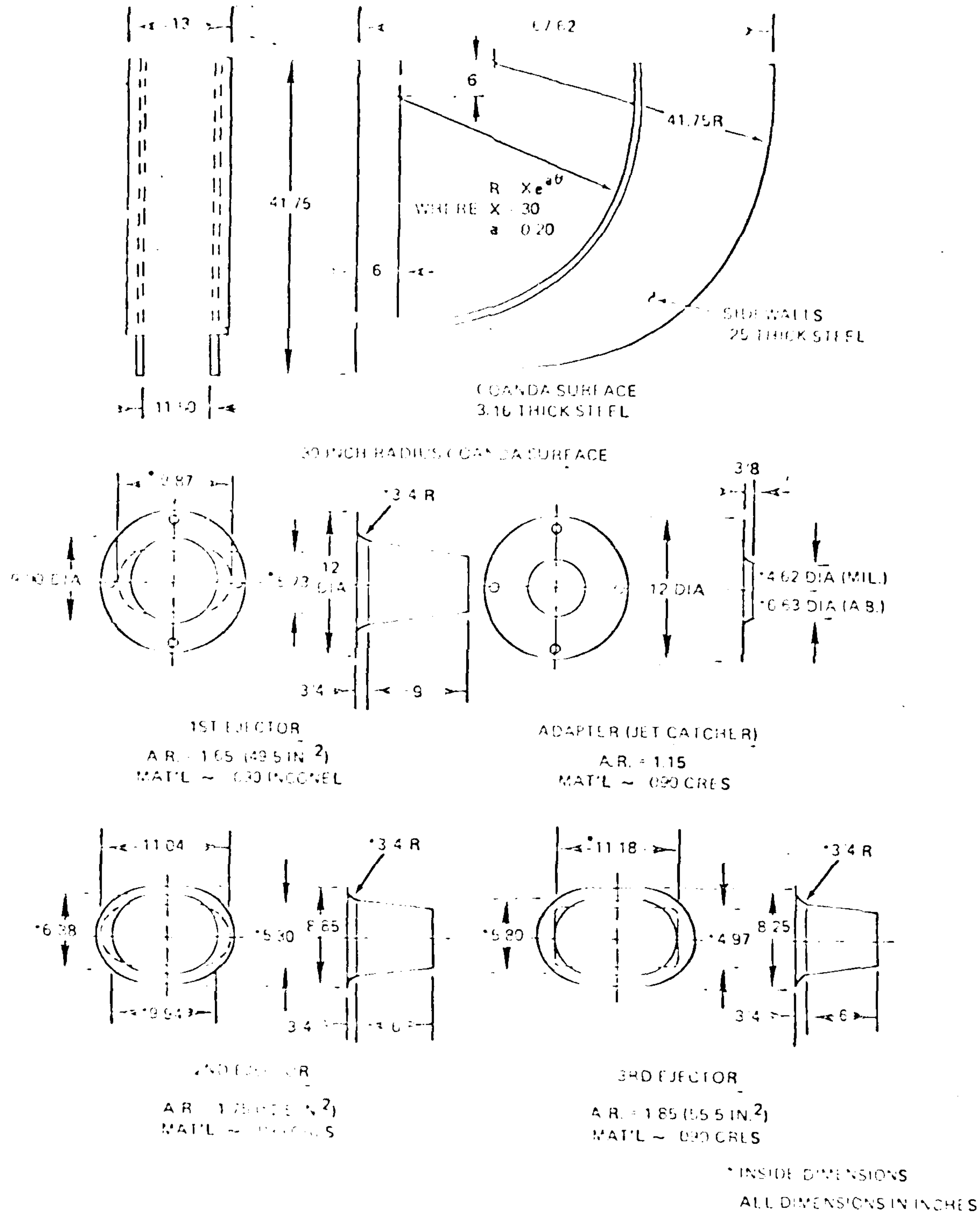
Fabrication of the hardware shown in Figures 22, 23, and 24 will begin immediately after the completion of the first test series unless redesign is indicated by that testing.

