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VOLUME I E
SUMMARY (U)
Phase II-A Data Submission

Prepared for
Office of Deputy Administrator for Supersonic Transport Development
Federal Aviation Agency
Washington, D. C.

November 1, 1964

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SUMMARY FOR SST - PHASE II-A

1. INTRODUCTION

The objective of the Phase II-A program was to arrive at an airplane-engine combination which could meet the overall performance and economic requirements of the SST. Pratt & Whitney Aircraft's efforts in Phase II-A were concentrated in two areas: (1) design and performance studies conducted in close cooperation with Boeing and Lockheed to determine the optimum powerplant cycle and design. (2) a comprehensive component test and analysis program aimed at verification of component design and performance. These efforts have resulted in a new turbofan design incorporating more advanced state of the art components and having a development objective of considerably higher turbine inlet temperatures than our Phase I powerplants.

The Phase II-A effort at Pratt & Whitney Aircraft was planned to utilize maximum latitude in ingenuity and explored many promising alternatives. A major portion of the design study effort consisted of a re-examination in greater depth of all engine cycles that appeared attractive for a supersonic transport cruising in the range of Mach 2.7 to 3.0. The results of this study have indicated that one cycle, the duct heating turbofan, and an airflow size of approximately 640 to 700 lbs/sec can best meet the overall requirements of the SST in the Phase II-A aircraft designs.

A comprehensive component verification program was also conducted. The programs contributed to the technology base from which the advanced components of the Phase II-A engines were designed. Investigations of fuel and oil requirements were conducted and preliminary specifications have been prepared. A study of the economic factors associated with the operation of the supersonic transport was conducted utilizing the Phase II-A powerplant design.

2. PHASE II-A ENGINE DESIGN

2.1 Cycle Selection

An objective assessment was made of three different turbojet cycles and two different turbofan cycles.[1] Every effort was made to incorporate the same advanced levels of technology in all of the various engine components to ensure that the comparisons would indicate the cycle best suited to meeting the performance and economic objectives of the SST. All engines in this study, although they involve development risk in different areas and in different degrees, were judged to be available in the same time period. The study results were provided the airframe contractors for use in studying each cycle in an optimized engine-airframe combination to form a basis for their cycle selection. After an extended period of mission studies, utilizing all of the turbojet and turbofan engines supplied by Pratt & Whitney Aircraft, both Boeing and Lockheed selected the STF219 duct heating turbofan as optimum for their Phase II-A designs. The optimization considered the airplane-engine combinations with respect to the parameters of range-payload, flight speed, take-off and landing conditions, sonic boom overpressures, noise levels, and overall utility and flexibility. In Lockheed's studies, the duct heating turbofan was clearly superior to the other fan and jet cycles. Boeing also selected the duct heating turbofan for Phase II-A, although the superiority of this cycle was not as clear-cut. The final effort in Phase II-A consisted of detailed work to optimize the engine selected by the aircraft contractors to the requirements of each installation. Intensified effort was expended in coordinating the areas of inlet compatibility, exhaust system optimization (including secondary ejector airflow), mount design, fuel and lubrication system interfaces, accessory drive and airbleed requirements. As a result, preliminary Engine and Performance Specifications and Installation Drawings of the selected powerplants are provided that are compatible with each airframe contractors Phase II-A design.

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[1] The engines included: a turbofan with duct heater augmentation (STF219), a turbofan with common afterburner augmentation (STF223), a turbojet without augmentation (STJ221), a turbojet with full afterburning augmentation (STJ222) and a turbojet with low augmentation afterburner (STJ227).

2.2 Engine Description

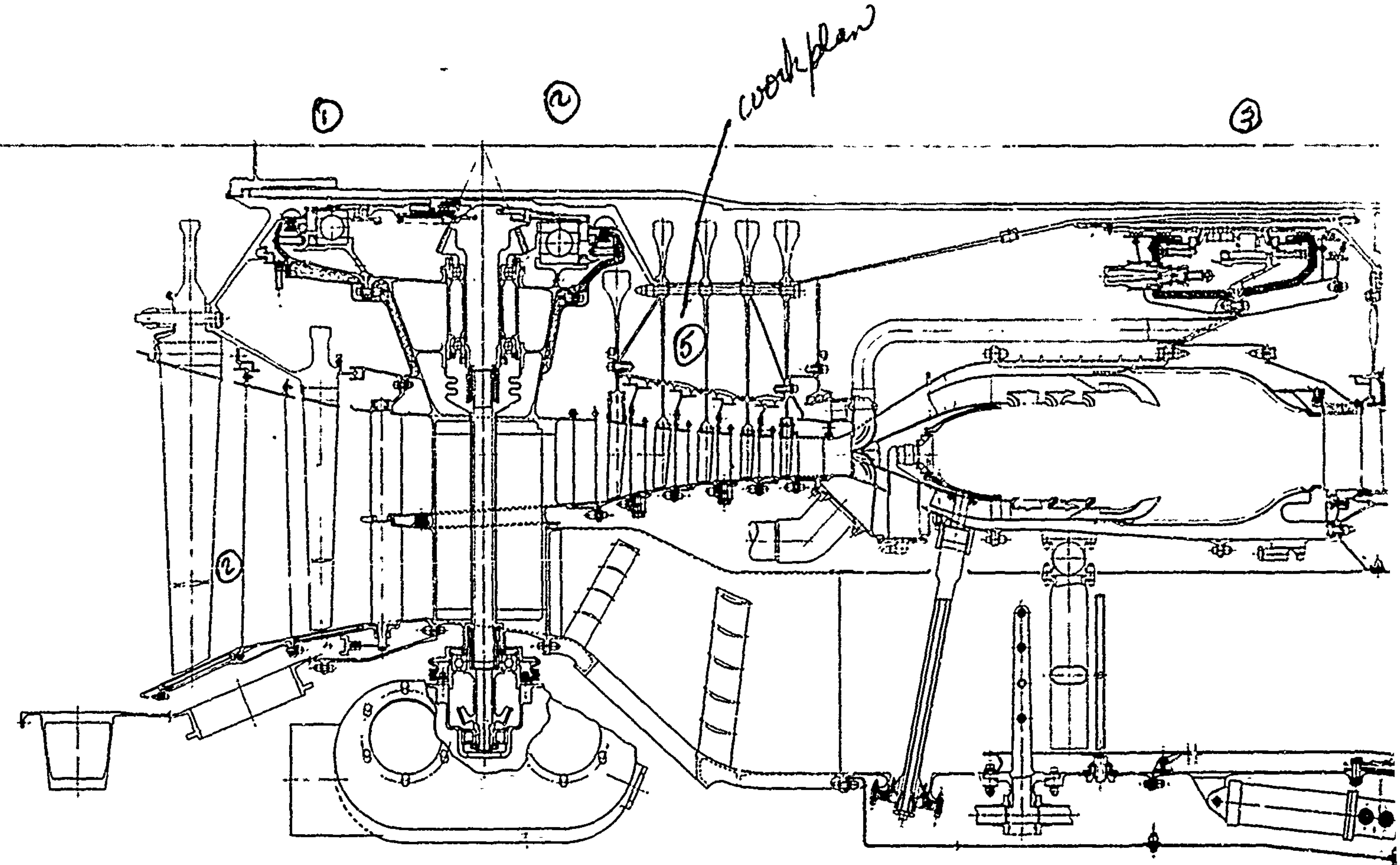
The STF219 engine is a twin spool duct-heating turbofan powerplant. The low pressure rotor consists of two fan stages driven by a two stage turbine. The high pressure rotor consists of a five stage compressor driven by a single stage turbine. Each rotor is supported on two bearings. A full-annular primary burner incorporating advanced features to provide high heat release rate and uniform temperature distribution is utilized. The duct heater incorporates a low-loss aerodynamic type flameholder to provide high efficiency at both maximum and partial augmentation conditions. A blow-in-door ejector is included as standard equipment and is engine mounted behind a variable-area duct-heater nozzle. A reverser is incorporated as an integral part of the ejector assembly.

