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POWERPLANT DEVELOPMENT-THIRTY-FIVE YEARS IN HELICOPTER INDUSTRY

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POWERPLANT DEVELOPMENT-THIRTY FIVE YEARS IN HELICOPTER INDUSTRY.

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"Klimov" Corporation revealed itself in the beginning of the Soviet helicopter industry developed the powerplant with twoGTD-350 gas-turbine engines and VR-2 main gearbox for MI-2 helicopter more than thirty-five years ago.
"Klimov" Corporation is still preserved the leading role of an advanced powerplants designer for medium-to-heavy - size helicopters, such as MI-8, MI-24, KA-50 with load-lifting capacity of 7-14 tons.Up to the present more than 30000 MGB and 65000 engines have been produced for different classes of helicopters.
Utilization of the advanced methods of design and engineering developments provides the powerplant parameters which correspond to the up-date level of technique and, as practice has shown, outstrips it, stipulating long service period of helicopters life with these powerplants used.
It is traced that reliability, service life, controllability, cost, reparability and high operational parameters of the powerplants are the result of the previous company's experience accumulated in each new model.
In this article there are given powerplants designs, developed for new helicopters.
New perspectives appear due to the changes in our society. Thanks to these changes new possibilities are opened for cooperation in the field of joint production, repair, sales, protection in certification agencies of different countries. Possible variants of such a cooperation have been proposed.

Klimov Corporation started to develop the first gas turbine helicopter engine in the end of the 50s. The company was already accumulated an experience in enginebuilding: the Corporation was founded in 1914 and its serial producted engine models powered "Iliya Murometz" aircrafts the largest of that time designed by I.I.Sikorsky as well as D.P.Grigorovich's "flying boats". During World War II 60% of national combat aircraft flew with M-105 engines designed by Klimov after whom the Corporation was named.

It was in 1946 when starting from TRD VK-1 Vladimir Klimov engine for Mig-15, Mig-17 fighters and Il-28 bomber gasturbine engines VK-7 and VK-15 development was initiated.

So, when by the mid of the 50s the crisis in piston engine helicopter development broke out, our Corporation was ready to tackle the new problems design of gas turbine engines for helicopters.

Klimov Corporation reaction to helicopter reduction in weight Requirements increase was that in 1959-1964 it designed simultaneously two twin-engine power plants incorporated in GTD-350 engine and VR-2 MGB for Mi-2 helicopter, and TV2-117 engine and MGB VRB for Mi-8 helicopter.And it allowed to continue the process of the above mentioned types of aircraft principle improvement which broke off by the ,mid of the 50s.

The Power plant (PP) is a higher level-aircraft subsystem, and it may be estimated by its performances, economical characteristics and by helicopter efficiency. In other words, there wouldn't be a successful helicopter model it helicopter and power plant design parameters are not coordinated.

Based on PP,(which was designed as a results of helicopter configuration forming) Requirements, the PP data are being brought to the optimal values. [There is another opportunity to adopt the existing aircraft construction or even to create a new aircraft construction and PP for the engines available.]

Since the transfer from piston engines to gas turbine rotor drive was realized as a general necessity for all helicopter classes, Klimov Corporation carried out some scientific and research works in the fields of helicopter application advanced engine nomenclature estimation , development of criteria equivalent to the new sphere of gas turbine engine application, as well as to the choice of the type of engine and ways of main gearbox development and transmission in order to the ensure established helicopter characteristics.

It is necessary to point out that during the following years the way our Corporation modified the power plants followed the principles of helicopter development and different spheres of their application. It was required to define the choice of PP type and its structure (composition), engine type and its scheme, engine operation parameters, main gear box type and structure, etc.

The analysis has shown that engine:
- shall be multi-functioning
- shall incorporating constant speed free power turbine.
- shall be equipped with helicopter integrated pitch-gas control system
- shall have free turbine characteristic optimization in conditions of rotational speed constancy and variable gas flow through turbine.
- shall be synchronized with the second engine in pair.
- shall be incorporated with higher stability compressor due to.the principle flow change at engine inlet by flight-cycle profile.
- shall be provided by special devices preventing free turbine rotor over speed - shall incorporate a twin engine power plant.

As a result power plants have been worked out the configuration of which are shown in table 1 fig.1.

