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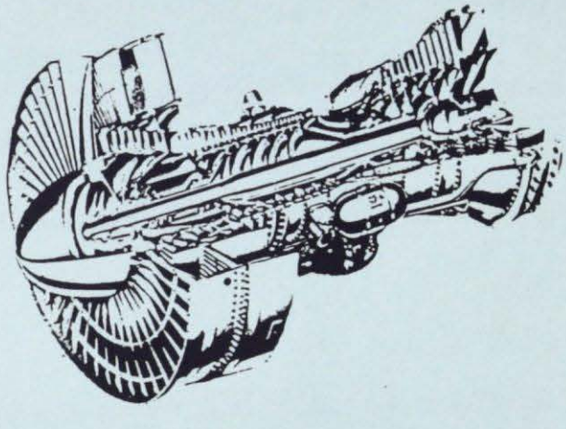
STUDENT WORKBOOK



GAS TURBINES

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GAS TURBINE WORKBOOK

IT IS INTENDED THAT THIS WORKBOOK BE USED UNDER THE SUPERVISION OF AN INSTRUCTOR, WHILE ATTENDING THE COURSE ON "GAS TURBINES".

IT IS NOT INTENDED TO BE A SELF STUDY PROGRAM.

THE FOLLOWING BOOKS ARE REQUIRED FOR REFERENCE PURPOSES:

1. Aviation Technician Integrated Training Program - Powerplant Section (EA-ITPP)
2. Aircraft Gas Turbine Engine Technology (Treager) 2nd Edition
3. Powerplant Handbook EA-AC65-12A
4. The Aircraft Gas Turbine Engine and its Operation (Pratt & Whitney) PWA 200

OBJECTIVES

The objectives of this course is for you to have a basic understanding of:

a) principles of operation of a Gas Turbine,

b) terms used relating to Gas Turbines,

c) various types of Gas Turbines,

d) construction and operation of the principal components,

e) engine systems and accessories,

f) operation, maintenance and safety procedures.

You should be able to carry out routine maintenance and servicing, and use the appropriate manuals to troubleshoot and make adjustments. If you fully understand the basic theory, you will have no problems when attending manufacturer's courses on specific gas turbines.

FOR TRAINING PURPOSES ONLY

NOTE: No information contained in this or any other training manual, supersedes or supplements that contained in any official document relating to the engines described.

GAS TURBINE READING ASSIGNMENTS EA-ITP-P

BOOK/PAGE		SUBJECT	SIGNATURE
2.1 - 9		Introduction & Types of Turbine Engines	
2.10 - 13		Principles of Physics	
2.14 - 21		Principles of Gas Turbine Operations	
2.22 - 26		Gas Turbine Performance	
2.26 - 53		Turbine Engine Design & Construction	
26 - 31	A	Inlet Ducts (7.14 - 16)	
31	B	Accessory Section	
32 - 43	C	Compressor Section (7.17 - 24)	
44	D	Diffuser Section	
44 - 47	E	Combustion Section	
47	F	Turbine Section (7.29 - 32)	
50 - 53	G	Exhaust Section (7.36 - 42)	
2.55 - 76		Inspection & Maintenance	
78 - 81		Turbine Engine Operations	
6.49 - 50		Principles of Turbine Fuel Systems	
50 - 70		Fuel Controls	
70 - 72		Water Inspection	
74		Power Ratings	
74 - 81		Fuel System Components	
83 - 84		Troubleshooting	
8.15 - 30		Lubricating Systems (Turbine)	
3.44 - 52		Ignition Systems	

GAS TURBINE READING ASSIGNMENTS EA-ITP-P

BOOK/PAGE		SUBJECT	SIGNATURE
5.20 -		Engine Instruments	
25 - 27		E.P.R.	
29 - 35		Thermocouple (E.G.T.)	
38 - 39		Engine Tachometers	
42 - 44		Torque	
45 - 50		Instrument Installations & Marking	
5.51 - 59		Fire Protection Systems	
7.48		Starter Systems	
48	A	Electric	
49 - 50	B	Starter Generator	
49 - 53	C	Air Turbine Starter	
53	D	Other Starting System	

AIR TRANSPORT ASSOCIATION SPEC. 100

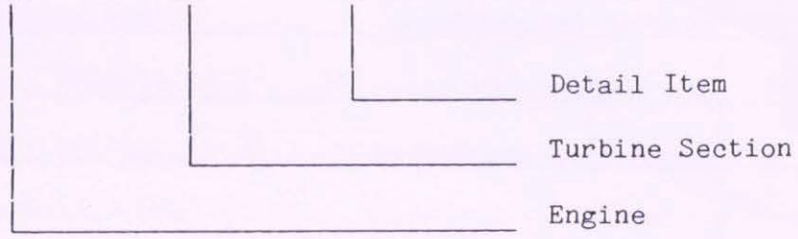
ATA - 100

Almost all major airlines are using aircraft and equipment that utilize the ATA - 100 numbering system. It is also being used by more operators of light aircraft and helicopters. For this reason it is important for you to be familiar with the numbers pertaining to powerplants.

