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AIRCRAFT
МиГ-25П

FLIGHT AND COMBAT EMPLOYMENT TRAINING MANUAL

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PAGES 444

The book contains 444 numbered pages and 4 insets:

Inset 1, between pages 2 and 3;
Inset 2, between pages 36 and 37;
Inset 3, between pages 36 and 37;
Inset 4, between pages 320 and 321.

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I N T R O D U C T I O N

The present Manual is intended for the flying personnel of the aviation units equipped with the МиГ-25П aircraft.

The main purpose of the Manual is to aid the flying personnel in mastering the МиГ-25П aircraft.

The present Manual covers recommendations for the command personnel on organization and realization of the training procedure, accomplishment of separate flight elements. The book deals with the methods and techniques used for training. The Manual sets forth the major problems involved in training the flying personnel in piloting the МиГ-25П aircraft, navigation under various flight conditions with complex employment of the airborne and ground navigation aids, as well as combat employment under adverse conditions when a potential enemy uses various means of radioelectronic suppression.

The Manual consists of two parts:

P a r t O n e - flying technique and air navigation;
P a r t T w o - combat employment.

The First Part contains a separate chapter presenting basic aerodynamic characteristics of the МиГ-25П aircraft which will enable the flying personnel to use within the full scope the combat capabilities of the interceptor in the course of practical flying.

The Second Part outlines peculiarities of the intercept flight at various altitudes and airspeeds when performing forward-cone and pursuit attacks, as well as possibilities of destruction of air enemy under the conditions of radioelectronic suppression.

The suggested flying personnel training procedure may vary to some extent and will depend on definite conditions. Therefore, the commanders of the units who organize and conduct flight training should bear in mind that only creative approach to training, discovering new ways, methods and procedures can provide high quality of flight training and flight safety. In all cases, basic attention should be given to training a pilot as a fighter.

CHAPTER I

AIRCRAFT AERODYNAMICS

AERODYNAMIC CHARACTERISTICS

1. AIRCRAFT AERODYNAMIC CONFIGURATION

Aerodynamic configuration of aircraft implies rational selection of configuration and geometrical dimensions of the wing, tail unit and fuselage, as well as their mutual arrangement to obtain the required flight performance and to provide flight safety in all operational flight conditions. Selection of the appropriate aerodynamic configuration is determined by the purpose of the aircraft, its tactical and technical specifications.

Aerodynamic configuration of any supersonic aircraft is selected by compromising, since it is impossible to obtain the characteristics adequate for subsonic, transonic and supersonic airspeeds due to contradictory properties of subsonic and supersonic aerodynamics.

The МиГ-25П aircraft is a single-seat interceptor-fighter. The aircraft is intended for destroying the air targets both in the daytime and at night, in fair and adverse weather conditions, within a wide range of airspeeds and flying altitudes, as well as under the conditions of radioelectronic suppression of the enemy.

The necessity of a long-time flight at high Mach-numbers, installation of powerfull rocket armament with preservation of the preset maneuvering characteristics of the aircraft within a wide range of altitudes and airspeeds of flight have required design of special aerodynamic configuration.

The aerodynamic configuration of the МиГ-25П aircraft is selected with the view of meeting the requirements of supersonic aerodynamics to the maximum.

The aircraft is a monoplane with an all-metal fuselage, moderate sweep wing, low-set movable stabilizer, vertical tail of twin-finned layout and side air intakes.

The fuselage of the МиГ-25П aircraft is a monocoque manufactured without fuselage-break joints by welding.

The nose fuselage of a round cross-section up to the air intakes has a cone angle of 29° and is skewed through 2°17' relative to the fuselage datum to improve the pilot's vision. Arranged in the nose section of the fuselage is the radio equipment.

The fuselage nose section located within the area of the aircraft radar antenna is made of a radio transparent material. To provide an access to the units of the aircraft radar, the fuselage nose section is shifted together with the metal section of the cone.

The rest part of the fuselage has a cross-section close to a rectangular shape. Arranged in the middle fuselage section are the integral tanks manufactured from stainless high-tensile steel.

The fuselage tail section accommodates two turbojet engines P15Б-300 supplied with air through lateral two-dimensional air intakes.

Installed at the bottom of the fuselage tail section are two ventral fins. Installed on the left ventral fin is a rod for automatic deployment of the drag chute. The drag chute is accommodated in the container arranged in the hump fairing of the fuselage tail section.

To improve the maneuvering characteristics of the aircraft and to ensure energetic braking, the upper and lower surfaces of the fuselage tail section mount two air brakes, 2.3 m^2 in total area. The maximum angles of deflection of the lower and upper air brakes amount to 45° and 43°30', respectively.

At Mach-numbers equal to or less than 1.5, only the upper air brake is extended. Both air brakes are extended at Mach-numbers exceeding 1.5. The extension of the air brakes is automatically interlocked with the aid of a special Mach-number relay.

The wing of the aircraft is a swept wing of a tapered shape in plan view. The wing sweepback amounts to 42°30' with reference to its leading edge and 9°30' with reference to its trailing edge. The wing aspect ratio amounts to 3.20.

The use of the moderate sweepback wing with relatively great aspect ratio (as compared with other series aircraft of this country) ensures high lift coefficient in the take-off/landing conditions. Besides, this type of the wing provides for improving its net volume for arranging the wing tanks.

High aerodynamic efficiency of the aircraft at supersonic airspeeds is ensured by a thin symmetrical profile with a sharp leading edge installed in the wing root section. Relative thickness of the profile amounts to 3.7% MAC.

To avoid early stalls at high angles of attack and subsonic airspeeds, the wing tips are constructed of high-lift cambered profiles with a relative thickness amounting to 4.7% MAC.

The relatively thin wing of moderate sweepback makes it possible to obtain good aerodynamic and maneuvering characteristics of the aircraft within a wide range of airspeeds and altitudes of flight.

For better longitudinal control at high angles of attack and subsonic airspeeds, the upper surface of the wing carries two stall fences having a relative height of 4% MAC.

To ensure adequate lateral dynamic stability, use is made of a wing with a dihedral angle of -5°.

The lower surface of the wing carries the pylons for attachment of missiles P-40.

The suspension of four missiles is accomplished with due account of air-stream interference and drag being close to an optimum one.

The wing tips are provided with booms carrying anti-flutter weights.

The wing is provided with the flaps having a maximum angle of deflection of 25° at take-off and landing. Installed in the wing tips are the ailerons with a maximum angle of deflection of $\pm 25^{\circ}$, having minimum overhang aerodynamic balance (18%) at supersonic airspeeds. The aileron control system incorporates an irreversible, two-chamber booster installed in the fuselage.

Employment of high-wing monoplane configuration in combination with high-lift lateral air intakes and flat-wide fuselage, which does not require auxiliary fillets and fairings, entails minimum losses of aerodynamic efficiency of the aircraft.

The horizontal tail of the aircraft is a controlled or differentially controlled horizontal stabilizer with a sweep angle of the leading edge amounting to $50^{\circ}22'$. The differentially controlled stabilizer is designed to control the aircraft in pitch and roll.

The deflection angles of the stabilizer leading edges measured normally to the axis of rotation are: $+12^{\circ}$ upwards and -33° downwards.

The stabilizer consists of two halves. Each half rests by two bearings on a boom arranged in the tail section of the aircraft fuselage.

The stabilizer axis of rotation has a sweep angle of 45° and passes through a point corresponding to 40% MAC, while on the aircraft provided with differentially controlled modified stabilizer it passes through a point which corresponds to 33% MAC. Displacement of the stabilizer hinge line forward made it possible to decrease an aerodynamic hinge moment of the stabilizer.

The stabilizer shape (in a plan view) is manufactured with a slight cut of the trailing edge. It is done to increase efficiency of anti-flutter weights and critical flutter speed. The angle between the stabilizer tip chord and the aircraft plane of symmetry is equal to 38°.

To exclude the effect produced by the gas flow of the engines on the stabilizer hinge moments, its trailing edge in the root section is cut at an angle of 15° to the aircraft axis of symmetry.

For better longitudinal control and stability characteristics, the horizontal tail is brought beyond the zone of the maximum flow braking behind the wing and positioned 14% MAC below the wing. It leads to a certain increase of the longitudinal control efficiency within the whole range of Mach-numbers, as well as to a material backward displacement of the aircraft gross aerodynamic centre at high angles of attack and subsonic airspeeds.

The vertical tail is swept-back type. It consists of two fins cambered out at an angle of 8° to the plane of symmetry. Such an arrangement prevents the rudder of the fin from the supersonic stall effect of the other fin, improves the tail fuselage lines, and decreases drag coefficient.

Besides, the vertical tail is made so as to exclude shading of the fins by the fuselage and to provide required efficiency of the stabilizer, which may be screened by the fin under certain conditions. The vertical tail leading edge sweepback amounts to 54°.

Each fin is attached to the fuselage in four points.

The two-finned layout of the vertical tail provides perfect directional stability of the aircraft at high Mach-numbers with a certain excessive efficiency of the directional control at subsonic airspeeds.

To increase critical flutter speed at minimum weight, the shape of the fins (in plan) has a deviation from a tapered one.

The angle between the fin tip chord and fuselage datum line amounts to $28^{o}30'$.

To decrease drag coefficient, the fin is made of a set of modified profiles with a sharp leading edge. The relative thickness of the profiles is equal to 4 - 4.5%.

Installed at the bottom of the aft fuselage are two ventral fins acting as additional fins; the total area of the ventral fins amounts to 3.55 m^2.

The rudders of the riveted structure are attached to the fins in three points. The rudder maximum angle of deflection normally to the axis of rotation amounts to $\pm 25^{o}$. To damper oscillation, each rudder is provided with a hydraulic damper located in the root section of the fin.

The air intakes of the aircraft are lateral, two-dimensional, with a sharp leading edge and variable geometry. The air intake geometry is controlled with the aid of high-lift horizontal ramps. Employment of the system of three oblique and one normal shock waves ensures minimum losses of the engine thrust with the surge-free operation within a wide range of airspeeds and angles of attack.

The air intakes of this structure make it possible to increase the aerodynamic efficiency of the aircraft as well as to decrease excessive longitudinal static stability at supersonic airspeeds.

The air intake duct is of a rectangular shape within the zone of adjustable shutters and of a round shape at the engine inlet.

The air intake lip is sharp and is skewed downward and backward.

Variation of the air intake duct area and the total angle of air flow deceleration is accomplished by changing the position of the ramp front and rear shutters.

For equalizing the velocity field, the provision is made for a turbulator mounted on the rear shutter of the ramp and a special duct for boundary-layer air bleed located between the fuselage and side walls of the air intakes. Boundary-layer suction is ensured due to the use of a perforated front shutter of the ramp.

The lower shutter of the air intake has three positions: one take-off and two flight positions. To decrease the losses of the total pressure during take-off up to the moment the landing gear is retracted, the shutter is set to the lower position (20^{o}).

After the landing gear is retracted, the shutter is automatically shifted to the second (intermediate) position and deflected upwards through 7^{o}, while at Mach-numbers of $M = 2.5 \pm 0.05$ it is set to the upper position (12^{o}).

Each air intake is provided with the system of the automatic and manual control of the ramp.

2. AERODYNAMIC CHARACTERISTICS OF AIRCRAFT

The aircraft flight performance is determined mainly by a drag (required thrust) and available thrust value of the power plant.

Required thrust. The required thrust for a sustained level flight counterbalances the drag. Numerically it is equal to it:

$$P_{req} = Q .$$

Drag force Q is determined from the following formula:

$$Q = 0.7p_{ram}M^2 SC_x,$$

where: $0.7p_{ram}M^2$ - is the ram;

S - is the wing area;

C_x - is a dimensionless drag coefficient depending on the aircraft geometry, Mach-number of flight and lift coefficient.

Coefficient C_x is equal to the sum of non-induced and induced drags. Components $C_{x\ 0}$ and $C_{x\ ind}$ are of different physical nature. Coefficient $C_{x\ 0}$ is a drag coefficient at zero lift. It takes into account the profile drag of friction and pressure. Coefficient $C_{x\ ind}$ is the induced drag coefficient which accounts of an increment of the drag due to the lift. Hence, drag is divided into two components: induced and non-induced, i.e.

$$Q = Q_o + Q_{ind}.$$

Magnitudes Q_o and Q_{ind} are determined from the following formulas:

$$Q_o = 0.7p_{ram}M^2 SC_{x\ 0};$$

$$Q_{ind} = 0.7P_{ram}M^2 SC_{x\ ind}.$$

Non-induced drag. It depends on coefficient $C_{x\ 0}$ and ram.

Coefficient $C_{x\ 0}$ practically depends on the Mach-number only (Fig. 1). At Mach-number being less than critical value

(M < 0.85), coefficient $C_{x\ 0}$ remains constant, and for the МиГ-25П aircraft it is equal to 0.0258.

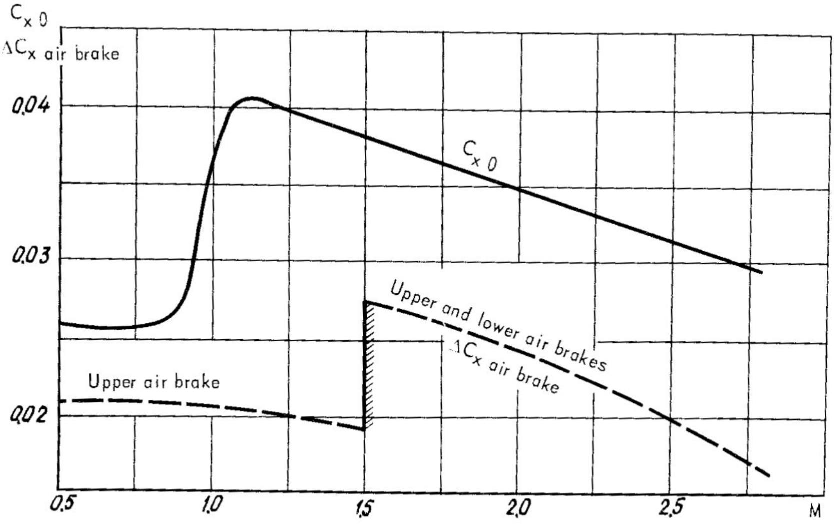


FIG. 1. NON-INDUCTIVE DRAG COEFFICIENT $C_{x}0$ VERSUS MACH NUMBER
(aircraft carries no missiles and pylons)

Due to the shock waves originated at the Mach-numbers higher than 0.85, coefficient $C_{x\ 0}$ sharply increases. At the Mach-number of M = 1.15 coefficient $C_{x\ 0}$ reaches its maximum value of 0.041. When the Mach-number continues increasing, the shock waves become oblique, their intensity diminishes and coefficient $C_{x\ 0}$ decreases.

Thus, until the shock stall appears, the non-induced drag increases proportionally to square of the Mach-number. The shock stall results in an intensive increase of Q_0. At supersonic airspeeds the rate of Q_0 decreases due to the decrease of coefficient $C_{x\ 0}$. As the flight altitude increases, the non-induced drag diminishes proportionally to the atmospheric pressure.

Induced drag. The induced drag depends on the ram and coefficient $C_{x\ ind}$ which is determined from the following formula:

$$C_{x\ ind} = AC_y^2.$$

The formula proves that $C_{x\ ind}$ depends on coefficient A and square of lift coefficient. Coefficient A, in its turn, is a function of Mach-number. In addition, at subsonic airspeed it depends on the wing aspect ratio and construction of the wing leading edge.

On the МиГ-25П aircraft at subsonic flow-past coefficient A remains constant and amounts to 0.175, while at supersonic flow-past it increases approximately proportionally to the Mach-number. It reaches its maximum value of 0.58 at the Mach-number of M = 2.8.

The induced drag in the level flight may be determined from the following formula:

$$Q_{ind.\ 1/f} = \frac{AG^2}{0.7P_{ram}M^2S}$$

The formula proves that the induced drag in a level flight with coefficient A being constant, decreases in inverse proportion to the square of the Mach-number. At supersonic flow-past, irrespective of an increase of inductance index A, value Q_{ind} continues diminishing, but slightly, since the increase of the Mach-number produces greater effect than, the increase of coefficient A.

As g-load increases the induced drag increases proportionally to the square of g-load:

$$Q_{ind} = Q_{ind.1/f}\ n_y^2.$$

As the flight altitude increases, the induced drag, all other things being equal, will also increase in inverse proportion to the atmospheric pressure.

Thus, the flight altitude and Mach-number produce an opposite effect upon the non-induced and induced drags. At low airspeeds and high altitudes the induced drag prevails within the total balance of drags, while the non-induced drag is a prevailing one at high airspeeds and low altitudes.

A boundary at which $Q_o = Q_{ind}$ is the most advantageous Mach-number. In this case, the total drag, and hence, the required thrust are minimum.

Relation between the drag and the flight speed at a given altitude plotted on the diagram is called as a r e q u i r e d - t h r u s t c u r v e . Fig. 2 presents the required-thrust curves of the МиГ-25П aircraft. The figure illustrates that the advantageous Mach-number increases together with the increase of the altitude (the curve minimum is shifted to the right).

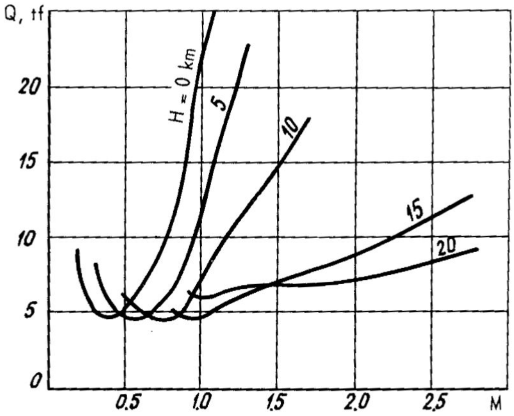


FIG. 2. REQUIRED-THRUST CURVES Q

The required thrust of the aircraft at the most advantageous Mach-number is minimum. The required thrust will increase no matter whether the Mach-number increases or decreases.

Within the subsonic range the most advantageous Mach-numbers for the МиГ-25П aircraft will correspond to indicated airspeeds of 500 - 550 km/h.

The required thrust curves are true for any ambient air temperature.

When flying the aircraft at low airspeeds it is necessary to remember that g-load unduly affects the required thrust due to a sharp increase of the induced drag during maneuvering.

<u>The available thrust</u> is the maximum thrust which may be obtained under specific flight conditions.

The available thrust should not be equated with the maximum test bench engine thrust since the engines mounted on the aircraft run under the specific arrangement conditions. These conditions may substantially differ from those of the engine being tested on a bench.

Available thrust P_{av} of two engines P15Б-300 installed on the aircraft, with the losses in the nozzles and ducts taken into account, is determined from the following formula:

$$P_{av} = (2P_{en} - \Delta P)\ (1 - \Delta\bar{P}_{int})\ (1 - \Delta\bar{P}_{noz}),$$

where: P_{en} – thrust of one engine;

ΔP – additional thrust losses due to an inlet pulse of incoming air;

$\Delta\bar{P}_{int}$ – air intake internal thrust losses;

$\Delta\bar{P}_{noz}$ – nozzle thrust losses.

The thrust losses depend on the power setting of the engines, as well as on flight altitude and airspeed. The total sum of the losses may amount to 500 – 1000 kgf. The available thrust curves for two engines with the losses taken into account are presented in Fig. 3.

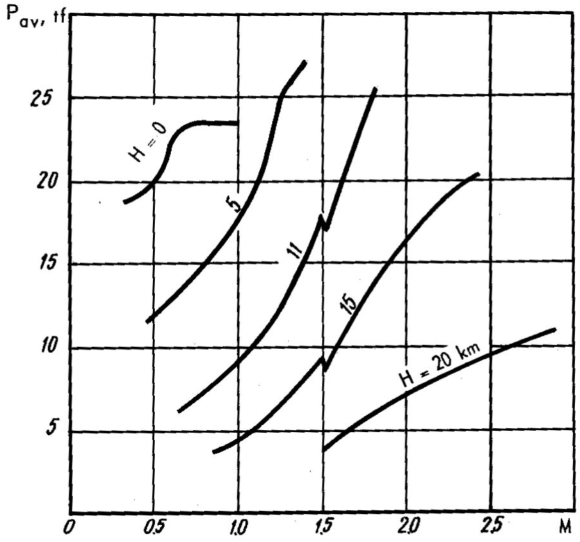


FIG. 3. AVAILABLE THRUST CURVES P_{av}

At the estimated power settings of the engines within the operational range of airspeeds the thrust increases together with an increase of the Mach-number and decreases as the flight altitude increases.

The decrease of the ambient air temperature with reference to the standard one by 1% entails the decrease of the thrust by 2% approximately.

At altitudes less than 6000 m and high indicated airspeeds the engine thrust at augmented power settings is limited by the capacity of the afterburner fuel pumps. This phenomena is determined by a typical sharp bend plotted on the available thrust curves.

At M = 1.5 the "2ND REHEAT" (II ФОРСАЖ) power setting is selected. This process is accompanied by a thrust drop followed by its more intensive rise.

3. FIRST AND SECOND FLIGHT REGIMES

For a sustained flight it is necessary to observe the equality of forces acting on the aircraft:

$$P = Q \pm G \sin \Theta,$$

where: P - is the engine thrust;
Q - is the aircraft drag;
G sin Θ - is the component of the aircraft weight (with sign "+" at climb and with sign "-" at descent).

In a sustained level flight this equation is as follows: P = Q.

The balance of forces may be steady or unsteady; depending on it there are the first and second flight regimes.

At a certain altitude, with the throttle control lever fixed, the equation of the available thrust and drag takes place at two points which correspond to two values of the flight speed.

When throttling the engines, there comes a point where the equation of the available thrust and drag is at one point corresponding to an airspeed located on the boundary between the first and second flight regimes.

Depending on a position of the throttle lever the regimes of the sustained level flight are determined by the points of intersection of the required thrust curve with the respective curve of the available thrust. For example, when the throttle lever is set to a position corresponding to 90%, the sustained level flight of the МиГ-25П aircraft carrying four missiles is possible at two indicated airspeeds: V_1 = 740 km/h and V_2 = 325 km/h (points 1 and 2 in Fig. 4).

If the pilot maintains an indicated airspeed of 740 km/h at a constant altitude, a positive thrust excess appears in case the indicated airspeed inadvertently decreases. This positive thrust excess restores the initial flight speed. It proves that the flight is accomplished at the first regime.

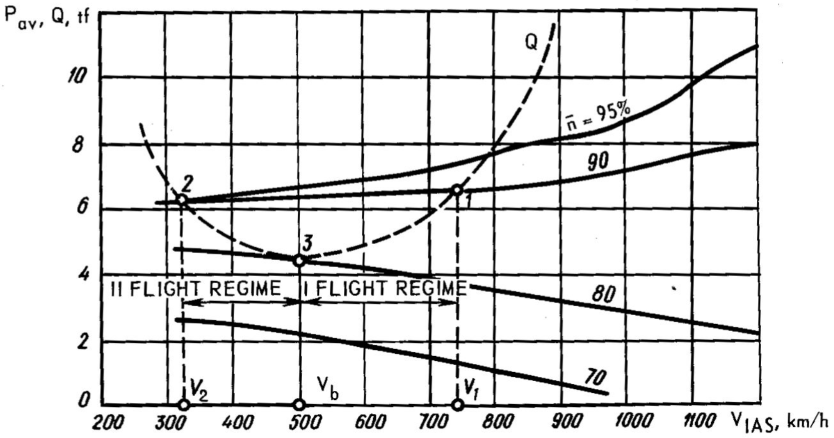


FIG. 4. CURVES OF REQUIRED AND AVAILABLE THRUSTS OF AIRCRAFT CARRYING FOUR MISSILES AT NON-REHEAT POWER SETTING (H = 5000 m)

Point 2 on the graph corresponds to the second regime, since the thrust excess, which entails further increase of the airspeed, arises as an airspeed exceeds 325 km/h. To maintain the initial flight speed, it is necessary to decrease the engine thrust first and then increase it, i.e. double displacements of the throttle lever will be required.

Point 3, at which the available thrust curve corresponding to 80% touches the required thrust curve, is a boundary of the first and second regimes. The indicated airspeed at this point is equal to 500 km/h (boundary airspeed V_b).

Thus, at an altitude of 5000 m and at indicated airspeeds exceeding 500 km/h the flight will be performed at the first regime, whereas at indicated airspeeds of less than 500 km/h it will be accomplished at the second regime.

The optimum airspeed, which amounts to 500 - 550 km/h for the МиГ-25П aircraft, may be considered with an adequate accuracy as a boundary dividing the first and second flight regimes. Thus, for the МиГ-25П aircraft the maneuvering speed at subsonic airspeeds is within the second flight regime.

The first and second flight regimes are typical not only for subsonic but also for supersonic airspeeds.

Possibility of the engine thrust control from the minimum to the full reheat has involved unstable equilibrium of the longitudinal forces, i.e. origination of the second regime of flight within the supersonic range of airspeeds at high altitudes and in the stratosphere.

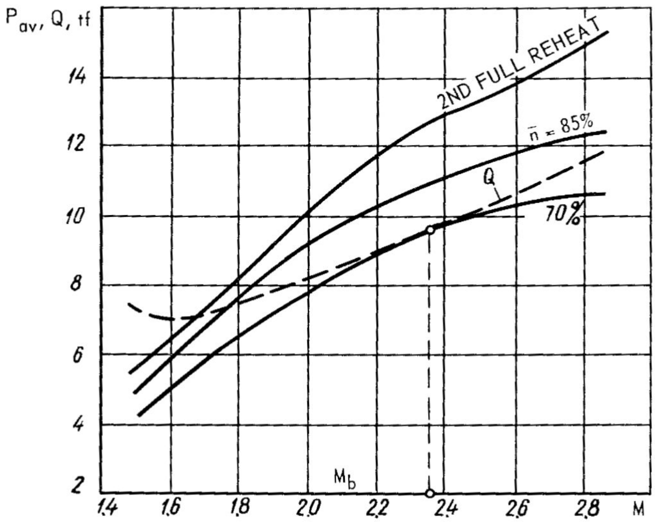


FIG. 5. CURVES OF REQUIRED AND AVAILABLE THRUSTS OF AIRCRAFT CARRYING FOUR MISSILES AT REHEAT POWER SETTING (H=18,000 m)

Fig. 5 illustrates the curves of the available thrust at various degrees of thrust augmentation and the required thrust curve of the МиГ-25П aircraft carrying four missiles at an altitude of 18,000 m. The boundary of the first and second regimes is determined by the tangency point of the required thrust and the partial reheat thrust curves.

