11. FLIGHT-TEST NACELLES

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SUMMARY

The incorporation of acoustically treated inlet and fan exhaust ducts into present commercial transport aircraft powered by turbofan engines requires redesign of some of the engine nacelle components. During the design of flight-test nacelles intended to validate acoustical design criteria, emphasis has been placed on incorporation of the results of ground tests into the flight nacelle while achieving the most advantageous commonality with the standard short-duct DC-8 nacelle. In addition, the flight-test-nacelle design must provide accurate aerodynamic and acoustic simulations of the nacelle modifications required to retrofit acoustically treated ducting to existing DC-8 airplanes.

INTRODUCTION

On the basis of results of the ground-runup tests reported in reference 1, it was determined that the combination of the one-ring inlet and 48-inch-long fan exhaust ducts would constitute a suitable design for the flight-test phase of the program. This paper discusses the mechanical design of four acoustically treated flight-test nacelles to be installed on a series 55 DC-8 airplane. Particular emphasis is placed on the design requirement that accurate aerodynamic and acoustic simulations of a design suitable for retrofit to present short-duct (24 inches) nacelle DC-8 installations be provided.

DISCUSSION

Flight-Test-Nacelle Design

The inlet duct design incorporates approximately 64 square feet of acoustic treatment on the cowl inner surface, the center body, and both faces of a concentric ring vane located as shown in figures 1 and 2. The overall cowl length of 45 inches is unchanged from the untreated cowl presently in airline service.

The concentric ring vane is supported by four struts attached to the leading edge of the ring and four identical struts attached to the trailing edge, These struts are on the vertical and horizontal center lines of the inlet as shown in figures 2 and 3. The size and shape of the strut reflect the requirement for anti-icing ducting in each strut to provide adequate ice protection for the vane and struts. No operative inlet duct anti-icing system will be provided for the flight-test nacelles, but space has been made available to assure aerodynamic similarity to the retrofit design.

Because the possibility of increased engine fan-blade vibratory stresses exists with the introduction of the wakes from the ring and struts into the engine inlet, a ground-test evaluation of the fan-blade stresses will be conducted by the engine manufacturer prior to flight testing of the complete nacelle.

The inlet duct also incorporates a 4° downward rake (fig. 2) to correct for wing upwash, nacelle attitude, and angle of attack. This rake duplicates that of the existing inlet duct.

In the interest of simplicity, the flight-test nacelles do not incorporate a full complement of nacelle subsystems. The pneumatic-system heat exchanger is eliminated, and the air-cooled engine-oil heat exchanger is replaced by a fuel-cooled engine-oil heat exchanger. Past experience and recent analysis have shown that satisfactory flight-test performance may be achieved and that limited but satisfactory aircraft pneumatic services may be obtained by using only the low-pressure engine air-bleed system. However, replacement of the engine-oil heat exchanger may require limitation of generator loading or fuel temperature at take-off to preclude exceeding the manufacturer's engine-fuel temperature limits, The auxiliary air inlet, which normally provides ambient air for these heat exchangers, is retained to assure external aerodynamic similarity but is physically blocked to prevent airflow into the cowl. This condition satisfactorily simulates cruising flight during which little or no external airflow is ducted to these subsystems. The engine performance change resulting from the elimination of the high-pressure engine bleed flow will be analytically estimated.

Application of the acoustical design criteria (ref. 1) to the design of fan exhaust ducts results in ducts 48 inches in length to provide the approximately 70 square feet of acoustical lining. This lining is applied to the ducting interior walls and to both faces of the flow splitters as shown in figure 4. The longer ducts require modifications to the engine power controls, to both engine and nacelle pneumatic ducting, to hydraulic system piping, to the engine bleed ducting, and to the engine overboard drains. Two major nacelle items require redesign: the engine access doors and the fan air thrust reverser. The engine access doors are simulated by 0.125-inch-thick aluminum-alloy sheet with no provision made for quick access to the engine. Space considerations do not permit retention of the cascade-type reverser presently in service. Space provisions have been made for a target-type reverser, but the reverser itself is not provided.

The primary exhaust thrust reverser and its fairing, as well as the primary exhaust nozzle and its fairing, are unchanged. However, the primary exhaust thrust reverser will be made inoperative for the flight-test phase.

The acoustic treatment will consist of a sandwich construction composed of an impervious backing, a honeycomb core material, and a porous facing. The specific materials to be used are listed in table I. The sandwich construction is formed by mechanical bonding of the component parts with an epoxy-resin adhesive.