2.5.1.3 Test Set-Up

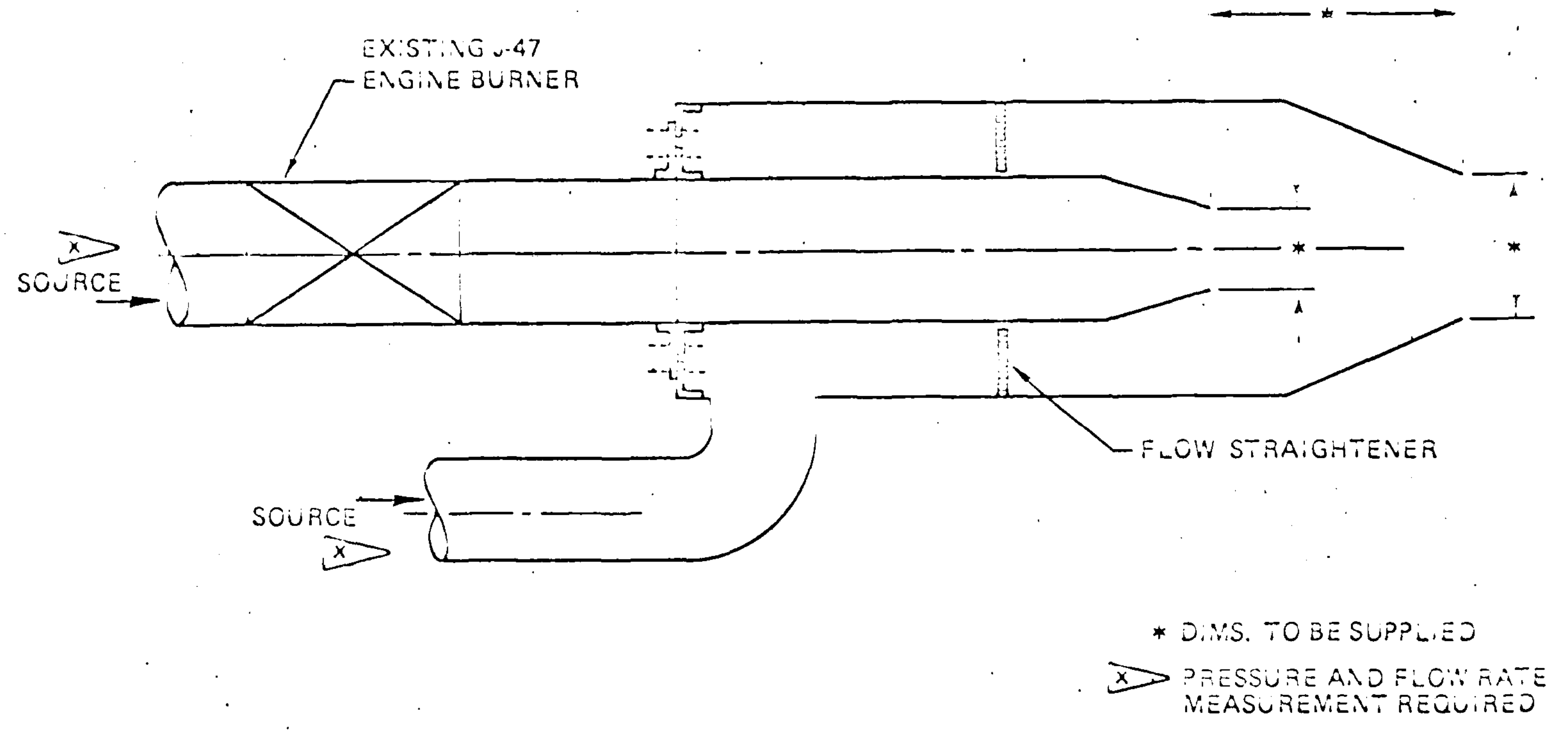
The model arrangement for the simulated aircraft tailpipe movement test is shown in Figure 18. The existing Coanda support frame from previous model tests (References 1 and 2) will be used. The ejectors, Coanda surface and adapters are those shown in Figure 21. The ejectors are positioned such that the exit plane of one coincides with the inlet of the next and will be aligned as close to the system centerline as possible.

The model and coannular flow burner set-up is shown in Figure 19. The model and support frame are the existing hardware from the misalignment test. The coannular flow rig details are shown in Figure 22. The same misalignment and fore and aft adjustments of the support frame are required as in the previous tests.

