МИНИСТЕРСТВО ОБЩЕГО И ПРОФЕССИОНАЛЬНОГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ

САМАРСКИЙ ГОСУДАРСТВЕННЫЙ АЭРОКОСМИЧЕСКИЙ УНИВЕРСИТЕТ имени академика С.П.КОРОЛЕВА

ГАЗОТУРБИННЫЕ ДВИГАТЕЛИ

(часть II)

Методические указания по английскому языку

САМАРА 1998

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Данные методические указания составлены в соответствии с требованиями программы по английскому языку для неязыковых вузов и предназначены для студентов II курса дневного отделения II факультета.

Методические указания содержат оригинальные тексты по тематике II факультета, различные грамматические и лексические упражнения.

Познавательный характер оригинальных научно-технических статей из английских и американских источников, их новизна, теоретическая и практическая значимость подводят студентов к чтению оригинальной литературы и научно-технических текстов, а также к их обсуждению.

Разработаны на кафедре иностранных языков.

Печатаются по решению редакционно-издательского совета Самарского государственного аэрокосмического университета имени академика С.П.Королева

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Sound suppression. The Noise Problem

1. Запомните следующие слова:

noise n	[nɔiz]	шум
take off n	['teikɔf]	взлет
landing n	['lændiŋ]	посадка
residential areas n	[,rezi'denʃnl 'ɛəriəz]	жилые кварталы
pattern n	['pætn]	образец, способ, пример
reciprocating engine n	[ri'siprəkeitiŋ 'endʒin]	поршневой двигатель
rise, rose, risen v	[raiz, rouz, rizn]	подниматься
reach v	[ri:tʃ]	достигать
relatively adv	['relətivli]	относительно, сравнительно
overlap v	[ouvə'læp]	перекрывать
frequency n	['fri:kwənsi]	частота
shear v	[ʃiə]	срезать,резать
bring down (brought,brought) v	['briŋ 'daun]	снижать
sound suppressor n	[saund sə'presə]	шумоглушитель
comparable adj	['kɔmpərəbl]	сравнимый
level n	[levl]	уровень
high-bypass-ratio n	['hai 'baipa:s 'reiʃiou]	высокая двухконтурность
inlet n	['inlet]	впуск, впусковое отверстие, вход
guide vane n	['gaid 'vein]	направляющая лопатка
fluctuation n	[,flʌktju'eiʃn]	неустойчивость, колебания
lining n	['lainiŋ]	облицовка
shroud n	[ʃraud]	кожух

Найдите синонимы к следующим словам, используя слова, данные под чертой.

pattern, reciprocating, reach, shear, vane, bring down, propeller, exhaust, occur, generate, velocity

piston, cut, blade, discharge, screw, lower, take place, produce, get, model, speed

2. Найдите антонимы.

approximately, sharply, produce, less, exhaust, elimination, reduction, rapidly

use, intake, increase, gradually, slowly, exactly, generation, more

3. Определите, в какой степени (положительная, превосходная) употреблены следующие прилагательные, назовите все три степени, переведите их,

less, more, further, farther, slower, lower, more, difficult

4. Найдите в тексте предложения с этими прилагательными, переведите их.

5. Переведите следующие словосочетания:

within the last several years; the pattern of sound; exhaust-gas velocity; comparable size; through the elimination; by spacing the outlet guide vanes farther away from the compressor

6. Прочтите и переведите интернациональные слова:

problem, commercial, military, airport, propeller, observer, peak, ordinary, result, reason, function, operation, limitation, integral

7. Прочтите текст.

SOUND SUPPRESSION. THE NOISE PROBLEM

The noise problem created by commercial and military jet take offs, landings and ground operations at airports near residential areas has become a very serious problem within the last several years.

The pattern of sound from a jet engine makes the noise problem even more bothersome than that coming from other types of engines. For example, the noise from a reciprocating engine rises sharply as the airplane propeller passes an observer on the ground and then drops off almost as quickly. A jet reaches a peak after the aircraft passes and is at an angle of approximately 45° to the observer. This noise then stays at a relatively high level for a considerable length of time. The noise from a turbojet is also more annoying because it overlaps the ordinary speech frequencies more than the noise from a reciprocating engine and propeller combination.

Since the noise is produced by the high-velocity exhaust gas shearing through the still air, it follows that if the exhaust velocity is slower and the mixing area wider, the exhaust noise levels can be brought down to the point where a sound suppressor is not necessary. The exhaust-gas velocity of a turbofan is slower than a turbojet of comparable size because more energy must be removed by the turbine to drive the fan. The fan exhaust velocity is relatively low and creates less of a noise problem, noise levels are also lower in the high-bypass-ratio turbofan engine through the elimination of the inlet guide vanes and the resulting reduction of the "siren" effect. The noise generated by this effect occurs when the columns of air created by the compressor inlet guide vanes are cut by the rapidly moving compressor blades, generating high-frequency pressure fluctuations. Further noise reductions are achieved by lining the fan shroud with acoustical materials, thus, dampening the pressure fluctuations and by spacing the outlet guide vanes farther away from the compressor. For these reasons, fan engines in general do not need sound suppressor.

The function of the noise suppressor is to lower the level of sound about 25 to 30 dB, as well as to change the frequency, and to do this with a minimum sacrifice in engine thrust or additional weight.

The two facets of the noise problem, ground operation and airborne operation, lend themselves to two solutions.

Noise suppressors can be portable devices for use on the ground by maintenance personnel, or they can be integral part of the aircraft engine installation.

Airborne suppressors are more difficult to design than ground suppressors because of the weight limitations and the necessity of having the air exit in an axial direction to the engine.

Notes: dB — децибелл

8. Ответьте на вопросы:

1. What problems is the text devoted to?
2. Why did the noise problem become one of the most important within the last several years?
3. What modern engines are less noisy and why?

4. Why does a turbofan need no sound suppresor?
5. What is the function of the noise suppressor?

9. Передайте краткое содержание второго абзаца. Озаглавьте его.

10.Переведите текст.

Lesson 2

Turnine Construction

1. Запомните следующие слова:

stressed part n	['strest 'pa:t]	нагруженная (напряженная) часть
severe adj	[si'viə]	суровый, жестокий
impose v	[im'pouz]	обусловливать
forge v	[fɔ:dʒ]	ковать
machine v	[mə'ʃi:n]	подвергать механической обработке
X-ray n	['eks 'rei]	рентгеновские лучи
rate n	[reit]	скорость, темп
hold v	[hould]	держать, удерживать
rivet v, n	['rivit]	клепать, заклепка
locking tab v,n	['lɔkiŋ 'tæb]	запирающий узел
prevent v	[pri'vent]	предотвращать
distortion n	[dis'tɔ:ʃn]	искажение
twist v	[twist]	крутить, скручивать, искривлять
pitch n	[pitʃ]	тангаж, шаг винта
seal n	[si:l]	герметизация
shrouding n	['ʃraudiŋ]	обшивка
recess n,v	[ri'ses]	углубление, делать углубление

replacement n	[ri'pleismənt]	замена
similar adj	['similə]	похожий, подобный
succeed v	[sək'si:d]	следовать за ч-либо
preceding adj	[pri'si:diŋ]	предшествующий
attach v	[ə'tætʃ]	прикреплять, присоединять
subject adj	['sʌbdʒikt]	подверженный, подчиненный
creep,crept,crept v	[kri:p], [krept]	ползти
bucket n	['bʌkit]	лопатка

2. Найдите синонимы:

shrouding, part, speed, control, assembly, inspect, blade, method, demand, similar

---

unit, velocity, detail, casing, manage, bucket, technique, check, like, require.

3. Найдите антонимы:

reduce, advantage, open, thin, drive, extract, in front of, preceeding

---

absorb, behind, succeeding, increase, thick, closed, disadvantage, stop.

4. Переведите следующие словосочетания:

under severe centrifugal loads imposed by high rotational speeds; within safe operating limits; the disk is machined all over; «fir-tree» design; blade –tip losses; high Mach number flights; in this case.