The addition of acoustically treated inlet and fan exhaust ducts will not increase either cockpit instrumentation or crew workload.

Retrofit-Nacelle Design

Although the design of a nacelle suitable for retrofit to existing short-duct nacelle DC-8 airplanes generally follows the design of the flight-test nacelle, a variety of refinements are necessary to assure the reliability and maintainability essential to commercial aircraft.

The retrofit-nacelle design will incorporate a 45-inch-long acoustically treated inlet duct having 64 square feet of acoustic treatment on the inner cowl wall, the center body, and both faces of a concentric ring vane. Inlet cowl subsystems will be similar to those of airplanes presently in service and will require modifications to assure noninterference with the acoustic treatment. However, the cowl ice-protection system will require extensive modification to provide ice protection for the ring vane and its supporting struts. This system will adhere to the design philosophy of the present cowl lip anti-icing system; that is, all anti-icing will be accomplished by engine bleed air, and ice buildup during worst-case icing conditions will not be permitted to exceed a triangular shape 0.152 inch high by 6 inches long. Sufficient heated air will be provided to the leading edge of the ring vane and struts to obviate the need for ice protection for the acoustic treatment itself. This anti-icing concept, illustrated schematically in figure 5, provides engine bleed air to the cowl lip and center body as in existing systems. Additional engine bleed air will be ducted into the leading edge of the ring vane through integral ducting in the two vertical struts, passing through one-half of the leading-edge circumference and exiting through the two horizontal struts to an overboard exhaust exit. This concept avoids mixing the anti-icing air with inlet airflow and, as a consequence, reduces the possibility of additional inlet performance degradation.

Although the maintainability of the nacelle subsystems will remain essentially unchanged, the addition of acoustically treated inlet and fan exhaust ducts will necessitate maintenance requirements in two areas - namely, access to the engine and maintenance of the acoustic treatment. Access to the engine fan blades for routine inspection and minor maintenance will be possible only by removal of 'the entire inlet cowl as a unit. However, access to the engine gearbox and accessories will be provided by an additional joint in the 48-inch-long fan air exhaust ducts. The forward section of the ducts will be removable in the same manner as the ducts presently in service, while the aft section will be hinged in a manner similar to the engine access doors. The acoustic treatment will require occasional cleaning to remove contaminants as well as repair when damaged by foreign objects ingested into the inlet.

The target-type fan air thrust reverser necessitated by space considerations consists of a hydraulically actuated single-panel deflector mounted on each side of the nacelle. Although the overall nacelle design benefits from the reduced weight of this type of reverser, a reduction in overall thrust-reverser effectiveness will be incurred. However, predicted overall effectiveness is comparable to that of the series 62 DC-8 airplane presently in airline service.

Although a broad variety of acoustic treatment materials are under investigation, the acoustic treatment will be of the general type used for the flight-test nacelles. For purposes of design analysis and cost, the materials of table I have been assumed, with the following exceptions:

Component	Impervious backing in –	
	Flight-test nacelle	Retrofit nacelle
Inlet center body	Fiber-glass laminate	Aluminum
Fan exhaust duct walls	Fiber-glass laminate	Titanium

The magnitude of the effort required to retrofit an acoustically treated nacelle to a JT3D-3B powered short-duct DC-8 airplane is briefly summarized in the following table:

Items changed:
- Air inlet and center body
- Fan exhaust ducts
- Fan air reverser
- Engine power controls
- Engine access doors
- Moderate revisions to engine piping and to hydraulic and pneumatic nacelle systems

Items unchanged:
- Engine mounts (fore and aft)
- Primary reverser and fairing
- Primary nozzle and fairing
- Pylon structure
- Pylon piping and electrical systems
- Pylon-nacelle interfaces
- Cockpit controls and instruments

CONCLUDING REMARKS

Although the nacelle modifications required to retrofit acoustically treated inlet and fan exhaust ducts to present DC-8 airplanes appear relatively extensive, the anticipated modifications do not introduce any insurmountable design or development problems. The simulation of the retrofit nacelles by simplified flight-test nacelles appears practical and promises to provide validation of the acoustic design during the flight-test phase in early 1969. These flight tests will provide final data on the acoustical and performance effects of the nacelle modifications developed in this study.

REFERENCE

1. Marsh, Alan H.; Zwieback, E. L.; and Thompson, J. D.: Ground-Runup Tests of Acoustically Treated Inlets and Fan Ducts. Conference on Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft, NASA SP-189, 1968. (Paper No. 10 herein.)