Cross-sectional drawings of the engine as optimized for Boeing (STF219-B) and Lockheed (STF219-L) during Phase II-A are shown in Figures 1 and 2.

The STF219 engine differs from the JT11F-12 proposed in Phase I primarily in that it is a twin spool instead of a single spool configuration and because its turbine design is targeted at achieving 2200°F cruise temperature, and therefore incorporates more advanced cooling techniques. The dual rotor design permits use of a higher bypass ratio and higher compression ratio without the added complexity of variable compressor geometry. This optimization permits higher compressor and turbine efficiencies and better component match than is obtained with single rotor designs.

Starter torque requirements are greatly reduced. The high performance duct heater augmentation system is retained in our Phase II-A design, and the low-loss characteristics of the aerodynamic flameholder as well as the predicted high level of efficiency have been verified by the Phase II-A program. A variable-area nozzle in the fan duct heater exit provides engine air flow scheduling under augmented and non-augmented conditions. The excellent subsonic, transonic and supersonic performance characteristics of the blow-in-door ejector nozzle assures optimum performance throughout the flight range while acting as an exhaust noise suppressor. A reverser is provided which stows conveniently in the ejector when not in use.

The design characteristics of the STF219-B (Boeing) and STF219-L (Lockheed) engines are tabulated in Table I and Table II, respectively. The basic engine performance is given at 2200°F cruise turbine inlet



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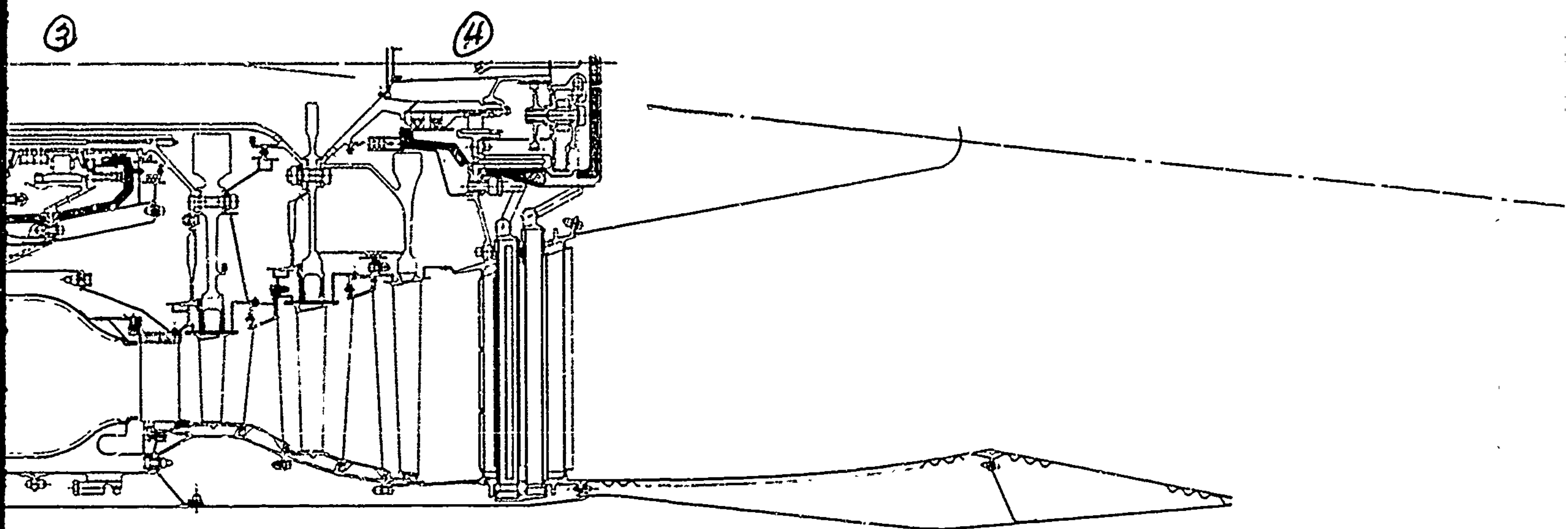
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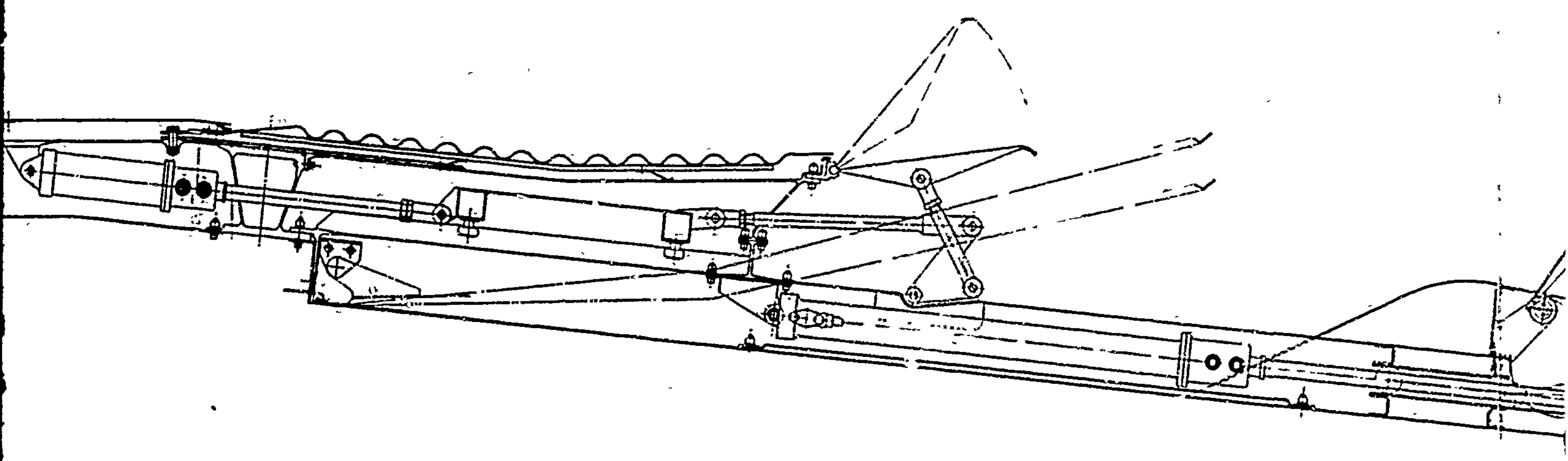