5. Прочтите и переведите следующие интернациональные слова:

turbine, temperature, accurately, control, statically, dynamically, machine, method, integrity, expansion, compressor, manufacturer, stamp, diaphragm.

6. Прочтите текст.

TURBINE CONSTRUCTION

The turbine wheel is one of the most highly stressed parts of the engine. Not only must it operate at temperatures of approximately 1800 F (983° C), but it must do so under severe centrifugal loads imposed by high rotational speeds of over 60.000 rpm for small engines to 8.000 rpm for the larger ones. Consequently, the engine speed and turbine inlet temperature must be accurately controlled to keep the turbine within safe operating limits.

The turbine assembly is made of two main parts, the disk and the blades. The disk or wheel is a statically and dynamically balanced unit of specially alloyed steel usually containing large percentages of chromium, nickel, and cobalt. After forging, the disk is machined all over and carefully inspected using X-rays, sound waves, and other inspection methods to assure structural integrity. The blades or buckets are attached to the disk by means of a "fir-tree" design to allow for different rates of expansion between the disk and the blade while still holding the blade firmly against centrifugal loads. The blade is kept from moving axially either by rivets, special locking tabs or devices, or another turbine stage.

Some turbine blades are open at the outer perimeter, whereas in others a shroud is used. The shroud acts to prevent blade-tip losses and excessive vibration. Distortion under high loads, which tend to twist the blade toward low pitch, is also reduced. The shrouded blade has an aerodynamic advantage in that thinner blade sections can be used and tip losses can be reduced by using a knife edge or labyrinth seal at this point. Shrouding, however, requires that the turbine run cooler or at a reduced rpm because of the extra mass at the tip. On blades that are not shrouded, the tips are cut or recessed to a knife edge to permit a rapid "wearing-in" of blade tip to the turbine casing with a corresponding increase in turbine efficiency.

Blades are forged from highly alloyed steel and are passed through a carefully controlled series of machining and inspection operations before being certified for use. Many engine manufactures will stamp a "moment weight" number on the blade to retain rotor balance when replacement is necessary.

The temperature of the blade is usually kept within limits by passing relatively cool air bled from the compressor over the face of the turbine, thus cooling the disk and the blade by the process of convection. This method of cooling may become more difficult, as high Mach number flights develop high compressor inlet and outlet temperatures.

Some gas turbine engines use a single-stage turbine, whereas others employ more than one turbine wheel. Multi-stage turbines are used where the power required to drive the compressor would necessitate a very large turbine wheel. Multistage wheels are also used for turboprops where the turbine has to extract enough power to drive both the compressor and the propeller. When two or more turbine wheels are used, a nozzle diaphragm is positioned directly in front of each turbine wheel. The operation of the multiple-stage turbine is similar to that of the single stage, except that the succeeding stages operate at lower gas velocities, pressures, and temperatures. Since each turbine stage receives the air at a lower pressure than the preceding stage, more blade area is needed in the rear stages to assure an equitable load distribution between stages. The amount of energy removed from each stage is proportional to the amount of work done by each stage.

Most multistage turbines are attached to a common shaft. However, some multistage turbine engines have more than one compressor. In this case, some turbine wheels drive one compressor and the remaining turbines drive the other.

The wheel is subjected to both high speed and high temperature. Because of these extreme conditions, blades can easily deform by growing in length (a condition known as "creep") and by twisting and changing pitch. Since these distortions are accelerated by exceeding engine operating limits, it is important to operate within the temperature and rpm points set by the manufacturer.

7. Ответьте на вопросы:

1. Why can we say that the turbine wheel is the most stressed part of the unit?
2. What are the main turbine parts?
3. What design is used to attach the blades to the disk?
4. What are the advantages of the shrouded blades?
5. How is the temperature of the blade kept within limits?
6. What turbines are used in gas turbine engines?
7. What is the operation difference of single-stage and multi-stage turbines?

8. Просмотрите текст и выполните следующие задания:

1. Найдите в первом и третьем абзацах модальные глаголы и замените их соответствующими эквивалентами.
2. Во втором абзаце найдите предложения со сказуемыми в страдательном залоге, определите время, переведите эти предложения.
3. Озаглавьте третий абзац, передайте его содержание.
4. Переведите четвертый и пятый абзацы.
5. Дайте письменный перевод 6,7,8 абзацев.

Lesson 3

Compressor stall

1. Запомните следующие слова:

airfoil n	['ɛə fɔil]	аэродинамическая поверхность
apply v	[ə'plai]	использовать
entire adj	[in'taiə]	полный,цельный,весь
close adj	[klous]	близкий
affect v	[ə'fekt]	воздействовать,влиять
leading edge n	['li:diŋ 'edʒ]	ведущая (передняя) кромка
preceding v	[pri'si:diŋ]	предыдущий, предшествующий
duct n	[dʌkt]	сопло, канал
rather than conj	['ra:ðə 'ðæn]	а не
determine v	[di'tə:min]	определять
stall v,n	[stɔ:l]	срыв
strike, struck,struck v	[straik], [strʌk]	ударять, бить
confuse v	[kən'fju:z]	смешивать, спутывать
incidence n	['insidəns]	наклон
foil n	[fɔil]	пленка
surface n	['sə:fis]	поверхность
destroy v	[di'strɔi]	разрушать
inlet n	['inlet]	впускное отверстие
choke n	[tʃouk]	дроссель (воздушная заслонка), дросселирование
experience n	[iks'piəriəns]	жизненный опыт
ram n	[ræm]	скоростной напор
spool n	[spu:l]	каскад
bleed valve n	['bli:d 'vælv]	спусковой клапан, продувной клапан
bleed,bled,bled	[bli:d]	выпускать, отвозить

2. Подберите синонимы к следующим словам:

apply entire, preceding, duct, inlet, blade, discharge, vary, velocity

---

bucket, intake, exhaust, nozzle, change, previous, whole, speed, use.

3. Подберите антонимы к данным ниже словам:

result in, increase, lift, action, generate, bleed, leave

---

reaction, admit, utilize, result from, decrease, enter, descend.

4. Переведите следующие словосочетания:

the picture is somewhat more complicated than is the case for a single airfoil; excessive fuel-flow schedule; inlet pressure may become too low in respect to the compressor discharge pressure; the front- end, low-speed, high- temperature stall condition; so that; this "cascade effect can be more readily understood.

5. Прочтите и переведите следующие слова:

Compressor, rotate, stationary, passage, cascade, effect, generate, problem, manufacturer, zone, turbulent, tendency, acceleration, operation.

6. Переведите словосочетания:

because of, due to, in respect to, too high, too great.

Примечания к тексту:

in turn – в свою очередь

i.e. = that is – т.е.

7. Прочтите текст.

COMPRESSOR STALL

Since an axial-flow compressor consists of a series of alternately rotating and stationary airfoils or wings, the same rules and limitations which apply to an airfoil will apply to the entire compressor. The picture is somewhat more complicated than is the case for a single airfoil, because the blades are close together, and each blade is affected at the leading edge by the passage through the air of the preceding blade.

This "cascade" effect can be more readily understood if the airflow through the compressor is viewed as flow through a series of ducts formed by the individual blades, rather than flow over an airfoil that is generating lift. The cascade effect is of prime importance in determining blade design and placement.

The axial compressor is not without its difficulties, and the most vital of these is the stall problem. If for some reason the angle of attack, i.e , the angle at which the airflow strikes the rotor blades, becomes too low, the pressure zones will be of low value and the airflow and compression will be low. (The angle of attack should not be confused with the angle of incidence, which is a fixed angle determined by the manufacturer when the compressor is constructed). If the angle of attack is high, the pressure zones will be high and airflow and compression ratio will be high. If it is too high the compressor will stall. That is, the airflow over the upper foil surface will become turbulent and destroy the pressure zones. This is, of course, decrease the compression and airflow. The angle of attack will vary with engine rpm, compressor inlet temperature, and compressor discharge or burner pressure. Decreasing the velocity of airflow or increasing engine rotor speed will tend to increase the angle of attack.

