United States Army Aviation Logistics School
Fort Eustis, Virginia

APRIL, 1994

THIS DOCUMENT HAS BEEN REVIEWED FOR OPSEC CONSIDERATIONS

STUDENT HANDOUT

POWERPLANT

071-626-12

The proponent for this SH is USAALS

SECTION II. - INTRODUCTION

TERMINAL LEARNING OBJECTIVE:

At the completion of this lesson you will:

ACTION: Analyze powerplant systems malfunctions.

CONDITIONS: Given an AH-64A helicopter, TM 1-1520-238-T series manuals, TM 55-1520-238-23 series manuals, TM 55-1520-238-10, TM 55-1520-238-CL, TM 55-1520-238-MTF, TM 55-2840-248-23, and a requirement to analyze AH-64A powerplant systems malfunctions.

STANDARDS: Analyze AH-64A powerplant systems malfunctions in accordance with the appropriate technical manuals.

SAFETY REQUIREMENTS: In addition to the specific safety requirements of this lesson plan, aviation shop and flight line safety standards established in the applicable manuals will be reinforced.

WARNING

NOISE

Sound of running engines can exceed U.S. Surgeon General's noise limits (TB MED 251). Ear plugs or aviation helmet must be worn when working on helicopter at these times. If injury occurs, seek medical aid.

WARNING

ENGINE EXHAUST

Stay clear of engine exhaust when engines are operating. Exhaust gases are hot and could cause burns. Particles in the exhaust could damage eyes. If injury occurs, seek medical aid.

WARNING

IGNITION IGNITER

The ignition system contains high-voltage electricity that can cause injury or death. Extreme caution must be used when working on the ignition system. If injury occurs, seek medical aid.

NOTES

WARNING

STARTING ENGINES AND AUXILIARY POWER UNIT

Be sure that the rotor and blast area is clear, and a fire guard is posted if available.

RISK ASSESSMENT LEVEL: Low

ENVIRONMENTAL CONSIDERATIONS: Dispose of all unwanted or unused jet engine fuel and lubricants in accordance with all federal, state, local, and unit SOP regulations and requirements.

EVALUATION: This lesson will be evaluated during Practical Written Evaluation 9C7-510-04.

SECTION III. - PRESENTATION

ENABLING LEARNING OBJECTIVE 1:

After this lesson you will:

ACTION: Describe the physical laws and basic turbine engine theory applicable to the T700-GE-701 and T700-GE-701C turboshaft engines.

CONDITIONS: Given FM 1-506 and the Student Handout.

STANDARDS: Describe by selecting from a list, the physical laws and basic turbine engine theory applicable to the T700-GE-701 and T700-GE-701C turboshaft engines, with a minimum of 70% accuracy.

AIRCRAFT POWER PLANT REQUIREMENTS

RELIABILITY

COMPACTNESS

HIGH SPECIFIC POWER OUTPUT

HIGH THERMAL EFFICIENCY

EASE OF MAINTENANCE

DURABILITY

LOW WEIGHT PER HORSEPOWER

REASONABLE COST

FREEDOM FROM VIBRATION

OPERATING FLEXIBILITY

04-94-04

NOTES

A. Aircraft powerplants must meet exacting requirements for dependability and endurance. In order to obtain engines suitable for aircraft, a powerplant must meet the following requirements.

1. Reliability (The most important powerplant requirement.)

2. Durability

3. Compactness

4. Low weight per horsepower (The T700-GE-701C develops 1,940 horsepower (contingency) and weighs 456 pounds maximum for horsepower-to-weight ratio of 4.25:1.)

5. High specific power output

6. Reasonable cost

7. High thermal efficiency (Thermal efficiency is a measure of the losses suffered in converting the heat energy in fuel into mechanical work.)

8. Freedom from vibration

9. Ease of maintenance

10. Operating flexibility

AIRCRAFT POWER PLANT REQUIREMENTS

RELIABILITY	DURABILITY
COMPACTNESS	LOW WEIGHT PER HORSEPOWER
HIGH SPECIFIC POWER OUTPUT	REASONABLE COST
HIGH THERMAL EFFICIENCY	FREEDOM FROM VIBRATION
EASE OF MAINTENANCE	OPERATING FLEXIBILITY

04-94-04

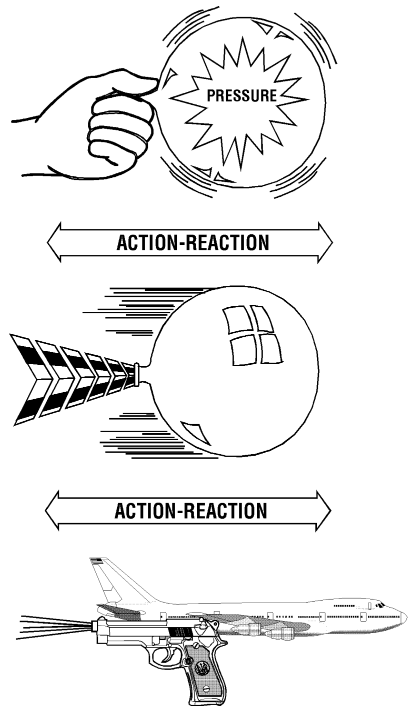
NOTES

A. To understand how a gas turbine engine operates, a knowledge of some basic physical laws is required.

B. The generation of power by a turbine engine can be explained using the following physical laws and principles.

26-12

NEWTON'S THIRD LAW OF MOTION



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NOTES

C. Newton's laws of motion

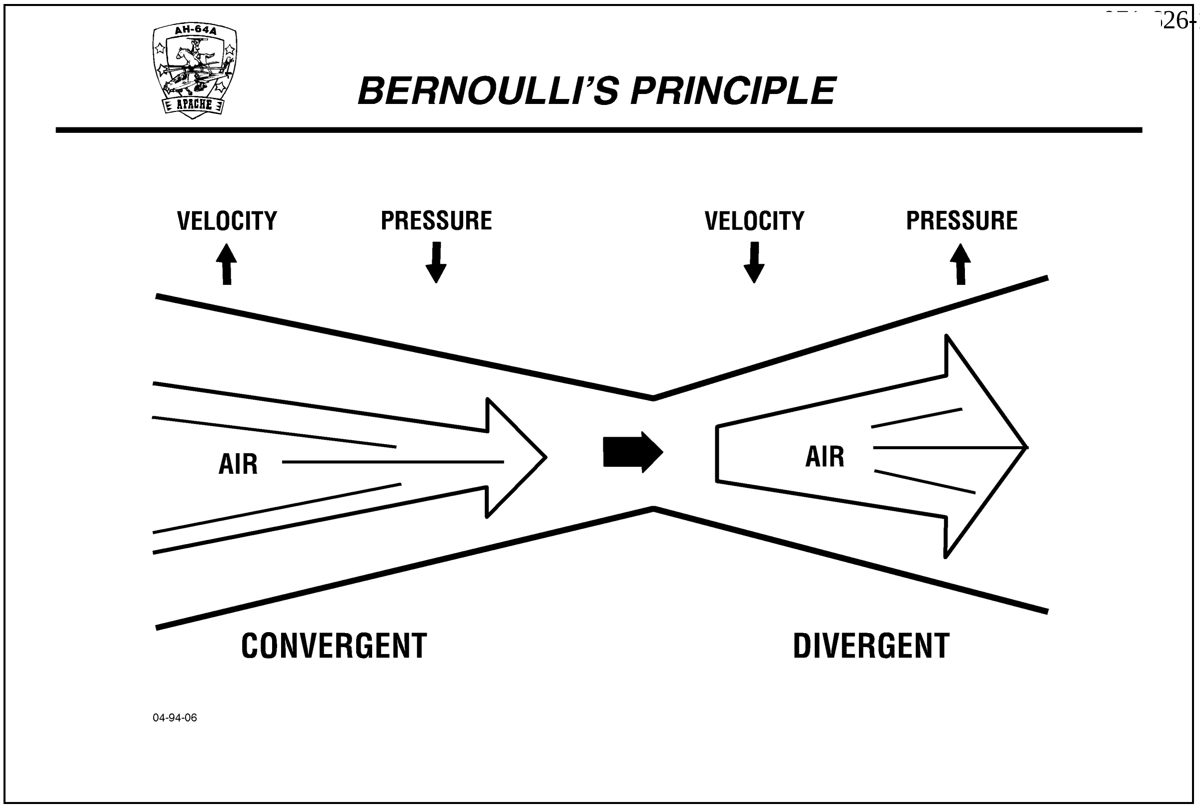
1. The power produced by a turboshaft engine is explained to a large extent by Newton's three laws of motion.

   a. First law. A body at rest tends to remain at rest and a body in motion tends to continue in motion in a straight line unless caused to change its state by an external force.

   b. Second law. The acceleration of a body is directly proportional to the force causing it and inversely proportional to the mass of the body.

   c. Third law. For every action, there is an equal and opposite reaction.

2. The second and third laws of motion are the most applicable to turboshaft engines.


BERNOULLI'S PRINCIPLE
VELOCITY
PRESSURE
VELOCITY
PRESSURE
AIR
AIR
CONVERGENT
DIVERGENT
04-94-06

NOTES

D. Bernoulli's principle

1. A turbine engine can be thought of as a pipe with gas flowing through it. It has areas where pressure and velocity are changed to achieve the desired results.

   a. The total energy in a flowing gas is made up of static and dynamic temperatures and pressures. Pressure can be viewed as potential energy and velocity viewed as kinetic energy.

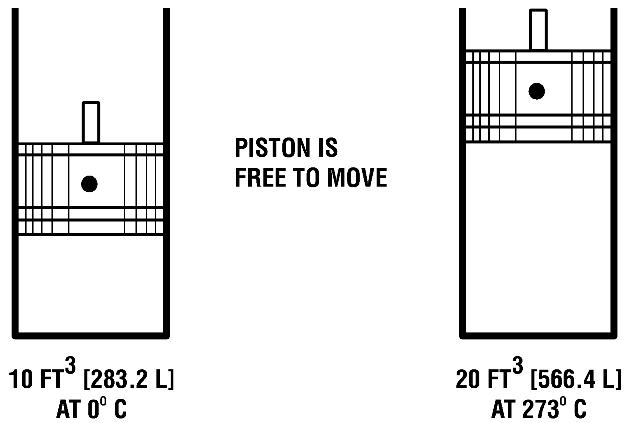
   b. When a gas is flowing through a convergent duct (as in a nozzle stator vane or venturi), its speed increases and its temperature and pressure decrease.

   c. If this area is a divergent duct (as in a diffuser), its speed decreases and its temperature and pressure increase.

   d. A nozzle or diffuser does not change the total energy level, but changes the energy from one form to another.

2. By varying the area of a pipe, or the ducting of a turbine engine, velocity can be changed into pressure, and pressure changed to velocity.

CHARLES' LAW



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NOTES

E. Charles' law

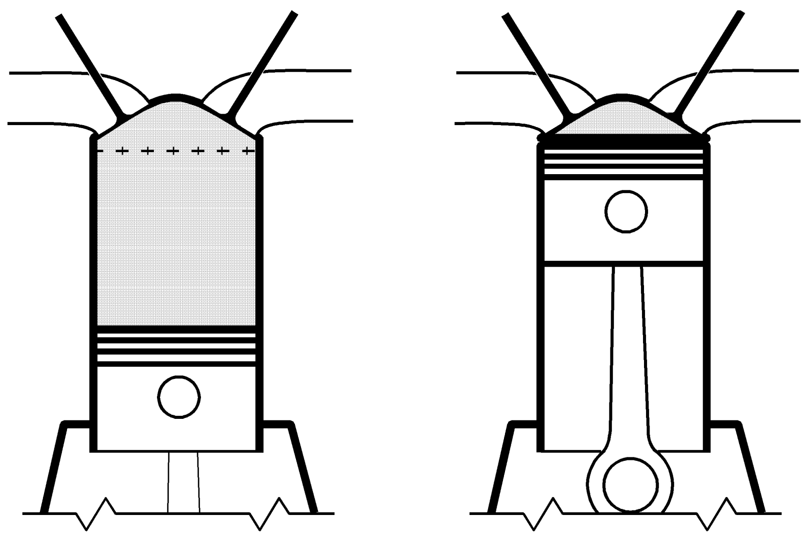
1. Charles' Law is used to explain the operation of the turbine engine combustion section.

   a. If a gas is under constant pressure, and is confined to a certain area so that it can expand, an increase in temperature causes an increase in volume.

   b. If you hold an inflated balloon over a stove, the increase in temperature causes the air inside the balloon to expand. If there is a sufficient amount of heat, the air within the balloon expands and causes the balloon to burst.

2. In a turbine engine the heat of combustion expands the air within the combustion section.

BOYLE'S LAW



NOTES

F. Boyle's law

1. Boyle's law defines the relationship between the pressure, volume, and temperature of a confined gas.

   a. If the temperature of a confined gas is not changed, the pressure increases in direct relationship to a decrease in volume. The opposite is also true; pressure decreases as volume increases.

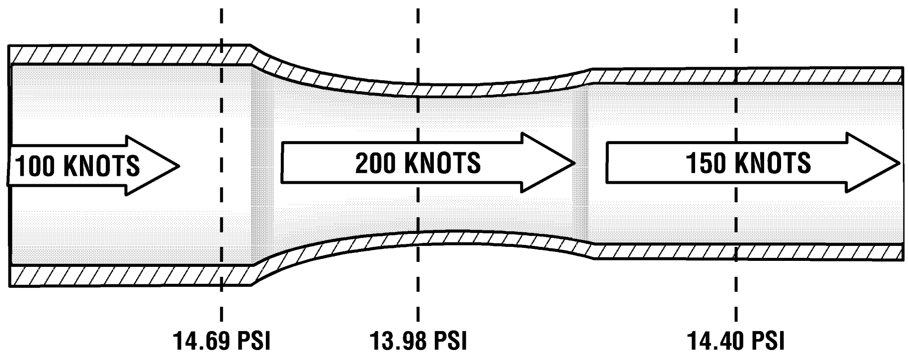
   b. An example of how this works is the piston and cylinder in a reciprocating engine.

      (1) As the piston moves downward, the volume of the cylinder increases and the pressure of the air in the cylinder decreases.

      (2) As the piston moves upward, the volume of the cylinder decreases and the pressure of the air in the cylinder increases.

2. In a turbine engine, air is compressed in the compressor section resulting in increased air pressure and decreased volume.

VENTURI EFFECT



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NOTES

G. Pressure and velocity

1. Air is normally thought of in relation to its temperature, pressure, and volume. In a turbine engine the air is put into motion, so velocity must be considered.

2. Consider a constant quantity of air flowing through a duct.

   a. As long as the duct cross-sectional area remains unchanged, air continues to flow at the same rate (disregard frictional loss).

   b. If the cross-sectional area of the duct should become smaller (convergent area), the air's velocity must increase if the same quantity of air is to continue flowing through the duct (Bernoulli's Principle).

   c. If velocity increases, pressure and temperature must decrease (law of conservation of energy).

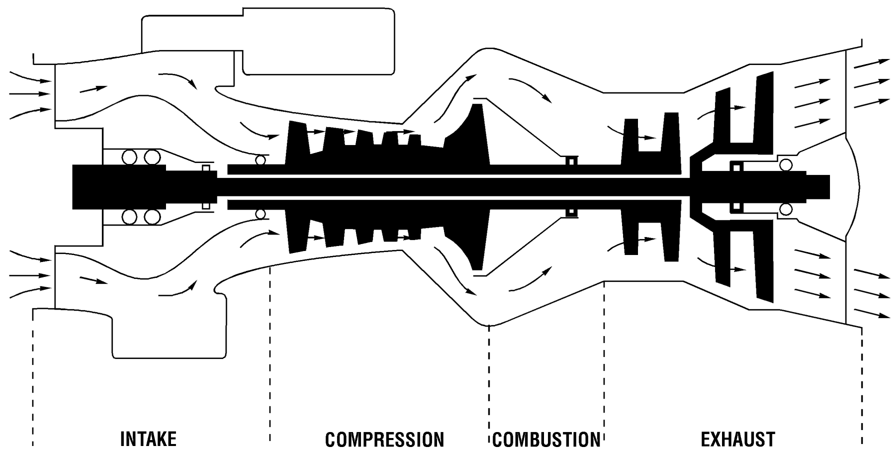
   d. The net result of flow through the duct is an increase of velocity and a decrease of pressure and temperature.

   e. The opposite is true if the air were to flow from a smaller duct to a larger duct (divergent area); velocity would decrease, and pressure and temperature would increase.

3. The throat of automobile carburetor is a good example of the effect of airflow through a restriction (venturi); even on the hottest day the center portion of the carburetor feels cool.

4. Convergent and divergent areas are used throughout a gas turbine engine to control pressure and velocity of the air-gas stream as it flows through the engine.

GAS TURBINE ENGINE PRINCIPLES



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NOTES

A. Gas turbine engine principles

1. A gas turbine engine is an air-dependent, thermal, jet propulsion device that uses exhaust-gas-driven turbine wheels to drive a compressor, making continuous operation of the engine possible.

