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# OVERVIEW OF THE QCSEE PROGRAM

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## INTRODUCTION

The objective of the QCSEE (Quiet, Clean Short-Haul Experimental Engine) Program is to develop propulsion system technology for future powered-lift short-haul aircraft. As the title of the program indicates, one of the specific objectives of the program is to develop technology that will permit the development of lower noise propulsion systems. Low noise is particularly important for short-haul aircraft because, by their very nature, these aircraft will operate out of small airports where the close surrounding community can be more easily disturbed. A second specific objective is to develop technology which will allow the production of propulsion systems that produce very low exhaust emissions. Because of the prospect of stringent future government regulations in this regard, it is important to minimize the emissions of future propulsion systems. And, finally, the QCSEE Program has the objective of providing acceptable propulsion system performance. This is a difficult task because low noise requirements generally result in performance penalties. However, it is a very important objective because of the recent interest in energy conservation and the need to provide a propulsion approach that will result in an economically viable short-haul aircraft.

In this paper an overview of the QCSEE Program is presented. Included in the overview will be a description of the technical requirements and the design features and characteristics of the two engines in the program. Finally, the progress made to date in the program will be reviewed.

Inasmuch as this paper is an overview of the QCSEE Program, the information presented is limited. For further details on the acoustic design of the engines, the reader is referred to reference 1. Further information concerning other areas of the QCSEE design can be found in reference 2.

## POWERED-LIFT CONCEPTS

In the QCSEE Program propulsion technology applicable to two powered-lift concepts is being investigated. The externally blown flap is one concept being investigated (see fig. 1). The propulsion system for this concept is installed under the wing (UTW) in much the same manner as it is in many conventional aircraft. The second approach, commonly referred to as the upper surface blown flap powered-lift concept, is illustrated in figure 2. Here, the propulsion system is installed in an unconventional manner: the engines are mounted over

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the wing (OTW). These alternative approaches have their advantages and disadvantages. The UTW concept, being more conventional, is simpler from both an aerodynamic and mechanical installation standpoint. But the OTW powered-lift concept offers the advantage of lower aircraft noise: The wing surface shields ground observers from much of the noise emanating from the aft end of the engine and also the powered-lift generated noise.

## PROPULSION SYSTEM REQUIREMENTS

The general technical requirements established for the QCSEE engines are listed in table I. As shown, the noise limits set for the engines are quite low. In regard to exhaust pollutants, the engines are being designed to meet the proposed EPA 1979 emission standards that are intended to apply to conventional types of aircraft. This is because of the absence of any specific proposed standards for the short-haul, powered-lift type of aircraft. The thrust requirements are primarily a result of the desire to provide technology in the 88 960-N (20 000 lb) thrust class of engine and the use of the F101 engine core which generally has the capability for this thrust class.

Another challenging requirement of the QCSEE engines is the high installed thrust-to-weight ratios. One of the important aspects of the program is to reduce the installation thrust and weight penalties. To illustrate the improvement in thrust-to-weight ratio being sought, the thrust-to-weight ratio of the CF-6 engine used in the DC-10 is about 3.5. And finally, we have set relatively short dynamic response times for the QCSEE engines because short response time is required in short-haul, powered-lift propulsion systems.

## UTW PROPULSION SYSTEM

A cross section of the UTW propulsion system, which also identifies the advanced technology features incorporated, is shown in figure 3. (For further detailed engine design information consult ref. 2.) As mentioned earlier, the F-101 engine core is used. The F-101 engine is being developed by the General Electric Company for use in the Air Force B-1 bomber. The engine core will employ a modified, preflight rating test (PFRT) combustor. In order to meet the stringent pollution goals in the program, a double annular, dome combustor is being adapted to the F-101 combustor envelope. This adaptation will be evaluated in combustor rig tests. The double annular, dome combustor concept is one of the more successful types that are undergoing development in the NASA Clean Combustor Program (ref. 3).

One significant feature of the engine is the variable pitch fan, which is attractive for lower pressure ratio fans because it results in a lighter weight, thrust reversing system than that obtained with the conventional target type of thrust reverser. It also offers other advantages, such as increased thrust response and improved engine performance and reduced noise under some operating conditions. A significant number of components of the engine are built of lightweight composite materials. They include the fan frame, fan blades and the nacelle. The use of composite materials in these components is expected to reduce their weight by some 25 to 30 percent below that of conventional metal components. These lightweight composite materials are important factors in obtaining the high propulsion system thrust-to-weight ratios that are a goal of the QCSEE Program.

