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AEROSPACE INFORMATION REPORT

AIR 1813

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Revised

THE COANDA/REFRACTION CONCEPT FOR GAS TURBINE ENGINE TEST CELL NOISE SUPPRESSION

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1. PURPOSE

1.1 To present an advanced technology in suppression of gas turbine engine exhaust noise in ground run-up test cells/systems. The discussion herein is limited to turbojet and turbofan type engines, although the concept is equally applicable to turboshaft and turboprop types.

1.2 To explain specific applications of this technique in various types of test cells.

2. SCOPE

2.1 Document provides information on how military/commercial/gas turbine engine test cell/system users may benefit from this unique Coanda/Refraction concept.

2.2 The information contains several factors which are considered essential for understanding the practical technical aspects of the concept. These are:

a) Operation Need, b) Concept Definition, c) Developmental Program and d) Program Results.

3. TEST CELL/SYSTEM NOISE SUPPRESSION REQUIREMENTS

3.1 General: One of the most important problems in ground testing of turbojet/fan aircraft engines is the extremely high noise level energy radiated from the test location which endangers operating personnel hearing and disturbs nearby communities. The intense noise levels produced by modern day high performance jet aircraft is creating hazards, both physiological and psychological.

3.2 Test Cell/System Design:

3.2.1 Gas turbine engine test cells/systems have many design requirements to satisy the complexity of aerodynamic, thermodynamic and acoustic performance characteristics. A delicate balance is necessary to assure that the gas turbine engine operates in a similar environment in the test cell/system as it does in the open air.

3.2.2 The physical dimensions and cross-sectional area of a test cell/system should be such as to assure that laminar air flow through the engine chamber is effected.

3.2.3 The principal structural components of the test cell/system are the primary air inlet, the engine chamber and the exhaust section. Each must be designed for its individual function and for its compatibility with the others, with respect to aerodynamics and acoustic performance. It is noted that the exhaust section includes the secondary air inlet and the exhaust stack.

3.3 Acoustic Properties: The overall acoustic performance of a test cell is a composite effect based upon the residual noise contributions emitted from the inlet, engine chamber walls and the exhaust section.

3.3.1 Inlet noise is predominately high frequencies - mostly from the engine compressor.

3.3.2 Engine chamber noise is mostly mid-band frequency distributed.

3.3.3 Engine exhaust section noise is predominately low-frequency.

4. OPERATIONAL NEED

4.1 General: The need for advanced technology in a specific commodity area is usually based upon the time-reduced capability of the state-of-the-art equipment to function effectively. In the gas turbine engine test cell/system, engine exhaust total flow energy and proportional acoustic energy - especially in high-performance, afterburning military engines - have increased beyond the capability of noise suppression equipment which can function without extensive maintenance, replacement of components and reduced life-cycle expectancy.

4.2 Military Procurements: Past equipment procurements and design studies have been limited to the state-of-the-art hardware and technology, which have not yet been developed for prolonged durability against the adverse effects of engine exhaust; viz high impact forces, excessive temperatures and entrained contaminants. Consequently, procurements of noise suppression equipment or test cell/system acoustic baffles have been diverse in origin and objectives, so that the existing acoustic support gear is not interchangeable. Despite procurement of suppressors designed for only one engine, the need exists for multi-engine usage. A diversity of equipment from different contractors lacks commonality to permit a practical, efficient logistics plan for support and replacement of deteriorating parts. The built-in replacement requirements of acoustic absorptive elements, and disadvantages in the state-of-the-art equipment due to corrosion required an improvement in noise reduction technology.

4.3 Disadvantages: Several characteristics which tend to reduce the life-cycle effectiveness of the state-of-the-art exhaust noise suppressors are:

4.3.1 Current ground run-up noise suppressors utilize instream turning vanes and perforated collanders to direct the horizontal, high temperature jet exhaust upward. This equipment requires heavy structures to withstand the jet exhaust forces. Most internal components (including acoustic absorptive baffles) are subject to deterioration and frequent maintenance.

4.3.2 A necessary function of the ground run-up suppressor is to reduce the hot exhaust gas velocity to the extent that the noise created by the flow exiting from the suppressor is below the design criteria. In the state-of-the-art equipment, the necessary energy transfer is accomplished by the use of perforated collanders to break up the flow and mix it with cooler induced air, or by injecting large volumes of water into the exhaust plume. Both of these methods are poor for use with afterburning engines, because the flow damages suppressor components and because excessively large amounts of water are required to reduce the exhaust temperature to acceptable levels.

5. THE COANDA/REFRACTION CONCEPT

5.1 General: The COANDA/REFRACTION concept for gas turbine engine exhaust noise reduction depends, essentially, on a combination of aerodynamic/acoustic phenomena which occur simultaneously downstream from the engine exhaust nozzle.

5.2 Concept Definition: The concept combines, for the first attempt in noise reduction applications, an aerodynamics phenomenon - The Coanda Effect - for jet exhaust bending/cooling without excessive structural requirements or turning vanes, and an acoustic principle - noise refraction by temperature/velocity gradients - for low-frequency tuned absorption.