2. Although the gas turbine engine differs radically in construction from the conventional four-stroke, four event cycle reciprocating engine, both operate on the same principle.

3. In the piston engine, intake, compression, combustion, and exhaust all take place in the same combustion chamber; therefore, each event completely occupies the chamber during its part of the combustion cycle.

4. In the gas turbine engine, a separate section is devoted to each function and all functions are performed at the same time without interruption. These sections are the air-inlet section, the compressor section, the combustion section and a turbine and exhaust section.

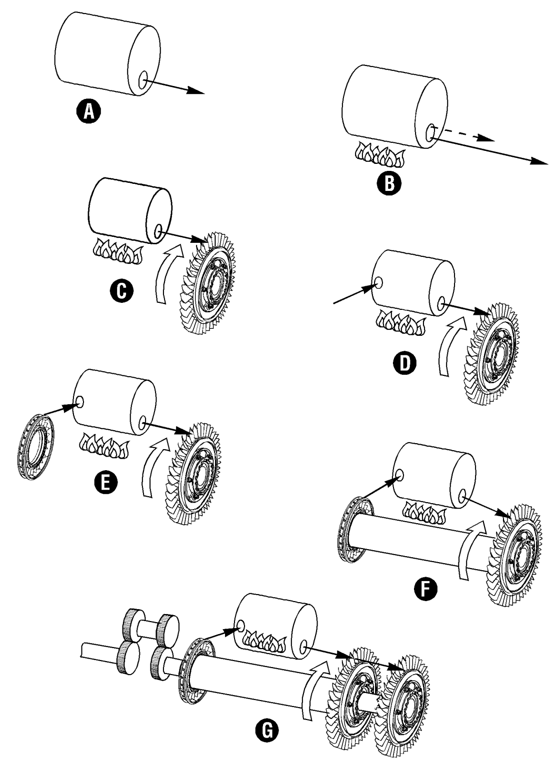
   a. The compressor brings in air from the inlet section, compresses it, and forces air into the combustion section.

   b. Fuel is then injected into the combustion area, where it mixes with the compressed air. The fuel and air mixture is ignited, and once started, combustion is continuous and self-supporting.

5. In gas turbine engines designed for Army use, nearly two-thirds of the energy from combustion is necessary to drive the compressor.

6. The power turbine is designed to extract as much of the remaining energy as possible and transform it into shaft horsepower which is used to drive an output shaft or propeller.

BASIC GAS TURBINE ENGINE OPERATION



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NOTES

B. Basic gas turbine engine operation.

1. A container of compressed air has been provided with an opening (nozzle) through which the air passes off into the atmosphere until the pressure is exhausted (A). This brief high-speed airflow (velocity) through the nozzle produces a mild momentary reaction force (solid arrow).

2. The density of the air can be increased by heating (B). The result of this increased volume is a greater velocity as indicated by the long arrow (heated air) as compared to the short broken arrow.

3. In (C), the heated air (solid arrow) is directed (impinged) onto the airfoil-shaped blades attached to the rim of the disc (turbine) causing the turbine to rotate on its shaft.

4. To provide for the continuous airflow, an opening is placed in the forward end of the container (D).

5. A mechanical pump (compressor) forces air (solid arrow) into the container (E).

6. With high-velocity air driving the turbine, the rotating motion of the turbine can be used to drive the compressor by joining the two rotating parts with a shaft (F).

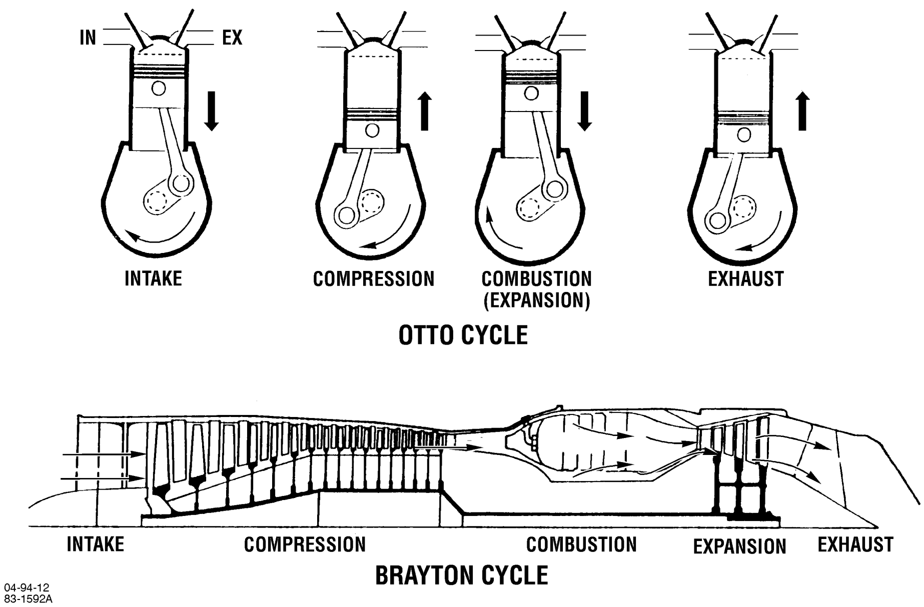
7. Up to this point the air container has only provided for the heating of the air by an outside means. The container becomes an engine combustion chamber when fuel is introduced, mixed with the air, and ignited internally.

8. Not all of the air entering the combustion chamber is needed for combustion. However, all of it is heated and expands rapidly. It exhausts as hot, high-velocity gas through the nozzle and is directed (impinged) onto the turbine.

9. As the gases pass across the turbine, approximately two-thirds of the available energy is used. The remaining energy still possesses a high work potential. Therefore, a second turbine is placed in the flow path of the hot, high-velocity gases and is driven in the same manner as the turbine driving the compressor.

10. The second turbine (power turbine), drives a system of reduction gears and the output shaft by means of a shaft system mechanically independent of the compressor turbine system. The output shaft is externally splined for turboprop application or internally splined for helicopter application (G).

ENGINE CYCLES



NOTES

C. Engine cycles

1. In all internal combustion engines, four basic events occur: intake, compression, combustion (expansion), and exhaust.

a. Reciprocating and turbine engines have similarities.

(1) Both powerplants are air-breathing engines.

(2) Both engines have the same series of events: intake, compression, combustion (expansion), and exhaust.

b. Basic differences between reciprocating and turbine engines exist.

(1) In a turbine engine intake, compression, combustion (expansion), and exhaust occur simultaneously, whereas in a reciprocating engine each event must follow the preceding event.

(2) In a turbine engine each event is performed by a separate component, whereas in a reciprocating engine all of the functions are performed in one component.

2. The processes of intake, compression, combustion (expansion), and exhaust is called a cycle. A cycle is a process that begins with certain conditions and ends with those same conditions.

a. In reciprocating engines, the cycle of intake, compression, combustion (expansion), and exhaust is called the Otto cycle.

b. In turbine engines, the cycle of intake, compression, combustion (expansion), and exhaust is called the Brayton cycle.

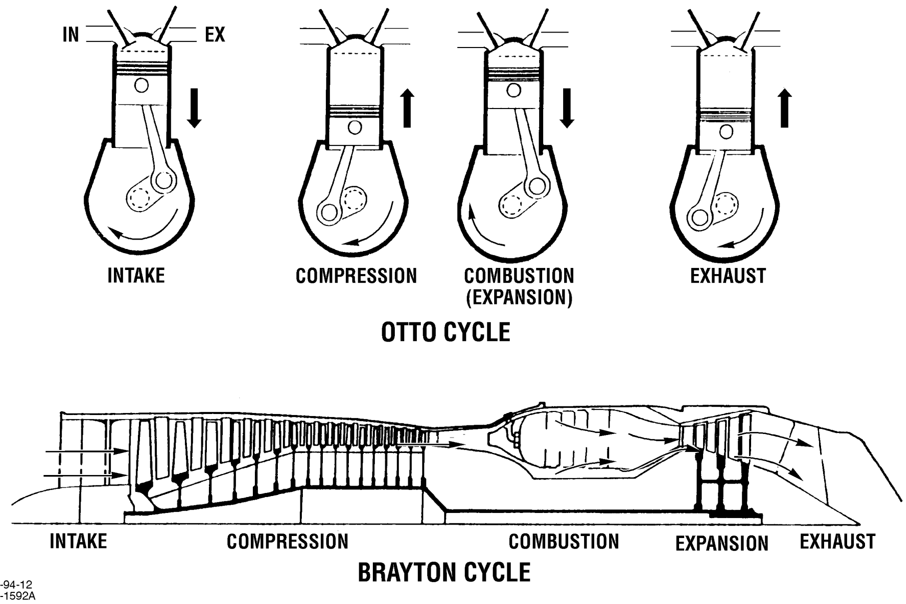
3. Otto cycle - In reciprocating engines all four events occur in sequential order in the cylinder.

a. Intake. Air and atomized fuel are pulled into the cylinder by the vacuum that is caused when the piston is pulled downward during the intake stroke.

b. Compression. The intake valve closes and, as the piston is forced upward by the crankshaft during the compression stroke, the pressure rises (Boyle's Law).

c. Combustion. When the piston reaches the proper point, (slightly before top dead center) the fuel-air mixture is ignited. As the fuel-air mixture burns, it expands (Charles' Law). This expansion results in a proportional increase in pressure, causing the piston to be forced downward during the power stroke. This is where the work (energy) is extracted from a reciprocating engine.

ENGINE CYCLES



NOTES

d. Exhaust. When the piston has traveled all the way to the bottom of the cylinder, the exhaust valve opens and the exhaust gasses are forced out of the cylinder as the piston travels upward on the exhaust stroke. It is at this point the cycle begins again.

4. Brayton cycle - In a gas turbine engine all four events occur simultaneously in different areas of the engine.

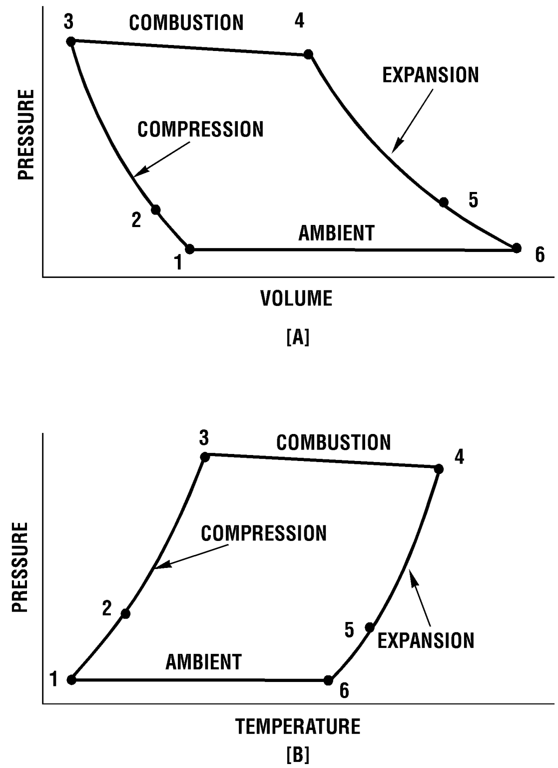
a. Intake. Air enters the front of the engine at ambient pressure and constant volume. The air travels rearward because of the operation of the engine's compressor, leaving the intake section at an increased pressure and decreased volume.

b. Compression. In the compressor section air is received from the intake at slightly above ambient pressure, and with a slightly decreased volume. Air enters the compressor where it is compressed, leaving with a large increase in pressure and decrease in volume. This is caused by the mechanical action of the compressor. The velocity of the air is then lowered by some form of a divergent duct and it's static pressure increases proportionally (Bernoulli's Principle).

c. Combustion. The compressed air is routed to the combustion section where atomized fuel is added. As the fuel-air mixture burns, the hot expanding gasses move rearward through the engine at an increased volume, but at a relatively unchanged pressure (Charles' Law).

d. Exhaust. Power is extracted by directing the hot expanding gasses through a nozzle onto the blades of a rotor, causing the rotor to turn. The rotor is bolted to a shaft which is attached to the compressor. This causes the engine to be self-sustaining. In a turbojet engine, the exhaust gases propel the aircraft (Newton's Third Law of Motion). Power for other uses, such as running the transmission of a helicopter is supplied by adding an additional and (sometimes) separate rotor to extract energy not extracted by the first rotor. The air then travels rearward and is exhausted from the engine.

BRAYTON CYCLE



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NOTES

D. Brayton cycle

1. The Brayton cycle is also known as the constant pressure cycle, and describes the events that take place in a turbine engine. The functions of air intake, compression, combustion, and exhaust as described by Charles' Law, Bernoulli's Principle, and Boyles' Law are performed simultaneously, but at differing levels of pressure, volume, and temperature within the gas turbine engine. The pressure/volume relationship is shown in table A.

a. Point 1 indicates the condition of the air in front of the engine before it is affected by the inlet duct of the engine.

b. When air enters the engine air inlet duct, it is diffused. This diffusion reduces the speed of the air, and causes the static pressure of the air to increase. Point 2 represents the condition of the air after diffusion and prior to entrance into the compressor.

c. The compressor decreases the air volume, but increases the air pressure substantially. This is shown graphically by the curve from point 2 to point 3.

d. The pressurized air is then directed to the combustion section. At point 3, the compressed air is mixed with fuel, and the resulting mixture is ignited.

(1) The burning of the air/fuel mixture causes a rapid increase in air volume and temperature.

(2) The design of the combustion chamber causes a slight air pressure drop as the velocity of the hot gas mixture increases at the rear of the combustion chamber.

(3) Although the pressure drop is slight, combustion occurs at a constant temperature.

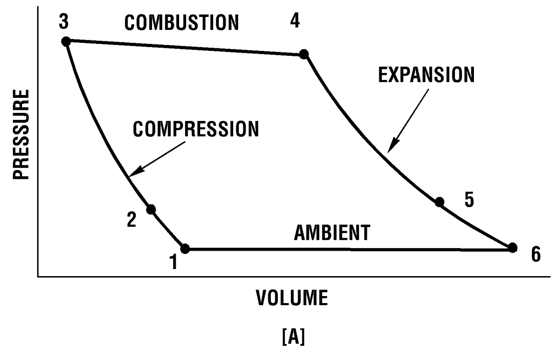
e. At point 4, the heated gases are then directed to the power turbine, which extracts as much of the gas energy as possible to drive an output shaft or propeller from a power shaft. This process causes a decrease in both temperature and pressure.

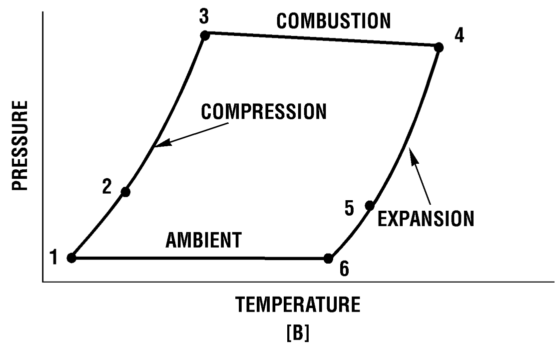
f. The curve between points 5 and 6 represent the residual gas energy that is vented out of the engine through the exhaust nozzle, as the gases flow out to ambient pressure.

2. The Brayton cycle also shows a temperature/pressure relationship using the same points used in the pressure/volume cycle. This is shown in table B.

a. The curve between points 2 and 3 represents an increase in air temperature because of compression.

BRAYTON CYCLE





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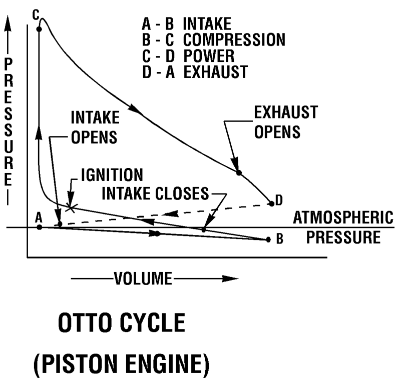
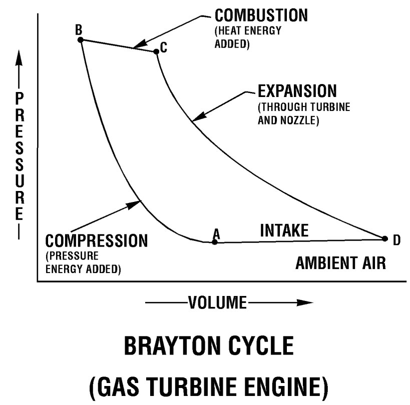
b. The curve between points 3 and 4 represents the slight air pressure drop and rapidly increasing air temperatures that occur as a result of the burning of the air/fuel mixture. Although the pressure drop is slight, combustion occurs at a constant temperature.

c. The curve between points 4 and 5 represents the expansion of the gases through the power turbine, where temperature and pressure of the gases are reduced to the point where they enter the atmosphere.

d. At point 6, the temperature of the gases is still above the ambient temperature of the atmosphere. The temperature decreases rapidly as the gases leave the jet nozzle and are dispersed into the atmosphere behind the engine.