The subsonic second flight regimes are characterized by the following peculiarities:

(a) the flight is accomplished at high angles of attack, i.e. the less flight speed and the higher altitude, the greater angle of attack;

(b) variation of the airspeed at the sustained level flight generates a need for a continuous manipulation of the throttle levers and the aircraft control stick to maintain the preset flight regime;

(c) decrease of the airspeed during level flight results in a rapid increase of drag and further progressing drop of the altitude;

(d) stability and controllability characteristics of the aircraft somewhat deteriorate.

The supersonic second regime characteristics possess the same peculiarities but they correspond to small angles of attack and high airspeeds, that is why they are not dangerous.

In flight practice the second regimes may develop in the following cases:

- pullup of the aircraft when taking off;
- an attempt to climb at a low speed or at an exessively great climb angle;
- a failure of one engine with the landing gear and flaps extended;
- pulling up the aircraft after passing the inner homing radio station;
- near non-reheat ceiling when performing maximum range or maximum endurance flight.

When it is necessary to perform the flight at the second regime, more attentively check the airspeed and select it in due time by displacing the throttle levers. It is important not to allow an airspeed less than the maneuvering one (especially when performing steady turns), since in case of considerable loss of the airspeed its further recovery may become impossible due to absence of the thrust excess. In this case, to increase the airspeed it is required to bring the aircraft to the descent attitude which is somewhat dangerous at low altitudes.

4. RANGE OF FLIGHT ALTITUDES AND AIRSPEEDS

The maximum and minimum airspeeds of a sustained level flight at a preset position of the throttle lever and at various altitudes may be judged by referring to the graph of the required and available thrust curves (Fig. 6). A sustained flight at a given altitude will be possible if the required thrust is less or equal to the available thrust.

The greatest airspeed at which these thrusts are equal is called as the m a x i m u m a i r s p e e d of the sustained level flight. Each maximum airspeed corresponds to its power setting.

As an altitude rises, the maximum airspeed increases and may exceed the maximum permissible speed.

An airspeed interval at which the sustained level flight is possible is assumed as the level flight a i r s p e e d r a n g e.

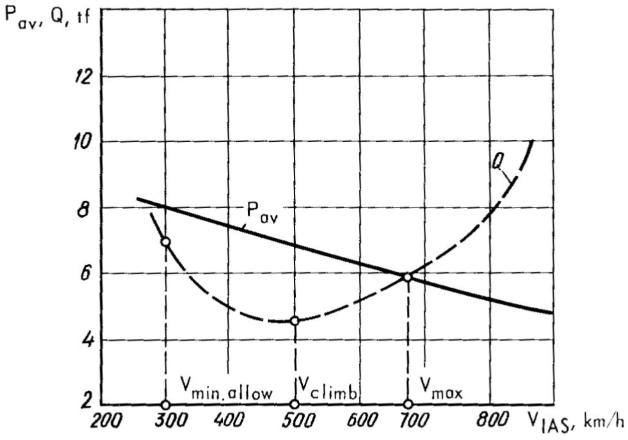


FIG. 6. CURVES OF REQUIRED AND AVAILABLE THRUSTS OF AIRCRAFT CARRYING FOUR MISSILES (non-reheat power setting, n_{en} = 80%, H = 0)

For the МиГ-25П aircraft the level flight airspeed range is limited by the maneuvering indicated airspeed, selected from the conditions providing normal controllability when maneuvering, and the maximum permissible speed.

Fig. 7. presents the altitude and airspeed range of the МиГ-25П aircraft carrying four missiles at various power settings of the engines.

The maximum permissible indicated flight speeds are limited with reference to the aircraft strength, as well as by a probability of flutter; for the aircraft not equipped with the stabilizer differential control system they are as follows: 1000 km/h at altitudes of up to 5000 m and 1100 km/h at altitudes over 5000 m. An indicated airspeed of not more than 1150 km/h within the altitude range of 8000 to 13,000 m at the programmed climb is allowed.

For the aircraft fitted with the stabilizer differential control system the maximum permissible airspeed at altitudes of up to 17,000 m is equal to 1200 km/h.

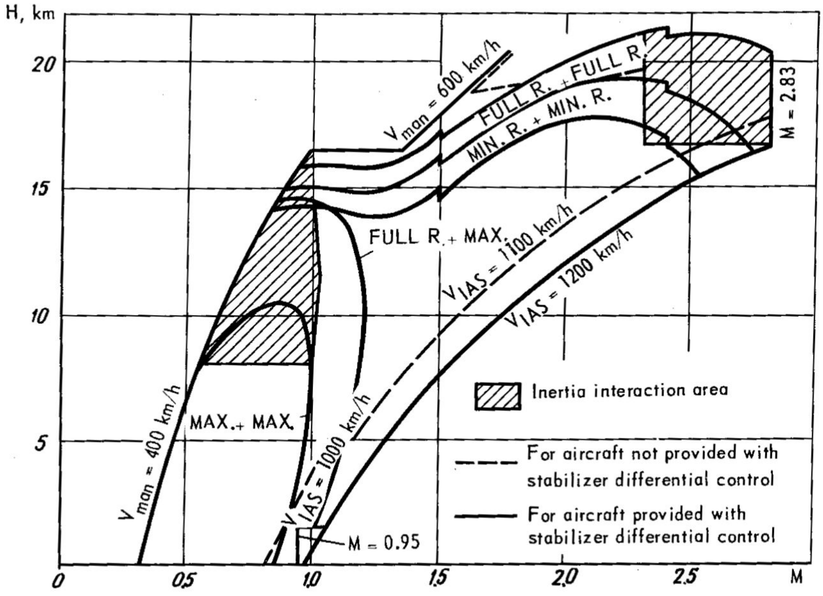


FIG. 7. ALTITUDE AND AIRSPEED RANGES OF AIRCRAFT CARRYING FOUR MISSILES

The maximum Mach-number of the aircraft with and without the stabilizer differential control system is limited with respect to thermal strength of the engines and it amounts to 2.83. For the same reason, the flight endurance at Mach-numbers exceeding 2.4 equals 15 min (at Mach-numbers M = 2.65 it amounts to 5 min). The flight time at Mach-numbers of M = 2.4 and less is not limited.

The maneuvering indicated airspeed of flight, with the permissible variants of missiles carried, is equal to 400 km/h at altitudes up to 16,500 m and 600 km/h at altitudes over 16,500 m.

The service ceiling of the aircraft carrying four missiles under standard atmospheric conditions is 20,500 m. In this case, the aircraft mass at the service ceiling equals 25,800 kg and the remaining fuel amounts to 3300 kg.

The average time of gaining an altitude of 20,000 m at M = 2.35 in standard atmosphere conditions, with the engines running at FULL REHEAT (ПОЛНЫЙ ФОРСАЖ), from the moment the take-off run is started is equal to 9.7 min for the aircraft carrying four missiles.

5. TAKE-OFF AND LANDING CHARACTERISTICS OF AIRCRAFT МиГ-25П

The take-off and landing characteristics are determined by the aerodynamic characteristics of the aircraft, its thrust-to-weight ratio, condition of the runway, as well as wind direction and velocity.

The thrust-to-weight ratio, in turn, depends on an aircraft mass, engine power settings, temperature and pressure of ambient air.

Take-off characteristics. The basic take-off characteristics are: the aircraft unstick speed and take-off run.

The unstick speed is a speed at which the sum of the lift force and vertical component of thrust counteracts the aircraft weight. Hence, the aircraft unstick speed depends on a take-off mass, angle of attack and engine available thrust during take-off.

Under standard atmosphere conditions unstick speed V_{unst} of the МиГ-25П aircraft is determined from the following formula:

$$V_{unst} = 14.4 \sqrt{\frac{G_{unst} - P_{av} \sin(\alpha_{unst} - \varphi_{en.set})}{C_{y\ unst} S}},$$

where: G_{unst} is the aircraft weight at unstick moment ($G_{unst} = mg$);

P_{av} is the engine available thrust;

$\varphi_{en.set}$ is the engine setting angle which is equal to 4°;

$C_{y\ unst}$ is the aircraft lift coefficient with the ground effect taken into account (it is a function of the unstick angle and the flap deflection angle);

S is the aircraft wing area which amounts to 61.73 m^2.

The unstick speed of the МиГ-25П aircraft carrying no missiles on a concrete runway is equal to 350 - 360 km/h and 360 - 370 km/h with four missiles suspended.

After unsticking the aircraft is stable, the effectiveness of the control surfaces is adequate. The take-off with four missiles carried has no peculiarities.

The t a k e - o f f r u n is a distance passed by the aircraft up to the moment of unsticking.

It depends on an average acceleration during take-off running and on the unstick speed:

$$L_{run} = \frac{V^2_{unst}}{2j_{av.acc}}.$$

For the МиГ-25П aircraft the average acceleration during taking-off running is determined from the following formula:

$$j_{av.acc} = \frac{g}{G_{av}} [P_{av} - f_{fr}G_{av} - 0.25\rho S (C_{x\ run} - f_{fr}C_{y\ run}) V^2_{unst}],$$

where: G_{av} is the average weight during take-off running ($m_{av}g$);

g is the free-fall acceleration;

ρ is the air density;

f_{fr} is the friction coefficient during take-off running;

$C_{x\ run}$, $C_{y\ run}$ are the coefficients of drag and lift of the aircraft during take-off running.

The take-off run of the aircraft carrying no missiles from the concrete runway is 1100 m, while with four missiles suspended it is increased by 150 m.

Effect of various factors on take-off characteristics.

Proceeding from the above formulas it is evident that the take-off characteristics are affected by:

- aircraft mass;
- angle of attack;
- power settings of the engines;
- temperature and pressure of ambient air;
- wind direction and velocity;
- condition and gradient of the runway.

Increase in the take-off mass entails decrease in the average take-off acceleration, increase in the unstick speed and take-off run. The average take-off acceleration decreases due to a drop of the thrust-to-weight ratio of the aircraft and increase of the friction forces.

With the engine average thrust being constant, an increase of the aircraft mass by 1% results in an increase of the take-off run by 2%, on the average.

An increase of the angle of attack during take-off involves a rise of the lift force coefficient, and hence, a decrease of the unstick speed and take-off run.

A delay in lifting the nose wheel and in creating the optimum take-off angle results in the aircraft unstick at a greater speed and increase of the take-off run.

A decrease of the angle of attack by 1% increases the take-off run by 8 to 9%. That is the cause of the take-off distance spread when taking off on one and the same aircraft under the same conditions. Comparatively small inaccuracies in maintaining the take-off angle lead to a change of the take-off run by 100 m and more.

The engine power setting exerts an effect on the unstick speed and average acceleration. As the thrust during take-off increases the unstick speed decreases due to an increase of the vertical component of the thrust force. But the effect produced by the vertical component of thrust on the unstick speed within the limits of the take-off angles can be disregarded. The engine power setting produces the main effect on variation of the average acceleration. As the thrust increases the average acceleration increases, too. Due to this, the take-off run decreases.

The take-off of the МиГ-25П aircraft is accomplished at the FULL REHEAT power setting, and at the maximum power setting in case of 50% fuelling.

The temperature and pressure of the outside air effect on its density on which the engine thrust, coefficients of the aircraft drag and lift and hence the unstick speed and take-off run depend.

As the temperature rises the air density decreases and the unstick speed increases. Simultaneously, the engine thrust and average acceleration decrease. It entails an increase in the take-off distance. In this case, variation of the engine thrust produces greater effect on the take-off distance than on the unstick speed.

An increase of the atmospheric pressure leads to a rise of air density, decrease of the unstick speed, increase of the engine thrust and average acceleration. As a result, the take-off run decreases.

An increase of the outside air temperature by 15°C or decrease of the pressure by 30 mm Hg results in an increase of the unstick speed by 2.5%. A decrease of the atmospheric pressure by

30 mm Hg or increase of the outside air temperature by 10°C from the standard values increases the take-off run by 10%.

The wind changes the take-off run. Irrespective of the wind velocity and direction, the unstick is performed at a definite airspeed. But the aircraft speed relative to the ground at the moment of the unstick at headwind is less, while at tail wind it is greater. Therefore, the take-off run and time are less at headwind and are greater at tail wind than in still air.

Depending on the wind direction the unstick ground speed will change by value $\pm U$ or its component directed along the runway centre line. Sign "plus" is taken at tail wind, and sign "minus" at headwind.

Generally, for calculating the take-off time and run it is necessary to take into account wind velocity or its component directed along the runway centre line.

The formula for calculating the take-off run will be as follows:

$$L_{run} = \frac{(V_{unst} \pm U)^2}{2j_{av.acc}}.$$

The time of take-off run at a wind can be determined from the formula:

$$t_{run} = \frac{V_{unst} \pm U}{j_{av.acc}}$$

Cross wind blowing at a speed of up to 10 m/s at an angle of 90° to the runway centre line practically does not affect the take-off. Accomplishment of the take-off at a cross wind of more than 10 m/s in speed has some peculiarities. It is dictated by the following reasons.

Cross wind initiates the cross-wind force which is counteracted by friction forces of the wheels during take-off (Fig. 8).

The МиГ-25П aircraft has a well-developed vertical tail unit; therefore, the cross-wind force is applied behind the main wheels. It tries to drift the aircraft downwind and to turn it upwind, especially during the second half of the take-off run with the nose wheel lifted. The pilot should counteract the moment created by the cross-wind force by applying the brakes and deflecting the rudders, i.e. he should try to keep the aircraft from turning upwind. The rudder margin of the МиГ-25П aircraft is enough for maintaining the direction at a cross wind component of up to 15 m/s.

Since the cross-wind force is applied above the longitudinal axis, it tends to roll the aircraft. In this case, one landing gear leg is unloaded, while the other is loaded. Friction forces of the wheels acting along the direction of flight will change in magnitude and create a moment turning the aircraft nose downwind. Thus, this moment will try to weaken the moment of the cross-wind force.

Depending on the nose wheel lifting rate and creation of the take-off angle at a cross wind of more than 10 m/s, the magnitude of the above moments may considerably change.

When the angle of attack increases rapidly, the moment created by the friction forces of the main wheels rapidly decreases, and the aircraft experiences a turning moment. Besides, if the pilot fails to have a chance to deflect the ailerons when unsticking from the ground, the aircraft will experience a rolling moment.

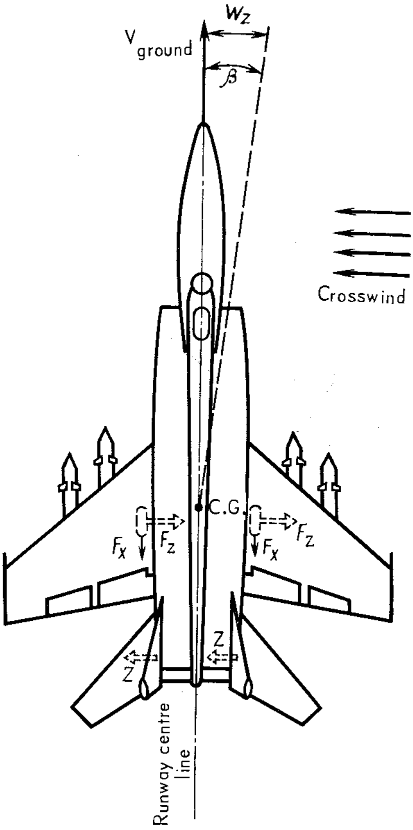


FIG. 8. ADDITIONAL FORCES AFFECTING AIRCRAFT DURING TAKEOFF AT CROSS-WIND

Hence, when taking off with the cross-wind, the pilot should create the take-off angle at somewhat slow rate. In this case, the unstick speed and take-off running time slightly increase.

Slightly increased time of take-off running is required for the pilot not only for creating the take-off angle of attack at a slow rate but also for trimming the aircraft with the aid of the ailerons and rudders. Thus, a safe unstick of the aircraft from the runway and further climb are provided.

Condition of the runway directly exerts an effect on the friction coefficient during take-off. For the dry runway with concrete pavement the friction coefficient for calculations is equal to 0.03. An increase of the friction coefficient leads to a decrease of acceleration during take-off, increase of take-off time and run when taking off and vice versa.

When taking off from the runway, having inclination angle θ, an additional force, i.e. the longitudinal component of weight (it amounts to $G \sin \theta$), will act along the aircraft longitudinal axis.

Due to this force the positive or negative acceleration (depending on an angle of inclination of the runway) is added to the horizontal take-off acceleration. Hence, when the take-off is performed downhill, the take-off run and time decrease, while when it is accomplished uphill, they increase. It is necessary to notice that the role of the runway inclination increases as the aircraft mass rises.

Usually, the angles of inclination of the runway are rather small (1 to 1.5°); their effect on the take-off run can be disregarded since it is insignificant.

Landing characteristics. The major landing characteristics of the aircraft are the landing speed and landing roll.

The l a n d i n g s p e e d of the МиГ-25П aircraft (in km/h) is determined from the formula:

$$V_{land} = 14.4 \sqrt{\frac{G_{land}}{C_{y\ land}\ S}},$$

where: G_{land} is the landing weight of the aircraft;

$C_{y\ land}$ is the lift coefficient of the aircraft with the ground effect at the touchdown moment taken into account; it is a function of the landing angle and flap deflection angle.

At a normal landing profile the landing speed of the МиГ-25П aircraft (carrying no missiles) at a remaining fuel of 3000 kgf and less amounts to 280 - 300 km/h.

The l a n d i n g r o l l is one of the important characteristics affecting the selection of the optimum dimensions of the runway for the given type of the aircraft. It is determined from the following formula:

$$L_{roll} = \frac{V^2_{land}}{2j_{av.roll}}.$$

The average deceleration rate during landing roll is determined as follows:

$$j_{av.roll} = \frac{1}{2} g \left(\frac{1}{K_{av.roll}} + f_{fr}\right),$$

where: g is a free-fall acceleration;

$K_{mean\ run}$ is the average efficiency at landing roll;

f_{fr} is the rolling friction coefficient (for a dry concrete runway, it is equal to 0.03 without applying the brakes and 0.28 with applying the brakes).

The landing roll for the МиГ-25П aircraft in the standard atmosphere conditions with the remaining fuel of 3000 kgf (with no missiles carried) with the employment of a cross-shaped parachute and application of the wheel brakes amounts to 800 m. The landing roll with the use of a round parachute equals 900 m. In still air when no brake parachute is used it is equal to 1550 m.

Effect of various factors on landing characteristics. The above formulas prove that the following factors exert an effect on the landing speed and roll:

- aircraft mass;
- outside air temperature and pressure;
- wind velocity;
- landing angle;
- degree of employment of the deceleration means.

The effect produced by the aircraft mass on the landing speed may be followed by the change of a specific load on the wing which varies from 390 kgf/m^2 (at a landing mass of 24,000 kg) up to 470 kgf/m^2 (at an aircraft limit landing mass of 29,000 kg). At such a change of the specific load on the wing the landing speed of the aircraft will increase from 290 to 320 km/h.

Thus, as the aircraft mass increases, the landing speed increases and, hence, the landing roll distance increases, too. Approximately we may assume that a change of the landing weight by one per cent involves a change of the landing roll also by one per cent.

The air density and, hence, the landing speed will depend on the air temperature and pressure.

The landing speed and roll vary inversely with the air density, i.e. inversely as the pressure and directly as the temperature.

An increase of the outside air temperature by 15°C or decrease of the atmospheric pressure by 30 mm Hg from the standard values will lead to the increase of the landing speed by 2.5% and the landing roll by 5%.

The effect produced by wind on the landing speed and run is the same as on the unstick speed and take-off run. When calculating the landing roll, the landing speed should be considered with wind taken into account:

$$L_{roll} = \frac{(V_{land} \pm U)^2}{2j_{av.land}},$$

where: $j_{mean\ land}$ is the average deceleration rate during landing; sign "plus" is taken at the tail wind, while sign "minus" is taken at the headwind.

The deceleration rate during the landing roll depends on the lateral component of wind. The average deceleration rate decreases by 30 to 35% at a wind lateral component of 10 m/s with the brake parachute used automatically. This decrease takes place due to the fact that it is impossible to use the brakes fully when maintaining the direction during landing roll. As a result of this the length of the braking portion of the landing roll increases and, hence, the total length of the landing roll increases.

The wind lateral component which amounts to 10 - 15 m/s increases the landing roll by 10 to 15%.

The aircraft angle of attack at the end of holding-off directly affects the landing speed and landing roll. A low landing speed corresponds to a high landing angle of attack and vice versa.

After touchdown the angle of attack should ensure the maximum total drag. The greater angle of attack during the landing roll, the greater drag, but the lesser pressure on the runway and frictional drag of the wheels.

When landing is performed into a wind or on a slippery runway, it is recommended to effect the landing roll with the nose wheel kept lifted as longer as possible. In case of the downwind landing and if effective braking is possible, it is necessary to lower the nose wheel earlier and start energetic braking.

The normal landing angle of the МиГ-25П aircraft amounts to 10 - 11°.

The aircraft may touch the runway by the ventral fins at a landing angle of 11.5 to 16.5° depending on a compression degree of the shock-absorbers. Therefore, it is not permissible to create an excessive landing angle, especially during a heavy landing.

The use of the braking means produces decisive effect upon the landing roll distance.

To shorten the landing roll the МиГ-25П aircraft employs the brake parachutes and brake system of all the wheels.

At high landing speeds the drag chutes offer great effect; they decrease the landing roll by 40 to 50%.

The speed of the wheel braking start of the aircraft is limited by 235 km/h. Therefore, on the first portion of the landing roll braking is effected due to the drag and deployment of the brake parachutes, while on the second portion, due to effective use of the brakes.

A delay in applying the brakes in speed by 15 km/h (braking is started at a speed of 220 km/h) will increase the landing roll by 100 m.

AIRCRAFT MANEUVERING CHARACTERISTICS

Depending on stability and controllability, as well as available normal g-loads permitted by the strength conditions, the МиГ-25П aircraft is a semi-aerobatic one.

The maneuverability is an ability of the aircraft to change its attitude in space by varying the airspeed in magnitude and direction during a definite time.

Finally, the characteristics of various maneuvers depend on what accelerations may be imparted to the aircraft in flight. Apart from the force of gravity which may either assist or hinder maneuvering, the accelerations are created by the same external forces as the g-loads. Therefore the generalized indices of the aircraft maneuverability are the maximum possible (available) g-loads.

1. AVAILABLE G-LOADS

The magnitudes of the available g-loads and the range of operational airspeeds determine the possibility of performing the assigned maneuvers (aerobatics), as well as indices of these maneuvers (duration, radii, angular velocities, etc.).

Vertical g-load n_y is created by the lift.

If when flying at a given altitude and at a preset airspeed one uses the aircraft capabilities in creating the lift, a g-load is achieved which is called an available g-load:

$$n_y = \frac{Y_{av}}{G} = \frac{0.7C_{y\ av}S_p\ M^2}{G},$$

where: Y_{av} is the available lift force;
G is the aircraft weight;
$C_{y\ av}$ is the lift available coefficient;
S is the wing area;
p is the pressure at the given altitude.

From the formula it is obvious that the available g-load should increase as the Mach-number increases. But it does not occur within the transonic speed region due to an abrupt drop of lift coefficient (Fig. 9). Therefore, the available g-load decreases even though the Mach-number rises at these airspeeds (Fig. 10).

At great Mach-numbers $C_{y\ max}$ practically remains constant and the available g-load increases as the Mach-number rises, but it is limited by the maximum deflection angle of the stabilizer.

As the altitude increases the available g-load decreases. It is proportional to air pressure at a preset Mach-number and with the weight being unchanged:

$$\frac{n_{y\ av\ 1}}{n_{y\ av\ 2}} = \frac{p_1}{p_2}.$$

Proceeding from this relation, one can determine the available g-load for any flight altitude knowing its initial magnitude.

In all cases the g-load should not exceed the maximum g-load permitted by strength.

Fig. 11 illustrates the maximum permissible g-loads of the МиГ-25П aircraft depending on a remaining fuel.

When maneuvering at a vertical g-load exceeding 1G, the МиГ-25П aircraft is stable in g-load until achieving the critical angle of attack. Pronounced buffeting precedes attaining the critical angles of attack. When approaching the critical angles of attack, the yellow pilot lamp on the ИП-155 g-load indicator lights up and the LIMIT MANEUVER (МАНЕВР ПРЕДЕЛЬНЫЙ) voice information is transmitted.

Longitudinal g-load $n_{x\ av}$ is obtained when the total available thrust is used in flight. For the level flight ($n_y = 1$) it is determined from the following formula:

$$n_{x\ av} = \frac{P_{av} - Q}{G} = \frac{\Delta P}{G},$$

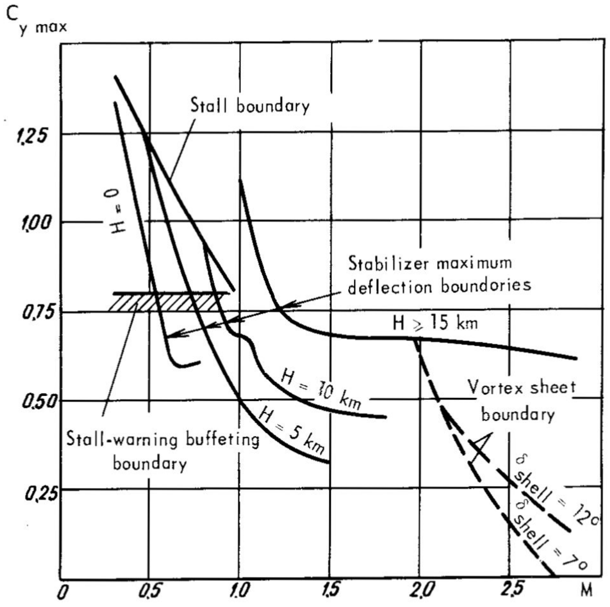


FIG. 9. MAXIMUM LIFT COEFFICIENT $C_{y\,max}$ VERSUS MACH NUMBER (aircraft carries four missiles)

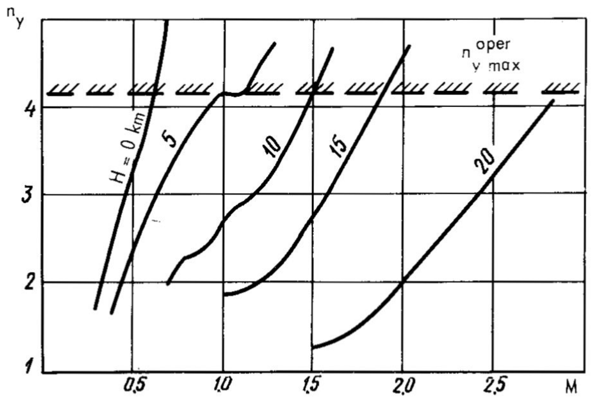


FIG. 10. AVAILABLE G-LOADS OF AIRCRAFT n_y VERSUS MACH NUMBER AND ALTITUDE OF FLIGHT (G= 30 tf)

where: P_{av} is the available thrust;
Q is the required thrust;
ΔP is the thrust excess;
G is the aircraft weight (mg).