5.3 The Coanda Effect: A non-rigorous technical statement of the Coanda Effect, based upon the original work of Dr. Henri Coanda, A Rumanian aerodynamicist, is presented as follows:

5.3.1 A turbulent jet, exiting from a rectangular nozzle into an ambient fluid, entrains fluid from the ambient field. A surface placed near the exiting jet inhibits entrainment on that side of the jet, causing a low pressure region to exist between the jet and the surface. With a pressure gradient thus imposed across the jet, it deflects toward the surface, thereby decreasing the surface pressure even more, until the jet eventually attaches to the surface. If there is a step-gap between the jet and the deflection surface, a trapped vortex will form between jet and surface. This phenomenon is known as the Coanda Effect.

5.3.2 Coanda-deflected jets entrain greater quantities of secondary-air than undeflected jets. Due to the lower static pressure on the bounded side of the jet, the pressure drop across the nozzle is greater, thereby increasing the jet velocity on that side -- the velocity of the bounded side being equal to that of the undeflected jet. The resultant average velocity in the deflected jet is greater than the undeflected jet, assuming equal nozzle exhaust pressure. Consequently, the deflected jet also possesses greater average momentum and greater eduction pumping efficiency than the free-jet mixing capability. As a side-effect to this greater-mass-airflow-entrainment, Coanda flow enhances jet ejector operation with lower ejector exit temperatures.

5.4 Acoustic Refraction: Refraction of acoustic energy occurs naturally in all gas turbine engine exhaust streams. Noise refracts, or radiates, out of the exhaust along paths which are perpendicular to characteristic contours of equal flow velocity and equal temperature.

5.4.1 Locations of refracted noise patterns, relative to the deflected jet flow, are geometrically predictable for exploitation in noise reduction attempts.

5.5 Application to Noise Suppression: Several factors for understanding the aerodynamics, thermodynamics and acoustics benefits derived from application to suppression of gas turbine engine exhaust noise in test cells are:

5.5.1 An additional feature of the Coanda Effect is that it is a natural fluid amplifier - the curved jet flow has a greater capability than normal jets for educting large volumes of ambient air from the immediate vicinity at the outer boundary of the deflected jet. In relation to jet engine testing this means that natural cooling of the superheated jet exhaust (caused by mixing and enthalpy exchange of educted ambient air with the rectangular jet core) is possible without the need for additional structural requirements of secondary air chambers. More important, it eliminates the need for cooling water and associated pump and piping systems. The actual ratio of cooling-to-primary-air was limited to ten-to-one in the experimental model tests.

5.5.2 Due to the proximity of a surface to the jet, a pressure gradient is formed which causes the jet to turn. This means that there are no components in the flow to create jet exhaust stagnation temperatures and pressures. The deflection surface may be film-cooled with entrained air from air slots along the surface.

5.5.3 The acoustic energy will now be refracted out of the exhaust flow. Acoustically tuned resonant chambers for absorption of specific frequency bands can be located adjacent to the high energy exhaust flow, instead of being located directly in the stream. This results in a significant increase in operating life, and provides a method for attenuating low frequencies.

5.5.4 The initial concept of a noise suppressor using the Coanda Effect and noise refraction principle is shown in Figure 1. This configuration consists of an adapter/transition section and a Coanda flow turning section. The adapter/transition section serves as an ejector -- it converts the round primary jet exhaust, mixed with entrained cooling air at the inlet, into a rectangular sheet of hot gasses at its exit. The curved deflection surface then turns the rectangular sheet flow upward 90 degrees, while reducing the flow velocity and refracting a large portion of the internally generated noise downward and to the rear where acoustic resonant chambers are located.

6. PROGRAM RESULTS

6.1 General: As a result of the overall developmental program, an advanced technology concept was proven feasible and practical for suppression of gas turbine engine exhaust noise in test cells/systems. This report has presented an explanation of the Coanda/Refraction concept and a description of the research work. The tabulated data, charts and graphs are too extensive to be presented herein, but are available in technical reports, as indicated in the listing of references.

6.2 Test Cell Exhaust System: The Coanda/Refraction system is an air-cooled, turbojet/fan engine exhaust noise suppressor which is attached to the aft wall of an engine test cell. The main components of the system are described as follows:

6.2.1 Iris Adapter -- an adjustable operative device which can be used to control the amount of cooling air which is pumped through the engine chamber, across the engine and into the first stage ejector. The IRIS is located on the aft test cell wall, concentric with the engine longitudinal centerline and at the inlet of the first stage ejector. The IRIS is adjustable for each engine type. The IRIS is not needed in the standard design Coanda system. However, the adapter is recommended for use in larger, turbofan-type exhaust systems and smaller turbojet engines.

6.2.2 Ejectors -- a three-stage set of augmentor devices which transition the hot engine exhaust from a round jet to a rectangular sheet flow suitable for introduction into the Coanda surface. The curve is logarithmic, instead of a constant radius to allow for better cooling air mixing with the primary engine exhaust core.