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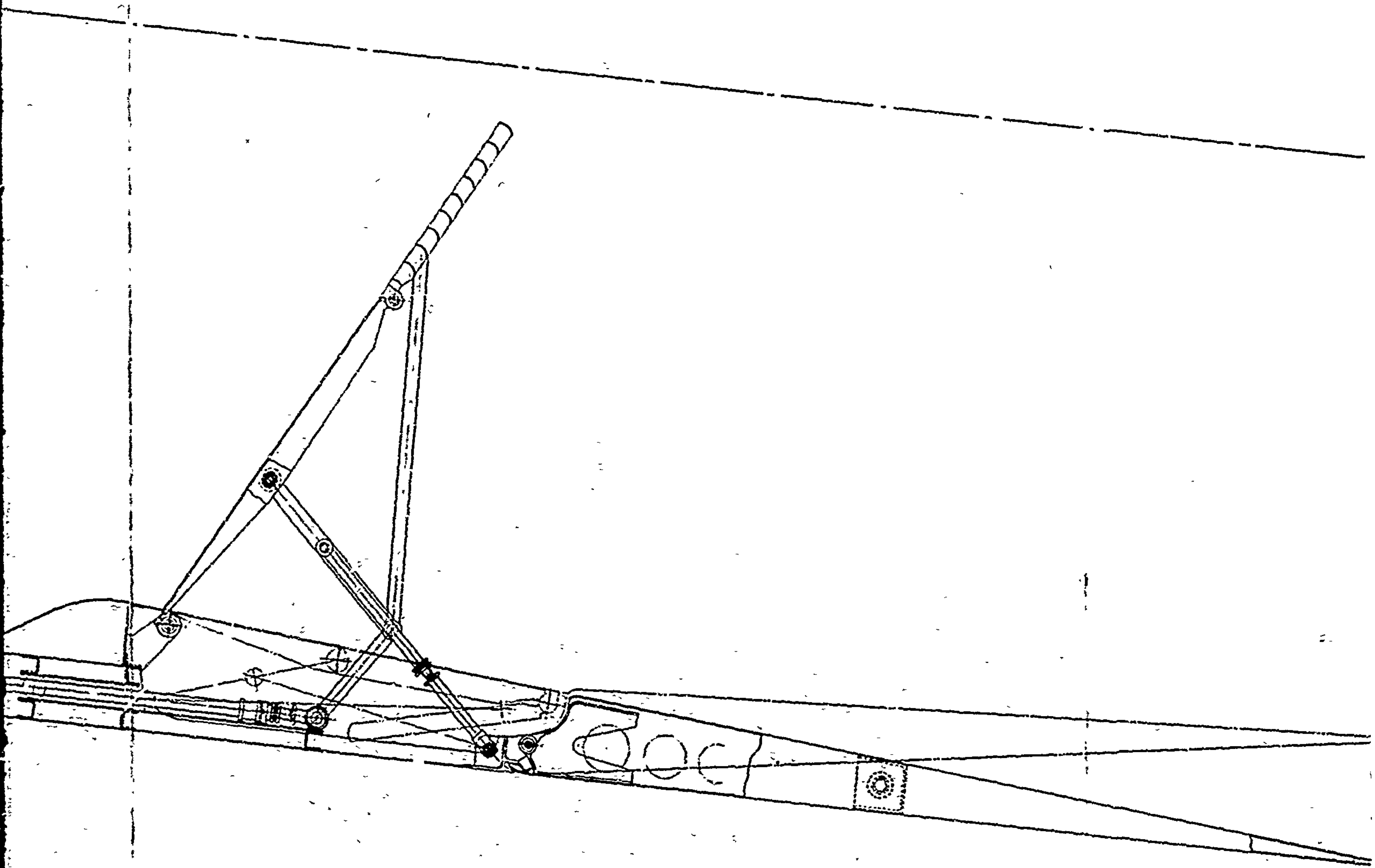