First engine for helicopter GTD-350 engine (the year of development beginning-1959, first flight - September 1961, in serial production from 1964, Zheshuv) has an axis-centrifugal compressor (7 axial and 1 centrifugal stages), single-stage compressor turbine, two-stage free turbine, intermediate built-in gearbox by which power is transmitted to the main gear box.

Table 1.

Model	GTD-350	TV2-117A	TV3-117II	TV3-117BMA	TVa-3000
Max. power at S.L. s.p.h.	400	1500	2200	2225	2500 (3750)
SFC at max. power g/sph, hrs	365	265	220	220	205
Pressure ratio at max. power	6.05	6.6	9.45	9.45	13.2
Size	1350x 522x680	2843x 550x748	2055x 650x728	2055x 650x728	1545x 690x995
Weight,kg	135	332	262.5	285	380
Total life, hrs.	4000	12000	1500	6000	20000 (d.l.)
Combined engine experience, hrs		$40x10^6$		$8x10^6$	
MTBF		$3x10^5$		$1x10^5$	
Applications (mgB)	+(VR-2)= Mi2	+(VR-8A)= Mi8	+(VR-14)= Mi14,Mi8MT Mi17	+(VR-24)= Mi24,Mi25 +(VR-80)=Ka50 +(VR-MB3)= =Mi28	+(VR-MB3)= =Mi38 +(VR-40)=Ka40

During engine creation: small-size mane assembly calculation and design procedures, the theory and rotor damping and self-alignment constructive measures have been worked out; for the first time each unit finishing methods at test benches were widely used; special equipment was used in order to provide a high level of small-size engine construction elements manufacturing precision. Power plant (GTD-350-VR2) are a new life for Mi-1 which was the first aircraft specially designed for national economic use.

TV2-117 engine (development beginning-1959, first flight - 1961 (1st half), serial production by Perm Motorbuilding Plant from 1965) incorporates a ten-stage axial-flow compressor with inlet variable guide vanes and 3-stage stator blades, as well as annular combustion chamber, two-stage turbines-compressor and free one.

The engine is equipped by tip shroud platform blades in order to increase efficiency and reduce alternating stress, as well as by integral turned compressor rotor out of titanium alloy.

Free (power) turbine over speed control unit is installed both on GTD-350 and TV2-117 engines

7 world records were wet up on board of Mi-8 helicopter.

The main engine characteristics are shown in table 1.

By GTD-350 and TV2-117 engines development Klimov Corporation was created a new class of engines for small and middle classes of helicopters.

During years of helicopter operation power plant were not subjected to any serious alternations.

However the power plants were constantly being modernized and developed in accordance to new spheres of helicopter application and in order to meet the new requirements, which came to appear as a result of large-scale operation and deferent regions of application.

The new opportunities which came with helicopter gas turbine engine PP application emancipated the helicopter designers.

TV2-117 serial production beginning in a year after production GTD-350.

The works at Mi-14 helicopter water landing takeoff and Mi-24 infantry support helicopter were started.

For new helicopters power plants were developed incorporating two engines and MGB: TV3-117 and VR-14 main gear box as well as TV3-117 and VR-24 main gear box.

The design requirements were very severe: simultaneously with power increase there was task to reduce the PP mass in comparison with the previous PP model.

It took some years to develop the engine: from beginning of 1971 engine serial production started up.

The engine configuration was preserved as approved, but this was already the engine of the next generation.

At the same air flow as at TV2-117, compression ratio increased up to 9.45, $t_{max.}$- from 1120°K up to 1250°K its weight was reduced from 332 to 262.5 kg.

Taking into account the optimal choice of the cycle parameters and the units efficiency high level (compressor efficiency-86%, compressor turbine efficiency - 91%, free turbine efficiency - 94%) this engine has become one of the best by its efficiency in its class.

It may be explained mostly by the use of new materials and technology improvement: precision and stability of dimensions of rotor blades and guide vanes, manufactured out of titanium alloy by the method of cool forge-rolling; optimal form of titanium compressor discs, connected into a drum by the arc beam welding with heat-resistant materials employment in turbine, allowing to make turbine with uncooled blades.

TV3-117 engine has a 12-stage axial compressor with intermediate pressure inlet guide vanes and 4 stages guide vanes, annular combustion chamber, 2-stage compressor turbine and 2-stage free turbine.