6.2.3 Coanda Deflection Surface -- a curved surface directly downstream from the exit to the third ejector stage. The curve is a logarithmic, instead of a constant radius. This design allows for better colling because of the more efficient mixing between hot exhaust gases and cool ambient air.

6.2.4 Acoustic Enclosure -- a structure which surrounds the ejectors and Coanda surface while also supporting the secondary air intake and the exhause stack. The hollow-design walls consist of an isolated inner wall and an outer wall which are designed to prevent excessive noise transmission through the structure. The side walls and back wall of the aft section (below the stack) of this enclosure should be acoustically treated with the broadband absorber panels set inside the isolated inner wall.

6.2.5 Secondary Air Intake -- the secondary air intake is located in the upper part of the enclosure just forward of the exhaust stack. It permits the flow of ambient air into the enclosure for the purpose of mixing with and cooling the hot jet exhaust. The inlets are lined with acoustic panels, to limit airborne noise propagation from within the enclosure. Moreover, the inlets are sized to maintain acceptable pressures within the enclosure.

6.2.6 Exhaust Muffler (Stack) -- acoustically lined and located at the aft end of the muffler section, this system provides the necessary noise attenuation for the mixed exhaust flow exiting into the atmosphere. A broadband acoustic absorber is used in the stack wall behind a multi-layered, perforated face sheet. The broadband absorbers, located in the aft end of the enclosure extending from the stack to the floor, are required to absorb noise refracted from the Coanda flow. The exhaust stack height may be designed to provide any desired far-field acoustic performance (within local site construction constraints), as explained in Reference 8.3.

6.3 Applications:

6.3.1 As a result of the final analytic design studies, functional noise suppression systems configurations have been identified for usage in ground run-up test facilities for Navy/Marine Corps turbojet/fan engines. These systems are also applicable in the present design form to USAF engines which are of the same types, but which differ only in model number from their counterparts in the Navy inventory.

6.3.2 The standard exhaust system for a prefabricated demountable type test cell is shown in Figure 5. This configuration is specifically designed to accommodate the exhaust airflow, temperature and pressure ratio parameters of the J52, J57 A/B, J79 A/B, TF30, TF30 A/B and TF41 engines. It is noted that the rear wall of the test cell engine enclosure is the forward wall and ejector inlet plane of the exhaust system. Also see Figures 2, 3, and 4.

6.3.3 Figure 6 shows the standard configuration which has been developed specially as a retrofit for replacement of deteriorated water-injection-type exhaust systems for the Navy standard concrete Class "C" test cell.

6.4 Advanced Technology; In addition to these design configurations, a working technology has been formulated and presented in a Design Configuration Handbook. (For details refer to Reference 8.2)

6.4.1 This technology is adequate for designing a specific "tailor-made" noise suppressor for any engine, or closely-related group of engines, in any type of ground run-up test cell enclosure, including Navy/Air Force test cells/ systems and Naval Air Rework Facility test cells (which have a variety of non-standard, unique configurations).

6.4.2 This is considered essential for design studies leading to a configuration for larger, high by-pass ratio turbofan engines, as well as the "PEGASUS" or F-402-RR-404 engine for the AV-8 Harrier aircraft.

6.4.3 This technique is equally applicable to commercial airlines engine test cells and engine manufacturers test cells.

7. APPLICATION TO AIRCRAFT HUSH-HOUSES

7.1 General: Recent developmental work by the U. S. Navy has been successful in applying the proven technology as an exhaust suppressor system for aircraft acoustical enclosures -- hush houses -- where the entire aircraft is enclosed in a test cell during ground run-up engine checks. Although the basic application is similar to the test cell system, the actual design development for single and dual-engine aircraft is considerably more complicated. A brief summary of this program is presented below.

7.2 One-Sixth-Scale Model Configuration;

7.2.1 The model configuration shown in Figure 7 is the experimental set-up for the aircraft run-up enclosure (Hush-House) series of tests.

7.2.2 In order to allow for the physical properties of single, as well as dual, engine aircraft, this flat-plate type ejector system was developed as another advanced technology feature to assure that the Coanda/Refraction concept was adaptable to the complex geometrical requirements of an exhaust system for a multi-aircraft Hush-House.

7.3 Flat-Plate Ejectors;

7.3.1 The hush-house exhaust system differs from the test cell exhaust system with respect to the basic transition/ejector configuration. Instead of the round-to-rectangular ejector geometry of the test cell system, the hush-house system incorporates an advanced technology flat-plate type ejector configuration.

7.3.2 Advantages are that the flat-plate ejectors are less sensitive to aircraft tailpipe movement during power-change surges of ground run-up tests, and dual-engine, as well as single-engine, aircraft can be accommodated on the same exhaust system without unnecessarily stringent and painstaking aircraft alignment/positioning.