In general, any action that decreases airflow relative to engine speed will increase the angle of attack and increase the tendency to stall. The decrease in airflow may result from the compressor discharge pressure becoming too high, for example, from excessive fuel-flow schedule during acceleration. On compressor inlet pressure may become too low in respect to the compressor discharge pressure because of high inlet temperatures or distortion of inlet air. Several other causes are possible.

During ground operation of the engine, the prime action that tends to cause a stall is choking. If the engine speed is decreased from the design speed, the compression ratio will decrease with the lower rotor velocities. With a decrease in compression the volume of air in the rear of the compressor will be greater. This excess volume of air causes a choking action in the rear of the compressor with a decrease in airflow, which in turn decreases the air velocity in the front of the compressor and increases the tendency to stall. If no corrective design action is taken, the front of the compressor will stall at low engine speeds.

Another important cause of stall is high compressor inlet air temperatures. High-speed aircraft may experience an inlet air temperature of 250° F (121° C) or higher because of ram effect. These high temperatures cause low compression ratios (due to density changes) and will also cause choking in the rear of the compressor. This choking-stall condition is the same as that caused by low compression ratio due to low engine speeds. High compressor inlet temperatures will cause the length of the airflow vector to become longer since the air velocity is directly affected by the square root of any temperature change.

Each stage of a compressor should develop the same pressure ratio as all other stages. But when the engine is slowed down or the compressor inlet temperature climbs, the front stages supply too much air for the rear stages to handle and the rear stages will choke.

There are five basic solutions which can be utilized to correct this front-end, low-speed, high-temperature stall condition:

1. Derate or lower the angles of attack on the front stages so that the high angles at low engine speed are not stall angles.

2. Introduce a bleed valve into the middle or rear of the compressor and use it to bleed air and increase airflow in the front of the compressor at low engine speeds.

3. Divide the compressor into two sections or rotors (the two-spool rotor) and design the front rotor speed to fall off more than the rear rotor at low speeds so that the low front rotor speed will equal the low choked airflow.

4. Place variable guide vanes at the front of the compressor and variable stator vanes in the front of the first several compressor stages so that the angles of attack can be reset to low angles by moving the variable vanes at low engine speeds. Some advanced engine designs also utilize the variable stator concept on the last several compressor stages.

5. Use a variable-area exhaust nozzle to unload the compressor during acceleration.

8. Просмотрите текст и выполните следующие задания:

1. Просмотрите первый абзац, озаглавьте его.
2. Передайте содержание второго абзаца на русском языке.
3. Переведите 3,4,5,6,7 абзацы; в 3 и 5 абзацах найдите союзы, переводимые следующим образом: из-за, по отношению к, вследствие.
4. Письменно переведите 7 и 8 абзацы.

9. Ответьте на вопросы:

1. What does an axial-flow compressor consist of?
2. What is the most vital problem of the axial-flow compressor?
3. When can the axial-flow compressor stall take place?
4. What are the main reasons of the axial-flow compressor stall?

5. How is it possible to prevent the axial-flow compressor stall?

Lesson 4

Construction Features of Centrifugal-Flow Compressor

1. Запомните следующие слова:

treat v	[tri:t]	обрабатывать
cast n	[ka:st]	литье, отливка
inducer n	[in'djusə]	возбудитель
impeller n	[im'pelə]	лопастное колесо, крыльчатка
vane n	[vein]	лопасть, лопатка
fit v	[fit]	подгонять, монтировать
case n	[keis]	кожух, обшивка
clearance n	['kliərəns]	зазор, вредное пространство
feeler gage n	['fi:lə 'geidʒ]	датчик, измерительный прибор
accomplish v	[ə'kɔmpliʃ]	выполнять
hole n	[houl]	дыра
hub n	[hʌb]	втулка
nut n	[nʌt]	гайка
support bearing n	[sə'pɔ:t 'bɛəriŋ]	опорный подшипник
ball bearing n	['bɔ:l 'bɛəriŋ]	шариковый подшипник
depend v	[di'pend]	зависеть
stainless steel n	['steinlis 'sti:l]	нержавеющая сталь
forging n	['fɔ:dʒiŋ]	ковка
remainder n	[ri'meində]	остаток, остальные
coat v,n	[kout]	покрывать, покрытие
wear out, wore worn v	['wɛə 'out], [wɔ:], [wɔ:n]	изнашивать(ся)
damage n	['dæmidʒ]	вред, повреждение

join together v	[dʒɔin təˈgeðə]	соединяться
rim n	[rim]	край, кромка
improve v	[imˈpru:v]	улучшать, совершенствовать
withstand v	[wiðˈstænd]	выдерживать, противостоять

2. Найдите синонимы к данным словам:

manufacture, duct, slight, vane, strike, case, inner, outer, instance, construction, vary

---

blade, little, produce, change, nozzle, shock, shroud, interior, example, design, external.

3. Найдите антонимы к данным словам:

forward, several, separately, solid, outer, bend, provide, various

---

together, inner, liquid, backward, smooth, use, single, the same.

4. Переведите следующие фразы:

heat-treated forged aluminium compressor; all full length; from between the blades; by reducing boundary layer flow separation; after assembly the compressor is balanced as a unit; the compressor case is one of the principal structural, load-bearing members of the engine.

5. Прочтите и переведите интернациональные слова:

minimize, direct, shock, maximum, efficiency, balance, material, compressor, turbine, variation, manufacturer, assembly, machine, titanium, bolt.

6. Используйте данные слова при переводе текста:

a stub shaft - укороченный вал

a spacer - прокладка, распорка

a tie bolt - крепежный болт

to anchor -фиксировать

bulged - деформированный, выпученный

knife-edge - заостренный, острый

a canted vane - наклоненная лопатка

serration - зубец, зубчатость

a spline - шлиц, шпонка
a dovetail - ласточкин хвост

7. Прочтите текст.

CONSTRUCTION FEATURES OF CENTRIFUGAL-FLOW COMPRESSOR

Centrifugal-flow jet engines use heat-treated forged aluminium compressors, although cast compressors are being used on small engines of this type. The aluminium or magnesium diffuser is also generally manufactured by casting. In many cases the inducer or guide vanes, which smooth and direct the airflow into the engine and thus minimize the shock in the impeller, are manufactured separately from the impeller or rotor. Rotor vanes may either be all full length, or some may be half length. A close fit is important between the compressor and its case in order to obtain maximum compressor efficiency. The clearance is usually checked with a feeler gage or with a special fixture. Balancing of the rotor may be accomplished by removing material from specified areas of the compressor or by using balancing weights installed in holes in the hub of the compressor. On some engines in which the compressor and turbine wheel are balanced as a unit, special bolts or nuts having slight variations in weight are used. Compressor support bearings may be either ball or roller, although most manufactures use at least one ball bearing on the compressor to support both axial and radial loads.

Axial-flow engines have compressors that are constructed of several different materials depending upon the load and temperature under which the unit must operate. The rotor assembly consists of stub shafts, disks, blades, ducts, spacers, and torque cones. The rotor blades are generally machined from stainless steel forgings, although some blades may be of titanium in the forward or colder part of the compressor; the remainder of the components are machined, low-alloy steel forgings. The clearance between the rotating blades and the outer case is most important with many manufacturers depending upon a "wear fit" between the blade and the compressor case. Many companies design their blades with knife-edge tips so that the blades will wear away and form their own clearance as they expand from the heat generated from compression of the air. Other companies coat the inner surface of the compressor case with a soft material which can be worn out without damage to the blade. The several stages of the compressor are composed of the disks which can be joined together by means of a tie bolt. Serrations or splines prevent the disks from turning in relation to each other. Other manufactures eliminate the tie bolt and join the stages together at the disk rim. Methods of attaching the blade to the disk also vary between manufactures with the majority using some variations of the dovetail to hold the rotor blade in the disk. Various locking methods are used to anchor the blades in place. The blades do not have a tight fit in the disk but rather are seated by centrifugal force during engine operation. By allowing the blades some movement, vibrational stresses, produced by the high-velocity airstreams from between the blades, are reduced.

8. Ответьте на вопросы:
1. What is the construction of the centrifugal-flow compressor?
2. What is the main principle of its operation?
3. What is the reason of airflow increase?
4. What may the stator vanes be?
5. What requirements must the centrifugal-flow compressor meet?