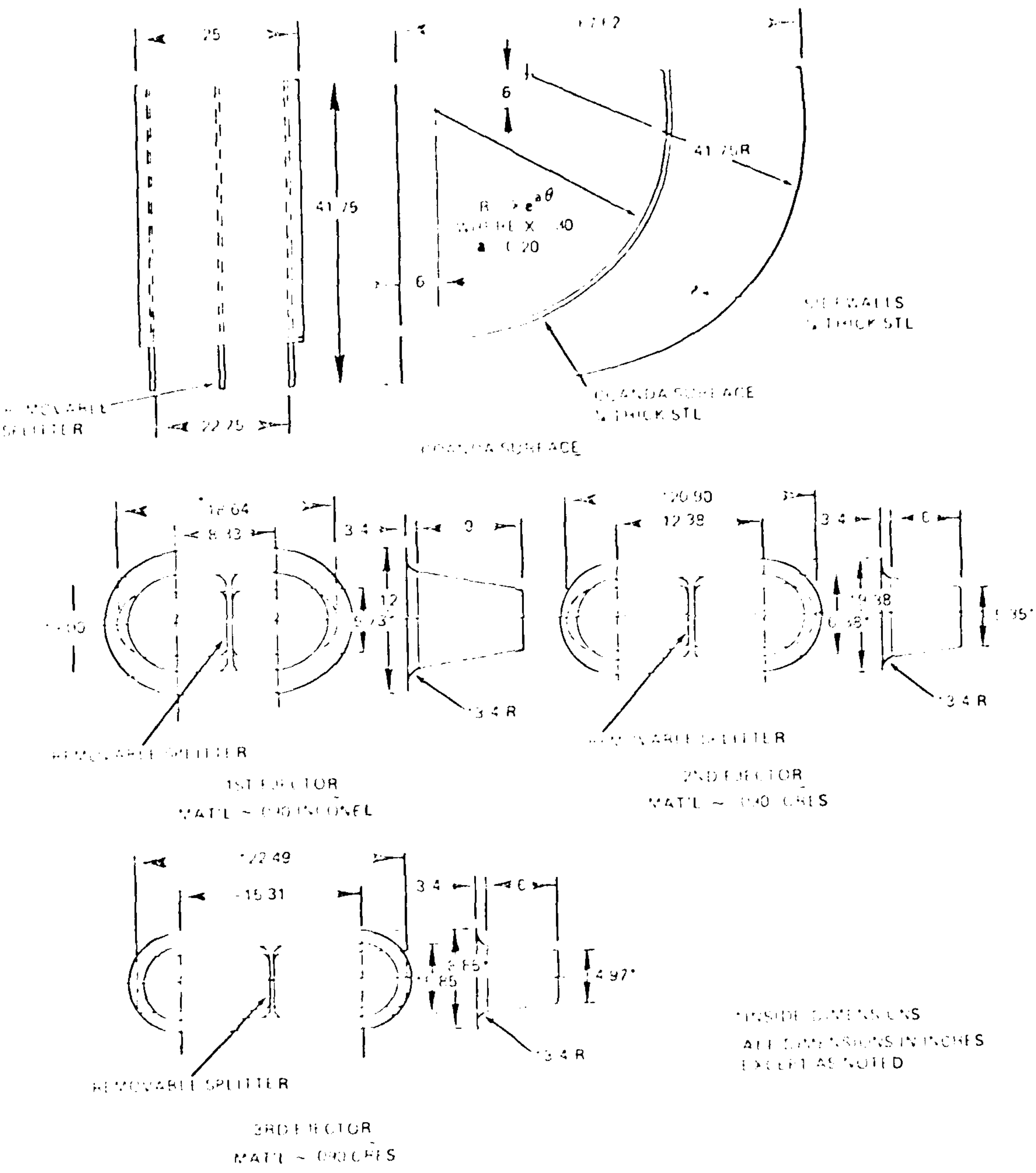
The model and dual burner arrangement for the twin engine suppressor test is shown in Figure 20. The ejectors and Coanda surface are shown in Figure 23 and the addition of the second burner is shown in Figure 24. A new support frame similar to the one for the single Coanda surface will be fabricated. The capability for moving the Coanda surface and ejectors up and down and to the side to simulate misalignment will be incorporated into this frame as it is on the single surface support frame.