The longitudinal g-load value depends on the flight mass, airspeed and altitude. Besides, the available longitudinal g-load is affected by the vertical g-load. The greater the vertical g-load (angle of attack), the greater drag and, hence, the lesser the available longitudinal g-load.

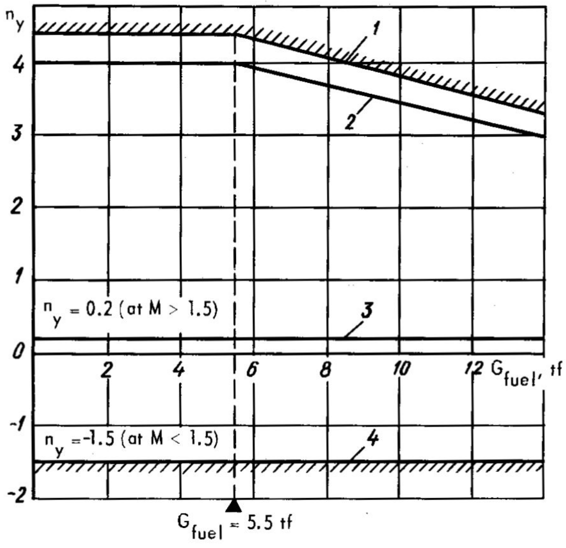


FIG. 11. MAXIMUM AND MINIMUM PERMISSIBLE G-LOADS n_y
1 – maximum permissible g-load during combat flights at all altitudes and during training flights at H>7000m experienced by aircraft without differential control of stabilizer, as well as by aircraft with differential control of stabilizer and reinforced wing in any flights at all altitudes; 2 – maximum permissible g-load experienced by aircraft without differential control of stabilizer during training flights at H<7000 m, as well as by aircraft with differential control of stabilizer and non-reinforced wing when performing any flights at all altitudes; 3– minimum permissible g-load experienced by aircraft at M>1.5; 4 – maximum permissible negative g-load experienced by aircraft flying at M<1.5

With the aircraft mass being constant, the longitudinal g-load varies in compliance with the same law as the thrust excess (Figs 12 and 13). As the flight altitude increases, a decrease of the excessive thrust and longitudinal g-load within the subsonic speed region takes place, while the positive thrust excesses and positive longitudinal g-loads are originated within the supersonic region.

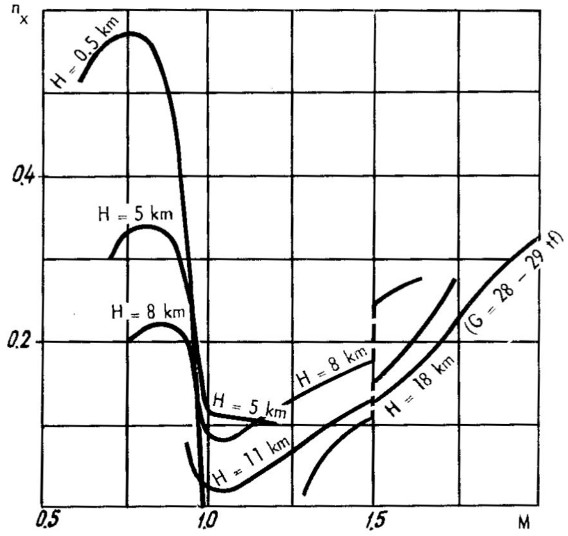


FIG. 12. LONGITUDINAL G-LOAD n_x DURING ACCELERATION AT FULL REHEAT POWER SETTING
(aircraft carries four missiles, G = 34 tf)

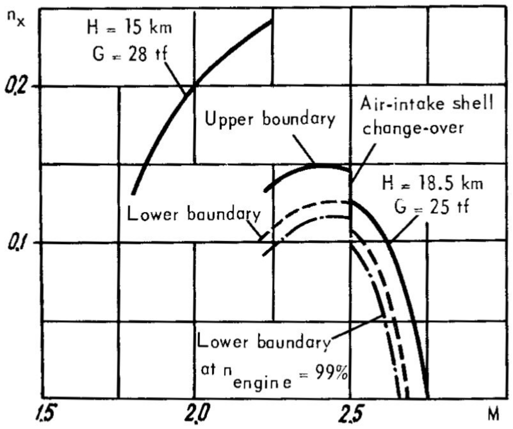


FIG. 13. LONGITUDINAL G-LOADS n_x IN ACCELERATION AT FULL REHEAT POWER SETTING
(aircraft carries four missiles, n_{en} = 100%)

At a Mach-number of M = 1.5 a jump of the longitudinal g-load occurs due to the selection of the 2ND REHEAT (II ФОРСАЖ) power setting. The jump of the longitudinal g-load at M = 2.5 is explained by switching over the air-intake lips from position II to position III. It entails abrupt increase of the engine thrust losses caused by a drag rise in the air-intake duct and, hence, a decrease of the longitudinal g-loads.

Spread of the longitudinal g-load at H = 18,000 m is explained by instability of the engine operation.

The longitudinal g-load is mainly affected by the temperature of the ambient air. If it is higher than the standard one, the available thrust at this altitude decreases and, hence, the longitudinal g-load drops. It leads to deterioration of the acceleration characteristics of the aircraft and its rate of climb.

2. MANEUVERABILITY OF AIRCRAFT IN HORIZONTAL PLANE

Maneuverability of an aircraft in the horizontal plane is evaluated by referring to the characteristics of the 360-deg coordinated turn, acceleration and deceleration.

A 360-deg turn is a curvilinear flight of the aircraft in the horizontal plane with a turn through 360°.

If in the course of a 360-deg turn the bank angle and flight-path trajectory do not change, this banked turn is referred as a 360-deg *steady banked turn*. If it is performed without slipping, it is called as a 360-deg *coordinated turn*. The forces acting upon the aircraft during the 360-deg coordinated turn are shown in Fig. 14. The 360-deg banked turn is the basis of the curvilinear maneuvers in the horizontal plane.

The 360-deg steady banked turn is characterized by the following relations:

1. $P - Q = 0$ or $n_x = 0$ (condition of the speed constancy);
2. $Y \cos \gamma - G = 0$ or $n_y \cos \gamma = 1$ (condition of the altitude constancy);
3. $Y \sin \gamma = const$ (condition of the 360-deg banked turn constancy).

When performing the 360-deg banked turn the condition of the altitude constancy proves that $n_y = \frac{1}{\cos \gamma}$. Thus, a g-load during the 360-deg coordinated turn depends on a bank angle. Quantitatively this relation is presented in Table 1.

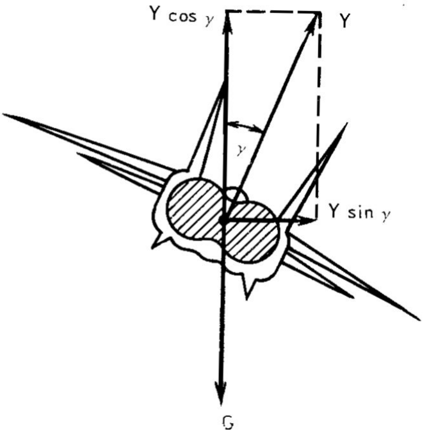


FIG. 14. FORCES DURING 360° COORDINATED TURN

Table 1

Relation between Bank Angle on 360-deg Banked Turn and G-Load

Bank γ°	0	15	30	45	50	55	60	65	70	75	80	85
G-load n_y	1	1.04	1.15	1.41	1.56	1.74	2	2.37	2.92	3.86	5.76	11.47

Table 1 illustrates that the normal g-load required for the 360-deg banked turn first increases slowly (as the bank angle increases), and then it rises rapidly. As the bank angle approaches 90°, the g-load tends to infinity. But accomplishment of the 360-deg coordinated turn with an infinitely great g-load is impossible since an infinitely great thrust is required and due to the g-load limitations. Therefore, the МиГ-25П aircraft is able to perform 360-deg steady banked turns at bank angles of up to 70° at non-reheat and reheat power settings of the engines.

When on a 360-deg banked turn, as the bank increases, pull the aircraft control stick backward to increase the attack angle so that the g-load corresponds to the bank. Simultaneously with the increase of the attack angle it is necessary to increase engine thrust so as to preserve constancy of speed.

In the course of a 360-deg steady banked turn the outer half-wing moves at a greater wing tip speed than the inner one, and the centre of pressure is displaced from the plane of symmetry towards the outer side, thereby producing an additional rolling moment. Therefore, the pilot should maintain the bank angle and manipulate the controls in a co-ordinated manner so as to avoid slipping. The greater the bank angle, the more exactly it should be kept since at great bank angles even its minor increase requires great rise of the vertical g-load. For example, increase of bank during a 360-deg banked turn from 70 to 75° requires increase of the g-load nearly by unity.

If the pilot does not increase the g-load in compliance with the bank, the lift vertical component appears to be less than the aircraft weight, and the flight path starts deviating downwards. When the vertical g-load is increased up to the required magnitude, the drag may overcome the thrust force and the 360-deg banked turn will be accomplished with deceleration.

Hence, exact bank holding is most important when performing a 360-deg banked turn.

If the relation between the bank and g-load is other than that specified in Table 1, the 360-deg banked turn path will go upwards (at an excessive g-load) or downwards (at an excessive bank).

Thrust limited 360-deg banked turns. Specific parameters of a 360-deg banked turn correspond to each magnitude of the available thrust at this or that altitude and airspeed of flight.

Increase of the bank angle (normal g-load) at a 360-deg co-ordinated turn should be accompanied by a growth of the aircraft lift which results in increase of drag. Increment in drag should be counteracted by increasing the thrust.

When the bank is being increased, the maximum available thrust of the engines will correspond to its certain magnitude.

Hence, the capabilities of the aircraft engines are the major limiting factor during performance of a thrust limited 360-deg banked turn.

Each airspeed and altitude value will be associated with definite bank angle and normal g-load values, which are also called thrust limited values.

If the pilot in performing a 360-deg banked turn pulls a g-load (banks the aircraft) in excess of the thrust limited value, the aircraft will lose speed even at full engine thrust. Therefore, the thrust limited g-load (bank) is the limit g-load (bank) involved in a continuous turn at the assigned airspeed.

The greater the available thrust, the greater will be the limit values of the bank angle and normal g-load.

Table 2

Characteristics of Thrust Limited 360-deg Banked Turns of Aircraft МиГ-25П Carrying No Missiles with Engines Running at MAXIMUM Power Setting

H, m	G_f, kgf	V_{IAS}, km/h																	
		550		600		650		700		750		800		850		900		950	
		n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o
500	11500	2.32	64.0	2.40	65.0	2.47	65.7	2.54	66.4	2.62	67.5	2.70	68.3	2.78	69.0	2.86	69.5	2.96	70.5
	8500	2.52	66.0	2.62	67.0	2.73	68.5	2.84	69.5	2.94	70.3	3.04	71.0	3.14	71.7	3.22	72.2	3.30	72.6
	5500	2.70	68.0	2.86	69.5	3.01	71.0	3.16	71.7	3.28	72.5	3.40	73.3	3.51	74.0	3.60	74.4	3.66	74.5
	2500	2.92	70.0	3.12	71.5	3.30	72.5	3.47	73.5	3.64	74.4	3.77	75.0	3.90	75.5	3.99	75.8	4.03	76.0
2000	11500	2.00	59.3	2.14	61.5	2.26	63.0	2.35	64.3	2.41	65.0	2.37	64.2	2.30	63.5	2.20	62.4	2.07	60.0
	8500	2.23	62.5	2.38	64.5	2.52	66.0	2.63	67.5	2.70	68.2	2.70	68.2	2.62	67.2	2.49	66.0	2.36	64.3
	5500	2.48	66.0	2.66	67.5	2.82	69.0	2.95	70.5	3.04	71.0	3.05	71.0	2.97	70.6	2.86	69.5	3.67	67.7
	2500	2.72	68.3	2.94	70.0	3.11	71.5	3.26	72.5	3.37	73.0	3.40	73.4	3.32	72.7	3.18	72.0	2.96	70.5
5000	11500	1.38	40.0	1.60	50.5	1.74	54.0	1.70	53.0	1.62	51.0	1.49	47.0	+	+	+	+	+	+
	8500	1.54	48.5	1.84	56.0	1.98	59.0	1.98	59.0	1.92	57.5	1.82	55.5	+	+	+	+	+	+
	5500	1.73	54.0	2.05	60.0	2.22	62.5	2.25	63.0	2.22	62.5	2.18	62.0	+	+	+	+	+	+
	2500	1.93	58.0	2.26	63.0	2.47	65.5	2.50	66.0	2.53	66.5	2.53	66.5	+	+	+	+	+	+
8000	11500	1.19	28.0	1.26	33.0	1.27	33.5	+	+	+	+	+	+	+	+	+	+	+	+
	8500	1.36	39.5	1.43	43.5	1.45	45.0	+	+	+	+	+	+	+	+	+	+	+	+
	5500	1.52	48.0	1.62	51.0	1.65	51.5	1.60	50.0	+	+	+	+	+	+	+	+	+	+
	2500	1.69	53.0	1.80	55.5	1.83	56.0	1.78	55.0	+	+	+	+	+	+	+	+	+	+

Note. In Tables 2 through 5 sign "+" means that the performance of the thrust limited 360-deg banked turn is impossible due to the thrust lack developed by the engines, while sign "X" designates that the accomplishment of the thrust limited 360-deg banked turn is impossible due to exceeding the maximum permissible g-load ($n_{y\,max}^{op}$).

Table 3

Characteristics of Thrust Limited 360-deg Banked Turns of Aircraft МиГ-25П Carrying No Missiles with Engines Running at FULL REHEAT Power Setting

2

H, m	G_f, kgf	V_{IAS}, km/h															
		750		800		850		900		950		1000		1050		1100	
		n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o
11000	8500	1.60	51.5	1.80	56.0	1.90	58.5	2.05	61.0	2.25	63.5	2.40	65.5	2.55	67.0	2.70	68.6
	6500	1.75	55.0	1.90	58.5	2.05	61.0	2.20	63.0	2.40	65.5	2.55	67.0	2.70	68.5	2.85	69.5
	4500	1.90	58.5	2.05	61.0	2.20	63.0	2.35	65.0	2.55	67.0	2.70	68.5	2.85	69.5	3.00	70.5
	2500	2.05	61.0	2.20	63.0	2.35	65.0	2.50	66.5	2.75	68.5	2.90	70.0	3.00	70.5	3.15	71.5
15000	6500	1.20	33.5	1.40	44.5	1.60	51.5	1.75	55.0	1.95	59.5	2.15	62.5	2.30	64.0	2.45	66.0
	4500	1.30	40.0	1.50	48.0	1.70	54.0	1.90	58.5	2.10	61.5	2.30	64.0	2.45	66.0	2.60	67.5
	2500	1.40	44.5	1.60	51.5	1.85	57.0	2.05	61.0	2.25	63.5	2.50	66.5	2.65	68.0	2.80	69.0
18000	6500	1.10	24.5	1.25	37.0	1.35	42.0	1.50	48.0	1.60	51.5	1.55	50.0	1.25	37.0	+	+
	4500	1.20	33.5	1.35	42.0	1.50	48.0	1.60	51.5	1.70	54.0	1.65	53.0	1.35	42.0	+	+
	2500	1.30	40.0	1.45	46.5	1.65	53.0	1.75	55.0	1.85	57.0	1.75	55.0	1.45	46.5	+	+
20000	6500	+	+	1.10	24.5	1.10	24.5	+	+	+	+	+	+	+	+	+	+
	4500	1.10	24.5	1.20	33.5	1.20	33.5	1.05	17.0	+	+	+	+	+	+	+	+
	2500	1.20	33.5	1.30	40.0	1.30	40.0	1.15	29.5	+	+	+	+	+	+	+	+

Table 4

Characteristics of Thrust Limited 360-deg Banked Turns of Aircraft МиГ-25П Carrying Four Missiles with Engines Running at MAXIMUM Power Setting

H, m	G_f, kgf	V_{IAS}, km/h 550		600		650		700		750		800		850		900		950	
		n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°	n_y	γ°
500	11500	1.95	59.5	2.10	61.5	2.20	63.0	2.30	64.0	2.35	65.0	2.40	65.5	2.30	64.0	2.20	63.0	2.00	60.0
	8500	2.15	62.5	2.30	64.0	2.40	65.5	2.50	66.5	2.55	67.0	2.60	67.5	2.50	66.5	2.40	65.5	2.20	63.0
	5500	2.35	65.0	2.50	66.5	2.65	68.0	2.75	68.5	2.80	69.0	28.5	69.5	2.80	69.0	2.70	68.5	2.40	65.5
	2500	2.65	68.0	2.80	69.0	2.95	70.0	3.15	71.5	3.20	72.0	3.25	72.0	3.15	71.5	3.05	70.5	2.70	68.5
2000	11500	1.85	57.0	1.95	59.5	2.05	61.0	2.10	61.5	2.15	62.5	2.15	62.5	2.10	61.5	1.90	58.5	1.40	44.5
	8500	2.05	61.0	2.15	62.5	2.25	63.5	2.30	64.0	2.40	65.5	2.40	65.5	2.30	64.0	2.05	61.0	1.55	50.0
	5500	2.25	63.5	2.35	65.0	2.50	66.5	2.55	67.0	2.65	68.0	2.65	68.0	2.65	67.0	2.30	64.0	1.75	55.0
	2500	2.50	66.5	2.65	68.0	2.80	69.0	2.90	70.0	2.95	70.0	2.95	70.0	2.85	69.5	2.55	67.0	2.00	60.0
5000	11500	1.25	37.0	1.40	44.5	1.55	50.0	1.65	53.0	1.65	53.0	1.45	46.5	+	+	+	+	+	+
	8500	1.35	42.0	1.55	50.0	1.70	54.0	1.80	56.0	1.80	56.0	1.60	51.5	+	+	+	+	+	+
	5500	1.50	48.0	1.70	54.0	1.90	58.5	2.00	60.0	2.00	60.0	1.80	56.0	+	+	+	+	+	+
	2500	1.70	54.0	1.95	59.5	2.15	62.5	2.25	63.5	2.25	63.5	2.00	60.0	+	+	+	+	+	+
8000	11500	1.05	17.0	1.10	24.5	1.05	17.0	+	+	+	+	+	+	+	+	+	+	+	+
	8500	1.15	29.5	1.20	33.5	1.15	29.5	+	+	+	+	+	+	+	+	+	+	+	+
	5500	1.30	40.0	1.35	42.0	1.30	40.0	1.10	24.5	+	+	+	+	+	+	+	+	+	+
	2500	1.45	46.5	1.50	48.0	1.45	46.5	1.20	33.5	+	+	+	+	+	+	+	+	+	+

Table 5

Characteristics of Thrust Limited 360-deg Banked Turns of Aircraft МиГ-25П Carrying Four Missiles with Engines Running at FULL REHEAT Power Setting

H, m	G_f, gf	V_{IAS}, km/h																									
		500		550		600		650		700		750		800		850		900		950		1000		1050		1100	
		n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o	n_y	γ^o
500	11500	2.45	66.0	2.70	68.5	3.05	70.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	8500	2.70	68.5	3.00	70.5	3.35	72.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5500	3.00	70.5	3.30	72.5	3.75	74.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	2500	3.40	73.0	3.70	74.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2000	11500	2.30	64.0	2.60	67.5	2.85	69.5	3.15	71.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	8500	2.50	66.5	2.85	69.5	3.15	71.5	3.45	73.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5500	2.80	69.0	3.15	71.5	3.50	73.5	3.85	75.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	2500	3.10	71.0	3.50	73.5	3.90	75.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5000	11500	2.10	61.5	2.30	64.0	2.50	66.5	2.70	68.5	3.00	70.5	3.20	72.0	X	X	X	X	2.65	68.0	2.55	67.0	2.50	66.5	2.45	66.0	2.40	66.5
	8500	2.30	64.0	2.50	66.5	2.70	68.5	2.95	70.0	3.30	72.5	3.60	74.0	X	X	X	X	2.90	70.0	2.80	69.0	2.75	68.5	2.70	68.5	2.65	68.0
	5500	2.55	67.0	2.75	68.5	3.00	70.5	3.20	72.0	3.65	74.0	X	X	X	X	X	X	3.25	72.0	3.10	71.0	3.05	70.5	3.00	70.5	2.95	70.0
	2500	2.85	69.5	3.10	71.0	3.35	72.5	3.70	74.5	X	X	X	X	X	X	X	X	3.65	74.0	3.45	73.0	3.40	73.0	3.35	72.5	3.30	72.5
8000	11500	1.65	53.0	1.85	57.0	2.10	61.5	2.30	64.0	2.35	65.0	1.85	57.0	1.80	56.0	1.90	58.5	1.95	59.5	2.00	60.0	2.05	61.0	2.10	61.5	2.15	62.5
	8500	1.85	57.0	2.05	61.0	2.30	64.0	2.50	66.5	2.60	67.5	2.05	61.0	2.00	60.0	2.05	61.0	2.15	62.5	2.20	63.0	2.25	63.5	2.30	64.0	2.35	65.0
	5500	2.00	60.0	2.25	63.5	2.55	67.0	2.80	69.0	2.85	69.5	2.25	63.5	2.20	63.0	2.30	64.0	2.35	65.0	2.40	65.5	2.50	66.5	2.55	67.0	2.60	67.5
	2500	2.25	63.5	2.55	67.0	2.85	69.5	3.10	71.0	3.20	72.0	2.55	67.0	2.50	66.5	2.55	67.0	2.65	68.0	2.70	68.5	2.80	69.0	2.85	69.5	2.90	70.0
11000	8500	+	+	1.65	53.0	1.40	44.5	1.35	29.5	1.45	46.5	1.50	48.0	1.60	51.5	1.70	54.0	1.85	57.0	1.95	59.5	2.10	61.5	2.15	62.5	2.20	63.0
	6500	+	+	1.75	55.0	1.50	48.0	1.45	46.5	1.55	50.0	1.60	51.5	1.70	54.0	1.80	56.0	1.95	59.5	2.10	61.5	2.20	63.0	2.25	63.5	2.30	64.0
	4500	+	+	1.90	58.5	1.60	51.5	1.55	50.0	1.65	53.0	1.70	54.0	1.80	56.0	1.90	58.5	3.10	61.5	2.25	63.5	2.35	65.0	2.40	65.5	2.45	66.0
	2500	+	+	2.05	61.0	1.75	55.0	1.70	54.0	1.80	56.0	1.85	57.0	2.00	60.0	2.10	61.5	2.30	64.0	2.45	66.0	2.60	67.5	2.65	68.0	2.70	68.5
15000	6500	+	+	+	+	+	+	+	+	+	+	1.15	29.5	1.30	40.0	1.50	48.0	1.65	53.0	1.80	56.0	2.00	60.0	2.15	62.5	2.15	62.5
	4500	+	+	+	+	+	+	+	+	+	+	1.25	37.0	1.40	44.5	1.60	51.5	1.75	55.0	1.95	59.5	2.15	62.5	2.35	65.0	2.35	65.0
	2500	+	+	+	+	+	+	+	+	+	+	1.35	42.0	1.55	50.0	1.75	55.0	1.90	58.5	2.10	61.5	2.35	65.0	2.50	66.5	2.50	66.5
18000	6500	+	+	+	+	+	+	+	+	+	+	1.05	17.0	1.15	29.5	1.30	40.0	1.40	44.5	1.55	50.0	1.55	50.0	1.40	44.5	+	+
	4500	+	+	+	+	+	+	+	+	+	+	1.10	24.5	1.25	37.0	1.40	44.5	1.55	50.0	1.65	53.0	1.65	53.0	1.50	48.0	+	+
	2500	+	+	+	+	+	+	+	+	+	+	1.20	33.5	1.35	42.0	1.50	48.0	1.65	53.0	1.80	56.0	1.80	56.0	1.60	51.5	+	+
20000	6500	+	+	+	+	+	+	+	+	+	+	+	+	1.05	17.0	1.10	24.5	1.05	17.0	+	+	+	+	+	+	+	+
	4500	+	+	+	+	+	+	+	+	+	+	+	+	1.15	29.5	1.20	33.5	1.15	29.5	+	+	+	+	+	+	+	+
	2500	+	+	+	+	+	+	+	+	+	+	1.10	24.5	1.25	37.0	1.30	40.0	1.25	37.0	+	+	+	+	+	+	+	+

The use of the augmented power settings of the engines makes it possible to considerably increase the available engine thrust, thereby to obtain the greater limited g-loads.

Thrust limited 360-deg turns at augmented power setting can be executed at a smaller radius and within a shorter time than at the MAXIMUM (МАКСИМАЛ) power setting.

Presented in Tables 2 through 5 are the thrust limited bank angles and respective normal g-loads of the МиГ-25П aircraft carrying four missiles or carrying no missiles, at various fuel remainders, altitudes and indicated airspeeds, in standard atmpsphere conditions, with the engine running at the MAXIMUM and FULL REHEAT power settings.

It is seen from the above tables that during engine operation at the MAXIMUM power setting within the entire range of altitudes and airspeeds of the МиГ-25П aircraft carrying four missiles (or carrying no missiles) with any fuel remainder the thrust limited normal g-load in a 360-deg turn will not exceed the maximum operational g-load. At FULL REHEAT power setting, with the aircraft proceeding at low and medium altitudes, the thrust limited normal g-load, depending on the fuel remainder, will reach the maximum operational value at indicated airspeeds of 600 to 650 km/h, but at high altitudes and in stratosphere the thrust limited normal g-load does not exceed the maximum operational g-load.

Thus, the МиГ-25П aircraft permits performing the thrust limited 360-deg banked turns at the MAXIMUM power setting within the entire range of altitudes and airspeeds and at the FULL REHEAT power setting at high altitudes and in the stratosphere, irrespective of the fuel remainder. The range of execution of thrust limited 360-deg banked turns at low and medium altitudes, with the engines running at FULL REHEAT power setting, is narrowed due to the aircraft g-load limitations.

The radius of a 360-deg banked turn (in m) is determined from the following formula:

$$r_{b.turn} = \frac{V^2_{b.turn}}{g\ tg\,\gamma}$$

or

$$r_{b.turn} = \frac{V^2_{b.turn}}{g\sqrt{n_y^2 - 1}}.$$

It is evident that the radius of a 360-deg banked turn is directly proportional to the square of the speed and inversely proportional to the tangent of the bank angle (magnitude $\sqrt{n_y^2 - 1}$).

The higher speed on a 360-deg banked turn, the greater will be the radius and vice versa. At a constant airspeed the greater g-load is associated with the smaller radius of a 360-deg turn.

