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MINISTRY OF EDUCATION AND SCIENCE
OF UKRAINE
National Aviation University

AIRCRAFT TECHNICAL OPERATION

**Guide to Laboratory Practical Works
for students of speciality
272 "Aviation Transport"
Educational Professional Program
"Aircraft and Aircraft Engine
Maintenance and Repair",
"Airport Technologies and Equipment"**

Київ 2019

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Практикум містить порядок виконання лабораторних робіт, заходи безпеки під час роботи з обладнанням, використовуваними матеріалами, запитання та завдання для підготовки до практичної частини.

Для студентів спеціальності 272 «Авіаційний транспорт» освітньо-професійних програм «Технічне обслуговування і ремонт повітряних суден і авіадвигунів», «Технології робіт і технологічне обладнання аеропортів».

Aircraft Technical operation: Laboratory work / Compilers:
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The Guide to laboratory practical works familiarizes students with the methodology of laboratory work performance, safety rules instructions, equipment and materials employed, as well as the lab execution procedures, questions and tasks for self-control.

For the students of speciality 272 "Aviation Transport" Educational Professional Program "Aircraft and Aircraft Engine Maintenance and Repair", "Airport Technologies and Equipment".

CONTENT

INTRODUCTION

Laboratory practical's (labs) are aimed at broadening students' knowledge of main aircraft (AC) maintenance principles.

The purpose of labs is to teach students to do research, analyze and apply their knowledge in practical problem-solving.

Lab topics are compiled in line with the relevant course syllabus.

Labs are classified into practicals, computations and tests.

Classes are conducted in the NAU research and training center, hanger and chair labs with available aviation equipment.

Students prepare for the classes using the recommended references.

After checking students' knowledge on basic theoretical issues a lecturer explains how to do the labs and informs about AC safety maintenance requirements while working with aviation equipment (AE).

The students with insufficient theoretical knowledge or those who are late are not allowed in the lab practicals.

The students are divided into two subgroups and supervised by the lecturer, an aircraft technician or laboratory assistant.

In each group the lecturer appoints a team leader who receives the tools and documentation (maintenance schedule, instructions, aircraft specifications) required for the practicals.

The aviation technician, if necessary, reiterates occupational health and safety rules for the work to be performed and the students put their signatures in the training log to be eligible for the practicals.

After finishing their work the students check the availability of the tools, sort out the equipment and clean their workplaces.

Then they prepare their lab reports; the lecturer examines and grades the students.

Laboratory work 1

AIRCRAFT PREPARATION FOR LONG-TERM STORAGE (ILLUSTRATED BY IL-62)

Objectives

– to consolidate the theoretical knowledge and to acquire practical skills in preparing aircraft for storage.

Main tasks

1. Read the guidelines for aircraft storage.
2. Simulate the IL-62 aircraft preparation for 3-year storage.
3. Study engine NK-8-2U preservation equipment.
4. Conduct internal engine preservation.

Theoretical framework

The scope of work for aircraft inactivation, storage and removal from storage is determined by the Maintenance Manual.

IL-62 aircraft storage maintenance includes:

– storage preparation;

– maintenance after 10 and 20 days of storage, up to 1- and 3-month storage;

– aircraft preservation.

Before exterior surface preservation they remove dust and corrosion from airframe and engine parts, components and units and apply corrosion-preventive grease to the unprotected areas. Exterior engine preservation provides for its removal from the aircraft for storage or repair.

The preserved aircraft are stored in the parking area, moored (if required in the maintenance manual), grounded, and protected with covers, caps and safety devices.

Aircraft storage encompasses snow, ice and dust removal, cover air-dry, airframe ventilation, mooring, grounding, fire extinguishing system serviceability inspection. The data about aircraft storage preparation, interval, flight preparation (de-preservation) are recorded in the relevant section of the item logbook (certificate).

They preserve the engine oil and fuel system if the aircraft is kept stored for more than one month or in case of engine removal.

The engine oil system is considered to be preserved if oil analysis complies with the relevant specifications otherwise they have to change oil.

When internally preserved the fuel system is fed with pure oil either from an oil servicing truck or pressure oil dispenser (Fig. 1.1).

Equipment, tools and materials

For the engines and their systems preservation they use:

– oil mixtures for TVD turboprop engines (75 % of transformer or MK-8 oil and 25 % of MS-25 or MK-22 oil);

– MK-8 oil for bypass turbo engines;
– MK-8 oil for turboprop and bypass turbo engines;
– MK-22 or MS-20 oil for piston engines;
– N58M oil for piston engine and cylinder cavities;
– K-15, K-5 corrosion-preventive, gun grease, and petrolatum.

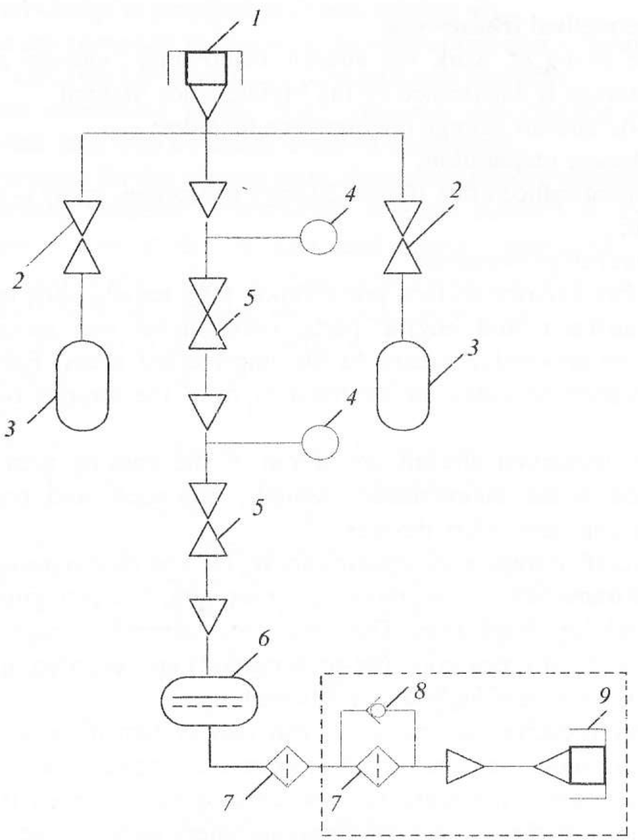


Fig. 1.1. Internal engine preservation diagram:
1 — air cylinder charge connector; *2* — air tank valves; *3* — air tank;
4 — pressure gauges; *5* — dispensing valve; *6* — oil tank;
7 — oil filter; *8* — bypass valve; *9* — preservation connector

Preservation oil must be moisture resistant and meet established specifications. DO NOT APPLY RECLAIMED AND USED OIL.

Lab execution procedures

In preparing the IL-62 aircraft for storage:

– clean dust and dirt off aircraft;

– apply a thin layer of ЦИАТИМ-201 to chrome surfaces of shock strut pistons, actuating cylinders, rails, roller flap carriages, actuating screws and LG locks;

– fuel all aircraft fuel tanks;

– drain condensate from the fuel system and inspect for freedom from water and impurities;

– change the oil in the aircraft units based on the IL-62 aircraft washing and lubrication task card;

– cover the aircraft with protective covers.

To preserve the fuel system, turbines and engine exhaust unit:

– shut off the fire valve and use SV-2476 unit to drain the fuel through DTSN-44T valve;

– connect the hose unit to DTSN-44T oil feed tube;

– disconnect the igniter starting feed fuel pipe from the starting fuel valve; connect SB-2303 mounting valve to the oil outlet pipe. Blank off the disconnected pipe with SB-2298. Remove the drain plug connector from ND-8 unit. Connect solenoid valve 1525.13.702 via SBR-010 adapter. Connect valve outlet with the tank via SBR-009 adapter;

– connect the solenoid valve with SBR-030 cable to the aircraft electric system.

Test oil for internal engine preservation; results compliance with the specifications proves oil system preservation.

Failure to meet the specifications requires:

– to drain oil from the oil pump block, filter and tank via the drain valves;

– to fill the tank with 35^{+2} — liter MK-8 oil (MES-2247A gauge).

Internal engine fuel system preservation provides for:

– opening the dispensing valve;

– using SB-2476, SBR-106 to pump DTSN-44TV-T oil through NR-8-2US low pressure filter, RT-8U fuel dispenser and OG-8-4 speed governor until oil appears at the drain taps;

– making five false starts (instructor's responsibility).

After the engine preservation:

– drain oil from the tank;

– disconnect all preserved units, blank them off and lock;

– connect the starting fuel pipe to the relevant valve and lock it out.

Upon engine presentation make entry into the aircraft logbook, maintenance release and a lab report.

Processing the results

The report should include:

– work name and purpose;

– safety rules and labor precautions during the aircraft storage preparation;

– storage preparation procedure;

– internal engine preservation;

– conclusions.

Questions for self-control

1. Explain the necessity of aircraft and its engines preservation.
2. Explain the essence of and the procedure for aircraft and engine preservation.
3. Explain the essence of and the procedure for engine oil system preservation.
4. What are the basic units of internal engine fuel system preservation?
5. Name and explain the operations for the internal engine fuel system preservation.
6. How and why is the engine fuel system pumped through?

Laboratory work 2

INVESTIGATION OF THE AIRCRAFT SYSTEMS FUNCTIONAL MAINTAINABILITY (ILLUSTRATED BY IL-62)

Objectives

– to practice skills in IL-62 aircraft units replacement, estimated man-hours, key indicator calculation, and the assessment of individual aircraft (AC) maintainability;

– to practice skills in the development of targeted recommendations and requirements for the improvement of aircraft design, maintenance and repair technology.

Main tasks

1. Get acquainted with the documentation necessary for work (regulations, technological instructions and others).

2. Execute units replacement (under teacher's instruction) measuring man-hours for each operation.

3. Calculate availability coefficient K_{av}.

Theoretical framework

Aircraft maintainability stands for the complex of its structural properties of maintainability and repair using the most economically effective processes. There are two methods of aircraft maintainability provision. The first is to adapt the structure to advanced maintenance and repair technologies, the second is to adapt to certain scheduled/non-scheduled maintenance and repair.

The level of aircraft maintainability depends on a number of its design features and operational factors.

Design properties include:

– designated unit availability;

– aircraft unit and component replaceability;

– unit interchangeability;

– unit and system inspection ability;

– ground facilities unification and standardization.

The operational factors include:

– the maintenance and repair system;

– the level of maintenance and repair automation and control processes;

– aircraft operation intensity (flight hours);

– specialized air units (aircraft types, scope of work, specialist proficiency, etc.);

– weather conditions.

Design properties are essential for aircraft construction. Operational properties are taken into account both during aircraft construction and operation.

Aircraft maintenance efficiency at the desired reliability and maintainability relies on the maintainability indicators, such as manpower input and aircraft idle period at maintenance and repair.

The system of generalized (complex) and individual indicators is applied to assess the maintainability of various aircraft designs under different operating conditions.

The generalized (complex) indicators are:

– average specific maintenance and repair manpower input K_{mpi}, man-hour per flight hour;

– average specific idle period at maintenance and repair per flight hour.

The individual indicators are considered as coefficients of unit and component availability (K_{av}), replaceability (K_{rep}), interchangeability ($K_{interch}$), ground support equipment consistency (K_{cons}), controllability (K_{contr}), etc.

The non-dimensional values of these coefficients may vary between $0 < K_i \leq 1$.

The design is deemed to meet the applicable requirements for one or other features if the relevant coefficient is less than or equals 1.

Equipment, tools and materials

The lab maintainability study can cover the following IL-62 aircraft control systems:

– aircraft control rod;

– turbo-cooling element of altitude system;

– exhaust valves of the altitude system.

Lab execution procedure:

1. Study the safety rules for aircraft component replacement.
2. Study the relative documents (regulations, standard practices and others).
3. Replace aircraft functional units (as directed by the teacher).
4. Replacing the aircraft unit requires each group of students to make entries into the appropriate task card (table 2.1).

Table 2.1

IL-62 aircraft unit replacement task card "____________"

Procedures	Tools	Performer involved	Chronometry, min	Manpower input per hour
1. Preparatory: – __________ – __________ Total:				
2. Basic: – __________ – __________ Total:				

Table 2.1. End

Procedures	Tools	Performer involved	Chronometry, min	Manpower input per hour
3.Work completion: – __________ – __________ Total:				

Point to the places of and the reasons for uncomfortable (poor) access to the unit and its attachments that complicate the work to do.

5. Clean the workplace, return tools and accessories.
6. Calculate K_d index according to equation and the basic data from table 2.1.
7. Draw conclusions about AC maintainability level.
8. Substantiate the proposals for higher level of AC maintainability at its creation, the improvement of technological methods of AC components replacement, and prepare the laboratory work report.

Processing the results

The report should contain:

- basic maintainability concepts;
- a unit sketch, diagram, areas, and the purpose of replacement;
- unit replacement data from table 2.1;
- equation solutions and those of the related sub-group;
- conclusions and recommendations how to improve the design, technological methods, mechanization and others.

Analysis of the results

The generalized (complex) and individual AC maintainability value is estimated in the special equation of statistical data collected.

In the lab, the level of aircraft system maintainability is estimated by the example of K_d.

Availability coefficient K_d is calculated by the expression:

$$K_d = 1 - \frac{T_{add}}{T_{add} - T_{main}},$$

where T_{add} is additional workload (preparatory and completion, table 2.1), man-hour; T_{main} is major workload for unit replacement (table 2.1), man-hour.

Questions for self-control

1. Define the concept of maintainability.
2. Name and describe individual and generalized maintainability data.
3. Explain how availability coefficient can be determined.
4. Name the preliminary, basic and work completion stages to replace the selected item of a functional system.
5. Substantiate the proposals for higher level of AC maintainability at its creation, the improvement of technological methods and mechanization of AC components replacement.

Laboratory work 3
ESTIMATION OF ANNUAL AVERAGE AIRCRAFT FLIGHT HOURS AT AVIATION ENTERPRISES

Objectives

– to consolidate the knowledge of evaluating efficient aircraft exploitation;

– to analyze the factors affecting the amount of the annual average aircraft flight hours;

– to develop the annual average aircraft flight hours planning technique.