7.3.3 The flat-plate system also assures that the mixed flow from two distinct exhaust nozzles of twin-engine aircraft (e.g. one engine at idle power and one engine at afterburner) will attach to the curved surface and deflect upward.

7.4 Summary of Results:

7.4.1 For complete aircraft ground run-up tests (in-airframe installed engines), a standard design configuration has been developed as a result of analytic studies, scale model tests and design studies.

7.4.2 This exhaust system for aircraft run-up enclosures (Hush-Houses) is shown in Figure 8. Here again, the exhaust system attaches to the rear wall of the standard aircraft acoustical enclosure. The range of Navy/Marine Corps single and dual engine aircraft for which this exhaust system configuration has been developed includes A-4, A-6, A-7, F-4, and F-14.

7.4.3 It is planned to develop a design configuration handbook for the hush-house flat-plate ejector system. Exhaust systems for other Navy, Marine Corps and Air Force aircraft types can be readily designed by using the technology from the handbook.

7.4.4 Hush-house exhaust noise suppressor systems for use during ground run-up tests, or in-airframe installed engine pre-flight trim checks, for commercial airlines and aircraft manufacturers can also be readily designed by using the technology from the handbook.

8. REFERENCES

8.1 ARP 741 - Gas Turbine Engine Test Cell Correlation

8.2 NAVAL AIR ENGINEERING CENTER, LAKEHURST, NJ DESIGN DATA 92-136, 30 March 1979, Design Configuration Handbook, Test Cell System, Coanda/Refraction Noise Suppression Concept.

8.3 NAVAL AIR ENGINEERING CENTER, LAKEHURST, NJ Technical Report 92-112, April 1979, Jet Engine Demountable Test Cell, Exhaust System Phase.

8.4 NAVAL AIR ENGINEERING CENTER, LAKEHURST, NJ Technical Report 92-113, May 1979, Jet Engine Class "C" Test Cell Exhaust System Phase.

8.5 NAVAL AIR ENGINEERING CENTER, LAKEHURST, NJ Technical Report 92-057, September 1975, Full-Scale Model Experimental Test Phase.

9. LIST OF FIGURES

10. APPENDIX A - THE DEVELOPMENTAL PROGRAM

10.1 General: The development of the Coanda/Refraction concept, from an untried combination of natural, physical phenomena to a proven, functional test cell exhaust noise suppressor system, required an extensive research program. In-depth analyses in aerodynamics, thermodynamics and acoustics were integrated with realistic model tests to generate conceptual design configurations and technology guidelines which are valid in the harsh, turbulent environment of gas turbine engine exhaust flow.

10.2 Overall Objectives; Based upon the operational need for improved noise suppression equipment, and based upon the potential threat of reduced air defense capability due to non-availability of environmentally compatible engine test facilities, the Naval Material Command sponsored a multi-year comprehensive program of Exploratory and Advanced Development Phases. The objectives were:

10.2.1 To determine the feasibility and configuration characteristics for applying the Coanda/Refraction Concept to the attenuation of radiated engine exhaust noise from turbojet/fan engine ground run-up testing. The concept was originally formulated by technically cognizant personnel from the Naval Air Systems Command Headquarters and the Naval Air Engineering Center.

10.2.2 To develop/define an advanced technology for noise suppression, based upon the concept, which would be a workable technique for usage in future engine/aircraft test facility design projects.

10.2.3 To generate functional configurations for exhaust noise suppression systems, based upon the proven technology, which are compatible with Navy/Marine Corps operational procedures for in-airframe and out-of-airframe engine ground run-tests.

10.3 Technical Aspects/Considerations:

10.3.1 As a deflection technique for gas turbine engine exhaust, the Coanda Effect requires optimum geometric configuration of the transition/ejector section and the deflector surface. The transition/ejector device collects the circular jet flow in the bellmouth inlet and ejects it from a rectangular exhaust nozzle slot at the aft end. This rectangular-shaped jet sheet, configured in the form most conducive to efficient Coanda flow, attaches to a curved surface, or series of successively included flat plates, which is immediately downstream of the exhaust nozzle, but separated from the nozzle slot. This turns the flow into an eddy, or vortex, which generates a low-pressure zone, causing the stream from the slot to bend and thus follow the contour of the deflection surface.

10.3.2 Thus the need is eliminated for massive structural frames to withstand jet impact forces and support turning vanes. Film cooling of the deflection surface by educted ambient air eliminates requirement for water spray rings and associated piping, since the hot exhaust jet does not touch the surface. The mixing of large quantities of ambient air with the original jet greatly dissipates the total energy in the flow, and allows for light-weight acoustical panels for reduction of the characteristic noise spectrum to satisfactory levels.

10.3.3 Research investigations were directed toward refining this flow phenomenon into a configuration to meet the extreme mass airflow and temperature requirements of jet engine exhausts. A stable Coanda flow effect depends on the appropriate adjustment of many factors, including the texture of the deflecting surface. The primary factor is the maintenance of the balance between the centrifugal force and the suction force as the stream flows from the afterbody of the nozzle around the shoulder. Particularly crucial for this balance is the slot aspect ratio of nozzle exhaust jet sheet width to thickness. It is this ratio which establishes the rectangular dimensions of the nozzle slot, which makes possible the attachment of the jet sheet to the deflector surface. An optimum ratio of 6:1 was experimentally determined.