The time required for accomplishing a 360-deg banked turn is determined as a relation between the flightpath length and speed of flight:

$$t_{b.turn} = \frac{2\pi\, r_{b.turn}}{V_{b.turn}} = \frac{2\pi\, V^2_{b.turn}}{g\, V_{b.turn}\, tg_\gamma} = 0.64\, \frac{V_{b.turn}}{tg_\gamma}$$

or $$t_{b.turn} = 0.64\, \frac{V_{b.turn}}{\sqrt{n_y^2 - 1}}.$$

It is more convenient to use the first formula when the bank angle is known, and the second formula when the g-load is known.

The МиГ-25П aircraft is a high-altitude high-speed interceptor with a small maximum permissible operational g-load. Therefore, the turns and 360-deg banked turns at high indicated airspeeds are characterized by considerable time and radius required for their accomplishment.

Acceleration of the aircraft occurs under the action of positive thrust excess. The greater the thrust at a constant weight the faster will be acceleration.

Intensity of acceleration is characterized by the rate of longitudinal acceleration:

$$j_{long} = g\, \frac{P - Q}{G} = g n_x.$$

If acceleration takes place in the inclined plane, its intensity is affected by acceleration produced by the weight longitudinal component (positive acceleration in descent and negative one in climb):

Then the total acceleration is as follows:

$$j_{long} = g n_x \pm g \sin \Theta = g\,(n_x \pm \sin \Theta),$$

where: g is the free fall acceleration;

Θ is the flightpath angle of inclination.

The time of acceleration and the distance covered are determined by the following formulas:

$$t_{acc} = \frac{V_{end} - V_{start}}{j_{mean\ long}}; \quad S = V_{mean}\, t_{acc}.$$

Figs 15 and 16 present acceleration characteristics of the МиГ-25П aircraft carrying four missiles at the FULL REHEAT power setting for altitudes of 8 and 18 km, respectively.

The МиГ-25П aircraft has a great power-to-weight ratio and it may rather easily exceed the IAS and Mach-number limitations. Especially it is typical for altitudes of up to 5000 m. In level flight at these altitudes, with the engines running at the FULL REHEAT power setting, at an IAS of nearby 1000 km/h the speed increment amounts to 15 - 20 km/h for 1 sec.

Behaviour of the МиГ-25П aircraft during acceleration within the entire range of the operational altitudes and airspeeds does not have peculiarities, but at M = 0.85 - 1.15 the aircraft experiences a certain instability in speed.

Angle-of-attack stability (when exceeding M = 1 during acceleration) materially increases due to considerable displacement of the aerodynamic centre backwards.

Deceleration of the aircraft is effected due to negative thrust excess which may be attained when disengaging the afterburners, throttling the engines at reheat and non-reheat power settings and extending the air brakes.

When extending the air brakes the aircraft trim somewhat varies. When only the upper air brake is extended, a nose-up moment appears, which may be counteracted by moving the control stick forward.

During deceleration when passing the sonic speed, a nose-up moment also arises, which results in spontaneous increase of the g-load with the control stick fixed. To keep the g-load constant within the specified range of Mach-numbers push the control stick forward.

When flying at M > 2.2 it is prohibited to throttle the engines lower the MAXIMUM stop since unsteady operation of the air-intakes and unsteady running of the power plant may occur. When flying at M < 2.2 it is allowed to throttle down the engines up to the IDLE (МАЛЫЙ ГАЗ) stop.

3. MANEUVERABILITY OF AIRCRAFT IN VERTICAL PLANE

The major maneuvers in the vertical plane permitted for the МиГ-25П aircraft are: zoom, diving and chandelle.

Curving of the flight path in the vertical plane takes place as a result of the centripetal force affecting upon the aircraft:

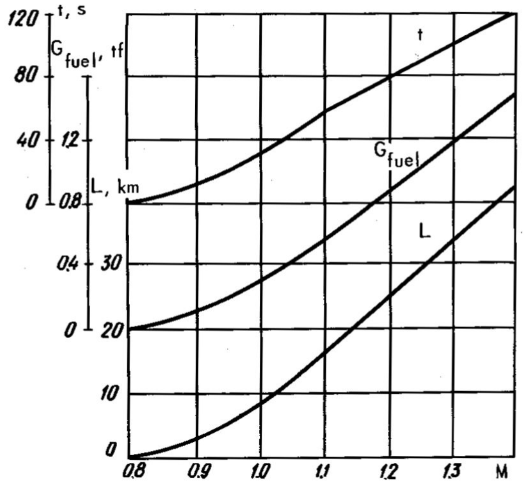


FIG. 15. ACCELERATION CHARACTERISTICS OF AIRCRAFT CARRYING FOUR MISSILES AT FULL REHEAT POWER SETTING (H=8000 m, G=30 tf)

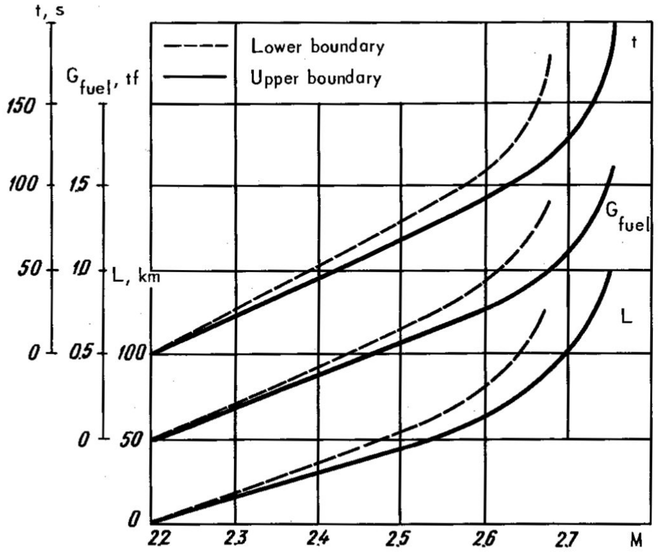


FIG. 16. ACCELERATION CHARACTERISTICS OF AIRCRAFT CARRYING FOUR MISSILES AT 2ND FULL REHEAT (H=18,000 m, G=25 tf, n_{en}=100%)

$$R_{c.f} = Y - G \cos \Theta,$$

where: Y is the aircraft lift force;

G is the aircraft weight;

Θ is the flight-path inclination angle.

The flight path curvature depends on a relation between the vertical g-load and cosine of the flight-path angle.

A zoom is a maneuver accomplished to reduce the time of climbing to the assigned altitude, as well as to intercept the targets flying at altitudes higher than that of an interceptor.

When the engine thrust is less or equal to the drag, the aircraft gains the altitude only at the expense of kinetic energy, i.e. due to loss of the speed at the zoom.

The МиГ-25П aircraft enters the zoom from level flight by applying the maximum permissible g-load at the reheat power settings of the engines.

Upon attaining the assigned angle of zoom the pilot maintains it until the recovery speed is reached. The greater the zoom angle, the higher should be the speed of recovery. Fig. 17 presents the zoom limit angles during the aircraft entry into the zoom at an airspeed close to the maximum permissible speed versus altitude of flight, while the indicated airspeeds of the zoom recovery are given in Fig. 18. In all cases, the recovery start speed is selected so as to bring the aircraft into the level flight at an airspeed which is not lower than the maneuvering one.

When the МиГ-25П aircraft performs zooms at limit angles with or without four missiles, the altitude gain with the entry effected from altitudes of 500 to 1000 m amounts to 6000 - 6500 m and 2500 to 3000 m from altitudes of 17,000 to 17,500 m.

It is recommended to recover the aircraft from the zoom by making a 90-deg turn or two successive half-rolls. Straight-flight recovery from the maneuver is accomplished at low climb angles only.

A dive is used for intensive loss of the altitude and aircraft acceleration by transforming its potential energy into kinetic one.

The МиГ-25П aircraft may be brought into a dive at angles of up to 45° from a turn, with the engines running at idle power setting.

When entering the maneuver from a turn the positive g-load prevents the flight path from curving down to a lesser extent.

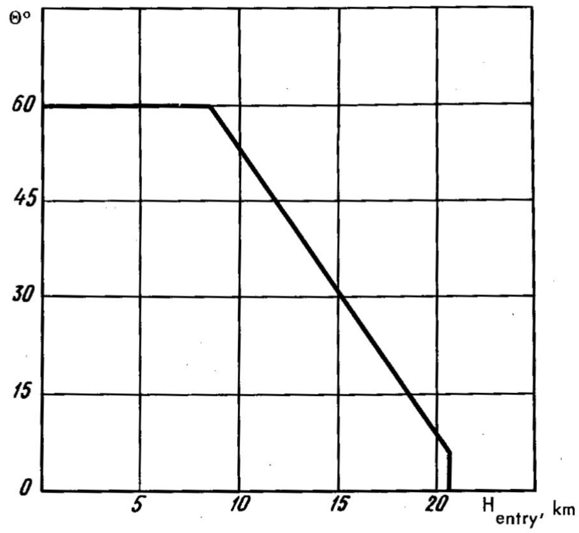


FIG. 17. LIMIT ZOOM ANGLES Θ VERSUS ALTITUDE OF FLIGHT (altitude of zoom entry H_{entry}).

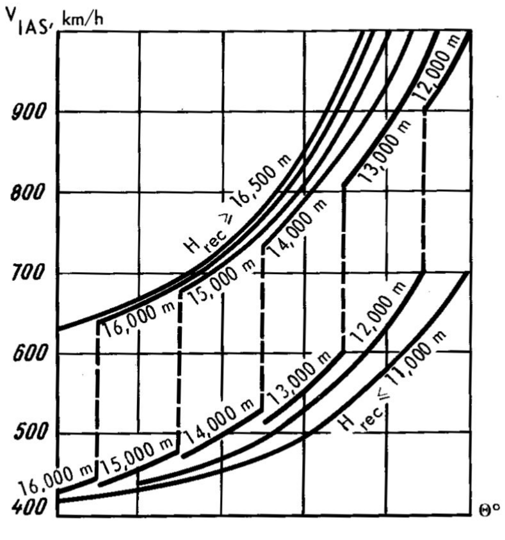


FIG. 18. INDICATED AIRSPEED V_{IAS} OF ZOOM RECOVERY INITIATION VERSUS ANGLE OF ZOOM Θ AND ALTITUDE OF RECOYERY INITIATION H_{rec}

Roll and turn involved in the dive entry maneuver not only allow to avoid the negative g-loads but make the entry more energetic. Intensity of the aircraft speed acceleration in the course of entry slows down appreciably either due to time shortening or due to increase of the drag initiated by a growth of the normal g-load. Besides, entry into the dive performed from a turn provides for a number of tactical advantages and allows the pilot to observe the target continuously.

When carrying out practical calculations of the vertical maneuvers involving climbing to the assigned altitude, it is most important to determine loss of altitude during dive recovery, especially when the maneuver is terminated at low and extreme low altitudes (Fig. 19).

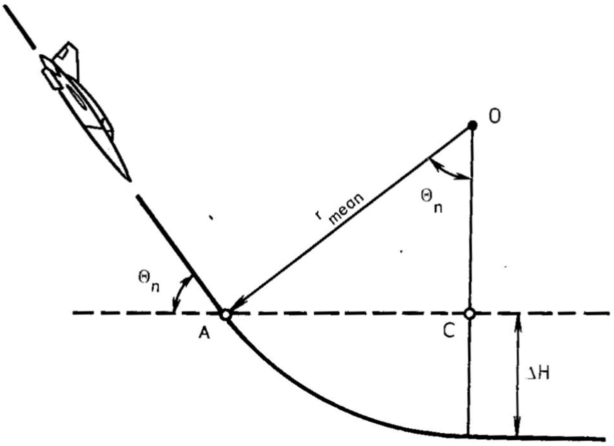


FIG. 19. DETERMINING LOSS OF ALTITUDE ΔH DURING RECOVERY FROM DIVE

Curvature radius r_{mean} of the flight path at dive recovery may be determined from the following formula:

$$r_{mean} = \frac{V^2_{aver}}{g\,(n_{y\,mean} - \cos \Theta_{mean})},$$

where: V_{aver} is the average speed at dive recovery (it is assumed equal to the recovery start speed);

$\Theta_{mean} = \frac{\Theta_{dive}}{2}$ is the mean angle at dive recovery.

Loss of altitude during the recovery from a dive is determined from the formula:

$$\Delta H = r_{mean} - r_{mean} \cos \Theta_{dive} = \frac{V_A^2 (1 - \cos \Theta_{dive})}{g (n_{y\ mean} - \cos \frac{\Theta_{dive}}{2})},$$

where: Θ_{dive} is the maximum dive angle;
V_A is the recovery start speed.

It is evident from the formula that the lower the speed at the beginning of recovery and the greater the mean g-load, the lesser will be loss of altitude during recovery from a dive.

The recovery from the dive of the МиГ-25П aircraft should be performed at an airspeed which is 100 to 150 km/h below the maximum permissible speed since energetic speed increment occurs in the course of dive recovery.

For the aircraft having no stabilizer differential control system a speed of recovery should not exceed 850 km/h.

Aircraft recovery from a dive is effected at a maximum permissible g-load applied within 3 to 5 s.

When recovery from a dive is accomplished at an angle of 45^{o} at altitudes of 3000 to 2500 m, altitude loss reaches 1500 m.

When recovering the aircraft from a dive with deceleration up to $M \approx 1.0$, the aircraft experiences tuck-in which is easily counteracted by applying the control stick forward.

AIRCRAFT STABILITY AND CONTROLLABILITY

The aircraft s t a b i l i t y is an ability of an aircraft to maintain the preset flight regime independently without interference of the pilot.

The c o n t r o l l a b i l i t y is an ability of an aircraft to respond to deflection of the aircraft controls, i.e. to change the initial flight regime.

The stability and controllability are closely associated with each other and in practice both of them are judged by referring to one and the same criteria.

To ensure simple, handy and accurate piloting, the stability and controllability characteristics should be within the specified limits set forth for each type of the aircraft.

The aircraft stability is integrally connected with its trimming, i.e. counteracting all the moments affecting the aircraft. Equilibrium is considered relative to three axes passing through the centre of gravity and in this connection equilibrium is divided into equilibrium about pitching axis, equilibrium about rolling axis and equilibrium about yawing axis.

Under the action of various factors (atmospheric turbulence, accidental deflection of the control surfaces followed by their recovery, etc.) the aircraft equilibrium may be disturbed.

An ability of the aircraft to create stabilizing moments tending to restore equilibrium disturbed are referred as static stability.

Equilibrium is not restored gradually since it is associated with the aircraft oscillation which results in the inertia and damping moments. At a certain combination of these moments the aircraft may not restore its equilibrium. In case of adequate damping the aircraft oscillation is dampered rapidly and the initial equilibrium is restored. An ability of the aircraft to restore the initial equilibrium is usually called as dynamic stability.

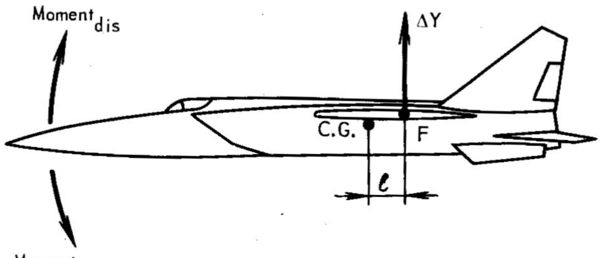
When analyzing stability and controllability, the motion of the aircraft is divided into longitudinal and lateral ones. In some particular cases there is an intimate cooperation between these motions. In this case such conventional division is impermissible.

1. LONGITUDINAL STABILITY AND CONTROLLABILITY

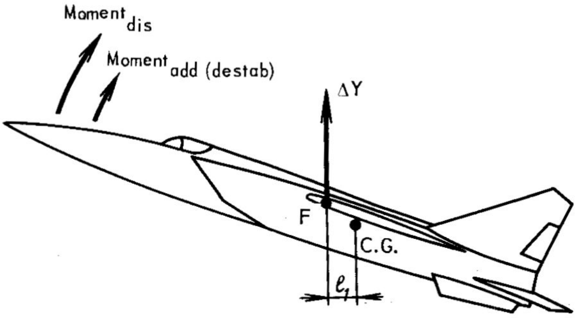
Aerodynamic forces and moments of the aircraft longitudinal motion are determined by an angle of attack (g-load) and flight airspeed. Under the action of various disturbing factors upon the aircraft, the above parameters vary in flight: an angle of attack (g-load) changes more rapidly than an airspeed. Since these parameters vary in a different way and not simultaneously, it is very important to know how the aircraft responds to a change of each of them. The aircraft longitudinal stability is distinguished respectively by angle-of-attack and speed stability.

Angle-of-attack stability. The aircraft is considered stable in angle-of-attack if in case the longitudinal stability is disturbed it has a tendency to retain the initial flying regime g-load at a constant airspeed without pilot's interference.

Angle-of-attack stability is determined by a position of the aircraft aerodynamic centre relative to the aircraft C.G. position. If the aerodynamic centre is behind the aircraft C.G., the aircraft is stable in angle of attack since in case of inadvertent variation of the attack angle, aerodynamic forces and their moments occur. These forces and moments contribute to the restoration of the initial attitude (Fig. 20, a). If the aerodynamic centre is ahead of the C.G., the aircraft is unstable in angle of attack since in case the longitudinal equilibrium is disturbed a destabilizing moment arises. This moment contributes to greater deviation of the aircraft from the initial attitude (Fig. 20, b).



a



b

FIG. 20. AIRCRAFT ANGLE-OF-ATTACK STABILITY

a – steady aircraft; b – unsteady aircraft

The major criterion used for evaluating the longitudinal stability of the aircraft is the angle-of-attack longitudinal static stability margin which determines the distance between the aerodynamic centre and the aircraft C.G. expressed in per cent (fractions) of the wing mean aerodynamic chord (MAC):

$$\bar{X}_{c.g.} - \bar{X}_F,$$

where: $\bar{X}_{c.g.}$ and $\bar{X}_F$ are the co-ordinates of the aircraft C.G. and aerodynamic centre, respectively, expressed in relative unities: fractions or per cent of MAC.

If the angle-of-attack stability minimum margin is negative and it is within a range of 3 through 12 - 15 per cent MAC, the aircraft is considered stable and controllable.

The position of the aerodynamic centre of the МиГ-25П aircraft carrying four missiles (with the engines running) versus Mach-number is presented in Fig. 21. It is evident from the chart that the aircraft flying within the range of subsonic airspeeds (up to M = 0.8) has a minimum angle-of-attack stability margin of 2.25 per cent MAC. It proves that the aircraft stability within these airspeeds is insufficient.

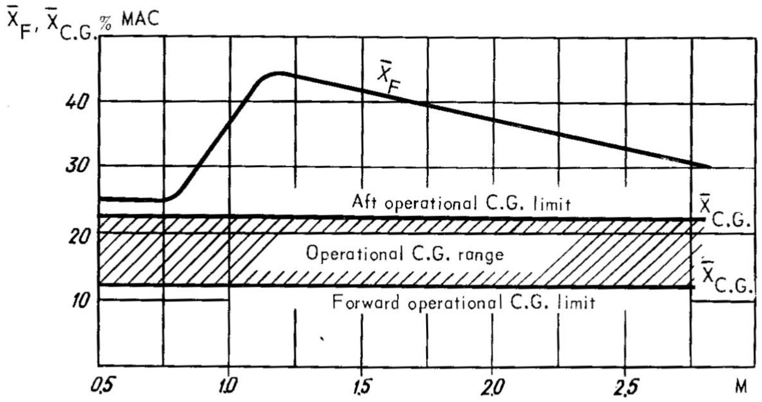


FIG. 21. DISPLACEMENT OF GROSS AERODYNAMIC CENTRE X_F VERSUS MACH NUMBER OF FLIGHT (the aircraft carries four missiles, with engines running)

At further increase of the Mach-number the minimum angle-of-attack stability margin essentially increases due to considerable displacement of the aircraft aerodynamic centre backward. At M = 1.2 the minimum angle-of-attack stability margin may reach 23.5 per cent MAC which indicates that there is an excess of the angle-of-attack stability margin. Within the range of high supersonic speeds due to a wing twist and increase of lifting ability of its root section the aerodynamic centre starts moving forward and the angle-of-attack stability margin decreases. At M = 2.8 it amounts to 8.5 per cent MAC.

It is necessary to take into account that the actual angle of attack stability margin is considerably higher than the minimum one, since a take-off of the aircraft carrying a great amount of fuel and flight within the range of subsonic speeds with great fuel remainders result in increase of actual angle-of-attack stability margin up to 8 - 10 per cent MAC.

Engagement of the pitch damper also entails increase of the angle-of-attack stability margin which is experienced by the pilot by increase of the required deflection of the control stick when pulling a g-load.

The minimum angle-of-attack stability margin with the pitch damper engaged in the pre-landing gliding conditions at aft C.G. operational limit amounts to 2.8 per cent MAC.

Variation of the angle-of-attack stability margin with due account for fuel utilization at subsonic speeds, with the pitch damper engaged, is shown in Fig. 22.

It is evident from the above said that the МиГ-25П aircraft carrying permissible external stores or carrying no external stores features adequate angle-of-attack stability within the entire range of operational airspeeds and altitudes of flight. This fact proves the nature of trimming ratios of stabilizer deflection versus lift coefficient at constant Mach-numbers (Fig. 23). Negative inclination of the curves proves that the aircraft possesses adequate angle-of-attack stability.

Jettison of missiles carried by the МиГ-25П aircraft results in increase of angle-of -attack stability margin both due to displacement of the aircraft C.G. forward and due to displacement of the aerodynamic centre backward. In this case an additional nose-down moment is originated, which is counteracted by deflecting the control stick backward.

<u>Velocity stability.</u> The aircraft is considered to be stable with respect to velocity if it tends to maintain the initial airspeed of flight independently, without interference of the pilot.

Generally, variation of the flight speed is determined not only by thrust forces P and drag Q, but also by weight component $G \sin \Theta$, depending on a flight-path angle (Fig. 24).

A change of the airspeed involves variation of P and Q, while $G \sin \Theta$ does not depend directly from the airspeed. It will change only in case of variation of the flight-path angle which, in turn, depends on variation of forces acting along axis Y, i.e. lift force (we assume that the aircraft weight is constant). For example, if as the airspeed increases the lift also increases and exceeds the weight of the aircraft, the aircraft will curve its trajectory and proceed with climbing. And vice versa, decrease of the lift associated with drop of the speed results in a descent of the aircraft.

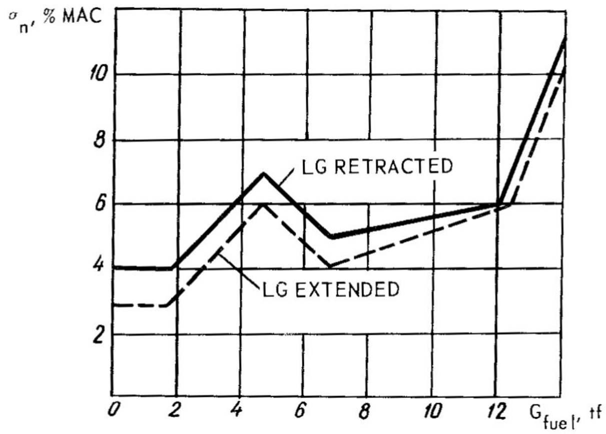


FIG. 22. VARIATION OF AIRCRAFT STABILITY MARGIN WITH RESPECT TO G-LOAD σ_n WITH FUEL UTILIZATION TAKEN INTO ACCOUNT (PITCH DAMPER IS DISENGAGED, AIRCRAFT CARRIES FOUR MISSILES, $M_{act} = 0.8$)

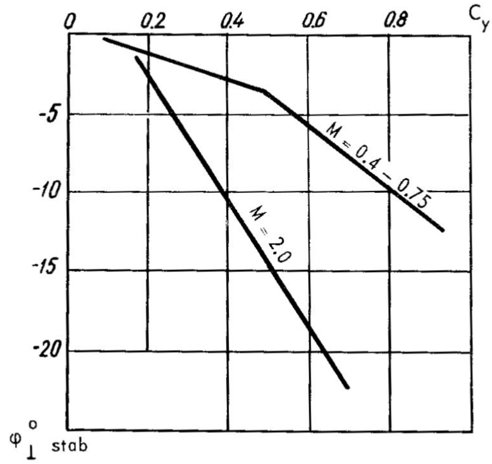


FIG. 23. TRIMMING RELATIONS BETWEEN DEFLECTIONS OF STABILIZER AND LIFT COEFFICIENT. AIRCRAFT CARRIES FOUR MISSILES ($\bar{X}_{C.G.}$=19% MAC, G=30 tf)

In the first case component G sin Θ is directed backward, i.e. it tends to decrease the airspeed, whereas in the second case it is directed forward, i.e. it tends to accelerate the aircraft up to the initial airspeed. Practical calculations prove

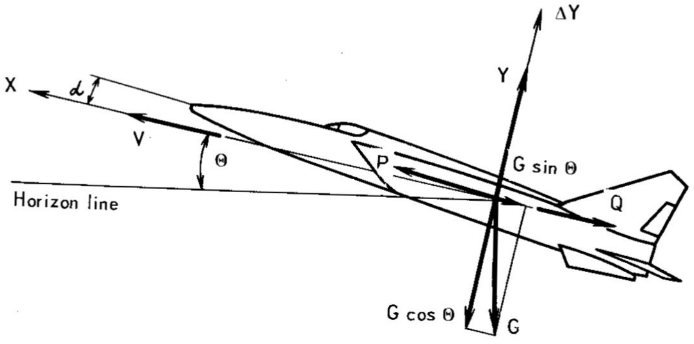


FIG. 24. DIAGRAM OF FORCES ACTING UPON AIRCRAFT IN FLIGHT

that force G sin Θ produces a greater effect on variation of the speed than forces P and Q. But since it is the lift which controls variation of the flight-path angle, finally the velocity stability is determined by the nature of lift variation with respect to airspeed: if the lift force grows as the flight airspeed increases and vice versa, the aircraft features adequate velocity stability.

The aircraft possesses velocity stability if in level flight as the airspeed increases the control stick deflects forward to ensure longitudinal trim (decrease of pull forces or increase of push forces). If the pilot has to pull the aircraft control stick backward (as the airspeed increases in the level flight to provide longitudinal trim (increase of pull forces or decrease of push forces), the aircraft features inadequate velocity stability.

The aircraft velocity stability may be judged by the curves illustrating relation between the stabilizer deflection angles versus Mach-number and the altitude of flight (Fig. 25).
It is evident from the curves that the МиГ-25П aircraft features adequate velocity stability within the entire range of operational altitudes and airspeeds of flight except M = 0.85 to 1.15 where an insignificant instability occurs which does not practically exert an effect on piloting technique in the level flight.

Velocity instability within the given range of flight airspeeds is explained by energetic displacement of the aerodynamic centre backward which creates a nose-down moment. In this case the aircraft trimming is disturbed and the aircraft starts decreasing an angle of attack. It results in decrease of the lift force coefficient. As a result, irrespective of the speed increase the lift force decreases and the aircraft starts descending, tending to increase the airspeed more materially.