Main tasks

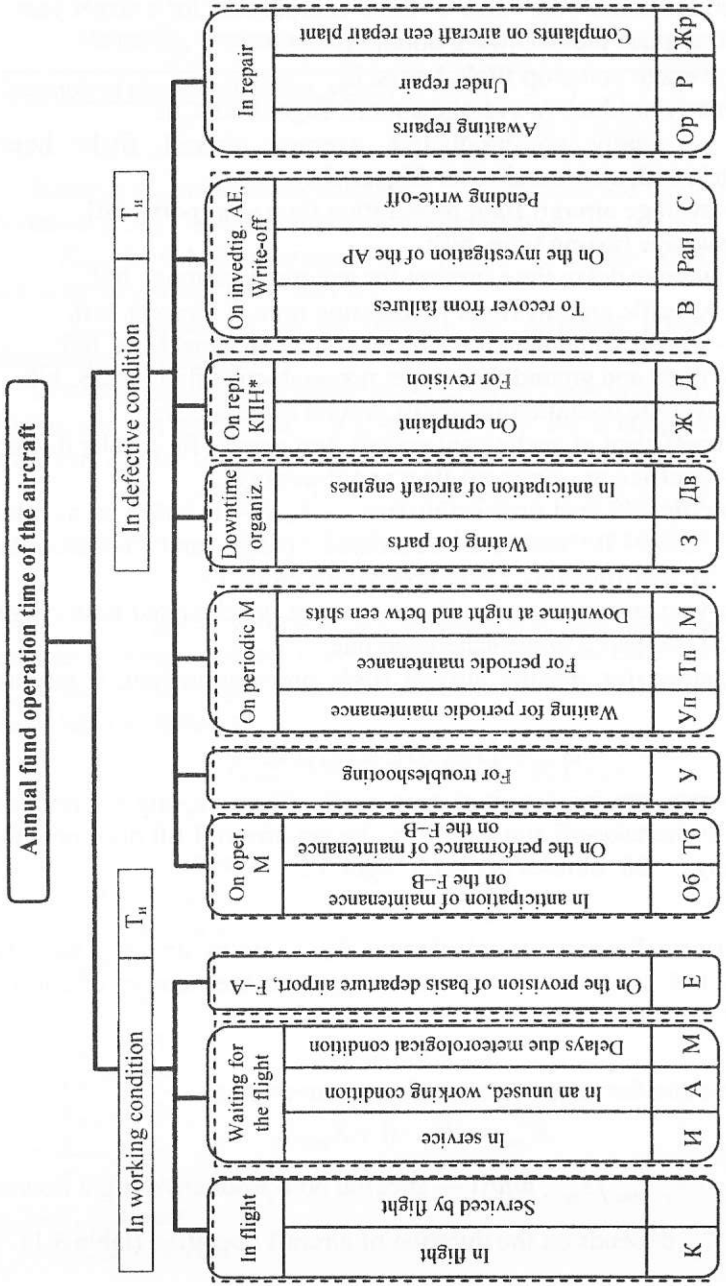
1. To analyze annual aircraft operational time.
2. To master the annual aircraft flight hours planning technique.
3. To calculate the annual aircraft flight hours plan.
4. To analyze the obtained results.

Theoretical framework

The annual aircraft operation time structure (Fig. 3.1) is the synergy of certain aircraft operation processes.

There two stages in aircraft flight planning.

The first stage defines how long aircraft calendar operation life lasts in a reference year.



*КТН — desing-manufacturing flaw

Fig. 3.1. Annual aircraft optrational time structure

The second estimates the value of these components for a target year.

Let us introduce the following notation:

$T_{n/s}$ — average non-stop flight hours, h;

T_y — yearly productive average aircraft flight hours, h;

$T_{y\,nonp}$ — yearly non-productive average aircraft flight hours (training, test and, check and other flights), h;

T_{airp} — average aircraft fight preparation time at airports, h/fl;

T_{gr} — average taxiing time, h/fl;

T_{del} — average delay time (except for technical reasons), h/fl;

K_{airp} — specific aircraft flight preparation time at airports, h/fl;

$K_{M\&R}$ — specific maintenance (*M*) and repair (*R*) lead time, h/fl;

K_{nonp} — flight and ground time as per nonproductive flight hours; h/fl;

T_{grd} — average operational aircraft ground time; h/day;

K_{res} — coefficient of operational aircraft fleet reserve for regular flights;

K_{serv} — coefficient of aircraft fleet serviceability.

The specific *MR* lead time estimation — K_{MR} — is based on aviation enterprise data. It includes scheduled (*MR*) and unscheduled (rectification, modification, claim procedures etc).

For a 5-year in-service aircraft, the average unscheduled time ranges 0.15 to 0.20 compared to the scheduled one.

The equation for specific aircraft flight preparation time at airports states:

$$K_{arp} = \left(T_{arp} + T_{gr} + T_{del}\right)/T_{ns}.$$

The average taxiing (towing) time — T_{gr} (from closing the door on the apron to the take-off run and from the landing roll till door opening after landing) is 20 minutes per each flight, i.e.

$$T_{gr} = 0.334\ \text{h/fl}.$$

ATC (air traffic control) calculates a T_{del} value by dividing the total delay time (all causes other than technical) into the number of sorties. The target value can be set at

$$T_{del} = 0.2\ \text{h/fl}.$$

The equation for nonproductive flight hours states:

$$K_{nonp} = \vec{E}_H \cdot \left(1 + K_{MR}\right),$$

where $\vec{E}_H = T_{y/nonp}/T_{gr}$, h/h/fl — specific non-productive flight hours.

Value $\vec{E}_H$ depends on the duration of aircraft operation (table 3.1).

Table 3.1

Value $\vec{E}_H$ dependence on the duration of aircraft operation

Duration of aircraft operation, years	1	3	5	over 7
$\vec{E}_H$	0.10	0.05	0.03	0.02

Reserve K_{res} and serviceability K_{serv} coefficients are rated by the Civil Aviation (CA) Department per each aircraft type:

– K_{serv} in CA is averaged 0.95 (i.e. 5 % of the total number of serviceable aircraft fleet reserve);

– K_{serv} ranges 65 to 80 percent for different types of aircraft depending on a season.

Operational aircraft ground time T_{grd} covers downtime at night (when flights are not performed), and ground hold for scheduled take-off in summer. T_{grd} for the reporting period is determined by the equation:

$$T_{grd} = 24\left(T_y / 365 \cdot K_{res}\right) \cdot \left(1 + K_{airp} + K_{MR} + K_{nonp}\right).$$

Taking into account eventual annual average aircraft flight hours:

$$T_y = 365 \cdot \left(\left(24 - T_{fld}\right) \cdot K_{res} / 1 + K_{airp} + K_{MR} + K_{nonp}\right).$$

With the given values of the average non-stop flight time T_{ns}, the average aircraft parking time at airports between code-sharing flights T_{airp} and actual flight time T_d, the maximum annual flight hours are calculated as follows:

$$T_{y\max} = \left(\left(365 \cdot T_d\right) / \left(T_{ns} + T_{airp}\right)\right) T_{ns},$$

where $T_d = 24 \cdot K_{serv}$, h.

Initial data for calculation (set by a teacher):

– aircraft type;

– target period year;

– $T_{n/s}$ = h;

– $\vec{E}_H$ =h/fl;

– T_{airp} = h/fl;

– T_{gr} = h/fl;

– K_{res} = 0.95;

– K_{serv} = %;

– T_d = 0.2 h/fl;

– T_y = h/year;

– T_{ynonp} = h/ year;

Use these data to predict the annual flight hours for an average aircraft T_{ty}, and the maximum possible flight hours for a given aircraft $T_{y\ max}$. In addition, draw the dependency diagram between eventual annual flight hours and non-stop flight duration.

Non-stop flight duration values vary depending on an aircraft type.

Present the obtained data with the graph and your summary report.

Processing the results

The report should include:

– brief theoretical information about the annual aircraft operation time structure;

– calculation of the annual average aircraft flight hours forecast;

– calculation of the maximum annual average aircraft flight hours;

– dependency diagram between the projected annual flight hours and non-stop flight duration;

– conclusions.

Questions for self-control

1. Describe the annual aircraft operation time structure.
2. Explain the annual average aircraft flight hours calculation technique.
3. Explain the maximum annual average aircraft flight hours calculation technique.
4. Explain the equation components for average and maximum annual flight hours.
5. Analyze the dependency diagram between the projected annual flight hours and non-stop flight duration.

Laboratory work 4

SELECTED FLIGHT FUEL QUANTIFICATION (ILLUSTRATED BY AN-24 AIRCRAFT)

Objectives

– to practice engineering and navigation fuel consumption calculations for a given flight;

– to develop recommendations on flight safety improvement in various conditions of a desired flight.

Main tasks

1. For a given flight distance L, determine the most advantageous flight altitude H_{best}.
2. Find the equivalent wind value (W–V).
3. Determine the amount of flight fuel consumption m_{cons}.
4. Make the required fuel reserve corrections.
5. Determine the required fuel quantity for a given flight.
6. Make a conclusion.

Theoretical framework

Crew members calculate and analyze weather conditions and their forecast for a particular en-route flight. Simultaneously, they consider possible alternative airports.

Having analyzed weather conditions and their forecast at the departure aerodrome, en-route and at a destination aerodrome a pilot-in-command takes the decision about flight performance. Based on the chosen flight option, they calculate maximum AC take-off weight and the amount of fuel required for a particular flight.

Fuel consumption in flight should be estimated for specific flight range and cruising altitudes, speed and wind angle vales (taking into account the effect of the equivalent en-route wind).

Then, they estimate the total amount of fuel load in the tanks, including fuel consumption during the engine start-up, ground movement, flight diversion, etc.

Actual take-off mass deviation from the calculated one need correction for some type of AC as per Flight Manuals (FM).

Draw a schematic diagram of AC fuel load and grade in tanks based on the AC specifications and FM.

Lab execution procedures:

To calculate fuel load you should determine H_{best} at a given L (table 4.1 and 4.2).

Table 4.1

AI-24, series 2, engine-driven AN-24 AC best climb rate in zero-wind conditions

Distance (L), km		100	200	300	400	500	600	700	800	900	1000	≥1100
H_{best}, m	less t_{MCA} $^{o}_{+10}$	900–1200	1500–2400	2400–3300	3300–4200	3600–4800	4800–5400	5400–5700				
	more t_{MCA} $^{o}_{+10}$	900–2100				2400–2700	2700–3000	3000–3300	3300–3900	3600–4200	3900–4500	5100–5400

Note 1. At take-off mass ≤ 19000 kg flight altitude increases by 300 m.

Note 2. In order to decrease fuel consumption the cruise altitudes should be chosen as close as possible to the upper limits H_{best}, given in table 4.1 and 4.2.

Note 3. If the equivalent wind value (W–V) increases in climb by more than 20 km/h, fuel consumption decrease and ground speed increase are possible at the best lower altitude.

Table 4.2

AI-24T engine-driven AN-24 AC best climb rate in zero-wind conditions (at any ambient temperature)

Distance (*L*), km	<100	100... 200	200... 300	300... 500	500... 700	700... 1000	>1000
H_{best}, m	900... 1200	1500... 2400	2400... 3300	3600... 4800	4800... 5400	5400... 5700	5700... 6000

H_{best} of flight is determined by fuel consumption per kilometer and depends on:

– distance between take-off and landing aerodromes (*L*);
– en-route speed and wind direction;
– aircraft take-off mass;
– ambient temperature.

The equivalent wind value W–V for the AC with the cruising speed ranging from 400 to 500 km/h can be determined by using table 4.3 (wind angle is known from navigation calculation and its speed and direction are known from meteorological conditions forecast for the given altitude).

The required take-off fuel m_{load} in AC tanks for the designated range is calculated as sum of:

$$m_{load} = m_{cons} + m_z + m_{non-consum} + m_{fr},$$

where m_{consum} — fuel amount between AC take-off and landing (take-off, climbing, level flight, descending, landing).

It is determined by the following graph (Fig. 4.1): m_z — engine ground run fuel consumption. For AN-24, it values at 10 kg/min. Ground operation (start-up, taxiing, clearance, running off the runway after landing, taxiing in for parking) takes 15 min.

$m_{non-consum}$ — unusable fuel mass. For AN-24, it values at 110 kg (or 50 kg for the AC with S/N 37300901).

Table 4.3

The AC equivalent wind values at 400...500 km/h cruising speed

Wind angle, degree	Wind speed, km/h 20	40	60	80	100	120	140	160	180	200	
0 360	20	40	60	80	100	120	140	160	180	200	Tailwind
5 355	20	40	60	80	100	120	140	160	180	200	
10 350	20	39	59	78	98	117	137	156	176	196	
15 345	19	38	58	77	96	115	134	152	171	190	
20 340	19	37	56	74	93	111	129	147	165	183	
25 335	18	36	54	71	89	106	123	140	157	173	
30 330	17	34	51	68	84	100	116	131	147	162	
35 325	16	32	48	63	78	93	107	122	135	149	
40 320	15	30	44	58	72	85	98	111	123	135	
45 315	14	27	40	53	65	77	88	99	109	119	
50 310	13	25	36	47	58	68	77	86	95	102	
55 305	11	22	32	41	50	58	66	73	79	85	
60 300	10	19	27	35	42	48	54	59	63	67	
65 295	8	15	22	28	33	35	41	44	46	48	
70 290	6	12	17	21	24	27	29	30	30	29	
75 285	5	9	12	14	16	16	16	15	13	10	
80 280	3	5	6	7	7	5	3	0	4	8	
85 275	1	2	1	0	2	5	9	14	20	27	
90 270	1	2	4	7	11	16	22	28	36	44	Headwind
95 265	2	5	9	14	20	26	34	42	51	62	
100 260	4	9	14	21	28	36	45	55	66	78	
105 255	6	12	19	27	36	46	57	68	80	93	
110 250	7	15	24	34	44	55	67	80	93	108	
115 245	9	18	29	40	51	66	77	91	106	121	
120 240	10	21	33	45	58	72	86	101	117	133	
125 235	12	24	37	51	65	80	95	111	127	145	
130 230	13	27	41	56	71	85	103	120	137	155	
135 225	14	29	44	60	76	93	110	127	145	164	
140 220	15	31	47	64	81	99	116	134	153	171	
145 215	16	33	50	68	86	104	122	140	159	179	
150 210	17	35	53	71	89	108	127	146	165	184	
155 205	18	36	53	74	93	112	131	150	169	189	
160 200	19	38	57	76	95	115	134	153	173	193	
165 195	19	39	58	78	97	117	137	157	176	196	
170 190	20	39	59	79	99	118	138	158	178	198	
175 185	20	40	60	80	100	120	140	160	180	200	

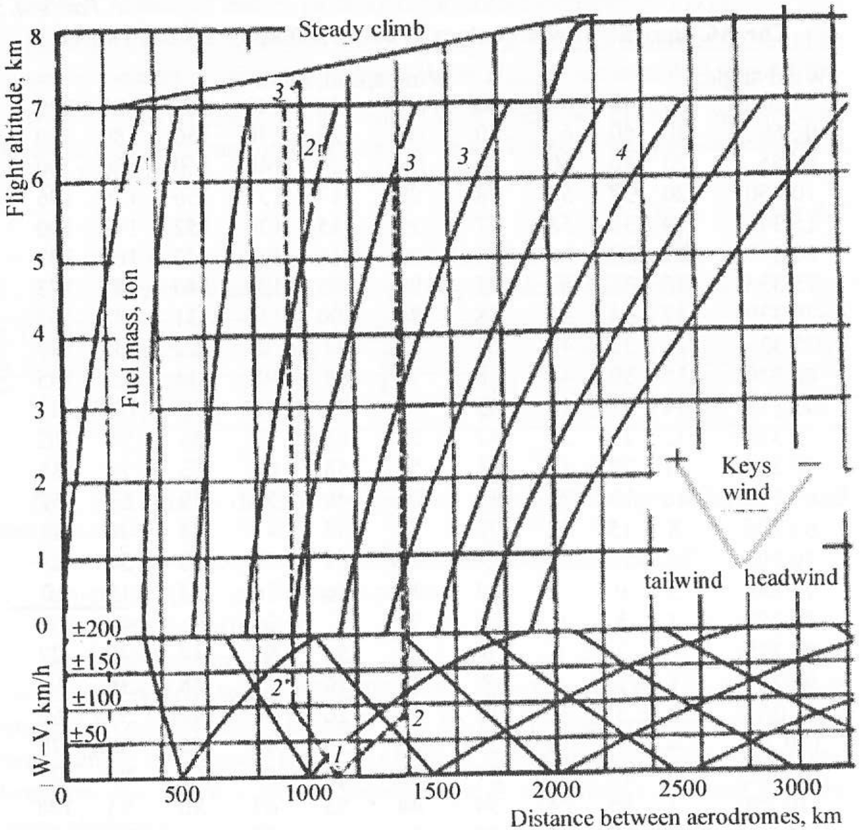


Fig. 4.1. Take-off to landing fuel consumption estimates

You can find the data on ground fuel consumption and remaining unusable fuel in the tanks in Flight Manuals (FM) for each type of the AC. m_{fr} — fuel reserve mass is shown in table 4.4 depending upon the distance between the alternative and intended destination aerodromes.