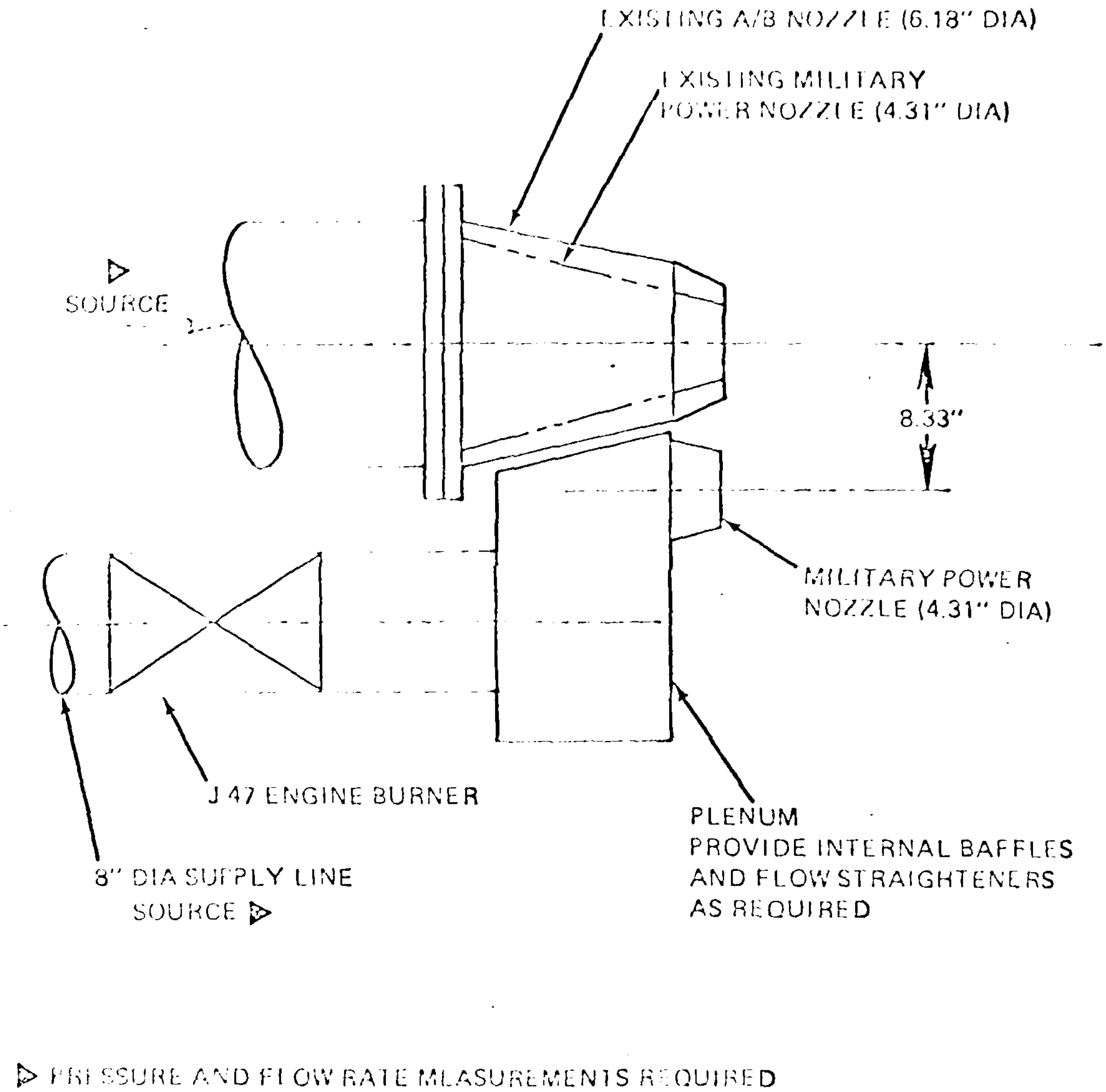
DIMENSIONAL DRAWINGS OF REVISED COANDA SURFACE EJECTOR AND ADAPTER DETAILS
FIGURE 21



COANNULAR FLOW ENGINE SIMULATION RIG
FIGURE 22



DIMENSIONAL DRAWINGS OF TWO ENGINE COANDA
SURFACE AND EJECTORS
FIGURE 23



ADDITION OF SECOND NOZZLE AND BURNER FOR
TWIN ENGINE SIMULATION
FIGURE 24

2.5.1.4 Instrumentation

The instrumentation required on the model for the aircraft tailpipe misalignment test is shown in Figure 18 and Table 10.