The measures have been undertaken increase the power plant autonomy: by pneumatic starting from the side compressor, rather not by storage battery starting. Integrated engine electronic-hydraulic control system is the one which provides each component full responsibility.

To increase service-life and to reduce negative sea effects some protection measures were undertaken and all engines production is being realized for sea use.

Taking into account conditions of application in deferent climatic and geographical zones TV3-117 engine modifications providing power sustainment up to H = 6 km. and T_a=+30 °C have been worked out.

Such TV3-117 engine characteristics improvement has allowed helicopters powered by Klimov power plants: to win the rest of the competitors: for example, Mi-8MT (Mi-17) helicopter can lift up to 4 tons at temperature limit T_a=+30 °C with external load.

The excellent results of the engine development drew attention to our products.

Kamov design bureau has ordered power plants and on the base of TV3-117 engine for coaxial-rotor helicopter family: including Ka-27 deck helicopter, K-32 transport helicopter, Ka-50 - "Black Shark"

The power plant contains a unique design of main gear box: with twin-engine inlet and coaxial shafts. The unique power plant feature allows a helicopter to carry out specific operations: Ka-32 is able to transport 5 tons by its external load, to unload containers from container-carriers on the go before parking in port; it is also very effective at timber trailing operations because of its small dimensions.In fig.4 Ka-32 helicopter on sea petrolium platform is shown.

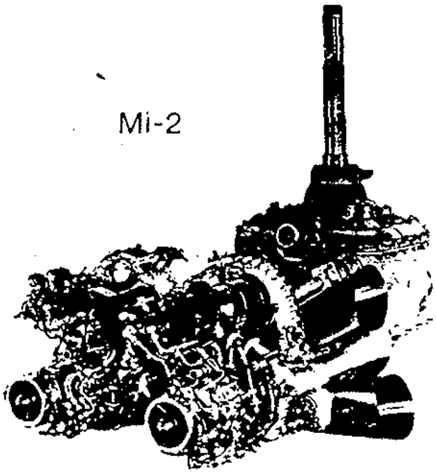
5 world records were wet up on board of Ka-32 helicopter.

A helicopter power plant does not exist without main gear box. Main gear box not only transmits engine power to the main rotor, but simultaneously operates as helicopter load-carrying structure unit.

Klimov's technical strategy comprises complex work by all power plants units including helicopter power plants.

Following this orientation, during many years Klimov Corporation provided new helicopter models development based on one engine family, creating new power plants by furnishing them with new main gear box constructions.
The common feature of their layout is two-engine power summing up at the inlet of MGB.
The main gear box shall be highly reliable, it means that main gear box development implemented on the base of the approved technical and technological means.
Main gear box general structure, component, bearing, supply system and etc. location in new model design is analogous to prototypes being in operation. This fact allows to forecast with confidence engine parts exact behaviour and interaction, and to reduce possible risk, related to constructive and technological innovations adoption, to a minimum.
Such "element conservatism" approach also leads to success in cases of development of devices which did not have no analogous versions in the field considered: This is coaxial rotor helicopter power plant gear boxes creation.
Klimov Corporation has created the main gear box construction, which is unique in the world helicopter building practice by the wide scope of its application: these are the VR252 main gear boxes for Ka-32, VR-80 for K-50 ("black shark") power plants for Kamov.