Fuel reserve is required for:

a) executing go-around from safe altitude;

b) avoiding thunderstorm;

c) climbing to H_{cruise} in alternative aerodrome flight;

d) flying to the alternative aerodrome at H_{cruise} = 2400 m with the velocity which corresponds the minimum fuel consumption per kilometer;

d) descending from cruise altitude to the go-around altitude;

e) circling flight (6 min) with fuel consumption of 15...20 kg/min;

f) approaching and landing at the alternative aerodrome.

Table 4.4

Fuel reserve value depending upon the distance between the alternative and intended destination aerodrome

Distance, km	Altitude, m	Actual speed, km/h	FR, kg	FR increase per each 10 km/h of headwind, kg
50	2400	405	700	5
100	2400	405	770	5
150	2400	405	870	5
200	2400	405	980	10
250	2400	405	1080	10
300	2400	405	1190	10
350	2400	405	1290	15
400	3300	400	1390	20
450	3300	400	1490	20

The fuel reserve should be available for at least a one-hour flight with minimum fuel consumption per kilometer (not less than 700 kg).

In the laboratory work, m_{fr} value is chosen according to the variant given by teacher [9]:

a) flight with alternative aerodrome;

b) flight without alternative aerodrome;

c) flight to the isolated aerodrome.

For the flight with using an alternative aerodrome $m_{alt\text{-}fl}$, FR is calculated to ensure:

– the go-around at the destination aerodrome, cruise climb level, en-route flight, descending, approach and landing at the alternative aerodrome;

– final fuel reserve m_{crit}, taking into account fuel for 30 min flight at the holding altitude of 450 m against the alternative aerodrome level upon landing.

The final fuel reserve is determined according to FM. If this value is not available in the FM, it is recommended to consider it as

$$m_{Kpp} = 0.03\, m_{cons}\,.$$

The typical equation for fuel reserve calculation is:

$$m_{fr} = m_r + m_{alt-fl} + m_{Kpp} + m_{extra} + m_{capt},$$

where m_r — contingency fuel reserve in the event of routing changes, wind speed increase and others; $m_{alt\text{-}fl}$ — fuel required for the flight to the alternative aerodrome; m_{crit} — final fuel reserve; m_{extra} — additional fuel reserve (if necessary); m_{capt} — fuel reserve upon captain's decision.

All these elements are shown in table 4.4, in column "FR".

For the flight without using an alternative aerodrome, fuel reserve is calculated to fly a turbine-powered AC at 450-m holding altitude against the alternative aerodrome for 60 min.

For the flight to the isolated aerodrome, fuel reserve is calculated to fly a turbine-driven AC at V_{cruise} and H_{cruise} for 2 hours.

The fuel reserve cannot be less than that stated the FM for the given type of aircraft.

Note 4. For the AN-24 aircraft with the stabilizer anti-icing system, the estimated fuel reserve should be increased by 3 %.

Note 5. For the AI-24T engine-powered AN-24 aircraft, the estimated fuel reserve should be increased by 4 %.

It should be noted that the methods of fuel amount calculation for each type of AC can vary from those given in AN-24 flight manual.

Example of refueling calculation

Calculate the required fuel amount for AI-24T engine-powered AN-24 aircraft. Initial data:

– the distance between take-off and landing aerodromes $L = 1100$ km;

– the wind speed at the given flight altitude $W = 80$ km/h;

– 160-degree wind angle.

Flight option: the flight with using alternative aerodrome 50 km from the main destination aerodrome.

Solution: To simplify calculation let's assume that AC is refueled at the apron, therefore it is necessary to take into account the fuel amount for start, warm-up, taxiing and take-off clearance).

According to table 4.2 we determine H_{best} of the level flight, which is 6000 m for $L > 1000$ km.

Refueling m_{refuel} illustrated in expression is estimated as follows:

1) in table 4.3, the equivalent wind speed W–V equals minus 76 km/h (minus corresponds to the headwind).

2) use the graph (Fig. 4.1) to determine en-route fuel consumption m_{consum}:

a) draw the given distance $L = 1100$ km on the horizontal graph axis (point *1*);

b) draw the equidistant line to value W–V = minus 76 km/h (point *2*) in the keys wind (right of Fig. 4.1) from point 1 along the line sloping right (for headwind), draw (point *2*);

c) draw the vertical line from point *2* to the intersection with the preset level flight altitude $H_{best} = 6000$ m (point *3*).

In point *3*, we get the approximate value of $m_{consum} = 2500$ kg.

3) add together the value of remaining unusable fuel reserve and ground fuel consumption during 15 min. The fuel reserve at the given distance to the alternative aerodrome of 50 km (Fig. 4.1) should constitute 700 kg. Taking into account (table 4.4) the additional fuel consumption (plus 5 kg per each 10 km/h of headwind), at W–V = minus 76 km/h, we obtain the fuel reserve correction value of 38 kg. Finally:

$$m_{fr} = 700 + 38 = 738 \text{ kg}.$$

In the AN-24 flight manual, the remaining unusable fuel mass $m_{noncons}$ equals 110 kg. AN-24 aircraft engine ground-run fuel consumption constitutes 10 kg/min. Ground operation (start-up, taxiing, clearance, running off the runway after landing, taxiing in for parking) takes 15 min. Consequently

$$m_z = 150 \text{ kg}.$$

Then: $m_{fr} + m_{noncons} + m_z = 738 + 110 + 150 = 960$ kg.

4) The required fuel quantity in AC tanks constitutes (Fig. 4.1):

$$m_{load} = 2500 + 960 = 3460 \text{ kg}.$$

In the AC powered by AI-24T engines, fuel reserve (see Note 5) should be increased by 4 % (plus 138.4 kg). Consequently, fuel quantity in tanks equals

$$m_{load} = 3598.4 \text{ kg or} \approx 3600 \text{ kg}.$$

A student does lab calculations based on the initial data of the variant number (table 4.5) that corresponds to the last figures of his/her record book.

Processing the results

The report should contain:

– initial data according to the variant;

– necessary calculations and illustrated (explanatory) graphs and tables;

– aircraft safety flight conclusions.

Table 4.5

Task variants

№ s/n	Distance from take-off to destination aerodrome *L*, km	Wind speed at given flight altitude W, km/h	Wind angle, degrees	Flight variant*
1	300	5	0	b
2	300	10	5	b
3	350	15	10	b
4	350	20	15	b
5	400	25	20	b
6	400	30	335	c
7	450	35	330	c
8	450	40	325	c
9	500	45	320	c
10	500	50	315	c
11	550	55	270	b
12	550	60	265	b
13	600	65	260	b
14	600	70	255	b
15	650	75	250	b
16	650	80	245	a
17	700	85	240	a
18	700	90	235	a
19	750	95	130	a
20	750	100	135	a

***Note.** a) flight with using an alternative aerodrome;
b) flight without using an alternative aerodrome;
c) flight to the isolated aerodrome.

Questions for self-control

1. Name the main stages of fuel reserve calculation for a given flight.
2. Give the definition of the best flight rate.
3. Define the fuel reserve concept and its components.
4. What is fuel quantity between take-off and landing and how is it graphed?
5. Explain the purpose of ground fuel consumption.
6. Explain the "flight time" concept according to Flight Regulation Manual of Civil Aviation.
7. Calculate what volume of the fuel tank will occupy 3600 kg of fuel.
8. Speak on the fuel load quality inspection.

Laboratory work 5

TAKE-OFF GROUND RUN EVALUATION (ILLUSTRATED BY AN-24 AIRCRAFT)

Objectives

– to obtain practical take-off navigational engineering calculation skills in the given aircraft take-off conditions and weight;

– to develop take-off safety improvement recommendations.

Main tasks

1. To check whether the specified in the work take-off conditions (aerodrome altitude and ambient temperature) allow normal and safe AC run and take-off.

2. To determine real AC run length using combined charts and taking into account aerodrome altitude, ambient temperature, wind, take-off weight, runway slope upon the given initial data.

Theoretical framework

The required take-off run and distance are calculated taking into account the actual runway length, its slope, weather conditions and, departure aerodrome height.

Take-off (gross take-off distance) L_{gt} includes the take-off itself (take-off length) L_t and initial climb distance L_{ic} [16]:

$$L_{tt} = L_t + L_{ic}.$$

The take-off distance L_t is the aircraft ground run from the standing start to a 10.7-meter climb (above the take-off surface) at the speed not less than the safe take-off speed

$$V_2 = 1.2V_s,$$

where V_s is the stalling speed. L_t is comprised of take-off run L_r and the distance of the 1st take-off segment L_1, i.e.:

$$L_t = L_r + L_1.$$

The take-off run L_r is the aircraft ground run from the standing start to its lift off the runway.

The gross take-off distance L_{gt} is the aircraft ground run from the standing start to a 400-meter climb (above the take-off surface) or to the point at which the aircraft completes the take-off transition to en-route configuration at $1.25V_s$ speed. L_{gr} encompasses AC and four climb segments:

1-st segment: climbing from AC lift-off to a 10.7-meter altitude;

2-nd segment: climbing from a 10.7-meter altitude to the initial climbing with the extended high-lift wings;

3-rd segment: a 120-meter climb with the extended high-lift wings;

4-th segment: climbing from 120 m to H = 400 m with the simultaneous speed increase and retracted high-lift wings.

These climb segments are characterized by a certain gradient h_g. Gradient h_g is defined as flight path tangent q_g and is expressed as a percentage:

$$h_g = \tan q_g \cdot 100\% = dH / dL \cdot 100\%.$$

The maximum aircraft climb gradient in a given operating conditions is called gross gradient (h_{gross}).

The gross all-engine climb gradient h_{gross} should be at least 5 % in the third segment and at least 3% in the fourth segment.

At the taxi holding and starting points AC is put into take-off configuration, all systems and equipment are being prepared for flight.

Normal take-off is the take-off with the normal operation of AC engines (take-off and emergency power), systems and components according to the flight maneuvers manual.

Continued (completed) take-off is considered normal until one of the engines fails during take-off; but the take off is continued with one engine.

Aborted take-off is considered normal until one of the engines fails, the take-off is rejected with the aircraft deceleration until its complete stop on the runway.

During the take-off run, you should push the steering wheel controlling the AC movement with pedals, i.e. rudder and nose landing gear wheel steering.

At rotation speed V_R, you should pull the steering wheel gently and continuously to reach the take-off angle of attack and lift-off at V_2 speed that is only 10 to 15 km/h higher than V_R.

Taking into account the small deference of speeds ($V_2 - V_R$), the AC rotation speed before lift-off comes to V_2, that actually provides safety lift-off. That is why nose landing gear retraction should begin at indicated speed V_R.

After the lift-off AC accelerates to climb at H = 10.7 m with its speed not less than V_2 = 1.2 V_C. The landing gear is retracted at the altitude not less than 5 m.

The second segment climb L_2 provides for increasing speed to V_2^{+20} km/h and maintaining it to the high-lift devices retraction (not less than 120 m).

In completing the high-lift devices retraction the speed should be as safe as at during flight configuration, i.e. $V_4 = 1.25V_s$.

The AC take off run is affected by life force Y, drag X, weight mg, thrust R, runway reaction force ($N_1 + N_2$), equal and opposite to the tire pressure force ($mg - Y$), and friction force.

The friction value is determined by the value of reaction force

$$N_1 + N_2 = mg - Y$$

and by friction coefficient f_{fr}, which depends on the runway surface condition.

The take-off run is the linear accelerated motion. To ensure acceleration the power plant thrust should be higher than the sum of friction and drag forces, i.e.:

$$P > \left(X + F_{fr1} + F_{tr2}\right).$$

At the lift-off the lift force should be equal to the AC weight, i.e.:

$$Y = C_y \frac{\rho V^2}{2} S = mg.$$

From this expression the lift-off speed V_{lift} is:

$$V_{lift} = \sqrt{\frac{2mg}{C_{ylif}\rho S}}.$$

The equation shows that the lift-off speed value depends on the AC take-off weight, air density and $C_{y\,lift}$.

If the lift-off speed V_{lift} and run time t_r are known, AC mean acceleration is expressed by:

$$j_{med} = \frac{V_{lift}}{t_r}.$$

Take-off run in this case is determined by the equation:

$$L_p = \frac{j_{med} \cdot t_r^2}{2}.$$

AC mean acceleration j_{med} during run depends on the thrust excess $dP = P - (X + F_{tr})$ and mass $m = G/g$; the higher the thrust excess and the smaller the weight, the higher acceleration is because:

$$j_{med} = \frac{\Delta P}{mg} = \frac{P - (X + F_{tr})}{mg}.$$

The take-off run value depends on various operational factors:

a) air density. With air density decrease (high temperature, low pressure, high-level aerodrome) the run increases. It can be explained as follows:

Firstly, the actual velocity of lift-off increases (indicated airspeed is constant), secondly, AC acceleration decreases because of the decreased thrust excess $dP = P - (X + F_{fr})$ caused by available thrust reduction.

The sum of drag and friction forces $(X + F_{tr})$ can hardly vary because decreased density at any actual take-off reduces both drag and lift forces, while friction force increases due to decreased lift.

b) AC take-off mass. The larger the take-off mass, the longer the run and higher the lift-off speed. As a result, acceleration j_{med} decreases considerably. Greater mass highly affects AC inertia. Friction increases; drag increases at higher speeds. Consequently, AC thrust excess and acceleration decrease.

c) high-lift wings. $C_{y\,lift}$ increases due to flaps and slats take-off setting; take-off speed and run decreases. The excess thrust dP and AC acceleration at such settings remain generally unchanged because the sum of drag and friction forces is constant that significantly reduces the run.

d) wind. The headwind take-off reduces the ground speed at lift-off to the wind speed value that, hence, reduces the run.

e) runway slope. Taking off from the sloping runway q_{runway} makes AC mass $(mg \cdot \sin q_{runway})$ parallel to the runway.

If the aircraft takes off on the sloping runway, mass component $(mg \cdot \sin q_{runway})$ is added to the power plant thrust and the AC has greater acceleration and shorter run, and vice versa.

f) angle of attack. During take-off you must remembered that each take-off mass $\alpha_{lift}(C_{y\,lift})$ has its own calibrated lift-off speed. If the pilot takes off the AC at this speed, it means that the take-off has occurred at the estimated angle of attack and acceleration (according to the take-off chart). In order to provide the AC take-off at the estimated speed it is advisable to start lifting the nose LG at the estimated speed V_R.

Maximum permissible take-off mass (weight) impact

In the event of critical engine failure, gross climb gradient h_{gr} should equal, according to [16]:

– not less than 0.5 % in the 1st climb segment;

– not less than 1.3 % in the 2nd;

– not less than 3 % in the 3rd; and

– not less than 1.7 % in the 4th.

The abovementioned values should be revised in various take-off phases with one failed engine in accordance with the equation (5.1).