The acoustic instrumentation will consist of placing two microphones at 45° each side of the exhaust centerline at a radial distance of 2 feet from the first ejector inlet plane and centerline intersection to gather acoustic data. The frequency range of interest is 315 Hz to 63 KHz (24 one-third octave bands) for model scale which corresponds to 50 Hz to 10 KHz full scale with the use of a 1/6 scale factor.

Instrumentation required on the model for the coannular flow test (shown in Figure 19) is the same as for the prior misalignment test since the same model hardware is to be used.

The instrumentation required for the model twin-engine suppressor test as shown in Figure 20 is presented in Table 11.

In addition to the individual model instrumentation listed above, Table 12 presents data that will be required for all test runs.

TABLE 10

TAILPIPE MISALIGNMENT INSTRUMENTATION REQUIREMENTS

TYPE & LOCATION	UNITS	QUANTITY	RANGE	ACCURACY
Static Pressure at Nozzle Exit	psia	4	13-15	± .02 psi
Static Pressure Ejector Walls	psia	12	10-16	± .02 psi
Static Pressure Coanda Surface	psia	10	10-Amb	± .02 psi
Total Pressure Coanda Exit Rake	psia	14	Amb-20	± 1%
Surface Temp Thermocouple Ejector Walls	^oF	12	Amb-1500^o	± 2%
Surface Temp Thermocouple Coanda Surface	^oF	10	Amb-1300^o	± 2%
Total Temp Coanda Exit Rake	^oF	14	Amb-1300^o	± 2%

TABLE 11

TWIN-ENGINE INSTRUMENTATION REQUIREMENTS

TYPE & LOCATION	UNITS	QUANTITY	RANGE	ACCURACY
Static Pressure at Nozzle Exit	psia	8	0-20	± .02 psi
Static Pressure Ejector Walls	psia	12	10-16	± .02 psi
Statis Pressure Coanda Surface	psia	10	10-Amb	± .02 psi
Total Pressure Coanda Exit Rake	psia	14	Amb-20	± 1%
Surface Temp Thermocouple Ejector Walls	^oF	12	Amb-1500^o	± 2%
Surface Temp Thermocouple Ejector Splitters	^oF	6	Amb-1500^o	± 2%
Surface Temp Thermocouple Coanda Surface	^oF	10	Amb-1300^o	± 2%
Surface Temp Thermocouple Coanda Splitter	^oF	5	Amb-1500^o	± 2%
Total Temperature Coanda Exit Rake	^oF	14	Amb-1300^o	± 2%

TABLE 12

GENERAL INSTRUMENTATION REQUIREMENTS

TYPE & LOCATION	UNITS	QUANTITY	RANGE	ACCURACY
Total Pressure Jet Exhaust	psia	1	0-35	± 1/2%
Total Temp Jet Exhaust	°F 2	1	0-1600° 2	± 2%
Airflow - Primary Jet	Lbs/Sec 3	1	0-8.0	± 1%
Airflow - Coannular or 2nd Nozzle	Lbs/Sec 3	1	0-10.0	± 1%
Fuel Flow - Primary Jet	gpm	1	0-3.5	± 1%
Fuel Flow - Coannular or Second Nozzle	gpm	1	0-0.7	± 1%
Ambient Pressure	psia	1	--	± 1/2%
Ambient Temp	°F	1	--	± 2%

1. One exhaust pressure and temperature required for misalignment test and two each for coannular and twin engine tests.

2. For A/B conditions (~3000°F) set up on a predetermined fuel and airflow rate. For non-A/B conditions measure temperature directly.

3. Measure and record standard flow nozzle P, ΔP and temperature; and calculate mass flow in a computer program.

2.5.1.5 Test Plan

The aircraft tailpipe misalignment tests will be run first. The model scale test hardware for the twin engine simulation and for the coannular flow tests will be designed based on results from the misalignment tests. Fabrication of the coannular and twin engine hardware will not proceed, however, until the misalignment tests have been completed. Therefore, there will be some time (approximately seven weeks) between the misalignment test and the coannular flow and twin engine simulation testing. Table 13 presents the test configurations for evaluating the tailpipe misalignment.

The coannular flow test will be run prior to the twin engine simulation test. Table 14 presents the test configuration for evaluating the coannular flow engine concept.

Table 15 presents the test configurations which will be evaluated for the twin engine simulations.