Chap. 70 - Standard Practices for Engines
71 - Powerplant General
72 - Engine (Turbine and Turbo Prop.)
73 - Engine Fuel and Controls
74 - Ignition
75 - Air
76 - Engine Controls
77 - Engine Indication
78 - Exhaust
79 - Oil
80 - Starting

Chapters are also divided into Sections and Detail.

eg. 72 - 50 - 02



ASSIGNMENT #1

Complete the following table by filling in the appropriate chapter, page and paragraph where you will find the required information:

	DC 8 - 63	Locheed 1011	Boeing 727
1. Oil Tank Capacity			
2. Rigging of Power Lever			
3. Igniter Plug Removal			
4. Engine Mount Bolt Torque			

ASSIGNMENT #2

Gas Turbines are classified as Turbo Jet
Turbo Fan
Turbo Prop.
Turbo Shaft

Give three (3) examples of each type, stating the model, manufacturer and aircraft in which each are installed.

TURBO - JET

1. _____

2. _____

3. _____

TURBO - FAN

1. _____

2. _____

3. _____

TURBO - PROP.

1. _____

2. _____

3. _____

TURBO - SHAFT

1. _____

2. _____

3. _____

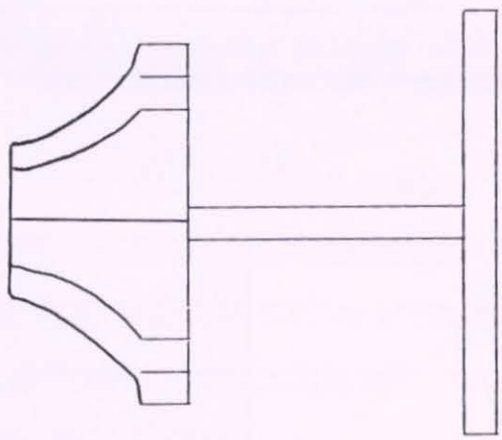
ASSIGNMENT #3

Compile a list of all the gas turbines in the Aircraft Maintenance Department at this Institute. (Include all sectioned and incomplete engines.)

Give the following information after each engine:

1. Manufacturer
2. Model
3. Type of Gas Turbine (Turbo _____)
4. Aircraft Used In
5. Maximum thrust, H.P., or E.S.H.P.
6. Simple line sketch, (components to be in proportion to the size of the engine) showing:
   a) type of compressor,
   b) number of compressor stages,
   c) number of turbine stages,
   d) final drive.

EXAMPLE



ASSIGNMENT #4

Typical Gas Turbine Flow Diagram (ORENDA)

1. Colour in the three graphs. Pressure, temperature and velocity.

2. Colour:
   - Inlet Guide Vanes - Blue
   - Compressor Stators - Green
   - Compressor Rotors - Red
   - Nozzle Guide Vanes - Yellow
   - Turbine Blades - Orange

3. a) What is the maximum pressure in the engine? _____

   b) Where is this pressure? _____

4. What is the air velocity through the compressor?

   _____ to _____

5. a) What is the maximum gas velocity _____ft/sec. _____MPH.

   b) Where is this velocity the maximum? _____

6. a) What is the temperature rise across the compressor?

   _____ degs. C.

   b) What is the temperature drop across the turbine?

   _____ degs. C.

7. a) If the engine is turning at 100%, what is the rpm? _____

   b) If the engine is turning at 35%, what is the rpm? _____

   c) If the engine is turning at 11%, what is the rpm? _____

8. What is the pressure drop through the combustion cans?

   _____ p.s.i.

9. a) What is the gas pressure in the tail pipe _____psig?