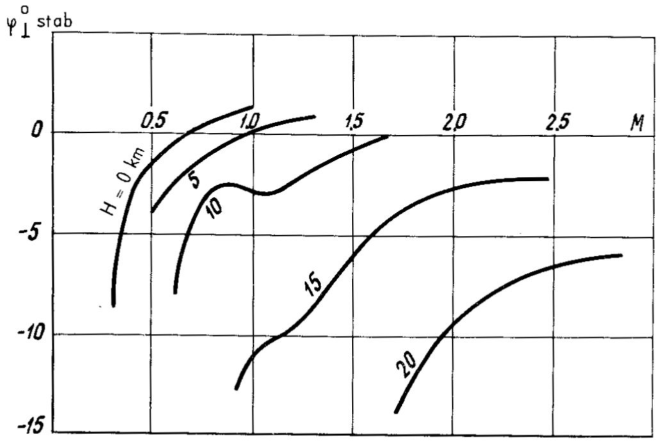


FIG. 25. DIAGRAM OF STABILIZER DEFLECTION ANGLES $\varphi_{\perp st}$ REQUIRED FOR STRAIGHT-AND-LEVEL FLIGHT VERSUS MACH NUMBER. AIRCRAFT CARRIES FOUR MISSILES ($\bar{X}_{C.G.}$= 19% MAC, G=30 tf)

When the Mach-number decreases from 1.15 to 0.85 the aerodynamic centre will move forward, the aircraft will experience a nose-up moment which increases the angle of attack. As a result, the aircraft starts climbing and loses airspeed more materially. Thus, within the range of M = 0.85 to 1.15 the МиГ-25П aircraft has a minor velocity instability.

The disturbed motion of the aircraft instable in velocity in contrast to the aircraft which features inadequate angle-of-attack stability always develops slowly and the pilot has enough time to interfere with the aircraft control and counteract the disturbances originated by an appropriate deflection of the control stick. Experience proves that small degrees of velocity instability involve some difficulties for the pilot in the process of tight flying only and practically they are not always noticed by the pilot during ordinary control of the aircraft.

But during deceleration of the МиГ-25П aircraft a speed pick-up may occur when passing the sonic speed range, which results in increase of the g-load even if the control stick is fixed. A speed pick-up is caused by:

(a) abrupt decrease of the angle-of-attack stability margin during deceleration due to displacement of the aerodynamic centre forward in the course of transition from the supersonic wing flow to subsonic one;

(b) restoration of the stabilizer effectiveness at Mach-numbers less than 1.0 (local supersonic zones disappear on the stabilizer surface);

(c) barometric instrument indication lag and, hence, the pilot response lag during transition from the supersonic speeds to the subsonic speeds of flight.

The pick-up intensity is determined by a rate of the aircraft deceleration and magnitude of the vertical g-load during deceleration when M = 1.0 is being passed.

When the aircraft is being decelerated in the level flight and descent, the effect of the speed pick-up practically is not evident. The pilot of the МиГ-25П aircraft clearly senses the pick-up effect when recovering from a dive with deceleration up to M = 1.

In case of excessive back stick pressure during entering into or recovering from vertical maneuvers, energetic maneuvering (chandelle, banked turn) performed within the range of the subsonic airspeeds of flight, the aircraft may experience a stall pick-up as inadvertent increase of the g-load with the control stick fixed.

The nature of this effect consists in that when the aircraft attains the above-mentioned flight regimes the outer wing tip stall occurs. As a result, the aerodynamic centre displaces forward and is found to be ahead of the aircraft C.G., thus motivating angle-of-attack instability and inadvertent tendency for increase of g-load by 1.5 to 1.7 per second.

Undue detection of this effect may result in excess of the g-load exceeding the permissible value for 2 to 3 s. Therefore, to avoid the stall pick-up, control the aircraft by smooth coordinated motions taking care not to overpull the control stick (to avoid the supercritical angles of attack). Besides, the pilot should constantly follow the readings of the ИП-155 g-load indicator.

Longitudinal controllability. The more stable the aircraft with reference to g-load, the greater deflection of the control surfaces and required forces are required to recover the aircraft from equilibrium and vice versa.

The basic characteristics of the aircraft controllability are the relations between control stick travel x^{n_y} and forces P^{n_y} required fcr increasing the g-load per unity versus the Mach-number of flight (Figs 26 and 27). Both characteristics depend on effectiveness of the stabilizer under specific conditions of flight.

The peculiarity of the МиГ-25П aircraft longitudinal controllability is a presence of great forces applied to the control stick in a number of the flight conditions, which are determined by the characteristics of the artificial feel unit and the АРУ automatic transmission ratio controller. Great forces applied to the control stick are selected so as to ensure flight safety at high indicated airspeeds at low and medium altitudes of flight. Decrease of forces applied to the control stick may result in inadvertent excess of strength-permitted g-load in a number of the flight regimes or undesirable hunting at high subsonic speeds and medium altitudes with the aircraft aft C.G. position.

When maneuvering at high supersonic speeds the time required for accomplishing the assigned maneuver is the determining factor since even at small forces (8 to 10 kgf) the pilot feels fatigue after 30 - 40 s. Therefore, even small forces applied to the control stick are recommended to be released by means of the trimming mechanism.

Engagement of the pitch dampers increases the required deflections of the control stick when pulling the g-load. In so doing, the required forces also increase.

Depending on the flight conditions, stabilizer deflection angles $\varphi_{st}^{n_y}$ and $\varphi_{st}^{C_y}$ required for increasing the g-load and lift coefficient by unity vary within the wide range (Figs 28 and 29). The particularly great variation of the required angles of the stabilizer deflection is experienced during transition from the subsonic speed to the supersonic speed. This fact is explained by an essential increase of the angle-of-attack stability margin.

In the flight configuration (with the landing gear and flaps retracted) at M = 0.5 to 0.6 the МиГ-25П aircraft may experience the nearstall angles of attack at $C_y \approx 0.7$, whereas in the take-off configuration (with the landing gear and flaps extended) the nearstall angles of attack will be attained at $C_y \approx 0.78$ at the

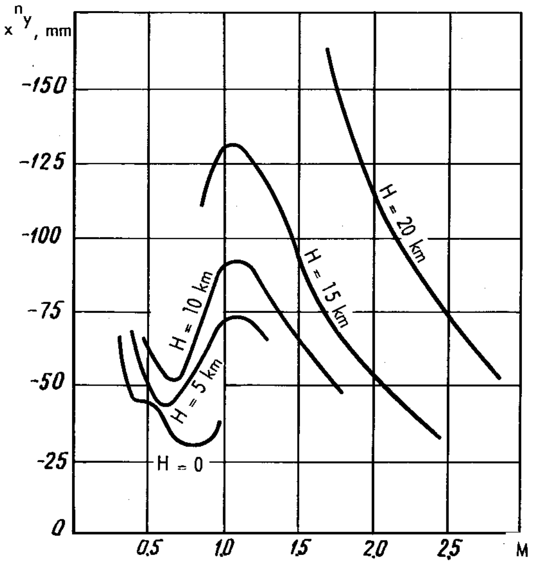


FIG. 26. DIAGRAM OF STICK TRAVEL x^{n_y} REQUIRED FOR PRODUCING G-LOAD OF 1 G VERSUS MACH NUMBER. AIRCRAFT CARRIES FOUR MISSILES ($\bar{X}_{C.G.}$=19% MAC, G=30 tf)

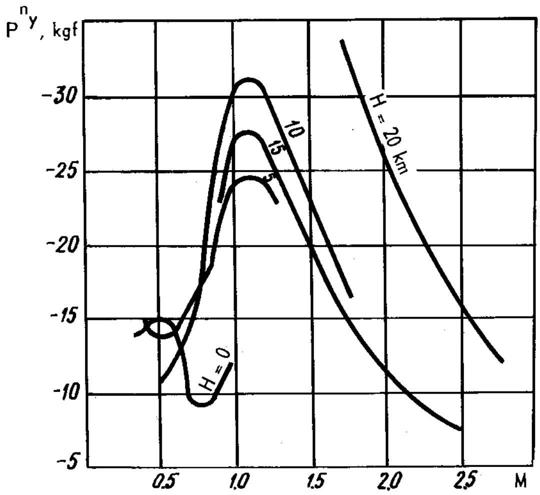


FIG. 27. DIAGRAM OF STICK FORCE P^{n_y} REQUIRED FOR PRODUCING G-LOAD OF 1G VERSUS MACH NUMBER. AIRCRAFT CARRIES FOUR MISSILES ($\bar{X}_{C.G.}$=19% MAC, G=30 tf)

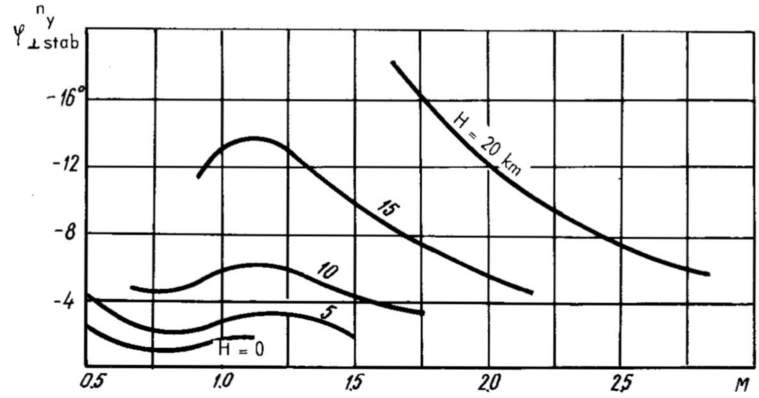


FIG. 28. DIAGRAM OF STABILIZER DEFLECTION ANGLES $\varphi^{n}_{\perp y}$ REQUIRED FOR PRODUCING G-LOAD OF 1G VERSUS MACH NUMBER. AIRCRAFT CARRIES FOUR MISSILES ($\bar{X}_{C.G.}$= 19% MAC, G= 30 tf)

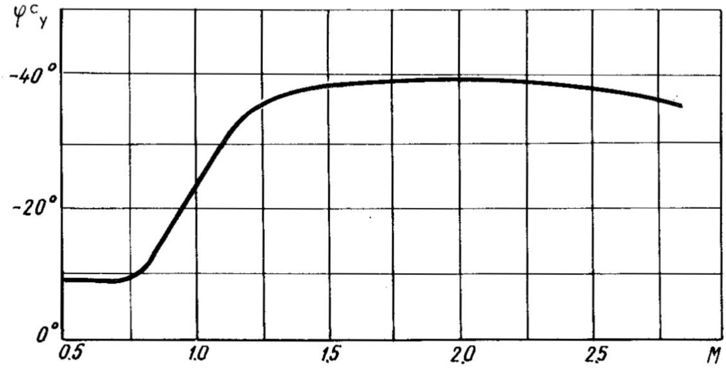


FIG. 29. VALUE $\varphi^{c}{}_{y}$ VERSUS MACH NUMBER (AIRCRAFT CARRIES FOUR MISSILES)

same Mach-numbers. Attaining the nearstall angles of attack is accompanied by perceptible stall-warning buffeting and great travels of the control stick.

At supersonic airspeeds of flight, attainment of great angles of attack and maximum available g-loads is possible only at full deflections of the control stick backward.

Combination of the aerodynamic characteristics of the flat air intakes and the wing results in displacement of the aircraft aerodynamic centre at high supersonic airspeeds. Displacement of the aerodynamic centre forward decreases the magnitude of the longitudinal static stability margin at high supersonic airspeeds and compensates drop of effectiveness of the longitudinal control as the Mach-number increases. It enables the pilot to trim the aircraft at great angles of attack and obtain the high lift coefficient (0.5 - 0.6) at Mach-numbers close to the limit values.

At $M > 2.0$ when pulling g-loads exceeding 2 to 2.5 (depending on an altitude and airspeed of flight), a vortex sheet effect appears caused by an unsteady boundary layer in the nose fuselage.

An unsteady boundary layer, associating with the air intake, entails high-frequency vibrations of the fuselage structure. These oscillations are sensed by the pilot as a drone or buzz. Besides, due to increase of losses in the air intake ducts the aircraft starts decelerating.

The characteristics of stability and controllability of the aircraft in case of a vortex sheet practically do not change.

Practically, the behaviour of the aircraft at low and medium altitudes, as well as during take-off and landing does not differ from the behaviour of the aircraft of other types.

Launching of missiles, extension of the landing gear, variation of the engine power setting do not appreciably affect the longitudinal stability and controllability of the aircraft.

Deployment of two brake parachutes at $M > 1.5$ results in minor nose-up moment.

At $M < 1.5$ only the upper air brake is extended. When the upper air brake is extended at transonic airspeeds vibration of the rudders may occur. It may be caused by unsteady local transonic flow between the fins. Therefore, it is prohibited to extend the upper air brake at altitudes lower 7000 m within the Mach-numbers of 0.85 to 1.1.

It is necessary to remember that under certain conditions the МиГ-25П aircraft may experience pitching oscillation.

Pitching oscillation may occur when the missiles are launched separately at high altitudes and limiting Mach-numbers at a g-load exceeding unity, as well as during automatic landing approach at altitudes lower than 50 m.

The cause of the pitching oscillation is coincidence of natural oscillation of the aircraft depending on an altitude and airspeed of flight, stiffness of the aircraft structure, degree of air turbulence and angle-of-attack stability margin with a frequency of forced oscillation.

The forced oscillation may be initiated by abrupt motions of the control stick to counteract inadvertent g-load pulse during extension of the air brakes, engagement and disengagement of afterburner, sharp reduction of the engine power setting. As a consequence, after several motions of the control stick the aircraft resonance pitching oscillation is originated which is characterized by rapid growth of an amplitude and alternating vertical g-load. As a rule, this phenomenon appears suddenly for the pilot.

To avoid the pitching oscillation at low angle-of-attack stability margin and high effectiveness of the stabilizer, restore the preset regime in airspeed (Mach-number) more gradually, do not manipulate the control stick and throttle lever abruptly, avoid extension of the air brakes and disproportionate motions of the control stick for counteracting the g-load.

In case pitching oscillation occurs it is necessary to stop manipulating the control stick and fix it in the position which is close to the neutral one (trimming position).

Under the action of the stability margin available, the aircraft will make several decaying oscillations and restore the initial flight regime.

2. LATERAL STABILITY AND CONTROLLABILITY OF AIRCRAFT

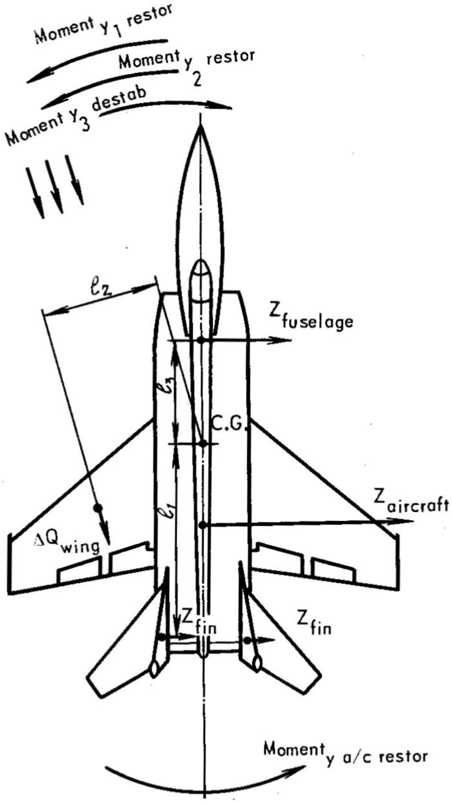
The lateral movement of the aircraft is a combination of two rotary motion (relative to axes OX and OY) and one progressive motion (along axis OZ).

Stability of the lateral motion is usually divided into directional and rolling stability.

Directional stability. The aircraft is considered to feature adequate directional stability if it tends independently, without interference of the pilot to restore the initial attitude in case the directional stability is disturbed.

The МиГ-25П aircraft is stable in direction within the entire range of the Mach-numbers. The forces and moments exerting an effect on the aircraft in case of disturbance of the directional stability are presented in Fig. 30. The figure illustrates that the restoring yawing moment ensuring static directional stability is basically created by the aircraft fin. As a rule, the fuselage produces destabilizing effect.

This is an angle of attack which affects the directional stability significantly. At high angles of attack the fin may be blanked by the fuselage and wing. It decreases the aircraft directional stability.



$$M_{y_1\ restor} = Z_{fin}\,\ell_1;$$

$$Moment_{y_2\ restor} = \Delta Q_{wing}\,\ell 2$$

$$Moment_{y_3\ destab} = Z_{fuselage}\,\ell 3;$$

$$Moment_{y\ a/c\ restor} = Moment_{y_1\ restor} + Moment_{y_2\ restor} - Moment_{y_3\ destab}$$

FIG. 30. FORCES AND MOMENTS ACTING UPON AIRCRAFT WHEN EQUILIBRIUM ABOUT YAWING AXIS

Besides, further deterioration of the directional stability is possible at great angles of attack since the fins come into the vortex zone formed due to pressure differential under the wing and fuselage and over them. The restoring moment from the fins decreases. But under these conditions the total restoring moment of the aircraft will remain approximately constant at the expense of the false keels.

Generally, the directional stability of the МиГ-25П aircraft possessing two-finned layout of the tail unit and false keels is not considerably affected by increase of the angle of attack.

The margin of the directional static stability is characterized by coefficient $m_y^{\beta^o}$ (Fig. 31).

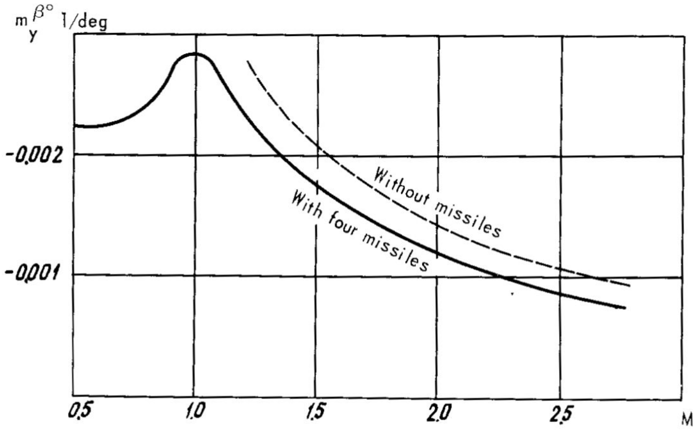


FIG. 31. STATIC DIRECTIONAL STABILITY COEFFICIENT OF AIRCRAFT VERSUS MACH NUMBER

At subsonic speeds the directional static stability margin grows as the Mach-number increases, while at supersonic speeds it smoothly decreases. Variation of the directional static stability margin is explained by the fact that as the Mach-number increases within the range of subsonic speeds, force Z of the vertical tail unit increases and considerably exceeds force Z of the fuselage, which creates the destabilizing moment. At Mach-numbers exceeding 1.2 to 1.3, force Z of the vertical tail unit starts decreasing, while force Z of the fuselage does not depend on the Mach-number and is nearly constant.

Therefore, at M = 1.2 to 1.3 difference between the forces of the vertical tail unit and fuselage starts decreasing. In turn, it will result in decrease of the restoring moment and aircraft directional stability. But in spite of some deterioration of the directional stability at supersonic speeds its margin is practically adequate. The directional stability margin of the aircraft carrying no missiles is somewhat higher than that of the aircraft with the missiles suspended.

Rolling stability. The aircraft is considered to feature adequate rolling stability if it tends independently, without interference of the pilot to eliminate the inadvertent bank after disturbing a rolling-moment balance.

The МиГ-25П aircraft possesses adequate rolling stability within the entire range of airspeeds and altitudes of flight.

Fig. 32 shows the forces and moments affecting the aircraft in case rolling stability is disturbed. The figure illustrates that the disturbed rolling stability is restored under the action of the following moments:

(a) moment of lift force increment ΔY_{slip} due to different conditions of flow over the half-wings;

(b) moment of increment of lift force ΔY_{sweep} due to change of an effective sweep of the half-wings during slipping;

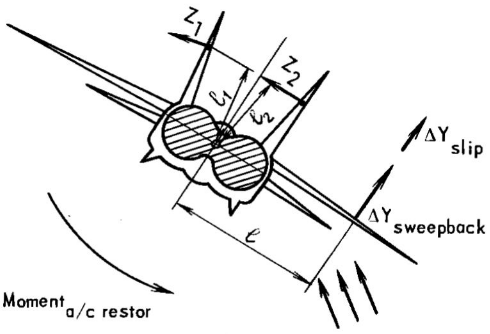


FIG. 32. FORCES AND MOMENTS ACTING UPON AIRCRAFT WHEN EQUILIBRIUM ABOUT ROLLING AXIS IS DISTURBED

(c) moment from a lateral force on the fins.

The determining factor for the aircraft with a swept wing is the restoring moment from the lift force increment due to variation of the half-wing effective sweep. The magnitude of this moment may be excessively high.

To obtain optimum rolling stability the wing of the МиГ-25П aircraft is provided with negative dihedral which amounts to -5°. The margin of the rolling static stability is characterized by coefficient $m_x^{\beta^o}$, which changes directly with the angle of attack (Fig. 33).

The rolling static stability margin within the Mach-number range of M = 0.9 to 1.3 is less than the directional static stability margin by 20 to 50 per cent.

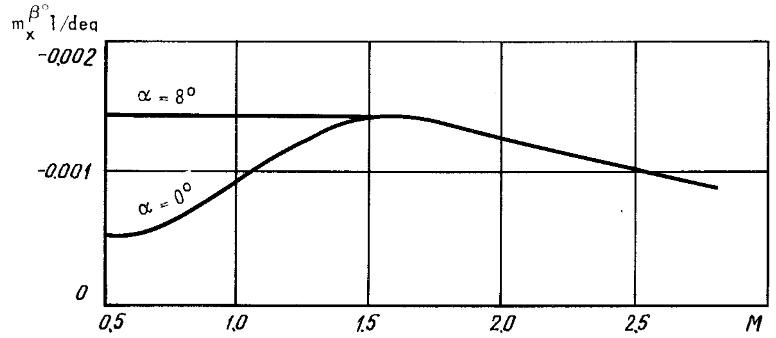


FIG. 33. LATERAL STATIC STABILITY COFFICIENT $m_x^{\beta^\circ}$ OF AIRCRAFT VERSUS MACH NUMBER

At M = 1.3 to 2.83 the rolling static stability margin prevails over the directional static stability margin. It is proved by relation between $m_x^{\beta^\circ}$ and $m_y^{\beta^\circ}$ which is equal to 1 - 2.

<u>Effect of the directional and rolling stability margin on the aircraft stability.</u> Increase of the Mach-number considerably changes all aerodynamic characteristics and especially the magnitude of the relation between the directional and rolling stability.

The magnitude of slipping angles and behaviour of the aircraft under the action of lateral disturbances depend on the magnitude of the directional and rolling stability margin. As it is known, the greater the rolling stability margin, the greater the angle of attack. At angles of attack close to zero the rolling stability margin numerically equals the directional static stability margin.

Since a flight at M > 2.0 is performed at high altitudes, where angles of attack in level flight amount to 3 - 6°, the total margin of the rolling static stability, as the Mach-number increases, decreases more slowly than the directional static stability margin.

As the rolling stability decreases rolling oscillations occur. Their period and amplitude increase. The minimum magnitude of the rolling stability margin ensuring flight safety at great

Mach-numbers corresponds to rolling oscillations with a period being not over 5 to 5.5 s.

Variation of relation between the directional and rolling components of the lateral stability results in variation of relation between the oscillation amplitudes of the aircraft roll and yaw rates in case of lateral disturbances. If the directional stability margin is higher than the rolling one by 2 or 3 times (at $M \approx 1$ to 1.5), the lateral disturbances of the aircraft involve yawing; in this case the aircraft banking is insignificant. At low directional static stability margin, when the lateral component becomes equal to the directional one or exceeds it, yawing is accompanied by oscillations in roll. In this case, a roll angle repeats variation of the slip angle. As the rolling stability decreases rolling oscillations increase.

At $M > 2.0$ presence of even small slip angles, corresponding to the lateral out of trim condition of 0.5 - 1 diameter of a ball, results in increase of the magnitude and rate of roll.

When the vertical g-load is being created, the slip angles increase due to gyroscopic torque, and the angular rates and roll angles increase, respectively.

As the flight altitude increases, the damping properties of air become weakened and therefore the rolling stability of the aircraft deteriorates.

Generally, the damping aerodynamic moments are determined by the wing area and wing span of the aircraft, as well as by dimensionless coefficients of damping, which depend on the configuration of the aircraft and flight conditions. As the damping moments decrease, the aircraft response lag increases and the originated oscillations do not attenuate for a long time.

To reduce oscillating motions at high altitudes and Mach-numbers, the use is made of the dampers of the CAУ automatic flight control system. They deflect the controls within a limited range proportionally to the applied disturbances.

At high altitudes and Mach-numbers exceeding 2.2, when creating vertical g-loads of 2 g and more with the dampers disengaged, the aircraft features increased roll response to the deflection of the rudders (creation of slipping). In this case, the roll is developed with a certain delay which is typical for high altitudes. Effectiveness of ailerons decreases as the g-load increases; therefore, the aircraft vigorously rolls to the side which is opposite to slipping (to the side opposite to that of the ball drift). In case of asymmetrical thrust, the aircraft rolls to the side of the engine with lesser thrust.

The roll angular rate increases as the vertical g-load rate grows.

Proceeding from this, it is necessary to perform all the maneuvers coordinatedly, avoiding slipping. Prior to performing a maneuver, make sure that the aircraft is trimmed in direction with the aid of the rudder trimmer.

With the dampers engaged the aircraft roll response to side-slipping considerably decreases. Therefore, flights at high altitudes and Mach-numbers exceeding 2.2 should be performed with the dampers engaged. It greatly facilitates the aircraft handling.

At altitudes less than 8000 m and high airspeeds the МиГ-25П aircraft displays increased rolling stability margin.

Productional-technological asymmetry of some aircraft may cause involuntary banking ("wingheaviness") at a rate of 6 to 8°/s when flying at altitudes of 3000 to 8000 m at indicated airspeeds over 850 km/h. As a rule, the aircraft experiences a left wing-heaviness.

In case the aircraft carries one missile or missiles are suspended asymmetrically, the aircraft is affected by the additional disturbances produced by the missiles. Weight of the missile and its drag create the rolling and yawing moments towards the missile. Besides, aerodynamic interaction of the missile with the pylon, wing, fuselage and tail of the aircraft involves additional aerodynamic moment of rolling and yawing.

