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APPLICATION OF GR/PMR-15 TO COMMERCIAL AIRCRAFT

PROPULSION INSTALLATION STRUCTURES

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Following from early experience with polyimides on the SST program and Shuttle aft flap studies The Boeing Company is now working on collaborative programs with its principal nacelle suppliers to pursue the development of Gr/PMR-15 nacelle components.

Two programs are currently in effect. The first program is directed specifically towards the flight test and service evaluation at the earliest possible date of a 747 nacelle core cowl structure. The second program seeks to firmly establish the producibility and cost of a 757 thrust reverser "C" duct in a production environment.

The near term objectives of these programs include (a) the comparison of estimated cost and weight of Gr/PMR-15 versus metal structure, (b) the engine test of representative composite structure, (c) the preliminary design and analysis of the "C" duct structure, and (d) the preparation of cost data and time schedules for the development and producibility program.

In addition to powerplant structure, the propulsion ducting system has shown to be a strong candidate for Gr/PMR-15 application. Currently, the Boeing 747 Organization is evaluating the use of PMR-15 matrix composites to replace nearly 800 lb of titanium ducting per airplane.

BACKGROUND

For some years The Boeing Company has recognized the significance of polyimide high temperative resins for use in commercial aircraft. Early stimulus for applications research was given by the SST program in the late 1960's. Problems with the condensation type resins available at that time prevented full adoption of the composite structure concepts.

The Boeing Commercial Airplane Company, building on the background gained from participation in the NASA composites for Advanced Space Transportation Systems (CASTS), by the Boeing Aerospace Company has extended PMR-15 technology to commercial airplane propulsion structures (fig. 1). In 1980, a program was initiated to identify Gr/PMR-15 characteristic behaviors, including degradation trends and failure modes due to long term exposure to temperatures up to 550 °F. The result of that program coupled with favorable weight trade data compiled for use of composites on the powerplant installation of the next Boeing aircraft encouraged the search for methods to acquire data on which to base product design. It was decided to seek out cooperative programs with principal nacelle suppliers to further the development of Gr/PMR-15 technology for commercial structures (figs. 2 and 3).

COOPERATIVE PROGRAM

The major program currently in work is the design, analysis, fabrication, and test of the Thrust Reverser Fixed Structure "C" duct of the 757 aircraft powerplant installation (fig. 4). This structure has similarities in function to the NASA QCSEE PMR-15 inner cowl, but is quite dissimilar in size and operational requirements (fig. 5).

The functional requirements of this structure include thermal management of the engine core compartment, acoustic attenuation of fan duct airflow noise, carriage of normal operational and emergency loads without excessive deflection at all operational conditions, prevention of fire propagation from the core compartment into the fan duct; and accommodation of incidental damage and thermal transients throughout the 50 000 cycle required lifetime without compromising the functional capability of the structure.

This cooperative program focuses the resources of each partner into three tasks: Design and Analysis, Testing, and Specifications and Manufacturing. Each of these tasks addresses major parts of the overall program.

The generalized schedule indicates the ambitious nature of this program, with the following major milestones.

Producibility Assessment	- 2nd Quarter 1983
Design Complete	- 1st Quarter 1984
Fabrication Complete	- 2nd Quarter 1984
Structural Testing	- 1st Quarter 1985

MAJOR CONCERNS

This program has proceeded well into the design and analysis, testing, and producibility phases and has exposed some major concern areas.

Included among these are:

(1) Long term thermal exposure durability requirements of the "C" duct. These appear to necessitate use of weavable PI sized fiber. However, the variable quality of currently available product is producing a downward bias in design data currently being generated.

(2) Current methods of obtaining high temperature design data provide results which are subject to excessive variability, and are obtained at high cost.

(3) Tooling techniques for building such a large, complex structure are presently unproven.

Efforts to alleviate these concerns are now underway among the participants in this program, with encouraging results being obtained.

TITANIUM DUCTING ALTERNATIVES

The 747 Engine Start and Thermal Anti-Icing Duct system has been identified as a very promising application for high temperature composites (fig. 6).

The current system, composed of titanium duct work, ranges from 2 to 7 in in diameter, and weighs upwards of 800 lb. Individual ductwork sections range from simple, 8 ft long pieces, to highly complex branded sections with varying diameters (figs. 7 and 8). All sections require end couplings and many sections have one or more bossed takeoffs (fig. 9).

The general design and objectives requirements of the composite system are as listed below.

- 50 psi maximum pressure
- 450° maximum temperature
- 50 ft/s maximum air flow
- 50 000 hr service life
- accommodate normal handling and service damage
- be repairable.