   b) What is this in psia? _____

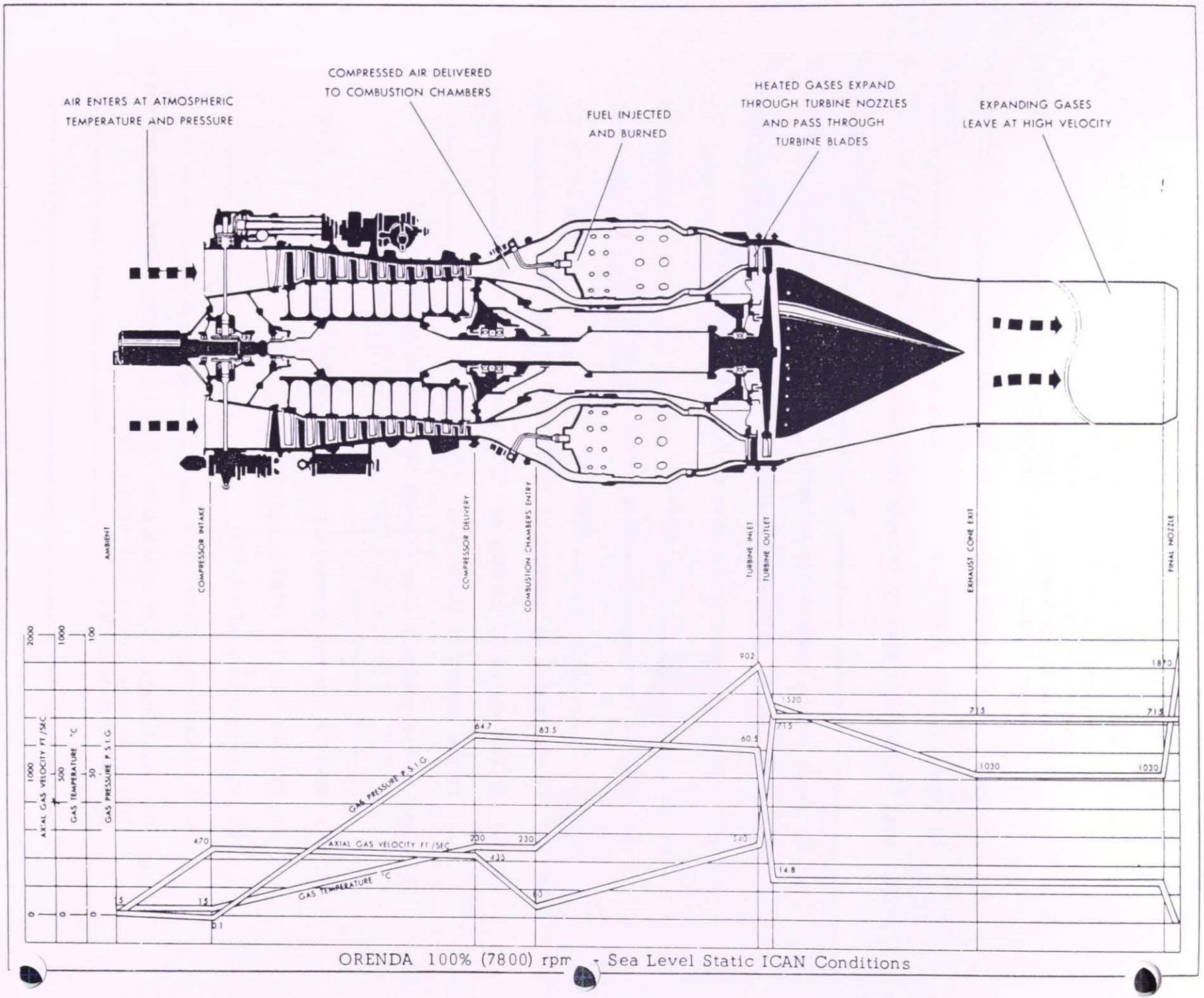
   c) What does psig stand for? _____

   d) What does psia stand for? _____

10. Sea Level Static ICAN Conditions (ICAN is no longer used, you are more likely to come across ICAO conditions).
    Define a STANDARD DAY _____

    _____

TYPICAL GAS TURBINE FLOW DIAGRAM



ORENDA 100% (7800) rpm - Sea Level Static ICAN Conditions

ASSIGNMENT #5

THE THRUST EQUATION

$$F_n = \frac{W_a}{g}(V_j - V_a) + \frac{W_f}{g}(V_j) + A_j (P_j - P_{am})$$

Where F_n - _____

W_a - _____

V_j - _____

V_a - _____

W_f - _____

A_j - _____

P_j - _____

P_{am} - _____

g - _____

1. What is the Net Thrust from an engine under static conditions if the mass air flow is 160 lbs/sec., jet velocity 2,000 ft/sec., fuel flow 900 Imp. gals/hr. (sp. gr. .8), area of jet is 400 sq. ", and the pressure at the jet nozzle is 20 psia. Ambient air pressure 15 psia.

2. What is the net thrust when all conditions are the same except that the engine is travelling at 300 mph, and the mass air flow has increased to 180 lbs/sec.?

NOTE: Newton's 2nd Law

FORCE = MASS + ACCELERATION

or $F = \frac{W}{g} + (V_2 - V_1)$

Net Thrust = Force from accelerating a mass of air rearwards.

plus

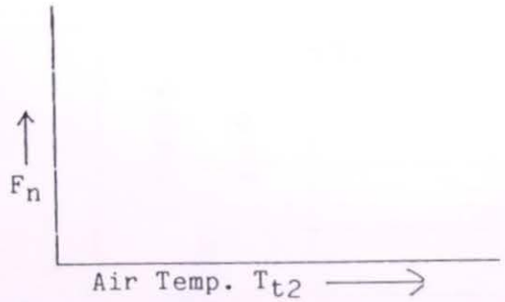
Force from accelerating a mass of fuel rearwards.