Mi-2



Mi-24

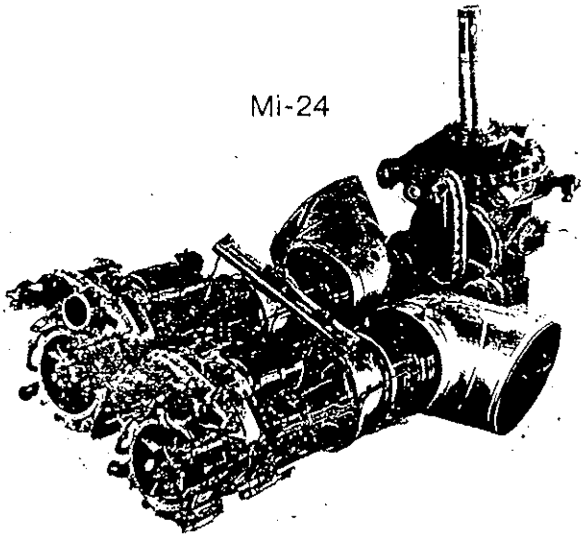
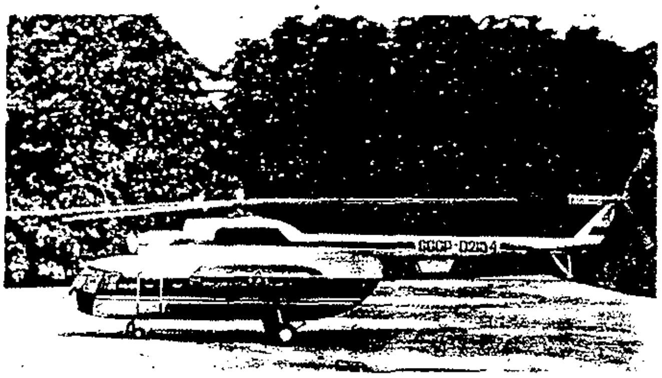
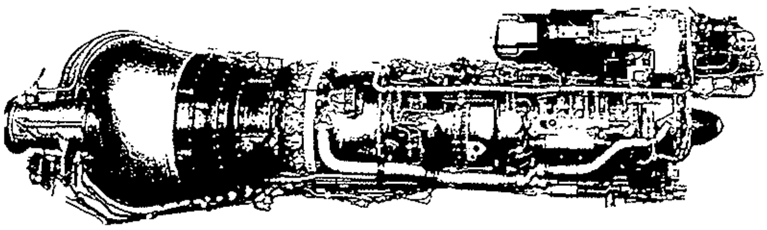


Fig.1



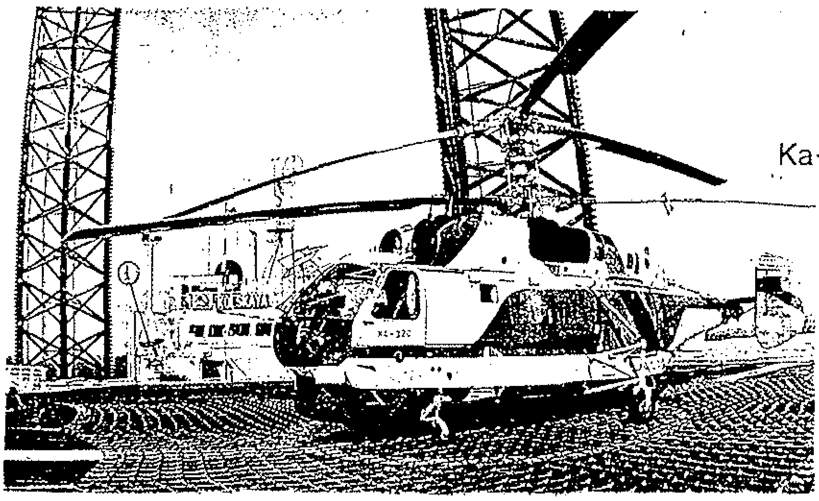
Mi-8TG

Fig.2



TV2-117TG

Fig.3



Ka-32

Fig.4

From TV2 to TV3 creation the problem of engine and gear box alignment was solved by employment of the joint attachment resistant to misalignment, so that the gear box safety was increased at the expense of its all-climate resistance design.

General designer of helicopter Mil's saying "Russian territory is specially designed for helicopters" is valid for Siberia in particular. The region is lacks roads but there is gas there. Klimov Corporation designed multifuel AGTD TV2-117 TG engine. Being designed and manufactured by Klimov Corporation jointly with LAKB, has passed through bench and flight tests on board of pilot Mi-8TG helicopter fig.2. The serial production is planned in Perm Motorostroitel enterprise in 1996.

The engine operates on liquefied natural gas types and engine fuels: petrols, kerosenes, diesel fuels and etc.

TV2-117TG engine was created on the base of serial TV2-117 A turboshaft engine, its take-off power was increased up to 1500 s.h.p fig.3.

Emergency rating-1670 s.h.p. S.F.C. at nominal rating - 295 g/h.p.·h, life - 12000 h.