The flow conditions contained in Tables 13 and 15 are defined as follows:

ENGINE CONDITION	P_t/P_2	T_j
Idle	1.05	270°F
Full Military	2.12	730°F
Full A/B	1.93	2920°F

TABLE 13

TAILPIPE MISALIGNMENT TEST CONFIGURATIONS
(ALL DIMENSIONS IN INCHES)

CONF NO.	PRIMARY NOZZLE	PRIMARY FLOW COND	ADAPTER	NOZZLE/EJECTOR MISALIGNMENT	DATA SURF P_s & T_m	DATA EXIT P_t & T_t	DATA ACOUSTIC
1	4.31 Dia	Full Military	None	None	X	X	
2			None	Nozzle 1" Up	X	X	
3			None	Nozzle 1" Down	X	X	
4			None	Nozzle 1" to Side	X	X	
5			4.62 Dia.	None	X	X	
6			4.62 Dia.	Nozzle 1" Up	X	X	
7			4.62 Dia.	Nozzle 1" Down	X	X	
8	4.31 Dia	Full Military	4.62 Dia.	Nozzle 1" to Side	X	X	
9	6.18 Dia	Full A/B	None	None	X	X	X
10			None	Nozzle 1" Up	X	X	
11			None	Nozzle 1" Down	X	X	
12			None	Nozzle 1" to Side	X	X	
13			6.63 Dia.	None	X	X	X
14			6.63 Dia.	Nozzle 1" Up	X	X	
15			6.63 Dia.	Nozzle 1" Down	X	X	
16	6.18 Dia	Full A/B	6.63 Dia.	Nozzle 1" to Side	X	X	

TABLE 14

COANNULAR FLOW TEST CONFIGURATIONS

CONFIGURATION NO.	* FLOW CONDITION (TF-41-2 ENGINE)	NOZZLE/EJECTOR MISALIGNMENT	DATA SURFACE P_s & T_m	DATA EXIT P_t & T_t
17	Idle	None	X	X
18	75%	None	X	X
19	Full Military	None	X	X
20	Idle	Nozzle 1" Up	X	X
21	75%	Nozzle 1" Up	X	X
22	Full Military	Nozzle 1" Up	X	X
23	Idle	Nozzle 1" Down	X	X
24	75%	Nozzle 1" Down	X	X
25	Full Military	Nozzle 1" Down	X	X
26	Idle	Nozzle 1" to Side	X	X
27	75%	Nozzle 1" to Side	X	X
28	Full Military	Nozzle 1" to Side	X	X

* Pressure ratio and temperature conditions to be provided later.

TABLE 15

TWIN ENGINE TEST CONFIGURATIONS
(ALL DIMENSIONS IN INCHES)

CONF. NO.	PRIMARY NOZZLE L.H.	PRIMARY NOZZLE R.H.	PRIMARY FLOW COND. L.H.	PRIMARY FLOW COND. R.H.	EJECTOR CONF	COANDA CONF	NOZZLE/EJECTOR MISALIGNMENT	DATA SURFACE P_s&T_m	DATA EXIT P_t&T_t
29	4.31 Dia.	4.31 Dia.	Idle	Idle	No Splitter	No Splitter	None	X	X
30	4.31 Dia.		Mili-tary	Idle				X	X
31	4.31 Dia.		Mili-tary	Mili-tary				X	X
32	6.18 Dia.		Full A/B	Idle	No Splitter			X	X
33	4.31 Dia.		Idle	Idle	with/ Splitter			X	X
34	4.31 Dia.		Mili-tary	Idle				X	X
35	4.31 Dia.		Mili-tary	Mili-tary				X	X
36	6.18 Dia.		Full A/B	Idle				X	X
37	4.31 Dia		Idle	Idle		with/ Splitter		X	X
38	4.31 Dia.		Mili-tary	Idle				X	X
39	4.31 Dia.		Mili-tary	Mili-tary				X	X
40	6.18 Dia.		Full A/B	Idle	with/ Splitter	with/ Splitter	None	X	X
41	4.31 Dia.		Mili-tary	Idle	[1]	[1]	Nozzle 1" Up	X	X
42	4.31 Dia.	4.31 Dia.	Mili-tary	Mili-tary	[1]	[1]	Nozzle 1" Up	X	X

[1] Configuration of ejectors and Coanda surface to be that judged to produce the best attachment from Configuration 29 through 40.