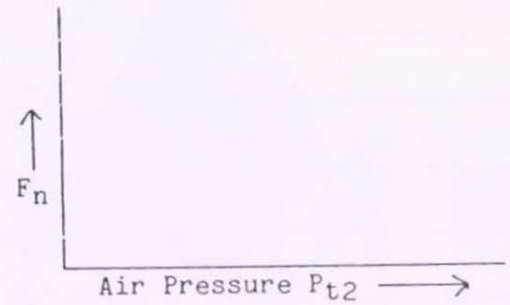
plus

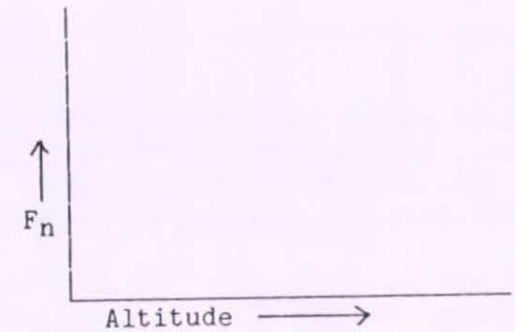
Force from differential pressure at jet nozzle.

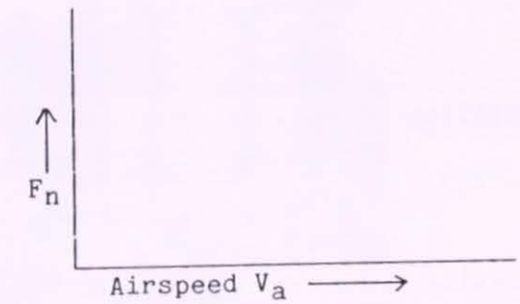
ASSIGNMENT #6

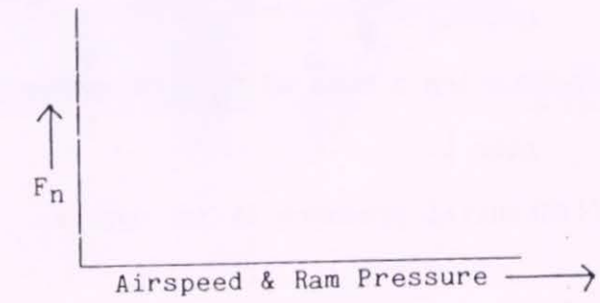
Complete the graphs to show how these variables affect Net Thrust.











GAS TURBINE AND PISTON ENGINE COMPARISON

The gas turbine and the piston are both **"INTERNAL COMBUSTION ENGINES"**, but they operate on different principles.

PISTON ENGINE . . . . . on the OTTO cycle.

GAS TURBINE . . . . . on the BRAYTON cycle.

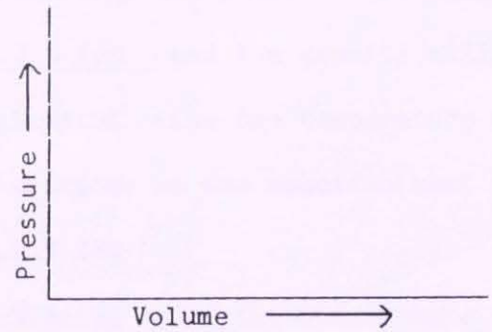
ASSIGNMENT #7

Complete the two Pressure/Volume curves, showing the difference between the two cycles.

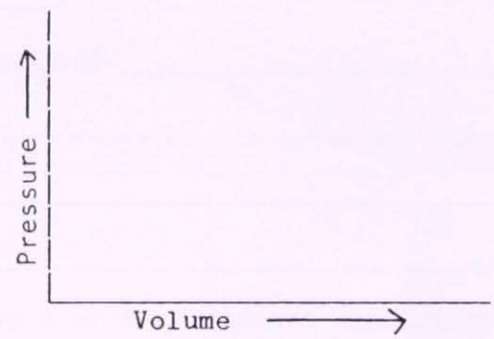
Identify the change in pressure and/or volume by using the numbers:

1 - 2 Compression
2 - 3 Combustion
3 - 4 Expansion
4 - 1
or
4 - 5 Exhaust

OTTO CYCLE



BRAYTON CYCLE



ASSIGNMENT #8

Define the following jet engine terms, symbols or abbreviations.
(Use symbols were applicable)

1) F_g

2) F_n

3) E.P.R.

4) Torque

5) N_1

6) N_2

7) N_g

8) N_f

9) O.A.T.

10) T.A.T.

11) E.G.T.

12) J.P.T.

13) T.I.T.

14) I.T.T.

15) T.T.

16) T_2

17) T_7

18) E.S.H.P.

19) δ

20) θ

21) I.G.V.

22) O.G.V.

23) V.B.V.

24) V.S.V.

25) C.I.T.

26) M.E.C.

