МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ

ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ АВТОНОМНОЕ
ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ
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AIRCRAFT ENGINE SYSTEMS

Рекомендовано редакционно-издательским советом федерального государственного автономного образовательного учреждения высшего образования «Самарский национальный исследовательский университет имени академика С.П. Королева» в качестве учебного пособия для обучающихся по основным образовательным программам высшего образования по направлениям подготовки 15.03.05 Конструкторско-технологическое обеспечение машиностроительных производств, 24.03.04 Авиастроение, 25.03.02 Техническая эксплуатация авиационных электросистем и пилотажно-навигационных комплексов, 27.03.02 Управление качеством и по специальности 24.05.07 Самолёто- и вертолётостроение

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В данное пособие включены тексты для чтения, пересказа, реферирования и аннотирования, лексико-грамматические упражнения, тестовые задания. Использована оригинальная литература по авиации.

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ОГЛАВЛЕНИЕ

UNIT 1. Engine systems

1. Discuss the following questions:

- What are the main functions of starting and ignition systems?

- Which indicating systems are included in electrical and electronic requirements for the engines?

- Do you know anything about original way of starting piston engines?

- Which method is in wide spread use now?

- How does electrical starting system operate?

- Describe the operation of twin-engine starting system.

2. Read the text to find the answers to the previous questions:

Engine systems. Starting and ignition

The aircraft engine is installed with many systems requiring electrical power. The predominant requirement (in terms of current consumption) is for the starting system. General aviation aircraft use electrical starter motors for both piston and gas turbine engines; larger transport aircraft use an air-start system (controlled electrically) derived from ground support equipment or by air cross-fed from another engine. Electrical starting systems on piston and gas turbine engines are very different. The trend towards the all-electric aircraft will see more aircraft types using electrical starting methods. The engine also requires electrical power for the ignition system. Once again, the needs of piston and gas turbine engines are quite different. Although starting and ignition systems are described in this chapter as separate systems, they are both required on a coordinated basis, i.e. a means to rotate the engine and ignite the air/fuel mixture.

Electrical and electronic requirements for engines also include the variety of indicating systems required to operate and manage the engine. These indicating systems include (but are not limited to) the measurement and indication of: rotational speed, thrust, torque, temperature, fuel flow and oil pressure. Indications can be provided by individual indicators or by electronic displays. This chapter describes engine starting, ignition and indicating system for both piston and gas turbine engines.

Starting and ignition in piston engines

The original way of starting piston (internal combustion) engines was by ‘swinging’ the propeller; this involves using the propeller as a lever to turn the engine shaft. The method in widespread use on most engines now is a starter motor powered by the aircraft battery. Basic electrical starting systems comprise a series or compound wound motor with engaging mechanism. The simplest method of physically connecting the motor to the reciprocating engine is via a pinion on the motor that engages with a gear ring attached to the crankshaft; this mechanism disconnects after the engine has started. This pinion and gear ring provide a gear ratio in the order of 100:1 to turn the engine at sufficient speed to overcome compression and bearing friction. Referring to fig. 1, the battery master switch is selected on; this energizes the battery relay and power is applied to the busbar and starter relay. When the starter switch is closed, this energizes the starter relay and applies power to the starter motor. As soon as the engine fires and starts, the starter switch is released and power is removed from the motor; this opens the starter relay contacts.

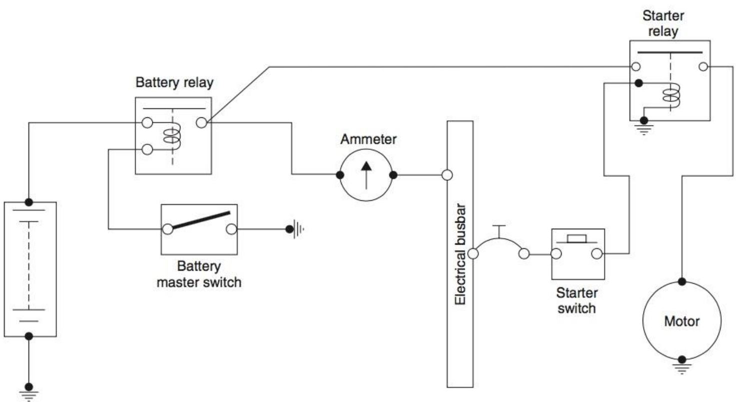

Fig. 1. Electrical starting system

Twin-engine (piston) starting system

The twin-piston engine aircraft is started in a similar way to the single engine. power is applied from the battery to the battery relays. When the battery master switch is turned on, power is available at both the starter relay. Power is also made available at the busbar and the starter circuit breaker is fed to the dual starter switch. Each engine is started by its own set of contacts. When an engine has been started the switch is released and the spring-loaded contacts return it to the centre-off position.

3. Are these statements true or false?

1. Piston and gas turbine engines use electrical starter motors.

2. Electrical starting systems on piston and gas turbine engines are very similar.

3. The function of starting and ignition systems is to rotate the engine and ignite the air/fuel mixture.

4. Electronic displays and individual indicators are used to measure rotational speed, thrust, torque, temperature, fuel flow and oil pressure.

5. Most engines now use the method of swinging the propeller to start the engine.

6. The twin-piston engine aircraft is started in a different way from the single engine.

4. Match the following words with their translation:

1. Starting system	a) коленчатый вал
2. Ignition system	b) двойной тумблер запуска
3. The engine shaft	c) вал двигателя
4. Reciprocating engines	d) трение в подшипниках

5. A pinion	e) система запуска двигателя
6. The crank shaft	f) поршневой двигатель
7. A gear ring	g) зубчатое кольцо
8. Bearing friction	h) система зажигания
9. A busbar	i) шестерня
10. The dual starter switch	j) силовая электрошина

5. Underline 7 terms related to the topic and translate them using a dictionary.

UNIT 2. Magneto ignition

1. Discuss the following questions:

1. Can you describe the process of generating ignition energy for piston engines?

2. Which principle does the magneto operate on?

3. Why are there 2 spark plugs each driven from a separate magneto in the aircraft engine?

4. What is polar inductor method?

5. What is the function of ignition cables?

2. Read the text to find the answers to the previous questions.

Magneto ignition (high-tension type)

Ignition energy for piston engines is generated from a **magneto**; this provides pulses of electrical power via a **distributor** to spark plugs in each of the engine cylinders. The magneto operates on the principle of electromagnet induction (fig. 2); it is a combined four-pole permanent magnet generator and autotransformer and can be used where there is no aircraft battery.

The engine drives the input shaft of the magneto rotor via a gearbox; the relative movement of transformer windings and the poles of a permanent magnet can be arranged in one of three ways:

1. The transformer coils are on the shaft and the magnet is fixed to the housing (rotating armature type)

2. The permanent magnet is rotated by the shaft within stationary coils of the transformer (rotating magnet type)

3. A soft iron inductor is rotated between the permanent magnet and transformer windings (polar inductor type).

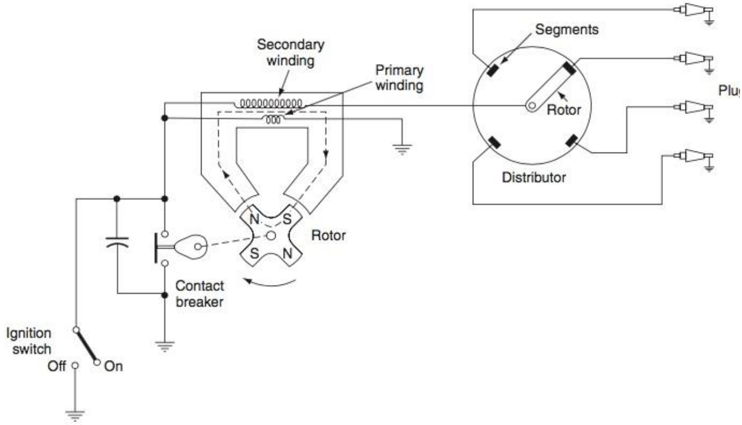

Fig. 2. Magneto ignition principles

For every revolution of the shaft, a cam opens the contact breaker, interrupting the primary current; this causes the electromagnetic field in the primary coil winding to collapse. As the field collapses there is a voltage generated across the **primary coil**. A capacitor connected across the contacts discharges when the breaker contacts are closed and charges when they open. When the capacitor discharges, a high current flows through the primary coil, inducing high secondary voltages. The capacitor also prevents arcing across the breaker contacts, and determines the voltage across the primary coil thereby controlling the rate at which the electrical energy dissipates through the primary coil. The magneto's output is directed to the spark plugs via a distributor. The distributor shaft is connected via gears to the magneto shaft; this ensures that energy is applied to the spark plugs with the correct timing.