Magnitude of the aerodynamic moments affecting the aircraft due to the missile relative to the longitudinal and vertical axes depends on the flight altitude, Mach-number and vertical g-load. In this case, variation of the moments for the missiles arranged on the inboard and outboard pylons are not similar.

If the missiles are suspended symmetrically, the rolling and yawing moments experienced by the aircraft compensate for each other. Suspension of missiles results in deterioration of the aircraft maneuvering performances due to increase of moments of inertia and drag, as well as due to a certain loss of the directional stability margin.

When the missiles are launched separately, the aircraft is affected by a short-time rolling moment produced by the operation of the launched missile motor and a constantly applied moment originated due to liftoff of one missile.

Lateral controllability of aircraft. To obtain adequate characteristics of lateral controllability within a wide range of airspeeds and altitudes, the МиГ-25П aircraft is provided with a combined lateral control at all flight conditions (simultaneous control of ailerons and stabilizer deflected differentially).

When the control stick is displaced through 1/2 of its full travel, deflection of ailerons through 1^{o} is accompanied by a simultaneous deflection of the differential stabilizer through an angle of 0.25^{o} at right angles relative to the stabilizer hinge line. Deflection of the control stick more than the half of its full travel will cause practically deflection of the ailerons only. In this case, the effectiveness of the system corresponds to the effectiveness of the ailerons only.

The МиГ-25П aircraft features adequate controllability within the all flight conditions. But it is necessary to distinguish two major regions of the flight conditions where aerodynamic characteristics differ from the ordinary ones. These aerodynamic characteristics involve some peculiarities in flying the aircraft.

The first region is the region of high altitudes (over 15,000 m) and great Mach-numbers (over 2.0). It includes the major conditions of flight typical for the МиГ-25П aircraft at which a flight of long duration is possible.

At great Mach-numbers the requirements for the directional trim of the aircraft either in level flight or in flight with vertical g-loads exceeding unity are increased.

Increased requirements for the lateral trim involve the necessity of a constant check of the position of the sideslip indicator ball. In case of sideslipping the pilot should counteract it by deflecting the rudders. Since the deflection of the pedal is associated with great forces to be applied to it, it is necessary to use the trimming mechanism to trim the aircraft.

To counteract the sideslipping moments, an additional aileron deflection is required. As the altitude increases the aileron deflection required to counteract the sideslipping moments also increases.

Thus, to avoid undesirable roll oscillations, the flight at great Mach-numbers should be performed without sideslipping. When doing so, keep the ball of the sideslip indicator within the centre by actively applying the pedals of the rudders. This requirement should be also fulfilled with the automatic control modes switched on, since no provision is made for stabilization of the sideslip angles (lateral g-load) by the САУ-155П automatic flight control system. It is necessary to remember that deviation of the sideslip indicator ball to one diameter corresponds to a lateral g-load of 0.07 g.

At high airspeeds the aircraft slowly gains the steady rotation regime. At the short-time deflections of the rudders the angular velocities do not reach the maximum magnitudes. It it is required 1.5 - 2 s to create the assigned roll at an altitude of 5000 m, at an altitude of 18,000 m the same roll may be created during 5 to 8 s.

Employment of the dampers at high altitudes and great Mach-numbers promotes damping of forced oscillations and provides for reasonable characteristics of controllability. Forces applied to the control stick, in this case, rather increase.

The second region is the region of altitudes less than 8000 m and high indicated airspeeds. It corresponds to the maximum g-loads applied to the aircraft.

The flights performed within this region are characterized by increased rolling stability margin and decrease of available roll rates.

The maximum magnitude of the available roll creation rates of the МиГ-25П aircraft is attained at altitudes of 10,000 m within the range of indicated airspeeds of 500 - 800 km/h, where the available roll creating rate amounts to 160 - 200°/s with the control stick deflected fully.

As the flight indicated airspeeds increase, the roll available rate decreases and reaches a minimum magnitude of 28°/s at an indicated airspeed of 1200 km/h within an altitude range of 0 to 500 m.

Decrease of the available roll rates is dictated by the following causes:

(1) Decrease of the aileron effectiveness. As the indicated airspeeds grow and dynamic heads increase, the elastic deformations of the wing and ailerons increase, wing twist to decrease of the angle of attack occurs due to misalignment of the flexural centre and centre of pressure (the flexural centre is ahead of the centre of pressure).

Increment of lift on the wing with the lowered aileron will be less than as expected. As a result, the roll rate decreases when the ailerons are deflected through 1°.

In this case the function of the differentially controlled stabilizer becomes the decisive one, since the available power of the aileron booster considerably limits the possible angles of aileron deflection.

Effectiveness of the ailerons materially decreases during take-off and landing. At moderate indicated airspeeds the function of the differentially controlled stabilizer in a total available effectiveness of the lateral controllability is relatively small, since the available power of the aileron booster allows to use full deflections of the ailerons; in this case the ailerons are enough effective.

At intermediate regimes of flight the available effectiveness of the ailerons is commensurable with the available effectiveness of the differentially controlled stabilizer.

Within the range of an indicated airspeeds of 500 to 800 km/h, the steady roll rate (with the ailerons deflected through 1°) is maximum and it amounts to 7 - 9.5°/s (Fig. 34).

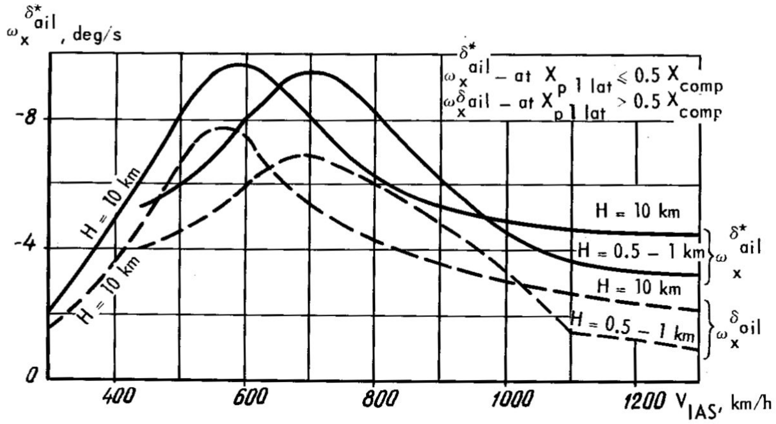


FIG. 34. VARIATION OF STEADY ROLL RATE $\omega_x^{\delta_{ail}}$ WITH AILERONS DEFLECTED THROUGH 1° VERSUS INDICATED AIRSPEED V_{ind} AND FLIGHT ALTITUDE H

The minimum steady roll rate is equal to 1.2 - 2.3°/s; it corresponds to the maximum indicated airspeeds.

(2) Appearance of "stops" of the control stick. The hinge moments of the ailerons and rudders reach the maximum magnitudes, and power of the boosters is not sufficient to fully deflect the control surfaces. When the deflection angles of the ailerons and rudders are equal to values at which the hinge

moments produced by them will be equal to full power of the boosters, the "stop" with reference to the booster power occurs.

At altitudes of 5000 to 6000 m and indicated airspeed of 1100 km/h the ailerons may be deflected up to the "stop" through an angle of 8^{o}, i.e. the available travel of the control stick will amount to 1/3 of the full travel. As the altitude increases (with Mach-number being constant) and as the Mach-numbers decrease (at a constant altitude) the "stops" are moved off the neutral position and the available deflections of the control stick increase.

Taking into account that the available deflections of the ailerons at high indicated airspeeds are limited by the booster power, it is necessary to pay special attention to the aircraft lateral trimming.

If when flying at altitudes of 3000 - 8000 m and at an indicated airspeed which is close to the maximum permissible one a trimming deflection of the control stick in roll exceeds ± 10 mm, the aircraft should be trimmed on the ground by setting "misalignment" of the stabilizer halves. Use of "misalignment" of the stabilizer halves for lateral trimming of the aircraft at high indicated airspeeds is dictated by the fact that the roll rate produced by "misalignment" of the stabilizer halves practically does not depend on a dynamic head and it is maintained up to an indicated speed of 1200 km/h. "Misalignment" of the stabilizer halves improves lateral controllability of the aircraft flying at high indicated airspeeds and does not affect the piloting technique during take-off and landing.

At high indicated airspeeds within an altitude range of 5000 to 8000 m the effectiveness of the rudder is small in roll control. The great directional static stability margin at a small magnitude of the lateral static stability margin in a combination with the limited available angles of the rudder deflection (presence of "stops") does not allow to create considerable roll rates with the aid of the rudder. For example, at an altitude of 5000 m and at an airspeed of 1100 km/h the available rate of the rudders amounts to 5 - 6^{o}/s.

Asymmetrical suspension of the missiles will result in additional deflection of the ailerons and rudders to counteract the roll and yaw moments.

When flying at M < 1.0 a minor deflection of the rudders is required to counteract the moments produced by asymmetrical suspension of missiles both on outboard and inboard pylons. As the Mach-numbers grow, the deflection of the ailerons and rudder for trimming also increases. Within a range of M = 1.0 to 2.4 asymmetry on the outboard pylons produces greater effect on deflection of the rudders than asymmetry on the inboard pylons.

At M > 2.4 the rolling and yawing moments produced by the outboard missile decrease, while those of the inboard one increase, and asymmetry on inboard pylons produces more greater effect on trimming deflections of the rudders.

In case of asymmetry of the outboard pylons, the maximum trimming deflections of the ailerons and rudders correspond to flights at altitudes of 8000 to 12,000 m and at an indicated airspeed of 1200 km/h. Asymmetry on the inboard pylons when flying at M = 1.5 to 1.6 does not involve great lateral out-of-trim of the aircraft. As the Mach-numbers increase from 1.5 to 2.83, the rudder deflections required to counteract the yawing moments produced by the inboard missile increase and reach the maximum value at altitudes of 17,000 to 20,000 m and M = 2.83.

For instance, at M = 2.5 the lateral g-load produced by the inboard missile (if not counteracted by the rudder pedals) reaches 0.3 g (four diameters of the sideslip indicator ball). Counteraction of a roll produced by such a great lateral g-load would require for deflection of the ailerons through an angle greater than 25°, which exceeds the available angle of their deflection. Therefore, for automatic compensation of the moments produced by launching the missiles from the inboard pylons at M > 2.4 the disturbance autocompensator comes into action. Its principle of operation consists in creation of "misalignment" of the stabilizer at the moment of the missile launch irrespective of an initial position of the aircraft control stick.

Liftoff of the missile from the right inboard pylon will result in deflection of the port half of the stabilizer with the leading edge upwards and starboard half downward through an angle of $2^{\circ}15'$ from the initial position. Liftoff of the missile from the left pylon involves opposite deflections of the stabilizer halves. If the missile is suspended only from one of the inboard pylons and the compensation system is set to any extreme position, "misalignment" of the stabilizer is eliminated after launching of the missile, i.e. the compensation system returns to the neutral position. Besides, the pilot's cabin is provided with the toggle switch labelled BANK ZERO (ОБНУЛ. КРЕНА). With the toggle switch turned on, the system is forced to the neutral position.

The autocompensation system operates only at generation of the signal indicating that the air-intake doors are set to the third position and during launching of the inboard missiles or in case of their asymmetrical suspension.

3. INTERACTION OF LONGITUDINAL AND LATERAL MOTIONS

In flight it is not always possible to divide the aircraft motion into longitudinal and lateral ones. Cross coupling between the longitudinal and lateral moments originating at change of the attack angle or Mach-number along with variation of the longitudinal moment will result in change of the rolling and yawing moments.

Such interaction is dictated by the following reasons:

(a) distribution of masses over the entire length of the fuselage at a low wing span;

(b) extensive scale of the longitudinal lateral and directional static stability margins during the maneuver within the entire range of airspeeds and angles of attack; their different variation depending on the altitude and airspeed during maneuvering what in most cases leads to their unfavourable interaction;

(c) considerable variation of effectiveness of the aircraft control surfaces versus attack angle and slipping.

The major types of interaction of the longitudinal and lateral motions of the aircraft are aerodynamic, kinematic and inertia interactions.

A e r o d y n a m i c   i n t e r a c t i o n is cross-coupling of aerodynamic longitudinal, lateral and directional moments.

Such an interaction is traced to aerodynamic reasons only expressed by the relation between the aircraft longitudinal moment (M_z) and sideslip angle, and between the roll and yaw moments (M_x and M_y) and angle of attack and Mach-number.

K i n e m a t i c   i n t e r a c t i o n is expressed as the attack angle converted into the sideslip angle or the sideslip angle converted into the angle of attack in the course of a turn of the aircraft about its longitudinal axis.

I n e r t i a   i n t e r a c t i o n   of the longitudinal and lateral motions is conditioned by origination of inertia forces and moments.

The most difficult case of interaction of the longitudinal and lateral motions is the interaction during space maneuvering of the aircraft performed at a roll rate. The rolling of the aircraft entails aerodynamic asymmetry and leads to additional angles of attack and sideslipping, as well as inertia moments produced from centrifugal forces.

In case the rotation rate is relatively small, and the longitudinal and lateral static margin is great enough, the aerodynamic pitch and yaw moments of the steady aircraft will trim the inertia moments preventing the attack and sideslip angles from increasing during rotation. The aircraft will tend to maintain the initial attack and sideslip angles rotating about the velocity vector at the constant normal and lateral g-loads which are equal to the initial ones. In this case, the motion of the longitudinal axis is effected along the screw-type line, and the aircraft performs a roll with a great radius. Since the rotation axis is not aligned with the principle axis of inertia the aircraft starts experiencing the inertia moments of roll and yaw produced by the centrifugal forces, approximately proportional to the attack and sideslip angles, respectively; these moments have a tendency to increase attack and sideslip angles.

Thus, during rotation the aircraft is affected by the oppositely directed aerodynamic and inertia moments of pitch and yaw.

The aerodynamic moments of the static stability does not depend on the rotation speed, whereas the inertia moments are directly poportional to the square of the roll rate. At small roll rates the inertia moments are considerably less than the aerodynamic moments of static stability, but as the roll rate increases, they may be equal to or even higher than the aerodynamic moments. Proceeding from the equality of the aerodynamic and inertia moments in roll and yaw, one may approximately estimate critical roll rate. When approaching the critical roll rate the aircraft displays some peculiarities in behaviour.

From equations $M_{z\ aer} = M_{z\ inert}$ and $M_{y\ aer} = M_{y\ inert}$ we obtain that

$$\omega_{x\ roll\ \alpha} = \sqrt{\frac{-m_z^\alpha S b_a q}{I_y - I_x}} \cdot 57.3;$$

$$\omega_{x\ roll\ \beta} = \sqrt{\frac{-m_y^\beta S l q}{I_z - I_x}} \cdot 57.3.$$

As a rule, the critical roll and yaw rates are not equal to each other. The determining rate is the critical rate lesser in magnitude; it is referred to as the f i r s t c r i t i c a l r a t e .

When the aircraft rotates at a great roll rate approaching the first critical one, the magnitude of the total stabilizing moment decreases due to development of the inertia moment and the aircraft has no time to "eliminate" the originating additional attack and sideslip angles. The rotation is accompanied by variation of the attack and sideslip angles and variation of the normal and lateral g-loads, respectively. The closer the aircraft rotation rate to the critical one, the lesser the stabilizing moment and the quicker and greater variation of the attack and sideslip angles in time. The developing sideslip angles become great so much that the roll rate of sideslipping will be determining one. In this case, deflection of the ailerons to the neutral position or against the rotation will not change the roll rate and the aircraft will continue rotating at the same rate. Such a rotation is called as i n e r t i a r o t a t i o n . Sometimes, the inertia rotation is termed as autorotation.

The flight path of a rapidly rotating aircraft even at significant normal and lateral g-loads experienced by the pilot is a three-dimensional curve (in earth's axes) with a mean magnitude of the normal g-load which is close to zero. Therefore, during long-time rotation at a great roll rate the aircraft loses altitude as a free-falling body.

In actual flight the critical roll rate may be obtained not at all the regimes of the flight, and not always the rotation at roll rates exceeding the critical ones results in loss of motion stability and entry into the inertia rotation. The МиГ-25П aircraft at altitudes less than 8 km does not experience the inertia rotation since the rotation stops when the controls are set to the neutral position.

As compared with other supersonic aircraft the МиГ-25П aircraft has the most favourable inertia characteristics. It is known that increase of the inertia moment relations (I_y/I_x and I_z/I_x) results in decrease of the critical roll rate. For the majority of the aircraft with a thin swept wing these relations are 10 to 15, while for the МиГ-25П they do not exceed 3 to 5. This is achieved due to a moderate sweep of the wing, wide fuselage and spaced engines.

As a result of flight research two zones of possible interaction of the longitudinal and lateral motions may be distinguished (Fig. 7). Common for both zones is that the available roll rate is greater than the first critical one.

The first zone is within the speed range from the maneuvering speed to an airspeed corresponding to M = 1.02 at altitudes higher than 8000 m.

The second zone is limited by the Mach-numbers ranging from 2.3 to the maximum one which amounts to 2.83 at altitudes over 17,000 m.

Besides, as a result of mathematic modelling the third region of possible inertia rotation of the МиГ-25П aircraft is revealed. This region is within the Mach-numbers ranging from 1.6 to 2.3 at altitudes higher than 18,000 m.

Combination of a number of factors practically rules out the possibility of inertia rotation of the МиГ-25П aircraft even in the first region of the flight regimes which is considered to be the worst region according to the theory.

On the one hand, presence of great available roll rate does not require for its realization in flight for the roll control; on the other hand, it is the distinguished region where high available roll moments allow to decelerate the speed of rotation initiated by external factors, such as: failure of the engine, asymmetrical suspension of missiles, getting into a wake, etc.

Within the zone considered the available roll rates may be attained from the lateral control system during more than 6 s with the control stick fully deflected. Rotation rate in level flight within the first zone amounts to 100 - 120°/s. The aircraft may reach the available steady rotation rate of 100 to 120°/s when it performs not less than two turns about longitudinal axis. In this case, as the normal g-load (angle of attack) becomes more than unity, the available roll rate decreases, while at negative normal g-loads the available rotation rate exceeds 200°/s.

Roll response to deflection of the rudder (and to sideslipping) at positive normal g-loads is direct and reverse at the negative g-loads (Fig. 35).

Variation of the aileron effectiveness and the aircraft roll response to deflection of the rudder (and to sideslipping) depending on the normal g-load (angle of attack) are the main causes of aerodynamic interaction of the longitudinal and lateral motions.

Important factor preventing the aircraft from attaining the maximum rates of steady rotation at an inadvertent short-time or excessively great deflection of the controls is a weak aerodynamic damping within the considered region of the regimes. The

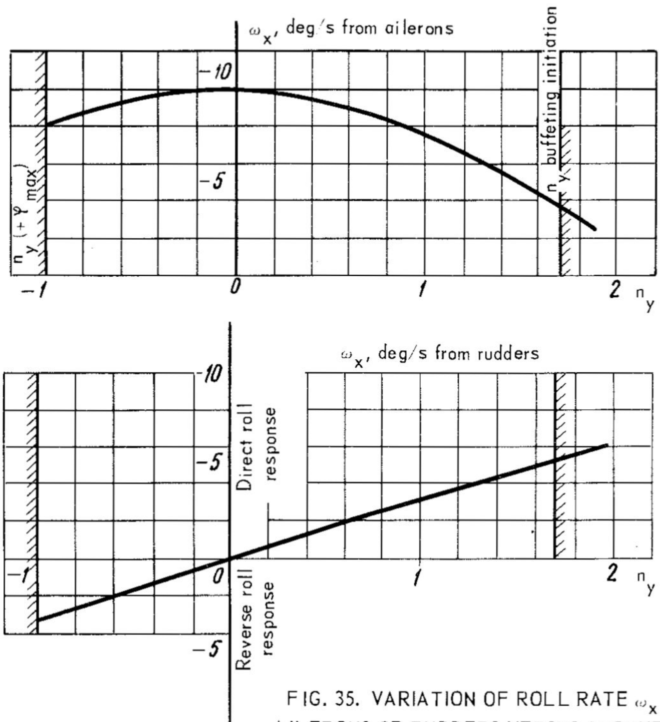


FIG. 35. VARIATION OF ROLL RATE ω_x CREATED BY AILERONS OR RUDDERS VERSUS AMOUNT OF NORMAL G-LOAD n_y (V_{ind}=500 km/h, H=10,000m, ω_x <60°/s)

aerodynamic damping decreases as the flight altitude increases proportionally to air density. At altitudes higher than 8000 m at subsonic airspeeds the aircraft reaches the maximum rotation rate 6 - 8 s after the rotation is started even at an instant reversal of the ailerons and their fixing in the deflected position.

When performing the major combat maneuvers with fixing the controls in the deflected position for 2 to 3 s the rotation roll rate does not exceed 60 per cent of the available one. Besides, increase of the normal g-load during rotation also prevents the aircraft from reaching the critical rotation rate at subsonic flight regimes.

Normal g-loads on the МиГ-25П aircraft at all operational values during roll rotation display positive increment (Fig. 36). When the roll rotation is effected at a rate of not more than 60°/s, the inertia interaction of the longitudinal and lateral motions does not take place irrespective of the roll rate and initial g-load.

When rotation is effected at a rate of 60°/s, variation of the initial g-loads becomes noticeable and relation between roll rate and deflection of the control surfaces becomes non-linear.

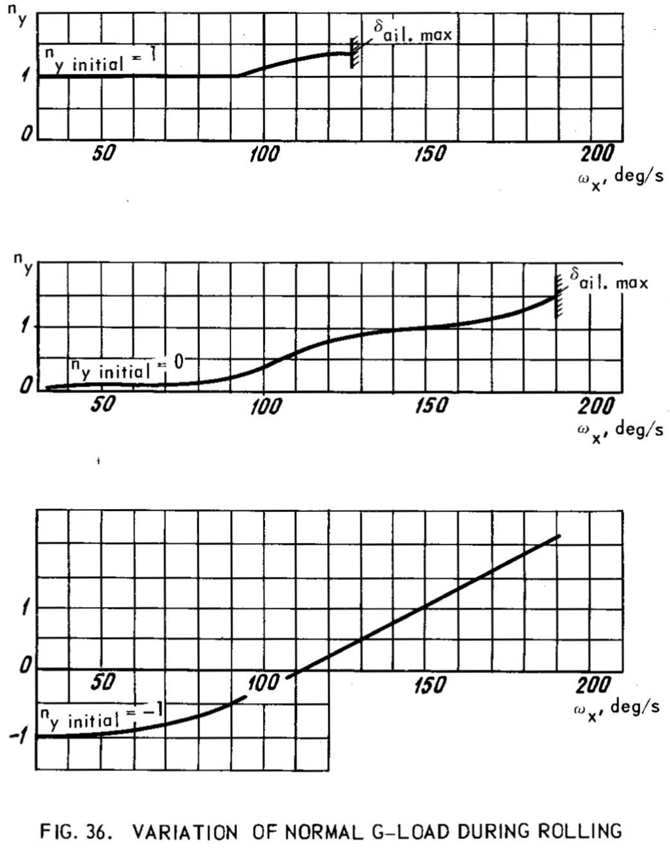


FIG. 36. VARIATION OF NORMAL G-LOAD DURING ROLLING WITH AIRCRAFT CONTROL STICK FIXED

At a long-time rotation about the longitudinal axis (more than one turn) at a roll rate exceeding $100^{\circ}/s$ (at negative initial normal g-loads) the aircraft attains the attack angles which are close to stall angles and enters the zone of aerodynamic buffeting even though the stabilizers are set to the fixed position corresponding to the initial negative g-load. The lateral g-load amounts to 0.5 - 0.7 g. Further rotation may result in the aircraft stalling which happens earlier than the rotation rate reaches its critical value.

Controllability in roll is maintained even at a rotation rate of $200^{\circ}/s$. With the ailerons deflected to the neutral position or in the direction opposite to that of rotation it stops after 4 - 6 s.

At high supersonic airspeed from $M > 2.3$ (the second zone) origination of the inertia interaction of the longitudinal and lateral motions depends on a combination of signs and magnitudes of the roll rate and lateral g-load (sideslipping) created by the pilot during flying. The beginning of the essential display of the inertia interaction is possible in case of rotation with sideslipping if the following factors simultaneously coincide: the roll moment from sideslipping is directed along the rotation, a roll rate is more than $90^{\circ}/s$ and the lateral g-load exceeds 0.3 g (the ball of the electric turn indicator is stopped in the corner). At a roll rate less than $90^{\circ}/s$ and lateral g-load less than 0.3 g the inertia interaction is practically not manifested and the aircraft displays no peculiarities in behaviour.

Flying performed with the dampers of the automatic flight control system disengaged with the maximum deflections of the ailerons and rudders in magnitude and rate of deflection may result in simultaneous creation of a roll rate exceeding $90^{\circ}/s$ and lateral g-load more than 0.3 g. This causes increase of the normal g-load and the aircraft enters the regime of "tuck-in". With the control stick deflected backward and the ailerons and pedals set to the neutral position, the aircraft fastly stops rotating.

The "tuck-in" effect is possible only at premeditated and full deflections of the control surfaces, which practically does not happen during the flights, and with the dampers of the automatic flight control system switched off. With the dampers of the automatic flight system turned on, energetic maneuvers with turns through less than 180° do not result in inertia rotation.

Hence, if the roll is not performed at supersonic airspeeds, there are no peculiarities associated with inertia interaction of the longitudinal and lateral motions at any other changes of the aircraft attitude. Maneuvers of the flight performed at supersonic airspeeds should be accomplished without sideslipping which is to be counteracted by applying the pedals within the entire range of their deflection angles if it is necessary.

Thus, when flying the МиГ-25П aircraft within the zones of possible interaction of longitudinal and lateral motions, it is recommended to do the following:

(a) take care not to allow a roll rate to exceed 90^{o}/s;

(b) limit energetic rotation of the aircraft about its longitudinal axis at subsonic airspeeds of flight with normal g-load exceeding 0.5 g by turning the aircraft through 360^{o}, and at negative and close-to-zero g-loads by turning the aircraft through 180^{o}; when doing so, it is necessary in all cases to deflect the rudders to stop rotation with a certain lead;

(c) at supersonic airspeeds limit continuous roll rotation by effecting a 180-deg turn irespective of the initial g-load;

(d) in case of increase of the normal or lateral g-load during rotation do not counteract increase of g-loads by deflecting the control stick in pitch or pedals; it is necessary to place the pedals and ailerons to the neutral position, after that deflect the control stick backward, avoiding abrupt deflections of the control surfaces;

(e) take care to prevent sideslipping,by counteracting it deflect the rudders up to the maximum deflection angles;

(f) the deflection angles of the control surfaces should not exceed 7 - 8^{o} when controlling the aircraft in roll;

(g) perform the flights with the dampers of the automatic flight control system switched on.