10.4 <u>Technical Approach</u>; The overall developmental program consisted essentially of various analytic studies and model tests.

10.4.1 The initial phase was an exploratory development effort to determine feasibility of the concept application to noise reduction and to conduct initial configuration sizing studies. This work consisted of analytic studies/calculations and breadboard hardware experiments. The theory equations, scientific assumptions and Navy noise suppression requirements were considered in the anlytic studies to define feasibility and to determine possible limitations in future designs or operating characteristics.

10.4.2 Results and conclusions from the initial phase were integrated with an experimental sequence utilizing breadboard, parametric, one-sixth scale models to verify initial calculations and to experimentally demonstrate the feasibility of adapting the two scientific principles to resolve the military problem of engine ground run-up noise reduction.

10.4.3 The model test plan consisted of using simulated engine air flows and real temperatures in conjunction with scaled, parametric configurations of Coanda adapters and Coanda curved deflection surfaces to determine the optimum set of adapter/deflector most conducive for jet bending and noise reduction. Dimensions for these parametric models were derived during the initial configuration sizing studies.

10.5 <u>One-Sixth-Scale Model Phase</u>:

10.5.1 The first five model tests were to establish the feasibility of using the Coanda flow turning and resulting noise refraction principles in a jet deflector/noise suppressor and to improve the system cooling and flow attachment.

10.5.2 The first model test was a parametric test with model variations such as transition ejector area ratio, exit aspect ratio, Coanda surface radius, and cooling slot size. The analytical study output was used to determine the ranges for these parameters to assure a span that encompassed the optimum value for each parameter. The results of this test were used to size models for subsequent tests.

10.5.3 The second, third, fourth and fifth series of tests were conducted on the experimental configurations which were iterations in design improvement between successive models in an attempt to streamline the internal model surfaces and eliminate "square" corners where gas flow stagnation zones may develop.

10.5.4 The second scale model incorporated staged ejectors as a means of improving Coanda surface temperatures. The effects of Coanda surface sidewall configuration was also studied.

10.5.5 The third model test configuration reduced the staged inlet ejectors from three to two while returning to a transition of the flow within the ejectors from round to rectangular at the Coanda entrance. The ejector area ratios were also reduced from that of the previous test. An enclosure with inlet panels was provided to determine the effect on flow attachment and system cooling.

10.5.6 The fourth model test configuation incorporated what was learned from the results of the previous tests relative to flow transitioning, system cooling, and flow attachment.

10.5.7 The fifth model test objective was to isolate and measure the individual system noise sources to determine the necessary acoustic treatment configuration. Four possible noise sources were:

a. Noise transmitted through the walls.

b. Noise emitting from the secondary air inlets.

c. Noise refracting out the exhaust opening from inside the enclosure.

d. The residual noise generated beyond the exit by the exit flow.

10.5.8 Based upon the results of all previous tests, the final model tests were conducted on a design which represented a progression of flow streamlining attempts relative to ejector and deflector geometry. The curved surface was a logarithmic spiral radius of curvature instead of a continuous radius. This final model design represented the acceptable geometry, which would be developed as the full-scale experimental model, and which had been successively "formed" to accommodate the J52, J57 A/B, J79 A/B, TF30, TF30 A/B and TF41 engines. All these engines exhaust parameters were simulated during each series of model tests to assure all engine compatibility.

10.6 Full-Scale Model Phase: A full-scale experimental model of a test cell exhaust suppressor system was developed based upon the successful test phases with the evolutionary one-sixth-scale model configurations. This model was fabricated, assembled and tested with a J-57 afterburning engine in an extensive evaluation test phase.

10.6.1 Aerodynamic, thermodynamic and acoustic operating characteristics for this model were based upon the most demanding exhaust flow parameters from the list of Navy engines; viz, the TF30-P-412 afterburning turbofan engine with 240 lbs/sec mass air flow and exhaust core temperature of 3100°F. Model physical dimensions were sized appropriately so that these criteria for internal surface cooling and low drag gas flow would be met with negligible effects on engine performance.

10.6.2 Acoustic performance goals for the experimental model design were:

Far Field: 90 dBA along a semi-circle of 250 feet radius from the engine centerline.

Near Field; 110 dBA along a rectangle of 20 feet distance from the engine centerline and the exhaust nozzle plane.

10.7 System Description;

10.7.1 The full-scale Coanda/Refraction exhaust noise suppression system, resulting from all the previously discussed analytic and experimental studies, was approximately 49 feet long, 23 feet wide, and 40 feet high to the top of the exhaust stack. Principal components of the suppressor system are the jet deflector system and the acoustical enclosure building.