The engine also incorporates lightweight, speed reduction gears between the low pressure turbine and the fan. Because of the relatively low pressure ratio fan and corresponding low tip speed, the use of reduction gears reduces the overall weight of the engine by significantly reducing the size and weight of the turbine. A unique high Mach number inlet is used to suppress fan inlet noise. In addition, acoustic wall treatment, which employs a number of advanced suppression concepts, is located in the inlet, the aft fan duct walls and the core nozzle. The acoustic design of the engine is described in more detail in reference 1.

And finally, the engine is controlled by an engine-mounted digital electronic control. This advanced control technique is ideal for the complex control problem involved in the UTW engine. In all, four variable engine components must be controlled. They include the usual fuel valve and the variable compressor stators as well as the variable pitch fan and the variable area exhaust nozzle.

## OTW PROPULSION SYSTEM

A cross section of the OTW propulsion system is shown in figure 4. The significant differences between it and the UTW propulsion system are (1) a fixed-pitch higher pressure ratio fan, (2) a combined core and fan flow exhaust nozzle, and (3) a target-type thrust reverser. The target-type thrust reverser is used in this engine because the higher fan pressure ratio results in a lighter weight system and the OTW installation lends itself to the upward and forward discharge of the engine exhaust which is advantageous. The combined flow exhaust nozzle permits configuring for good powered lift in OTW installations. The digital control contains an advanced feature, which is referred to as the "failure indication and corrective action system", that allows the control to function in the event that one or more of the engine sensors fail. This feature will enhance digital control system reliability. The engine also uses the high Mach number inlet, reduction gears, and a composite material fan frame much the same as the UTW engine.

## ENGINE CHARACTERISTICS

Table II shows some UTW and OTW engine characteristics at takeoff. As can be seen, both engines have high bypass ratios. These bypass ratios are about twice that of current modern engines. The high bypass ratio is a consequence of the low fan pressure ratios. Low fan pressure ratios are necessary to reduce the combined noise of the engine and that generated by the powered lift. The moderately higher fan pressure ratio of the OTW engine is a result of the noise shielding benefits of the OTW type of installation. Higher fan pressure ratios result in increased performance and accordingly decreased fuel consumption in a flight application. Higher overall pressure ratios can be obtained by the addition of booster stages and their incorporation would also improve performance. Doing this is not a technically difficult task; however, it is expensive and, accordingly, it was not attempted in the QCSEE Program.

## PROGRAM SCHEDULE

A schedule of program milestones is shown in figure 5. The major part of the program is being done by private companies under contract to the NASA Lewis Research Center. The prime contractor, the General Electric Co., is designing, fabricating, and testing two QCSEE engines. As indicated in figure 5, the design work is complete, the UTW engine assembly is nearing completion, and the assembly of the OTW engine has begun. The first of the UTW engine tests will begin in June. The program is about a month behind schedule. Following testing of both engines, they will be delivered to Lewis near the end of 1977. NASA tests will include acoustic evaluation of the engines with wing and flap sections installed to simulate the powered-lift condition, and additional evaluation of the control system and the engine altitude performance.

A photograph of the composite fan frame prior to assembly into the engine is shown in figure 6. The frame is 1.98 m (78 in.) high and weighs about 217.5 kg (480 lb). In the photo the fan outlet guide vanes (viewing upstream) can be seen along with the core flow passage towards the center of the frame. The frame is constructed primarily of graphite fibers in an epoxy resin matrix.

## APPLICATION OF ADVANCED TECHNOLOGY

The QCSEE Program is investigating a broad range of advanced propulsion technologies. Although the main thrust of the program is directed toward powered-lift aircraft applications, many of the technology elements can be applied to other types of airplanes. (See table III.) Thus the technology developed in the program is expected to have the potential for wide application to future propulsion systems.

## CONCLUSIONS

The QCSEE Program has progressed through the design phase and is well into the fabrication phase of the two engines in the program. In the near future the first engine will be tested. A wide range of advanced propulsion system technologies are being investigated. These new technologies can be grouped into the areas of noise, emissions, and performance. Although the program is directed toward providing propulsion technology for powered-lift, short-haul aircraft, many of the technology elements in the program can be applied to other types of aircraft.