OTTO CYCLE vs. BRAYTON CYCLE





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NOTES

E. Otto Cycle vs. Brayton Cycle

1. When comparing reciprocating and turbine engines, another major difference is noted.

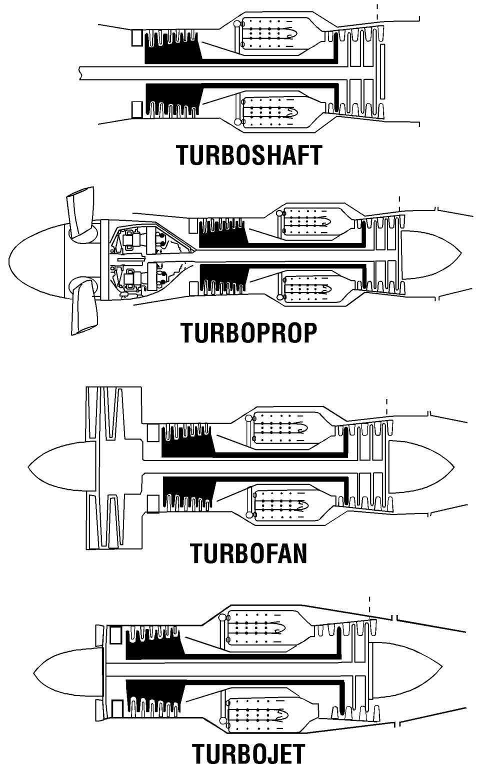
   a. The piston engine produces a relatively high pressure in its cylinder and uses this pressure to force the piston downward. The higher the pressure, the greater the amount of work that can be obtained from a given amount of fuel, thereby raising the thermal efficiency of this type of engine. Therefore, the limiting factor of how much power can be produced in a piston engine is how much pressure the cylinder and related parts can withstand.

   b. A turbine engine's thermal efficiency is limited by the ability of its compressor to build up high pressures without excessive temperature rises. Ideally, a turbine engine should burn as much fuel as possible in order to raise the gas temperature and increase the useful output. The limiting factor of a turbine engine, then, is how much heat the internal parts of the engine (especially the stage one turbine nozzle) can withstand.

2. While a reciprocating engine uses all of the available air in the cylinder for the combustion process, a gas turbine engine can only use about 25% of it's available air for combustion. The remaining 75% is being used to cool the engine internally.

6-12

TYPES OF GAS TURBINE ENGINES



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NOTES

A. Types of gas turbine engines

1. The gas turbine engines most commonly used today are divided into four types.

   a. Turboshaft engine - an engine in which net energy available is transmitted from the exhaust gas-driven turbine wheel and power shaft to a transmission or gearbox to turn a helicopter powertrain system.

   b. Turboprop engine - a turboshaft engine in which power is transferred from the power shaft through reduction gearing to a propeller. The major difference between the two engines is the gear reduction.

   c. Turbofan engine - in principle, the same as a turboprop, except that the geared propeller is replaced by a duct-enclosed, axial-flow fan driven at engine speed.

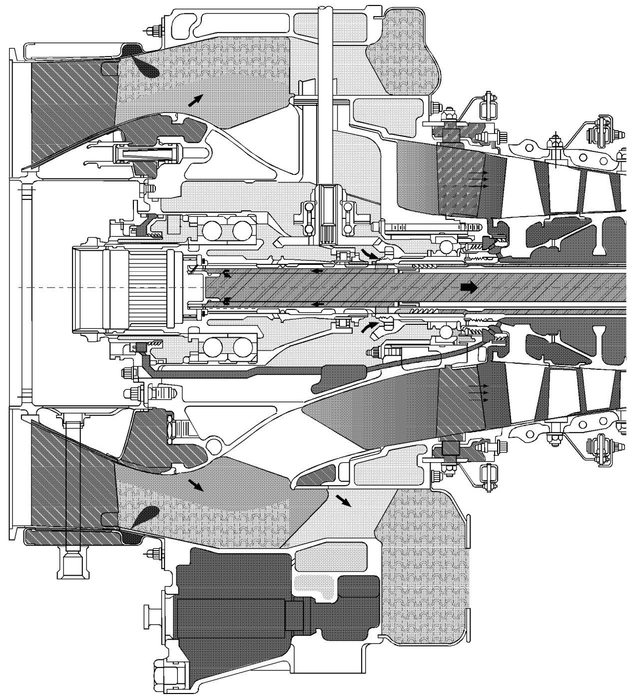
   d. Turbojet engine - a **gas turbine** engine in which the energy that is used for propulsion is solely in the form of a jet discharging through a propelling nozzle or nozzles; or a **jet engine** whose air is supplied by a turbine-driven compressor, the turbine being driven by exhaust gases.

2. The term "turbo" means "turbine." Therefore, a turboshaft engine is an engine that delivers power through a shaft, which, in turn, is powered by a turbine wheel.

3. Army aircraft gas turbine engines are generally the free-type power turbine turboprop or turboshaft engines. Having a free power turbine enables the power output shaft to turn at a constant speed while the power producing capability of the engine can be varied to accept increased loads applied to the power output shaft.

4. Turbine engines may also be classified into two general groups, centrifugal-flow and axial-flow, depending on the type of compressor used. However, most gas turbine engines in Army aircraft employ a combination of both types called a dual compressor.

INLET SECTION AIRFLOW



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NOTES

A. Airflow and theory of operation for the T700-GE-700 series turboshaft engines

1. Air is drawn into the intake of the engine where a swirling motion is induced by the swirl vanes on the swirl frame.

    a. The swirling motion is used for particle separation to remove any sand, dust, and other foreign objects that may be in the air.

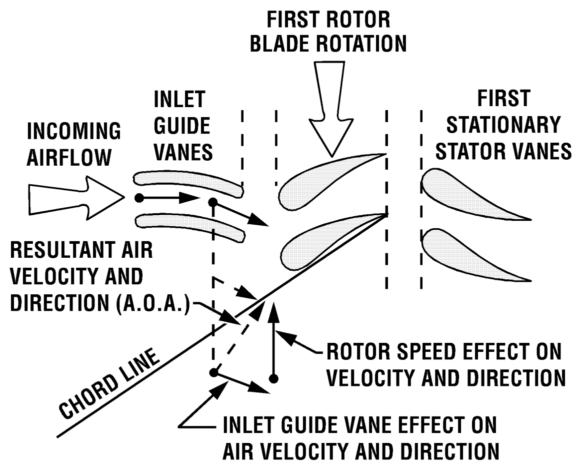
    b. As the air moves rearward in a swirling motion, centrifugal force causes the particles to move to the outer portion of the main frame, through a series of scroll vanes and into the scroll case.

    c. The particles are sucked from the scroll case by the inlet particle separator blower and exhausted overboard.

2. Air that remains after particle separation is carried to the front frame deswirl vanes which straighten and direct it in an axial path to the inlet of the compressor.

3. The T700-GE-701/701C engine has a dual stage compressor. The first five stages of compression are axial and the last stage is centrifugal.

INLET GUIDE VANE EFFECTS



The air leaving a stage of axial flow compression is at essentially the same velocity as when it entered, but its pressure is increased.

04-94-17

NOTES

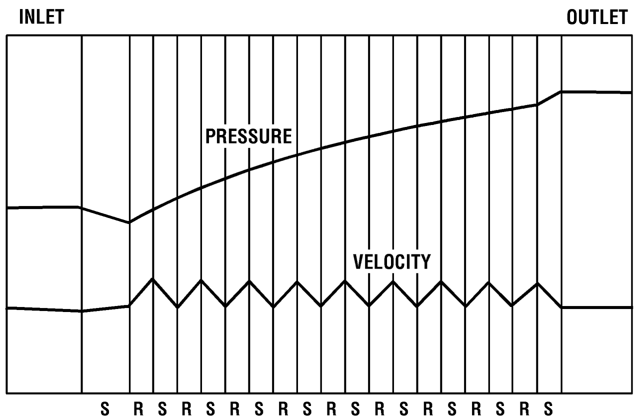
4. After being delivered to the face of the compressor by the air inlet duct, incoming air passes through the inlet guide vanes. The inlet guide vanes direct the air at the optimum angle to enter the first stage of compression.

   a. After the air passes the IGVs, the first stage of compressor rotors increase the velocity of the air. However, velocity increases are held to a minimum by the shape of the compressor blades. (Due to the airfoil shape of the compressor blades, adjacent blades form a divergent duct).

   b. The air then enters the first stage stator vane. The first two stages of stator vanes on a T700-GE-700 series engine are variable geometry, that is, their angle of attack can be changed to accommodate different Ng speeds.

   c. The stator vanes direct the airflow to the next set of rotor blades and act as a divergent duct to limit airflow velocity.

PRESSURE AND VELOCITY CHANGES



Pressure and velocity changes as air passes through each stage of an axial flow compressor.

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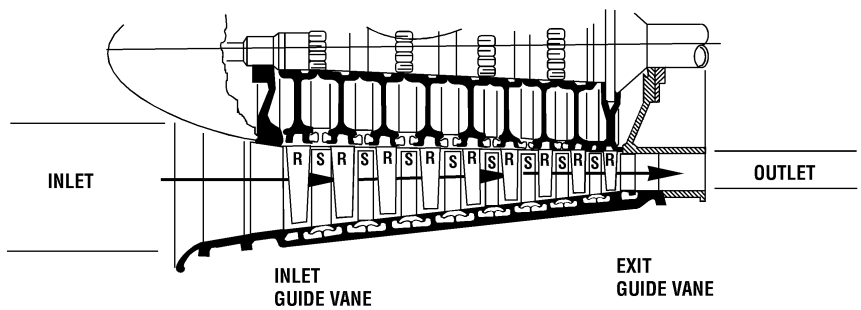
NOTES

d. The air leaving a stage of axial flow compression is at essentially the same velocity as when it entered, but its pressure is increased.

COMPRESSOR AIR VELOCITY



To prevent the air velocity decreasing as the pressure increases, the area of the outlet of an axial flow compressor is smaller than its inset.

04-94-19

NOTES

e. To prevent the air velocity decreasing as the pressure increases, the area of the outlet of an axial flow compressor is smaller than its inlet, forming a convergent duct.

f. There are several advantages of an axial flow compressor. They are:

(1) High peak efficiencies from ram, created by its straight-through design.

(2) High peak pressures attainable by addition of compression stages.

(3) Small frontal area resulting in low profile drag.

g. The disadvantages of an axial flow compressor are:

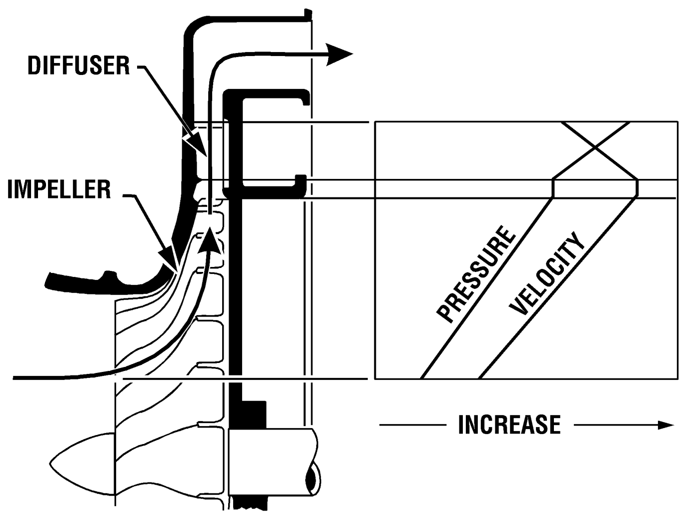
(1) Difficulty of manufacture and high cost

(2) Relatively high weight

(3) High starting power requirements

(4) Low pressure rise per stage, approximately 1.27:1

CENTRIFUGAL COMPRESSION



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NOTES

5. Once the air has passed through the five axial stages of compression, it enters the last stage, which is centrifugal.

   a. The centrifugal portion of the compressor consists of the impeller and diffuser. It receives air, from the axial stages, at its center and accelerates it outward by centrifugal force.

   b. Advantages of centrifugal compressors are:

      (1) High pressure rise per stage - as much as 10:1 to 17:1

      (2) Good efficiency over a wide rotational range, idle to approximately Mach 1.3 tip speed. (The pressure within the compressor casing prevents airflow separation and provides a high transfer of energy into the airflow.)

      (3) Simplicity of manufacture and relatively low cost

      (4) Low weight

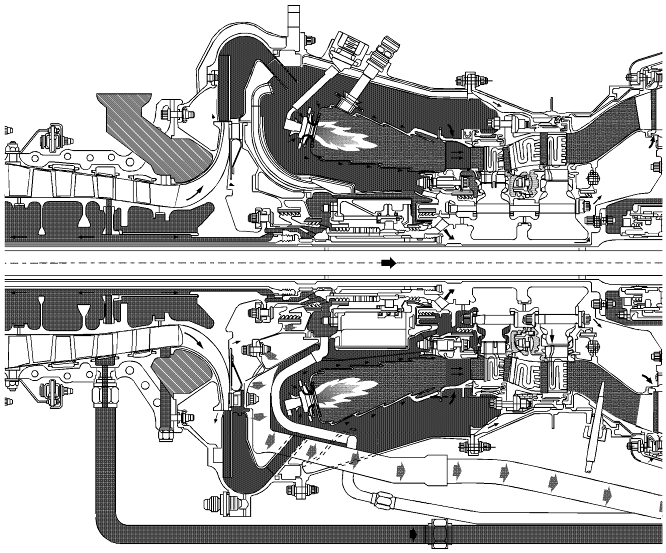
      (5) Low starting power requirements

   c. Disadvantages of a centrifugal compressor are:

      (1) Large frontal area for a given airflow

      (2) More than two stages are not practical because of the energy losses between the stages.

HOT SECTION AIRFLOW


04-94-21

NOTES

6. After leaving the centrifugal compressor, the air then flows into the diffuser. The diffuser is a divergent duct and adds the final stage to the compression process by again decreasing velocity and increasing pressure. (Bernoulli's Principle)

7. From the diffuser, the air enters a set of vanes that straighten out the air flow and direct it into the combustion section. This part of the engine is sometimes referred to as the compressor manifold.

8. Approximately 25% of the air from the compressor is used for combustion, the rest is used to cool the engine and pressurize seals. (Seal pressurization requires only a small portion of the total amount of air.)

    a. The air routed into the combustion section to be used for combustion is referred to as primary air.

        (1) The primary air enters the combustion liner, is combined with atomized fuel, and ignited.

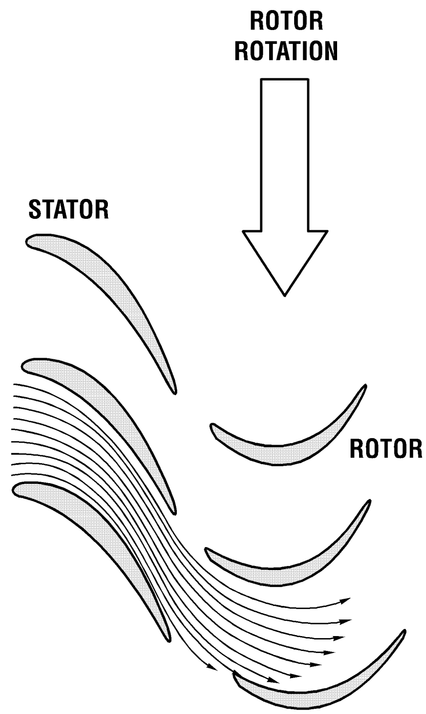
        (2) As the air is heated by the combustion process it expands and its volume increases, but its pressure remains relatively constant.

    b. The air routed into the combustion section to be used for cooling is referred to as secondary air.

        (1) The secondary air forms an air blanket around the burning gases and dilutes the temperature. This ensures that the turbine section is not destroyed by excessive heat.

        (2) Secondary air is controlled and directed by holes and slots in the combustor liner that creates an insulating layer of air along the inner wall of the combustor liner. The insulating layer prevents burning of the liner walls.

STAGE ONE TURBINE NOZZLE



04-94-22

NOTES

9. The air from the combustion liner then enters the stage one turbine nozzle.

   a. The turbine nozzle is a convergent duct that causes an increase in velocity and directs the air at the best angle to strike the turbine rotor blades.