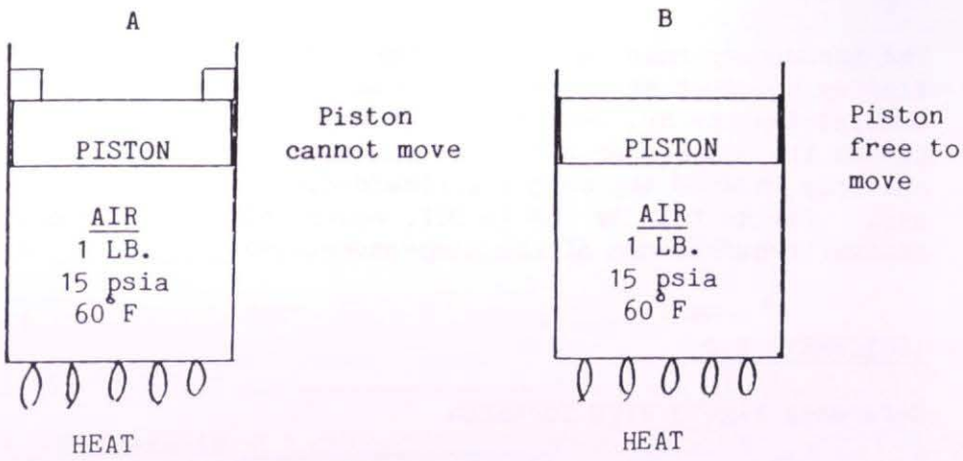
27) C - D

28) T.S.F.C.

29) P.P.H.

30) P_b

ASSIGNMENT #9



Fill in the spaces in questions 1 and 2 with either increase, decrease or same.

1. If heat is applied to cyl. A, the pressure will _____,

   the mass will_____ and the density will _____.

2. If heat is applied to cyl. B, the pressure will _____,

   the mass will _____ and the density will _____.

3. How much heat is required to raise the temperature of "A" one deg. F

   _____ and is known as the specific heat of air at constant

   _____.

4. How much heat is required to raise the temperature of "B" one deg. F

   _____ and is known as the specific heat of air at constant

   _____.

5. Why are these not the same? _____

   _____

   _____

   _____

6. Which of the two above A or B represents what happens when there is a change in atmospheric conditions?

   _____

7. Is it possible for the atmospheric pressure to remain constant while the O.A.T. increases or decreases?

   _____

HORSEPOWER REQUIRED TO DRIVE THE COMPRESSOR

The horsepower requied to drive the compressor or fan can be determined by finding how much energy has been put into the air by the compressor. Multiplying the sp. heat of air at constant pressure by the temperature rise across the compressor will give the energy put into each pound of air. Multiply this be the mass air flow/sec. to give the total energy in one sec.. Divide this by 550 (1 H.P. equals 550 ft-lbs/sec.) to give the horsepower requirements of the compressor.

ASSIGNMENT #10

Reference Fig. 3 JT9D Turbofan

1. What is the mass airflow through the fan? _____ lbs/sec.

2. What is the temp. rise across the fan? _____ degs. F.

3. What is the specific heat of air at constant pressure? _____

4. How many B.T.U.'s to raise the temp. of 1 lb. of air through the fan?

   _____

5. How many B.T.U.'s to raise the temp. of _____ lbs. of air through the fan: _____

   _____

6. If 1 B.T.U. is equal to 778 ft.-lbs. of work, then what is the work per sec. required to drive the fan?

   _____

7. If 1 horsepower equals 550 ft. lbs/sec., then the horsepower required to drive the fan equals:

   H.P. (Fan Air) = _____

   _____

   H.P. (Primary Air) = _____

   _____

   Total H.P. = _____

   _____

   _____

   NOTE: There is no need to work out each step. You may use a calculator to help arrive at the correct answer.

ASSIGNMENT #11

Complete the following statements.

1. 990 degs. C. = _____ degs. F. = _____ degs. R.

2. 990 degs. F. = _____ degs. C. = _____ degs. R.

3. 1970 degs. F. = _____ degs. C. = _____ degs. R.

4. The Greek symbol for Delta is _____.

   Theta is _____.

   Beta is _____.

   Alpha is _____.

5. The formula for the speed of sound is ft/sec. where the temperature is known in degs. Rankine is _____

6. Speed of sound at -40 degs. F. = _____ ft/sec.

7. Speed of sound at 60 degs. F. = _____ ft/sec.

8. Speed of sound at 850 degs. F. = _____ ft/sec.

9. 1 Micron = _____ inches.

10. 30 Microns = _____ inches.

11. 6 Joules = _____ Watt hours.

12. 20" Hg. = _____ " water.

13. 20" Hg. = _____ Millibars.

14. If the wet bulb temperature is 65 degs. F. and the dry bulb temperature is 78 degs. F., what is the relative humidity?