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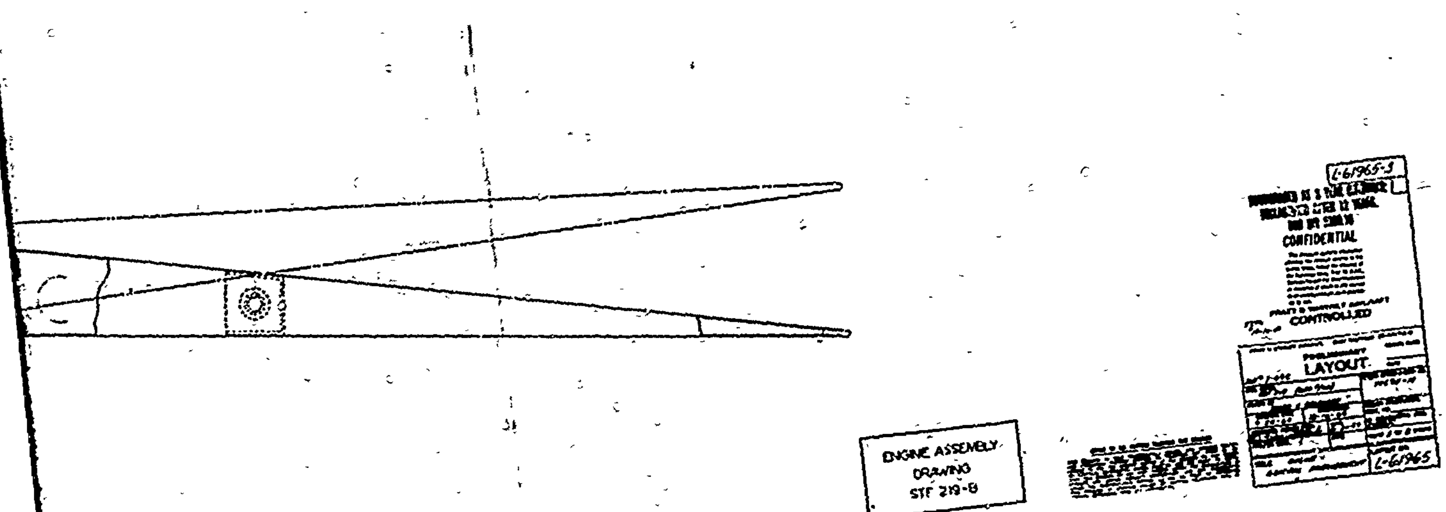
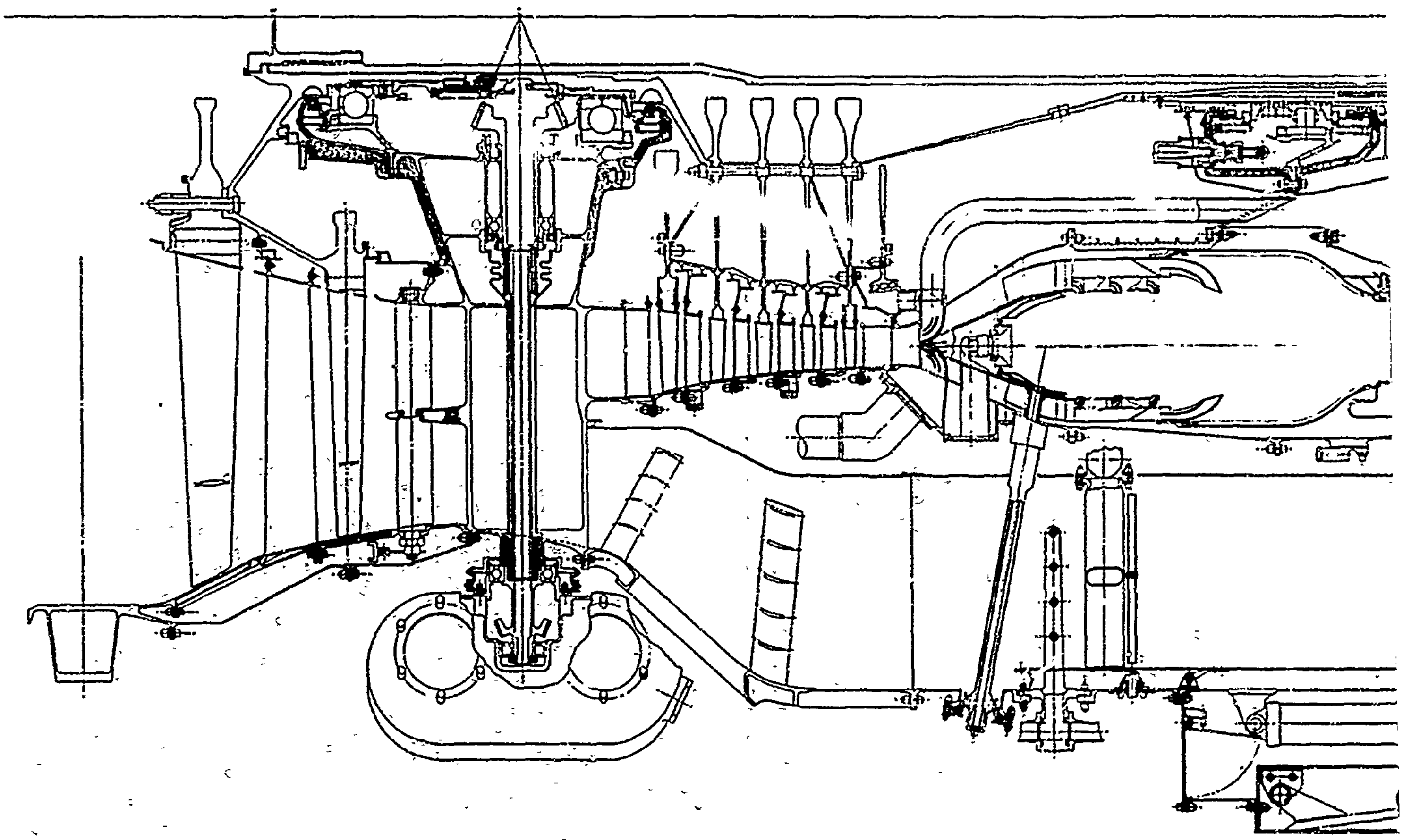