In the aircraft engine, each cylinder normally has two spark plugs, each driven from a separate magneto. This arrangement provides redundancy in the event of failure of one of the magnetos. Two sparks per cylinder also provides a more complete and efficient burn of the fuel/air mixture. The magneto's simplicity and self-contained design provides reliability as well as light weight. An on/off switch controls the system; in the off position, the primary winding is connected to ground, and this prevents current from being induced in the primary windings.

Magneto ignition (low-tension type)

A larger piston engine has more cylinders and is designed to operate at higher altitudes. Decreased atmospheric pressure means that the high-tension magneto system is prone to electrical insulation breakdown in the distribution cables. The low-tension magneto system is based on the **polar inductor** method. The output from the magneto is a low voltage; this is increased to a high voltage by secondary transformers located near the plugs. This reduces the length of high-tension cable and reduces the risk of insulation breakdown in the distribution cables. Brushes and commutators form the low-tension magneto distributor. **Ignition cables** carry the high energy from the magneto to the plugs. The single core of stranded conductors is insulated by a substantial thickness of material.

3. Are these statements true or false?

1. A magneto generates pulses of electrical power to spark plugs in the engine cylinders.

2. Electromagnet induction is the main principle of a magneto operation.

3. Each cylinder in the aircraft engine usually has one spark plug.

4. Larger piston engines are designed to operate with the high-tension magneto system.

5. To provide the plugs with the high energy from the magneto ignition cables are required.

4. Match the following words with their Russian definitions.

1. Spark plugs	a) катушка трансформатора
2. Electromagnet induction	b) свечи зажигания
3. Input shaft	c) ведущий вал редуктора

4. Gear box	d) распределительный вал
5. The transformer coil	e) электромагнитная индукция
6. Secondary voltages	f) провода системы зажигания
7. The distributor shaft	g) вторичное напряжение
8. Insulation breakdown	h) редуктор
9. Ignition cables	i) пробой изоляции

5. Make up your own sentences using the active vocabulary from activity 4.

UNIT 3. Spark plugs

1. Discuss the following questions:

1. What is the main function of the spark plugs?

2. Where is the plug located?

3. Which conditions does the plug have to operate on?

4. Which materials are commonly used in spark plug installations?

2. Read the text to check your answers.

These conduct the high-energy output from the magneto across an air gap. The fuel/air mixture across the gap is an insulator; as the voltage from the magneto increases, it alters the structure of the fuel/air mixture between the electrodes. Once the voltage exceeds the dielectric strength of the fuel/air mixture, it becomes ionized. The ionized fuel/air mixture then becomes a conductor and allows electrons to flow across the gap. When the electrons flow across the gap, this raises the local temperature to approximately 60,000K. The electrical energy is discharged as heat and light across the air gap, thereby appearing as a spark with an audible 'clicking' sound. This energy ignites the fuel mixture in the cylinder. The plug is fitted into the cylinder head's combustion chamber and is therefore exposed to high pressures and temperatures; plugs have to operate with minimal deterioration over long periods of time in this harsh environment. The outer shell of the plug is made from high tensile steel with close tolerance threads to locate the plug in the cylinder head; a copper crush-washer completes the seal against high gas pressures. The outer shell is connected electrically to the cylinder head through its body. The centre electrode carries the high tension energy to the spark gap; this is formed from a material that is resistant to the repetitive arcing, typically nickel, platinum or iridium. An insulator separates the inner and outer sections of the plug, typical materials include mica, ceramic, aluminium oxide ceramic. Examples of spark plug installations, together with ignition cables, are shown in fig. 3 and fig. 4.

Fig. 3. Spark plugs (new and used)

Fig. 4. Spark plug installation

3. Translate the words and phrases into Russian. Make up your own sentences using them:

1. An insulator
2. To become ionized
3. A conductor
4. To ignite the fuel mixture
5. To be exposed to high pressures and temperatures
6. Harsh environment
7. With minimal deterioration
8. The outer shell
9. To be resistant to something

4. Match the beginning of the sentences with their ending. Translate.

1. An insulator is made from …

2. The energy ...

3. The outer shell of the plug is made from ...

4. Plugs have to ...

5. The plug is fitted ...

6. The centre electrode is formed from ...

7. Spark plugs ...

a) conduct the high energy output.

b) high tensile steel.

c) ignites the fuel mixture in the cylinder.

d) into the cylinder head's combustion chamber.

e) operate with minimal deterioration over long periods of time in harsh environment.

f) ceramic, aluminium oxide ceramic.

g) nickel, platinum or irridium.

5. Underline several terms related to the topic and make up sentences using them.

UNIT 4. Turbine engine starting

1. Discuss the following questions:

1. Can you describe the general features of a gas turbine engine?
2. Which requirements should the starter motor meet?
3. What is necessary for starting gas turbine engines?
4. What does HEIU abbreviation stand for?
5. How many HEIUs are required per engine?
6. What is stored in HEIU?
7. What is self-sustaining speed?

2. Read the text to find the answers to the previous questions.

Starting a turbine engine requires a higher-duty motor compared with piston engines; the motor has to overcome higher inertia and needs to achieve higher cranking speeds. The general features of a gas turbine engine are illustrated in fig. 5. Air is compressed through a multi-stage system before entering the combustion chamber where it is mixed with fuel and ignited. The expanding exhaust gases are then directed through a turbine to produce thrust. The turbine also turns shafts to drive the compressor stages.

The starter motor has to overcome the inertia of the compressor; a large volume of air has to be drawn through engine and then accelerated and compressed until the engine's **self-sustaining speed** is reached. Self-sustaining speed is when sufficient energy is being developed by the engine to provide continuous operation without the starting device. When the turbine engine is driving a propeller (commonly called a **turboprop**) the starter has to overcome the additional inertia of the propeller (helicopter engines are normally connected to the rotor via a clutch).

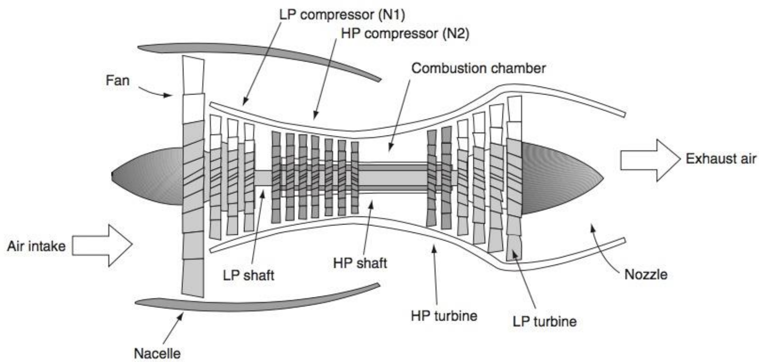

Fig. 5. Gas turbine engine features

A typical turbine engine starter circuit is illustrated in fig. 6. Current from the busbar is connected to the coil of a starter relay via a push-button switch. This makes a circuit to a timer switch and starter motor via a limiting resistor. (The resistor limits excessive currents that would otherwise occur in overcoming the initial torque of the motor.) Once the motor speed has reached its nominal operating speed, its starting torque reduces and the timer switch operates contacts for the shorting relay. With the relay energized, current from the busbar is switched directly into the motor, i.e. bypassing the resistor. Ignition is switched on when self-sustaining speed is reached; power to the motor is removed.

The initial current through the turbine engine starter motor is in the order of 1000-1500A, hence the need for a limiting resistor and timing circuit.

High-energy ignition is required for starting gas turbine engines; a dual system is normally installed for the main engines. The system comprises two HEIUs and two igniter plugs per engine. A typical HEIU installed on an engine is shown in fig. 7. Turbine ignition systems are switched off after the engine has reached self-sustaining speed; the system is used as a precaution during certain flight conditions e.g. icing, rain or snow. **In-flight start** uses the wind-milling effect of the engine within the specified flight envelope of air speed and altitude. High voltages are required for the igniter plugs to accommodate the variations in atomized fuel over the range of atmospheric conditions. Electrical energy is stored in the HEIU and then dissipated across the igniter plug.