    _____

15. What is the temperature correction factor if the O.A.T. is 40 degs. F.? _____

16. What is the pressure correction factor is the Barometeric Pressure is 31.3" Hg.? _____

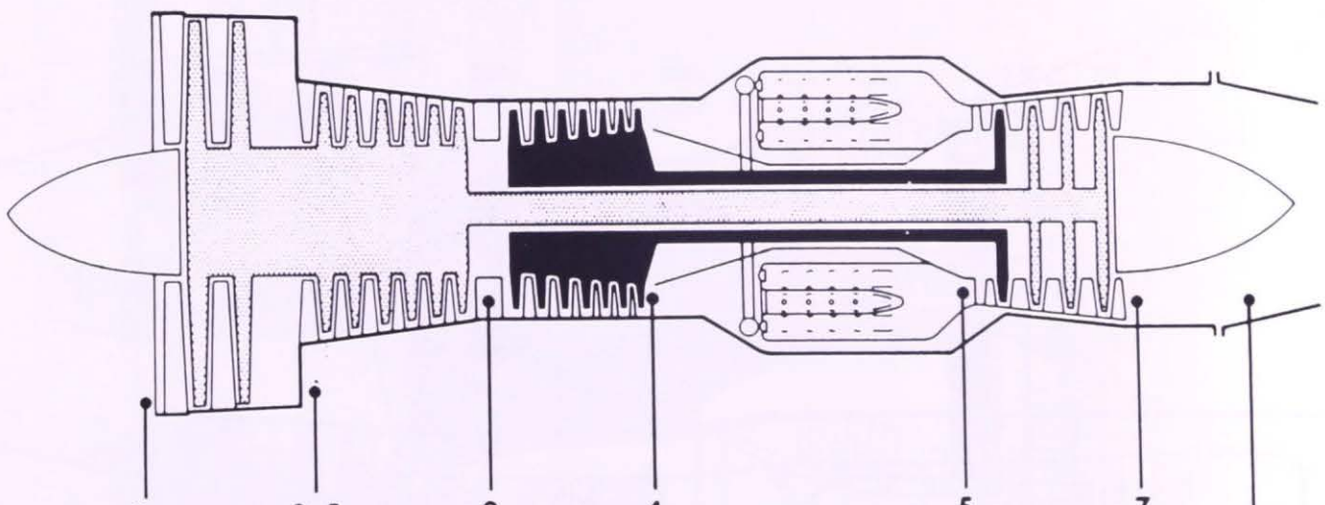
ASSIGNMENT #12

Reference Internal Pressures and Temperatures on the JT 3D, JT 8D and JT 9D turbofan engines. Fill in the following chart.

	JT 3D	JT 8D	JT 9D
P_{t2}			
T_{t2}			
P_{t4}			
T_{t4}			
P_{t5}			
T_{t5}			
Primary airflow lbs/sec.			
Secondary airflow lbs/sec.			
Primary exit velocity ft/sec.			
Secondary exit velocity ft/sec.			
# of Fan stages			
# of H.P. comp. stages			
# of L.P. turbine stages			
Compressor pressure ratio			

JT3D-3B TURBOFAN

INTERNAL PRESSURES AND TEMPERATURES



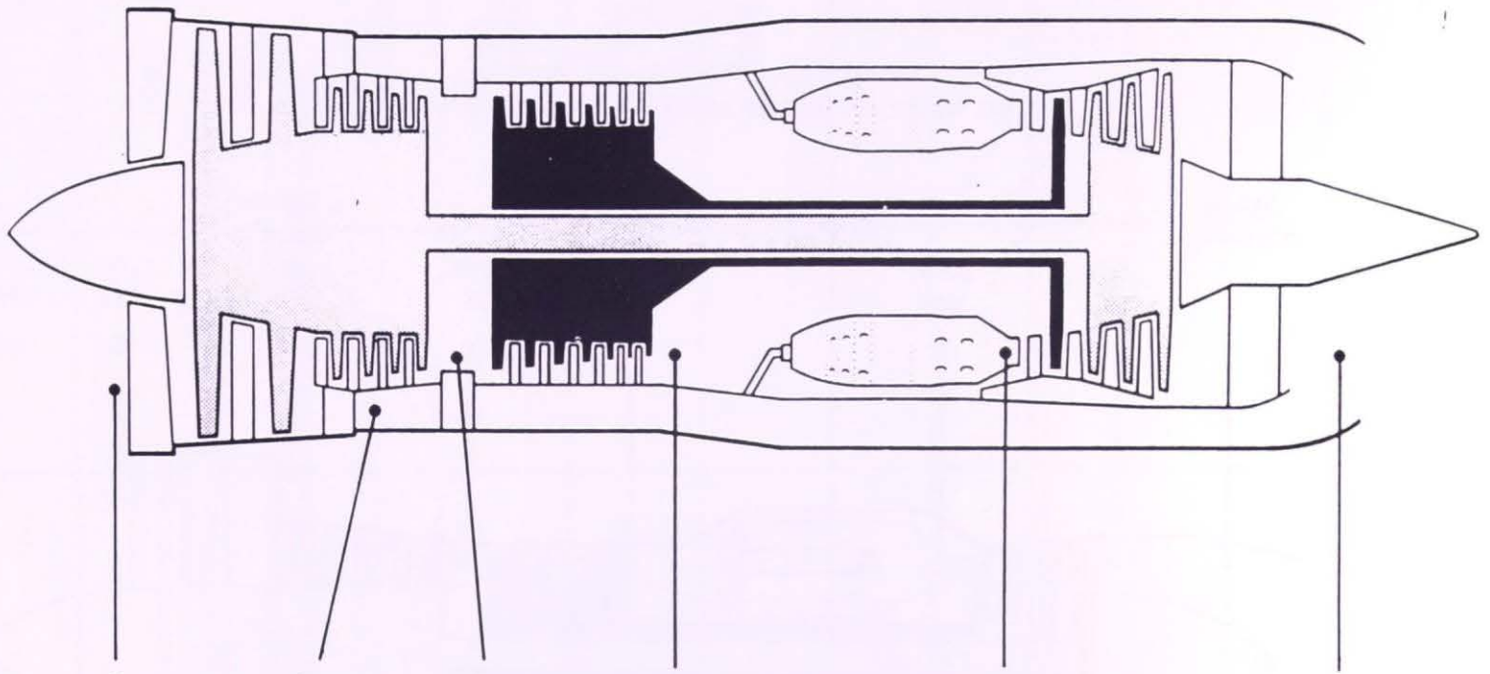
STATION	2	2.5	3	4	5	7	
P_t (PSIA)	14.7	26	63	200	190	28	
T_t (°F)	59°	170°	360°	715°	1600°	890°	
		V_{jf}=990 FT/SEC					V_{jp}=1560 FT/SEC