Fuel supply system was modernized in the part of liquefied fuel supply accessories development and their control (pump, metering device, nozzles distributor), and devices, preventing ecologically harmful gas fuel components emissions into atmosphere at engine start and stop.
This engine leads a way for the new direction in avionics engine building development.
Klimov Corporation is not simply active in the market, but it is also very initiative at expanding the sale volumes. Among these activities: to the Joint Ventures foundation: our partnership with Pratt and Whitney Canada (PWC) lead as to PW/Klimov Joint Venture registration in August, 1993.

The new Company (51% PWC and 49% Klimov shares) is aimed at engine development, production, sales and servicing at the world market. Specifically PW206 engines are offered for Mil and Kamov Design Bureau's helicopters. Manufacturing facilities have been prepared for manufacturing 200 of per year. Among other Klimov offers a new TVa-3000 helicopter engine fig.6. and 2600 kW (3750 h.p.) take-off and TV7-117V turboshaft engine of 2500 h.p. take-off power are of interest for the Joint production.

Klimov is still initiative in definition and gratification of at its future customer requirements.TVa-3000 free turbine turboshaft engine is being developed for Mi-38 (fig.7) helicopter power plant application. The engine is made of centrifugal single-rotor two-stage compressor, which allows the engine to satisfy the technological and operational characteristics: increased operability at dust conditions and reduced by -1000 quantity of parts; module design provides the modern level of reparability, especially change of exhaust unit modules and accessory drive gear box without engine removal from the aircraft. ACS - electronic - hydraulic system remarkable for its responsibility and developed fault diagnosis system.

Minimum of control errors positively effects on helicopter performances.

Modernization in the field of multy fuel application is provided.

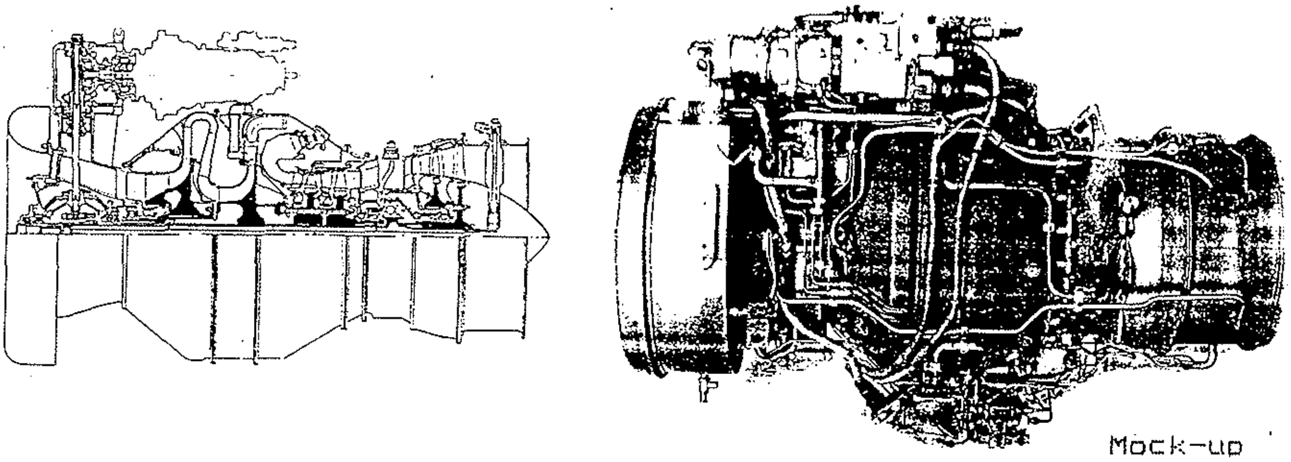
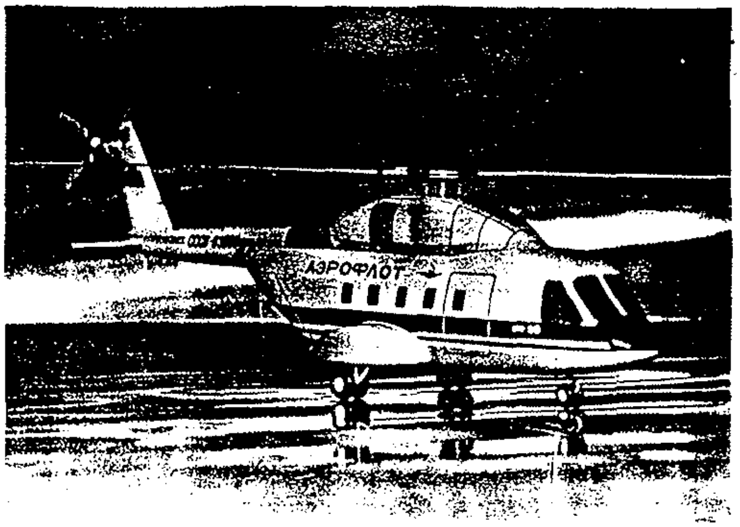