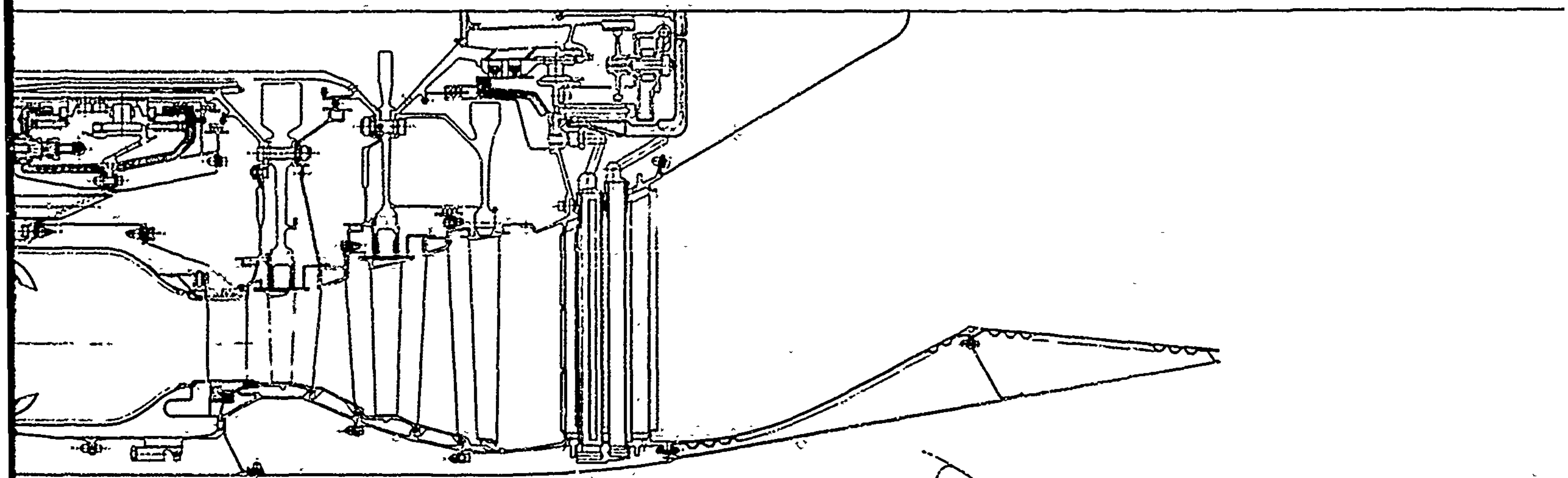
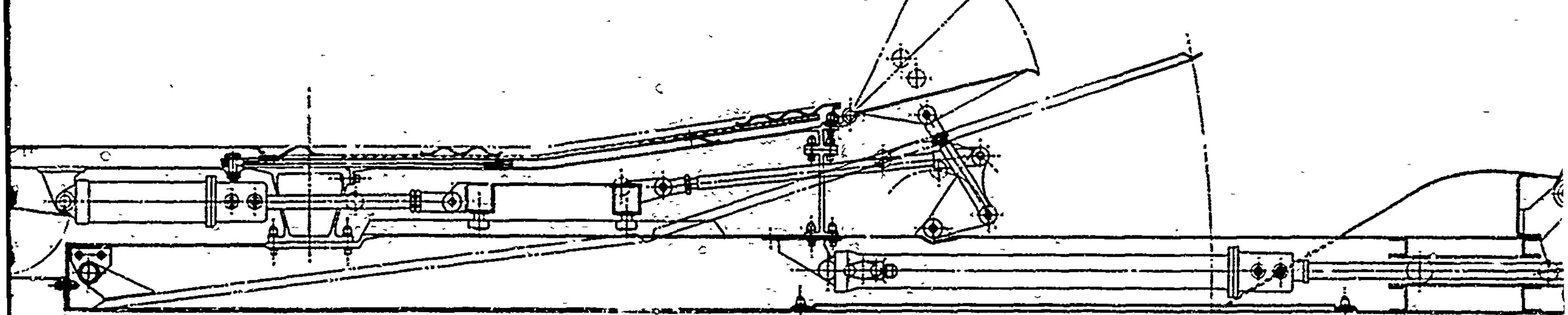
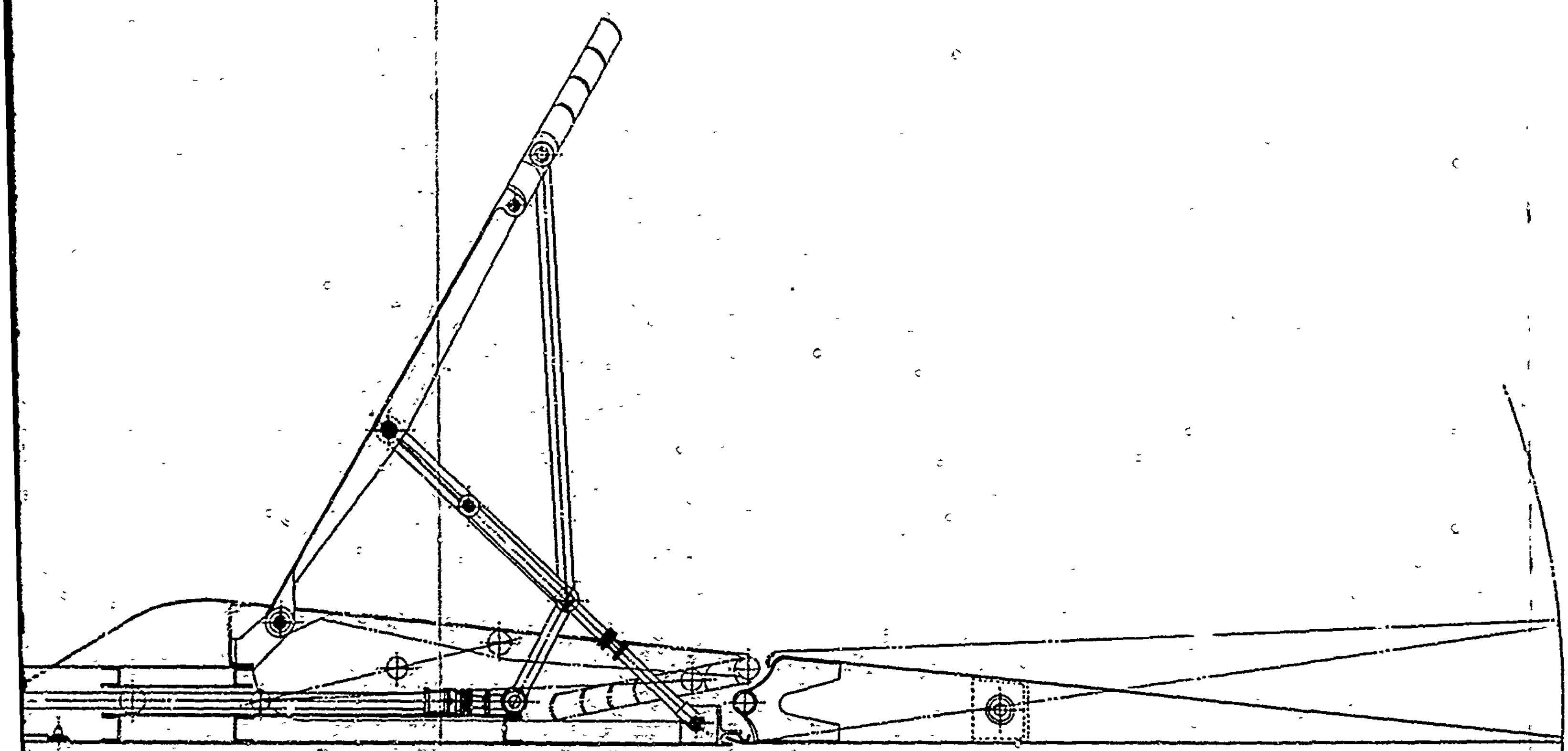