9. а) Просмотрите первый абзац:
- найдите эквиваленты слов: по крайней мере; для того, чтобы; с помощью (за счет); или...или; И...и;
- найдите слова, связанные с конструкцией и работой центробежного компрессора.

б) Переведите второй абзац и озаглавьте его.

в) Просмотрите третий абзац:
- найдите в нем синонимы слов: supply, bucket, ability, effectiveness, decreasing, outer, shroud
- можно ли было вместо "few" употребить "little" в словосочетании "in the first few stages"?

г) Дайте письменный перевод 3 и 4 абзацев.

Lesson 5

The Convergent-Divergent Nozzles

1. Запомните следующие слова:

incur v [ɪn'kɜː] подвергаться, навлекать на себя

entrance n	['entrəns]	вход, доступ
convergent adj	[kən'və:dʒənt]	суживающийся
cause n,v	[kɔ:z]	причина, основание; вызывать
turn v	[tə:n]	вращать, превращаться
occur v	[ə'kə:]	происходить
divergent adj	[dai'və:dʒənt]	расходящийся
convergent-divergent nozzle n		сверхзвуковое сопло
supersonic adj	['sju:pə'sɔnik]	сверхзвуковой
grease n,v	[gri:z]	смазка; смазывать
rubber n	['rʌbə]	резина
funnel n	['fʌnl]	раструб, воронка
rate n	[reit]	скорость, темп
smooth adj	[smu:ð]	гладкий, ровный
afterburner n	['a:ftə,bə:nə]	форсажная камера
incorporate v	[in'kɔ:pəreit]	включать
variable adj	['vɛəriəbl]	меняющийся, переменный
eyelid n	['ailid]	створка, регулируемое сопло
clamshell n	['klæmʃəl]	грейфер
orifice n	['ɔrifis]	отверстие, выход, сопло
flap n	[flæp]	заслонка, щиток
airflow n	['ɛəflou]	воздушный поток
		обтекаемый
overlap n,v	['ouvəlæp]	нахлестка; перекрывать
rear adj, n	[riə]	задний, тыл
contribute v	[kən'tribju:t]	способствовать
idle adj	['aidl]	холостой, без действия
available adj	[ə'veiləbl]	имеющийся в наличии
penalty n	['penlti]	искажение, ухудшение

2. Подберите синонимы:

nozzle, blade, utilize, occur, velocity, flow, incorporate, eject, link, in addition to

take place, speed, stream, vane, comprise, duct, exhaust, besides, connect, use.

3. Подберите антонимы:

convergent, accelerate, exit, inlet, increase, turbulent, variable, main

decrease, constant, auxiliary, smooth, entrance, divergent, decelerate, outlet.

4. Переведите следующие словосочетания:

across the duct; most of the expansion; variable-area exhaust nozzle; thereby; convergent-divergent elector type; two-piston eyelid; the pressure can be turned into velocity.

5. Прочтите и переведите следующие интернациональные слова:

Approximately, individual, gas, molecule, accelerate, control, action, produce, experiment, normal, effect, condition, turbulent.

6. Примечание к тексту:

Mach number – число Маха (отношение скорости полета самолета к скорости звука)

7. Прочтите текст.

THE CONVERGENT-DIVERGENT NOZZLE

If the pressure at the entrance to a convergent duct becomes approximately twice that at the exhaust nozzle, the change in velocity through the duct will be enough to cause sonic velocity at the nozzle. At high Mach numbers the pressure ratio across the duct will become greater than 2.0, and unless this pressure can be turned into velocity before the gases exit from the nozzle, a loss of efficiency will occur. Since the maximum velocity that a gas can attain in a convergent nozzle is the speed of sound, a convergent-divergent nozzle must be used. In the diverging section, the gas velocities can be increased above the speed of sound. Since the individual gas molecules cannot be pushed by the pressure or molecules behind them, the gas molecules can be accelerated only by increasing the gas volume outward and rearward. The diverging section of the convergent-divergent nozzle allows expansion outward, but also holds in the expansion so that most of the expansion is directed rearward off the side wall of the diverging section. In other words, the diverging action accelerates the airflow to supersonic velocities by controlling the expansion of the gas so that the expansion (which is only partially completed in the converging section) will be rearward and not outward to the side and wasted. An example of the action that produces an increase in thrust through a diverging nozzle can be shown with the following experiment. If a greased rubber ball is pushed down into a funnel and then released, the ball would shoot out of the funnel. If only the funnel were released, it would move away from the ball. What is happening is that the ball is partially compressed when it is pushed down the funnel, increasing the pressure of the air inside the ball. When the funnel is released, the air in the ball expands, returning the ball to its normal size and pushing the funnel away. This same type of action occurs in the diverging section of a converging-diverging nozzle. As the gasses expand against the side of the duct, they produce a pushing effect even though they are decreasing in pressure.

To sum up then, supersonic, or compressible, flow through a divergent duct will result in increasing velocity above the speed of sound, decreasing pressure, and decreasing density (increasing volume).

Unfortunately the rate of change in the divergent duct may be too large or small for a given engine operating condition to allow a smooth supersonic flow. That is, the rate of increase in area of the duct is not correct for the increase in the rate of change in volume of the gases. If the rate of increase is too small, maximum gas velocities will not be reached. If the rate of increase is too great, turbulent flow along the nozzle wall will occur. To correct this problem, and for use with an afterburner, all engines capable of supersonic flight incorporate a variable-area exhaust nozzle. Older engines utilized a two-position eyelid or "clamshell" type of variable-area orifice, but modern jet nozzles are infinitely variable aerodynamic converging-diverging ejector types utilizing primary and secondary nozzle flaps to control the main and secondary airflows. The converging section is formed by a series of overlapping primary flaps through which the air is accelerated to sonic velocity. The diverging section may be formed by a secondary airflow instead of a metal wall. The ejector action produced by the main airflow shooting out of the primary nozzle or nozzle flap draws the secondary flow into the outer shroud and ejects it out the rear end. The ejected secondary air which comes from the outside of the engine will be accelerated to a higher velocity and will therefore contribute to jet thrust. The nozzle and shroud flap segments are linked to open and close together.

In addition to forming an aerodynamically correct shape for supersonic flow, modern variable-area exhaust nozzles can be used to advantage to improve engine performance in other ways. For example, by keeping the nozzle wide open, the engine idle speed can be held high with a minimum of thrust produced. This is beneficial since maximum available thrust can then be made available quickly by merely closing the nozzle, thereby eliminating the necessity of having to accelerate the engine all the way up from a low-idle rpm. High-idle rpm will also provide a higher quantity of bleed air for operation of accessories and in addition, make "go-arounds" safer. Of course, variable-area nozzles incur a penalty in the form of additional weight and complexity, and at the present time are being used only on aircraft operating at sufficiently high Mach numbers to make their use worthwhile.

8. 1. Найдите в первом абзаце:
- английские эквиваленты союзов: так как; если не;
- наречия, выражающие направление;
- английский эквивалент термина "сверхзвуковое сопло";
- синонимы слов "to reach", "to permit", "так, чтобы";
- антоним слова "behind";
- дайте основные формы глагола "to hold", переведите его, найдите его в тексте, замените его другим глаголом, не меняя смысл предложения;
- переведите предложения с этими словами.

   2. Во втором абзаце;
- обратите внимание на значение слова "that";
- -найдите антоним слова "completely";
- найдите синоним слова 'occur";
- переведите словосочетание "even though";
- переведите предложения с этими словами.

   3. Просмотрите четвертый абзац, передайте его содержание.
   4. Переведите четвертый абзац.

9. Ответьте на вопросы:
1. When will the pressure ratio across the duct become greater than 2,0?
2. When must a convergent-divergent nozzle be used?
3. What does the diverging section of the convergent-divergent nozzle allow?
4. What is the result of the flow through the diverging duct?
5. Why do all the supersonic engines incorporate a variable-area exhaust nozzle?
6. How is the converging section formed?
7. What is the aim of the converging section?