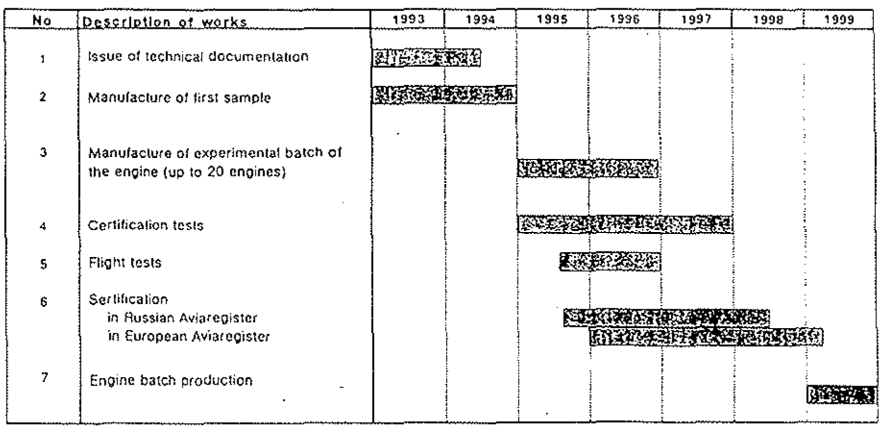
Fig.6



Mi-38

Fig.7

TVA-3000 ENGINE SCHEDULE



The Main characteristics are:

Rating	Power, h.p.	Inlet temperature sustain
30 sec. power	3750	+ 15°C
2 min. power	3600	+ 15°C
30 min power	2900	+ 35°C
take-off*	2500	+ 40°C
max continuos	2100	+ 40°C
cruising **	1900	+ 40°C

Normal range

temperature (°C): from - 50 up to +50

altitude (km): from 0 to 6

* specific flow   0.205 kg/h.p. hour

** specific flow   0.225 kg/h.p. hour

There is presented a TVa-3000 engine shedule diagram.

The engine shall be esserted for official tests in 1997, serial manufacture mastering - in 1996, serial production in 1998.

The engine was designed using the experience of defferent application items development approaches and constructive solutions were tested in practice.

TVa-3000 engine symbolic "geneology" is shown in fig.5. All results achieved, all the failure conclusion which were accumulated during the decades of esperience gained we use with new developments.