Figure 1. Engine Cross-Sectional Drawing STF219-B









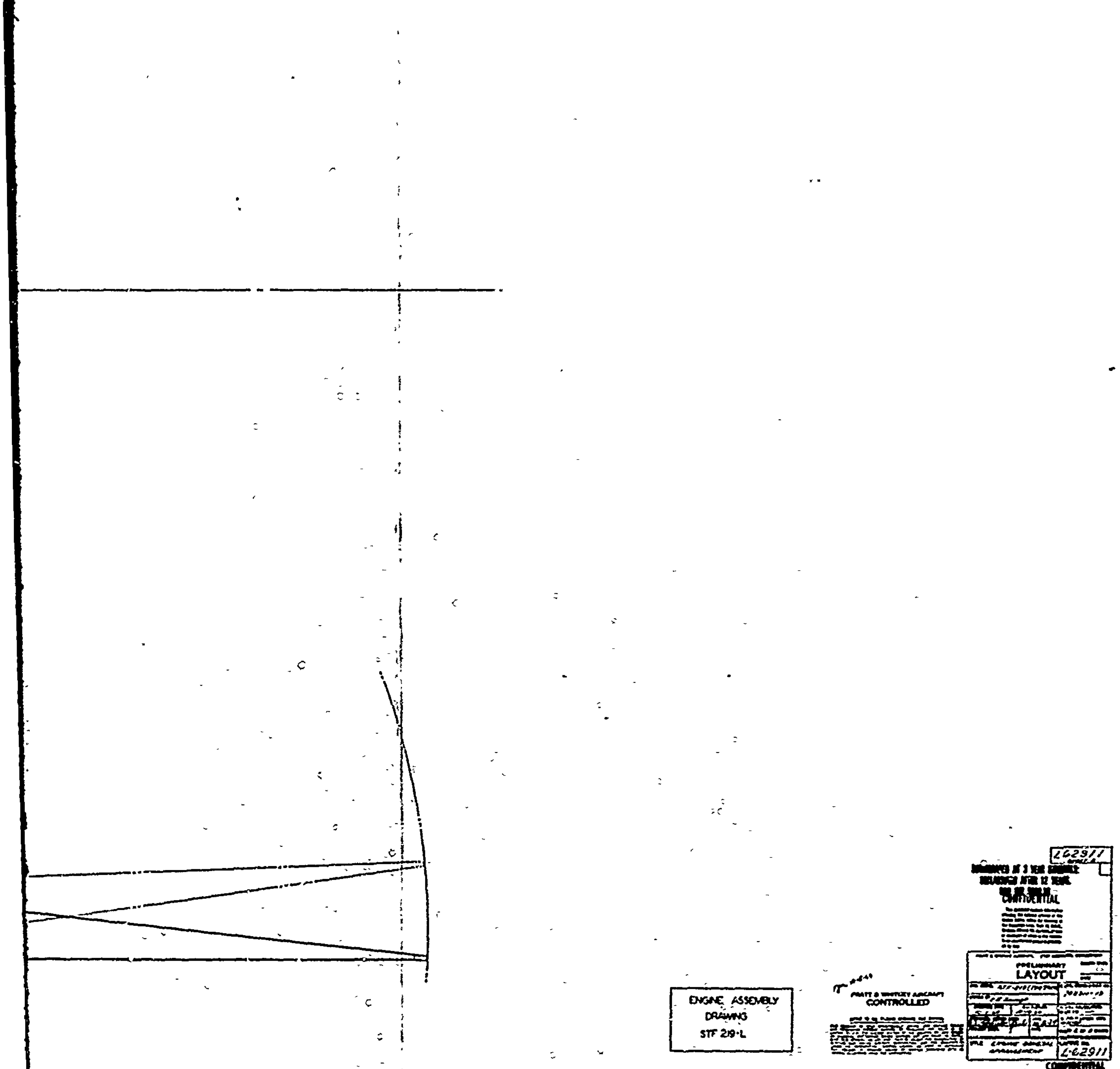


Figure 2. Engine Cross-Sectional Drawing STF219-L

TABLE I

ENGINE DESIGN CHARACTERISTICS

	STF219-B		
	Basic	Initial Production	JT11F-11 (Scaled)
Sea Level Static			
Thrust (lbs): (Max Augmented)	56000	51500	51100
(Max Non-Augmented)	36000	31500	33800
Weight: Dry (lbs)	9790	9790	9960
Thrust/Weight (Max Augmented)	5.72	5.27	5.13
Thrust/Weight (Max Non-Augmented)	3.68	3.22	3.39
Airflow (lbs/sec)	640	640	640
Transonic Acceleration - 45000 ft, Mach 1.2			
Thrust/Weight (Max Augmented)	1.96	1.84	1.78
Design Cruise Mach No.	2.7	2.7	2.7
Supersonic Cruise			
Mach No.	2.7	2.7	2.7
Altitude (ft)	65000	65000	65000
Ram Recovery	0.85	0.85	0.85
Minimum TSFC	1.49	1.53	1.51
Subsonic Cruise			
Mach No.	0.9	0.9	0.9
Altitude (ft)	36000	36000	36000
Minimum TSFC	0.92	0.89	0.93
Loiter			
Mach No.	0.6	0.6	0.6
Altitude (ft)	15000	15000	15000
Minimum TSFC	0.89	0.86	0.91
Acceleration Thrust (lbs)			
Mach 1.2			
36000 ft	29900	27800	27200
40000 ft	24700	23000	22500
45000 ft	19400	18000	17700
Ground Reverse Thrust			
(% Max Non-Augmented Thrust)	28	32	40
Turbine Inlet Temperature (°F)			
Take-Off	2300	2000	2000
Supersonic Cruise	2200	1900	1900
Transonic Acceleration	2300	2000	2000
Augmentation Temperature (°F)			
Take-Off	3100	3100	3100
Supersonic Cruise	1800	1900	2000
Transonic Acceleration	3100	3100	3100
Design Pressure Ratio	11.9	11.9	10.0
Design Bypass Ratio	1.3	1.3	1.08
Initial Recommended T.B.O.	-	600	600

TABLE II

ENGINE DESIGN CHARACTERISTICS

	STF219-L		
	Basic	Initial Production	JT11F-12 (Scaled)
Sea Level Static			
Thrust (lbs) (Max Augmented)	61200	56300	55900
(Max Non-Augmented)	39400	34400	37000
Weight: Dry (lbs)	10355	10355	10470
Thrust/Weight (Max Augmented)	5.91	5.44	5.35
Thrust/Weight (Max Non-Augmented)	3.81	3.32	3.54
Airflow (lb/sec)	700	700	700
Transonic Acceleration - 45000 ft, Mach 1.2			
Thrust/Weight (Max Augmented)	2.05	1.90	1.85
Design Cruise Mach No.	3.0	3.0	3.0
Supersonic Cruise			
Mach No.	3.0	3.0	3.0
Altitude (ft)	75000	75000	75000
Ram Recovery	0.81	0.81	0.81
Minimum TSFC	1.58	1.64	1.61
Subsonic Cruise			
Mach No.	0.9	0.9	0.9
Altitude (ft)	36000	36000	36000
Minimum TSFC	0.92	0.89	0.93
Loiter			
Mach No.	0.6	0.6	0.6
Altitude (ft)	15000	15000	15000
Minimum TSFC	0.89	0.86	0.91
Acceleration Thrust (lbs)			
Mach 1.2			
36000 ft	32700	30400	29800
40000 ft	26900	25000	24600
45000 ft	21200	19700	19400
Ground Reverse Thrust			
(% Max Non-Augmented Thrust)	40	40	40
Turbine Inlet Temperature (°F)			
Take-Off	2300	2000	2000
Supersonic Cruise	2200	1900	1900
Transonic Acceleration	2300	2000	2000
Augmentation Temperature (°F)			
Take-Off	3100	3100	3100
Supersonic Cruise	1800	2000	2000
Transonic Acceleration	3100	3100	3100
Design Pressure Ratio	11.9	11.9	10.0
Design Bypass Ratio	1.30	1.30	1.08
Initial Recommended T.B.O.	-	600	600

temperature, 2300°F turbine inlet temperature for transonic acceleration. A column representing the Phase I engine with overflow fan (JT11F-11/12) is also included to permit a comparison of the Phase I and Phase II-A engines. The blow-in-door ejector and reverser have been optimized in cooperation with the aircraft contractors for best overall installation and performance.

2.3 Turbine Inlet Temperature

The studies of the airframe contractors have shown that the range-payload objectives stated in the Phase II-A contracts require turbine inlet temperatures as high as 2200°F for cruise operation.

The STF219 turbine design has as its objective the ultimate attainment of a turbine inlet temperature of 2300°F for take-off and transonic acceleration and 2200°F for supersonic cruise in commercial service operation. This is an extremely ambitious goal and is in our opinion by far the greatest technical risk in the propulsion area of the SST program. In order to fully appreciate the degree of the problem one must be aware of the operating requirements and difficulties associated with the successful introduction of a new powerplant into commercial service. Operational considerations which must be taken into account are:

1. The requirement for a high degree of reliability so that maximum daily utilization of the aircraft may be maintained. In order to make an SST airplane competitive on an economic basis with subsonic commercial jet transports operating in the same time period, it is necessary to assume that the SST will be available approximately the same number of hours per day, will be as reliable, will have comparable TBO's, and will be as cheap to maintain and overhaul on a relative basis. These assumptions depend primarily on the SST powerplant having approximately the same order of reliability as present day subsonic jet engines which are being operated at turbine temperature levels of approximately 1450 - 1500°F for cruise and 1700 - 1750°F for take-off.

2. High turbine inlet temperatures result in development problems throughout the hot section of the engine. While the turbine vane and blade cooling systems tend to receive the majority of attention due to the ability to review their design in greater detail based on analysis and component rig testing,

commercial experience has time and again reminded us of the critical nature of other hot section parts such as burner liners, transition ducts, rotating seals, etc.

A recent experience on a current commercial program provides a worthwhile example. On the JT8D, which has recently entered service on the Boeing 727 aircraft, the burner cans encountered severe cracking and burning under extended altitude cruise operation in spite of the most extensive commercial development program, as measured by test hours, yet undertaken by Pratt & Whitney Aircraft. The testing, which included sea level and altitude running and 1000 hour simulated service testing, failed to uncover the problems which were quickly apparent in airline service operation. It has been our general experience that not only are problems such as the one cited above always to be expected on the initiation of service operation, but also that all hot section parts contribute significantly to the engine maintenance parts cost.

Therefore, the development program must include substantial effort on all the engine components exposed to increased operating temperature levels as turbine inlet temperatures are increased.