## REFERENCES


1. Loeffler, Irvin J.; Smith, Edward B.; and Sowers, Harry D.: Acoustic Design of the QCSEE Propulsion Systems. Powered-Lift Aerodynamics and Acoustics, NASA SP-406, 1976. (Paper no. 21 of this compilation.)
2. Quiet Clean Short-Haul Experimental Engine (QCSEE). Preliminary Analyses and Design Report. Volumes I and II. (R74AEG479, General Electric Co.; NAS 3-18021.) NASA CR-134838 and NASA CR-134839, 1974. (FEDD distribution.)
3. Bahr, D. W.; and Gleason, C. C.: Experimental Clean Combustor Program. Phase 1. (GE-74AEG380, General Electric Co.; NAS 3-16830.) NASA CR-134737, 1975.


TABLE I. - QCSEE REQUIREMENTS

| | | |
|---|---|---|
| NOISE at 152.4-m (500-ft) sideline and 400 300 N (90 000 lb) thrust | | |
| Takeoff and approach - EPNdB | 95 | |
| Reverse thrust - PNdB | 100 | |
| Pollution | EPA 1979 emission levels | |
| Thrust, N(lb) | | |
| Forward - | Uninstalled | Installed |
| UTW | 81 400 (18 300) | 77 400 (17 400) |
| OTW | 93 400 (21 000) | 90 300 (20 300) |
| Reverse | 35% of forward thrust | |
| Thrust-to-weight ratio: | | |
| UTW | 6.2 | 4.3 |
| OTW | 7.4 | 4.7 |
| Dynamic response: | | |
| Approach to takeoff thrust, sec | 1.0 | |
| Reverse thrust, sec | 1.5 | |

TABLE II. - TAKEOFF ENGINE CHARACTERISTICS

| | UTW | OTW |
|---|---|---|
| Bypass ratio | 12.1 | 10.1 |
| Fan pressure ratio | 1.27 | 1.34 |
| Fan tip speed, m/sec (ft/sec) | 289 (950) | 354 (1162) |
| Overall pressure ratio | 14.3 | 17.3 |
| Thrust, N (lb) | 77 400 (17 400) | 90 300 (20 300) |

TABLE III. - APPLICATION OF QCSEE ADVANCED TECHNOLOGY

| Technology area | Type of aircraft | | |
|---|---|---|---|
| | Powered-lift short haul | Conventional short haul | Long haul |
| Powered-lift aerodynamics and acoustics | ✓ | | |
| High bypass ratio | ✓ | ✓ | |
| Variable pitch fan | ✓ | ✓ | |
| Reduction gears | ✓ | ✓ | ✓ |
| Noise reduction | ✓ | ✓ | ✓ |
| Emissions reduction | ✓ | ✓ | ✓ |
| Variable fan nozzle area | ✓ | ✓ | ✓ |
| Composite material frame | ✓ | ✓ | ✓ |
| Composite material blades | ✓ | ✓ | ✓ |
| Composite material nacelle | ✓ | ✓ | ✓ |
| Digital electronic controls | ✓ | ✓ | ✓ |

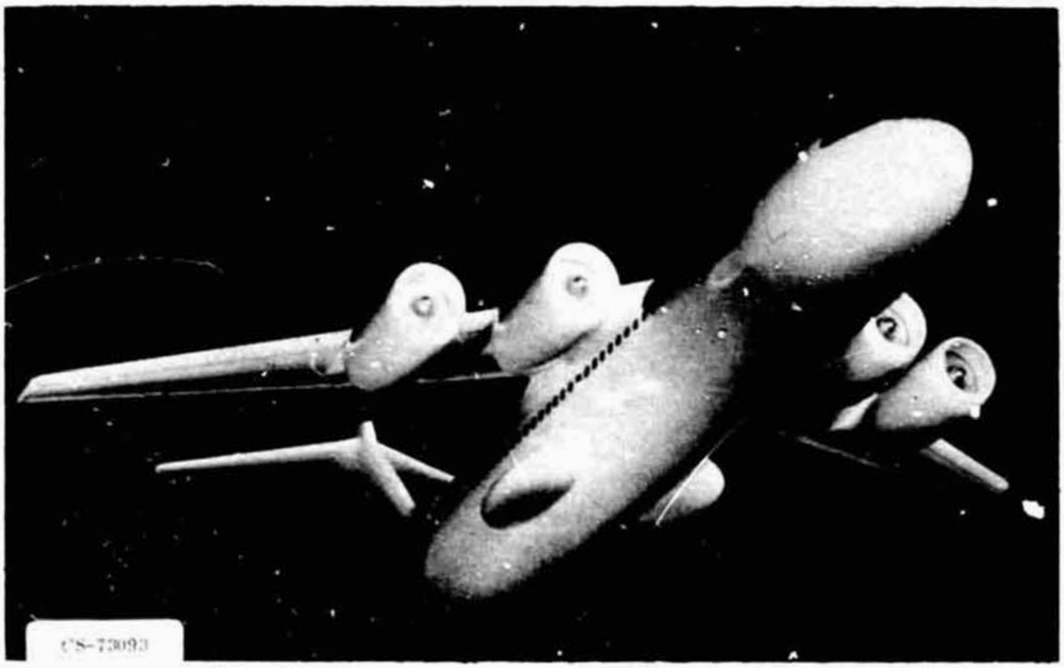

Figure 1.- Conceptual UTW short-haul aircraft.