The gross gradient is obtained in the trimmed zero-sideslip flight. If the AC is trimmed with sliding, drag increases, but excess thrust dP, the angle of climb and climb gradient decrease but not more than 1 % in the 2nd, 3rd and 4th climb segments, i.e. net climb gradient h_{gr} in the 3rd stage should not be less than 2 % at $V_2 = 1.2$ Vs.

This method of determining the maximum permissible weight can be explained as follows. Climb angle is determined by:

$$\sin q_{cl} = dP/mg = (P - X - mg \cdot \sin q_{cl})/mg >> \text{tg}\, qcl, \qquad (5.1)$$

and gradient $h_{gr} = \text{tg}\, q_{cl} \cdot 100$ %.

This means that the climb gradient indicates the angle of climb for small angles of climb $\text{tg}q_{cl} >> \sin q_{cl}$. The value of excess thrust dP, angle of climb and climb gradient during zero-sideslip flight is determined by the available thrust. With increasing the altitude (decreasing atmospheric pressure and air temperature) the available thrust and excess thrust decreases, therefore, to save the angle and climb gradient ($\sin q_{cl}$ and $\text{tg}q_{cl} \cdot 100$ %) weight should be reduced (eq. (5.1)).

As pointed out above, rotation speed V_R is to ensure AC safe lift-off speed by stalling speed V_s exceed with $V_R = 1.15 V_s$. The safe initial climb speed with retracted landing gear is expressed by $V_2 = 1.2\, V_S$.

Let's consider the decision speed (V_1) conditions.

Firstly, this speed should correspond to

$$V_{\min cs} < V_1 < V_R,$$

where $V_{\min cs}$ is minimum control speed

In the event of critical engine failure during the take-off run at $V_{\min cs}$ the AC straight and level flight is controlled aerodynamically (by the rudder).

Secondly, the decision speed:

$$V_1 = V_{1en.f} + dV/dt.$$

The equation shows that the pilot takes the decision to continue or reject take-off at a higher speed rather than at the critical engine failure speed.

Decision speed V_1 must not exceed rotation speed V_R as in 2 ... 3 sec. the AC lifts off from the runway.

Take-off rejection is prohibited after the lift-off as the AC heavy load and complicated piloting can't ensure safe landing.

Having lifted off the AC influenced by high angles of pitch (attack) and asymmetric thrust turns and rolls towards the failed side engine. The pilot counteracts the turn through rudder and aileron deflection. However, the reduced engine thrust and deflected rudder during landing can turn and roll the AC towards the operating engine providing simultaneous descent and increased angles of attack resulted in a rough main wheel landing at the high angles of attack and side AC take-off weight impact.

This can also cause AC stall. Thus, it is required to continue the take-off with the inoperative critical engine and the decision speed V_1 should not exceed V_R, i.e. $V_1 \leq V_R$. These decision speed (V_1) requirements are subject to the piloting technique.

At the same time, V_1 should ensure aborted and continued take-off safety when one of the engines fails during the take-off run.

Aborted take off at speed V_1 stops the AC at the end of the accelerate-stop distance.

Continued take-off at speed V_1 lifts off the AC at the design speed V_{lift} to fly 0.5 L_1 to cover the required take-off distance and to climb 10.7 meters for speed V_2.

Given this, reject the take-off when the engine fails at speed V_1 inc., and continue it at a higher speed.

Lab execution procedures

The lab execution is guided through the sample of AN-24 aircraft take-off run calculations.

Initial data:
- AC take-off weight — m_t = 20.000 kg;
- Engine power — take-off;
- Flaps setting — at 15°;
- Lift-off angle of attack - 9.4°;
- Aerodrome elevation, H_{aer} = 1.000 m;
- Runway surface — dry concrete;
- Air temperature, t = + 35 °C;
- Runway slope — up 1.5 %;
- Wind — headwind 8 m/s.

Solution: To determine the AC take-off run in the given conditions refer to the AC FM and charts. Water injection into the engine inlet in order to increase their power requires specific charts. If water is not injected into the system or the take-off is carried out without water injection, the AC run with reduced engine power is longer than that with the water injected engine.

Determine first that take-off conditions (airfield elevation and air temperature) allow carrying out AC normal run and take-off.

Higher temperature and 1000-meter aerodrome elevation require water injection into the engines. To confirm this assumption you should refer the appropriate chart. For this purpose, we use the chart (Fig. 5.1).

On the ordinate find a predetermined height of the aerodrome (1000 m), select the curve corresponding to the air temperature plus 35 °C and from the point of intersection descend down to the abscissa axis where we can find the maximum take-off weight of the aircraft. In this case, it is 20.300 kg. Take-off weight in this example is 20.000 kg, i.e. actual weight is less than the maximum design one.

The take-off mass (weight) is determined by the climb gradient of 2.5 % in the second segment. Engine power is maximum; flaps setting is 15 °C.

Determine the AC actual run using combination charts (Fig. 5.2, 5.3) taking into account the aerodrome elevation, air temperature, AC take-off mass (weight), runway slope and wind.

The design take-off run calculation for the initial data based on the given "key" gives 850 m.

To learn how to determine AC take-off run at different take-off weight and conditions make basic engineering calculations using one of the discussed techniques and pointing out
- engine take-off power;
- flaps — setting at 15 °C;
- runway — dry concrete surface;
- water injection into the engine — N/A.

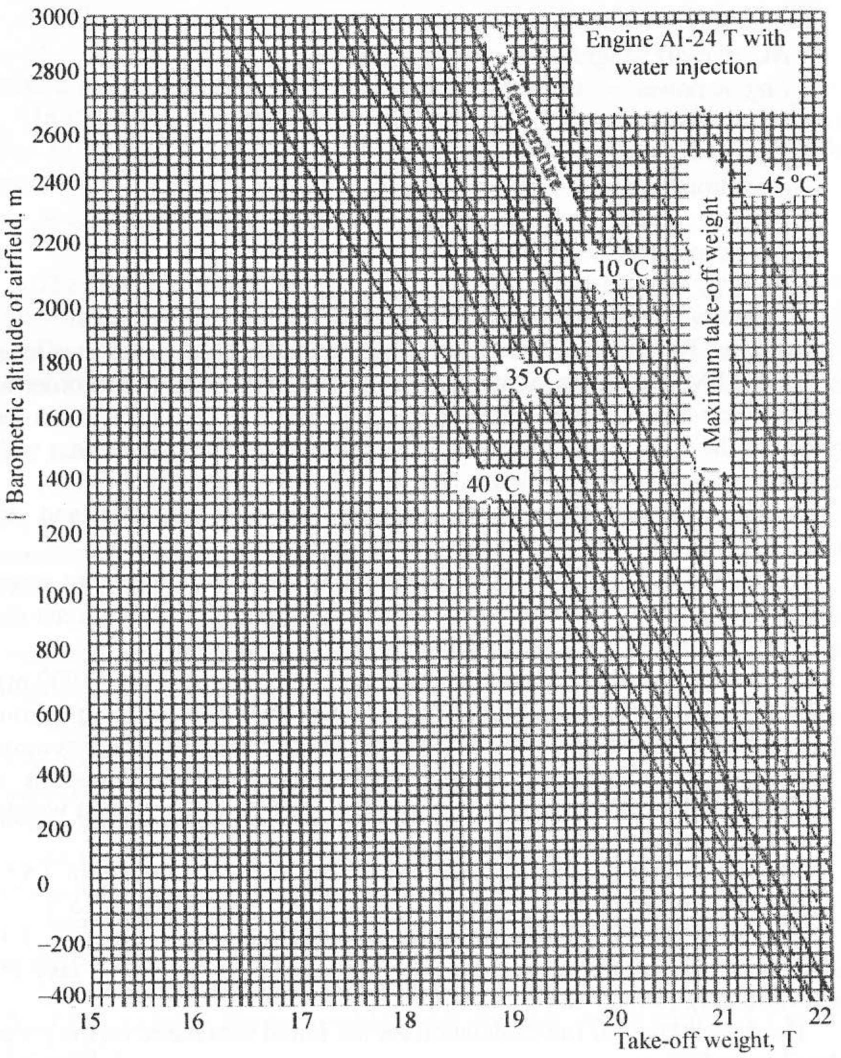


Fig. 5.1 Maximum take-off weight according to height of an airport and air temperature

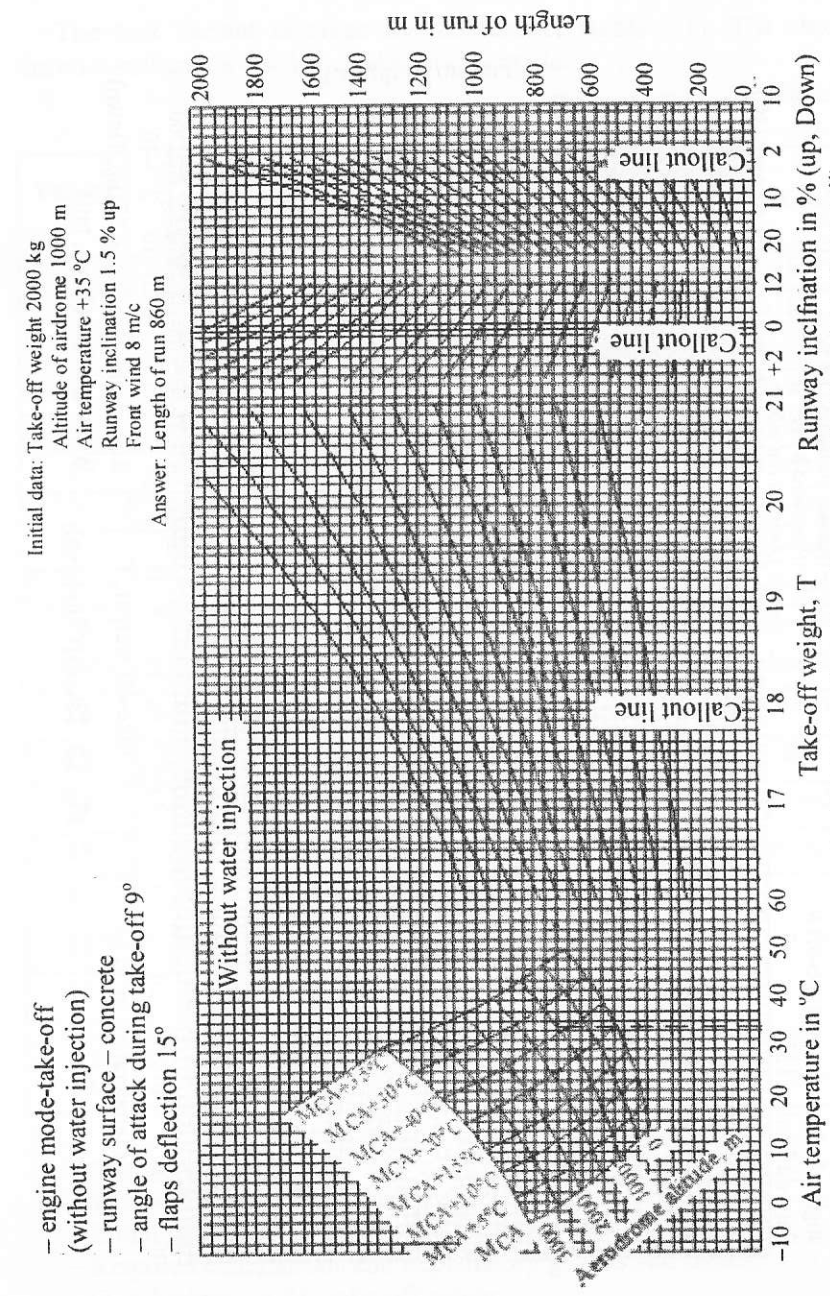


Fig. 5.2. Take-off run length

– engine mode-take-off
(without water injection)
– runway surface – concrete
– angle of attack during take-off 9°
– flaps deflection 15°

Initial data: Take-off weight 2000 kg
Altitude of airdrome 1000 m
Air temperature +35 °C
Runway inclination 1.5 % up
Front wind 8 m/c
Answer: Length of run 860 m

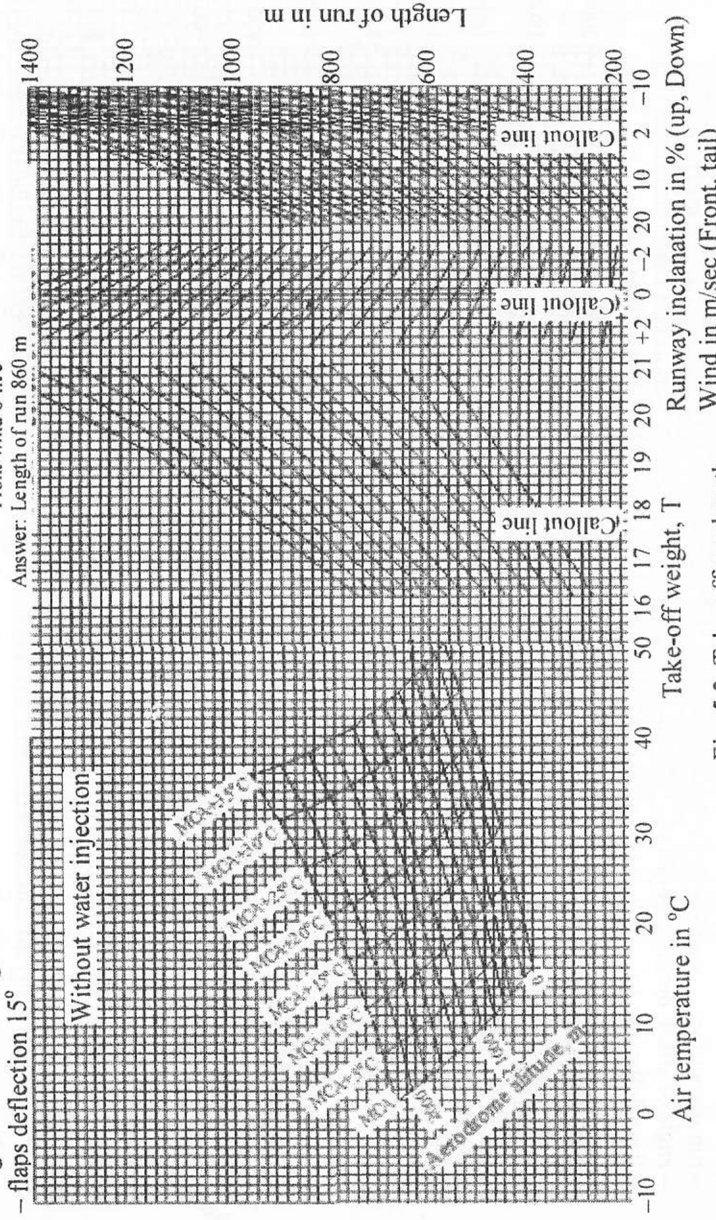


Fig. 5.3. Take-off run length

The task variant is given by the teacher (table 5.1). The student draws conclusions upon the calculations made.