3. Hot section parts temperature margins are required to an even greater extent than on subsonic jets. One of the principal reasons for the requirement for greater margin is the effect of inlet distortion on the temperature pattern throughout the hot section. Information available on supersonic inlets indicates that a much higher level of inlet distortion will be experienced and for longer time periods at high power settings than is now experienced on the subsonic jet engines. In addition there are the normal margins required to account for uneven temperature patterns resulting within the combustion section itself, some deterioration of this temperature pattern with time, as well as the requirement for a margin in turbine out temperature (exhaust gas temperature) which is instrumented to provide the crew with an in flight engine monitoring parameter.

All of the operational factors described above must be taken into account in establishing a design turbine inlet temperature and design metal temperatures for all the hot section parts. The net result is that the hot section development work must be done to a level of temperature considerably higher than the average temperature which goes with the performance indicated by the engine rating.

For the above reasons it is our firm conviction that a design and development program aimed at 2300°F turbine inlet temperature for acceleration and 2200°F for supersonic cruise will be no more than sufficient to assure acceptable engine durability at the initial airline service operating temperatures of 2000°F for acceleration and 1900°F for supersonic cruise. Therefore, should SST service operation be scheduled to commence in the early 1970's, then initial certification and service operation of the engine will probably have to be at 1900°F cruise turbine inlet temperature and 2000°F for transonic acceleration. If airline passenger service is not required until a later time period, the initial level of turbine inlet temperature for service operation will be dependent upon the development and operating experience that has been accumulated to the time of initiation of such commercial service. The initial use of turbine inlet temperature levels considerably below the design level should provide the durability required to obtain the utilization necessary for successful initial passenger-carrying operation. This operating experience at the initial level of temperatures is an essential complement to a continuing engine development program if higher operating temperatures are to be achieved in service. Turbine inlet temperature levels will be increased to the 2200°F/2300°F level as soon as airline operating experience and the engine development program show that it is practical to do so. Provisions for this added development are included in the estimated program development cost and estimated engine price information being furnished as part of our Phase II-A report.

Both the prototype and the production engines will be designed and developed with target turbine inlet temperatures of 2200°F for cruise. Prototype qualification of the STF219 engine will be accomplished at 2200°F for cruise and 2300°F for maximum to permit flight test evaluation of the SST at the full basic specification performance levels. By this means, the earliest possible experience will be obtained in flight testing to provide definition of the post-certification problems to be expected as the turbine inlet temperature is increased in service operation.

The approach which we have outlined is intended to provide the highest degree of confidence in reaching the SST program objectives on the earliest schedule while limiting the risk involved in introduction to airline service.

2.4 Development Risk

The risk in development of a turbofan engine has been shown by subsonic experience to be no greater than for a turbojet of the same overall compression ratio and operating at the same turbine inlet temperature. Starting at a much later date, the JT3D turbofan engine, the engine powering the aircraft (707-320B, DC-8-50) to which the FAA has chosen to compare the SST designs for Phase II-A, has demonstrated reliability equal to or better than the turbojet engines that preceded it in commercial service. Further, its rate of growth of TBO has been equally rapid. The JT8D promises to follow with an equally impressive record. Both the JT3D and JT8D are dual rotor turbofan engines. The JT8D uses a long duct as proposed for the STF219.

The STF219 engines at a bypass ratio of 1.3 utilize a gas generator with an airflow of 278 to 305 lbs/sec. This puts the gas generator components in the same airflow size classification as the JT4 (250+lbs) and J58. Thus, gas generator component size should not be considered an element of development risk. The configuration of the engine draws heavily upon the STF200 demonstrator engine which has been running since April 1964. Such innovations as the fan without inlet guide vanes, the four bearing support system, short annular burner, and lightweight compressor and turbine technology are all running currently in the STF200 engine. Table III below compares the main elements of the two engines:

TABLE III

COMPARISON OF MAIN ELEMENTS OF STF200, STF219-L AND STF219-B ENGINES

	STF200 (Demonstrator)	STF219-L	STF219-B
Airflow - total	800 lb/sec	700 lb/sec	640 lb/sec
Airflow - gas generator	267 lb/sec	305 lb/sec	278 lb/sec
Main Bearings	4	4	4
Fan Stages (Low Rotor)	2	2	2
Compressor Stages (High Rotor)	9	5	5
Turbine Stages (Low Rotor)	2	2	2
(High Rotor)	2	1	1
Annular Primary Burner	Yes	Yes	Yes
Compression Ratio	20.0	11.9	11.9

The duct heater augmentation system, the variable area convergent nozzle and the blow-in-door ejector and reverser are new to commercial transport applications. However, significant development experience and military operational experience will have been accumulated prior to their service use in the SST.

In the TF30 engine, a common afterburner is used, requiring that the two streams (fan and gas generator) be brought together prior to burning. Although the streams are brought together, essentially no mixing occurs and the fan air stream is heated by a similar type of duct heating system as proposed for the STF219. The development of this fan air heating system for the TF30 has proceeded quite satisfactorily and would indicate no basic problems in this area for the SST engine design.

The duct heater, while new to commercial transport engines, is expected to be less of a durability challenge than the high performance afterburners on which experience has been accumulating for over ten years. While the duty cycle in the SST will require operation of the duct heater augmentation system during supersonic cruise, the level of temperature during cruise will be substantially reduced below the maximum temperature used for transonic acceleration (average temperature is reduced at least 600°F, from 3100°F at maximum to 2250-2500°F at cruise). Relatively low temperature cooling air from the fan stream (850°F max. at Mach 3 cruise) should further contribute to duct durability. Accordingly, the duct heater durability is not expected to be a limiting factor on engine or aircraft utilization. The development risk is less than for a high performance afterburner which would normally depend on either high temperature turbine discharge gas or relatively high temperature compressor bleed air for cooling.

Details of the background on duct heater development are found in our Phase I proposal and Phase II-A report. Testing during Phase II-A has confirmed the level of combustion efficiencies assumed for the STF219 performance (93% N_c for acceleration and 95% N_c for cruise). We have also run a large-scale full annular duct heater under conditions simulating transonic acceleration and cruise. Operation was stable and soft lights were reliably obtained. Efficiencies were measured to be higher than for similar configurations in two dimensional scale rigs, thus confirming that these rigs where cold end walls exist give results that are conservatively low.

A variable nozzle and blow-in-door ejector combination are incorporated in the TF30 augmented turbofan engine being developed for the F111 program. Prototypes of this powerplant have already been delivered and substantial flight experience (estimated at more than half a million engine hours by 1971) will be available on these components prior to SST service operation.

The reverser design has achieved relatively modest loads by pressure balancing the aerodynamic forces and relieved the temperature durability requirements by stowing the reverser in a cool environment when not in use.

The variable area exhaust nozzle is also new to commercial transport engines, although again more than 10 years military experience has been accumulated to date. The variable area nozzle is required for cycle optimization and airflow scheduling to meet the demands of supersonic inlets. As in the duct heater, relatively cool fan duct air is used for cooling the flaps. Actuator cylinder cooling is accomplished by the fuel used as the actuating fluid.

The design of the STF219 engines draws heavily on the experience gained in the J58 engine development and from flight experience in the YF12A aircraft. Operation in these aircraft has provided considerable insight on the effects of high Mach number operation. The design and materials selection for the SST powerplant and in particular for the hot section components have benefited from the experience gained in the J58 program.