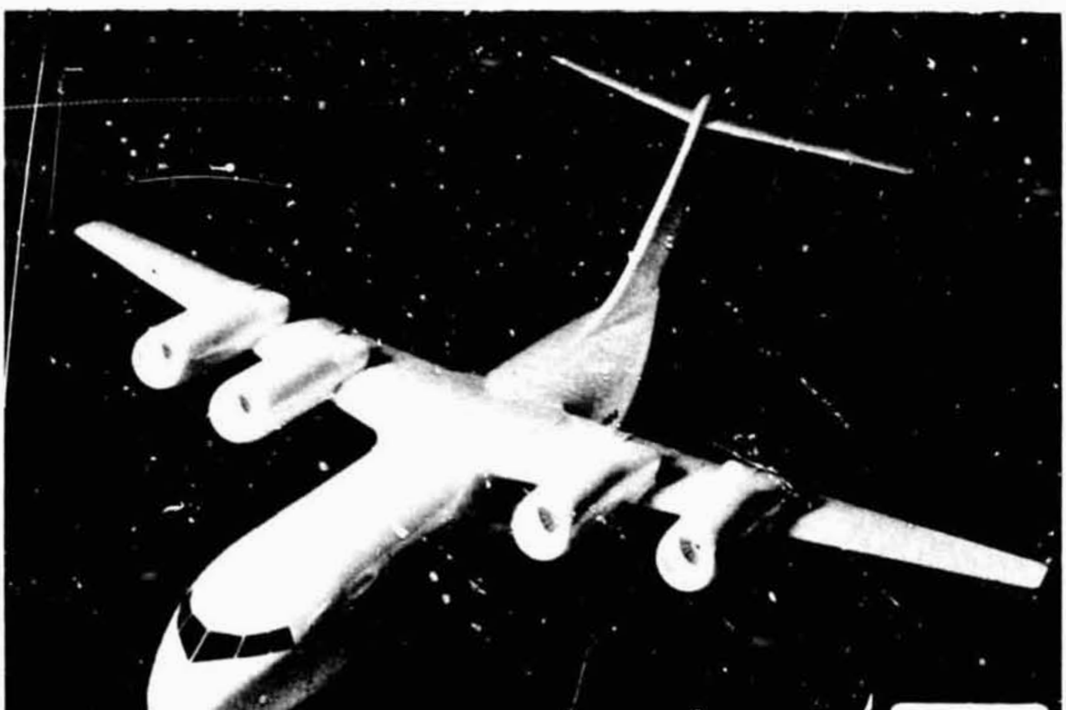

Figure 2.- Conceptual OTW short-haul aircraft.