Comparison and Evaluation of Turbojet, Turboprop, and Turbofan Engines

1. Запомните следующие слова:

comparison n	[kəm'pærisn]	сравнение
evaluation n	[i,vælju'eiʃn]	оценка
convert v	[kən'və:t]	преобразовывать, превращать
horsepower n	['hɔ:s,pauə]	мощность в лошадиных силах
consumption n	[kən'sʌmpʃn]	расход, потребление
per pound of thrust	[pə'paund əv θrʌst]	на фунт тяги
forward speed	['fɔ:wəd 'spi:d]	поступательная скорость
take off roll n	['teik ɔf 'roul]	прокатка при взлете
specific fuel consumption	[spə'sifik 'fjuəl] [kən'sʌmpʃn]	удельный расход топлива
ground clearance	['graund 'kliərəns]	расстояние до земли
result in v	[ri'zʌlt]	приводить к , быть причиной
propulsive efficiency	[prə'pʌlsiv i'fiʃənsi]	эффективность двигателя
specific weight	[spə'sifik weit]	удельный вес
quantity n	['kwɔntiti]	количество, величина
superior adj	[sju:'piəriə]	лучший, превосходящий
approximately adv	[ə'prɔksimətli]	приблизительно
because of prep	[bi'kɔ:z əv]	из-за
shock-wave	['ʃɔk weiv]	ударная волна
unlike adv	['ʌn'laik]	в отличие от
Mach n	[ma:h]	число Маха (отношение скорости самолета к скорости

		звука)
penalize v	['pinəlaiz]	ухудшаться
range n	[reindʒ]	дальность полета, предел
noise supressor	[nɔiz sə'presə]	глушитель шума
ratio n	['reiʃiou]	коэффициент, отношение
bypass adj	['baipa:s]	двухконтурный
inlet n	['inlet]	вход
guide vane	[gaid vein]	направляющая лопатка
wake n	[weik]	след, спутная струя

2. Прочтите и переведите интернациональные слова:

to convert, characteristics, frontal, problem, efficiency, indicate, combination, reverse, economy.

3. Найдите в правой и левой колонках слова с одинаковым значением:

1. convert	1. amount
2. speed	2. show
3. currently	3. transform
4. develop	4. velocity
5. indicate	5. at present
6. propeller	6. screw
7. quantity	7. create

4. Найдите в правой и левой колонках слова с противоположным значением:

1. like	1. In the past
2. inlet	2. less
3. more	3. Improve
4. large	4. eliminate
5. increased	5. unlike
6. penalize	6. exit
7. develop	7. small
8. currently	8. decreased

5. В третьем абзаце найдите:
- предложения со словами "because of", переведите их;
- эквивалент глагола "can";
- прилагательные в сравнительной степени.

6. Переведите словосочетания:
fuel consumption; specific fuel consumption; relatively high fuel consumption; relatively high thrust specific fuel consumption; reduced problem; reduced ground-clearance problem; high bypass ratio fan engine; fan-noise-reducing features; long range relatively high-speed flight; prolific gas turbine family.

7. Найдите английский эквивалент словосочетания: расход топлива на фунт тяги.
   Переведите оставшиеся словосочетания:
- fuel consumption per horse power;
- fuel consumption per pound of thrust;
- miles per hour.

8. Найдите в тексте и расшифруйте сокращения: TSFC, mph, km/h.

9. Просмотрите текст. Выделите преимущества и недостатки турбореактивных, турбовинтовых и турбовентиляторных двигателей.

10. Укажите, для каких целей используются эти типы двигателей и почему.

11. В каких типах двигателей используется принцип двухконтурности.

12. Дайте на английском языке определение удельного веса двигателя.

13. Переведите текст.

COMPARISON AND EVALUATION OF TURBOJET, TURBOPROP, AND TURBOFAN ENGINES

By converting the shaft horsepower of the turboprop into pounds of thrust, and the fuel consumption per horse –power into fuel consumption per pound of thrust, a comparison between turbojet, turboprop, and turbofan can be made.

Turbojet Characteristics and Uses

1. Low thrust at low forward speeds.
2. Relatively high thrust specific fuel consumption (TSFC).
3. Long takeoff roll required.
4. Small frontal area results in reduced ground-clearance problems.
5. Lightest specific weight (weight per pound of thrust produced).
6. Ability to take advantage of high ram-pressure ratios.

These characteristics would indicate that the turbojet engine would be for high-speed, high-altitude, long-distance flights.

Turboprop Characteristics and Uses

1. High propulsive efficiency at low airspeeds, which falls off rapidly as airspeed increases. This results in shorter takeoff rolls. The engine is able to develop very high thrust at low airspeeds because the propeller can accelerate large quantities of air at zero forward velocity of the airplane.
2. More complicated and heavier than a turbojet.
3. Lowest TSFC.
4. Large frontal area of propeller and engine combinations necessitates longer landing gears for low-wing airplanes, but does not necessarily increase parasitic drag.
5. Efficient reverse thrust possible.

These characteristics show that turboprop engines are superior for lifting heavy loads off short and medium runways.

Turboprops are currently limited in speeds to approximately 500 mph (805 Km/h), since propeller efficiencies fall off rapidly with increasing airspeeds because of shock-wave formation.

Turbofan Characteristics and Uses

1. Increased thrust at forward speeds similar to a turboprop results in a relatively short off. But unlike the turboprop, the turbofan thrust is not penalized with increasing airspeed, up to approximately Mach 1 with current fan designs.
2. Weight falls between the turbojet and turboprop.

3. Ground clearances are less than turboprop, but not as good as turbojet.
4. TSFC and specific weight fall between turbojet and turboprop. This results in increased operating economy and aircraft range over the turbojet.
5. Considerable noise level reduction of 10 to 20 percent over the turbojet reduces acoustic fatigue in surrounding aircraft parts and is less objectionable to people on the ground. No noise suppressor is needed. On newer fan engines the inlet guide vanes have been eliminated in an attempt to reduce the fan noise, which is considered to be a large problem for high-bypass-ratio fan engines. The noise level is reduced by elimination of the discrete frequencies that are generated by the fan blades cutting through the wakes behind the vanes. Other fan-noise-reducing features are also incorporated.
6. Superior to the turbojet in "hot day" performance.
7. Two thrust reversers are required if the fan air and primary engine air exit through separate nozzles. The advantage of the separate fan nozzle is the short fan duct with corresponding low duct loss.

From the above characteristics it is obvious that the fan engine is suitable for long-range relatively high-speed flight, and has a definite place in the prolific gas turbine family.

14. Составьте краткое описание каждого двигателя на английском языке.

Supplementary Reading

THE PRATT AND WHITNEY JT3 ENGINE

The Pratt and Whitney JT3 engine is the commercial version of the J57 engine. This engine has been chosen to power (1) the first American jet air liners, the Boeing 707 and the Douglas DC-8.

Performance and Specifications

Since no two engines of the same model provide exactly the same performance, the following figures are approximate; however, they serve to give a good indication of the capabilities of the JT3 engine.

Thrust	9,500 – 10,000 lb
Weight	4,200 lb

Specific weight	0,44 lb per pound of thrust
Specific fuel Consumption	0,76 – 0,80 lb per pound of thrust per hour
Diameter	40 in
Length (including exhaust cone)	155 in

General Description

The Pratt and Whitney JT3 engine is a split-compressor axial-flow engine comprising two independently rotating compressors and three turbine stages.

The JT3 engine may be divided into three principal sections: 1 – the compressor section; 2 – the combustion chamber and turbine section; 3 – the accessory section. These are major divisions, but each is made up of many parts.

The compressor of the JT3 engine consists of two sections. The forward section is low-pressure compressor and is designated N1. This section receives the incoming air and compresses it to almost four times the pressure at the inlet. The rear section of the compressor is the high-pressure section and is designated N2. This section is a seven-stage axial compressor, and it increases the pressure of the air delivered from the N1 section about three times. Thus the overall pressure ratio (2) of the compressor is approximately 12:1

The split-compressor feature provides several advantages. The fuel --control unit, which includes the speed governor, is driven through the accessory-drive section which, in turn, is driven from the shaft of the high-pressure compressor (N2). Thus, the high pressure compressor is the governed section, and the N1 rotor is free to turn at its own best operating speed. This permits a higher pressure ratio without sacrificing power.