Certainly the most powerful factor affecting development risk is the high level of turbine inlet temperature required. In view of the lack of operating experience at the temperature levels which the Phase II-A studies have shown to be required for the SST, it must be concluded that the major portion of the development job lies in the area of attaining commercial durability and reliability at temperatures where present experience has been limited to short runs on test stands in a simulated high Mach number environment.

3. PROPOSED PROGRAM

The STF219 engines will require an intensive development effort to assure that the advanced lightweight components and high temperature components will have the required reliability in commercial operation. It is planned to start development during Phase II-B utilizing the large scale rigs already available to provide information during the detail design phase of the engine. With this effort early in the program, the development schedule for the STF219 is comparable to that proposed for the JT11F-12 in Phase I.

The major milestones applicable to the availability of the STF219-B or STF219-L engines are shown in the table below. These availabilities are calculated from the date of go-ahead on a prototype development program. The engine orders must also be provided as required. Based on our preliminary Phase II-B work statement, the effective go-ahead date could be December 1, 1964, provided adequate funding for development hardware procurement and the follow-on phases is made available as required.

ITEM	FROM GO-AHEAD
Installation Design Mock-Up Engine Delivery (Orders to be placed 6 months prior to scheduled delivery)	1-1/2 years
Initial Ground Test Engine Delivery (Orders to be placed 2 years prior to scheduled initial delivery)	3 years
Completion FTS Test	3-1/2 years
Initial Prototype Engine Delivery (Orders for total quantity required, to be placed 2 years prior to scheduled initial engine delivery)	3-1/2 years
Completion of Engine Certification TC Test	6 years
Initial Production Engine Delivery (Orders to be placed concurrent with orders for SST aircraft and not less than 2-1/2 years prior to scheduled initial engine delivery)	6 years

4. COST ESTIMATES

Detailed development and production cost estimates are presented in Tables IV and V, respectively. Detailed breakdowns of these estimates are given in Volumes XI-E and XII-E.

The Phase II-A estimates differ from the Phase I estimates because of the differences in engine designs and development programs, and also are in accordance with the revised rules established by the FAA in Phase II-A SST Economic Model Ground Rules, dated July 10, 1964 (revised September 15, 1964). The Phase II-A estimates are given in 1964 dollars whereas Phase I estimates included anticipated escalation of labor and material.

Both production and development costs include the ejector and reverser which are standard equipment on the Phase II-A engines.

TABLE IV

ESTIMATED DEVELOPMENT COSTS prior to an assumed mid-1972 airplane certification - 1964 dollars

STF219-B (Boeing)		
Total Estimated Phase II-A Cost		$ 5,000,000
Total Estimated Phase II-B Cost		$ 11,600,000
Estimated Phase III Costs:		
Design Engineering	$167,332,800	
Test Article Fabr.	408,723,900	
Test Effort	191,213,200	
Program Management	13,170,200	
Computer Utilization	3,105,600	
Mockups	854,300	
Fabrication of Prime Items*	78,750,000	
Total Estimated Phase III Costs		$863,150,000
Total Estimated Cost** (Phases II-A, II-B, and III)		$879,750,000

STF219-L (Lockheed)		
Total Estimated Phase II-A Cost		$ 5,000,000
Total Estimated Phase II-B Cost		$ 11,600,000
Estimated Phase III Costs:		
Design Engineering	$189,100,200	
Test Article Fabr.	459,582,200	
Test Effort	216,513,800	
Program Management	14,872,100	
Computer Utilization	3,477,400	
Mockups	854,300	
Fabrication of Prime Items*	78,750,000	
Total Estimated Phase III Costs		$963,150,000
Total Estimated Cost** (Phases II-A, II-B, and III)		$979,750,000

* Ground test and prototype engines.

** General and Administrative Expense included in the Total Estimated Cost.

TABLE V

ESTIMATED PRODUCTION COSTS
based on 200 airplanes
with appropriate spares
1964 dollars

STF219-L (Lockheed)	
Purchased Parts	$ 337,443
Raw Material	323,692
Total Material	$ 661,135
Labor	$ 89,520
Manufacturing Overhead*	$ 276,617
Total Manufacturing Cost	$1,027,272
STF219-B (Boeing)	
Purchased Parts	$ 311,867
Raw Material	$ 284,868
Total Material	$ 596,735
Labor	$ 83,081
Manufacturing Overhead*	$ 256,720
Total Manufacturing Cost	$ 936,536

*Production Engineering and tooling costs are included in Manufacturing Overhead.

5. FACILITIES

Pratt & Whitney Aircraft has for many years invested heavily in providing all the facilities necessary for large aircraft engine development. As a result, we do not anticipate that major new facilities are required for undertaking development of the STF219-L or STF219-B engines. Additions or modifications to our existing facilities and equipment at the Florida Research and Development Center, where the majority of the STF219 development would be carried through as well as minor modifications to East Hartford facilities and equipment are estimated to cost approximately $33,800,000. With these additions the STF219-B or STF219-L engines could be tested over the major portion of the supersonic transport flight envelope.

6. DIRECT OPERATING COSTS

The factors of fuel cost, engine price, eng development costs and engine maintenance labor and material costs influence the direct operating cost of the supersonic transport. Fuel cost is the major item in this context. The proposed engines have been designed to accept fuel characteristics that oil companies estimate will be available at no increase in cost in the 1970 time period.

Maintenance material costs have been estimated to be $70 per hour for STF219-B and $75 per hour for STF219-L for 1900°F. cruise and 2000°F. acceleration temperatures after an initial break-in period. Labor costs have been analyzed and are on the order of $7.50/hr for the aforementioned engines.

We anticipate establishment of an initial target TBO of 600 hours with a normal FAA/industry engine sampling procedure. If operation is continued at 1900°F. cruise, we anticipate the engine TBO will increase as indicated in our Phase I proposal, Vol. M-VI. Subsequent increases in TBO and/or cruise temperature are dependent upon experience and would be worked out with the airline operators to obtain the most economical trade-offs between TBO and increased temperature.

SUMMARY

The STF219 engine design which evolved from our Phase II-A effort has permitted substantial improvements in SST aircraft performance and economics over that obtainable with our Phase I engine designs.

The selection of the STF219 duct heating turbofan cycle by both the airframe contractors makes possible a concentrated effort on this cycle in Phase II-B. Further, the preferred airflow sizes, 700 lbs/sec at Lockheed and 640 lbs/sec at Boeing, are sufficiently close to indicate the possibility that the selection of a single airflow size for continued work in follow-on SST program phases can be made at an early date.

Our Phase II-A program has made it possible to detail many of our management functions in greater depth. At the same time we are prepared to undertake the management of the major engine development program with a plan which is deeply rooted in the methods we have used in our successful subsonic commercial engine programs.

ESTIMATED PRODUCTION ENGINE PRICES

The estimated production unit selling prices in 1964 dollars, for use in accordance with the FAA Phase II-A SST Economic Model Ground Rules, dated July 10, 1964, are:

STF219-L........$2,000,000
STF219-B........$1,825,000

These prices include all standard equipment as listed on the engine specification including the ejector and reverser. The prices are based on a 200 aircraft program at a stabilized production rate of 2.5 aircraft per month, and, in accordance with the FAA's request, include amortization of the company absorbed estimated development costs subsequent to an assumed aircraft certification date of mid-1972 but none of the estimated development costs prior to aircraft certification.