TABLE 15 Cont'd

CONF. NO.	PRIMARY NOZZLE L.H.	PRIMARY NOZZLE R.H.	PRIMARY FLOW COND. L.H.	PRIMARY FLOW COND. R.H.	EJECTOR CONF	COANDA CONF	NOZZLE/EJECTOR MISALIGNMENT	DATA SURFACE P_s&T_m	DATA EXIT P_t&T_t
43	6.18 Dia.	4.31 Dia.	Full A/B	Idle	[1]	[1]	Nozzle 1" Up	X	X
44	4.31 Dia.		Mili-tary	Idle			Nozzle 1" down	X	X
45	4.31 Dia.		Mili-tary	Mili-tary			Nozzle 1" down	X	X
46	6.18 Dia.		Full A/B	Idle			Nozzle 1" down	X	X
47	4.31 Dia.		Mili-tary	Idle			Nozzle 1" to side	X	X
48	4.31 Dia.		Mili-tary	Mili-tary			Nozzle 1" to side	X	X
49	6.18 Dia.	4.31 Dia.	Full A/B	Idle	[1]	[1]	Nozzle 1" to side	X	X

[1] Configuration of ejectors and Coanda surface to be that judged to produce the best attachment from Configuration 29 through 40.

2.5.1.6 Data Reduction

Reduced data will be printed out on-line from computerized recording. The performance printout will be similar to that shown in Figure 25. The following data for each test condition will be tabulated:

Atmospheric Pressure	P_a (psia)
Atmospheric Temperature	T_a (^oF)
Jet Temperature	T_j (^oF)
Primary Flow Total Pressure	P_t (psia)
Primary Flow Pressure Ratio	P_t/P_a
Air Flow	$\dot{W}_p$ (Lbs/Sec)
Nozzle Area	A_p (In^2)
Fuel Flow	$\dot{W}_f$ (gpm)

Duplicate data to that above will be recorded for the secondary flow of the coannular flow test and the second nozzle of the twin engine simulation test.

Acoustic data for the two microphones in the misalignment test will be recorded using the General Radio 1921 real time analyzer and Varian computer for an on-line data reduction. The printout from the printer will be similar to that shown in Figure 18.. Sound Pressure Level (SPL) will be tabulated for one-third octave band frequencies converted to full scale equivalents (i.e., frequency shift of data by a factor of 1/6 and multiplying distance by six to account for the scale factor). Overall Sound Pressure Level (OASPL) and "A" weighted dBA levels will be computed and tabulated for each microphone location for each test condition.

Photographs will be taken of all model hardware and setups. Identification information such as run number, model configuration, scale factor, date and meteorological information will be provided on each page of data.

ACOUSTIC ARENA DATA
NAVY COANDA/REFRACTION NOISE SUPPRESSOR

Configuration (description) ____

Run (Number) ____ Conf.(Number) ____ (date) ____

P_{AMB}	PSIA	____	T_{AMB}	°F	____
P_{T1}	PSIA	____	P_{T2}	PSIA	____
T_{T1}	°F	____	T_{T2}	°F	____
$\dot{W}_{A1}$	Lb/Sec	____	$\dot{W}_{A2}$	Lb/Sec	____
$\dot{W}_{F1}$	gpm	____	$\dot{W}_{F2}$	gpm	____
A_P	$In.^2$	____	A_S	$In.^2$	____

Ejector P_S	1	PSIA	____	T_S	1	°F	____
	2		____		2		____
	3		____		3		____
	-				-		____
	-				-		
	-				-		
	12		____		12		____
Coanda P_S	1	PSIA	____	T_S	1	°F	____
	2		____		2		____
	3		____		3		____
	-		____		-		____
	-				-		
	-				-		
	10		____		10		____
Rake P_T	1	PSIA	____	T_T	1	°F	____
	2		____		2		____
	3		____		3		____
	-				-		
	-				-		
	14		____		14		____
Nozzle P_S	1	PSIA	____				
	-		____				
	4		____				

FIGURE 25

PROPOSED PERFORMANCE OUTPUT FORMAT

2.5.1.6 Data Reduction Cont'd.

A run log will be kept, along with any information that might be pertinent to the test results including general comments.

All adjustments and changes to the equipment and instrumentation will be recorded.