Table 5.1

Task variant

Variant No	Take-off weight m_t, Kg	Air temperature ta, °C	Aerodrome elevation H, m	Runway slope, %	Wind, m/s
1	18 000	+15	–50	down 1.5	headwind 1.5
2	18 000	+20	–50	down 1.5	headwind 1.5
3	18 000	+25	–50	down 1.5	headwind 1.5
4	18 000	+30	–50	down 1.5	headwind 1.5
5	18 500	+10	500	up 1	0
6	18 500	+ 5	500	0	headwind 1
7	18 500	+30	500	down 1.5	headwind 2
8	18 500	+40	500	0	headwind 3
9	19 000	+15	100	up 1	headwind 3
10	19 000	+20	200	0	headwind 3
11	19 000	+25	300	down 1	headwind 3
12	19 000	+30	400	up 1.5	headwind 3
13	20 000	+15	100	up 1	0
14	20 000	+20	200	0	headwind 5
15	20 000	+25	300	down 1	tailwind 5
16	20 000	+30	400	up 1.5	0
17	20 500	+20	50	0	0
18	20 500	+25	50	0	headwind 5
19	20 500	+30	50	0	tailwind 3
20	20 500	+35	50	0	headwind 8

Processing the results

The report should contain:

– Initial data in accordance with the task variant;

– Required calculations and explanatory graphs and tables;

– Conclusions on AC take-off safety.

Questions for self-control

1. Describe the concept of "gross take-off distance".
2. Name the take-off run phases.
3. Explain the concept of "continued (completed) take-off".
4. Explain the concept of "rejected (aborted) take-off".
5. Explain the dependence of AC take-off run on air density, runway slope, wind velocity and take-off weight.
6. Explain the concept of "decision speed".

Laboratory work 6

ASH-62IR ENGINE START-UP AND TEST

Objectives

– to practice engine preparation for start-up, start, warm-up, test and shutdown.

Theoretical framework

Start-up is the process of setting engine from rest to a minimum idle power by a starter. Idle power (IP) is engine operation mode not affected by foreign impacts. IP thrust constitutes 3 to 5 % of the thrust at maximum mode; IP rotation frequency

– for turbojet engines equals (0.2 ... 0.4) n_{max};

– for turboprop engines equals (0.7 ... 0.85) n_{bal};

– for piston engines (PE) equals 500 ... 600 rpm.

Engine ground start-up preparations:

– remove caps just before start to avoid ingress of foreign objects;

– check wheel chocks availability;

– inspect the parking place, bottom of the nacelle and wing (for fuel leakage);

– check availability and serviceability of ground-based fire extinguishing system in the parking place;

– verify cleanliness of parking place;

– remove unauthorized persons: not closer than 10 m in front and no closer than 50 m behind;

– check the grounding;

– check the ease of rotor rotation (for TJE by rotating with a special wrench; for TPE by rotating the propeller, and for PE by rotating the starter or a special device);

– check propeller blades fittings at the minimum risk angle;

– launch starters alongside;

– arrange ground starters to avoid any collision and damage during AC sudden breakaway;

– establish connection with cabin.

Engine start-up preparations in the cabin:

– check LG retraction valve in the extended and locked position;

– ensure that the wheels are on the parking brake;

– check the amount of fuel through cabin indicators;

– check the movement of engine control levers (throttle) and return them in their extreme position;

– switch on the required automatic circuit breakers (CB);

– turn on power supply switches to the "BOARD" position;

– check the voltage of all energy sources;

– check on-board fire extinguishing system.

Preparation on the start control panel:

– check the temperature limit switch;

– set the GROUND START — FLIGHT START switch in the appropriate position;

– set the START — MOTORING switch in the appropriate position;

– set the engine selection switch in the appropriate position;

– push the START button.

The startup duration is determined by two mutually requirements:

– for quick departure - startup as short as possible;

– for normal engine gas flow duct — maximum startup duration.

Optimal startup per engine takes 1 to 1.5 minutes.

Engine start-up is a complex and vital process and only specially trained and certified technicians and crew members are admitted.

The start-up process includes:

– rotor starter spinning;

– starting fuel supply and ignition;

– main fuel supply;

– rotor starter and turbine spinning;

– recovery from idle power.

The startup rate is the ratio between the available and required power excess created by augmented temperature, therefore the startup is considered off-design and requires strict exhaust gas temperature control T^*_g.

Discontinue startup if there is:
– fire in engine;
– no fuel ignition if required;
– unavailable rotation (hovering);
– gas temperature is steadily kept above normal;
– no oil pressure;
– oil temperature is above normal;
– unavailable fuel pressure;
– premature starter shutdown or vice versa;
– with an electric starter — the voltage drops below normal; with an air starter — air pressure is below normal.

To stop the start-up at the initial stages you need to push the START DISCONTINUE button and then shutoff the fuel valve.

Engine operation test

Objectives: to make sure in serviceable engine operation and its systems. It is performed after the start and warm up before the flight, after required engine maintenance, troubleshooting and adjustments.

It is performed on operational modes according to special program which is determined by the control graph. The graph is built up in certain consequence taking into account systems readiness for check and minimum possible change of engine operation mode. Graphs coordinates are: abscissa axis — engine operating time; ordinate axis: values of engine operation modes.

During the test, all controlled engine operating parameters are compared with design specifications stated in FM and AMM. Stable operating modes for tests are: idle, cruise, nominal and take-off. Moreover, the operation stability is checked along with the transient operation (engine acceleration).

Piston engine (PE) test features:

The piston engines are controlled by two levers (sectors):
– the power lever which changes air-fuel mixture flow through the throttle valve;
– the propeller pitch lever which is used to change propeller blade pitch angle.

But during the test, the blade pitch angle should be minimal and does not change, that is why the PE operation mode at the test is determined by rotational speed and the control graph is drawn in "rotational speed vs operating time" coordinate system.

In the stable operational modes, they test such parameters as:
– rotational speed;
– cylinders head temperature;
– oil pressure and temperature;
– fuel pressure;
– pressure of air-fuel mixture (boosting pressure);
– vibration parameter.

In the transient mode, they test:
– engine acceleration;
– ignition system operation;
– propeller and rotational speed governor compatible work;
– engine operation at equilibrium speeds;
– altitude corrector operation;
– feathering system operation (if available).

Piston engine acceleration check

PEs have high excess of power and lower values of inertia moment of rotor, therefore they have high acceleration — 1.5...2 sec., and while checking it the throttle valve should be opened slightly by the power lever during 1.5...2 sec. Sharp opening causes mixture over-rich, lack of air in the engine and rotational speed decrease.

Piston engine ignition system test.

In order to provide full fuel combustion every PE has two magneto installed providing spark in both spark plugs of every cylinder. The test in 0.9 nominal mode (0.9*N*) provides for shutting down each of two magneto with one operative spark plug; combustion will be insufficient and rotational speed will decrease. If the decrease does not exceed 100 rpm, the operating magneto is serviceable and adjusted correctly. The higher decrease shows incorrect adjustment or unserviceability.

Piston engine cooling and shutdown.

At the rotational speed of more than 800 to 1000 rpm it is necessary for the engine to operate until gas temperature drops to 140...170 °C. At that, cowling flaps should be opened for better cooling. But at the small rotational speed, spark plugs are poorly cleared from carbon deposits, therefore before shutdown, they should be burned through. You should increase rot speed up to 1600...1800 rpm to operate for 5...10 sec, then decrease the rotation again to 800...1000 rpm, turn off fuel supply and when no flash appears in cylinders, open the throttle valve by the power lever (to clean cylinders from combustion products and cool cylinder walls by pure air). Then turn off the ignition, close the throttle and fire shutoff valves.

Lab execution procedures (computer simulation software)

Engine startup (location of indicators and switches, Fig. 6.1):

1. Check ignition turn-off (PM-1 magneto switch No 2 above the left instrument panel is set to "0").
2. If negative temperatures — close cowl flaps. To do this, pull pressure switch No 19 "COWL FLAPS" on the central panel.
3. Close the oil cooler doors. Pull pressure switch No 18 "OIL COOLER DOORS" on the central panel. Control the doors position by the indicator (in front of the throttle lever).
4. Check the installation of carburetor inlet temperature lever 17 (green color). "OFF" position.
5. Check propeller control lever No 20 "PITCH CONTROL LEVER". LOW PITCH POSITION — extremely forward.
6. Check mixture control knob No 22 (leftmost MIXTURE CONTROL KNOB). Extremely pulled and sealed (maximum enriched).
7. Pull shutoff valve No 16.
8. Install a 4-way fuel flow valve in the medium position 'OPENED TANKS" for simultaneous tanks opening
9. Switch on PT-125 transducer circuit breaker No 10.
10. Switch on SBES-1447 fuel gauging circuit breaker No 11.
11. Switch on 3-pointer EMI-ZK circuit breaker No 12.
12. Switch on circuit breaker No 13 for UZP-47 flap position indicator and UPZ-48 oil cooler doors.
13. Switch on TUE-48 temperature circuit breaker.
14. Set PO-500 (115V) transducer switch No 7 ON.
15. Set the START circuit breaker No 20 ON in the upper left control panel.
16. Set magneto 2 switch in the 1 + 2 position.
17. Pull KS-3 button handle No 3 (PN-45M switch in "MOTORING" position) and hold it ON, check the voltmeter 6 arrow, while slowing its movement in the range of 40 ... 80A, set switch 3 in the "CONTACFT FORCE" position (press button KS-3) and hold it ON during the engine start.
18. Control Monitor:
 - electric inertia starter cranking (10 ... 12 sec);
 - TE-45 tachometer readings (engine rotation speed increase ranges 0 to 400 rpm as per tachometer 1);
 - three-pointer EMI-3K (25) gage (P_{oil} ups, P_{fuel} = 0.2 ... 0.25 kg/cm^2);
 - P_{dif} increase according to MV-16U (4) vacuum pressure gauge.
19. After the engine starts, release start button 3 and turn off START-1 circuit breaker No 20.

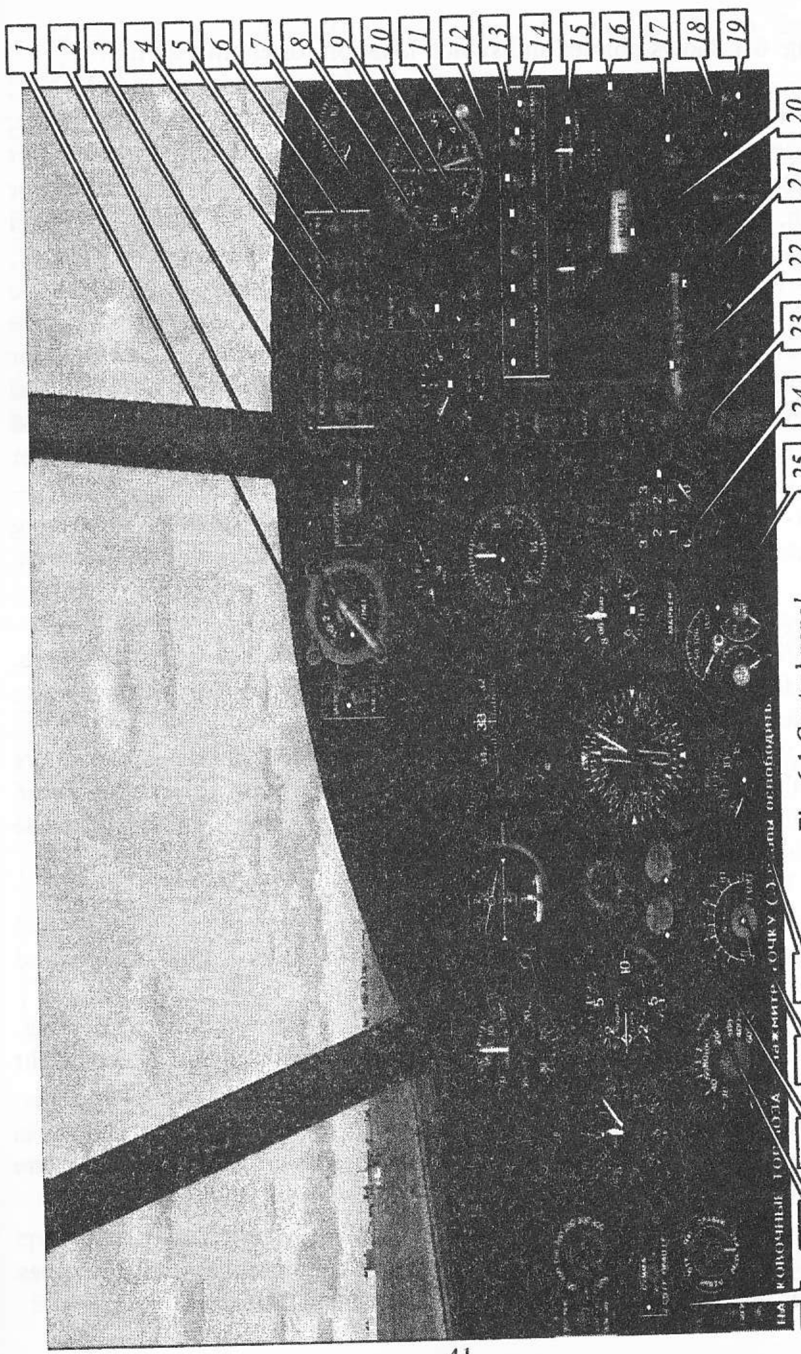


Fig. 6.1 Control panel

Fig. 6.1 shows pointer and switch location for engine startup:

1 — startup circuit breaker-20; *2* — ignition switch (magneto) PN-1; *3* — PN-45 starter switch; *4* — MV-16U vacuum pressure gauge; *5* — generator operation light; *6* — VA-3 generator volt-ampere meter indicator; *7* — PO-500 switch; *8* — generator switch; *9* — accumulator switch; *10* — PT-125 transducer circuit breaker; *11* — SBES-1447 fuel gauging circuit breaker; *12* — 3-pointer EMI-ZK circuit breaker No 12; *13* — UZP-47 and UPZ-48 circuit breaker; *14* — TUE-48 temperature circuit breaker; *15* — UPZ-48 oil cooler door indicator; *16* — engine shutdown lever; *17* — carburetor heating lever; *18* — oil cooler door control; *19* — cowl flap control; *20* — pitch lock lever; *21* — normal gas lever; *22* — mixture control knob; *23* — 2TTsT-47cylinder head temperature gauge *t* °C; *24* — TE-45 tachometer; *25* — three-pointer EMI-3K indicator; *26* — carburetor mixture indicator *t* °C; *27* — SBES-1447 fuel gauge indicator; *28* — 2R critical fuel remaining indicator; *29* — 2L critical fuel remaining indicator; *30* — fuel gauge switch.

Engine warm-up:

1. After the engine start close the cowl flaps and the oil cooler doors, run it for at least 3 minutes at 700 ... 800 rpm (with low pitch) to raise the inlet oil temperature to 20 ... 25 °C.

In warming up the engine close the cowl flaps and oil cooler doors until the cylinder head heats to 120 °C and oil to 50 °C (to avoid scotching burning out the paint open slightly the cowl flaps at the cylinder head temperature of 100 °C).

2. Turn on the generator at 1000 ... 1200 rpm speed.

3. Increase the rotation speed to 1200 rpm (in winter, to 1400 rpm) and run the engine to warm up the cylinder head to at least 100 °C and oil to at least 30 °C.

4. Gradually increase speed to 1600 rpm and continue heating. While warming up check the engine operation both on the left and right tanks switching the 4-way fuel valve for at least 1 min.

Note: If the warming up is at the air temperature of plus 5°C and below, in snow or rain, it is necessary to heat the carburetor and maintain the mixture temperature at 5 °C.

With flashes in the carburetor or uneven engine operation it is necessary to immediately stop it and check the condition of flame tubes (flashes occur during air heating in case of fame tube burn).

In winter, the oil cooler tunnel should be closed by a thermal insulation pad.