The starter of the engine is engaged to the high-pressure turbine shaft only. This makes it possible to employ a lighter-weight starter than would be necessary if the rotor were in one piece. When the starter is energized, the N2 rotor is turned. This produces a flow of air through the engine and causes the N1 rotor to turn.

An additional advantage of the split compressor is found in altitude operation. Since the speed of the N1 compressor is not governed, it is free to increase speed as the compressor load decreases in the low-density air of high altitudes. As the compressor speed increases, thereby increasing airflow, the loss of thrust which would normally occur at high altitudes is reduced to some extent.

The two compressor rotors, or "spools", are installed so that the forward rotor N1 is driven by the two rear turbine wheels. The N1 compressor rotor is supported by roller bearings at the forward end and by ball bearings at the rear. A hollow drive shaft extends from the rear turbine wheels, through the centre of the N2 rotor drive shaft, to drive the forward compressor. The front compressor turbine shaft is supported by a roller bearing inside the N2 rotor shaft and by a rear turbine bearing which is mounted in a support installed in the turbine exhaust case at the rear of the turbine wheels.

The rear compressor section N2, also called the high-pressure compressor, is supported by a roller bearing at the front and ball bearings at the rear. The ball bearings serve as axial thrust bearings (3). The shaft which drives the rear compressor section may be called the rear compressor turbine shaft. This is a hollow steel shaft through which the front compressor turbine shaft extends, as explained previously. The rear compressor drive shaft is supported at the front by the rear compressor rear bearing and at the rear by the turbine front bearing. It is also stabilized by the turbine intershaft bearing which is inside the shaft.

The two compressors each consists of a series of steel disks separated by spacers. The assembly of disks is supported at each end by a hub which provides the bearing support for the compressor. Steel compressor blades are mounted on the rims at the disks.

Turbines

The compressors of the JT3 engine are driven by three reaction-type turbine wheels. The front turbine is coupled to the N2 compressor, and the centre and rear turbines are joined together to drive the N1 compressor.

Approximately 33,000 hp is developed in the engine at full power for driving the compressors. Slightly more than half the power is extracted by the forward turbine to drive the N2 compressor. The remainder of the power is extracted by the two rear turbines to drive the N1 compressor.

The three turbine wheels are arranged with a nozzle (stator vanes) at the front of each wheel. The steel nozzle vanes (4) direct the air flow in the proper manner to produce the maximum effect.

The turbine disks have rotor blades or "buckets" attached to the rims of the disks by means of "fir-tree" serrations (5). They are secured in place with rivets. The blades are of the shrouded type; that is, the outer ends fit together to form an almost solid rim or shroud. This construction aids in preventing loss of power through tip loss and bypassing of air (7).

Combustion Chambers

The stainless-steel combustion chambers of the JT3 engine are designed and mounted in what is commonly called a "can-annular" or "canular" arrangement. This is because the individual combustion chambers ("cans") are placed within an annular chamber. Each of the eight combustion chambers in the JT3 engine is a small annular combustion chamber.

Each of the combustion chambers is supplied with fuel through six dual fuel nozzles mounted at the forward end of the chamber. The nozzles are attached to the manifold in eight clusters of six nozzles each. Primary air for the combustion of fuel enters the chamber through guide vanes arranged circumferentially around the nozzles. The vanes cause the air to flow with a swirling motion, thus providing for good mixing of the fuel and air.

Secondary air enters the combustion chambers through the inner liners to provide a relatively cool centre in the chamber. The inner liners are perforated to permit the air to enter the combustion areas. Secondary air also enters the combustion chambers through perforations.

In the outer liners, as has been previously explained, secondary air aids in cooling the burning mixture to a level which will not damage the turbine nozzles or blades. Also, the secondary air expands because of the heat and increases the velocity of the gases. In the JT3, engine the gas temperature leaving the combustion chambers is between 1500 -1600° F. Where the combustion takes place, the temperature is over 3000° F.

The combustion chambers are interconnected by welded steel flame tubes. They are to provide flame propagation from one chamber to another when the engine is started. Openings are provided in two of the chambers for spark plugs.

The Lubrication System

The lubricant used with the JT3 engine is a synthetic type. Specification MIL-L-7808. The engine is equipped with a gear- type pressure pump (8) and a number of scavenge pumps to provide a recirculating system. The oil is circulated through the various bearings and accessory drives and then returned to the tank which the heat of the oil is transferred to the fuel.

The Fuel System

The fuel and control system of the JT3 engine is conventional, with a hydromechanical fuel-control unit. The fuel pump is a constant-displacement, gear-type, dual pump which can provide a pressure of 750 psi. Fuel flow is from pump to the hydromechanical control, thence through a pressurising and dump valve (9) to the dual manifold and fuel nozzles.

The hydromechanical control provides for automatic starting and responds to engine speed, acceleration, inlet-air temperature and burner pressure. Provision (10) is also made to prevent excessive turbine temperature.

Notes to the text

1. to power – оснащать (устанавливать на самолете)
2. over-all pressure ratio – общая степень сжатия
3. axial thrust bearing – двухрядный упорный подшипник (подшипник, воспринимающий осевую тягу)
4. nozzle vanes – лопатки направляющего аппарата
5. by means of "fir-tree" serrations – елочным замком
6. shrouded type – закрытого типа
7. through tip loss and bypassing of air – которая происходит за счет концевых потерь и за счет перетекания воздуха
8. gear type pressure pump – шестеренчатый нагнетающий насос
9. pressurizing and dump valve – нагнетательный и аварийный клапан
10. provision – зд. Приспособление

HISTORY OF THE PEGASUS VECTORED THRUST ENGINE

Stanley Hooker

1 The cost of the development and production of strike-fighter aircraft increased rapidly in the 1950s because of the ever-increasing sophistication of the electronics and the bombs and missiles carried, together with the demand for supersonic performance of at least Mach 2. In a forlorn attempt to reverse this tendency in England, W.E.Wpetter, designer of the Canberra bomber, proposed the Gnat fighter, weighing less than 10,000 lb and limited to high subsonic performance, in the hope that such an aircraft would be inexpensive and easy to produce. Gen.Norstadt of the

U.S. Air Force, Supreme Commander of NATO, supported the concept, bur added that it should be capable of taking off and landing on 2000 ft grass strips, which he described as "cow pastures".

2 The specification of the NATO Light Fighter, as it came to be known, closely followed those of the Gnat, except that this aircraft was to have high-pressure tires and thus could not operate from grass fields. Peter, being the obstinate fellow he was, steadfastly refused to change and, therefore, opened the field to D'Assault, Breguet, and Fiat; thus the lightweight fighter competition began.

3 In the background, Col.John O'Driscoll of the U.S.Air Force was the driving force behind the competition and had inspired Gen.Norstadt to issue his requirements. At the time, O'Driscoll was the executive head of the Mutual Weapons Development Program (MWDP) in Paris, and had funding available for development projects of interest to NATO. He was also a man of great vision and experience, and the resuscitation of the German and Italian aircraft industries and air forces owes much to the vigor with which he pursued both the competition and selection of the lightweight fighter. He also held the purse strings and dealt most effectively with the competitors, despite the enormous pressures to which he was subjected.

4 The Bristol Engine Company had proposed the Orpheus engine as the power plant for the Gnat. This engine had an air mass flow of 80 lb/s, a compression ratio of 4,5/1 a thrust of 4850 lb for a weight of 800 lb. As such, it was easily the lightest engine available and was subsequently adopted by all the aircraft competitors as the desired power plant. Thus, Col.O'Driscoll had few problems in the choice of the engine, and after the technical details had been scrutinized at Wright-Patterson Air Force Base and Theodore van Karman, he was able to give immediate financial support for the development of the engine. The arrangement was that MWDP would pay 75% of the development cost and the Bristol Engine Company fund the remainder.

5 The Orpheus had a seven-stage axial compressor, an annular combustion chamber, and a single-stage turbine (the compressor ratio having been chosen for this purpose).