CHAPTER II

DAYLIGHT FLYING UNDER VFR CONDITIONS

Mastering the daylight VFR flying technique is the primary stage of handling the aircraft.

Flying technique is the basis of flight training. High quality of flying technique ensures successive mastering of the elements of air navigation and combat employment in various conditions. Besides, it is one of the conditions determining flight safety.

Flying technique training is aimed at forming firm habits of the pilots in handling the aircraft and engines at all stages of flight from take-off to landing. High individual proficiency in flying technique within the entire range of operational altitudes and airspeeds with the proper use of aerodynamic characteristics of the aircraft is the fundamental principle required for training of a pilot as a fighter.

All actions of the pilot in handling the aircraft and controlling the engines should be based on profound and fundamental knowledge of aerodynamic characteristics of the aircraft, operational limitations and peculiarities involved in flying technique of the МиГ-25П aircraft.

The pilots acquire the necessary knowledge and habits of flying in the course of theoretical training, exercises on simulators and cockpit drills, as well as during familiarization, check and training flights performed for mastering flying technique.

Practical training of the МиГ-25П aircraft pilots in flying technique in daylight VFR conditions includes circling flights, maneuvering flights, instrument flights, as well as flights at supersonic airspeeds and flights in stratosphere.

CIRCLING FLIGHT

The elements of flying technique practised in the course of circling flight are the major components of any flight.

Success of further mastering the flying technique and combat skill depends on successive and sound mastering of the circling flight elements.

The training circling flights consolidate the habits of the pilot in performance of take-off, estimation of landing and landing proper, as well as in handling of the aircraft during flight. Besides, during the circling flights the pilot acquires habits in employment of the airborne and ground navigation aids during landing approach. The initial stage of training landing approach includes complex employment of the two-beacon landing system and ground-controlled approach system and further use of the POLJOT-1И system.

As a rule the circling flights are performed at a 50 per cent fuel load.

1. TAXIING

After running up the engines it is necessary to set the throttle lever to the IDLE (МАЛЫЙ ГАЗ) position, give a command to the technician to disconnect the cord of the aircraft interphone system and request the flight control officer for taxi clearance. On obtaining taxi clearance, order the technician to remove the chocks.

On making sure that the chocks are removed and there is no obstacles for taxiing, increase the engine speed up to 55 - 60%, release the brake lever and start taxiing. When starting taxiing, gradually reduce the engine speed to the minimum one. It is recommended to perform taxiing at the idle rating of the engines. Since the aircraft has a tendency to increase speed even at idling, it is necessary to apply the brakes regularly to maintain the required speed during taxiing.

The taxiing speed depends on condition of the taxi strip, presence of obstacles, aircraft flight mass and visibility conditions, but in all case it should not exceed 30 km/h.

During taxiing the МиГ-25П aircraft is enough stable and well controllable. To maintain the assigned direction, slight deflections of the pedals are required.

When taxiing, turn the aircraft at a speed of not more than 20 km/h. To effect a turn, apply the pedal to the side of the required turn. Considerable effort is required to deflect the pedals for this purpose.

Radius of the turn depends on the force applied to the pedal and taxiing speed. The greater the deflection of the pedal, the more energetic the turn. With the pedal fully deflected, the turn through 8° of the nose wheels is provided.

To decrease the turning radius, make use of the STER (МРК) button located on the control stick. When this button is depressed and the pedal is fully deflected, the turn of the nose wheel through 43° to the side of the deflected pedal is provided. Prior to turning, it is necessary to depress the STER button on the control stick and then smoothly deflect the pedal to the side of the desired turn. The radius of the turn should be adjusted by the force applied to the pedal.

The button labelled STER on the aircraft control stick may also be used in the course of the turn. But it should be kept in mind that depression of the button results in an abrupt decrease of the turn radius and a great load applied to the outboard wheel. Therefore, depress the STER button only at low deflection of the pedals and small taxiing speed.

Use the STER button with the flaps retracted only. With the flaps extended, the cock ensuring turning of the nose wheels through great angles becomes disengaged.

Prior to taxiing to the runway, make sure that there are no landing aircraft and taxi to the runway on receiving the permission from the flight control officer.

Having taxied onto the runway, position the aircraft along the runway centre line and apply the brakes. Keeping the aircraft on the brakes, proceed as follows:

- extend the flaps;
- check extension of the flaps by referring to the FLAPS DOWN (ЗАКРЫЛКИ ВЫПУЩЕНЫ) lamp located on the ППС-2МК LG and flaps position indicator;
- unlock the landing gear control valve handle;
- apply the nose wheel brake;
- check the readings of the flight and navigation instruments and engine instruments;
- lock the shoulder straps;
- ascertain that there are no obstacles in front of the aircraft;
- request the flight control officer for clearance to take off.

Besides, on the aircraft equipped with unmodified antiskid device МРК-20, disengage the STER button.

2. TAKE-OFF

<u>Take-off at maximum power setting.</u> Take-off at maximum power setting should be accomplished at 50% fuel load only.

After getting take-off clearance, start the clock and, while keeping the aircraft on the brakes, smoothly shift the throttle lever to the MAXIMUM (МАКСИМАЛ) position.

While accelerating the engines to the maximum speed, check closing of the by-pass bands by referring to extinguishing of the BAND OPEN (ЛЕНТА ОТКРЫТА) lamps on the annunciator.

Having ascertained that the engines are accelerated to the MAXIMUM power setting, check the engine speed, exhaust gas temperature and oil pressure, gradually release the brake lever and start the take-off run.

From the moment of beginning of the take-off run the pilot should concentrate his attention on maintaining the direction of take-off. To maintain the take-off direction align the aircraft with the runway centre line or with landmark selected.

At the beginning of the take-off run slight deviations of the aircraft from the runway centre line should be counteracted by deflecting the pedals slightly and smoothly without applying the brakes; on the aircraft equipped with unmodified МРК-20 drive the direction is maintained with the brakes applied.

Deflect the pedal to the side opposite to the direction of the aircraft deviation from the runway centre line in proportion with the deviation occurred.

At the beginning of the take-off run, keep the control stick in the neutral position.

Gaining of speed is checked by a short-time glance to the speed indicator in the cockpit. Upon gaining a speed of 220 to 240 km/h, smoothly shift the control stick backward through 2/3 of its full travel. At this moment the main attention should be concentrated on maintaining the direction and determining the nose wheel lift-off moment.

The nose wheel clears the ground at a speed of 280 to 290 km/h. At the normal take-off angle (a pitch angle of 10 to 11°), the horizon is projected on the lower base of the canopy windshield (Fig. 37). Keep the aircraft at this position until it clears the ground.

The take-off run of the aircraft on two wheels is steady.

Soft shock-absorption system of the aircraft ensures smooth unsticking of the aircraft from the runway, without jerks and oscillations. The pilots who are taking off for the first time should bear it in mind so as to avoid premature retraction of the landing gear.

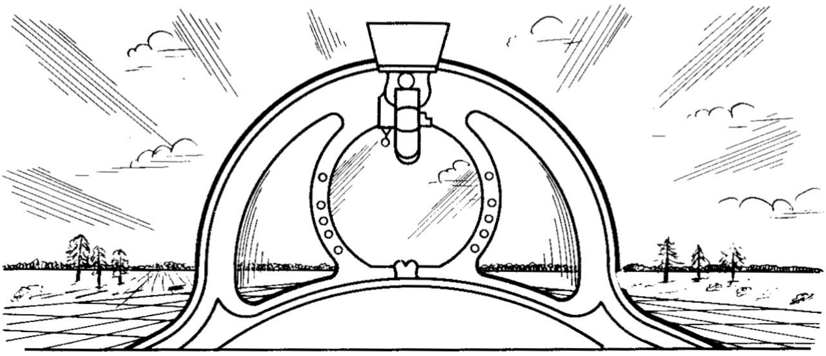


FIG. 37. POSITION OF AIRCRAFT NOSE SECTION WITH RESPECT TO HORIZON DURING TAKEOFF AT SECOND STAGE OF TAKEOFF RUN

The unstick speed depends on the aircraft mass, outside air temperature and atmospheric pressure; therefore, the pilot should know the nature of effect of these factors on the unstick speed.

The МиГ-25П aircraft carrying a 50-per cent fuel load without missiles unsticks at a speed of 320 to 330 km/h. After unsticking the aircraft is steady. Effectiveness of the control surfaces is adequate to counteract the deviations.

Take-off at full reheat. Keeping the aircraft on the brakes, accelerate the engines to the maximum speed and check their operation for 3 - 5 minutes. The difference in speed of the port and starboard engines at the maximum power setting should not exceed 2 per cent. Upon making sure that the engines are running properly, shift the throttle levers to the FULL REHEAT (ПОЛНЫЙ ФОРСАЖ) position.

Check engagement of the afterburners of both engines by illumination of the pilot lamps labelled REHEAT (ФОРСАЖ) which indicate that electric power is supplied to the afterburner system, as well as by a short-time drop (for 3 - 5 s) and subsequent rise of the turbine exhaust gas temperature in excess of the value at the maximum power setting, but not over than 820°C.

Ignition of the afterburner is accompanied by slight jerks which may be not noticed by the pilot during the first flights.

Upon checking the engagement of the afterburner, release the brake lever and start the take-off run. The actions of the pilot in the course of taking off at the FULL REHEAT power setting are similar to those of the take-off performed at the maximum power setting. In this case, acceleration during the take-off run is higher and the pilot should have prompt actions in maintaining the direction of the take-off.

Special attention should be paid to holding the direction at the beginning of the take-off run, since at this moment a deviation of the aircraft is most likely due to a misalignment of the aircraft with the runway centre line.

The МиГ-25П aircraft carrying a 100-per cent fuel load unsticks at a speed of 350 to 360 km/h.

A crosswind component of up to 10 m/s practically does not affect the take-off technique. At a crosswind of more than 10 m/s the aircraft has a tendency to turn against the wind which is counteracted by the deflection of the nose wheel and rudders.

The rudder deflection margin is adequate to maintain the direction at a crosswind component of up to 15 m/s.

3. CLIMB

Having ascertained that the aircraft lifts off the ground at the assigned take-off angle, set the landing gear control valve to the RETRACTED (УБРАНО) position at an altitude of 10 to 15 m.

In the course of the landing gear retraction, take care to prevent increase of the airspeed in excess of 600 km/h. Increase of the airspeed in excess of 600 km/h may result in incomplete retraction of the landing gear and damage to the wing flaps.

Check that the landing gear is fully retracted by referring to the indication of the red pilot lamps on the ППС-2МК LG and flaps position indicator and by increase of pressure in the hydraulic system (against the pressure gauge) to 210 kgf/cm^2. The landing gear retracted, use the КПП-1 flight director indicator to select a pitch angle of 10° when taking off at the maximum power setting and 12 - 15° when taking off at augmented power setting.

If as a result of exceeding of the airspeed over 600 km/h even though one landing gear strut fails to retract (the red pilot lamp does not illuminate), increase the climb angle, establish an airspeed of 550 - 500 km/h, set the landing gear control valve to the NEUTRAL (НЕЙТРАЛЬНО) position and then to the RETRACTED position. Make sure that all three red pilot lamps glow on the ППС-2МК indicator; after that place the landing gear control valve to the NEUTRAL position.

At an altitude of not less than 100 m retract the flaps. To do so, depress the RETRACTED button and keep it depressed until the flaps are fully retracted. If during retraction the aircraft energetically banks, immediately depress the EXTENDED (ВЫПУЩЕНЫ) button and eliminate the bank. Do not retract the flaps repeatedly, report the matter to the flight control officer and follow his instructions.

The МиГ-25П aircraft is fitted with the floating flaps which are retracted under the action of an incoming flow of air at an airspeed of more than 700 km/h if the pilot forgets to retract them. At a speed of less than 700 km/h the flaps extend again; it will involve increase of fuel consumption.

The retracted position of the flaps is checked by referring to extinguishment of the FLAPS DOWN (ЗАКРЫЛКИ ВЫПУЩЕНЫ) lamp on the ППС-2МК indicator.

In the course of climbing beginning from the moment of the aircraft unstick up to the retraction of the flaps the pulling forces increase on the control stick. These forces are removed with the aid of the stabilizer trimming mechanism.

While climbing at an airspeed of not less than 450 km/h, check operation of the АРУ-9 automatic transmission ratio controller by referring to extinguishment of the STAB LAND SET (СТАБИЛИЗ. НА ПОСАД.) lamp on the annunciator and displacement of the pointers on the УПУ-9С and УПУ-9Р indicators from the small arm to the large one.

Having set the climbing mode, it is necessary to look around, check the readings of the flight and navigation instruments, as well as of the engine instruments.

Turn off the afterburners successively at an airspeed of not less than 600 km/h.

4. ROUTE PLOTTING

At an altitude of 1000 m after disengagement of the afterburners look round and perform the turns on the cross-wind and downwind legs with a bank of 30° at an airspeed of 600 km/h in close succession. In the course of the turn continue climbing.

Let us consider a wide pattern at an altitude of 2000 m with subsequent descent to an altitude of 800 m. Figs 38 and 39 present route plotting and circling flight pattern.

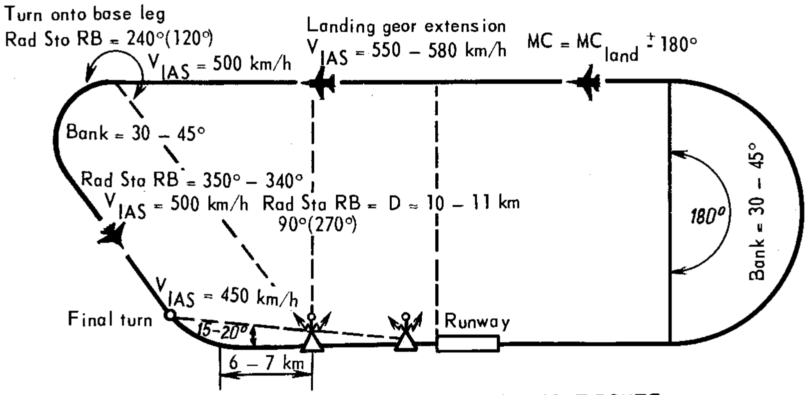


FIG. 38. PLOTTING OF CIRCLING FLIGHT ROUTE

When performing a turn, it is recommended to distribute attention in the following way:

- flight director indicator (roll, pitch);
- the ДА-200 combined instrument (climb rate);
- flight director indicator;
- airspeed indicator;
- altitude indicator;
- combined course indicator (flight course).

At 100 - 150 m to the assigned altitude start gradually decreasing the climb angle and engine speed. At an altitude of 2000 m maintain airspeed 600 km/h. An engine speed of 78 - 80% corresponds to an airspeed 600 km/h.

The moment of the turn recovery is determined by referring to the course indicator and visually.

After reversing the course double your attention and make sure that other aircraft do not interfere with further circling.

Besides, continuously analyse the radio conversation between the flight control officer and other pilots being in air. It allows to estimate indirectly the air situation within the area of the airfield.

When other aircraft perform circling flight, to provide for flight safety and normal landing approach, it is necessary to maintain the preset distance to a leading aircraft. As a rule, in this case, the pilots radio the flight control officer about the legs being effected.

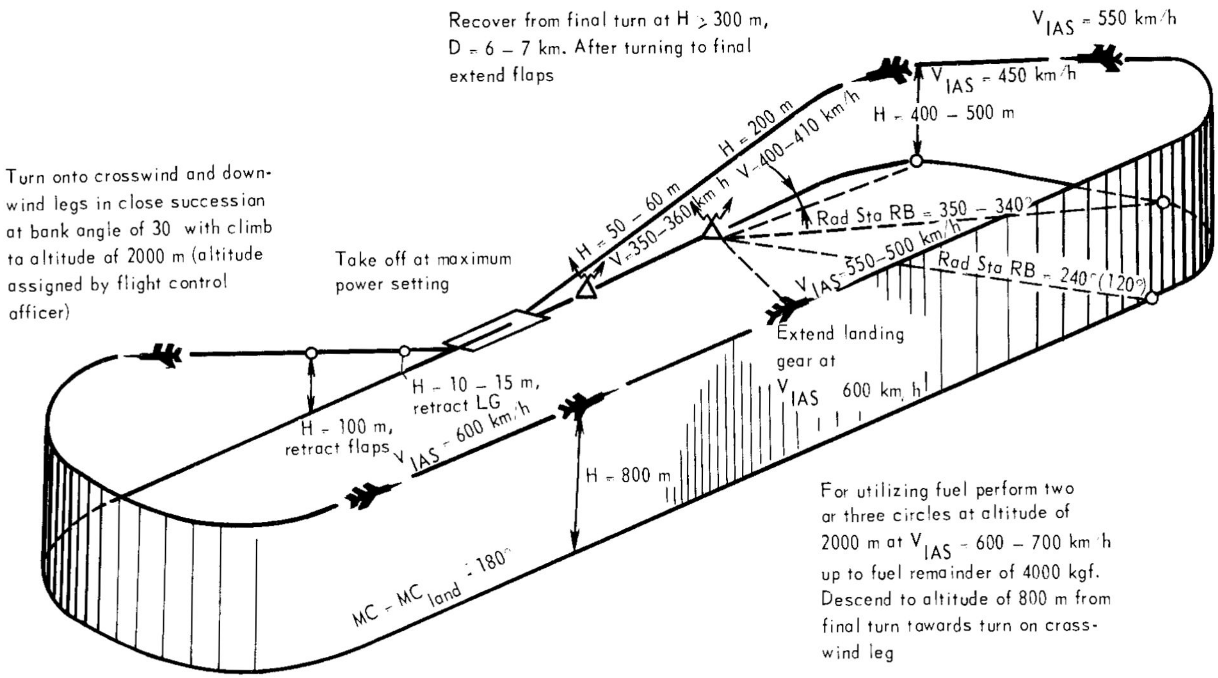


FIG. 39. CIRCLING FLIGHT PATTERN

At an altitude of 2000 m perform the circling flight until the fuel load amounts to 4000 kgf (or assigned by the commander). After that perform landing approach on permission of the flight control officer.

To perform landing approach, descend from an altitude of 2000 m to 800 m when flying from the base-leg turn to the turn on the cross-wind leg. While descending, maintain a progressive airspeed of 600 km/h, and a vertical speed of 15 m/s up to an altitude of 1000 m. When descending from an altitude of 1000 m to 800 m, maintain a descent rate of 10 m/s.

At an altitude of 800 m bring the aircraft into level flight. To maintain an airspeed of 600 km/h an engine speed of 75 to 78% is required.

The turns on the cross-wind and downwind legs should be performed in close succession at a bank angle of 30° intercept to the course opposite to the landing course.

From the turn on the downwind leg to the turn onto the base leg the aircraft should fly in parallel with the runway; the side distance amounts to 10 - 11 km. The side distance is checked by referring to the ШПД-2 range indicator and typical landmarks.

At this flight stage the pilot should check the following:

- pressure in the hydraulic system (210 kgf/cm^2);
- air pressure in the main and emergency air systems (100 to 130 kgf/cm^2);
- engagement of the anti-skid unit;
- engagement of the nose wheel brake.

In the first solo flights the brake parachute deployment switch should be set to the MAN (РУЧН.) position.

When abeam the outer marker beacon (Rad Sta RB = 270° with the left-hand traffic circuit or Rad Sta RB = 90° with the right-hand traffic circuit), reduce an airspeed up to 550 - 580 km/h. After that place the landing gear control valve knob to the DOWN position.

Check the extension of the landing gear by illumination of the green pilot lamps and restoration of the pressure in the hydraulic system up to 210 kgf/cm^2.

The landing gear control valve knob should remain in the extended position until the aircraft is parked.

With the landing gear extended, set an airspeed of 500 km/h. In this case, the engine speed will be within the range of 75 to 78%.

5. LANDING APPROACH AND ESTIMATION FOR LANDING

Before turning onto the base leg it is necessary to look round, request clearance for landing and at Rad Sta RB = 240° (120°) perform the turn onto the base leg through an angle of 100 to 110° at an airspeed of 500 km/h with a bank of 30 to 45° in the horizontal plane.

Recovery from the turn onto the base leg should be completed at Rad Sta RB = 345 to 340° with the left-hand traffic circuit or at Rad Sta RB = 15 to 20° with the right-hand traffic circuit.

After turning onto the base leg, bring the aircraft into a descent at a vertical rate of 5 to 7 m/s, set the engine speed of 74 to 76% and extend the flaps. In this case, make sure that an airspeed is 450 km/h. Accuracy in maintaining the airspeed is corrected by changing the engine speed within 1 - 2%.

Check extension of the flaps by referring to illumination of the FLAPS DOWN pilot lamp. If the wing flap extension causes energetic rolling of the aircraft, immediately depress the RETRACTED button, go around and report the matter to the flight control officer.

In this case, perform landing with the wing flaps retracted.

After turning to the base leg, descend the aircraft so as to enter a turn to final at an altitude of 400 to 450 m and at an airspeed of 450 km/h.

The final turn is performed at an airspeed of 450 km/h at a runway sighting angle of 15 to 20° so that the recovery from the turn is completed at an altitude of not less than 300 m at a distance of 6 - 7 km from the runway.

Accuracy of interception of the runway centre line is adjusted by changing the bank in the course of the turn. In case of inaccurate interception of the landing course, it is necessary to correct the error before flying over the outer marker beacon by turning the aircraft to the left or to the right through an angle of not more than 15°. If it is impossible to correct the error before flying over the outer marker beacon, the pilot must go around, report the matter to the flight control officer and effect a repeated approach with the errors made during the first approach taken into acount .

After the final turn gradually bring the aircraft to the descent attitude at a vertical rate of 5 to 3 m/s. Depending on a direction and force of the wind, as well as on the fuel remainder, select an engine speed of 68 to 70%. In this case, fly over the outer marker beacon at an airspeed of 420 to 400 km/h at an altitude of 200 m. As an airspeed decreases up to 400 km/h, it is necessary to check the position of the АРУ-9 automatic transmission ratio controller: the pointers on the УПУ-9С and УПУ-9Р indicators should be in the lower position (in the SMALL ARM position, the STAB LAND SET lamp on the annunciator should glow).

Fly over the inner marker beacon at an altitude of 60 to 50 m and at an airspeed of 360 to 350 km/h. After flying over the inner marker beacon, keep descending into the flare-out point located at a distance of 100 to 200 m from the runway approach end at an airspeed of 340 to 330 km/h.

Thus, in the course of the prelanding gliding it is necessary to constantly check the altitude and airspeed of flight.

If the landing is performed without missiles at a fuel remainder amounting to 3000 kgf, establish an airspeed of 330 to 340 km/h by the moment the flare-out procedure is to be started. The aircraft glide speed and flare-out speed should be increased by 5 to 10 km/h per each 1000-kgf landing weight increase.

Due to a stepped variation of the engine thrust at a speed of 67 to 69% caused by the operation of the jet nozzles and increase of the time of thrust response, when gliding after having passed the outer marker beacon select an engine speed of not less than 65%. To maintain the assigned gliding speed, change the engine speed by 2 - 3% by gradually shifting the throttle levers.

Abrupt shifting of the throttle levers may considerably increase the engine speed and, hence, thrust of the engines and gliding speed. As a result, the aircraft may intercept the flare-out point at an increased airspeed and the landing will be performed with overshooting.

After flying over the outer marker beacon, finalize the approach heading and descent angle and check for absence of roll and sideslip. As approaching the flare-out point, maintain the airspeed more accurately.

Accurate estimation for landing ensures descent of the aircraft to the flare-out starting point at a gliding speed corresponding to a specific fuel remainder and weather conditions. If a descent is performed to a point located at a longer distance from the runway approach end than the flare-out starting point, the aircraft touches down short of the runway. To eliminate undershooting, it is necessary to increase the engine speed so that with the preset airspeed maintained the glide path passes through the flare-out starting point.

If the flare-out point is selected too close to the runway approach end, the aircraft will overshoot. To eliminate overshooting, reduce the engine speed (but not less than 65%) and, maintaining the preset airspeed, direct the glide path to the flare-out starting point.

The pilot may check correct maintaining the glide path by referring to the following data:

(a) an altitude of 300 m and an airspeed of 420 to 400 km/h of the aircraft with the wing flaps extended correspond to a distance of 6 to 7 km from the runway approach end;

(b) the outer marker beacon is passed over at an altitude of 200 m and at an airspeed of 420 to 400 km/h;

(c) after flying over the outer marker beacon the vertical descent rate is equal to 5 - 3 m/s;

(d) the inner marker beacon is passed over at an altitude of 60 to 50 m and airspeed of 360 to 350 km/h with a vertical descent rate being equal to 2 - 3 m/s;

(e) the aircraft descends to the flare-out starting point; the aircraft flare-out speed amounts to 340 - 330 km/h.

6. LANDING

On making sure that estimation of the distance and direction is correct and maintaining the preset descent regime, direct your glance from a height of 30 - 20 m to the ground through the front left side of the canopy through an angle of 10 to 15° in the direction of descent.

The pilot should distribute his attention in the following succession:

- distance to the ground (determine the moment the flare-out procedure is started);
- direction of flight;
- absence of roll and drift of the aircraft;
- airspeed of flight (330 to 340 km/h by the moment the flare-out procedure is started).

At a height of 10 to 8 m start decreasing the gliding angle by deflecting the control stick backward in smooth manner so as to finish the flare-out at a height of 0.7 to 1 m.

In the course of the flare-out procedure distribute your attention in the following sequence:

- determination of the distance to the ground;
- direction of flight;
- absence of roll and drift;

- determination of the moment to shift the throttle levers to the IDLE position.

At the end of the flare-out smoothly shift the throttle levers to the IDLE stop.

In the course of the holding-off, as the aircraft descends and airspeed decreases, continue smoothly pulling the aircraft control stick backward so as to land the aircraft without pancaking and rolling at a normal landing angle of 10 - 11°.

In case of a normal landing profile (the landing angle amounting to 10 - 11°), the aircraft touchdown speed when carrying a fuel load of 3000 kgf and less and without external stores amounts to 280 - 290 km/h. The maximum landing ground speed should not exceed 320 km/h.

When the aircraft touches the runway with the main wheels, stop manipulating the control stick. Leave the control stick in the position attained when touching the runway.

Having ascertained that the aircraft does not unstick the runway, shift your glance ahead through the canopy front glazing and maintain the direction of the landing roll by referring to the runway centre line. At a speed of not more than 300 km/h depress the appropriate button to deploy the brake parachute. Deployment of the brake parachute is sensed by the pilot by pronounced deceleration of the aircraft.

The aircraft is stable in the landing roll. Direction of the roll is easily maintained by deflecting the pedals.

After the nose LG leg is lowered apply the brakes. A force applied to the brake lever depends on a length and condition of the runway, wind velocity and direction, accuracy of estimation and landing ratio of the aircraft.