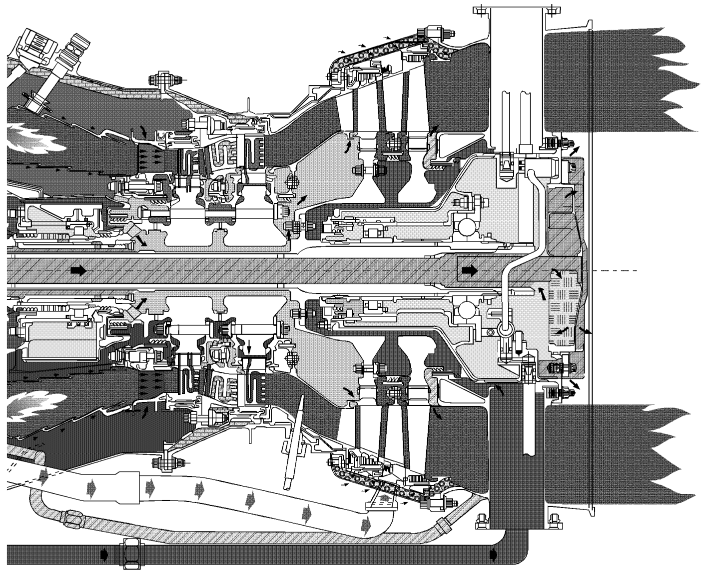
   b. As the air strikes the blades, it causes the turbine rotor blade disk to turn. This is where the energy from the combustion process is extracted and made to do work in a gas turbine.

   c. The first two stages of turbine rotors are bolted together on a shaft that rotates the compressor rotor. This is known as the gas generator (N_G) section.

   d. Nearly three-fourths of all of the energy available from the combustion process is used by the N_G section to drive the compressor rotor. This is also where most of the secondary air is used to cool the turbine nozzles and rotor blades.

   e. The stage one nozzle is the hottest part of the engine and its ability to withstand heat is the limiting factor when considering how much horsepower the engine can produce.

POWER TURBINE SECTION AIRFLOW



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NOTES

10. The air flow continues back through the engine to two more sets of turbine nozzles and rotors. This is the power turbine (N_P) section.

    a. The N_P section is similar in function to the N_G section, but it's construction is different in that it is a totally uncooled section.

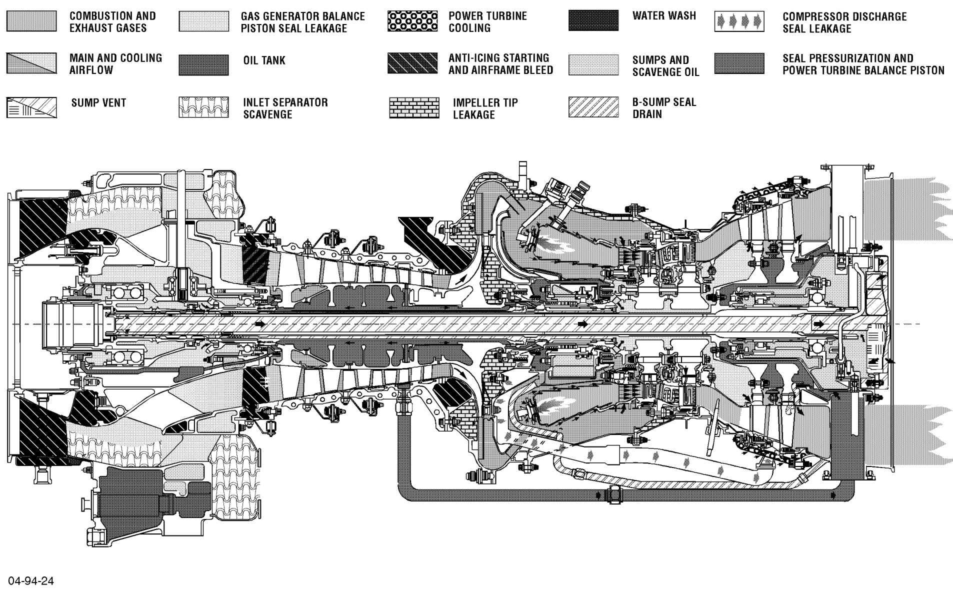
    b. The airflow at this point has lost enough heat energy from turning the Ng section rotors and from cooling by secondary airflow that further cooling is unnecessary.

    c. The power turbine rotors are bolted to a shaft that passes through the length of the engine to supply power to the airframe.

    d. Although nearly three-fourths of the available energy was extracted to keep the engine self-sustaining, over 1800 shaft horse power is delivered to the drive train by the N_P section. (T700-GE-701C)

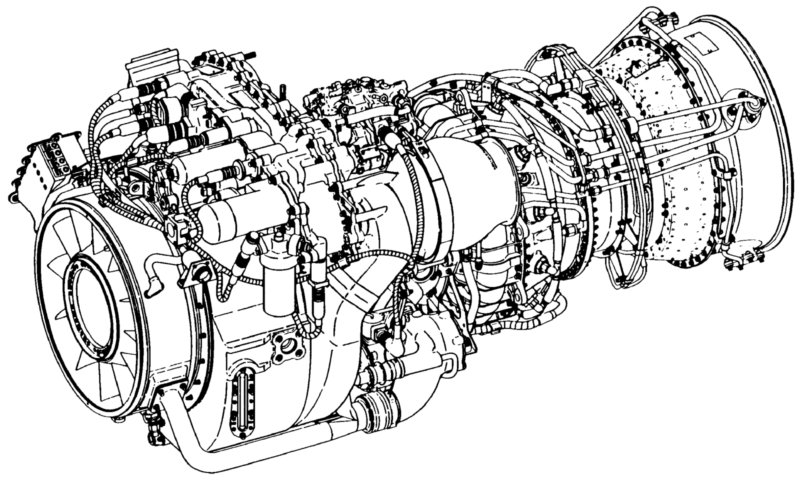
11. From the power turbine section the air is exhausted overboard. On the AH-64 the exhaust gases are combined with ambient air to lower the infrared signature caused by the hot exhaust.

ENGINE AIRFLOW



NOTES

T700-GE-701C ENGINE



04-94-25

NOTES

A. Powerplants purpose, location, and description

1. The engines provide power to drive the rotor system.

2. The purpose of the engine related subsystems is to:

a. Control the engines

b. Control engine exhaust

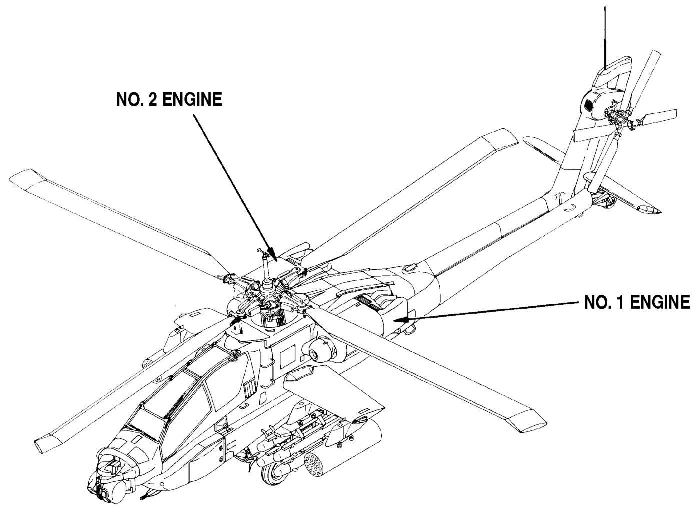
c. Provide engine anti-ice

d. Provide engine start

e. Provide engine ignition

f. Provide engine cooling

ENGINE LOCATION



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NOTES

3. The engines are mounted in nacelles on the left and right side of the helicopter. The nacelles protect the engines from the environment.

4. Engine 1 is on the left side of the aircraft and engine 2 is on the right.

5. Like engines are installed on the aircraft; mixing the T700-GE-701 and the T700-GE-701C on the same aircraft is not authorized.

6. The major components of the powerplant system are two T700-GE-701 or T700-GE-701C front drive, turboshaft engines and their related subsystems.

T700-GE-701/701C CHARACTERISTICS

MANUFACTURER:	General Electric Aircraft Engines, Lynn MA.	**MODEL:**	T700-GE-701/701C
ENGINE TYPE:	Turboshaft	**OUTPUT POWER:** **T700-GE-701:** **T700-GE-701C:**	 1690 SHP IRP (30 minute limit) 1800 SHP IRP (30 minute limit) 1890 SHP Max (10 minute limit) 1940 SHP Contingency (2.5 min. limit)
COMPRESSOR TYPE:	Combined axial/centrifugal consisting of six stages, five axial and centrifugal	**VARIABLE GEOMETRY:**	Inlet guide vanes, stage one and two stator vanes
COMBUSTOR:	Single annular chamber with axial flow	**ENGINE WEIGHT (DRY):**	427 lb. (dry) no oil or fuel
LENGTH:	46.12 in. (117 cm.)	**DIAMETER:**	25 in.
LOCATIONS:	All locations, clock positions, and directions of rotation are as viewed from the rear.	**ROTATION DIRECTION:**	Direction of rotation is clockwise.
TIME BETWEEN OVERHAUL:	The engine has no designated time between overhaul limit and is overhauled on a condition basis only.	**LOCKWIRE:**	Lockwire has been replaced by self-locking nuts and inserts.
TOOLS:	Maintenance can be accomplished using only ten hand tools.	**LRU RETENTION:**	Line replaceable units (LRU's) are retained with captive bolts.
LINES and HOSES:	External lines and hoses for fuel and oil have been reduced by internal routing.		

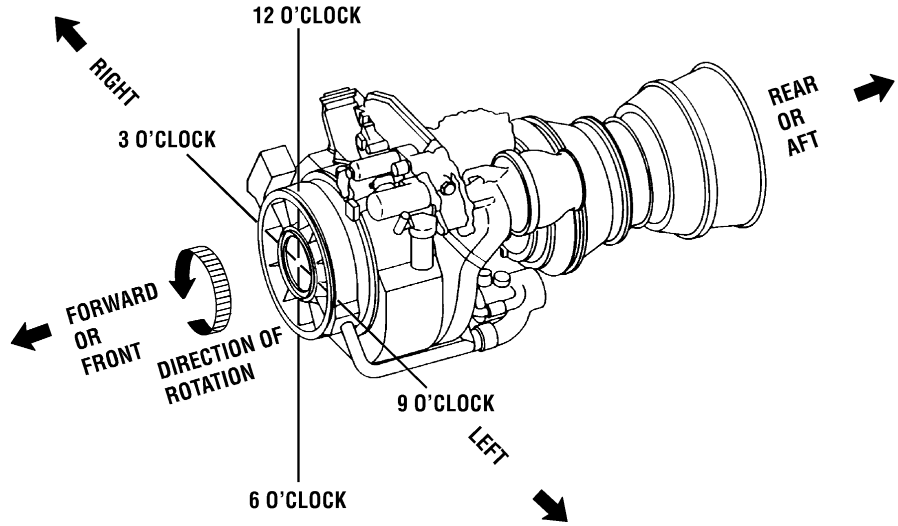
04-94-26

NOTES

B. T700-GE-701/701C characteristics

MANUFACTURER:	General Electric Aircraft Engines, Lynn, MA.
MODEL:	T700-GE-701/701C
TYPE OF ENGINE:	Turboshaft
OUTPUT POWER:	T700-GE-701: 1690 SHP IRP (30 minute limit) T700-GE-701C: 1800 SHP IRP (30 minute limit) 1890 SHP Maximum (10 minute limit) 1940 SHP Contingency (2.5 minute limit)
TYPE OF COMPRESSOR:	Combined axial/centrifugal consisting of 6 stages, 5 axial and one centrifugal.
VARIABLE GEOMETRY:	Inlet guide vanes, stage 1 and 2 stator vanes
COMBUSTOR:	Single annular chamber with axial flow
ENGINE WEIGHT (DRY):	427 lbs. (dry) no oil or fuel
LENGTH:	46.12 inches (117 centimeters)
DIAMETER:	25 inches
LOCATIONS:	All locations, clock positions, and directions of rotation are as viewed from the rear.
DIRECTION OF ROTATION:	Direction of rotation is clockwise.
TIME BETWEEN OVERHAUL:	The engine has no designated time between overhaul limit and is overhauled on a condition basis only.
LOCKWIRE:	Lockwire has been replaced by self-locking nuts and inserts.
TOOLS:	Maintenance can be accomplished using only 10 hand tools.
LRU RETENTION:	Line replaceable units (LRU's) are retained with captive bolts.
LINES AND HOSES:	External lines and hoses for fuel and oil have been reduced by internal routing.

ENGINE ORIENTATION



83-621

NOTES

C. Directional references and stations

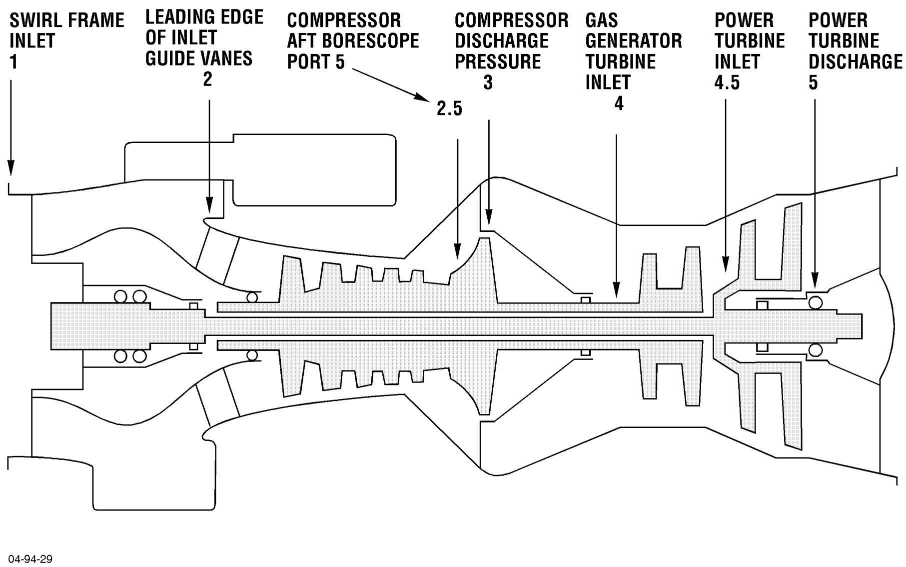
1. Directional references

a. All directional references are common to the -701 and the -701C engines.

b. All locations are oriented to clock positions, as viewed from the rear (aft) of the engine.

c. The direction of rotation of the gas generator and power turbine rotors are clockwise, as viewed from the rear (aft) of the engine.

ENGINE STATIONS



NOTES

2. Engine stations

   a. The engine station designation system has been devised to identify certain locations, along with temperature and pressure parameters.

   b. The station system coincides with various components to simplify location descriptions and parts recognition.

      (1) Station number 1 - swirl frame inlet

      (2) Station number 2 - compressor inlet; leading edge of inlet guide vanes (IGVs). (i.e. T-2 air)

      (3) Station number 2.5 - compressor aft borescope ports

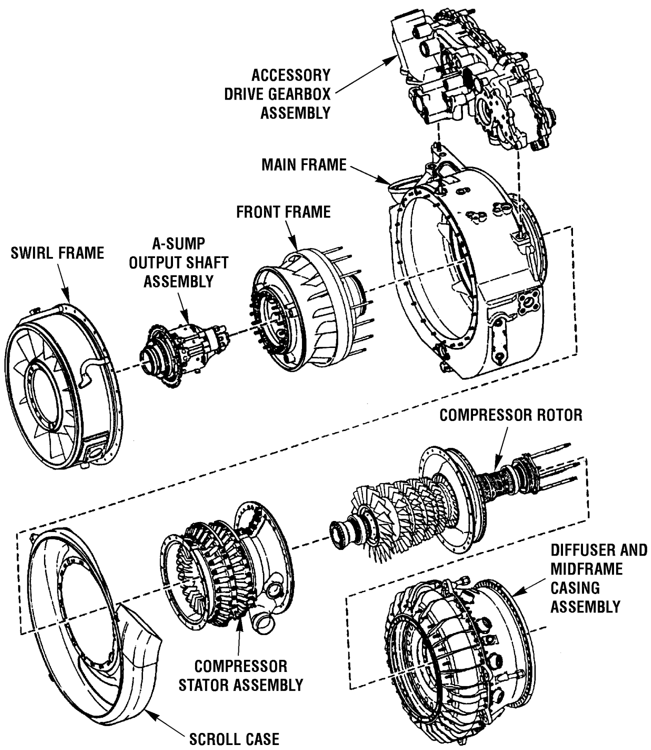
      (4) Station number 3 - diffuser case to midframe flange-compressor discharge (i.e. P-3 air)

      (5) Station number 4 - leading edge; stage 1 turbine nozzle-turbine inlet

      (6) Station number 4.5 - thermocouple ports-power turbine inlet (i.e. T4.5. This is the designation given to TGT in TM 55-2840-248-23.)