6 The basic new feature was the large-diameter, thin shaft connecting the turbine and compressor which eliminated all whirling problems and enabled two main bearings to be used - one at the front of the compressor and the other at the rear of the turbine. Hitherto, axial engines had always had a three-bearing arrangement, which necessitated a coupling in the centre of the compressor-turbine shaft where the third bearing was situated. The Orpheus was the first jet engine to avoid this complication,

weight and cost. Additionally, the turbine was mounted on the shaft by Firth couplings. This simple device proved to be a very accurate centering mechanism, allowing the turbine to be removed and replaced without the need for dynamic rebalancing.

All of these features have now become standard design techniques in modern engines, but were initiated on the Ofpheus and made a substantial contribution to its low cost, light weight and reliability. The engine met all of its performance requirements, and ran like a "watch".

In the meantime, the aircraft competition had been won by Fiat, where Gabrielli had designed the G91. Hundreds of this aircraft were produced in both Germany and Italy, and the Orpheus engine was likewise produced by Fiat in Italy and Klockner-Humbold Deutz in Germany. In fact, in the postwar era, the first 1000,000 h of flying by the Luftwaffe were all with the G91 and the Orpheus.

Col.O'Driscoll had always considered short takeoff and landing to be a prime requirement in the European theater, which at that time was very short of cocrete runways, all of which were highly vulnerable. Having launched the G91 and the Orpheus, he thus turned his attention to vertical takeoff and landing (VTOL).

In Paris at the time, was a famous French aircraft designer, Michele Wibault, who was unattached to any aircraft company and was being supported by Winthrop Rockefeller. Wibault had an idea for a vertical takeoff fighter, which consisted of a turbine engine (in his case the Bristol Orion engine) driving through gearboxes and cross shafts four centrifugal compressors, two on each side of the aircraft. The Volutes could be rotated through 90 deg, so the jets of air from the four blowers could be directed vertically downward to lift the aircraft or rearward for propulsion. Thus, the idea of rotating nozzle was born.

O'Driscoll was interested in the Wibault concept and invited the Bristol engineers to Paris to hear a presentation by Wibault. We were not impressed, except for the intriguing idea of rotating the jets. However, we came under pressure from O'Driscoll and Professor Markham of MIT (brought in by Rockefeller) to do something about the Wibault concept. Our first idea was to substitute one axial compressor (or fan) for four centrifugal blowers.

The Orion turboprop engine specified by Wibault had been designed for future Brittania aircraft and, in the event, never went into production. Accordingly, we abandoned this and began to look at the Orpheus engine as the power plant to drive the axial compressor, particularly as light weight was the essence of the exercise. The resulting thrust was much too low, unless the axial compressor or fan were increased in capacity and used to supercharge the Orpheus as well as supplying the rotating nozzles.

Thus, through several variations the Pegasus I engine evolved. It consisted of a two-stage fan supercharging what was essentially the Orpheus engine, the fan being driven by a two- stage turbine by a shaft through the conveniently large-diameter shaft of the Orpheus.

At this stage, Col.O'Driscoll left MWDP, and was replaced by Col. (later Gen.) Willis Chapman of the US AF.

Chapman rapidly moved to the point of ordering six Pegasus I engines, four for bench development and two to be held in reserve for flight in a possible aircraft yet to be designed. Again, the arrangement as to funding was 75% MWDP and 25% Bristol.

At that stage, the Pegasus project had rotating nozzles at the front only, that hot gas from the turbine being taken in a straight pipe. This was simply because we felt that the disposal of the exhaust gas was very much bound up with the aircraft design and could not be finalized until that was forthcoming. Camm's proposal dealt with this point, because he split the exhaust gases into two parts, each issuing through rotating nozzles on each side of the P1127.

It is worth remembering here that Camm already had experience with divided or bifurcated exhaust pipes since his first jet aircraft in 1946.

Thus, early in 1958, the design and manufacture of the Pegasus I engine began in earnest. At the same time and at their own expense, Hawker began the design and manufacture of the first prototype P1127.

The calculation of the gyroscopic forces on the fan due to fighter maneuvers compared with those on the propeller of a piston engine showed that these were much higher and that the fan could, therefore, with safety be overhung so that no bearing in front of the fan would be required. The radius of gyration of the fan is about one-quarter that of a typical propeller and the weight less than one-half. The rotational speeds are in the ratio 6/1.

At the same time, the intake guide vanes, which were a standard feature of axial compressors and whose original function had been to keep the Mach number at entry to the compressor below 1.0, could be deleted, since the age of the supersonic fan was just beginning. This was a great simplification, since not only was a bearing eliminated but the complication of anti-icing vanes was also eliminated.

With some trepidation, but ultimately with complete success, we decided to use an intershaft bearing at the turbine end of the Orpheus high-pressure unit. Thus the main bearings on the Pegasus were reduced to the irreducable four in number.

In consultation with Camm, we decided to go all the way and counterrotate the fan and the high-pressure unit, this being essential for the elimination of the gyroscopic forces on the aircraft during the hover and transition phases of flight. By luck and the Grace of God, the greater weight and radius of inertia of the fan and two-stage turbine was just about compensated for by the different rotational speeds of the two units and the net overall gyroscopic forces were reduced to negligible proportions. The weight of the fan and low-pressure turbine is about 1.5 times that of the high-pressure compressor and turbine and the radii of gyration in the ratio 1.5/1. The rotational speeds are approximately 10,000 rpm for the high-pressure unit and 6000 rpm for the fan.

23 For counterrotation, the net force is the difference between the two angular moments, i.e., 35%, and for the same rotational direction 235%. Thus the net gyroscopic force on the aircraft during any perturbation is reduced roughly to one-seventh by counterrotatoin.

24 The original concept of the P1127 was that the aircraft would be stabilized during the period of hover and transition to wing lift by air "puffer" jets at the wing tips, nose and tail, and that these would be supplied by low-pressure air from the fan and thus not affect the thermodynamic cycle of the engine. However, the size of ducts required was so large that they could not be accommodated in the wing; thus, high-pressure air direct from the combustion chamber had to be used. This inevitably involved a loss of thrust, so to recoup this, the capacity of the core: i.e., the old Orpheus axial compressor, was increased by redesigning the blading.

25 However, the first engine did not have this feature, and first ran in September 1959 at a derated figure of 9000 lb thrust. It served to prove that the new design worked satisfactorily.

26 We gave great consideration to the nozzle operating mechanism, since we realized that malfunctioning of these was a killer. The Plessey Company evolved a twin servo/motor unit driven by high-pressure air from the engine combustion chamber, which operated through a differential gearbox to rotate the nozzles. Thus, if one motor failed, the other could still drive the nozzles, albeit at only half speed. The drive was taken from the motors by shafts and, ultimately, by chains to rotate the nozzles. There was one extra positioning lever required in the cockpit so that the pilot could set the nozzles at any desired angular position from vertically downward to the horizontal.

27 We had had qualms about the nozzle bearings on the rear hot nozzles. They were destined to operate in a very hot environment, since the exhaust gas temperature

in the nozzles was on the order of 700° C. We discovered by chance that the fan air pressure was always greater than the jet pipe pressure, and hence a pipe from the fan outlet to a volute surrounding each bearing allowed cool fan air (about 100° C) to pass through the bearing into the exhaust nozzles, and there was no possibility of a reversal of flow. Thus the bearings were cooled and functioned perfectly.

28 The second Pegasus engine had the increased capacity high-pressure compressor and first ran in February 1960. It was cleared for flight, initially at 11,000 lb and subsequently at 12,000 lb with a life of 15 h.

29 In august 1960, the prototype P1127 complete with engine was wheeled from its hanger at the Hawker airfield in Dunsfold, Surrey, and in September 1960 the Hawker chief test pilot, Wing Commander Bill Bedford made the first historic hover flight.

30 However, it was not until a year later in September 1961 that Bedford made the first transition from hover to wing- borne flight.

31 On the initial design of the engine, the plenum chamber which collects the air from the fan and passes it to the two front rotating nozzles was specified in fiberglass, as were the two front nozzles themselves. It seemed an ideal application for this man-made material, since the air temperatures and pressures were well inside the operational limits for fiberglass.