10.7.2 Within the basic building, the jet deflector system consists of the three-stage ejector, Coanda surface, and support structure. This assembly is shown on Figure 2. All components were fabricated from A36 mild steel. The forward end of the Coanda surface is supported on the ejector stand. The Coanda surface and ejectors contain provisions for thermal growth. The Coanda surface is segmented in three sections for handling ease and supported by a tripod assembly.

10.7.3 The Coanda exhaust system full-scale test setup is shown on Figure 3. The configuration consists of the Coanda exhaust suppressor and J57-P-21 after= burning turbojet test engine.

10.7.4 The final assembly is shown in Figure 4. Since the forward portion of a test cell would normally have the engine enclosed and suppressed, an 18-foot acoustically treated barrier was erected to block engine case and inlet noise radiated into the far field. Air inlets are required to provide cooling air to the ejectors and Coanda surface to maintain temperatures below 1000 F.

10.7.5 The design of the enclosure walls, to prevent acoustic transmission at low frequency, was one of the most important technical challenges of the program. Using strictly mass to prevent low frequency acoustic transmission would make the modular construction required of a demountable unit somewhat untenable. One might use less mass by lining the interior of the enclosure with sound absorber to lower the interior acoustic levels. However, this would be very costly. The scale model results indicated interior lining was not required to meet far field noise goals if the acoustic energy transmission through the structure could be eliminated. The enclosure walls and ceiling design consist of a double-walled steel panel system weighing 20 pounds per square foot. The outer wall is constructed from one-quarter inch steel flat panels attached to 8-inch deep channel frames. The inner wall, constructed from one-quarter inch steel panels, is vibration isolated from the channel frames with neoprene isolators. Inner and outer panel sizes were chosen such that their resonant frequencies are less than 30 Hz. This ensures that the panel will be in the mass low frequency range at the lowest frequency of interest (63 Hz octave band). The 10-inch air gap is sealed. The combined double-wall structure with confined air gap exhibits transmission loss characteristics superior to an equivalent 20 lb/ft. single-wall structure.

10.8 Comparison of State-of-the-Art Equipment With Coanda/Refraction Type:

The subject advanced technology noise suppression equipment incorporates design features to enhance transportability/interchangeability, durability, and complete frequency spectrum noise attenuation characteristics. The impact of such equipment on engine test facility design and logistics support planning is as follows:

10.8.1 No cooling water requirements at test sites.

10.8.2 No need to support test facility with base water supply, especially at air stations in dry locations where water is a critical commodity.

10.8.3 A dry system will eliminate the visible plume and harmful fallout of "soggy soot" from proposed test cell exhaust stacks - this problem is prevalent in the vicinity of test facilities, where there are numerous complaints of damage to housing, ground support equipment and automobiles.

10.8.4 This concept is favorable for current, related efforts in test cell/system exhaust emissions pollution control programs, by inducing reduction of visible smoke. This requires further consideration.