5. Engine is considered warmed when the cylinder head temperature reaches at least 150 °C, and oil is heated to at least 60 °C.

Note: When the engine is warned up on the ground, it should not run long at below 700...800 rpm to prevent sparks from fouling and oil from overflowing caused by poor scavenge at low rotation speeds.

The highest temperature for cylinder head temperature is 215 °C and for oil it stands at 75 °C.

In winter, when the cylinder head and oil reach the said temperature, shut down the engine and take the oil cooler pillow off the tunnel. Then start and run up the engine adjusting the cylinder head and oil temperature and opening the related cowl flaps and oil cooler doors.

Engine run-up

The run-up should be scheduled.

1. Switch the engine into the rated power slowly:

$$n = 2100 \text{ rpm}, P_k = (900 \pm 10) \text{ mm Hg}.$$

Fill in table 6.1 with actual instrument readings.

Table 6.1

Rated power instrument readings

Data	Readings	
	Standard	Actual (*to fill in*)
Oil pressure, kgf/cm^2	4...5	
Fuel pressure, kgf/cm^2	0.2...0.25	
Oil temperature, °C	+ 60...75	
Cylinder head temperature, °C	+ 150...215	

Note: The engine has to work steadily and without vibration. To avoid overheating due to insufficient air flow on the ground the rated power run-up should last not more than 15 ... 20 seconds, depending on the ambient and engine temperature.

2. Reduce the engine speed to 2000 rpm and test magneto and spark plug serviceability. Turn off each magneto for 8...10 sec. When switching from one to other magneto, turn on both magnetos for 5...8 sec. to "burn" the spark plugs.

Note: If you switch to one magneto motor must work steadily and without vibration. Falling speed should not exceed 100 rpm.

3. Check propeller and its control mechanism operation. For this set the throttle at 1850...1900 rpm and without changing its position increase the pitch with the decreased rotation to 1450 ... 1500 rpm.

Note: Decreasing the high throttle pitch to a lower level increases engine shaft rotation to the initial rate.

To warm up the engine in winter carry out two or three similar conversions in the propeller hub.

4. Check the propeller speed at equilibrium rotations:

– after replacing the propeller;
– after replacing the R9SM propeller control;
– after Schedule maintenance;
– after replacing (adjusting) the R9SM propeller control units.

5. Check the carburetor heater operation.

Heating air at 1850 rpm decreases air bleeding, gradually reduces rotation by 150 ... 250 rpm, and increases mixture temperature (as per thermometer).

Note: When heating, the mixture temperature should not exceed + 45 °C. If it is above, shut down the engine and check the status of flame tube exhaust manifold.

In "OFF" control lever, the carburetor mixture temperature should be below the ambient temperature by 5 ... 10 °C.

6. Check generator voltage.

a) ON the load;

b) press the voltamperemeter battery button and keep it while changing rotation within 1650...2100 rpm. The voltamperemeter should indicate 28.5 V (for GSN-3000 generator at 60...80 A load);

c) OFF the load.

7. Check engine operation at the take-off mode for at least 5 seconds.

In this mode, the engine low pitch rotation equals 2150...2200 rpm at least 1050 mm Hg air bleed.

Note: For better run-in the take-off mode is applied after the first 10 operation hours.

8. Check engine idle power.

The engine should operate slowly and steadily without vibration, fill in table 6.2 with actual readings.

Table 6.2

Engine idle power readings

Data	Readings	
	Standard	Actual (fill in)
Oil pressure, kgf/cm^2	> 2	
Fuel pressure, kgf/cm^2	> 0.15	
Oil temperature, °C	+ 60	
Engine shaft rotation, rpm	500	

9. Check the engine acceleration slowly 2 ... 4 sec moving the power control lever (PCL) from the minimum speed to the rated power (engine should gain the required rotation speed slowly rather than rough). The check is carried out at a low propeller pitch.

When checking the acceleration, the cylinder head temperature must be at least 150 °C (see table 6.1) at engine speed 1200...1400 rpm.

10. After the run-up check the engine cylinder-piston group operation (check engine against vibration):

a) raise the cylinder head temperature up to 150 °C at the engine speed of 1200...1400 rpm;

b) decrease the engine speed to 750...800 rpm and operate in this mode for 2 min;

c) increase the engine shaft rotation to the rated power for 2...4 sec, by moving the throttle.

Increasing rotation can cause engine vibration. If vibration stops at 1600 rpm and the engine is running slowly, the cylinder-piston group considered serviceable. If vibration continues, shut off the engine and take the required actions.

Engine shutdown.

To avoid board battery discharge before the engine shutdown you should turn off all electrical units, but cabin lighting, navigational lights and engine indicators.

Engine shutdown by the fuel shutoff valve:

1. Fully open the oil cooler doors and turn off carburetor heater.

2. Reduce the engine shaft rotation to 800...900 rpm and maintain it until the cylinder head temperature is reduced to plus 120...140 °C.

3. Push the throttle at "IDLE POWER" to shut down the engine.

4. Increase rotation to 1700 rpm and maintain it for 5...6 sec to "burn out" the spark plugs and pump out the oil from the crankcase.

5. Pull the throttle for FUEL ON at 1100...1200 rpm. Forward the throttle slowly for 3...5 sec with flare out. When the propeller stops, turn off ignition, open the sliding window and report the ground technician about the OFF switch.

If the fire shut off valve can't shut down the engine, turn off its ignition.

Engine shutdown by ignition turnoff:

1. Cool the engine (the same as with the engine shutdown by the fire shutoff valve).

2. Increase engine rotation to 1900 rpm (for 5...10 sec) and then reduce speed to 900 rpm; turn off the ignition and slowly open the throttle fully.

3. When the propeller stops, set the throttle to idle power and close the fuel valve.

Warning: Do not shut down the engine by depleting fuel or closing the 4-way fuel valve (to prevent fire)!

4. After engine run-up and shutdown:

a) close the oil cooler flaps. In winter, close the oil cooler tunnel with a thermal insulation pad;

b) drain fuel sediment from the filter sump;

c) as soon as the cylinder head temperature drops to plus 80 °C, close the cowl flaps; if long aircraft parking is expected, cover the engine with protective covers when the exhaust pipe gets cold;

d) before covering the engine protect flame tube intakes with caps regardless of the season.

On the airplanes with a fixed air filter, leave it turned on or turn it off (close the filter valve) if it is turned off.

e) inspect the power plant for fuel and oil leak.

Processing the results

The report should contain:

– short theoretical data about piston engine start, warm-up, run-up, and shutdown;

– engine operation data during start in various run-up modes;

– comparative analysis of engine standard and actual operational values;

– conclusions on magneto, spark plugs and pitch control mechanism serviceability.

Questions for self-control

1. Define "engine start" and "idle power".
2. Classify engine start stages.
3. Name the main preparatory stages for engine ground and cockpit start.
4. Explain the concept of "aircraft engine operational check".
5. Explain the piston engine start, inspection, cooling and shutdown procedures.
6. Name piston engine start and inspection data.
7. Explain the magneto, spark plugs, (propeller) pitch control mechanism and propeller inspection procedures.
8. Name the piston engine shutdown stages.

Laboratory work 7

AIRCRAFT MAINTENANCE CHECKS QUANTIFICATION. SERVICE LIFE EXTENSION AND SCHEDULED MAINTENANCE EFFICIENCY ESTIMATES (PART 1)

Objectives

– to consolidate lecture course knowledge of aircraft maintenance organization;

– to master the methods for determining the required number of operational and periodical maintenance checks, as well as for estimating aircraft life extension efficiency and scheduled maintenance checks.

Main tasks

1. The analysis of the AC main maintenance types and checks. Their classification, purpose, task and schedule.

2. The solution of a series of tasks.

3. The analysis and summary of the results.

Theoretical framework

AC technical operation is the system of engineering, technical and organizational measures carried out in the process of AC exploitation to ensure:

– high reliability of the AE and its components operation on the ground and in flight;

– AE characteristics maintenance within the assigned service life and time limits;

– the most efficient AC exploitation at rational labor and material costs.

Maintenance is a part of the technical operation and is a complex of work carried out in order to prepare the AC for flights and to ensure their non-failure operation within the assigned service life.

Maintenance includes scheduled checks, troubleshooting, fuel, lubricant, special fluid and gas services, appropriate entries in technical publications.

The civil aviation industry currently points to the scheduled aviation equipment preventive maintenance.

The main documents regulating the scope of work and periodicity of AE maintenance during operation and storage are maintenance schedule manuals for each type of aircraft. They also provide line and periodic maintenance between overhauls.

The main objectives of line maintenance are to eliminate in-flight failures and malfunctions and to prepare AC for the next flight. The line maintenance is carried out before AC departure or after arrival.

Modern AC are subject to A (F–A) and B (F–B) line maintenance checks. Some AC undergoes C (F–C) checks.

A-check is conducted:

– after every AC landing if there is no need for more complicated maintenance;

– before departure and after periodic M;

– before departure if the AC parking after any check exceeds the specified calendar period.

B-check is made at a base airport after a calendar operation period (7…10 days) if a periodic maintenance is not required.

C-check is made before AC departure if the scheduled flight has been cancelled and the turnaround time is over the specified.

The line maintenance provides for AC meeting, inspecting, servicing, parking and departing. The AC is parked when it is subject to maintenance at an aviation enterprise.

Periodic M is conducted at a base airport after the assigned flight hours performed. It is to identify and eliminate AE malfunctions and failures, take preventive measures to prevent them. The periodic M is more time and labor consuming than the line maintenance.

The periodic M check for modern gas turbine engine-driven AC depends on flight hours performed:

– Check 1 (F–1) – after every 300 $\pm$50 h;

– Check 2 (F–2) – after every 900 $\pm$150 h;

– Check 3 (F–3) – after every 1800 $\pm$300 h.

For special operation conditions, periodicity is set by a calendar period or landings.

Each subsequent periodic M includes all previous checks plus additional ones. Consequently, the complexity and duration of work increase.

The periodic maintenance covers preparatory, basic, inspection, maintenance and work completion procedures.

Except periodical and line maintenance, there are other types of M.

Required M checks estimation.

Basic data:

– list of line and periodic M for the given type of AC (A, B, C, 1, 2, 3, etc.);

– M schedule τ_f and TBO period T_{life};

– average non-stop flight endurance $T_{n/s}$;

– total flight hours T of all types of aircraft for given time period.

To calculate the number of maintenance checks you should first quantify overhauls p_{oh}:

$$p_{oh} = T/T_{life}.$$

Then quantify periodic maintenance checks starting from the most labor-intensive with the highest values of periodicity:

$$p_{f\text{-}3} = (T_{life}/\tau_{f\text{-}3}) - p_{oh};$$

$$p_{f\text{-}2} = (T_{life}. /\tau_{f\text{-}2}) - p_{oh} - p_{f\text{-}3};$$

$$p_{f\text{-}1} = (T_{life}/\tau_{f\text{-}1}) - p_{ov} - p_{f\text{-}2} - p_{f\text{-}3}.$$

The number of B-check line maintenance is estimated by:

$$p_{f\text{-B}} = (P{\cdot}K/\tau_{f\text{-B}}) - (p_{oh} - p_{f\text{-}1} - p_{f\text{-}2} - p_{f\text{-}3}),$$

where K — number of aircraft; P — period under consideration in days.

A-check maintenances are calculated by:

$$P_{f\text{-A}} = (T/T_{n/s}){\cdot}K_{f\text{-A}} - p_{f\text{-B}}, \quad (7.1)$$

where $K_{f\text{-A}}$ — coefficient of repeated A-checks after long AC turnaround or B-checks if scheduled:

$$K_{f\text{-A}} = 1.02…1.05.$$

Equation (7.1) does not consider periodic maintenance checks as A-checks are done after any periodic M.

The following tasks with explanations help master students' calculation skills.

Task 1

Estimate the number of line and periodic maintenance checks on the aircraft (K = 1) with the served TBO T_{life} = 9000 flight hours. Use the following basic data:

– average non-stop flight endurance $T_{n\,s}$ is 2 hours;

– periodic maintenance checks F–1, F–2, F–3 are done after 300, 900 and 1800 flight hours ($\tau_{f\text{-}1} = 300$; $\tau_{f\text{-}2} = 300$; $\tau_{f\text{-}3} = 300$);

– annual flight time T_y for typical AC is 2250 hours;

– B-check is done every 10 calendar days.

Task 2

Determine how the value of the specific line maintenance and overhaul period K_t will change amid the altered TBO and scheduled maintenance period.

Basic data:

– annual flight time for typical AC is 1500 hours;

– average non-stop flight endurance $T_{n\,s}$ – 2 hours;

– number of engines on the AC n_{eng} – 3;

– engine ground run vs in-flight operation (including taxing, start-up, run-up and adjustment) is 5 %;

– coefficient of early engine replacement K_{adv} = 0.2 (including engine replacement caused by failure and before TBO expiration).

The TBO and scheduled maintenance value change in accordance with table 7.1.

Table 7.1

TBO and scheduled maintenance change

Types of maintenance	Scheduled maintenance and duration			
	Before changing TBO and scheduled maintenance («Was»)		After changing… («Become»)	
	Time limits, flight hours	Calendar downtime, days	Time limits, flight hours	Calendar downtime, days
Line:				
F–A	–	$T_{f\text{-A}} = 1.5$	–	$T_{f\text{-A}} = 1.5$
F–B	–	$T_{f\text{-B}} = 6.0$	–	$T_{f\text{-B}} = 6.0$
Periodic:				
F–1	$\tau_{f\text{-}1} = 200$	$T_{f\text{-}1} = 34.0$	$\tau_{f\text{-}1} = 300$	$T_{f\text{-}1} = 35.0$
F–2	$\tau_{f\text{-}2} = 600$	$T_{f\text{-}2} = 60.0$	$\tau_{f\text{-}2} = 900$	$T_{f\text{-}2} = 63.0$
F–3	$\tau_{f\text{-}3} = 1200$	$T_{f\text{-}3} = 86.0$	$\tau_{f\text{-}3} = 1800$	$T_{f\text{-}3} = 90.0$

Table 7.1. End

Types of maintenance	Scheduled maintenance and duration			
	Before changing TBO and scheduled maintenance («Was»)		After changing… («Become»)	
	Time limits, flight hours	Calendar downtime, days	Time limits, flight hours	Calendar downtime, days
Engine replacement	$T_{e\,life} = 800$	$T_{rep.} = 10.0$	$T_{e\,life} = 1000$	$T_{rep} = 10.0$
Aircraft major overhaul	$T_{life} = 6000$	$T_{oh} = 24$ days	$T_{life} = 9000$	$T_{oh} = 24$ days

Additional instructions.

Specific line maintenance period is determined by the equation:

$$K_t = (T_{line}+T_p+T_{oh})/T_{life} + T_{rep}\cdot\eta/T_{e\,life}\,(1 - K_{adv}),$$

where T_{line}, T_p — the total time for all line and periodic maintenance checks within the AC TBO T_{life}; T_{life}, T_{oh} — scheduled TBO and average AC maintenance period, h; T_{rep} — average engine replacement period, h; $T_{e\,life}$ — engine TBO, h; $K_{adv.}$ — coefficient of early engine replacement; η — coefficient of engine replacements beyond the scheduled checks.