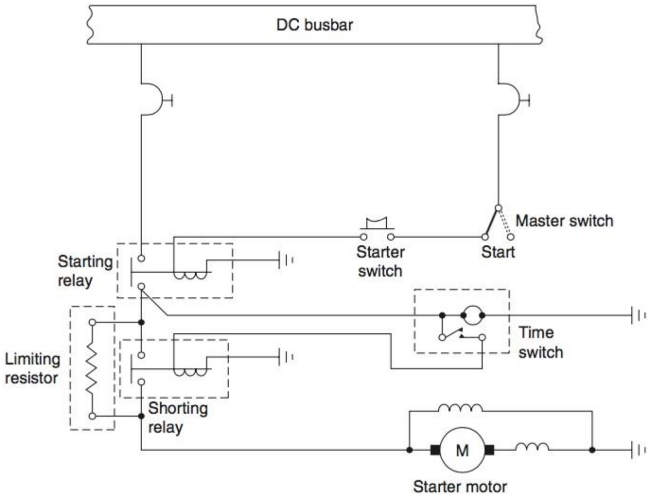

Fig. 6. Turbine engine starter circuit

The very high voltage output from an HEIU is potentially lethal. The HEIU can remain charged for several minutes; always refer to the maintenance manual for operating procedures.

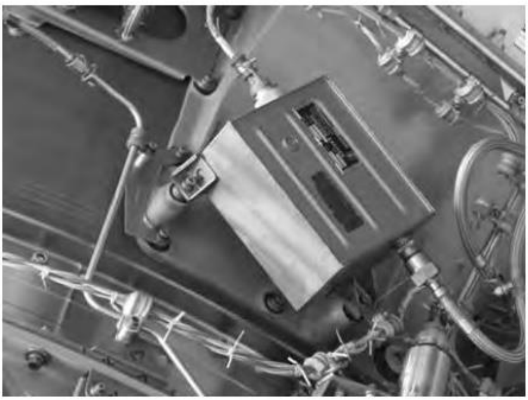

Fig. 7. Ignition unit installation

3. Are these statements true or false?

1. Turbine engines require the same motors as piston engines.

2. Thrust is produced by the expanding exhaust gases directed through a turbine.

3. To start a gas turbine engine high energy ignition is necessary.

4. The main engine system typically consists of one HEUI and one igniter plug per engine.

5. HEUI's voltage output is not dangerous.

4. Match two parts of the sentences.

1. Starting a turbine engine ...

2. The starter motor has to overcome ...

3. The initial current through the turbine engine starter motor ...

4. Turbine ignition systems are switched off ...

5. The HEIU ...

a) is in the order of 1000-1500A.

b) can remain charged for several minutes.

c) requires a higher-duty motor compared with piston engines.

d) after the engine has reached self-sustaining speed.

e) the inertia of the compressor.

5. Underline several terms related to the topic, translate them using a dictionary.

UNIT 5. Main engine start

1. Answer the following questions:

1. How are main engines normally started?

2. Which sources of air for starting the main engine do you know?

3. What is low-energy ignition? When is it selected?

4. Do you know the starting sequence for a gas turbine engine?

2. Read the text to check the answers to the previous questions.

The main engines are normally started via air-driven motors; there are three sources of air for starting the main engines:

- APU
- ground air supply cart
- another engine.

Valves, controlled either manually or automatically, are operated by motors. With the APU started and running at normal speed, a switch on the start control panel opens the APU bleed valve. Air is directed through the isolation valve and engine bleed valve to the engine start valve.

When using the ground air supply cart, an external connection is made and air is directed through the engine bleed valve to the start valve, or through the isolation valve and engine bleed valve to the start valve. When using another engine (that is already running), air is supplied from its bleed valve, through the isolation and bleed valves of the engine to be started and through to the start valve.

For illustration purposes, a twin-engined aircraft starting and ignition system is described. There is a combined start and ignition control panel located in the overhead panel; this is fitted with a rotary switch for each engine. The operation and functions of this switch are identical for each engine. The switch has to be pushed in before any selections can be made; this is to prevent accidental movement of the switch. Selecting ground (GRD) connects 28V DC to energize the start switch holding coil.

The circuit is completed through the cut-out contacts in the engine starter valve. The start switch is now held in the GRD position and the ground start sequence is initiated. The 28V DC supply also energizes the start valve solenoid and this opens the valve, supplying air to drive a small turbine in the starter motor. The turbine connects through an accessory gearbox onto the engine's HP compressor shaft.

At approximately 16% of maximum rotational speed, the start lever is moved from the cut-off position to 'idle'. This applies 28V DC through a second pair of contacts of the start switch and ignition switch to supply the HEIU. Each igniter plug discharges at a high level, typically 20 joules of energy, at 60-90 discharges per minute. (This can be heard outside the engine as an audible 'clicking' sound.) At a pre- determined cut-out speed, the centrifugal switch in the starter motor opens: the start switch is de-energized and returns (under spring force) to the off position. The 28V DC power supply is removed from the HEIU and the start valve motor drives to its closed position. The engine continues to accelerate to the ground idle speed; this is slightly above self-sustaining speed and occurs when the engine has stabilized. For a twin-shaft axial flow engine, ground idle is typically 60% of the high-pressure (HP) compressor speed.

Low-energy ignition (typically 4 joules of energy, at 30 discharges per minute) is used in certain phases of flight including take-off, turbulence and landing. Furthermore, if the aircraft is flying through clouds, rain or snow, continuous low-energy ignition is selected on the control panel. This closes a contact on the rotary switch and applies power to a second HEIU input.

In the event of an engine flameout during flight, the crew will attempt an in-flight start of the engine; this requires a modified procedure to that of the ground start. The engine will be wind-milling due to the forward speed of the aircraft. The starter valve and motor are not selected as with the ground start. Low ignition (LOW IGN) and flight (FLT) are manually selected on the control panel until the engine reaches flight idle speed. In-flight restarts can only be attempted within certain airspeed and altitude limits.

Gas turbine engines sometimes suffer from a starting problem that results in fuel entering the combustion chamber, but no ignition; this is sometimes referred to as a wet start.

The starting sequence for a gas turbine engine is to: (i) develop sufficient airflow to compress the air, (ii) turn on the ignition, and (iii) open the fuel valves. This sequence is critical since there must be sufficient airflow through the engine to support combustion before the fuel/air mixture is ignited.

3. Match the following words with their translation:

1. Bleed valve	a) поворотный переключатель
2. Isolation valve	b) скорость самоподдержания работы
3. A rotating switch	c) происходящий в воздухе, на борту самолета
4. Cut-out speed	d) клапан отбора воздуха от двигателя
5. Self-sustaining speed	e) самовыключение двигателя
6. Engine flameout	f) перекрывной клапан
7. In-flight	g) предельная скорость

4. Are the following statements true or false?

1. There is one source of air for starting the main engine.

2. Low-energy ignition is only used in case of turbulence.

3. An in-flight start of the engine is required in the event of an engine flameout. 4. In-flight restarts can be attempted at any speed and altitude.

5. GTEs sometimes suffer from a starting problem called a ‘dry start’.

6. The starting sequence for a GTE is not important.

5. Underline several terms related to the topic and make up sentences with them. Translate.

UNIT 6. Auxiliary power unit (APU) start and ignition

1. Answer the following questions:

- What are the car engine components?

- How does a driver start a car engine?

- Are there any critical differences in the engine start processes of a car and an aircraft?

2. Read the text to check the answers to the previous questions.

The APU on large transport aircraft is started electrically; air is then bled into the air distribution system for the main engines, see fig 8.

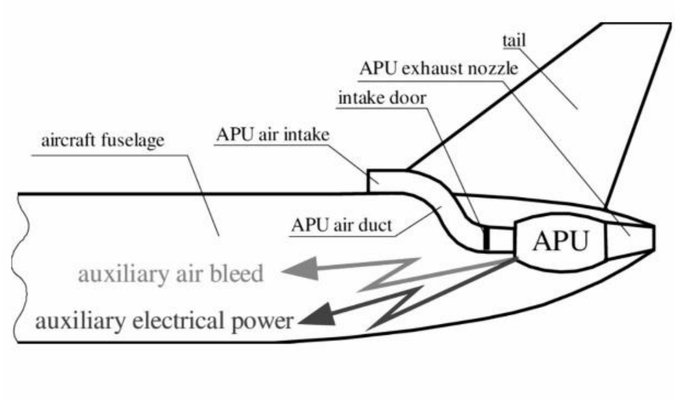

Fig. 8. Airplane APU

The APU starter motor is engaged and disengaged automatically as part of the starting system. A centrifugal switch connected to the APU shaft controls the start sequence via three sets of contacts that operate at 35%, 95% and 110% of maximum speed. An oil pressure switch ensures that the system cannot start until the lubrication oil pump builds up sufficient pressure.