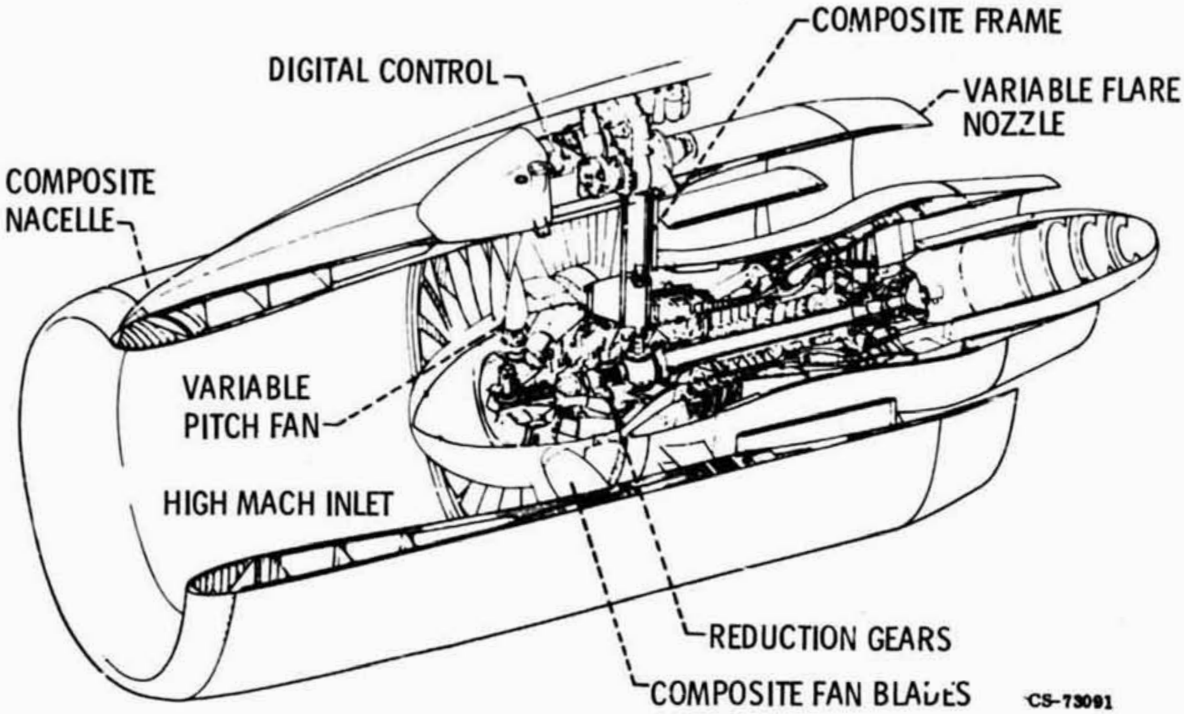


Figure 3.- QCSEE UTW engine.

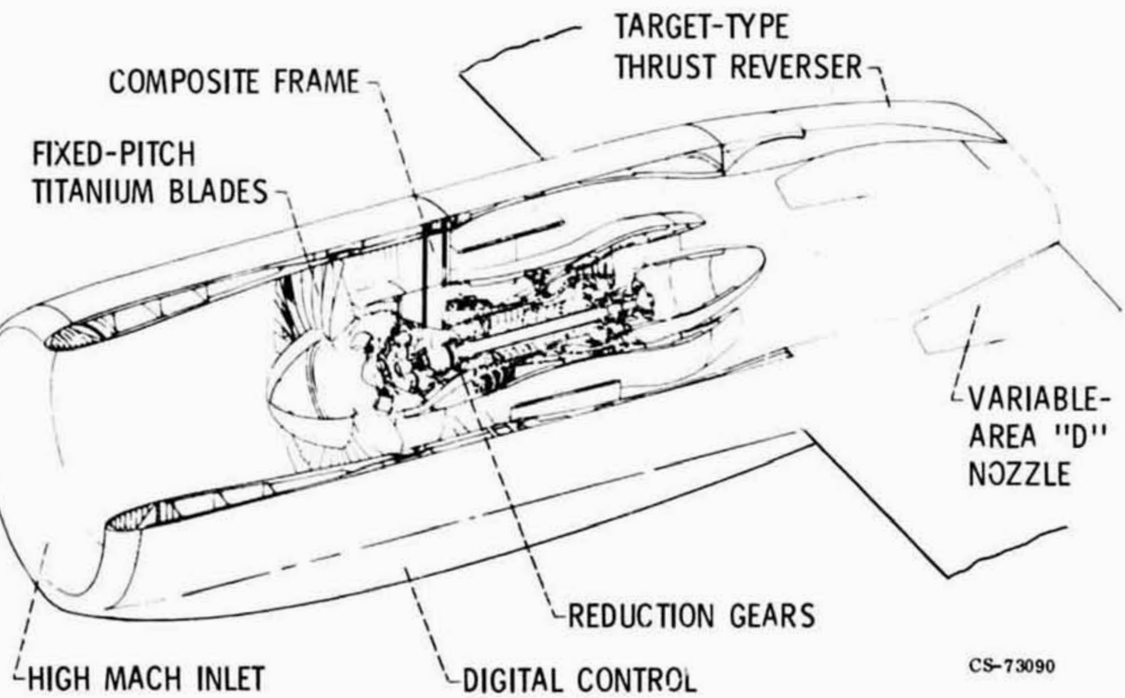


Figure 4.- QCSEE OTW engine.