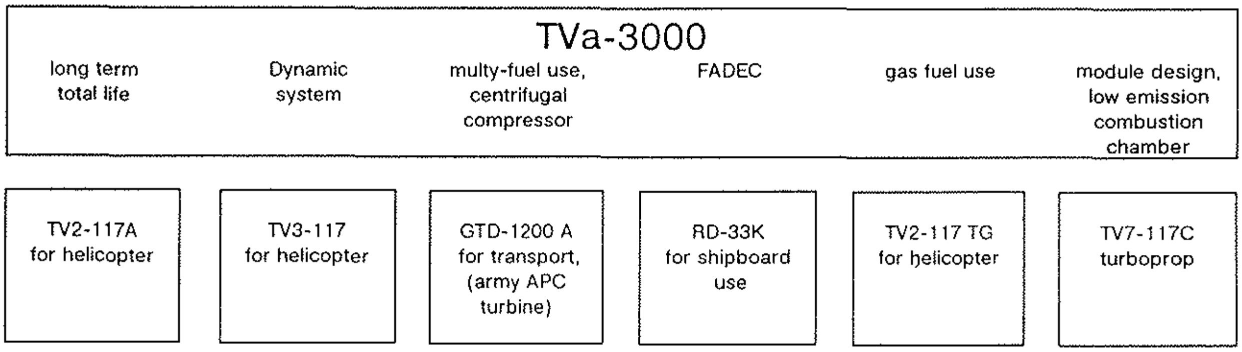
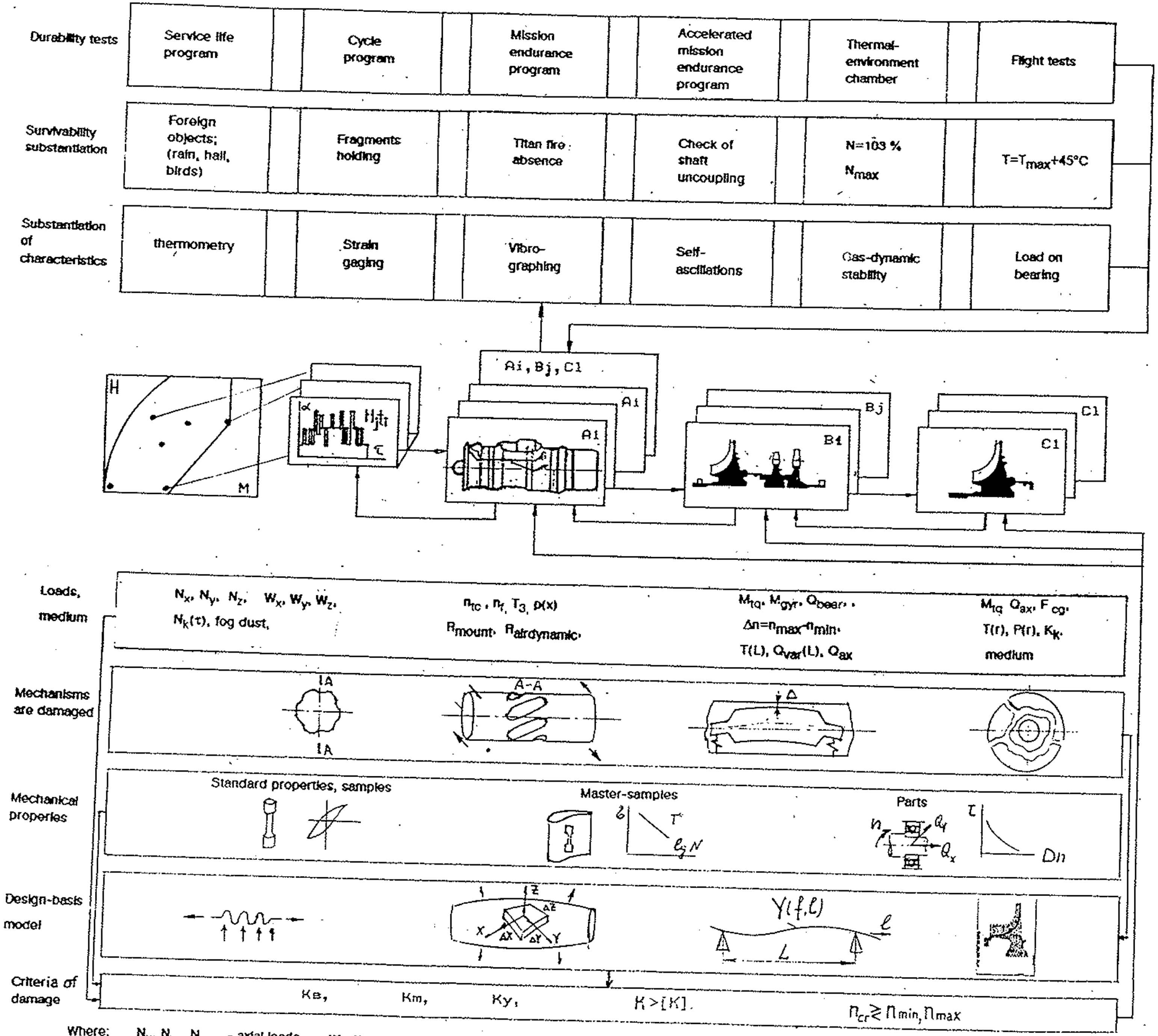


Fig.5

In order to get rid of the barriers to Klimov power plant helicopter operations Kamov and Klimov Corporations have abstained the receiving of certificat for Ka-32 helicopter and TV3-117 engine for civil aviation application. The certificate was received on the base of the special certificate requirements, summarizing engine test requirements, which are developed by Klimov Corp. (NLG-32.37) and stated in FAR-33, JAR-E, NLGV-2.