With the system circuit breaker closed, and the start switch selected, the start and control relays are supplied via the closed 110% switch contacts; the starter motor is now connected to the electrical supply via the start relay. The starting sequence is confirmed via a green annunciator light on the control panel, the light is connected to the power supply via contacts on the control relay. The fuel solenoid holding relay (FSHR) is operated via the control relay, and the 35% switch contacts; the low-pressure (LP) fuel pump motor is connected to the power supply via the FHSR. The start switch is now released; the starter circuits are maintained via the FHSR, 100/35% switch contacts and control relay. When the oil lube pump builds up sufficient pressure, this closes a switch that provides a retaining supply for the FSHR. The high-pressure fuel shut-off valve is then energized open (allowing fuel to be delivered under pressure into the APU) and the ignition system is supplied via the 95% contacts. The APU continues to accelerate; at 35% engine speed, the start and control relays open; the starter motor is disengaged, and the 'start' light is switched off. At 95% of maximum speed, the contacts open and the ignition is switched off. The APU start sequence is now completed, and the engine runs constantly at 100% r.p.m. (there is no throttle control on the APU).

The APU can be shut down either manually (by selecting the APU to off) or automatically. Loss of oil pressure at any time will automatically shut the APU down. An overspeed condition (sensed by the 110% switch opening its contacts) will de-energize the fuel solenoid holding relay, close the high-pressure fuel shut-off valve and remove power from the low-pressure booster pump.

3. Say if these statements are true or false:

1. The APU starter motor is engaged and disengaged manually.

2. The oil pump builds up sufficient pressure and only after this the oil pressure switch ensures safe system start.

3. The starter motor is now connected to the electrical supply via the start relay.

4. The LP valve is the only one taking part in the start process.

5. The starter motor is disengaged at 35% engine speed.

6. The APU is possible to be controlled with a throttle control.

7. There are 2 ways to shut down the APU.

4. Translate the following words and classify them according to their part of speech (Nouns, Verbs, or Adjectives / Participles):

To engage, centrifugal, to disengage, switched off, shaft, lubrication, sufficient, pump, to ensure, control, to supply, ignition, completed, to complete, throttle, holding.

5. Make 7 meaningful word collocations using the text and exercise 3:

- the starter motor is disengaged

- start sequence is completed

- ...

UNIT 7. Engine indicating systems overview

1. Read the passage about primary engine indicating systems and do the activity that follows:

Engine indications can be broadly divided into primary and secondary systems. Some indication systems are unique to gas turbine, turboprop or piston engines, some are common to all types. Primary indicators include:

- speed

- temperature

- thrust

- fuel flow.

2. Try and predict what engine secondary indicators might include. Make a list.

3. Read the text to check your ideas.

Engine indications can be broadly divided into primary and secondary systems. Secondary indicators include (but are not limited to):

- oil temperature

- oil quantity

- oil pressure

- vibration.

Measurements are made by a variety of **transducers**; these are devices used to convert the desired parameter, e.g. pressure, temperature, displacement etc. into electrical energy. The location of engine instruments is normally between the two pilot's panels, see fig. 9.

Fig. 9. Typical engine instruments

Engine speed

This is a primary engine indication used on both piston and gas turbine engines. It is one of two methods used to indicate thrust on gas turbine engines (the other being EPR). In gas turbine engines, the usual practice is to display a **percentage** of maximum revolutions per minute (r.p.m.) rather than actual r.p.m. Typical gas turbine engine speeds are in the order of 8000-12,000 r.p.m. Engine speed is monitored by the crew at all times; particularly during start and take-off to make sure that engine limits are not exceeded. The two principal types of engine speed transducer are the tachometer and variable reluctance device.

Tachometer system

The **tachometer** indicating system is a small three-phase AC generator connected via a mechanical link to engine accessory gearbox. A tachometer system is found on most general aviation aircraft. Referring to fundamental principles, the tachometer's output increases with increased engine speed; the output is rectified and connected to a moving coil meter. The output from the generator is supplied to a three-phase AC synchronous motor in the indicator.

3. Complete the following sentences with the words from the box:

transducers	instruments	engine	speed
start and take-off	tachometer	indicator	

1. ______________ are devices used to convert the desired parameter, e.g. pressure, temperature, displacement etc. into electrical energy.

2. The location of engine ______________ is normally between the two pilot's panels.

3. ______________ is a primary engine indication used on both piston and gas turbine engines.

4. Engine speed is monitored by the crew at all times; particularly during ______________.

5. The ______________ indicating system is a small three-phase AC generator.

6. The output from the generator is supplied to a three-phase AC synchronous motor in the ______________.

4. Draw and label a simple diagram of an engine tachometer. Describe its functions and operation to your partner in class.

UNIT 8. Engine temperature

1. Make your judgements about the following statements:

- Engine temperature is measured only inside the combustion chamber.

- Ambient air composition and temperature are of no effect on the engine performance.

- You can get more accurate readings if you install a few thermocouples to pick up and interpret the temperature parameters.

2. Read the text to learn true information about the engine temperature and the ways it is monitored.

Exhaust gas temperature is a primary gas turbine engine indication. Engine temperature is closely monitored at all times, particularly during start and take-off, to make sure that engine limits are not exceeded. It is sometimes referred to as:

- turbine inlet temperature (TIT);

- inter-turbine temperature (ITT);

- turbine outlet temperature (TOT);

- exhaust gas temperature (EGT);

- turbine gas temperature (TGT);

- jet pipe temperature (JPT).

The type of measurement depends on where the probe is located and according to individual engine manufacturer’s terminology; fig. 10 illustrates some of these locations. The turbine section runs at very high temperatures, typically 1000 C; the transducer used in this application is the **thermocouple** (sometimes referred to as a ‘temperature probe’).

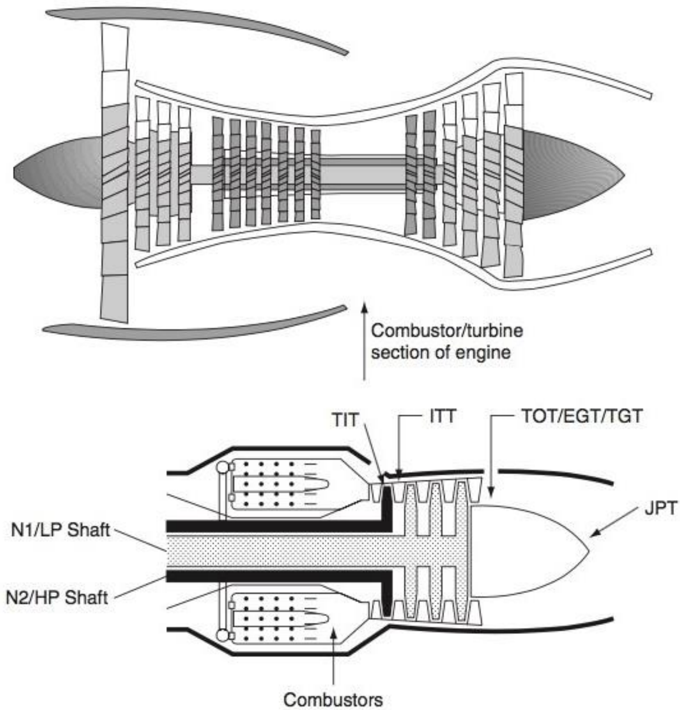

Fig. 10. Engine temperature measurement

Some installations feature a thermocouple that has two or even three hot junctions within the same outer tube. This arrangement provides an average of temperature within the zone to provide an average temperature at different immersion distances in the engine.

Small gas turbine engines are normally fitted with several thermocouples to provide an average temperature and some redundancy in case of failure. Larger engines can be fitted with up to 21 thermocouples; these are connected in parallel to provide an average reading of the gas temperature in the exhaust zone. The interconnecting cables between the thermocouple(s) and indicator have to be of the same material throughout the system otherwise addition junctions will be formed, thereby generating unwanted voltages.

Key maintenance point

Thermocouple cables are colour-coded to reduce the likelihood of different materials being cross-connected, or mixed in the same installation (note that these codes vary in some countries; always refer to the maintenance manual):

- nickel-chrome (white)

- nickel-aluminium (green)

- iron (black)

- constantan (yellow)

- copper (red).

3. Answer the following questions to the text:

1. Why is engine temperature closely monitored at all times?

2. How does the termocouple/probe location affect the type of measurement?

3. Why are small gas turbine engines normally fitted with several thermocouples?

4. Why do the interconnecting cables between the thermocouple(s) and indicator have to be of the same material throughout the system?