      (7) Station number 5 - power turbine casing to exhaust frame flange-power turbine discharge

T700-GE-701/701C MAJOR ENGINE COMPONENTS (1)



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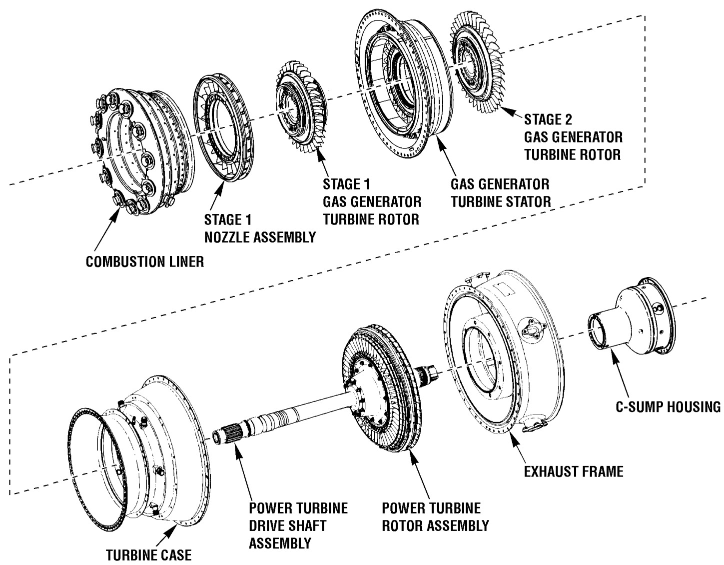
NOTES

D. T700-GE-701 Engine - major components:

1. Accessory drive gearbox assembly
2. Swirl frame
3. A-sump output shaft assembly
4. Front frame
5. Main frame
6. Scroll case
7. Compressor stator assembly
8. Compressor rotor
9. Diffuser and midframe casing assembly

T700-GE-701/701C
MAJOR ENGINE COMPONENTS (2)



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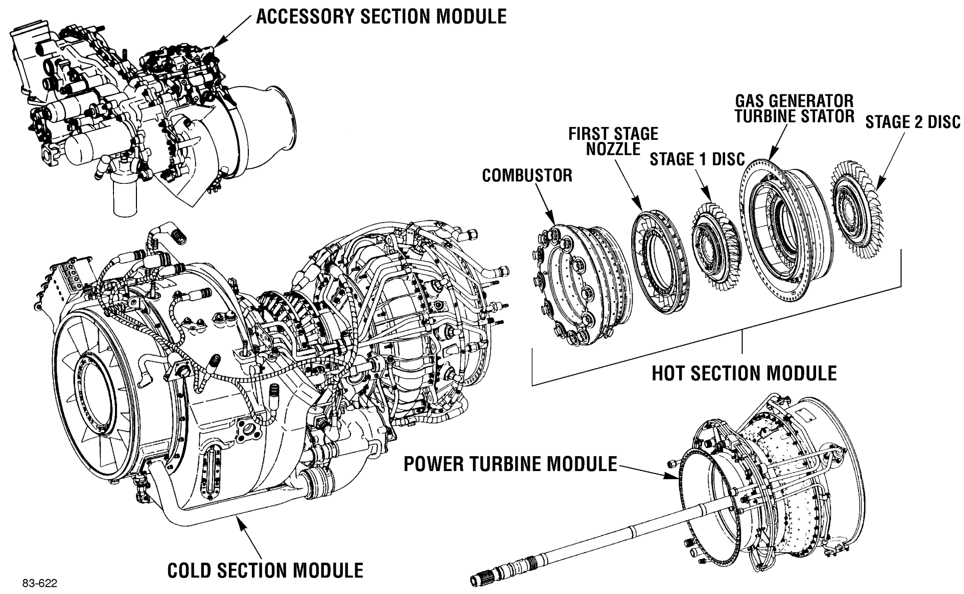
NOTES

10. Combustion liner
11. Stage 1 nozzle assembly
12. Stage 1 gas generator turbine rotor
13. Gas generator turbine stator
14. Stage 2 gas generator turbine rotor
15. Turbine case
16. Power turbine drive shaft assembly
17. Power turbine rotor assembly
18. Exhaust frame
19. C-sump housing

26-12

ENGINE MODULES



NOTES

E. Engine modules

1. The engine is divided into four modules:

   a. Cold section module

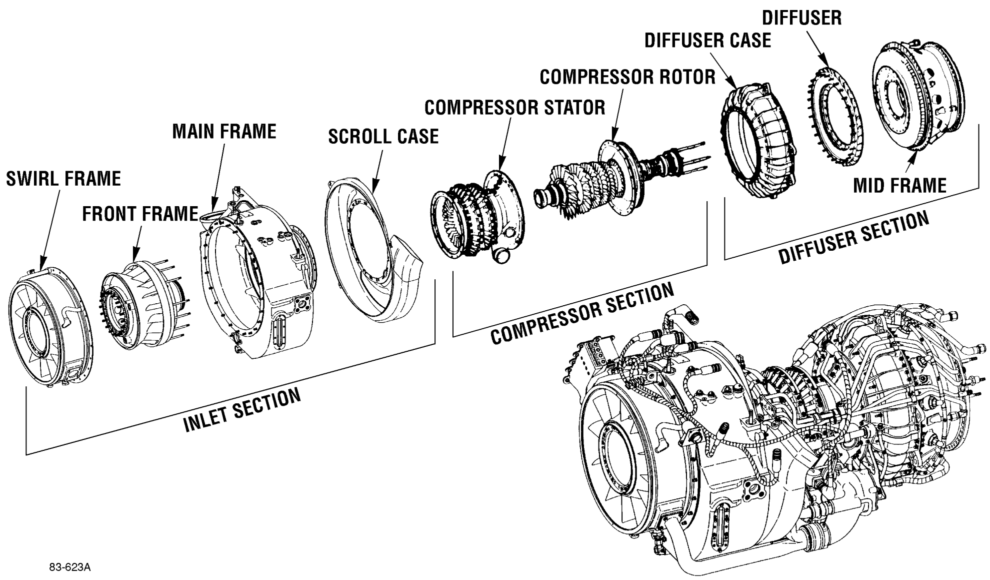
   b. Hot section module

   c. Power turbine module

   d. Accessory section module

2. The module concept allows replacement of entire subsystems in a minimum amount of time.

COLD SECTION
MODULE COMPONENTS



NOTES

F. Cold section module.

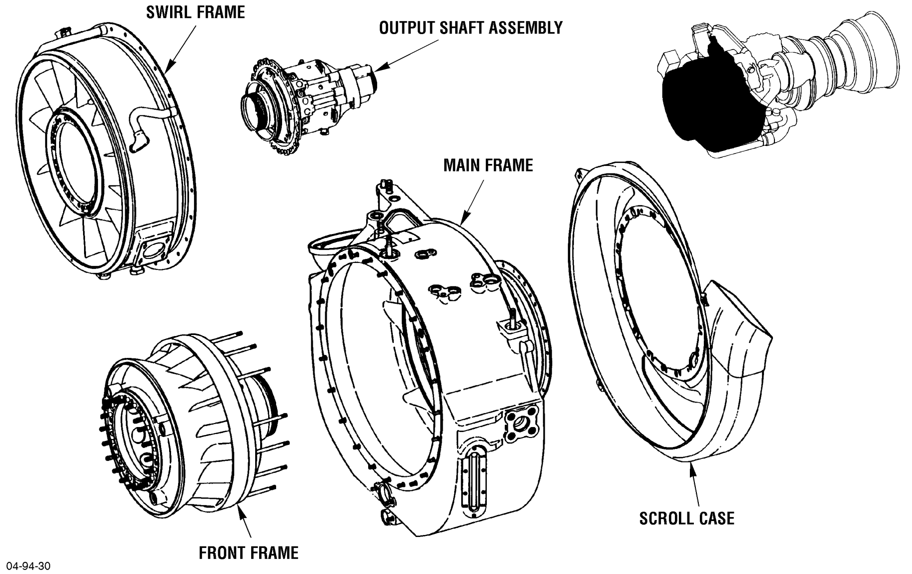
1. The cold section module consists of the following sections.

a. Inlet section

b. Compressor section

c. Diffuser section.

INLET SECTION



NOTES

G. Inlet section

1. Cleans and directs airflow.

2. The inlet section consists of the swirl frame, front frame, main frame, and scroll frame.

a. Swirl frame

(1) Causes intake air to swirl for particle separation.

(a) Houses 12 fixed swirl vanes that induce rotation to the airflow.

(b) The swirl vanes are hollow to accept de-icing bleed air.

(2) Houses engine wash manifold to allow internal cleaning of the compressor inlet area.

(3) The inner hub of the swirl frame supports the output shaft assembly and contains a bolt circle for engine/powertrain interface.

(4) The swirl frame outer shell contains integral tubing for the engine lubrication system.

b. Front frame

(1) Straightens airflow for entry into the compressor.

(2) Supports the A-oil sump and output shaft assembly.

(3) Output shaft assembly:

(a) Splined to power turbine driveshaft

(b) Transmits power to the nose gearbox (NGB)

c. Main frame

(1) Supports accessory section module

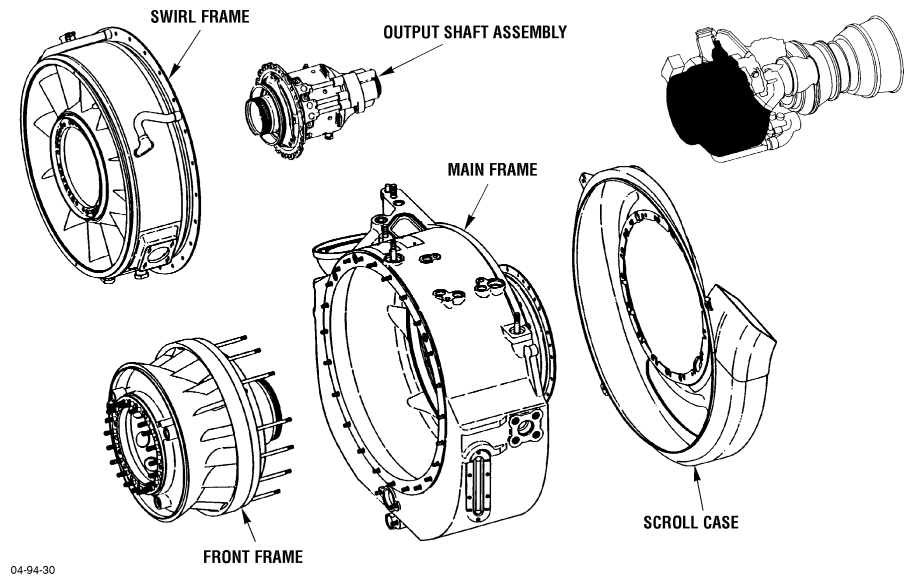
(2) Contains accessory gearbox supports

(3) Forms the outer surface of the compressor inlet flow path

(4) Contains 7 integrally-cast scroll vanes

(5) Houses oil tank and oil level indicators

INLET SECTION



NOTES

(6) Contains a borescope inspection port at the 1 o'clock position

(7) Provides three engine mounting pads

(8) Contains cored passages for the engine lubrication system

(9) The aft hub of the main frame mounts and supports 18 variable inlet guide vanes (IGVs).

(a) The IGV spindles are connected to a lever arm and actuating ring.

(b) Circumferential movement of the actuating ring causes the IGVs to open or close.

(c) IGVs are anti-iced by compressor bleed air.

d. Scroll case

(1) Fiberglass shell

(2) Collects particles from inlet airflow

(3) Provides cooling air for ECU

(4) Attaches to the aft flanges of the main frame

(5) Provides the flow path for scavenging of foreign particles via the inlet particle separator (IPS) blower of the accessory module

(6) Includes cooling port for electronic control unit (Port exists for the digital electronic control unit on the -701C)

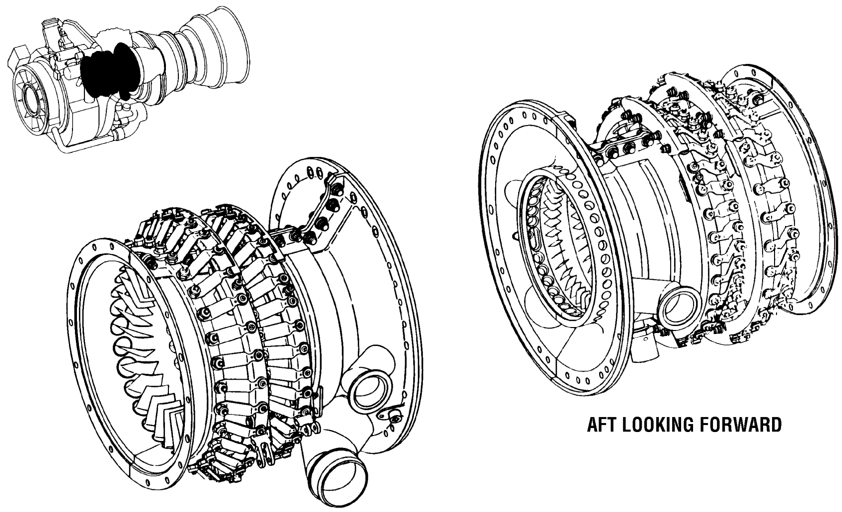
(7) Contains holster for the hydromechanical unit (HMU) T-2 sensor

H. Compressor section

1. Increases air pressure and velocity

2. Consists of a compressor stator assembly and compressor rotor assembly

COMPRESSOR STATOR ASSEMBLY



NOTES

a. Compressor stator assembly

(1) A stator is part of an assembly that remains stationary with respect to a moving part. Stator vanes are the stationary set of airfoils in a compressor.

(2) Stator vanes change the direction of the airflow as it leaves each stage of the compressor and give it proper direction for entrance into the next stage.

(3) Due to stator design, the stator decreases air velocity and increases pressure.

(4) The stator on the T700-GE-701/701C engine has the following characteristics:

(a) Split vertically for maintenance

(b) Made of titanium

(c) First two stages of stator vanes are variable

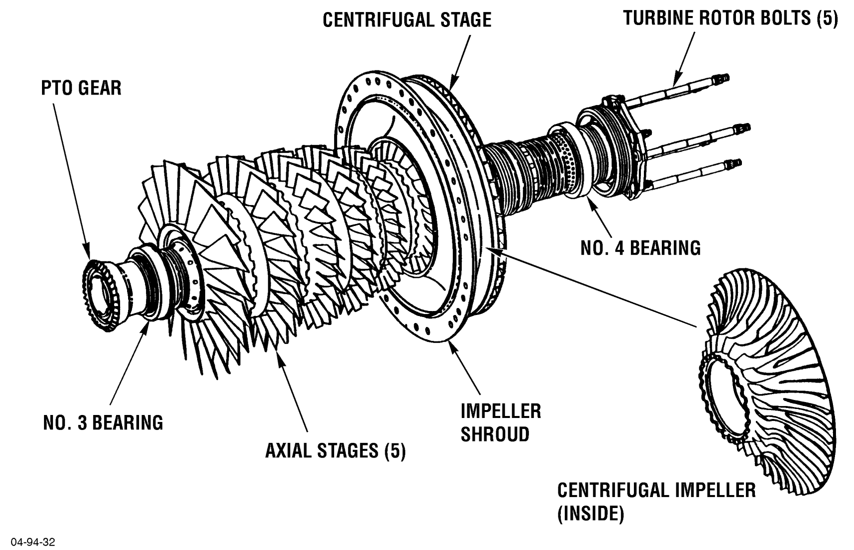
1) Controlled by HMU

2) Aligns air at optimum angle for compression during starts to full power

(d) Last three stages of stator vanes are fixed

(e) Three ports for bleed air

COMPRESSOR ROTOR ASSEMBLY



NOTES

b. Compressor rotor assembly

(1) A compressor rotor consists of rotor blades mounted in disks or a one piece blade disk assembly called a "blisk."

(2) Rotating compressor rotor blades increase air velocity.

(3) The compressor rotor assembly on the T700-GE-701/701C engine has the following characteristics:

(a) Five axial stages

1) Axial stage "blisks" are manufactured by machining the blade and disk as a single unit.

2) 1:1 pressure rise per stage

3) Holes in 4th stage allow bleed air to pressurize seals.

(b) One centrifugal stage - 7:1 to 15:1 pressure rise

(c) The rotor assembly is driven by the gas generator (N_G) section.

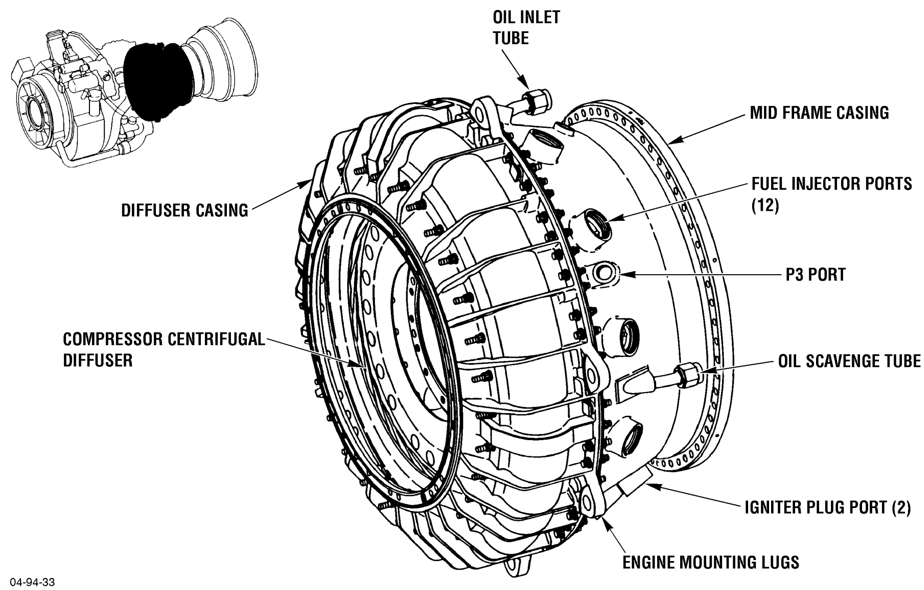
(d) PTO gear provides power to accessory gear box.