PREPARED BY
SAE COMMITTEE EG-1
AEROSPACE PROPULSION SYSTEMS SUPPORT EQUIPMENT

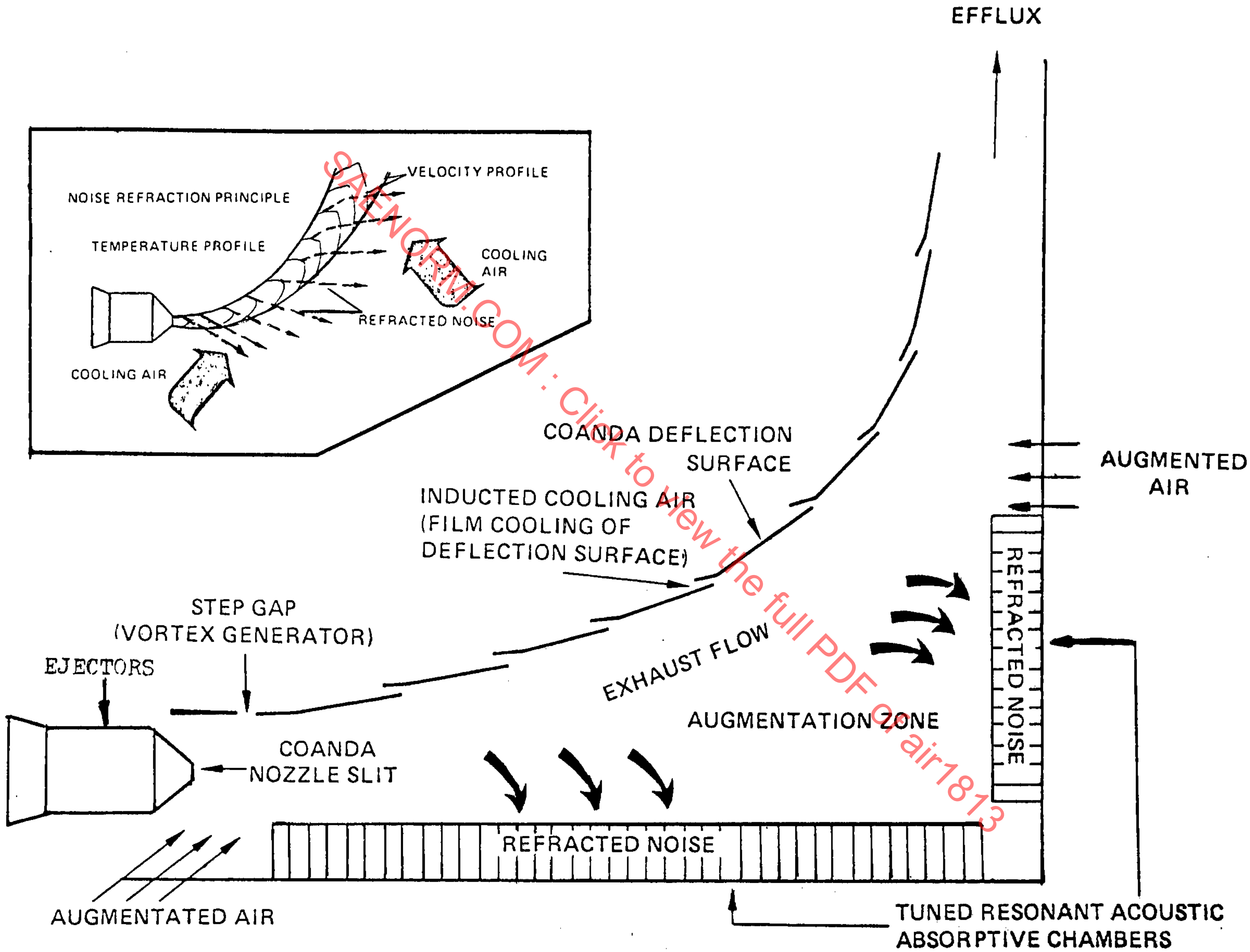

FIGURE 1. THE COANDA/REFRACTION NOISE SUPPRESSION CONCEPT