5. What method is used to o reduce the likelihood of different materials being cross-connected?

4. Match the terms with their definitions:

Terms

1. Exhaust gas   2. Measurement   3. Thermocouple

4. Average temperature
5. Immersion
6. Redundancy
7. Junction
8. Voltage
9. Colour-coded
10. Manual

Definitions

a. a point where two or more things are joined

b. a book giving instructions or information

c. the action of putting something in a liquid

d. the inclusion of extra components which are not strictly necessary to functioning, in case of failure in other components

e. a system of marking things with different colours as a means of identification

f. waste gases or air expelled from an engine, turbine, or other machine in the course of its operation

g. usual or standard temperature

h. the size, length, or amount of something, as established by measuring

i. a thermoelectric device for measuring temperature, consisting of two wires of different metals connected at two points, a voltage being developed between the two junctions in proportion to the temperature difference.

j. the action of measuring something

UNIT 9. Engine pressure ratio

1. Answer the following questions:

- What are the main engine parameters to be monitored in operation?
- Is there a connection between the engine pressure ratio and thrust?
- What is torque?
- Is it measured mechanically or electrically?

2. Read the text to check your answers.

Engine pressure ratio (EPR) and Torque

Engine pressure ratio is a primary gas turbine engine indication system and is one of two methods used to indicate thrust (the alternative method is described under engine speed). The principle of an EPR indication system is to measure the exhaust and inlet pressures and derive a ratio between them. EPR probes are located at the inlet and exhaust of the engine, see fig. 11. The inlet pressure probe is a single device, located in the nacelle; there can be several exhaust probes connected via a manifold.

Pressures from the inlet and exhaust are sent via small diameter pipes to the EPR transducer; this comprises pressure sensors (capsules). These are coupled to a mechanism that determines the displacement of the capsules as ratio. Outputs from the ratio sensor are sent via a linear variable differential transformer (LVDT) to the indicator. The EPR signal from the transducer is transmitted as a voltage to the indicator. The typical range of EPR indications is between one and two.

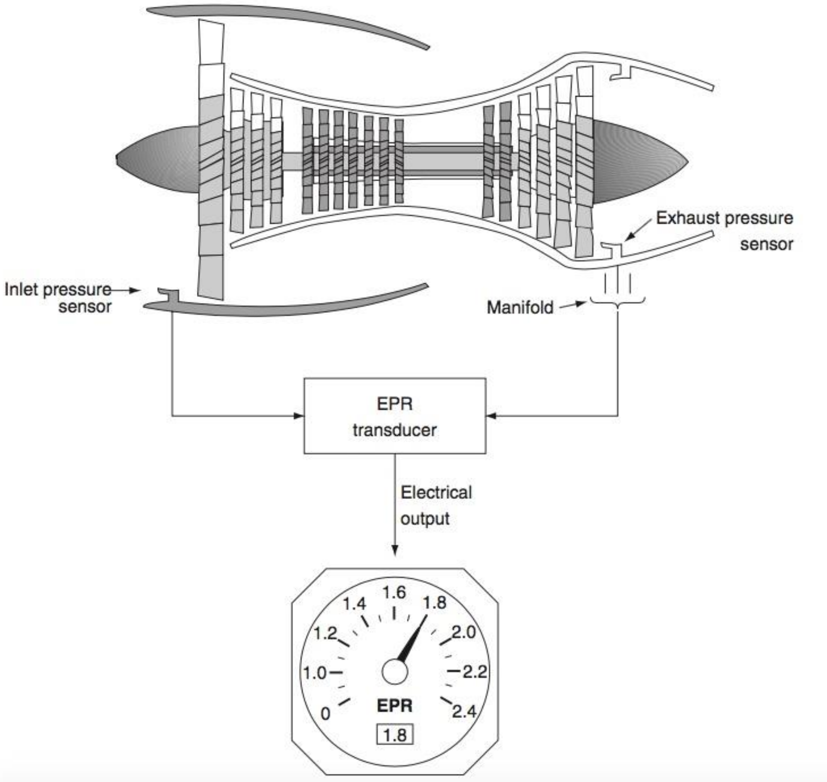

Fig. 11. EPR schematic

Torque. The power delivered by the engine to the propeller shaft can be derived from the relationship:

Power x torque = speed

Power is derived from measuring both torque and speed; the indication is normally used for turboprops and helicopter rotors. Indicators are calibrated in a percentage of maximum torque or shaft horsepower (SHP). A typical torque indicator used on a twin-engined helicopter is shown in fig. 12.

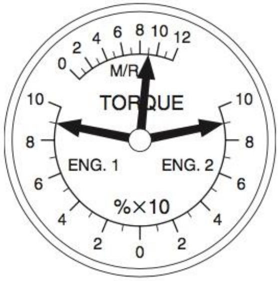

Fig. 12. Typical helicopter torque indicator (twin engine)

Indications are given for the output from both engines and main rotor (M/R) torque. This is the most effective way of indicating the power being produced by the engine.

There are several methods used to measure torque. The torque shaft is formed with toothed or phonic wheels, see fig. 13. As the applied torque changes the phase difference between the signals obtained from the two speed sensors increases. The torque applied to the shaft results in a phase difference between the outputs of the two sensors, see fig. 13.

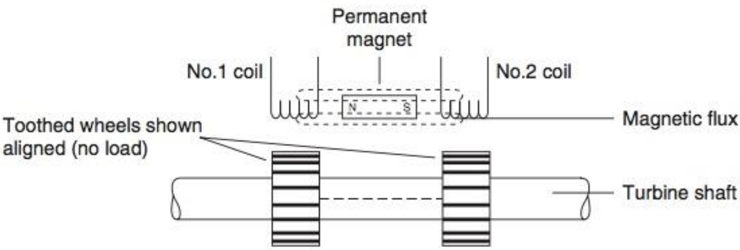

Fig. 13. Torque transducer principles

Torque can also be measured by embedding strain gauges into the shaft to measure the deformation (strain) of the shaft; these can either be metallic foil or semiconductor piezo-resistors.

3. Complete the following sentences by underlining the correct word/word-collocation.

1. Engine pressure ratio is a primary gas turbine engine indication system.

2. The inlet pressure probe is a single device, located in the nacelle.

3. Pressure sensors are coupled to a mechanism that determines the displacement of the capsules as ratio.

4. The EPR signal from the transducer is transmitted as a voltage to the indicator.

5. As the applied torque changes the phase difference between the signals obtained from the two speed sensors increases.

6. Strain gauges can either be metallic foil or semiconductor piezo-resistors.

4. Fill in the gaps using the words in the box.

basically (x2)	call	effectively	essentially	imagine
other picture	refer	simple	simply	

1. Function: simplifying the language.

Words / Phrases: in simple terms / put ______ / in ______ words / ______

2. Function: simplifying the concept.

Words / Phrases: ________ / ________ / ________

3. Function: focusing on technical terms.

Words / Phrases: what we ________ / what we _______ to as

4. Function: illustrating with images.

Words / Phrases: if you ________ / if you ________

5. In pairs, practice explaining the technical terms in the text using the simplified words and phrases in Exercise 4.

UNIT 10. Electronic indicating systems

1. Answer the following questions:

- How do pilots get information about aircraft systems?

- What is the best way to display this information?

- Which color is the alert one: red or amber?

- What is the difference between alert and advisory signals?

2. Read the text to check your answers.

EICAS and ECAM

There are two formats of electronic indicating systems in widespread use on larger passenger aircraft: EICAS and ECAM. The Engine Indication and Crew Alerting System (EICAS) is a Boeing-developed system that provides all engine instrumentation and crew annunciations in an integrated format. The system used on Airbus aircraft is the Electronic Centralized Aircraft Monitoring (ECAM) system. The two systems operate on different philosophies; however, their basic functions are to monitor aircraft systems and display relevant information to the pilots. Both systems produce warnings, cautions and advisory messages that need to be evaluated by the crew. In certain cases, the system provides the procedures required to address the problem. Each colour display unit uses either an active matrix liquid crystal display (AMLCD) or a cathode ray tube (CRT).

EICAS is arranged with two displays in the centre instrument panel (upper and lower), see fig. 15. ECAM uses either a left and right display, see fig. 14, or an upper and lower arrangement. The information displayed by EICAS/ECAM includes engine thrust, engine r.p.m., fuel flow, oil temperature and pressure. Graphical depiction of aircraft systems can also be displayed; this includes electrical, hydraulic, de-icing, environmental and control surface positions.

Fig. 14. ECAM

Fig. 15. EICAS

ECAM

ECAM is a flight-phase-related architecture; displays are automatically selected for:

- pre-flight
- take-off
- climb
- cruise
- descent
- approach.