Where: N_x, N_y, N_z, - axial loads W_x, W_y, W_z, - axial angular speed K_B - damage strength margin K_m - local stress strength margin K_y - stability margin

n_{cr} - critical r.p.m. t_c - gas generator of fan power turbine T_3 - turbine inlet temperature P(x) - gas flow pressure

Fig.8

For engine compliance with NLG-32.33 approvement USA Aviation Federal Administration recommendation circular letter and Aviation interstate Committee compliance definition methods were employed.

By this action the way was opened for national certifications of Mi-8MT, Mi-8MTV-1, Mi-8AMTV, Mi-14, Mi-17, Mi-28, Mi-172, Mi-24, Ka-32, V-80 helicopters.

At present certifications are being carried out in India, Canada, Switzerland, China and etc.

Engine certificate requirements provision works structure is presented in Fig.8. As it shows the works on integrity are being carried out at all stages of engine development and with all units and elements.

The company has at its disposal the bank of programs, providing all kinds engine systems and units analytic optimization, engine unit and full-scale test experimental data processing, complex of engine testing benches, including open test benches, special unit treatment benches: compressor turbines, combustion chambers and devices for special tests performance in accordance with Aviaregister certification requirements, by laboratory equipment. The specialists are highly qualified and experienced.

Russian aeroengine industry is highly developed, but nowadays our penetration into the international market is limited, the cause of the fact is in inadequate servicing and maintenance support abroad, as well as lack of sufficient practice in the sphere of certification in accordance with the standards which differ for those accepted in this country.

We hope that West European users will be able to appraise the advantages and values of our product and final the ways of active cooperation with Klimov and to overcome the problems of technical and legislative interpretation understanding.

Domestic market is not filled and the international market is opened for several helicopter types powered our power plants.

We suppose the following spheres of activity may be of great interest for mutual cooperation:

I. Expert assistance and cooperation for progress of proposals and for practice of contracts conclusion.
   - study of expenditure for engine and power plant creation in partner countries.

II. Delivery of engines and gear boxes for power plants:
   - analysis of changed parts stock and spares storage possibilities;
   - arrangement of joint data banks on operation, monitoring, demands keeping and spares storage organization;
   - organization of buyers service and assistance in service centres, and their equipping with training airas and physical facilities;
   - equipment for service stations as well as for training centres and centrelized service, which provide assistance and other service for users

III. The engines adaptation to power plants of available helicopters, which can be modernized.

- technical staff joint seminars on the international and CIS standards, the requirements of which shall be taken into account at engine and power plant design, operational development of produced samples, power plant qualification tests and service arrangement.
- technical consultation and examination of designing helicopter power plants including those ones for CIS market.
- power plants accessories development (starters, gas equipment).
- joint programs of engine conversion for gas fuel. Gas manufacturing companies are invited for cooperation.
- participation in arrangement and filling up of joint banks which include data of measures on helicopter power plants failures.
- technical diagnostics of power plants failures.

IV. Joint manufacture of power plants accessories for CIS helicopters and for support of sales in international market.

- preliminary analysis and conclusions similarity evaluation on the level of production requirements and recommendations on future actions (required).
- productive facilities modernization and development by their change to adapt to production standards, methods and organizations.
- training of operators by the subject of work with new equipment and specialists to operate new equipment..

V. General efforts for certification practice and examination of how engine constructions and operational processes can correspond to the international requirements including the following spheres:

- verification of understanding of the difference between Russian and West European JAR Technical and procedural requirements.
- international certification procedure details and demonstrative information
- certification methods and CIS rules
- Klimov engines and power plants analysis from the standpoint of certification.
- documentation and translation.

Conclusion

Practically during this period of time in Klimov Corporation aviation power plant design and calculation school was formed which is now highly experienced and has its traditions. Furthermore a staff was formed, which is capable to create perfect construction prototypes as well as to tackle and solve more complicated advanced engine development problems.

Philosophy of the development envisaging obtain of all the thermodynamical, power and strength and reliable power plant parameters simultaneously, was a new one at its time, and it was fully justified by faultiness 30 years operations of helicopter power plants world wide.

Active support of Klimov engine production program by many manufacturing plants is a positive indicator of the company's stable in the aeroengine market..