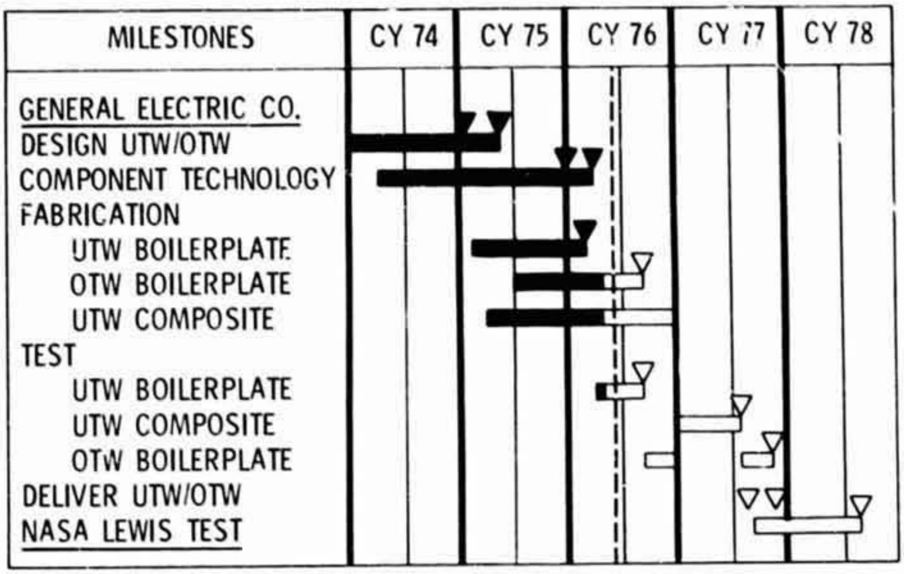


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Figure 5.- QCSEE Program schedule.

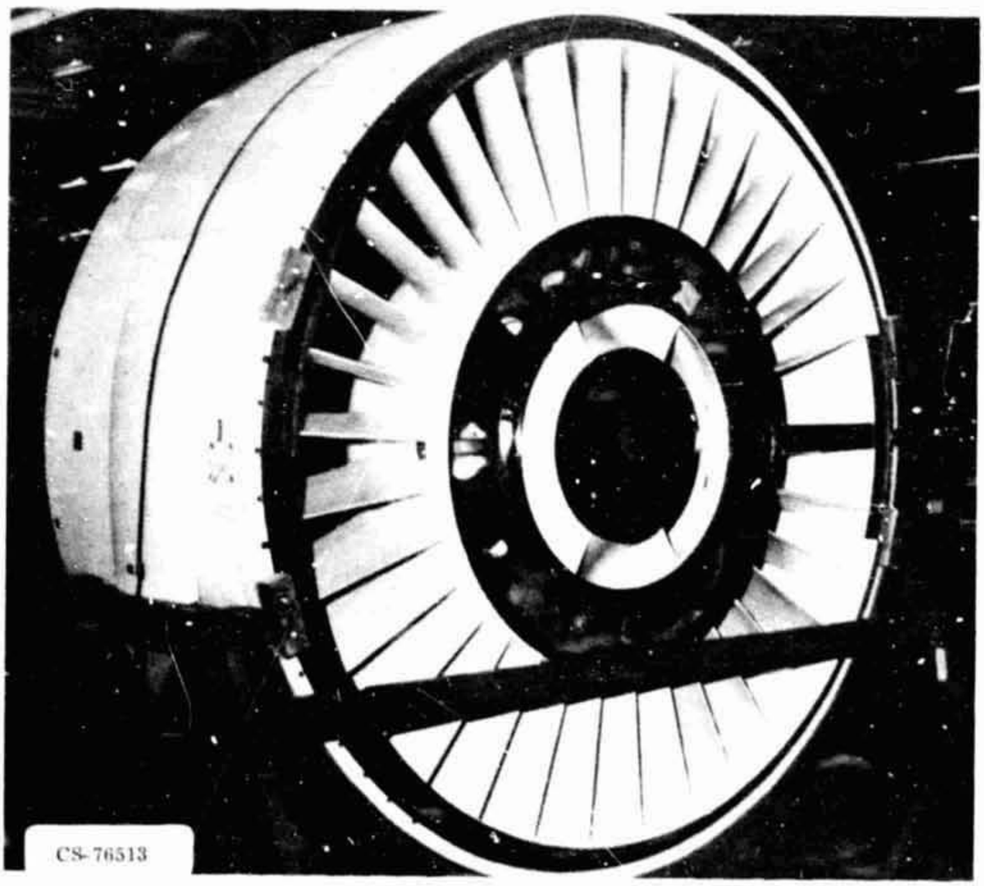


Figure 6.- Composite material fan frame.