To illustrate ECAM features, during the pre-flight phase, checklists are displayed on the left-hand screen; this includes information such as brake temperatures, APU status and advisory messages. During the pre-flight checks, the right-hand display provides a graphic representation of the aircraft, e.g. if doors are open or closed. The system automatically changes to the relevant pages needed for the next flight phase. System warnings are prioritized, ranging from level one to level three; the warning hierarchy is similar to EICAS. Both EICAS and ECAM reduce flight deck clutter by integrating the many electro-mechanical instruments that previously monitored engine and aircraft systems. Reliability is increased, and the pilot work load is reduced.

EICAS

System features include:

- primary engine parameters displayed on a full- time basis
- secondary engine parameters displayed as required
- automatic monitoring of systems
- fault codes, fault history, self test (lower display)
- two computers (includes interfaces, symbol generator, memory)
- select panel, control switches, annunciation, standby display.

This integrated system improves reliability through elimination of traditional engine gauges and simplifies the flight deck through fewer stand-alone indicators. EICAS also reduces crew workload by employing a graphical presentation that can be rapidly assimilated. A typical EICAS comprises two large high-resolution colour displays together with associated control panels, two or three EICAS data concentrator units and a lamp driver unit. The primary EICAS display presents primary engine indication instruments and relevant crew alerts. It has a fixed format providing engine data including:

- engine thrust (EPR)

- engine rotational speed (N1)

- exhaust gas temperature (EGT).

If N1 or EGT limits are exceeded, their respective pointers and digital readouts change from white to yellow, and eventually to red. Exceedance information is stored in non-volatile memory (NVM) for access by maintenance engineers when troubleshooting the systems.

Messages are displayed as part of the Caution Alerting System (CAS); these are colour-coded to indicate their importance. Typical messages include low-pressure in the fuel or hydraulic oil systems, doors not closed etc. System warnings are automatically colour-coded and prioritized; they are accompanied by an audible warning depending on the message priority:

- **warning** messages are red, accompanied by an audio alert (prompt action is required by the crew)

- **caution** messages are yellow accompanied by an audio alert (timely action is required by the crew)

- **advisory** messages are yellow, no audio alert (time available attention is required by the crew).

The secondary EICAS display indicates a wide variety of options to the crew and serves as a backup to the primary display. Pages are selectable using the EICAS control panel and includes many types of system information, for example:

- hydraulic systems pressure
- flying controls position
- cargo bay temperature
- brake temperatures
- tyre pressures.

3. Match parameters from the box with ECAM or EICAS. Scan the text above for information. Sometimes these parameters will fit both systems.

two displays in the centre instrument panel
either a left and right display
engine thrust, engine r.p.m., fuel flow, oil temperature and pressure
pre-flight/take-off/climb
APU status
fault codes, fault history, self test
hydraulic systems pressure
doors not closed

ECAM (Airbus): …

EICAS (Boeing): …

4. Say if these statements are true or false:

1. There are five formats of electronic indicating systems on bif aircraft.
2. These systems operate on different philosophies.

3. Systems produce warnings, cautions and advisory messages.

4. Messages of the systems are d to be evaluated by the crew.

5. In ECAM during the pre-flight phase, checklists are displayed on the left-hand screen; this includes information such as brake temperatures, APU status and advisory messages.

6. In ECAM the right-hand display provides flashing warning light to signal if doors are open or closed.

7. In EICAS system warnings are automatically colour-coded and prioritized.

5. Translate this supplementary text into your language.

Messages are displayed as part of the Caution Alerting System (CAS); these are colour-coded to indicate their importance. Typical messages include low-pressure in the fuel or hydraulic oil systems, doors not closed etc. System warnings are automatically colour-coded and prioritized; they are accompanied by an audible warning depending on the message priority.

The information on the aircraft system data buses is routed to both EICAS displays and both multifunction displays. A data concentrator unit (DCU) receives data in various formats from a variety of sensors, including the high- and low-speed ARINC 429 bus, from analogue and discrete inputs from the engines and other aircraft systems. In the event of a display system failure, the other system displays essential information in a compacted format. Primary engine indications are as before, secondary indications are digital readings only. In the event that both systems fail, a standby LED display is used for EPR, N1 and EGT.

TEXTS FOR SUPPLEMENTARY READING

Engine and Fuel Systems

Text 1

Oil/fuel temperature

There is a need for accurate measurement of fluid temperatures on and around the engine, e.g. fuel, engine lubrication (lube) oil and hydraulic oil. The typical temperature range of these fluids is between 40 and 150°C. When lube oil operates at high temperatures, its viscosity reduces and its lubrication performance decreases. This leads to engine wear and eventual failure of bearings or other engine components. When lube oil operates at low temperatures, its **viscosity** increases, which has an effect on starting. When fuel is exposed to high temperatures, it can vaporize, causing fuel delivery problems and a potential risk of explosion; at low temperatures, ice formation can occur leading to blocked filters.

The flight compartment indicator is a moving coil meter connected in series with the resistance winding of a resistance temperature device (RTD). As the temperature changes, the resistance changes and this causes the pointer to respond accordingly. The meter is acting as an ammeter, but since there is a linear relationship between temperature and resistance, and since we know (from Ohm's law) that the current in a circuit will vary in accordance with resistance, the moving coil meter can be calibrated as a temperature indicator.

This is all very well provided that the power supply voltage does not change. To illustrate this problem, assume a given temperature and hence a specific resistance of the RTD. The effect of a varying power supply voltage will be to vary the current through the RTD and meter; this would change the reading even though temperature has not changed; an undesirable situation. The method employed to overcome this is a circuit called the **Wheatstone bridge**. This circuit has a number of applications and is ideally suited for the RTD.

Text 2

Vibration

Unbalanced shafts on a gas turbine engine can cause damage, particularly at high rotational speeds. These conditions can be anticipated by measuring the engine's vibration. Sensors used to detect vibration are based on **piezoelectric** crystals; a small electrical charge is created when the crystal is vibrated. Each engine has a sensor(s) located at strategic locations; the output is fed into a processor and displayed on an indicator.

The output from the processor can also be used to illuminate a warning light when pre-determined limits are exceeded. A test switch (incorporated into the light) is used to energize a relay (or equivalent electronic switch); this inserts a known frequency into the processing circuit to generate a warning. The vibration warning circuit also activates the master caution system.

Fluid pressure

Typical fluid pressures being measured on the engine include lubrication oil and fuel. There are two basic methods used to measure fluid pressure: the Bourdon tube or a capsule. The **Bourdon tube** comprises a tube formed into a curved or spiral shape. As the applied pressure from the fluid system increases, the tube will tend to straighten out, while a reduced pressure will cause the tube to return to its original shape. This movement is transferred via the gear mechanism to move a pointer. The pointer moves across a scale, thereby providing a **direct reading** of pressure. The other method used for measuring fluid pressure is with a **capsule**. As pressure is applied by the fluid, the capsule expands. This moves an iron bobbin within the envelope of two inductor coils.

Text 3

Propeller synchronization

This is a mechanism that automatically synchronizes all propellers of a multiengine aircraft to ensure that they rotate at the same speed. The main reason for synchronizing the propeller speed is for the comfort of crew and passengers; propellers that are turning at slightly different speeds create a 'beat' through **heterodyning**. This is the creation of new frequencies through mixing two different frequencies; one at the difference of the two mixed frequencies, and the other at their sum. Heterodyning creates beats that can become very tiresome to persons inside the aircraft over long periods of time. Some aircraft are installed with a visual indicator of propeller synchronization.

Pilots can use this indicator to decide whether or not to engage automatic synchronization, or to assist with manually synchronization of propeller speeds by adjusting the throttles.

Fuel management

The management of fuel is essential for the safe and economic operation of aircraft. The scope of fuel management depends on the size and type of air- craft; fuel is delivered to the engines using a variety of methods. The system comprises fuel quantity indication, distribution, refuelling, defuelling and fuel jettison. On a typical passenger aircraft, the fuel is contained within the sealed wing box structure. The fuel tanks are divided into main tanks, reserve tanks and centre wing tanks. Fuel tanks on general aviation (GA) aircraft are rubberized bags (bladder tanks) contained within the structure of the aircraft; smaller GA aircraft use metal fuel tanks attached to the wings and/or fuselage.

In the first instance, we need to measure the quantity of fuel on board the aircraft. Various technologies and methods are used to measure fuel quantity: this depends mainly on the type and size of aircraft. Technologies range from sight gauges through to electronic sensors. On larger aircraft, fuel is fed to the engines by electrically driven pumps.

On smaller aircraft, an engine-driven pump is used with electrical pumps used as back-up devices. Solenoid or motorized valves are used to isolate the fuel supply to engines under abnormal conditions. On larger aircraft, the fuel can be transferred between tanks; this is controlled manually by the crew, automatically by a fuel control computer. This chapter provides an overview of fuel management on a range of aircraft types.