(e) The front shaft and stage one blade disk are machined as one piece.

(f) Blisks are bolted together on the compressor tie rod.

(g) The assembly is sealed with polyamide rings.

DIFFUSER AND MIDFRAME ASSEMBLY



NOTES

I. Diffuser section

1. Decreases air velocity and causes increase in air pressure.

2. Consists of the diffuser, diffuser case, and midframe.

   a. Diffuser

      (1) The diffuser increases the compressor discharge area. This reduces the velocity of the air flow, thereby causing the air pressure to increase.

      (2) Once pressurized, the diffuser directs the air to the diffuser case.

   b. Diffuser case

      (1) Directs compressor discharge air to the combustion chamber

      (2) Houses the centrifugal stage of the compressor

      (3) Bolted to the aft flange of the stator case

   c. Midframe

      (1) Houses the combustion liner

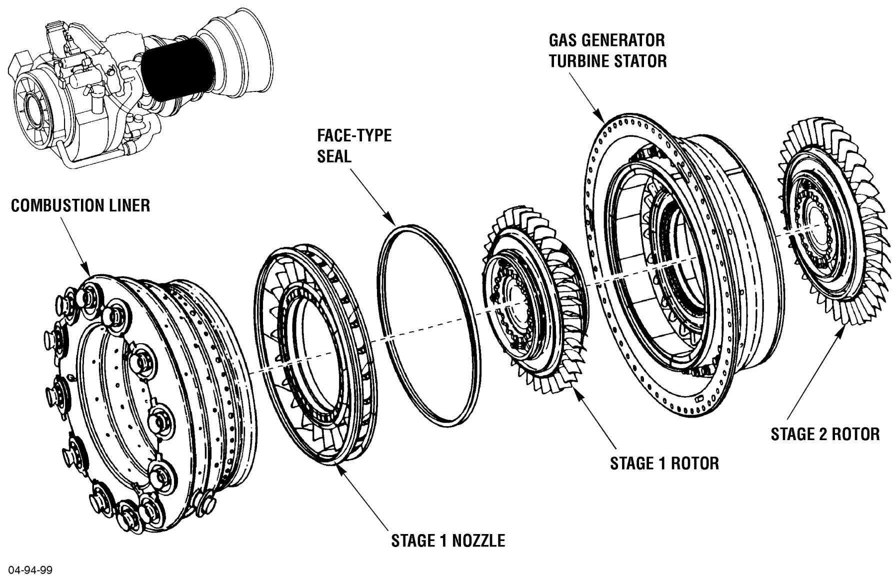
      (2) Has ports for 12 fuel injectors

      (3) Has ports for 2 ignitor plugs

      (4) P3 air port at the 11 o'clock position

      (5) Houses the B sump and associated tubing

HOT SECTION MODULE COMPONENTS



NOTES

A. Hot section module

1. Provides area for mixing fuel and air for combustion.

2. Converts heat energy into mechanical energy to rotate compressor and accessories.

3. 100% N_G = 44,700 RPM.

4. The hot section module consists of the following components.

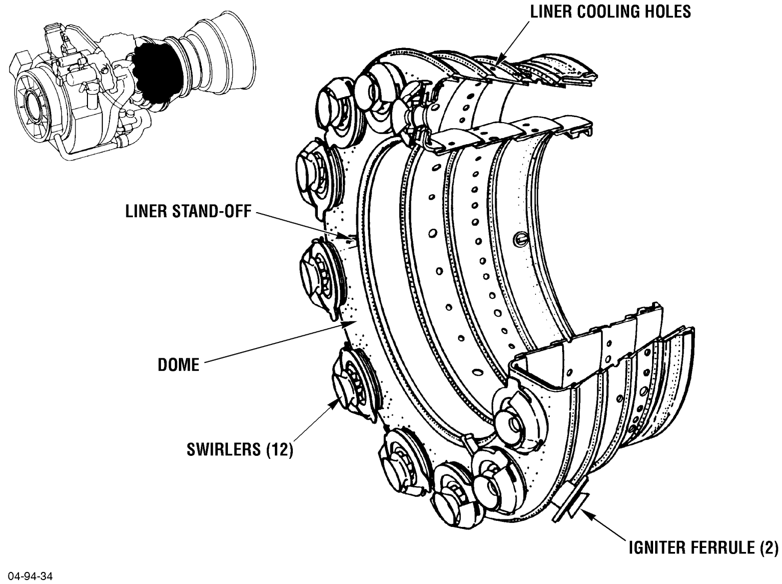
   a. Combustion liner

   b. Stage one nozzle

   c. Gas generator (N_G) stator

   d. Gas generator (N_G) turbine rotor (stages 1 and 2)

COMBUSTION LINER



NOTES

B. Combustion liner

1. Provides area for combustion

2. One piece welded assembly

3. 12 fuel injectors are installed into swirlers in the liner dome. The swirlers create a concentric air vortex pattern that breaks the fuel from the injectors into extremely small particles.

4. Two igniter ferrules provide access for igniters.

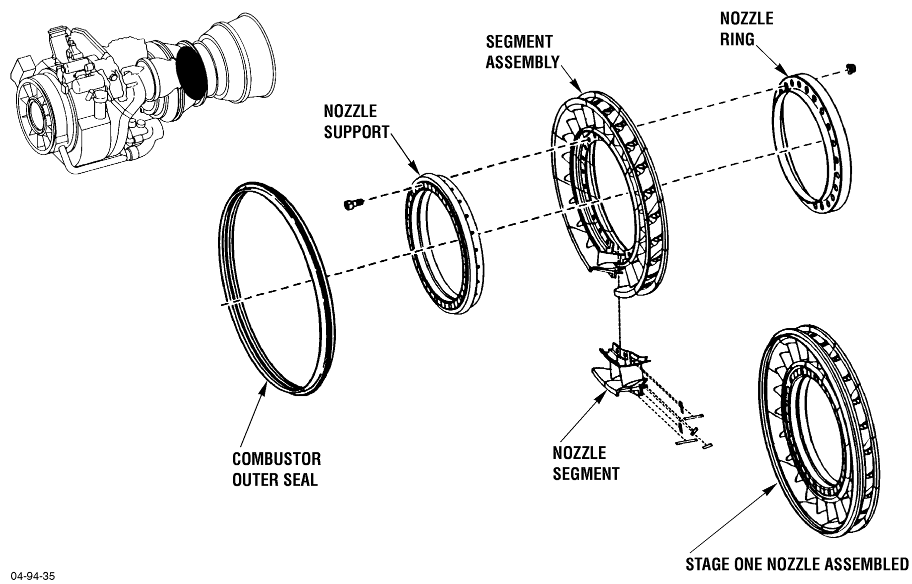
5. Cooling

   a. Liner cooling holes permit secondary air to contain the flame.

   b. Combustion liner cooling holes form a film of air on the inner and outer walls of the liner to prevent liner burning.

   c. Additional cooling occurs when secondary air strikes the dome of the combustion liner.

STAGE ONE NOZZLE COMPONENTS



NOTES

C. Stage one nozzle assembly

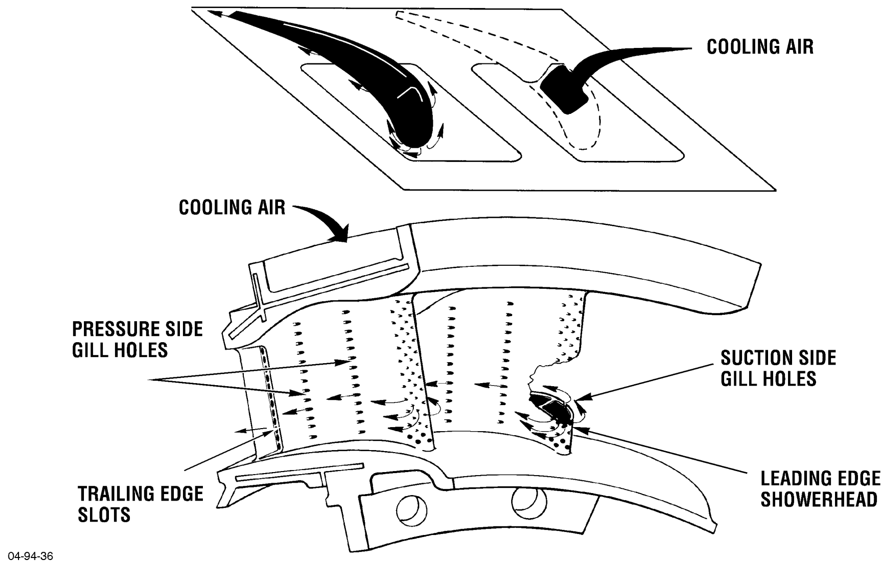
1. Directs air flow from combustion liner to proper angle for the stage 1 gas generator turbine disc.

2. Contains 24 air cooled vanes cast in pairs. (segments)

3. Hottest area of the engine.

4. The stage one nozzle is a convergent duct, therefore the velocity of the air increases as it passes through the nozzle. This allows the rotors to extract mechanical energy from the hot expanding gases. (Potential energy is changed to kinetic energy.)

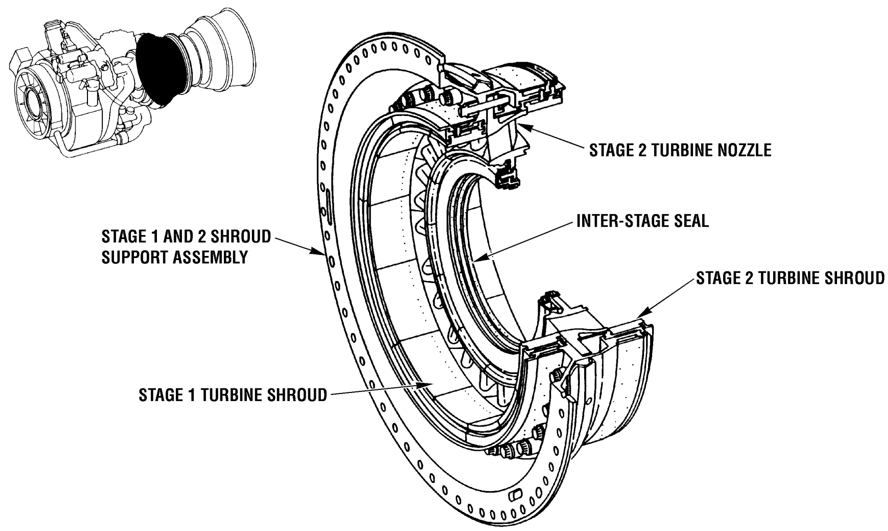
STAGE ONE TURBINE NOZZLE COOLING



NOTES

5. Cooling - The stage one nozzle is cooled by compressor discharge air (P_3).

GAS GENERATOR TURBINE STATOR



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NOTES

D. Gas generator turbine stator

1. Houses the stages one and two gas turbine generator rotor and the stage two turbine nozzle segments.

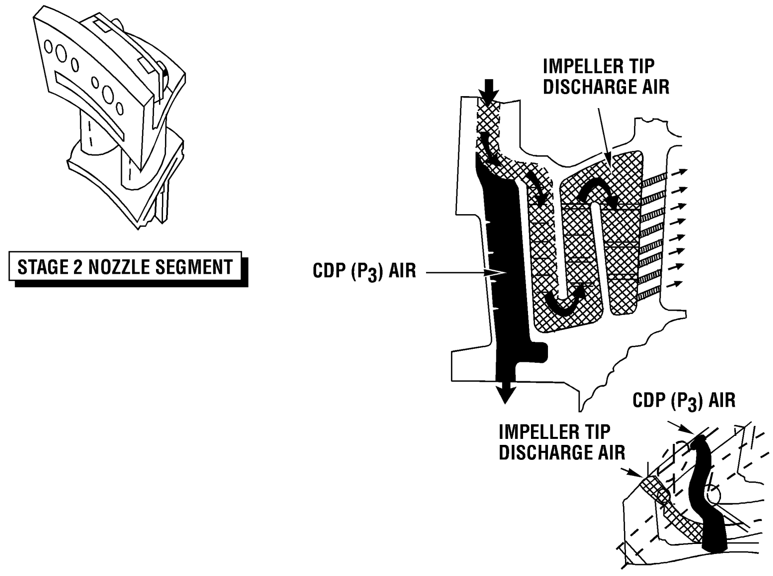
2. The stator is air-cooled by centrifugal compressor impeller tip leakage.

3. Turbine shrouds

   a. T701 - Stainless steel

   b. T701C - Ceramic material

STAGE TWO TURBINE NOZZLE COOLING



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NOTES

4. Stage two turbine nozzle

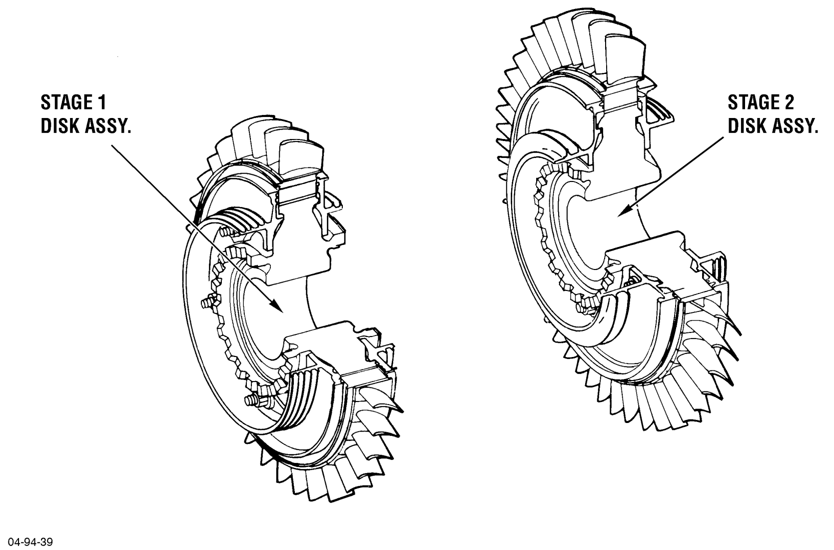
   a. Directs air flow from the stage 1 gas generator turbine disk to the proper angle for the stage 2 gas generator turbine disk.

   b. -701 model uses a straight-through flow design.

   c. -701C model uses serpentine cooling and turbulators.

   d. The stage 2 turbine nozzle uses compressor discharge air (P_3) and centrifugal compressor impeller tip leakage for cooling.

GAS GENERATOR TURBINE ROTOR ASSEMBLY



NOTES

E. Gas generator (N_G) rotor assembly

1. Extracts heat energy from the exhaust gases to drive the compressor and AGB.

2. The rotor assembly is a two-stage air cooled, high performance axial design of simple, rugged construction.

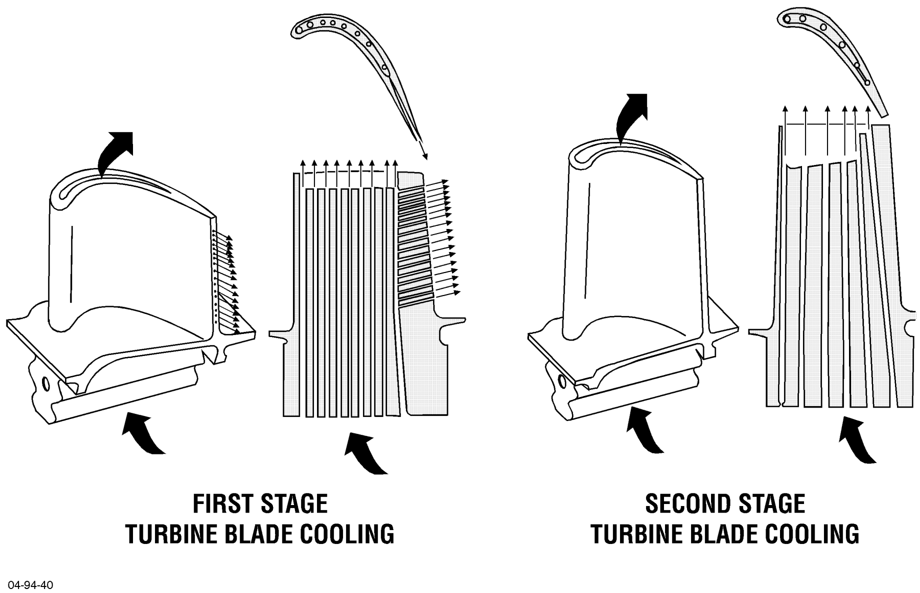
   a. The first stage of the gas generator rotor consists of a turbine disk, 34 air-cooled blades and dampers, forward and rear cooling plates, and five clamping bolts and nuts.

   b. The second stage is similar in construction but has 38 blades and is not dampened.