Due to the very long service life requirement in the 350 to 450 °F temperature range, PMR-15 matrix composites are considered to be prime candidates for this application. However, the considerations of material properties and manufacturing cost will provide a strong influence on the final choice of material.

At present, this project is in the early stages of feasibility assessment. One approach being considered is developing the manufacturing base concurrently with the investigation of the long term characteristics of the candidate materials operating in the duct system environment. Another important aspect of this application is that having demonstrated proper function, weight savings, and cost effective manufacture, composite ducting would be implemented immediately on new 747 aircraft, and on selected 747's on a refit basis. Similar applications exist on the 757 and 767 aircraft models as well.

CONCLUSION

In conclusion, Boeing Commercial Airplane Company is making considerable forward strides in the application of PMR-15 technology to commercial aircraft. This progress is a direct result of highly productive cooperative development programs with principal suppliers. With the current state of the commercial aircraft industry, the enthusiasm and commitment that these cooperative program members have shown must be applauded. Even as the program meets the challenges of developing a new material for propulsion systems, additional applications such as the 747 ducting have come forward, raising the possibility for further cooperative composite development programs.

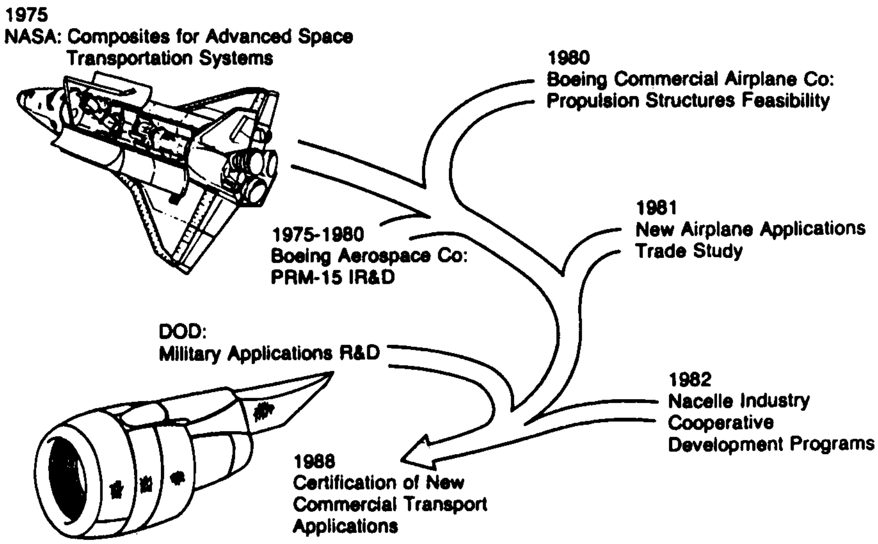

Figure 1. - Development of PMR-15 for commercial applications.

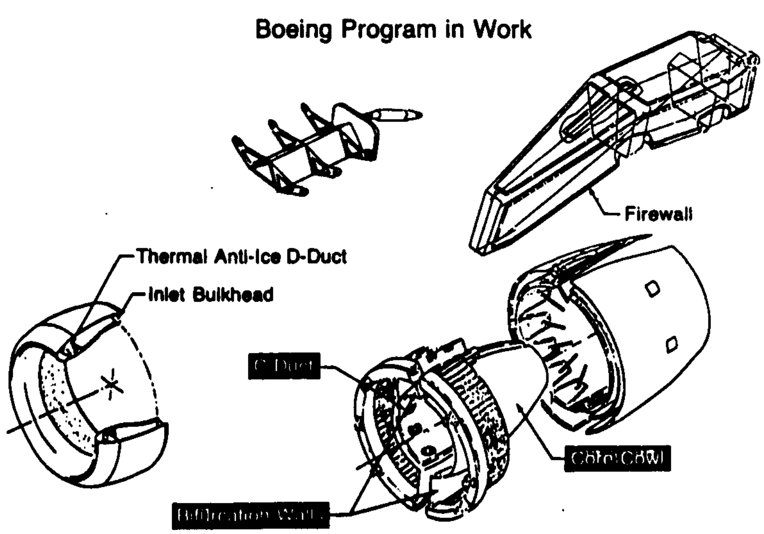

Figure 2. - PMR-15 candidate components.

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ITEM	WEIGHT (lb)
Inlet bulkhead	60
Thrust reverser fixed structure	250
Core cowl	50
Ducting	50
Firewalls	30
PMR-15 composites weight	440 lb/nacelle or 880 lb/airplane
Weight savings	220 lb/airplane

Figure 3. - Weight estimate - propulsion installation PMR-15 composite usage.