Text 4

Storage overview

Rigid tanks are usually found in smaller general aviation aircraft. They are installed within the fuselage and/or wings, and are designed to be removable for inspection, replacement, or repair. They do not form an integral part of the aircraft structure.

Bladder tanks are reinforced rubberized bags installed within specific areas of aircraft structure. The bladder can be inserted/removed via the fuel filler inlet or a dedicated access panel; the bladder is then secured to the airframe by clips inside the compartment.

Integral fuel tanks are located within the structure on larger aircraft; these are sealed to accommodate fuel storage. These tanks form part of the aircraft structure; they cannot be removed for service or inspection. Access panels are installed to allow internal inspection, repair, and servicing. On large passenger aircraft, there are four main tanks, two in each wing. The area between the forward and aft spars is divided into tank sections by solid ribs. The wing skin (upper and lower surfaces) completes the tank. Wing ribs act as baffles to prevent the fuel from ‘sloshing’ around the tank. The inter-spar area of the wing centre section is also used to store fuel. This centre wing tank is similar in construction to the main tanks.

Text 5

Fuel quantity measurement and indication

Various technologies and methods are used to measure and display fuel quantity: this depends mainly on the type and size of aircraft. The fuel quantity methods described here could equally apply to other fluids, e.g. oil, hydraulic fluid or water. Some of the methods used are not actually part of an electrical system; however, they are described here to provide a complete review of the methods employed across a range of aircraft types. The methods used for measuring fuel quantity can be summarized as:

- sight glass
- float gauge
- resistance gauge
- under-wing measurement
- capacitance units.

Sight glass

The **sight glass** method is based on a simple glass or plastic tube located on the outside of the tank, and visible to the pilot. Fluid level in the tube is the same as the level in the tank; graduations on the tube provide an indication of tank contents. The advantage of this method is that it has no moving parts and is suitable for fuel or oil. This method is suitable for small aircraft where the pilot can see the sight glass; alternatively, it is suited for ground serving applications.

Float gauge

The **float gauge** uses a rod projecting through a hole in the tank cap. A float is attached to the base of the rod and this rises and falls with the fuel level. The pilot checks the amount of rod protruding through the cap and this provides a direct reading of fuel quantity. One disadvantage of this method is that it is not very stable during aircraft manoeuvres.

The majority of small general aviation (GA) aircraft use a float gauge system similar to that used in motor vehicles; this is based on a float connected to a variable resistor adjacent to the tank. The variable resistor is connected into a **DC ratiometer** circuit where two opposing magnetic fields are created in each of the coils. The pointer is formed with a permanent magnet and is aligned with the resulting magnetic field created by the coils; the pointer moves in accordance with the ratio of currents in the coil.

Text 6

Under-wing measurement

Under-wing measurement of fuel quantity is used during ground servicing only. The drip stick method uses a hollow tube pushed into the tank. During flight, the tube is stowed into a latched position, which is flush with the aircraft wing or fuselage surface. To take a reading, the tube is released from its stowed position and slowly withdrawn from the tank; when fuel starts to drip from the tank, a reading is taken from graduations on the tube.

A safer alternative to the drip stick method utilizes a transparent plastic rod. This method uses the principle of **light refraction**, and is based on fuel and air having different refractive indexes. When the tip of the rod is moved above/below the surface of the fuel, the light intensity emerging from the viewing end of the rod changes. A reading is then taken from graduations on the rod.

Another version of the under-wing fuel gauge uses a **floatstick** that comprises a rod, float and magnets located inside the tank. The floatstick is stowed when not in use and released via a quarter-turn cam mechanism; it slides out of the tank until the two magnets align and is then retained in this position. The floatstick is moved in and out of the tank until the attraction of the magnets can be sensed. The fuel quantity reading is then taken from a reference point on the surface of the wing. When the reading has been taken, the rod is pushed back and locked into the stowed position.

Floatsticks can be used when the electronic fuel quantity system (see capacitive fuel quantity system) is unserviceable. All floatsticks are read for each tank and the measurements recorded, the quantity is then calculated from tables in the aircraft documentation. A typical medium-sized aircraft has six floatsticks in each wing tank and four in the centre tank.

Text 7

Density compensation

The volume of fuel in a tank varies with temperature; as the temperature changes, the mass of fuel remains the same, but the volume changes. The dielectric is therefore affected by fuel **density**; this density will change with temperature. Increased density is a result of reduced temperature that will cause increased capacitance. Changes in fuel density are measured by a **compensation unit**. This is an additional tank unit located in the bottom of the fuel tank, therefore it is always immersed in fuel. The compensating unit is connected into the impedance bridge such that changes in fuel density cause the bridge to become unbalanced and this compensates for the change in fuel level.

Multiple tanks

Multiple tank units are often employed in larger aircraft. On a typical medium- sized passenger aircraft there are twelve capacitive tank units in each main fuel tank, and nine in the centre fuel tank. The construction of all the tank units is the same, except for their length; this depends on the depth of the tank at that particular location. Each tank unit consists of two concentric aluminium tubes and a terminal block. The aluminium tubes are anodized and polyurethane coated to protect against corrosion. The air gap between the tubes is relatively wide to avoid electrical short-circuiting, caused by contami- nation in the fuel or fungus coating on the tubes.

A tank unit wiring harness attaches to the terminal block of the tank unit. The terminals on the tank wiring harness and the terminal posts have different dimensions to prevent cross-connection during installation. Tank unit end caps are insulated to ensure that the unit does not short to the ground; they also control stray capacitance that forms between the tank unit and ground plane (**capacitance fringing**). Two brackets made of nonferrous glass-filled nylon attach each tank unit to the fuel tank structure.

Text 8

Intrinsic safety is a technique used for safe operation of electrical and electronic equipment in explosive atmospheres. It is essential that the available electrical and thermal energy in the fuel quantity system is always low enough that ignition of the hazardous atmosphere cannot occur.

GA aircraft are normally fitted with an **engine-driven pump** (EDP), with electrical **boost pumps** fitted to prime the system during starting. The electrical boost pumps also provide fuel pressure should the EDP fail. A simple fuel pump system comprises an electrically driven boost pump motor controlled by an on/off switch.

This system is enhanced by a two-stage throttle control system. When the boost pump selector switch is set at the ‘low’ setting, electrical power is switched through the resistor and the motor runs at a low speed. With the engine running, the selector is moved to the ‘high’ setting; this provides power through the normally closed (NC) contacts of the throttle micro-switch. When the throttle is set below one-third open, the resistor remains in series, and the motor continues to run at the low speed. When the throttle is advanced, the throttle micro switch changes over via the normally open (NO) contacts to bypass the resistor and apply full power to motor.

Text 9

Fuel distribution

The typical fuel feed arrangement on a medium- to large-sized passenger aircraft comprises two booster pumps for each main tank; the motor is located on the tank bulkhead, with the pump located inside the tank. The **fuel distribution** system requires electrical power and is controlled by a panel in the flight compartment. Fuel shut-off valves are connected to the battery bus, and controlled by the engine start lever and fire handle. The fuel system normally has the means of transferring fuel between tanks (see fuel transfer); this is controlled by a selector switch that operates a cross- feed valve. Each boost pump is driven by a 115V AC three-phase motor selected on/off on the control panel via a relay.

The delivery output from each pump feeds into the system via a non-return valve (NRV). Under normal operating conditions, each pump feeds own engine via a motor driven **low-pressure (LP) cock**. If a centre tank is fitted as part of a three-tank instalation, this can feed either engine by a **fuel transfer** system. On some aircraft, tank pumps are located in a dry area of the wing root; on other aircraft the pumps are actually inside the fuel tank. In the latter case, the crew have to maintain certain minimum fuel levels. Control switches for all pumps, cocks and valves together with warning indications are located on the overhead panel or the flight engineer’s station. LP cocks are automatically closed if the fire handle is activated.

This system is used to selectively transfer fuel between tanks; electrically driven fuel pumps and motorized valves are controlled either manually by the crew or by an automatic control system. Fuel can be cross-fed between the left and right tanks. On larger aircraft, the complexity of this fuel transfer system increases. The system comprises a number of motorized valves. Engine valves are activated by the start lever or fire handles. The left, centre and right refuel/defuel valves are operated from an under-wing panel. Bypass valves (BPV) are operated if an elec- trical pump’s fuel filter is blocked. (The BPV senses differential pressure across the filter.) Controls and indications are located on an overhead panel or flight engineer's station. An electrically operated cross-feed valve normally closed unless fuel is being transferred.