2.6 Task VI

Task VI consists of disposition of the experimental hardware and documentation of the results of testing, including engineering analyses, design studies and drawing preparation.

2.6.1 Demonstrator Hardware Disposition

All hardware developed under the contract will be the property of the Navy. When the full scale demonstrator testing is completed the test site will be restored and the experimental hardware will be disassembled and shipped to a Navy facility which will be designated by the Navy. Disposition of the one-sixth scale model hardware will be determined at the conclusion of the model tests.

2.6.2 Model Test Report

A final report in Boeing format will be prepared upon completion of the scale model testing. This report will be a detailed analysis of the test results and an aircraft system study to determine specific problem areas in adapting the Coanda concept to in-airframe engines.

2.6.2.1 Model Test Results

The results of the one-sixth scale model testing will be included in the report in the form of pertinent graphs, charts, and tables, as well as observations of operational trends. The results will be presented in a form which will enable Navy technical personnel to determine the [illegible] operational characteristics.

2.6.2.2 Aircraft System Studies

The one-sixth scale model tests to be accomplished are primarily a preliminary investigation into adapting the Coanda Suppressor concept to in-airframe engine installations. Aircraft system studies to determine the following information will be accomplished from the model test results:

2.6.2.2 Aircraft System Studies - Cont'd.

a. Feasibility of applying the Coanda Suppressor concept to aircraft systems.

b. Aircraft tailpipe movement effects on jet deflection and gas dynamics through the transition section.

c. Jet sheet interaction between two different power flows in the same chamber; requirements for divider wall between separate chambers; results of simulation tests for twin engine aircraft.

2.6.3 Demonstrator Test Cell Cost Analysis

A preliminary cost analysis for estimating the cost-per-unit of the test cell exhaust noise suppressor will be conducted during the early stages of Task I. This cost estimate will be a letter report submitted concurrent with the aircraft system studies early in the third quarter of Fiscal Year 1975.

2.6.4 Demonstrator Test Cell Final Report

The demonstrator test cell final report will include the test results, engineering and operational analysis and design studies for the full scale studies, as well as a summary of the one-sixth scale model test results from the model scale final report. This report will fulfill the requirement designated as A004 on Form DD1423 of the contract and will be on GSFD format.

2.6.4.1 Operational Analysis

An important aspect of the data analyses is to define test cell exhaust system configuration requirements, as related to the listing of engines in Table 1. Studies will be performed and reported to predict, based on observed trends, the operational characteristics of the following suppressor systems:

a. A "universal" configuration for all engines listed in Table 1.

b. A group of configurations, each limited to a specific airflow handling capability, over the range of engines up to 600 lbs/Sec airflow.

c. One configuration that could satisfactorily handle all engines with airflows up to 600 Lbs/Sec.

2.6.4.2 Demonstrator Program Results

The final report will include the results of all pre-test development and design studies, all test configuration results and the analyses of test results. All significant test data will be analyzed and operational trends reported. Full scale data will be compared to data/predictions from previous scale model programs wherever possible. Acoustic attenuation and jet deflection will be related to actual variations in test hardware geometry. The program results will be presented in enough detail to enable Navy technical personnel to determine the operational characteristics for future noise suppressor systems based on the Coanda/Refraction concept.

2.6.5. Design Drawings

Detail design drawings will be generated for use in fabrication of the prototype and/or production unit, as determined by the Navy. This will be accomplished upon completion of all testing and configuration design studies. The drawings will be per Specification MIL-D-1000, Category E, G, and I, which will fulfill the requirement designated as A003 on Form DD1423 of the contract.

3.0 REFERENCES

1. D3-9068, "Feasibility and Initial Model Studies of a Coanda/Refraction Type Noise Suppressor System", January 1973

2. D3-9258, "Configuration Scale Model Studies of a Coanda/Refraction Type Noise Suppressor System", October 1973

3. T.O. 33D-4-444-1, "Technical Manual, Operation and Maintenance Instructions".

4. T.O. 2J-J75-6, "Technical Manual, Field Maintenance Instructions, USAF Models J75-P-17, J75-P-19, and J75-P-19W Aircraft Engines".

5. Contract N00156-74-C-1710 between Naval Air Engineering Center (NAEC), Philadelphia, Pennsylvania 19112, and The Nacelle and Noise Abatement Branch-The Boeing Company, Wichita, Kansas 67210

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