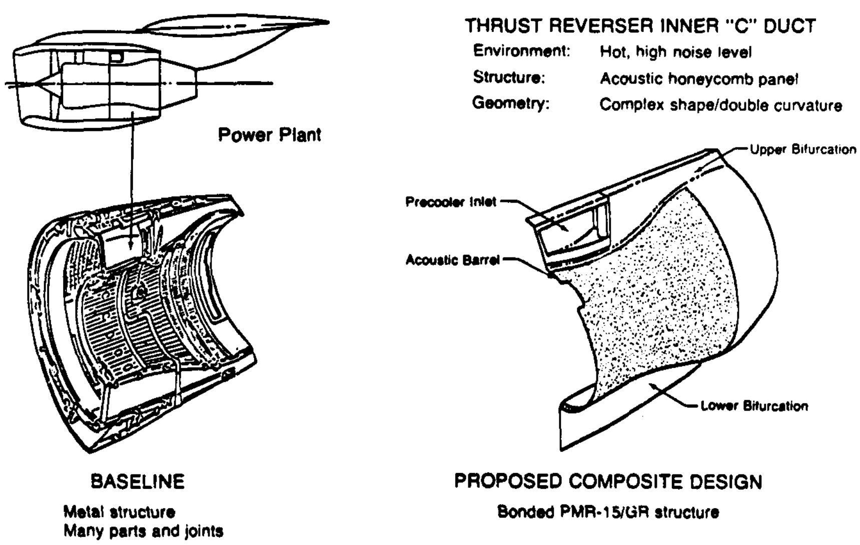


Figure 4. - Schematic of Thrust Reverser Fixed Structure "C" duct of 757 aircraft.

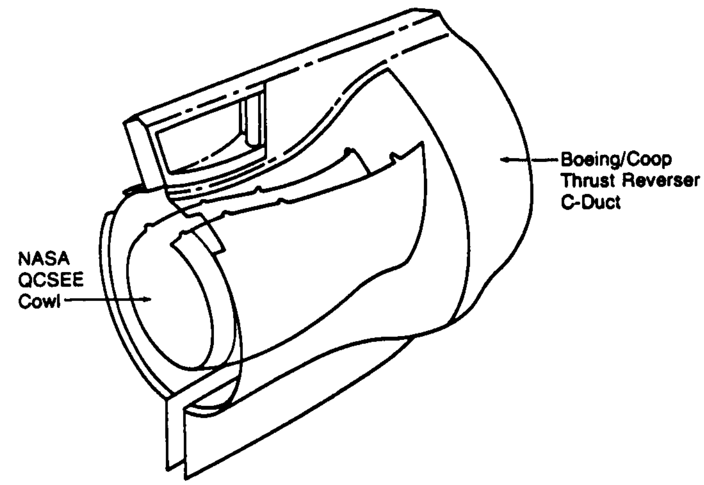
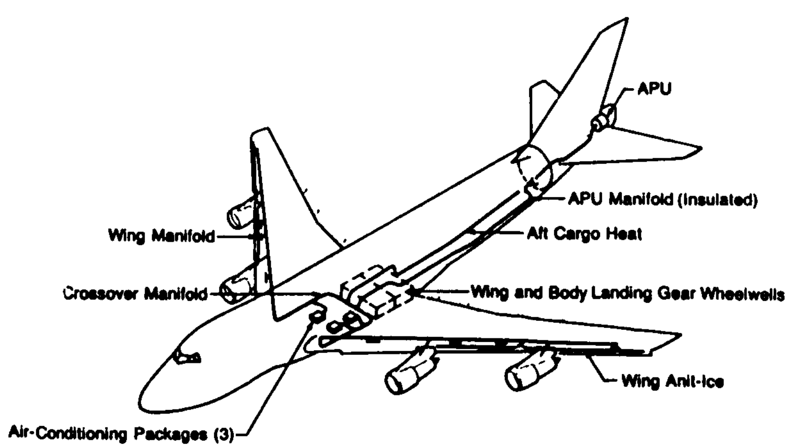


Figure 5. - Size comparison versus QCSEE inner duct.

747 Transport With Graphite/PMR-15 Ducting



- 500 lb PMR-15 Composite/Airplane
- 300 lb Saved/Airplane

Figure 6. - Potential near term applications of PMR-15.