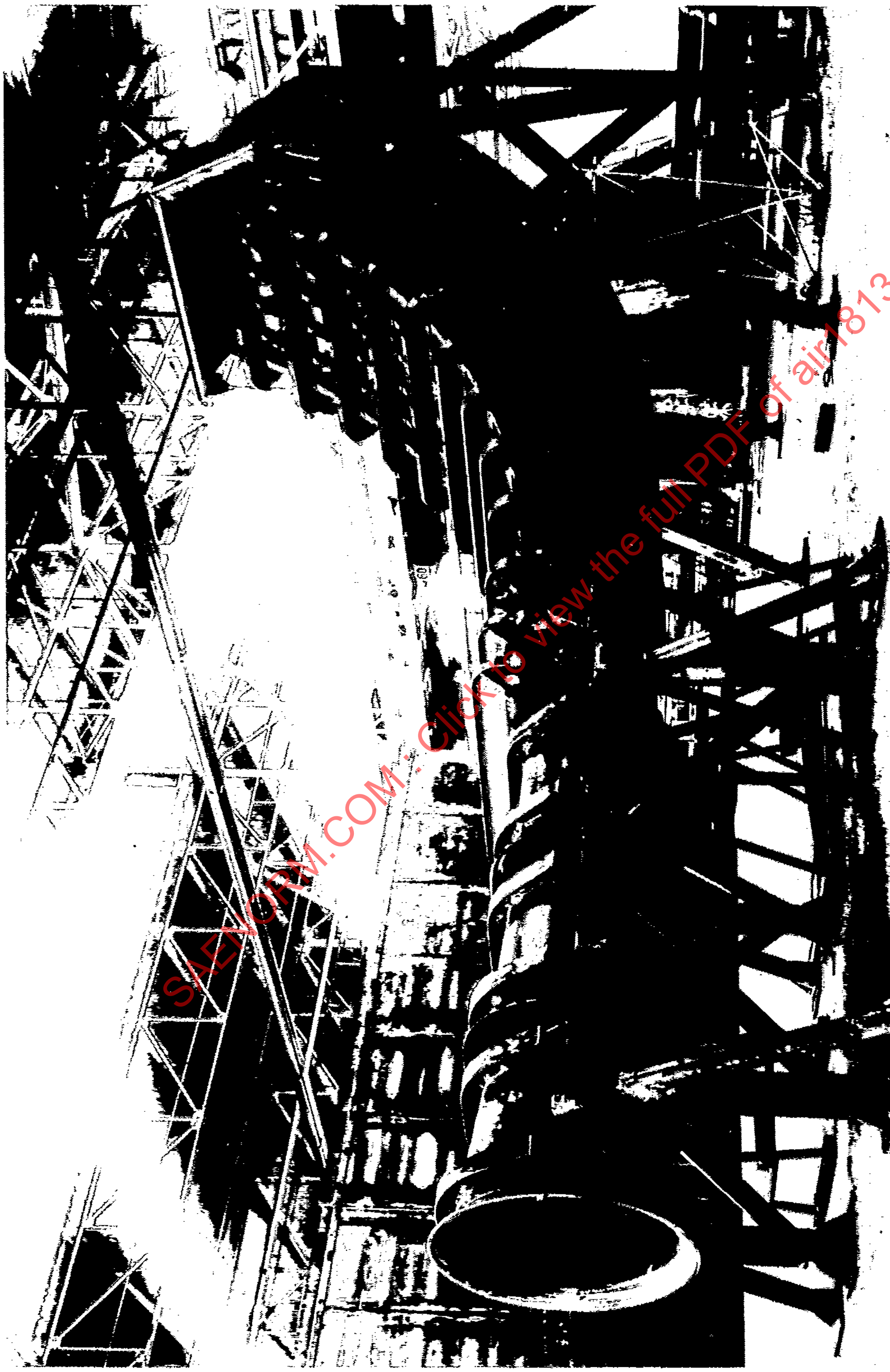

FIGURE 2

EJECTORS AND
COANDA DEFLECTION SURFACE

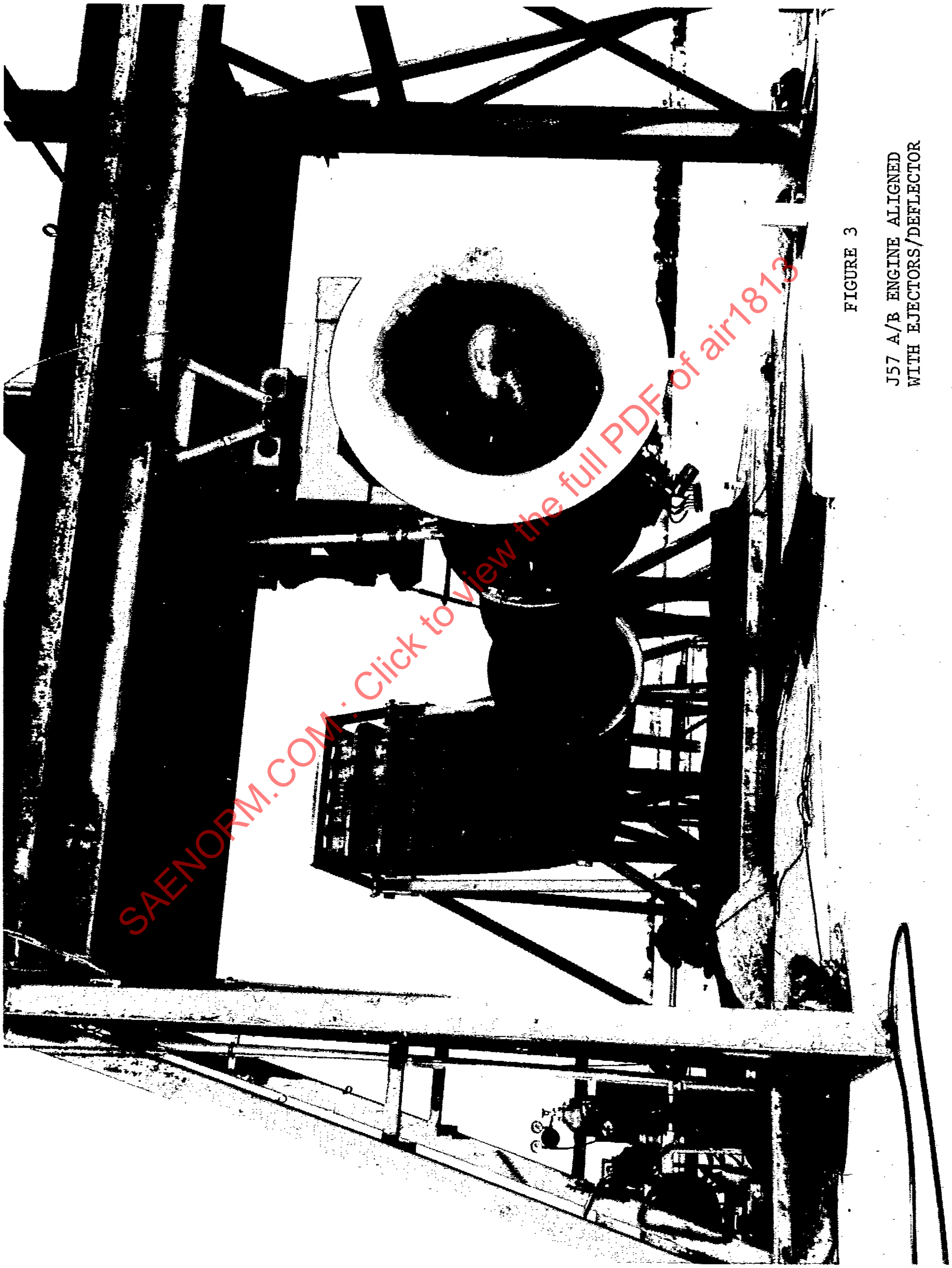

FIGURE 3
J57 A/B ENGINE ALIGNED
WITH EJECTORS/DEFLECTOR