AT SEA LEVEL STATIC TAKEOFF THRUST OF 18000 LBS,
W_{af}=265 LBS/SEC, W_{ap}=195 LBS/SEC

Figure 1

JT8D TURBOFAN

INTERNAL PRESSURES AND TEMPERATURES



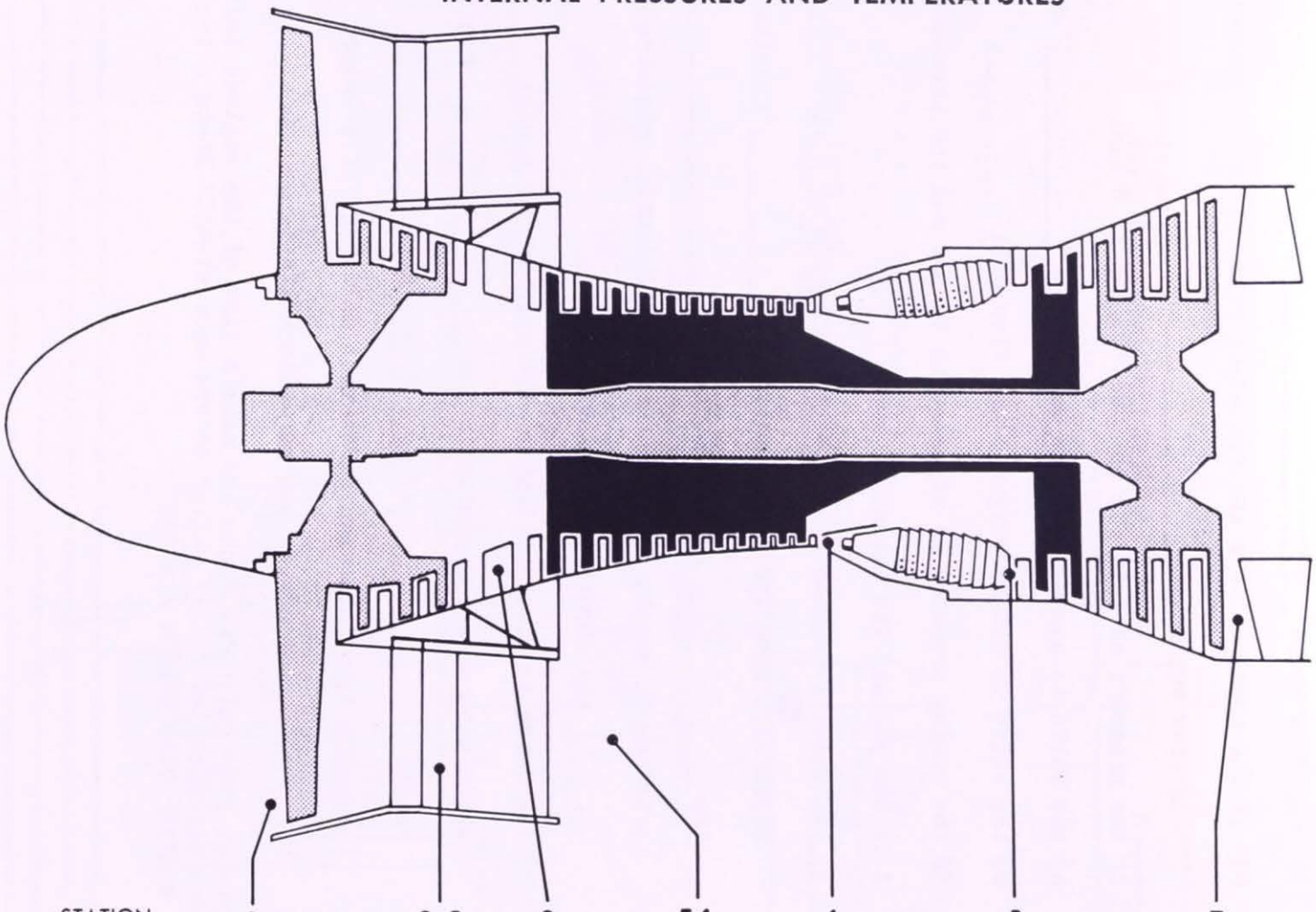
STATION	2	2.5	3	4	5	7
P_t (PSIA)	14.7	28	60	233	220	29
T_t (°F)	59°	190°	355°	800°	1720°	890°
						V_{jm}=1450 FT/SEC