The problem solution is based on estimating the number of all types of maintenance, including engine replacement, TBO and scheduled maintenance changes beforehand and afterwards. The number of aircraft engine replacements within TBO can be calculated by:

$$P_{e\,repl} = T_{life}\cdot p_{eng}\cdot 1.05/\,T_{e\,life}\,(1 - K_{adv}).$$

The conventional value K_{adv} is supposed to equal 20 % of the total engine replacements. The calculation results are summarized in table 7.2.

Table7.2

Calculation results

Types of maintenance	Number of maintenance checks		Maintenance check period	Total for one maintenance check or overhaul	
	Before	After		Before	After
Line:					
F–A					
F–B					
Periodic:					
F–1					
Etc.					
η					
Total maintenance checks and overhaul period					
Specific line maintenance and repair K_t period					

Laboratory work 7

DETERMINATION OF THE REQUIRED AIRCRAFT MAINTENANCE CHECKS NUMBER. ESTIMATION OF SERVICE LIFE EXTENSION AND SCHEDULED MAINTENANCE EFFICIENCY (PART 2)

Task 3

Quantify engine replacements on all such type aircraft at an aviation enterprise per year relying on the following data:

– number of AC on 01.01 — 20;

– retired 01.04 — 2;

– received 01.07 — 4;

– scheduled AC flying time per year — 2000 hours;

– aircraft engine quantity — 3;

– engine TBO — 1500 h;

– engine ground run vs in-flight operation (including taxing, start-up, run-up and adjustment) is 5 %;

– coefficient of early engine replacement $K_{adv} = 0.2$

Problem-solving procedure.

1. Estimate the average number of AC in the division per year p_{ac} by dividing the total operational fleet (including initial number of AC, after disposal of two AC and after receiving four AC) into the total calendar period of review (in months):

$p_{ac} = (20\cdot4 \text{ months} + (20–2)\cdot2 \text{ months} + (20–2+4)\cdot6 \text{ months})/12 \text{ months}.$

2. Calculate the total flight time $T_{y\Sigma}$ of all such type AC in the division per year:

$$T_{y\Sigma} = T_y \cdot p_{aC}. \quad (7.2)$$

3. Quantify engine replacements on all such type AC in the division per year by equation (7.2) substituting $T_{y\Sigma}$.with T_{life}.

Task 4

Calculate cost-efficiency for extended aircraft engine TBO and assigned service life relying on the following data (conditional):

1. Assigned life extension from 8000 to 1000 h.
2. TBO extension from 2000 to 2500 h.
3. Overhaul cost — USD 9,000.
4. Engine replacement cost — USD 3,000.
5. Scheduled AC flying time — 1600 h.
6. Airline's aircraft fleet: on 01.01 — 24;
   – received in operation 01.04 — 6;

   – retired from operation 01.05 — 2.
7. Aircraft engine quantity — 2.
8. Initial aircraft engine price — USD 9.000.
9. Engine salvage value – USD 600
10. The prime cost per 1 ton/km — USD 0.25.
11. Depreciation cost per 1 ton/km — 18 %.
12. Average flight efficiency — 200 ton-km/h.
13. Engine ground run *vs* in-flight operation — 5 %.

Note: Cost-efficiency contains new engine purchase cost reduction; engine repair and replacement cost reduction; depreciations rate alteration; price change per 1 ton/km and surplus in this regard.

Problem-solving procedure:

1. Calculate annual flight time for all aircraft.
2. Determine the demand for an aircraft engine (served life) based on the expired and new life.
3. Calculate cost-efficiency by reducing the demand for aircraft engines at their fixed purchase price.
4. Calculate the number of overhauls as per the expired and newly assigned TBO.
5. Calculate cost-efficiency due to the reduced number of engine overhauls.
6. Quantify engine replacements as per the expired and newly assigned TBO.
7. Calculate cost-efficiency due to the reduced number of overhauls.
8. Summarize cost-efficiency by decreasing the demand for new engines, overhauls and engine replacements.
9. Rate depreciation alterations per 1 hour of engine run, in USD.
10. Calculate airline fleet depreciation cost efficiency per flight hours a year.
11. Calculate airline's cost reduction per 1 ton/km and annual savings.

Additional instructions

Depreciation refers to the monetary compensation of fixed assets wear (engine herein) caused by gradual transfer of assets cost to newly created products.

Depreciation costs should cover all primary costs on assets generation (acquisition), as well as all expenses on their partial recovery and modernization.

Depreciation costs are rated as percentage of the initial price or unit elapsed time (e.g. 1 hour of operation).

The depreciation rate $N_{el\,t}$ (CU) per aircraft engine operating hour can be expressed in the equation:

$$N_{el\,t} = (C_p + C_{oh} + C_m + C_o)/T_{dep},$$

where C_p — prime engine cost, conventional unit; COH — general cost of overhauls during the assigned depreciation service life; C_m — modernization cost; C_o — engine retire cost; T_{dep} — assigned service life, hours.

Processing the results

The report should contain:

– theory overview;

– required maintenance check quantification for all 4 tasks;

– basic estimation data for 4 tasks;

– calculation results;

– conclusions.

Questions for self-control

1. Name and describe AC line and periodic maintenance checks.
2. Explain the line and periodic maintenance check estimation equations.
3. Explain the prime cost per ton/km and depreciation cost per 1-hour aircraft engine operation.
4. Describe the aircraft engine replacement quantification.
5. Explain the effect of TBO and periodic maintenance value change on the specific line maintenance and overhaul period.
6. Explain the effect of extended assigned and TBO lives on all types of cost-efficiency.

Laboratory work 8

AIRCRAFT SYSTEMS LOADING WITH FUEL AND LUBRICANTS (ILLUSTRATED BY IL-76)

Objectives

– to consolidate knowledge of aircraft fuel and oil systems structure, fuel, oil and tanker services;

– to practice aircraft fuel and oil loading skills.

Main tasks

1. To provide over-the-wing refueling and pressure refueling.
2. To provide tank sump drains.
3. To provide oil servicing.
4. To drain oil from the oil system.
5. To make advisory notes on fuel and oil capability for sustained operation.

Theoretical framework

The aircraft fuel system must ensure:

– fire safety during aircraft fuelling;

– maintainability and reparability;

– proper fuel filtering;

– sustained engine fuel supply at all operational modes and flight altitudes;

– smooth transition from one type of fuel to another without any system adjustments;

– sustained; engine fuel supply at in-flight overloads;

– automatic fuel supply at all possible types of tanks fuelling;

– independent transfer and boost pump start and stop in over-the-wing refueling;

– required pressure and fuel flow for in-flight engine start;

– ground, pre-flight and in-flight system serviceability inspection;

– convenient and rapid AC ground refueling.

Brief description of the IL-76 fuel system.

The fuel system consists of tanks, engine fuel supply subsystems, auxiliary power unit (APU), fuel transfer and drain systems, fuel line, metering and monitoring devices.

The fuel system is designed to supply fuel to the aircraft engines, APU and inert gas generator. Fuel is stored in 12 integral tanks (Fig. 8.1) located along the wing span between the front and rear spars.

All tanks form four isolated groups (according to the number of engines), three tanks in the group. Each group consists of:

– the main (M) tank;

– the additional (A) tank;

– the reserve (R) tank.

The fuel tanks are rigged with the drain system both for the LH and RH wing tanks. Each half wing has two drains: primary and secondary.

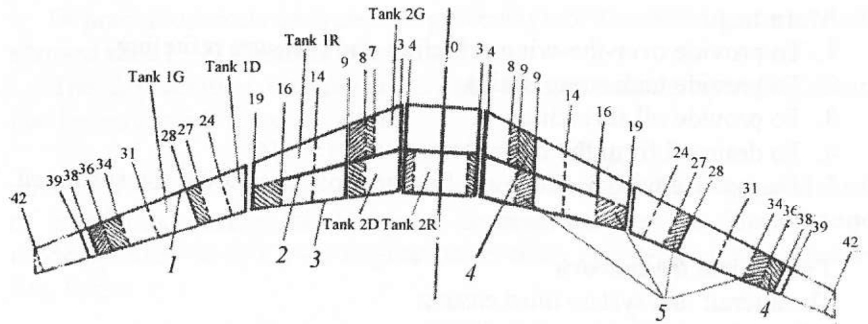


Fig. 8.1. Schematic diagram of fuel tanks:
1, 2, 3 — spars; *4* — accumulator tank; *5* — reservoir tank

At the wing tips, there is a drain tank for fuel collection from the drain pipe. The fuel accumulated in the drain tanks automatically transfers to the engine reserve tanks № 3 and № 4 by centrifugal pumps.

Fuel consumption procedure.

Fuel is fed to the main fuel tank reservoir from the reserve tank, auxiliary and main fuel reservoirs.

All tanks have accumulators with two transfer pumps. The main fuel accumulator tanks have one transfer pump.

The main fuel tank is rigged with two booster pumps.

The recuperator fitted in a pump prevents negative overloads.

The other pump is covered with the protective screen against emergency slowdown during landing.

To prevent the pressure increase in the reservoir tank two safety valves are installed on its walls ($\Delta P = 0.45$ kgf/cm^2).

The reservoirs are always filled with fuel and under transfer pump pressure ($\Delta P = 0.07$ kgf/cm^2) at the take-off fuel consumption of the engines or $\Delta P = 0.45$ kgf/cm^2 if fuel is not consumed.

The boost pumps supply fuel to the engines through the special pipelines connected by the cross-feed valves.

Consumption sequence is provided through special sensor signals of the fuel gauge located in tanks.

Lab execution procedure

Before the AC refueling you should make sure that:

– the aircraft and tanker are grounded;

– the main landing gear and tanker wheels are chocked;

– safety bar is installed at frame 67;

– fuel tanks drainage system caps are removed;

– fuel sediment is drained from the tanks;

– avionics maintenance and battery replacement are completed.

The fuel truck should be at least three-meter off the aircraft to allow AC maneuvering.

The fuel truck is inspected for:

– serviceable filtering, locking, feeding devices and grounding;

– filler, filter and connection unit seals;

– fuel certificate signed by the person responsible for fueling;

– fuel sediment (drained from the fuel truck and is checked for the presence of water, ice crystals and metal particles.

Fire extinguishers should be on hand.

Fuel quantity depends on a flight mission to be performed.

Fuel pressure feed is provided through two standard refueling connectors in the main landing gear door fairing. Refueling is controlled from the panel located close to the connectors. Over-the-wing fueling requires fuel tank filler necks.

After 5 minutes after refueling (for fuel sediment) the condensate is drained into a container for a test sample. Fuel purity is examined either visually or by using special devices, e.g. syringe to filter the fuel through the special filter paper.

Compare the obtained stain with the reference and find out fuel contamination and water saturation level. For visual check of fuel purity the object is shaken by circular motion in the result of which part of water and dirt appears in the bottom center of the cone (funnel).

Fuel tank drain valves serve for fuel drainage. Some tanks have the drain valves on the engines.

Actions against spilled fuel.

Large fuel spill requires the following safety measures to be taken:

– to immediately terminate any refueling;

– to warn crew members;

– to de-energize all ground power units, other engines or electric motors in the refueling zone (avoid further starts);

– to warn line maintenance personnel to leave the refueling zone;

– to alert airport fire brigade;

– to inform aerodrome executives;

– to tow the AC to a safer place, if required.

Oil system

The oil system is designated to store oil for main engines and APU operation, to lubricate and cool their parts, to scavenge and cool oil. The engine has its own autonomous oil system.

To lubricate engines mineral oil MK-8 (or MK-8P) and synthetic oil VNII-1-4F is used(mixture of mineral and synthetic one is not allowed).

Operating pressure in the discharge line is 4…5 kgf/cm^2. Engine oil system capacity is 35^{-1} liters. Oil tank capacity is 25 liters.

Oil refilling and draining

There are two types of oil refilling: gravity and pressure (through the de-energized refilling connector).

Minimum oil quantity in the engine tanks:

– before flight (and for ground engine run) — 6 l;

– before next APU start — 8 l.

Oil is drained for oil and fuel systems preservation, oil unit replacement, oil grade change and if the available oil does not meet the set requirements.

Oil is drained by the hose through the engine drain valve (de-energized). Close the valve after draining.

Processing the results

The report must contain:

– work objectives;

– brief description of oil and fuel systems;

– lab execution procedure;

– conclusions on fuel and oil systems serviceability.

Questions for self-control

1. Name the main fuel system requirements.
2. Explain the fuel system structure.
3. Tell about the over-the-wing and pressure fueling.
4. Name the main fueling safety measures.
5. Tell about fuel tank drain.
6. Briefly describe fuel purity testing.

Laboratory work 9

INVESTIGATION OF DISASSEMBLY, ASSEMBLY AND CHECKS EFFICIENCY IN AIRCRAFT UNIT REPLACEMENT (ILLUSTRATED BY AIRCRAFT PROPELLER REPLACEMENT)

Objectives

– to consolidate theoretical knowledge of AC unit replacement maintainability;

– to practice assembly, disassembly and defective inspection skills in AC unit replacement.

Main tasks

1. To assemble/disassemble AC propeller.
2. To conduct AC propeller defect inspection.
3. To calculate specified maintainability indices.
4. To make conclusions on AC propeller serviceability for further operation.

Theoretical framework

AC components are replaced because of:

– the elapsed service life;

– the non-repairable defects;

– the replacement of serviceable units from non-operated AC to the operated one.

The AC unit replacement process is one of the most labor intensive and durable in AC maintenance. It depends on how the AC units are adapt to maintenance, i.e. on their maintainability.

Maintainability is featured in:

– availability;

– ease of removal;

– interchangeability;

– controllability;

– ground maintenance means continuity, etc.

Unit replacement includes:

– assembling/disassembling;

– testing;

– adjusting;

– cleaning;

– preserving and de-preserving.

Testing is one of the most responsible operations in AC unit replacement because equipment reliability and hence, flight safety strongly rely on its accuracy.

Laboratory work is performed on the AV-72 propeller.

An AC propeller is designed to produce thrust as reaction of airstream thrown by the propeller.

The AC propeller contains a kit of propeller blades, hub, cylindrical group (cylinder, piston group, oil pipelines and other protective equipment). In-service propellers require thorough inspection due to their design complexity and stresses.

One of the most often propeller damages in operation are blades mechanical damages (dents, nicks, scratches) generally caused by foreign object ingestion into the prop plane from the taxiways, runways and AC parking places. Any mechanical damage of the blades is dangerous stress concentrator (centrifugal force of propeller blade for some types reach 50 tons of force and even more), that is why during the inspections it is necessary to inspect them carefully.

Also, the most usual propeller operational failures and damages are:

– imbalanced blades;

– feathered and unfettered blades;

– oil leakage from the propeller hub cowling;

– failed anti-icing system.

There are allowable and inadmissible propeller unit damages.

The allowable propeller blade damages (Fig. 9.1) (with further troubleshooting during maintenance):

– up to 12-mm misshape (bending) as a result of a collision with foreign object;

– 5 to 9 mm leading edge dents at 100 mm from one another between the blade airfoil portion and the electro-thermal strip;

– up to 8 mm trailing edge dents found at 100 mm from the leading edge dents;

– up to 10 mm blade airfoil portion dents and nicks;

– up to 0.4 mm lateral dents and minor scratches between the blade section and shank;

– up to 0.6 mm lateral dents and minor scratches between the blade section and shank;

– perimeter-wise corroded protection strip close to the *m*-visual corrosion of any type. Blade corrosion can cover not more than 5 cm^2 in 10 areas each located not as close as 60 mm one from another.