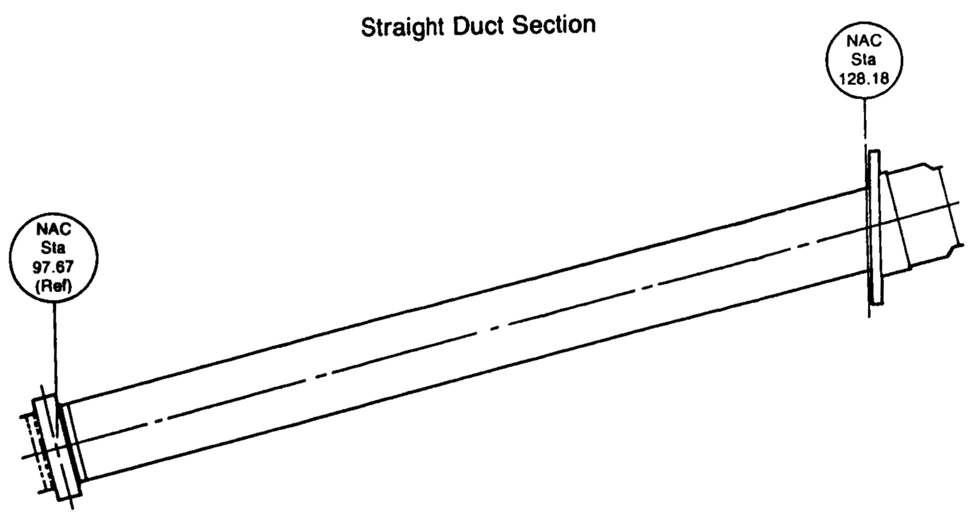


Figure 7. - 747 pneumatic duct.

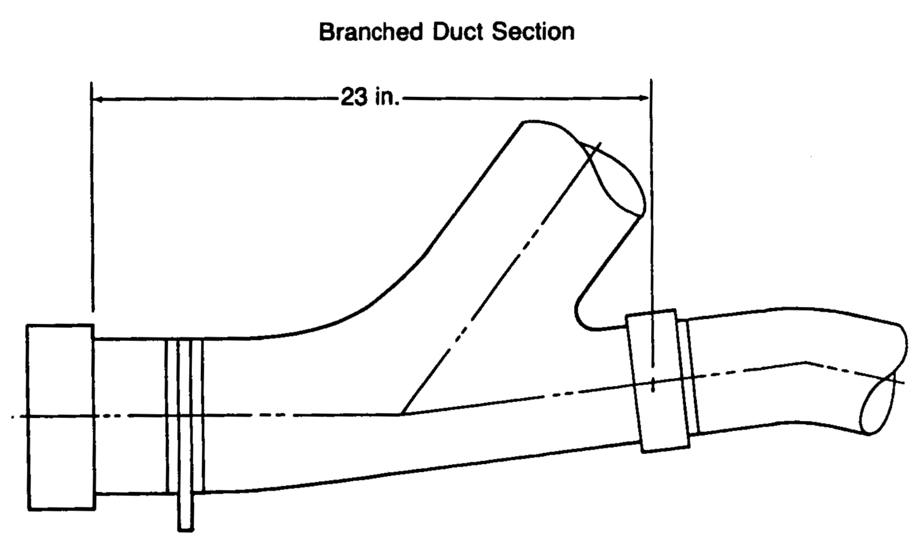


Figure 8. - 747 pneumatic duct.

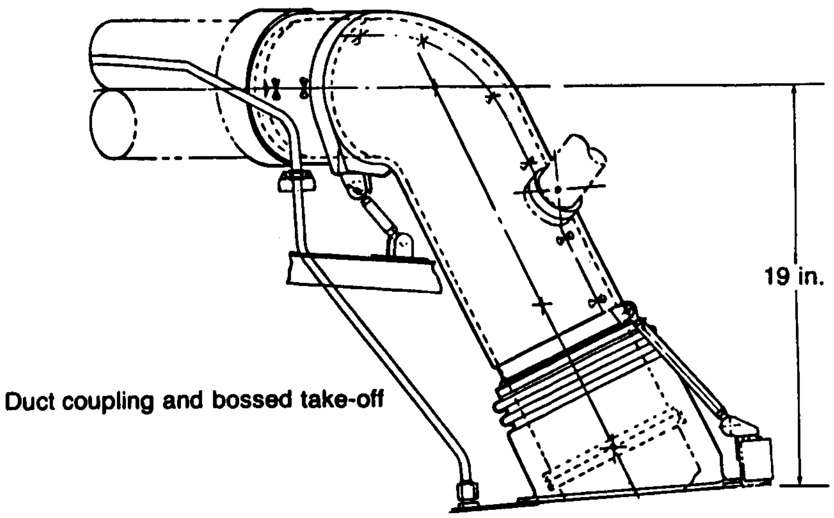


Figure 9. - 747 pneumatic duct.