TABLE I.- ACOUSTIC-TREATMENT MATERIALS USED IN FLIGHT-TEST NACELLES

Component	Impervious backing	Honeycomb	Porous facing
Cowl	Aluminum	3/4-inch cell, 3/4-inch-deep HRP fiber glass	0.040-inch-thick 10-rayl fiber metal
Center body	Fiber-glass laminate	3/4-inch cell, 3/4-inch-deep HRP fiber glass	0.040-inch-thick 10-rayl fiber metal
Ring vane	Steel	3/4-inch cell, 1/2-inch-deep HRP fiber glass	0.040-inch-thick 10-rayl fiber metal
Inboard wall	Fiber-glass laminate	3/4-inch cell, 1/2-inch-deep HRP fiber glass	0.040-inch-thick 8-rayl fiber metal
Outboard wall	Fiber-glass laminate	3/4-inch cell, 3/4-inch-deep HRP fiber glass	0.040-inch-thick 8-rayl fiber metal
Splitters	Steel	3/4-inch cell, 1/2-inch-deep HRP fiber glass	0.040-inch-thick 8-rayl fiber metal

ACOUSTICALLY TREATED FLIGHT-TEST TURBOFAN NACELLE

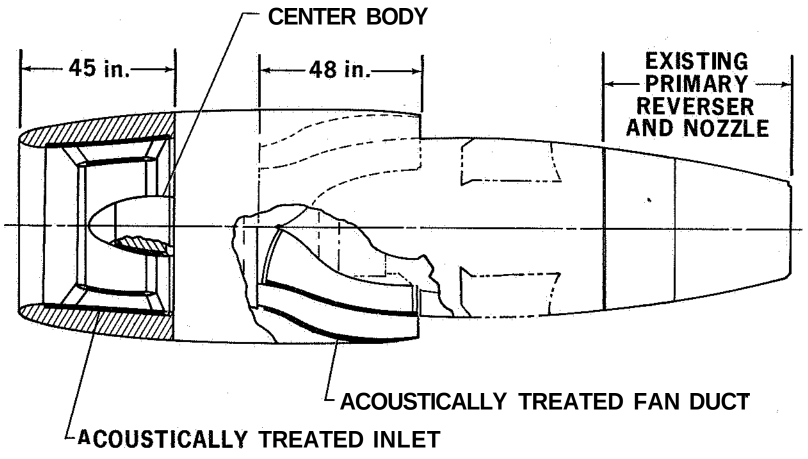

Figure 1

ONE-RING INLET

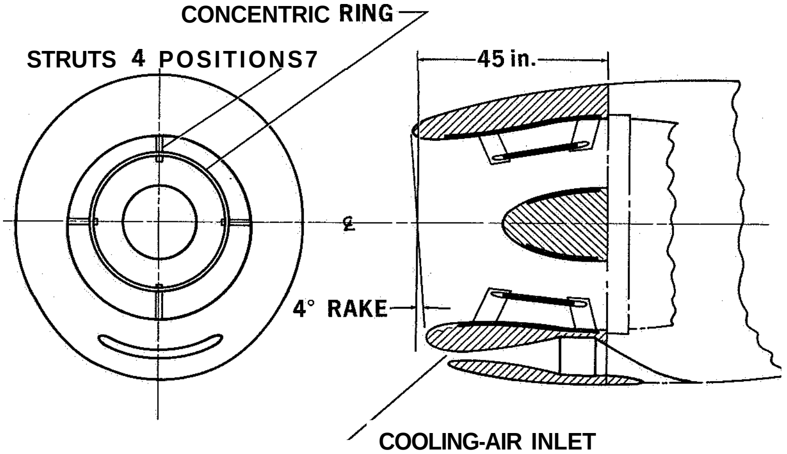

Figure 2

ACOUSTICALLY TREATED TURBOFAN ENGINE INLET

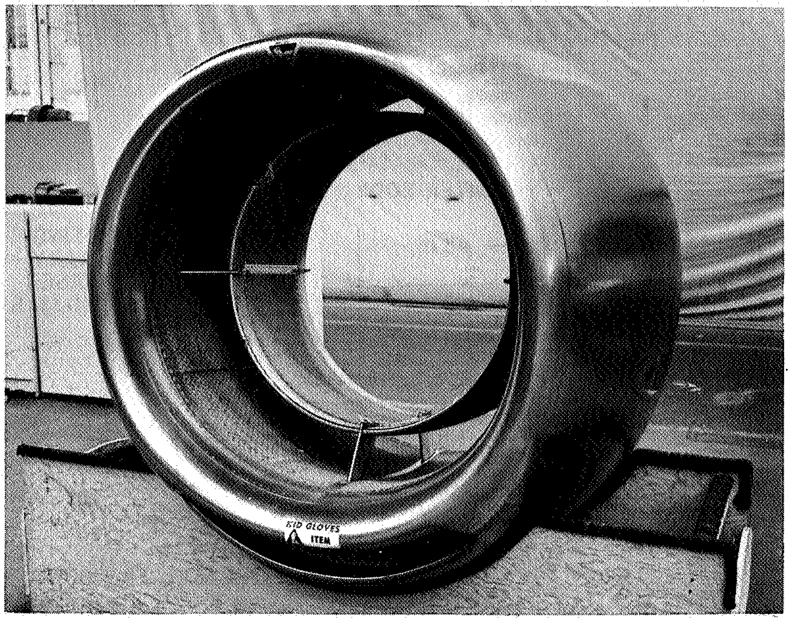

Figure **3** **L-68-8563**

FAN-DUCT INNER WALL AND FLOW SPLITTERS

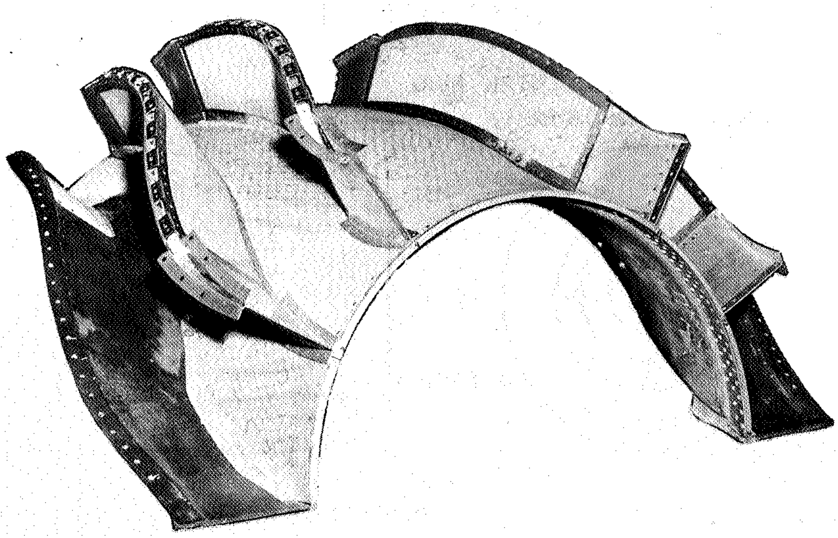

Figure **4** **L-68-8564**

INLET ICE-PROTECTION CONCEPT

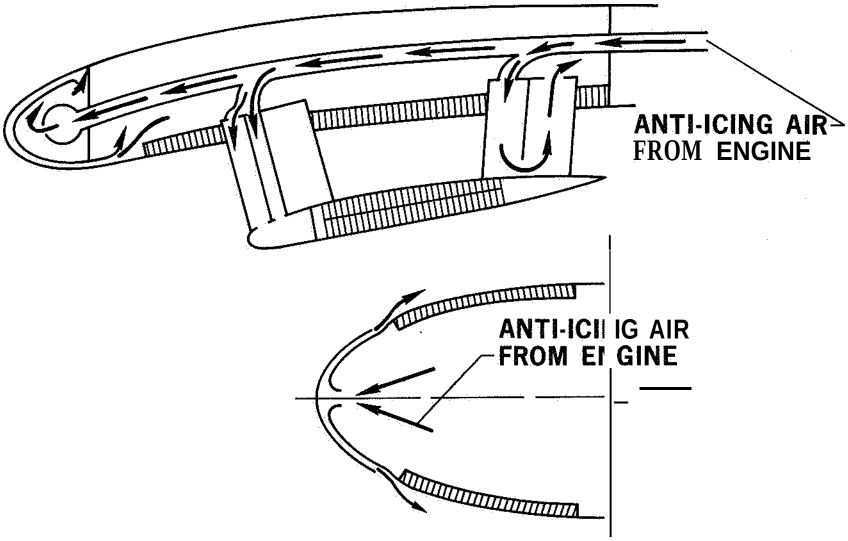

Figure 5