AT SEA LEVEL STATIC TAKEOFF THRUST OF 14000 LBS,
W_{af}=165 LBS/SEC, W_{ap}=150 LBS/SEC

Figure 2

JT9D TURBOFAN

INTERNAL PRESSURES AND TEMPERATURES



STATION	2	2.5	3	F4	4	5	7	
P_t (PSIA)	14.7	22.6	32.1	22.4	316	302	20.9	
T_t (°F)	59°	130°	210°	130°	880°	1970°	850°	
				V_{jf}=885 FT/SEC				V_{jp}=1190 FT/SEC

AT SEA LEVEL STATIC TAKEOFF THRUST OF 43,500 LBS, W_{af}=1248 LBS/SEC, W_{ap}=247 LBS/SEC

Figure 3

ASSIGNMENT #13

Reference "Two Basic Methods of Controlling Fuel Flow"
Colour the inlet pressure A - Red, outlet pressure B - Blue.

1. Fig. 1 For the fuel to flow as shown, the pressure at A must be _____ than at B.

2. Fig. 2 a) If the pressure at A was increased from 100 psi to 120 psi, the flow would _____.

   b) If the pressure at A was decreased from 100 psi to 80 psi, the flow would _____.

3. Fig. 3 If the pressure at A is 800 psi and 760 psi at B and:

   a) the valve is opened the flow would _____.

   b) the valve is closed slightly the flow will _____.

4. Fig. 4 If the spring pressure is adjusted to 40 psi and the pressure at A is 800 psi and 760 psi at B, and:

   a) the valve is opened slightly, the pressure at B will _____, which will move the piston to the _____, resulting in the _____ of port C, and an _____ in pressure A, maintaining a constant differential pressure of _____ psi across the variable oriface.

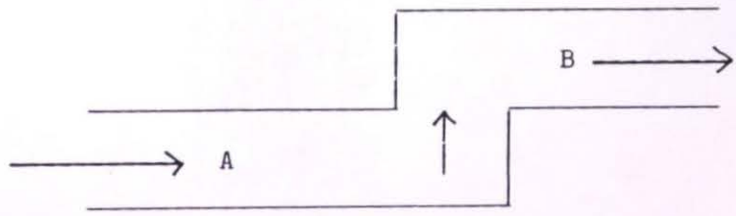
   b) the valve is closed slightly, the pressure at B will _____, which will move the piston to the _____, resulting in the _____ of port C, and an/a _____ in pressure A, maintaining a constant differential pressure of _____psi across the variable oriface.

5. Look through your reference books and make a list of the engines that use a "pressure differential relief valve" or the equivalent. State - book - page - fig. # after each engine listed.

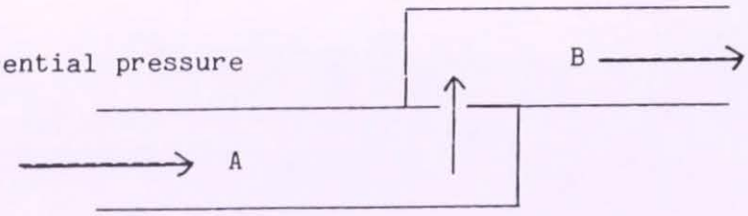
_____
_____
_____
_____
_____
_____

TWO BASIC METHODS OF CONTROLLING FUEL FLOW

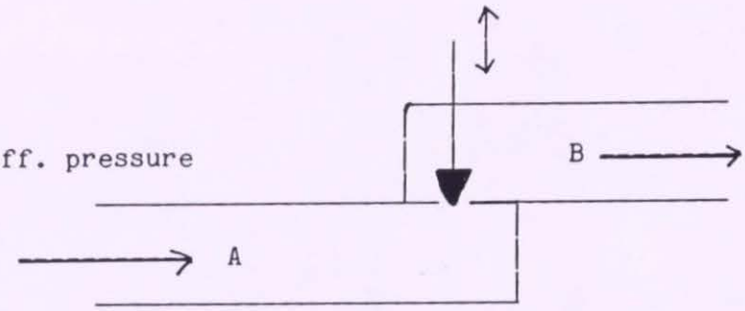
1. No control



2. Fixed jet
   Vary differential pressure



3. Vary jet
   Constant diff. pressure



4. Differential
   Relief
   Valve