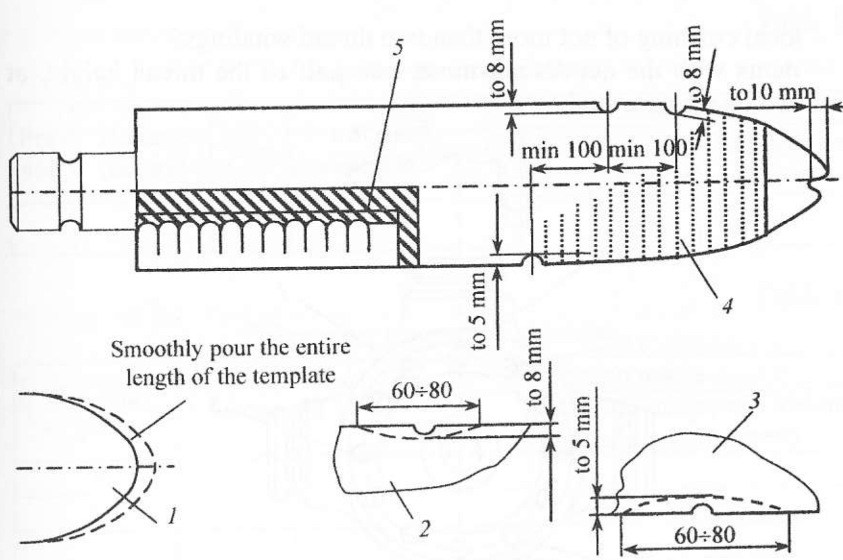


Fig. 9.1. In-service AV-72 propeller blade dent elimination tolerance:
1 — blade tip; *2* — trailing edge; *3* — leading edge;
4 — possible pitting corrosion area; *5* — possible slot corrosion under the electro-thermal strip and fiberglas cuff (seal)

Corrosion signs are:

– isolated grey pitted surface;

– paint swelling and blistering on the blade surface;

– numerous light and dark grey traces of corrosion or paint swelling along the electro-thermal strip.

The AC propeller is considered serviceable with:

– aged thermal strip rubber grid;

– damaged protective cover plate if it is not perforated and does not break insulation resistance;

– at least 5 unglued thermal strip lugs on every side.

The propeller become unserviceable with

– cracks, regardless of their size and location;

– burnouts, mechanical punctures in protection strips; outing area;

– protection strip rubber swelling, cracking or co lour staining.

The AC propeller can be replaced either in scheduled maintenance and if any non-permitted defects or damages are found.

Allowable stud mechanical damages (Fig. 9.2):

– thread strip page;

– local crushing of not more than two thread windings;

– dents with the depths not more than half of the thread height, at least two on a single stud.

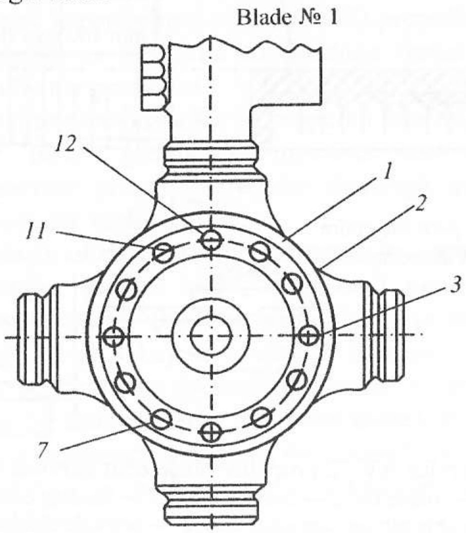


Fig. 9.2. Propeller studs scheme

Lab execution procedure

1. Prepare for propeller disassembly.
2. Disassemble he propeller.
3. Remove the propeller and place it on the pedestal.
4. Check the propeller condition and make entries in table 9.1.
5. Prepare the propeller for assembly.
6. Install propeller in the aircraft.
7. Use the torque wrench and fix the propeller to the gearbox shaft (table 9.2) as follows:

– MI 789 wrench with MI 799 adapter ....130–150 N;

– 24-9020-500 wrench with 24-9020-915 adapter....94–108 N;

– 24-9020-500 wrench with 24-9020-917 adapter....88–101 N.

8. Finish the work and clear the workplace.
9. Add assembly labour intensity data in table 9.3.
10. Make necessary notes, calculations and conclusions on placing propeller in service.

Table 9.1

Propeller blade checklist

Pro-unit	Damage (failure)	Size	Note		Conclusion		
			Acceptable	Unacceptable	Serviceable	Eliminate during M	Replacement (discard)

Table 9.2

Propeller torque nut checklist

Pro stud p/n	Torque nut	Inspection results	
		standard	Nut tightening (with locking plate replacement)
1			
2			
...			
...			
12			

Table 9.3

Propeller assembly-disassembly labour intensity

Kind of work	Work description	Tool, equipment	Labour intensity (min)	Notes
Availability coefficient K_{av} calculation				
Preparatory				
Basic (disassembly)				
Basic (assembly)				
Final				
Ease removal coefficient K_{ease} calculation				
Basic				

While performing the work, calculate maintainability using the labour input values of a single technological process, i.e.

– availability coefficient (K_{av}):

$$K_{av} = 1 - \frac{T_{add}}{T_{main} + T_{add}};$$

where T_{main} — propeller assemble/disassembly main operation labour intensity, manpower/h; T_{add} — additional work labour intensity (preparatory and final), manpower/h.

– ease removal coefficient (K_{ease}):

$$K_{ease} = 1 - \frac{\Delta T_{basic}}{T_{inso}},$$

where ΔT_{basic} — assembly-disassembly labour intensity deviation from the basic index, manpower/h.

The basic index is considered an ease removal index of the product, taken as standard one.

In the laboratory work we assume ΔT_{basic}= (0.5...0.75) manpower/h; T_{inse} — assembly-disassembly labour intensity as well as failure inspection, adjustment and rectification, manpower/h.

Processing the results

The report should contain:

– table 9.1 with propeller blade condition check data;

– table 9.2 with propeller torque nut tightening data;

– table 9.3 with propeller assembly/disassembly labour intensity data;

– investigation outcomes.

Questions for self-control

1. Briefly describe maintainability indices.
2. Name typical AC component and unit replacement processes.
3. Name typical propeller failures and damages.
4. Explain the propeller disassembly and assembly procedure.
5. Explain maintainability index calculations (availability and ease removal coefficients).

Laboratory work 10

AIRCRAFT AND ITS ENGINE DETAILS AND UNITS PHYSICAL NON-DESTRUCTIVE TESTING METHODS IN THE OPERATING CONDITIONS

Objective

– to learn physical non-destructive testing methods and their use in operating conditions;

– to learn aircraft and its engine parts and components subject to NDT;

– practice NDT skills.

Theoretical framework

Testing (technical testing) is an evaluation of an object condition correspondance to the accepted technical requirements.

Physical non-destructive testing is based on physical properties of details condition. Among the instrumental non-destructive testing there are the following:

– magnetic particle;

– liquid penetrant;

– eddy-current;

– ultrasonic;

– radiographic (*x*-ray, gamma ray testing), and others (acoustic emission, optical microscopy, electrical impedance, infrared and thermal testing, etc.).

Before the application of any testing method, the aircraft and its engine details and units must be subjected to the visual inspection, visual inspection with lens, the cranked flaw detector of type — PDK-60, periscope or microscope (depending on detail sizes and location, type and size of possible defects).

Safety precautions

– be careful with the devices, avoid their hits, jilting, fallings down and prevent against excess humidity;

– do not use devices with inadequate electrical insulation;

– power cords must be laied on in the way not to be damaged or interfere movement;

– give special attention to the feeler gages and protect them against the damages.

Lab execution procedure

– to familiarize with physical methods of control, equipment and tools used during in-service maintenance;

– to familiarize with specific malfunctions of aircraft structure and engines on disassembled units and parts;

– to use various NDT equipment and inspect technical condition of units. In doing so, a student should determine the nature and cause of the defect, and suggest a repair method;

– to record inspection results in the fault detection data sheet;

– to make a lab report.

Magnetic particle NDT

Magnetic particle testing is used to inspect ferromagnetic materials only.

where T_{main} — propeller assemble/disassembly main operation labour intensity, manpower/h; T_{add} — additional work labour intensity (preparatory and final), manpower/h.

– ease removal coefficient (K_{ease}):

$$K_{ease} = 1 - \frac{\Delta T_{basic}}{T_{inso}},$$

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– to record inspection results in the fault detection data sheet;

– to make a lab report.

Magnetic particle NDT

Magnetic particle testing is used to inspect ferromagnetic materials only.

It detects surface defects, cracks up to 0.001 mm wide, as well as surface defects up to 1 mm deep.

Magnetic particle testing is based on the property of magnetic flux lines to deform in the areas of metal permeability change.

The magnetic flux lines are not deformed in the monolithic metal areas with constant magnetic permeability. The magnetic permeability is low near or on the surfaces of defects, cracks and faulty fusion thatcauses magnetic flux linedeformation. Some extend beyond the unit boundaries and create a non-homogeneous field over the defect.

The magnetic dispersion field is indicated by 10 x-power magnifier with the help of ferromagnetic liquid (1:1 mixture of transformer oil and kerosene or pure kerosene with magnetic particles, dark or light, to provide enough contrast with the inspection area).

The magnetic particle testing is applied to the aircraft nose landing gear wheel axles, landing gear lock strut bolts, etc.

The testing procedure (with 77 PMD-3M flaw detector) provides for:

– cleaning the inspection area from dust, deposits, corrosion and paint if its thickness is morethan 0.2...0.3 mm;

– magnetizing the parts for inspection (as per flaw detector manual) by connecting the flaw detector to 24 V dc power supply and turning on ELECTROMAGNATIC and MAGNETIZATIONswitches.

An electromagnet must be turned on during the inspection time (controlled magnetic field). Small-sized parts are magnetized by permanent magnetsapplying magnetic fluid onto the inspection area or dipping them into a bath (magnetic fluid must be intensively mixed before application).

Cracks are detected with ferromagnetic partciles.

The inspected parts must be demagnetized with demagnetization test.

Liquid penetrant method:

Dye penetrate crack detection is based on the dye penetrant property to wet metals and penetrate into surface defects, and special white dye property to absorb the penetrant and detect the defect on the dyed surface.

This method is used to inspect all types of materials and find surface cracks directly on an aircraft.

The liquid penetrant testing is used for landing gear strut crack detection, engine support inspection, etc. if no other advanced methods are available.

The inspection tools required:

A. K-type red liquid penetrants (dyes) and M-type white developers;

B. Four TSAN sprays:

– spray No 1 — blue cleaner;

– spray No 2 — dark red indicator fluid;

– spray No 3 — orange paint remover;

– spray No 4 — purple penetrant developer.

Inspection steps:

A. Applying K- and M-type dyes:

– remove paint and degrease the inspection area with acetone (it is not advisable to use kerosene as it easily spreads into the cracks and prevents major penetrants to pass through);

– apply 2–3 layers of red dye penetrant "K" to the inspection area by a hair brush within 3–5 minutes not less than 30 minutes after degreasing;

– remove the red paint with the 30-percent kerosine and 70-percent transformer oil wetted cloth before the last layer is dried. Then wipe the surface with dry and clean cotton or gause cloth within a minute;

– spray or use squirrel-hair brush to cover the surfuse with thin and even layer of "M" dye not later than 3 minutes after removing of oil-kerosene mixture remains;

– inspect the painted area in an hour;

– remove developer with an acetone-wetted cloth.

Any red line, zig zag scratch, stain or spot against white paint indicate defects on the inspection area.

Note: 1. Check paint quality on the sample before the inspection.
2. Perform work at the temperature not less than +5 °C.

B. TSAN-based inspection:

– apply a cleaning agent from spray No 1 (blue colour) onto the inspection area to remove oil-based mud.

Remove the excess agent with a dry and clean cloth:

– apply a penetrant layer from spray No 2 (dark red colour) to cover the surface defect before the upper layer is dried;

– apply the cleaning agent from spray No 3 (orange colour) over the penetrant to remove the excess.

Clean rather than sop up the surface with a dry and clean cloth (not shaggy). Clean until red penetrant remannts appear on the surface:

– apply a developer layer from spray No 4 (purple colour) until you see a contrast image on the defective area.

Any red line, zig zag scratch, stain or spot against the dried developer indicate defects on the inspection area.

Note: 1. Perform work at the temperature ranging 15 to 40 °C.

2. Consumption rate: one spray is applicable for 0.12 m^2 of the inspection area.

Eddy current testing method

The purpose of an eddy current flaw detector during maintenance is to detect surface defects (cracks, pits) in aircraft parts and components made of non-magnetic, ferromagnetic, heat-resistant, titan materials and alloys. For defect detection they use a high-frequency AC electromagnetic coil as a sensor (transducer). When a current passes through the coil eddy currents are induced. Moving the transducer along the metal surface towards the defect changes an interval between impulses, and the altered acoustic signal frequency indicates transducer proximity to the defect.

In the laboratory work we use TVD flaw detector of Pencil- and G-shape type with identical electrical characteristics for aircraft front wheel flanges, gas turbine blades, piston engine cylinder head control.

This method is applicable for material discontinuity flaws under the paint thickness 0.2 – 0.3 mm.

Before testing adjust the transducer as per the reference sample:

On the instrument panel, choose one of three "CHECK" switch buttons for specific types of materials, namely:

– button "M" for ferromagnetic materials;

– button "N" for non-magnetic materials;

– button "T" for titanium heat-resistant alloys.

Turn the "ADJUSTMENT" handle slowly and tune the transducer as per the refencence flaw to check its proper operation at:

– rapid microammeter pointer deviation rightwards;

– light indication;

– low frequency (~ 400 Hz) high speaker signals.

After tuning the flaw detectorthe transducer is moved along, but not lifted off, the material surface for defect finding.

The found defects are checked against activated indicators.

Ultrasonic testing

Ultrasonic testing is used to find internal defects, their location and identify inspection area thickness at one-side access.

This method is based on the property of ultrasonic vibrations to spread in the form of directed beams (radiations) and fully reflect at the boundary of two materials having difference acoustic impedance.

The flaw detector can be used soon after turning it on. Its run time is unlimited. It is tuned as per the given reference defect.

The required sensitivity is set as per the reference sample.

A grease layer is applied to the reference surface. Move the flaw detector probe over the reference surface to get the maximal signal from near- and far-surfaces of artificial defects.

Recommendations for flaw detector use:

– as a receiving electro-acoustic transducer is highly sensitive to mechanic influences protect the ultrasonic probe and electronic device from hitting, falling and strong vibrations;

– when moving the flaw detector probe to the other inspection area,release the pushbutton and keep the probe off the inspection area. Do not move the pressed probe over the surface;

– when operating at rapid ambient temperature change (e.g. item moverment from outdoors to a warm premise in winter) keep the item in the closed case during 0.5–2 hours before its use. If immediate procedure is required, time delay can be reduced. Temperature and humidity jumps lead to item service life reduction;

– avoiding ultrasonic gauge falls attach a lanyard to the gauge handle and put it on the wrist.

Processing the results

The report should include:

1. Short description of non-destructive testing methodsused.
2. Compile a defect list.
3. The list of inspected items with drawings and work description.
4. Conclusions concerning performed work.

Questions for self-check

1. What are the principles of non-destructive testing methods?
2. Name the aircraft parts subject to NDT.
3. Explain each NDT procedure.

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(Англійською мовою)

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РУГАЙН Олександр Володимирович
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