3. Both stages are bolted to gas generator turbine shaft by five long tie-bolts captive in the shaft.

4. Turbine blade cooling

FIRST AND SECOND STAGE TURBINE BLADE COOLING (-701)



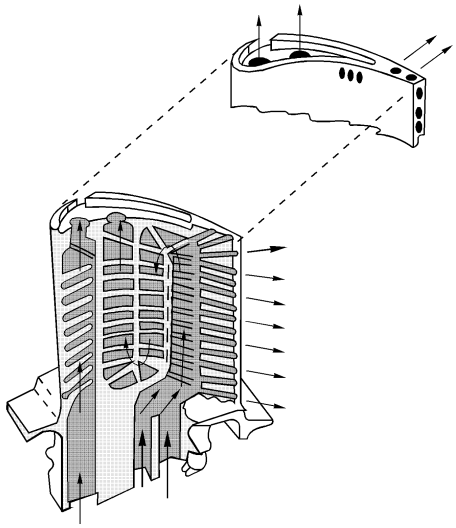
NOTES

a. -701 engine

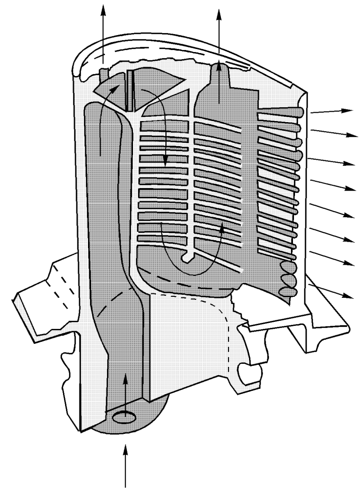
(1) Cooled by compressor discharge air (P_3).

(2) -701 turbine blades use a straight-through flow design for cooling.

FIRST AND SECOND STAGE TURBINE BLADE COOLING (-701C)



FIRST STAGE TURBINE BLADE COOLING



SECOND STAGE TURBINE BLADE COOLING

04-94-41

NOTES

b. -701C engine

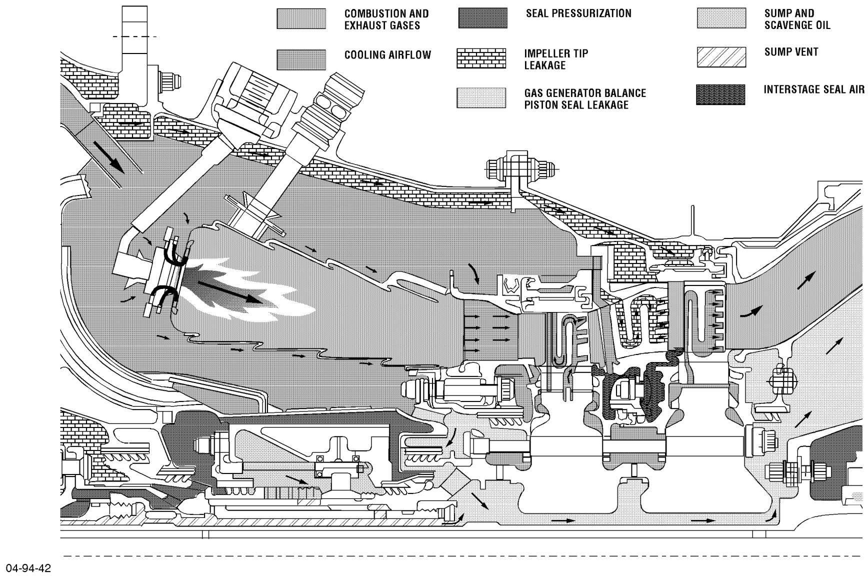
(1) Cooled by compressor discharge air (P_3).

(2) Stage 1 and 2 blades are cooled using turbulators and serpentine cooling.

(3) The use of serpentine cooling and turbulators allows for more metal surface-to-air heat convection.

(4) The greater heat convection allows the -701C model to operate at higher temperatures, thus producing more horsepower than the -701 model. (1,800 SHP for the -701C vs. 1,690 SHP for the -701)

HOT SECTION AIRFLOW



NOTES

F. Hot section airflow

1. Approximately 25% of the air from the compressor is used for combustion, the rest is used to cool the engine and pressurize seals.

   a. Primary air is routed into the combustion section to be used for combustion.

      (1) The primary air enters the combustion liner, is combined with atomized fuel, and ignited.

      (2) As the air is heated by the combustion process its volume increases, but its pressure remains relatively constant.

   b. Secondary air is routed into the combustion section for cooling.

      (1) The secondary air forms an air blanket around the burning gases and dilutes the temperature. This ensures that the turbine section is not destroyed by excessive heat.

      (2) Secondary air is controlled and directed by holes and slots in the combustor liner that creates an insulating layer of air along the inner wall of the combustor liner. The insulating layer prevents burning of the liner walls.

2. The air from the combustion liner then enters the stage one turbine nozzle.

   a. The turbine nozzle is a convergent duct that causes an increase in velocity and directs the air at the best angle to strike the turbine rotor blades.

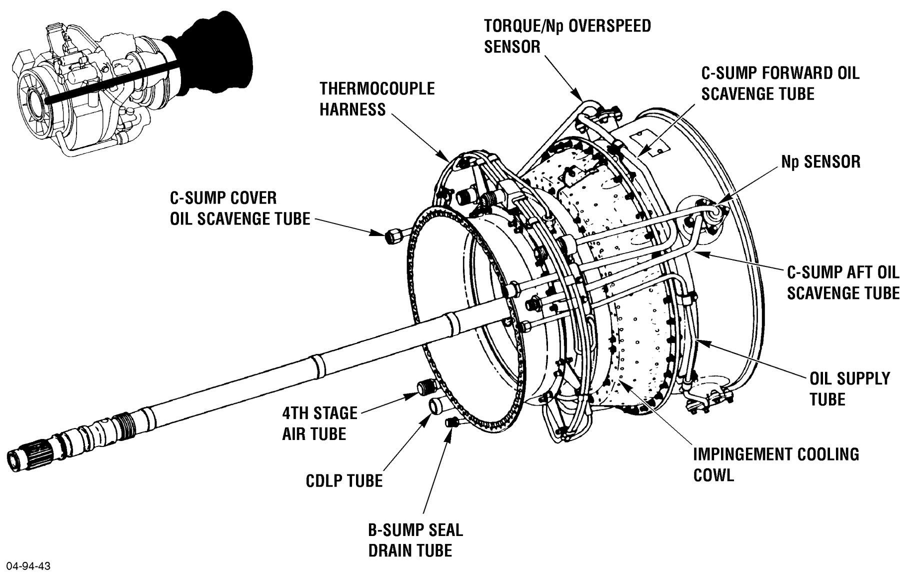
   b. As the air strikes the blades, it causes the turbine rotor blade disk to turn. This is where the energy from the combustion process is extracted.

   c. The first two stages of turbine rotors are bolted together on a shaft that rotates the compressor rotor.

   d. Nearly three-fourths of all of the energy available from the combustion process is used by the N_G section to drive the compressor rotor. This is also where the most of the secondary air is used to cool the turbine nozzles and rotor blades.

   e. The stage one nozzle is the hottest part of the engine and its ability to withstand heat is the limiting factor when considering how much horsepower the engine can produce.

POWER TURBINE MODULE



NOTES

071-626-12

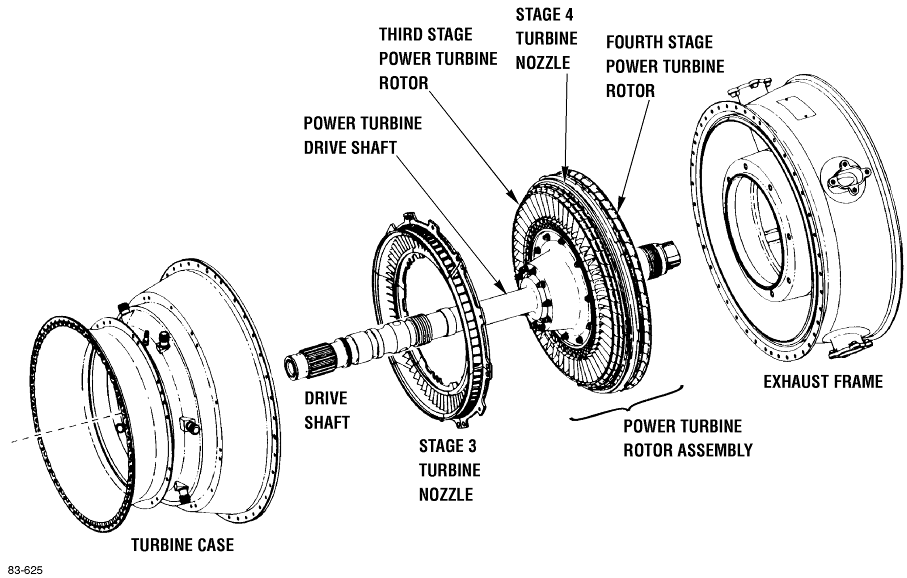
A. Power turbine module

1. Converts heat energy into mechanical energy to drive the aircraft powertrain.

2. The power turbine module is completely uncooled except for the turbine case on T701C.

3. 100% N_P = 20,900 RPM.

POWER TURBINE MODULE COMPONENTS



NOTES

4. The power turbine module consists of the following major components.

   a. Turbine case

   b. Stage 3 turbine nozzle

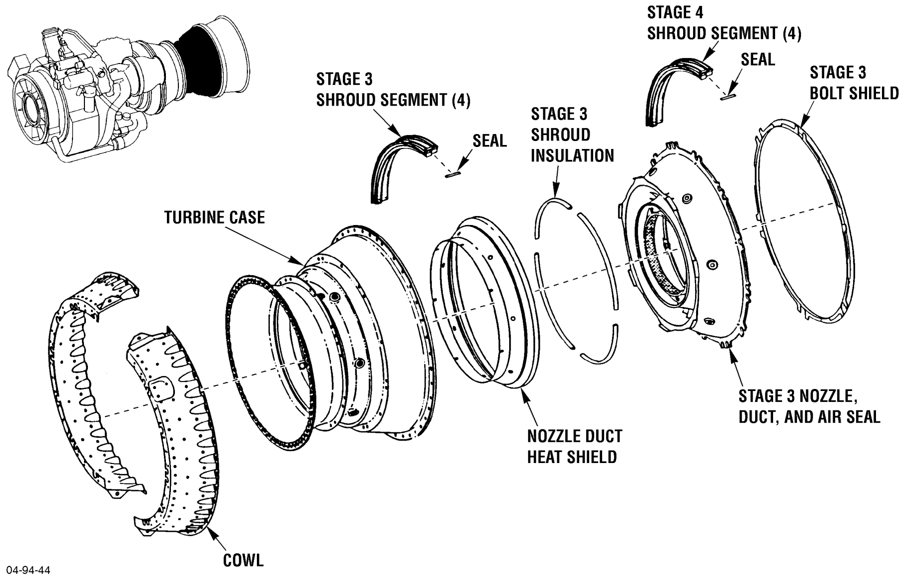
   c. Stage 4 turbine nozzle

   d. Power turbine (N_P) rotor assembly

   e. Drive shaft

   f. Exhaust frame

POWER TURBINE STATOR COMPONENTS



NOTES

B. Turbine case

1. Houses the power turbine rotor assembly and stage 3 turbine nozzle.

2. The T700 and T701 turbine case is a welded fabrication that is uncooled.

3. The T701C turbine case is a casting that is cooled by an impingement cooling cowl. Cooling is necessary because the material and method of manufacture of the T701C turbine case has a larger coefficient of expansion than that of the T701 turbine case.

   a. The cooling cowl is a stainless steel two-piece assembly.

   b. Engine bay air is drawn through impingement holes in the cowl, across the casing skin, and exhausted through an ejector in the turbine case/exhaust frame joint.

4. Blade tip shrouds are housed in the casing.

   a. There are four 90E sectors per stage.

   b. The shrouds are open honeycomb construction.

   c. The shrouds provide a close tolerance between the turbine case and the power turbine rotor blade shrouds.

5. The thermocouple assembly is installed on the turbine case.

C. Stage 3 turbine nozzle

1. Directs air flow from the gas generator rotor to the proper angle for the stage 3 power turbine rotor.

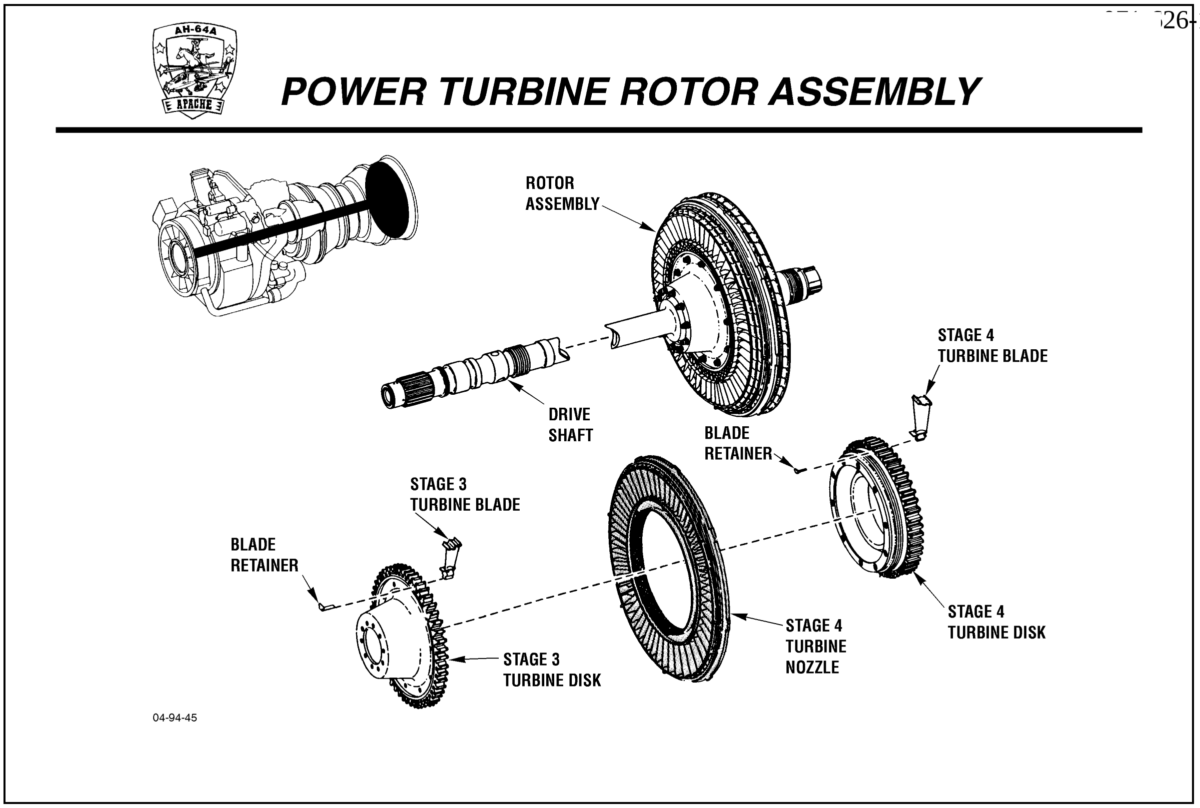
2. The stage 3 nozzle is a one-piece nozzle duct assembly.

D. Stage 4 turbine nozzle (not shown)

1. Directs air flow from the stage 3 power turbine rotor to the proper angle for the stage 4 power turbine rotor.

2. The stage 4 nozzle is a one-piece casting.

3. The stage 4 nozzle is sandwiched between stage 3 and 4 rotors, but is stationary.


AH-64A
APACHE
POWER TURBINE ROTOR ASSEMBLY
ROTOR ASSEMBLY
DRIVE SHAFT
STAGE 4 TURBINE BLADE
BLADE RETAINER
STAGE 3 TURBINE BLADE
BLADE RETAINER
STAGE 4 TURBINE NOZZLE
STAGE 4 TURBINE DISK
STAGE 3 TURBINE DISK
04-94-45

NOTES

E. Power turbine (N_P) rotor assembly

1. The power turbine (N_P) rotor assembly converts energy from the exhaust gases into mechanical energy to drive the helicopter powertrain.

2. The power turbine (N_P) rotor assembly consists of stage 3 and 4 turbine disks bolted to the drive shaft.

   a. Supported by the number 5 and 6 bearings at the rear.

   b. Rotor blades

      (1) The blades are tip shrouded to reduce blade vibration.

      (2) The weight of the shrouded tip is offset by the blades being thinner and more efficient.