32 The early flight engines were so equipped, until Bill Bedford had a strange failure in flight. He was on a straight, level speed run when the aircraft began to vibrate badly. Not knowing what had happened, he prepared for an emergency landing; but, when he put down the nozzles for landing, the aircraft went into an uncontrollable roll. Bedford ejected safely, but the aircraft was completely destroyed.

33 We were still debating the cause of the accident a few days later, when a local farmer walked in with a complete fiberglass in his hand, asking if it belonged to us. All was now clear. The fiberglass nozzle had failed at its attachment flange and had been blown off. Thus the air jet came cut at right angles to the flight path and, when the nozzles were put down for landing, only the undamaged one rotated, causing the aircraft to roll.

34 We rapidly changed the design from fiberglass to titanium, but this cracked badly on test. After a further attempt using aluminum sheet, we finally settled for steel, as on the hot nozzles which had never given any problems.

<u>Pegasus Mark 103</u>

Airflow	430 lb/s
Velocity and temperature of air:	

Through front jets	1200 ft/s, 110°C
Through rear jets	1800 ft/s, 670°
Fan compression ratio	2,4/1
Overall compression ratio	Nearly 15/1
Thrust t/weight ratio	Nearly 6/1

35 We had already modified the Pegasus 2 to give 13,500 lb thrust by adding one extra stage to the front of the high-pressure compressor and one to the high-pressure turbine (Pegasus 3); but more was required.

36 The fan was changed from two to three stages and the airflow increased. Variable intake guide vanes were added to the front of the high-pressure compressor, the tubular combustion chamber was changed to the annular vaporizing type, and the first-stage high-pressure turbine blades were aircooled. The resulting engine was designed, the Pegasus 5, giving 15,5000 lb thrust.

37 Later, the second stage high-pressure turbine blades were aircooled, and water injection added, thus allowing the combustion temperature to be raised.

38 By 1965 the production specification of the Pegasus 101 was available and the thrust raised to 19,000 lb. The final version, the Pegasus Mark 103 has now been in service for 10 years at 21,500 lb and powers all Harriers.

39 The Pegasus Mark 103 includes the gas turbine starter, which can also run and test all of the systems on the engine and aircraft for ground checks, and makes the Harrier independent of ground services. With a thrust-weight ratio of nearly 6/1, the engine has maintained its preeminent position in the VSTOL field for the past 10 years.

40 One powerful reason the single-engine vectored thrust solution – as embodied in the Harrier – was pursued was the essential simplicity of the concept. The basic principle of vectored thrust is that all of the power plant thrust can be pointed in any direction between the horizontal and vertical, so that it provides lift as well as propulsion. Given sufficient thrust to lift off vertically, an aircraft can make a smooth transition from hover to forward flight. Vectored thrust, as represented by the Pegasus/Harrier combination and its derivatives therefore has the following characteristics and advantages:

1. A single engine located near the aircraft centre of gravity, with a rotating nozzle system producing a thrust resultant vectorable between horizontal and vertical.
2. Engine and nozzles together forming a compact, selfcontained power unit.

3. Rapid nozzle vectoring (over90 deg/s) actuated by a powerful but lightweight air motor drive system, using enginesupplied air.

4. Short takeoff, at weights substantially greater than those which would be possible for vertical takeoff. is effective and easy, since all of the thrust is available for ground acceleration, lift off and transition. Also, rolling vertical takeoff and short takeoff techniques minimize the impact of jets on the ground or ship's deck.

5. The pilot has only one extra level in the cockpit. Since the engine spools rotate in opposite directions, there is no gyroscopic effect and control of the aircraft during hover and transition is not dependent on the electronic controls.

6. The single engine also means minimum development, procurement and operating costs, as well as minimum volume which leaves more room for fuel and stores.

Thrust vectoring in forward flight (VIFF) can be used to increase maneuverability in combat.

WATER- COOLED GENERATOR

The world now has a new type of turbogenerator with complete water cooling. Retaining all the operating characteristics, the new generator is distinguished for using up fewer specific materials.

Until now hydrogen was used for cooling the working parts of the turbogenerator -- either in combination with water or in pure form. Designers at Elektrosila electro-engineering production association in St.Petersburg-- the leading Russian factory for producing heavy electrical machines -- managed to produce a series of generators, the entire "interior" of which is cooled by ordinary water.

The new machine no longer needs fans built into the stator, bulky gas-cooling systems, or oil seals for the shaft. The water systems have been tested and found highly reliable. This, plus the lower level of vibration and mechanical stresses in the construction, make the generator more reliable.

While developing this construction,the experts worked out many fundamentally new and highly economical solutions. For instance, what should be done to "make" water pass along the channels of the revolving rotor in order to cool its winding? Previously this was done on account of the difference between the atmospheric pressure and the pressure of the hydrogen, but now there is none -- the whole turbogenerator is filled with nitrogen, the pressure which is approximately that of the atmosphere. The experts created a system now known as a self-pressured system. The water used for cooling the winding first passes through the revolving rotor, where it receives centrifugal acceleration. Its pressure is what enables the hydraulic resistance of the channels, in which the winding is located, to be overcome.

The tests and then the experimental trials of the TZV-800-2 generators, working in combination with a steam turbine, show that on the basis of this construction (800 megawatts) it is possible to make a machine with a nominal capacity of 1,000 megawatts. It possesses high manoeuvrability, is simple to service, while the number of its starts and stops is virtually unlimited. The use of the complete water cooling makes it possible to raise efficiency and lower the specific consumption of materials by 25-30 per cent. The new generator weighs 34 tons less than that of the machine of the same capacity with hydrogen-water cooling. Among the other advantages of the design of this new generator is that no expenses for the maintenance of the hydrogen system are required and safety arrangements can be saved: the generator with complete water cooling presents no fire or explosion hazard either.

THRUST AUGMENTATION

Auxillary devices and methods for increasing turbo-jet engine thrust are called thrust boostes or thrust augmenters.

One or the more promising of these thrust-augmentation methods involves the injection and burning of additional fuel in the tail-pipe gasses downstream of the turbine.

Afterburning is feasible because the hot gasses from the main burners decrease in temperature as they pass through the turbine and exposed parts downstream of the turbine are not highly stressed. Thus, with oxygen available for combustion and with conditions permitting a considerable temperature rise in the tail pipe, energy can be added and used to increase the jet velocity.

Tail-pipe combustion is closely similar to that in the ram jet. The tail pipe is modified in shape so that the gasses from the turbine are slowed in a diffuser section to velocities which will not cause blow out of the tail-pipe flame. Fuel is admitted through spray nozzles, and flame holders are used to stabilize burning. Since optimum jet-nozzle area is different with afterburning, a suitable method of varying the exit area is necessary.

The effect of tail-pipe burning at optimum conditions indicates the importance of afterburning as a means of increasing the thrust of the basic turbojet engine, but the accompanying high fuel rates preclude the use of tail-pipe burning for most types of continuous operation. However, for take-off and climb, and for increasing top speed for short periods of time, afterburning is an attractive answer.

The rather pronounced effect (значительное влияние) of ambient air temperature suggests the possibility of increasing turbojet engine performance by cooling the charge of air

By saturating the inlet air with a water spray, a considerable increase in thrust is possible particularly at the higher flight speeds.

For saturation, heated air requires more water than colder air. By injecting enough water saturate the air leaving the compressor (discharge saturation), much greater thrust augmentation is possible.

As compared to afterburning, water injection as a method of thrust augmentation is somewhat more economical of fuel. However, for any considerable period of operation with water injection, the weight of water that must be carried becomes critical. Available space for water tanks as well as weight limitations tend to restrict the use of water injection to short periods such as take-off and climb.

Numerous other methods of thrust augmentation such as the air bleed system and the ducted fan have been investigated to a greater or less extent. Each of these methods of thrust boosting offers certain performance advantages, but each is accompanied by increased complexity of the machine and, in general, fuel consumption is more than proportionately increased.

ГАЗОТУРБИННЫЕ ДВИГАТЕЛИ (часть II)

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