Text 10

Fuel temperature and refuelling and defuelling

It is essential that **fuel temperature** is monitored, either manually or automatically. The maximum fuel temperature is typically 49°C; the minimum fuel temperature is –45°C or freezing point 3°C, whichever is higher; the typical freezing point of Jet A1 fuel is 47°C. Fuel temperature is measured by an RTD. If the fuel temperature is approaching the lower limits, some fuel could be transferred between tanks; alternatively the aircraft would have to descend into warmer air or accelerate to increase the kinetic heating.

Refuelling and defuelling

A refuelling control panel and pressure connections are normally located in one or both of the wing areas allowing the fuel to be supplied directly into the main fuel system. A **bonding lead** is always connected between the fuel bowser and aircraft to minimize the risk of static discharge. The fuel tank supply line is connected to the aircraft and pressure applied. Selective control of the system's motorized valves allow specific tanks to be filled as required. **Defuelling** is often required before maintenance, or if the aircraft is to be weighed. The fuel is transferred from the aircraft into a suitable container, typically a fuel bowser. This is achieved via a defuelling valve and applying suction through valves.

Text 11

Fuel jettison and fuel tank venting

When an aircraft takes off fully loaded with passen- gers and fuel, and then needs to make an emergency landing, it will almost certainly be over its maximum landing weight. Fuel has to be disposed of to reduce the aircraft weight to prepare for the emergency land- ing. A large aircraft such as the Boeing 747 can be carrying over 100 tonnes of fuel; this is almost 50% of the aircraft's gross weight. One way of burning off fuel and reducing aircraft weight is to fly in a high drag configuration, e.g. 250 knots with the gear down (speed-brakes will further increase the drag). Aircraft can be certified for landings up to the maximum takeoff weight (MTOW) in an emergency; however, overweight landings would only be made if burning off fuel exposed the aircraft to additional hazards. Some aircraft are installed with a **fuel jettison**, or **fuel dumping** system. This provides a means of pumping fuel overboard to rapidly decrease the aircraft's weight. Fuel can normally be jettisoned with landing gear and/or flaps extended. Two **jettison pumps** are installed in each main tank, fuel is pumped via a jettison manifold to nozzle valves located at each wing tip trailing edge.

Fuel tank venting

The venting system takes ram air from intakes on the underside of the wing for two specific purposes. When the aircraft is flying, ram air is used to pressurize the fuel to prevent vaporization at lower atmospheric pressures. The ram air also pressurizes the fuel tanks to ensure positive pressure on the inlet ports of each pump. The expansion space above the fuel, called **ullage**, changes with aircraft attitude. Float-operated vent valves are located at key points in the tank to allow fuel to escape into the vent system. Venting tanks (sometimes called **surge tanks**) in the wing tips collect this overspill from the main tanks; the fuel is then pumped back into one of the main tanks. Float-operated vent valves prevent inadvertent transfer of fuel between the tanks.

GLOSSARY

Cabin atmosphere control systems.

absolute pressure

абсолютное давление (относительно полного вакуума)

air cycle machine (ACM)

турбохолодильник

air-condition unit

блок кондиционирования воздуха

air-to-air heat exchanger

воздухо-воздушный радиатор (ВВР)

altitude

высота

ambient temperature

температура забортного воздуха

by centigrade

по шкале Цельсия

by Fahrenheit

по шкале Фаренгейта

bypass valve

перепускной клапан

cabin altitude

"высота в кабине"

continuous-flow regulator

дыхательный кислородный прибор без отсечки (обычно для пассажиров)

depressurization

разгерметизация

diluter-demand regulator

дыхательный кислородный прибор с отсечкой (обычно для членов экипажа) emergency depressurization

аварийная разгерметизация

heat exchanger

теплообменник

isolation valve

перекрывной клапан

negative pressure valve

клапан отрицательного перепада

outflow valve

выпускной клапан

overpressure

перенаддув

oxygen

кислород

oxygen generator

химический источник кислорода

oxygen mask

кислородная маска

pressure

давление

pressure relief valve

предохранительный клапан

pressure-reducer valve

редукционный клапан

pressurization system

система регулирования давления в кабине

ram-air temperature rise

температура торможения (на суб- и сверхзвуке)

supercharger

компрессор наддува (на высотных поршневых самолетах)

vapor cycle system

фреоновый охладитель (на поршневых самолетах) water separator

водоотделитель

Engine – general

accessory drive gearbox

коробка приводов самолетных агрегатов

annular-type combustion chamber

кольцевая камера сгорания

axial-flow compressor

осевой компрессор

bearing

подшипник

blade (или vane)

лопатка (компрессора или турбины)

bottom dead center

нижняя мертвая точка

breaker-distributor

прерыватель-распределитель

can-type combustion chamber

трубчатая камера сгорания

centrifugal-flow compressor

центробежный компрессор

combustion chamber

камера сгорания

compression ring

компрессионное кольцо

compression stroke

сжатие

compressor

компрессор

connecting rod

шатун

cowling

капот

crankshaft

коленчатый вал

cylinder

цилиндр

exhaust collector

выпускной коллектор

exhaust pipe

выхлопная труба

exhaust stroke

выхлоп

exhaust valve

выпускной клапан

fan

вентилятор

four-stroke cycle engine

четырехтактный двигатель

gearbox

коробка приводов (в общем случае)

ignitor plug (или spark plug)

свеча зажигания

in-line reciprocating engine

поршневой однорядный двигатель

inlet duct

воздухозаборник

intake stroke

всасывание

intake valve

впускной клапан

jet pipe (или jet nozzle)

реактивное сопло

magneto

магнето

oil control ring

маслоудерживающее кольцо

oil scraper ring

маслосъемное кольцо

opposed reciprocating engine

оппозитный двигатель

piston

поршень

power stroke

рабочий ход

pulse-jet engine

пульсирующий реактивный двигатель

radial reciprocating engine

звездообразный двигатель

reciprocating engine

поршневой двигатель

rocket engine

ракетный двигатель

schroud

кожух

shaft

вал

stage

ступень (компрессора или турбины)

surge valves

клапаны перепуска воздуха

thrust reverser

реверсивное устройство

top dead center

верхняя мертвая точка

turbine

турбина

turbine nozzle vane assembly

сопловой аппарат

turbofan engine

турбовентиляторный двигатель

turbojet engine

турбореактивный двигатель

turboprop engine

турбовинтовой двигатель

two-stroke cycle engine

двухтактный двигатель (в авиации не используется)

V-type reciprocating engine

V-образный двигатель

valve-operating mechanism

механизм газораспределения

variable-geometry inlet duct

воздухозаборник с изменяемой геометрией (обычно сверхзвуковой)

vortex destroyer

система струйной защиты двигателя

Engine fuel and fuel metering systems

accelerating pump

ускорительный насос (в поршневом двигателе)

boost pump

подкачивающий топливный насос

carburetor

карбюратор

fuel

топливо

fuel control unit

в поршневых двигателях: устройство регулирования качества fuel nozzle

топливная форсунка

fuel tank

топливный бак

fues scheduling system

система управления топливом

gravity fueling

открытая заправка

pressure fueling

централизованная заправка

transfer pump

насос перекачки

vapor lock

"паровая пробка"

venturi

трубка Вентури (в измерительных системах)

Engine starting systems

cranking

прокрутка двигателя

hot start

заброс температуры на запуске

hung start

зависание оборотов на запуске

ignition

зажигание

overheat

заброс температуры

overspeed

заброс оборотов

starter

стартер

Lubrication and cooling systems

breather

система суфлирования

breather centrifuge

центробежный суфлер

fuel-oil heat exchanger

топливно-масляный радиатор (ТМР)

oil

масло

oil cooler

маслорадиатор

oil pump

маслонасос

oil tank

маслобак

pressure oil pump

питающий маслонасос

scavenge oil pimp

маслонасос откачки

Propellers

automatic propeller

винт с изменяемым (автоматически) шагом

blade

лопасть

blade tracking

регулировка относительного положения лопастей

controllable-pitch propeller

винт с изменяемым (вручную) шагом

effective pitch

поступь винта

fixed-pitch propeller

воздушный винт постоянного шага

geometric pitch

шаг винта

ground-adjustable propeller

воздушный винт с регулируемым (только на земле) шагом

pitch

установочный угол лопасти

pitch change mechanism

механизм изменения шага

propeller

воздушный винт

propeller balancing

балансировка винта

pusher propeller

толкающий винт

reduction gear assembly (или reducer)

редуктор

slip

скольжение

tractor propeller

тянущий винт

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