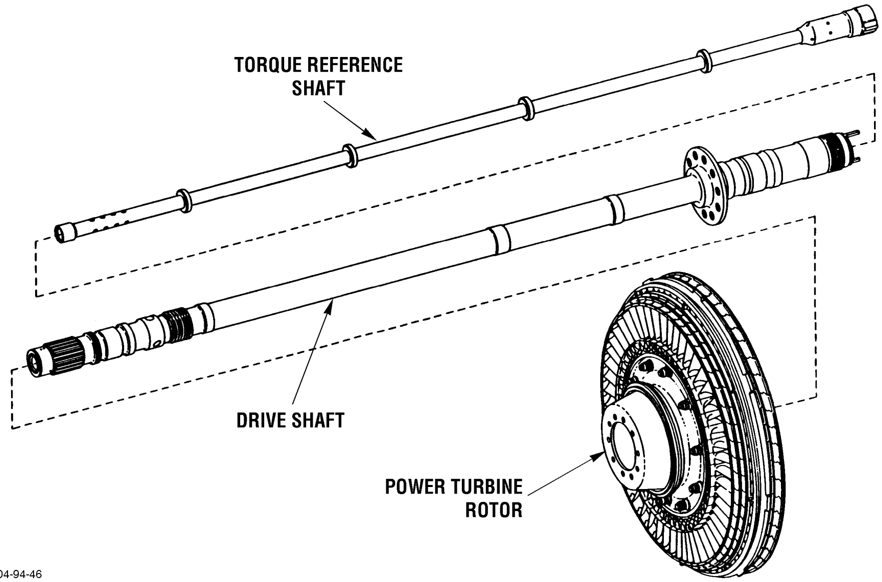
      (3) The blades are attached to the disk by a conventional dovetail and retained by locking strips.

      (4) The outside of the shroud has a knife-edge seal that fits in close tolerance to the turbine case shrouds. The knife edge seal:

         (a) Reduces air losses at blade shroud tips.

         (b) Keeps airflow in an axial direction.

DRIVE SHAFT ASSEMBLY



NOTES

F. Drive shaft assembly

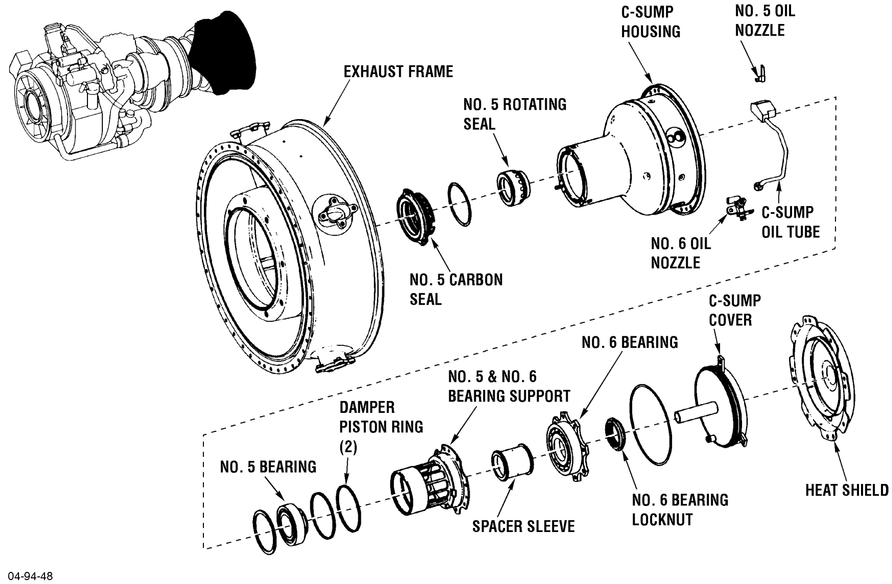
1. Hollow drive shaft

2. Splined at the front to couple with the output shaft

3. Flanged at the rear to accept the power turbine rotor

4. The torque sensor reference shaft is assembled inside the driveshaft and pinned at the forward end.

EXHAUST FRAME COMPONENTS



NOTES

G. Exhaust frame

1. Provides a diffusing exhaust path.

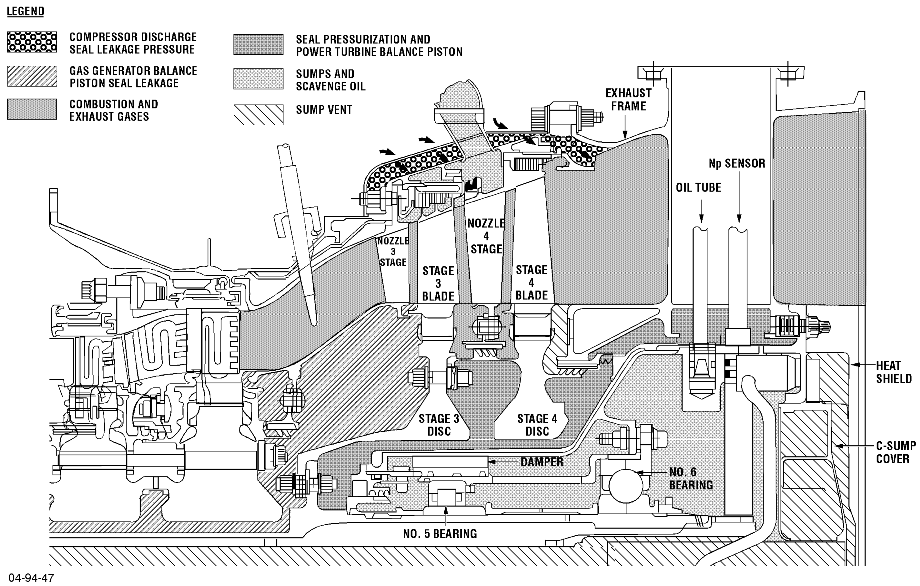
2. Contains the C-sump.

3. Bolts to the aft flange of the power turbine case.

4. Four struts support the C-sump and provide housings for oil and scavenge lines, and the torque and overspeed sensors.

5. The C-sump contains the number 5 and 6 main engine bearings.

POWER TURBINE AIRFLOW



NOTES

H. Power turbine airflow

1. Power turbine balance piston

   a. Uses 4th stage bleed air to counteract the rearward axial thrust of the power turbine rotor assembly.

   b. This reduces the axial thrust load on, and increases the life of, the number 6 main engine bearing.

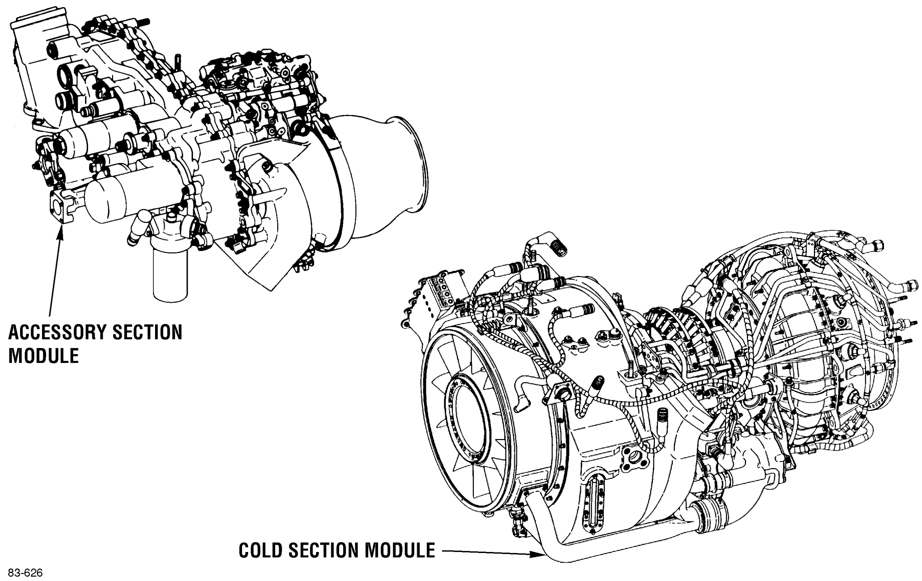
2. 4th stage bleed air

   a. Pressurizes the No. 5 carbon seal and the power turbine balance piston seal in the C-sump.

   b. Piped externally from the 5 o'clock position on the compressor stator to the 4:30 o'clock position on the exhaust frame.

3. TGT thermocouple elements - The thermocouple elements extend into the exhaust gas stream and are installed in front of the stage 3 turbine nozzle.

ACCESSORY SECTION MODULE



NOTES

A. Accessory section module

1. The accessory section module includes a top-mounted accessory drive gearbox and attached components.

2. The accessory section module is driven by the compressor rotor through the power takeoff bevel gear and radial drive shaft assembly.

3. The accessory drive gearbox performs the following functions:

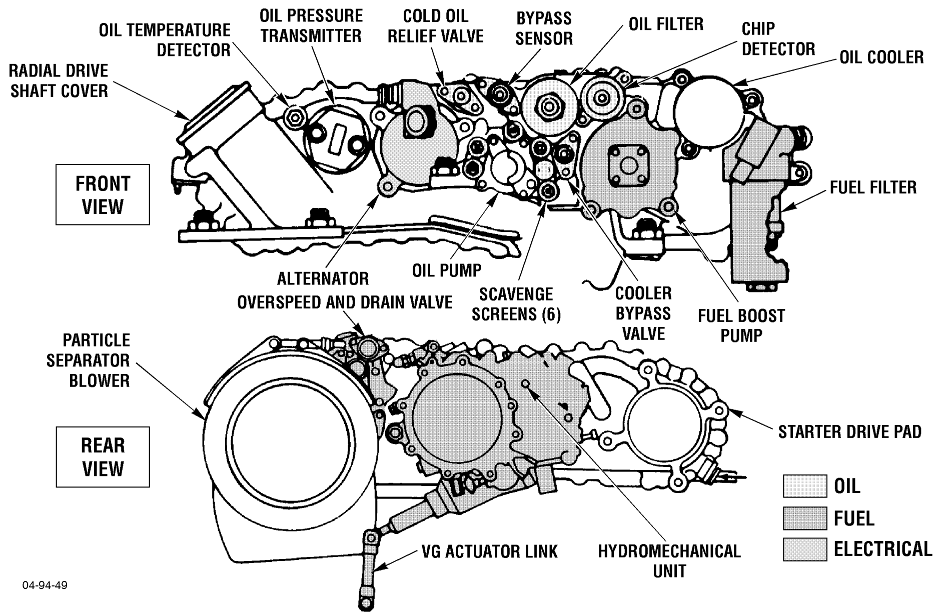
   a. Transmits torque from the air turbine starter during engine starts.

   b. Drives the components that mount on the gearbox pads.

4. The gearbox has internal passages for oil and fuel, thus reducing external lines and fittings.

5. Mounting pads and bosses are provided on the front and rear.

ACCESSORY SECTION MODULE COMPONENTS



NOTES

6. Accessory gearbox components

   a. Lubrication system components

      (1) Oil pressure transmitter

      (2) Cold oil relief valve

      (3) Bypass sensor

      (4) Oil filter

      (5) Chip detector

      (6) Oil cooler

      (7) Oil pump

      (8) Oil cooler bypass valve

      (9) Scavenge screens

   b. Fuel system components

      (1) Overspeed drain valve (ODV)

      (2) Hydromechanical unit (HMU)

      (3) Fuel filter

      (4) Boost pump

   c. Alternator

   d. Air turbine starter

B. Axis identification is as follows:

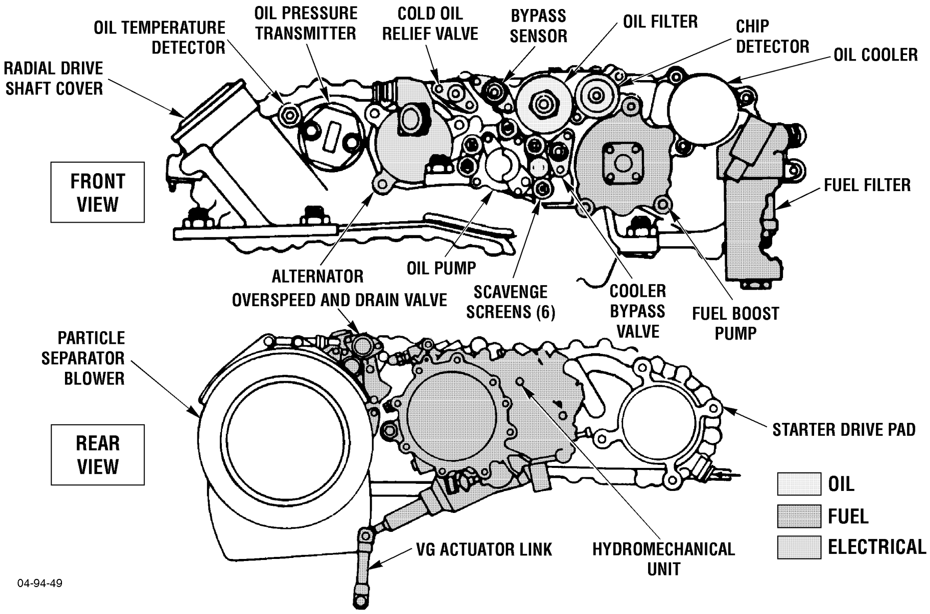
1. Axis A - radial drive shaft

2. Axis B - starter drive (29,045 RPM)*

3. Axis C - idler gear

4. Axis D - alternator (21,357 RPM)*

ACCESSORY SECTION MODULE COMPONENTS



NOTES

5. Axis E - oil pump (forward face) (9,947 RPM)*

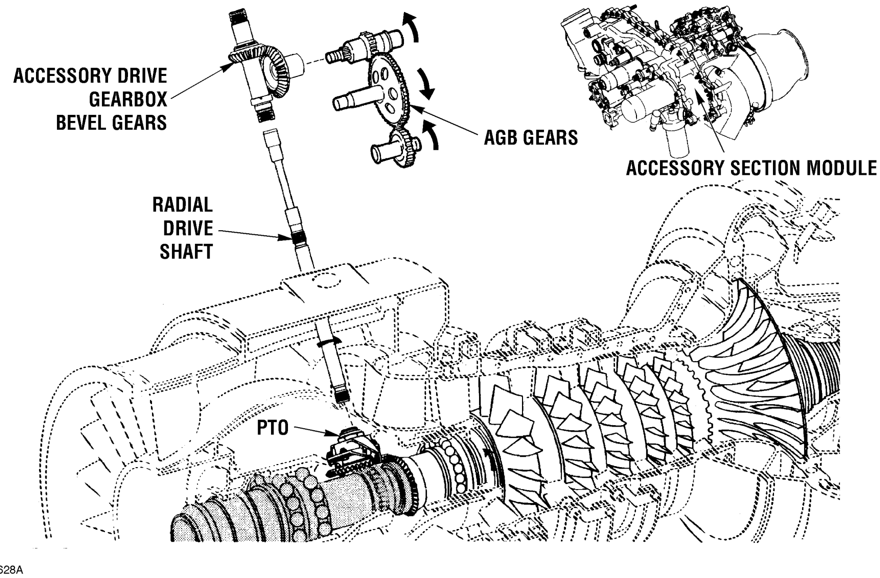
6. Axis E - HMU (aft face) (9,947 RPM)*

7. Axis F - fuel boost pump (10,678 RPM)*

8. Axis G - inlet particle separator (IPS) blower (29,045 RPM)*

*At 44,700 RPM N_G

ACCESSORY SECTION MODULE DRIVE



NOTES

C. Radial drive shaft

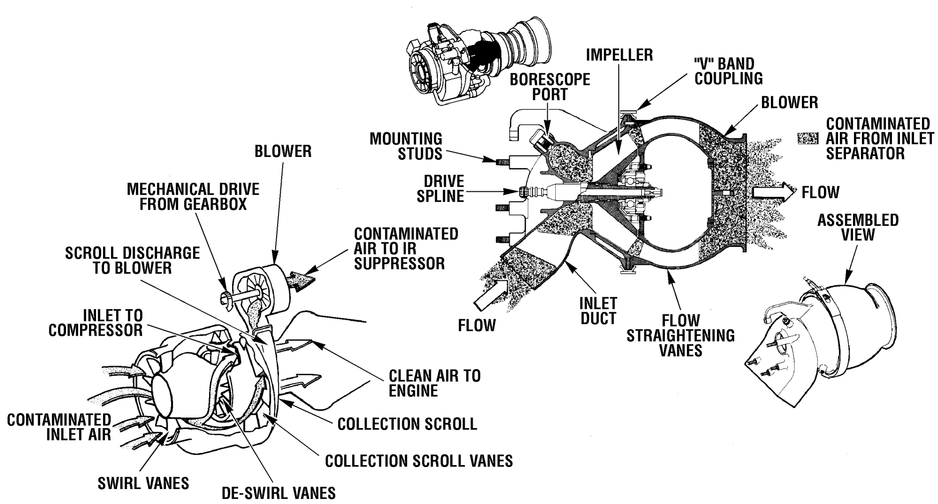
1. Receives torque from the compressor rotor to drive the accessory section module.

2. Transmits torque from the air turbine starter to rotate the compressor rotor for engine starting.

3. Splined at the lower end and connected to the compressor rotor via a bevel gear system.

4. Can be used to manually rotate the compressor section using a socket and ratchet.

INLET PARTICLE SEPARATOR



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NOTES

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D. Inlet particle separator blower

1. Provides suction to draw foreign objects from engine inlet air

2. Made of aluminum alloy

3. Has a single impeller driven at 29,045 rpm at 100% Ng

CLASSIFICATION OF LUBRICANTS

ANIMAL

VEGETABLE

MINERAL

SYNTHETIC

04-94-50

NOTES