The landing roll in standard conditions with deployment of the brake parachute and application of the wheel brakes at a fuel remainder of 3000 kgf (with no missiles carried) amounts to 800 m.

In favourable conditions (strong headwind, runway length in excess of 2500 m) it is permissible to perform landing without use of the brake parachute. In this case, after touchdown, maintain the aircraft landing angle up to a speed of 240 to 250 km/h; then, lower the nose wheel and start braking at a speed of not more than 235 km/h. When performing the first solo flights, effect landing with the use of the brake parachute only.

At the end of the landing roll retract the flaps and release the brake parachute. Release the brake parachute at a speed of 10 to 20 km/h.

After clearing the runway shut off the left engine and continue taxiing to a prescribed parking area.

In subsequent solo flights use should be made of automatic deployment of the brake parachute. To this end, before the flight, place the brake parachute deployment switch to the AUTO (ABTOM.) position. The brake parachute is automatically deployed when the aircraft touches the ground.

In case of a low-lifted nose wheel landing or failure of the brake parachute deployment system, deploy the brake parachute manually.

Landing at a crosswind of up to 10 m/s is allowed to be performed with deployment of the brake parachute. At a crosswind of 10 to 15 m/s deploy the brake parachute manually after the nose LG wheel is lowered.

When rolling after touchdown the aircraft tends to turn into the wind. Counteract the turn by an appropriate deflection of the pedals.

The deployment of the brake parachute results in a material turning moment. To counteract this moment, deflect the pedals to a greater value. When doing so, remember that when the aircraft nose LG wheel touches the runway a considerable turning moment may occur if the pilot fails to set the pedals to neutral. Therefore, prior to lowering the nose LG wheel, set the pedals to neutral and, after the nose wheel touches the runway, deflect the pedal again to counteract the turn.

When landing at a crosswind, due to the fact that it is impossible to use the brakes fully, the landing roll of the aircraft increases. For example, at a wind lateral component of 10 to 15 m/s, the landing roll increases by 10 to 15%, respectively.

Landing with the wing flaps retracted is performed if it is impossible to extend them due to some reasons or if the pilot has revealed asynchronism in extension of the wing flaps and removed them immediately.

When landing with the wing flaps retracted the airspeed at gliding after turning to final up to the beginning of the flare-out should be by 20 to 30 km/h higher than during the landing performed with the flaps extended. Fly over the outer marker beacon at an altitude of 200 m. After flying over the outer marker beacon, glide towards the flare-out point so as to pass the inner marker beacon at a height of 30 to 40 m. Flare out the aircraft more smoothly than during landing with the flaps extended, avoiding ballooning. The aircraft flies over the ground longer than usually; therefore, the pilot should gradually pull the control stick backward all the time as the aircraft approaches the ground and he should not try to land the aircraft prematurely.

The touchdown speed increases respectively by 20 - 30 km/h as compared with the landing performed with the wing flaps extended.

After touchdown, deploy the brake parachute manually not exceeding the speed of 320 km/h.

The decision to go around to ensure flight safety should be taken well in advance at an altitude of not less than 50 m, since the time of engine acceleration from the idle to the maximum speed amounts to 11 - 14 s. But in case of an emergency it is permitted to go around from any altitude, down to touching the runway with the wheels, take-off run and further unsticking followed by the aircraft acceleration.

Having taken a decision to go around, without reducing the descent rate, smoothly increase the engine speed up to the maximum one, place the brake parachute deployment switch to the MAN position and on obtaining an airspeed of 340 to 350 km/h gradually bring the aircraft to climbing attitude. After that set the landing gear control valve to the RETRACTED position. In the course of climbing avoid decrease of the airspeed. Retract the wing flaps at an altitude of not less than 100 m.

7. TYPICAL ERRORS MADE BY PILOTS IN CIRCLING FLIGHT AND THEIR REMEDY

Positioning of the aircraft at an angle with respect to the runway centre line before take-off results in deviation of the aircraft towards the edge of the runway as the aircraft starts take-off running. To correct the error it is necessary to stop further deviation of the aircraft by smoothly applying the appropriate pedal. When doing so, do not try to align the aircraft with the runway centre line, but maintain straight take-off run by keeping the aircraft from the further deviation.

The lift-off angle of the nose section of the fuselage is small. This error may occur due to the fact that the pilot stops pulling the control stick backward at the moment of the nose-wheel lift-off. The aircraft continues running with a low-lifted nose wheel (a pitch angle as read off the flight director indicator is less than 10°, the horizon is projected higher of the lower base of the canopy windshield). It will cause the aircraft unstick at an increased speed and an increased load will be applied to the main wheels.

To correct this error, the pilot should deflect the control stick backward smoothly to increase the pitch angle so that the horizon is projected to the lower base of the windshield of the canopy glass.

The climb angle after the aircraft unsticks the ground is insufficient. The climb angle is set and maintained with the aid of the flight director indicator. Failure to maintain the preset pitch angle, especially when taking off at the augmented power setting, may result in an energetic increase of the airspeed in excess of 600 km/h before the complete retraction of the landing gear.

To correct this error, the pilot should manipulate the control stick to set the assigned pitch angle by referring to the flight director indicator and trim out the control stick by means of the stabilizer trimming mechanism.

Failure to maintain the preset gliding speed after flying over the outer marker beacon. This error occurs in case the engine speed does not correspond to the preset gliding speed. It results in that the airspeed will be higher or lower than the preset one after the aircraft passes over the outer marker beacon.

Elimination of this error by the МиГ-25П aircraft has the following peculiarities: at the initial moment after the engine speed decreases (increases) the airspeed decreases (increases) slowly, and then starts changing energetically. Due to this double movement of the throttle levers is required. As the airspeed decreases, it is necessary to increase the engine speed by 3 - 4% first, and as soon as the airspeed starts increasing, reduce the engine speed by 1 - 2%. When increasing the airspeed, set the engine speed of 65 to 66%, as soon as the airspeed starts dropping, increase the engine speed by 1 - 2%. Thus, the pilot should check not only the flight speed, but constantly notice the tendency for its variation.

Low pull-up. This error is a result of late elimination of undershooting. The low flare-out forces the pilot to decrease the gliding angle or bring the aircraft into the level flight at a low altitude at a considerable distance from the flare-out starting point.

Usually, in such cases the aircraft approaches the runway approach end at an increased airspeed and a height of more than 1 m.

It may result in more serious errors in landing approach estimation and landing proper. Hence, the pilot should decide to go-around and eliminate the error in due time before the aircraft descends to an altitude of 50 m.

High flare-out. The error arises due to incorrect direction of the pilot's glance, distraction of glance in the course of flare-out and abrupt manipulation of the control stick. Besides, this error may be caused by wrong adjustment of the pilot's seat with respect to his height.

In case of the high flare-out, do not push the control stick forward, but hold it rather and then pull the control stick adequately backward as soon as the aircraft nears the runway approach end.

Special attention should be paid to counteraction of the aircraft rolls in time.

Ballooning or bouncing of the aircraft into the air during landing.

This error may occur when approaching the runway at an excessive airspeed due to the low flare-out and abrupt movement of the control stick backward effected to recover the aircraft from the gliding angle, as well as due to the fact that the pilot's glance is directed too far forward.

In case of ballooning or bouncing of the aircraft into the air at a high speed it is necessary first to stop further lift-off of the aircraft from the ground by short double manipulations of the control stick. Then, as the aircraft approaches the ground, bring the aircraft onto the runway by smoothly pulling the control stick backward and avoiding rolling. When doing so, it is prohibited to push the control stick forward to place the aircraft to descent attitude after ballooning.

When ballooning at a low speed, it is necessary to hold the control stick in the position at which it was at the moment when the aircraft lifts off the ground and take care to avoid rolling. In this case it is also prohibited to push the control stick forward. As the airspeed decreases and the aircraft approaches the ground, it is necessary to pull the control stick smoothly backward to effect normal landing. The back stick pressure rate should correspond to the descent rate of the aircraft.

MANEUVERING FLIGHTS

Maneuvering flights are intended for mastering firm habits in maneuvering required for the flying personnel when mastering combat employment and for more effective use of combat capabilities of the МиГ-25П aircraft.

The МиГ-25П aircraft carrying four missiles or without missiles may be used for performing the following maneuvers:

- 360° turns;
- zooms;
- chandelles;
- diving;
- rolls;
- spirals with various banks, ascending and descending spirals at the maximum permissible g-loads indicated by the movable sector of the ИП-155 g-load indicator.

Peculiarity involved in flying the aircraft within the maneuvering area consists in that abrupt changes in trimming characteristics of the aircraft at variations of the airspeed and engine power settings result in the necessity of constant use of the stabilizer trimming mechanism in order to decrease pressure applied to the control stick of the aircraft.

A sound knowledge of peculiarities involved in the maneuvering flights on the МиГ-25П aircraft allows the flying personnel to master handling of the aircraft for considerably short time and avoid such blunders that may result in wrong evaluation of the aircraft and its high flight performance.

During the initial stage of training, the flying technique should be practised at the optimum airspeeds and altitudes at which the maneuvering procedure is rather simple and it allows the pilot to become proficient sufficiently in handling the aircraft. Then, as the flying personnel master the habits in handling the aircraft, the pilots should master the flying technique within the entire range of permissible altitudes and airspeeds of flight.

It is allowed to climb with the engines running at the maximum and reheat power settings.

When flying to the maneuvering area it is recommended to maintain the following flight conditions:

- take off with the engines running at the FULL REHEAT power setting; cut off the afterburners at an indicated airspeed of not less than 600 km/h;

- attain an altitude of 2000 m at the maximum power setting with acceleration of the aircraft to a true airspeed of up to 900 - 920 km/h;

- further climb to the assigned altitude should be effected at a true airspeed of 900 to 920 km/h.

1. 360° TURN

The МиГ-25П aircraft performs the 360° turns within the wide range of airspeeds and altitudes. The power setting of the engines on a turn is selected in compliance with the airspeed required.

360° steady turns may be effected at bank angles of up to 70° both at non-reheat and reheat power settings (Fig. 40). Fig. 41 illustrates the relation between the g-load at a 360° steady turn and altitude of flight at the FULL REHEAT and MAXIMUM power settings.

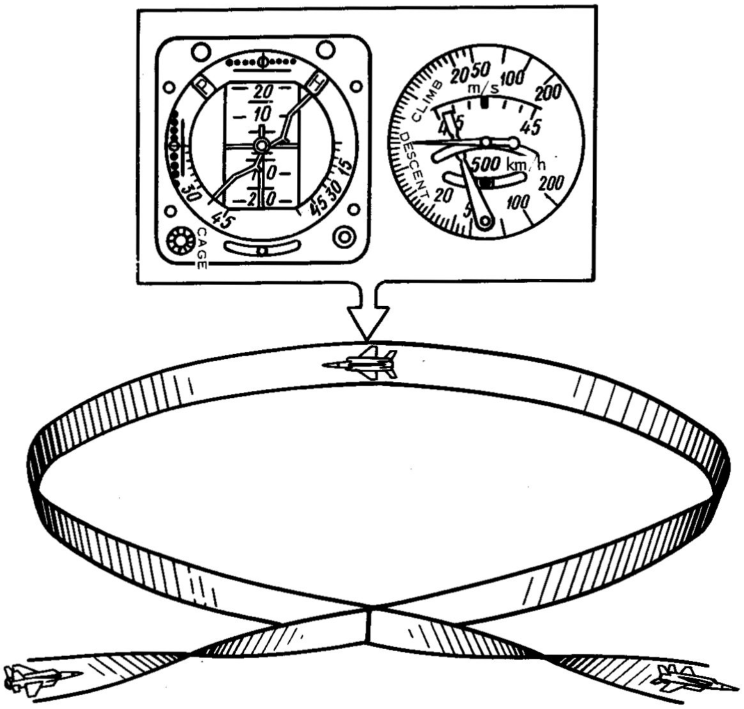


FIG. 40. 360° TURN PATTERN

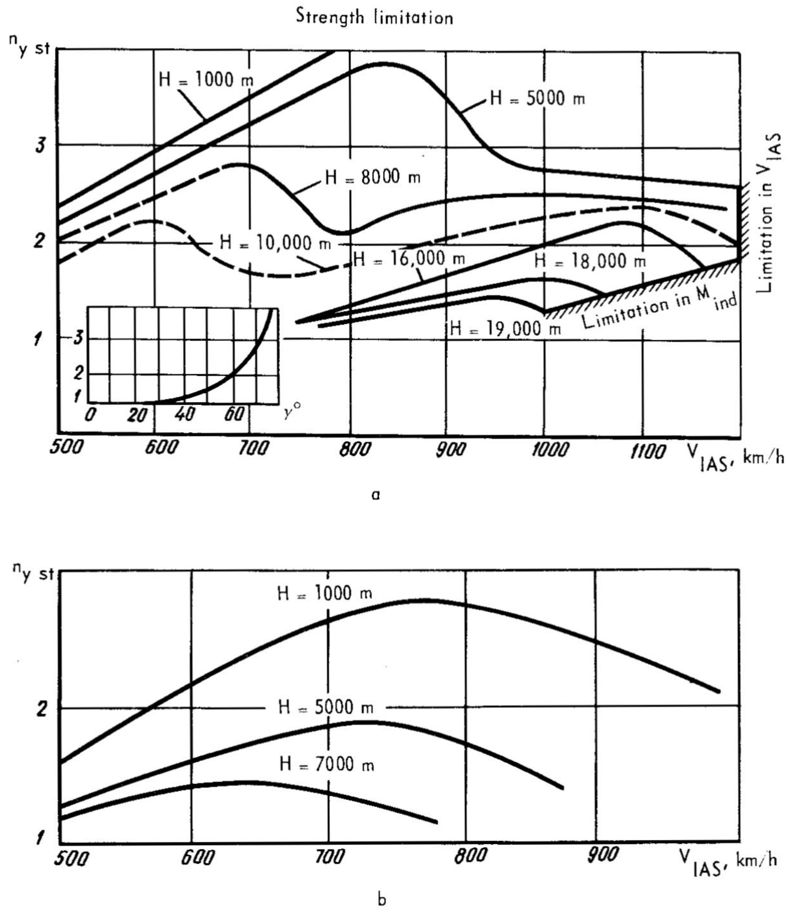


FIG. 41. G-LOAD $n_{y\ st}$ IN STEADY 360° TURN VERSUS V_{IAS} AND FLIGHT ALTITUDE H

With the engines running at the FULL REHEAT power setting, execution of the 360° steady turns on the aircraft carrying four missiles P-40 or without missiles is possible at altitudes of 10,000 to 16,000 m; at altitudes below 10,000 m a 360° steady turn may be performed by the aircraft carrying four missiles P-40 only.

When the aircraft carries no missiles, the 360° steady turns are performed at altitudes below 10,000 m with both engines running at non-reheat power setting or with one of the engines running at the maximum power setting and the other at full augmented or partially augmented power setting. When performing the 360° steady turns with the engines running at the different power setting, it is recommended that the outer (with respect to the direction of the turn) engine runs at the augmented power setting, whereas the inner one runs at the maximum power setting.

The technique involved in performing the 360° turns on the МиГ-25П aircraft does not radically differ from that used for performing the 360° turns on other types of aircraft.

There is no difference involved in performing left and right 360° steady turns.

In training flights 360° turns at medium altitudes at bank angles of up to 60° are executed at an indicated airspeed of 650 to 700 km/h.

Before entering a 360° turn at non-reheat power settings of the engines, establish an assigned airspeed in the level flight, trim out the aircraft control stick and pedals by means of the trimming mechanisms, check the readings of the engine instruments, look around and memorize the 360° turn entry course by referring to the combined course indicator.

In case there is a well-observed landmark within the area of flying, the 360° turn entry and recovery may be executed in the direction of this landmark. In case of absence of typical landmarks or in adverse weather conditions it is possible to enter the 360° turn and recover from it towards the outer marker beacon of the home airfield by referring to the automatic radio compass pointer.

To enter the 360° turn, deflect the control stick and pedals in a coordinated manner. Coordination during entry and in the course of the turn is checked by the sideslip indicator ball.

During entry into the turn the МиГ-25П aircraft tends to lower the nose down; therefore, it is necessary to relieve the pulling forces from the control stick by the stabilizer trimming mechanism, simultaneously bringing the aircraft into the turn.

As the bank and the angular rotation increase, the engine speed increases so as to correspond to the assigned airspeed of the 360° turn by the moment the aircraft reaches the assigned bank. Slow entry into the 360° turn and early increase of the engine speed result in increase of an airspeed at the 360° turn. Energetic entry into the turn and late increase of the engine speed result in a certain decrease of the airspeed during the turn.

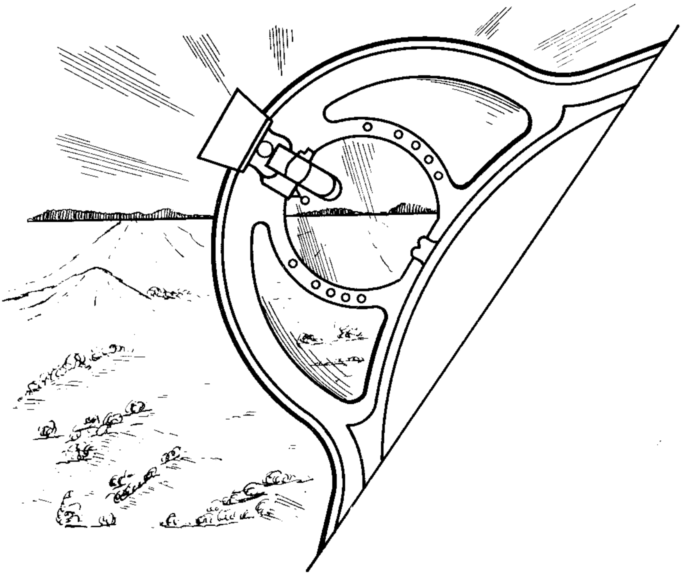


FIG. 42. POSITION OF CANOPY FRONT SECTION WITH RESPECT TO HORIZON DURING 360° TURN AT BANK ANGLE OF 60°

It is necessary to check proper execution of the 360° steady turn by referring to the flight instruments and the position of the canopy front section with respect to the natural horizon. Fig. 42 shows the position of the canopy with respect to the horizon when executing the turn at a bank angle of 60°.

When executing the 360° turn, concentrate your attention successively so as to maintain the assigned bank, altitude, airspeed with respect to the flight path, angular velocity and to avoid sideslipping.

It is recommended to start recovering the aircraft from the turn 10 - 15° before the planned recovery course or before the direction towards the landmark.

Recovery should be accomplished by coordinated and smooth deflections of the control stick and pedals with simultaneous decrease of the engine speed so as to ensure the preset airspeed of flight.

When recovering from the turn, take into account that the aircraft tends to increase the pitch angle. Therefore, it is necessary to trim out push forces from the control stick with the aid of the trimming mechanism of the stabilizer when simultaneously decreasing the bank angle.

In addition to the 360° steady turns executed at non-reheat or reheat power settings of the engines, the МиГ-25П aircraft is able to perform 360° unsteady (accelerated) turns.

The technique involved in performing the 360° accelerated turn rather differs from that of the 360° steady turn. The 360° accelerated turn involves a drop in airspeed and g-loads exceeding the maximum values with respect to thrust.

As the bank increases in excess of the maximum permissible value for the 360° steady turn, pull the control stick backward so as to attain the assigned g-load and, as the airspeed decreases, maintain it by pulling the control stick backward.

When executing the 360° unsteady turns the g-loads should not exceed the maximum permissible ones indicated by the ИП-155 g-load indicator movable sector.

Check approach to the limit angles of attack by referring to illumination of the yellow warning lamp on the ИП-155 indicator. Relieve pulling forces or rather move the control stick forward when the warning lamp comes on.

At altitudes higher than 5000 m and $M > 1.0$, the 360° unsteady turns are accomplished with the control stick deflected fully back or close to the back position.

Typical errors committed when performing the 360° steady turn are:

- aircraft sinking at entry;
- failure to maintain the assigned airspeed and altitude;
- excessive pulling the control stick backward.

Aircraft sinking at entry. The main causes of the aircraft sinking at entry are:

- the g-load does not correspond to the aircraft bank angle;

- excessive deflection of the pedal in the direction of the turn;

- entry into the turn is effected at a sink rate available;

- considerable pulling forces applied to the control stick, which are not trimmed out by the pilot with the aid of the stabilizer trimming mechanism.

As a rule, the aircraft performs a spiral descent at a great bank and g-load. In this case, the translational speed and vertical velocity continuously increase.

The pilot's attempt to stop descending at great bank angles by pulling the control stick backward results in increase of the angular rotation (g-load) and contributes to further sinking of the aircraft.

If the sink rate is not more than 10 to 15 m/s, decrease the bank angle and eliminate descent by deflecting the control stick backward. This done, continue executing the turn. In case the sink rate is 15 m/s and more, eliminate the bank completely, bring the aircraft into level flight and repeat entry into the 360° turn.

Failure to maintain the assigned airspeed and altitude in the course of executing the 360° turn. This error is typical for the initial stage of the flying technique training. Usually, as the pilot gains experience in flights in the maneuvering area, this error is eliminated.

Excessive pulling the control stick backward. This error may result in exceeding the g-load limitations and entry of the aircraft into the critical angles of attack. When entering the critical angles of attack, the aircraft energetically stalls (mostly rightwards) and then enter a dive. When the pilot timely pushes the control stick forward behind the neutral position, the aircraft performs an inverted roll and its airspeed sharply decreases. Prior to stalling, a typical aerodynamic buffeting of the aircraft occurs.

In case of excessive pulling of the control stick backward (slight buffeting arises), it is necessary to release back stick pressure (apply forward stick pressure) and reduce the angular rotation.

Further on, watch the readings of the ИП-155 g-load indicator more attentively and manipulate the controls more smoothly.

2. DIVE

On the MиГ-25П aircraft, dives are permitted at angles of up to 45° within an altitude range of 5000 to 15,000 m, with the engines running at the idle power setting.

For training purposes, dives are practised at medium and high altitudes, at angles of 20, 30 and 45° successively, at an entry airspeed of 450 to 500 km/h (Fig. 43).

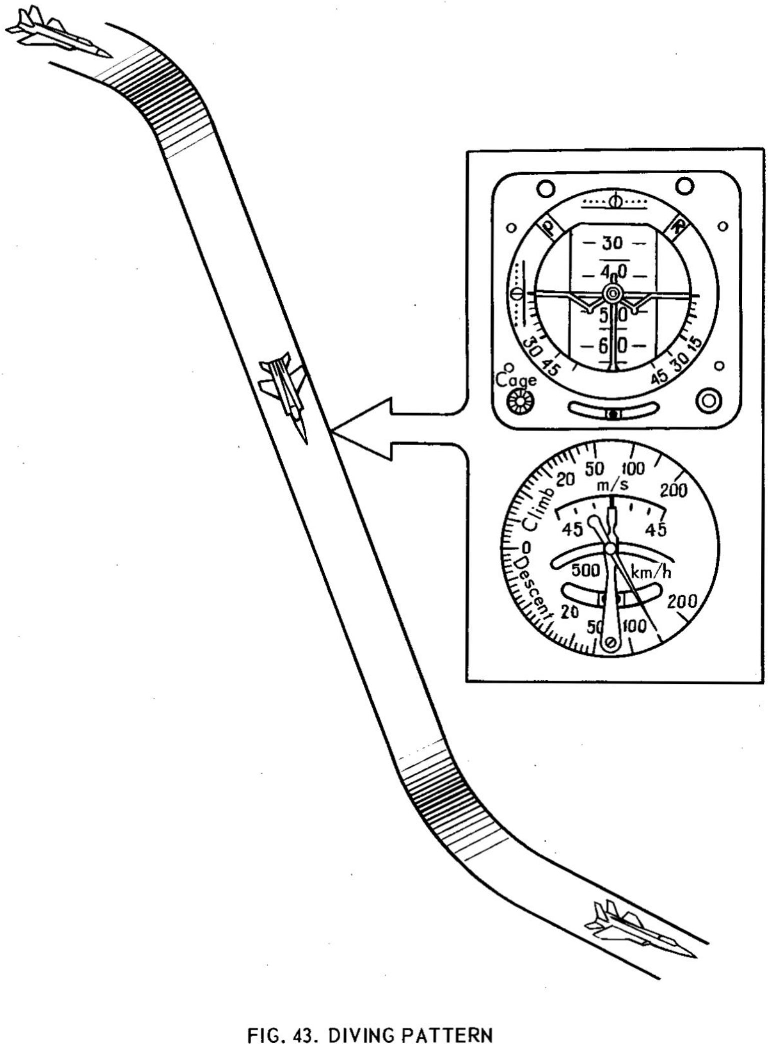


FIG. 43. DIVING PATTERN

As a rule, dive entry for training purpose is accomplished from a turn, since in this case it is easy to set the assigned dive angle and avoid a negative g-load. Besides, when entering the dive from a turn the minimum altitude loss and a slower rate of airspeed rising are obtained.

Prior to entering a dive, it is necessary to set an airspeed of 450 to 500 km/h, then manipulate the control stick and pedals in a coordinated manner to enter a descending turn. When performing the descending turn, set the throttle levers to the IDLE position. When doing so, it should be remembered that it takes a long time for the МиГ-25П aircraft to enter a dive, which results in a great loss of altitude.

During the primary training stage, when entering the dive the bank angles should not exceed 60°, whereas during further mastering of the flying technique the dive may be entered at bank angles of up to 80°. The greater the bank at entry, the lesser the altitude loss and airspeed increment during the time of establishing the assigned diving angle.

As the assigned diving angle is obtained, roll out the aircraft. Maintain the direction of diving by referring to a landmark.

In the course of diving, it is necessary to avoid banking or slipping. Carry out the check by referring to the landmark, gyro horizon on the flight director indicator and sideslip indicator.

The dive recovery should be started at an indicated airspeed of 800 km/h and at a maximum permissible g-load read by the ИП-155 g-load indicator movable sector, which should be introduced for 3 to 5 s. Due to a long time of engine acceleration, it is recommended to increase the engine speed well in advance in the course of diving in compliance with the further flight conditions.

When recovering from the dive, pay special attention to absence of banking or slipping and follow the g-load rising rate. Abrupt deflection of the control stick backward may result in increase of the g-load in excess of its maximum permissible value read off the movable sector of the ИП-155 g-load indicator.

The typical errors likely to be made during execution of the dive consist in failure to maintain the preset dive angle and diving accompanied with a bank. The errors are eliminated easily as habits in handling the aircraft are acquired.

3. ZOOM

Zooms on the МиГ-25П aircraft are performed at the reheat and non-reheat power settings (Fig. 44).

Entry into the zoom is allowed from the level flight at the airspeeds (Mach-numbers) of up to the maximum permissible ones and altitudes of up to 18,000 - 19,000 m.

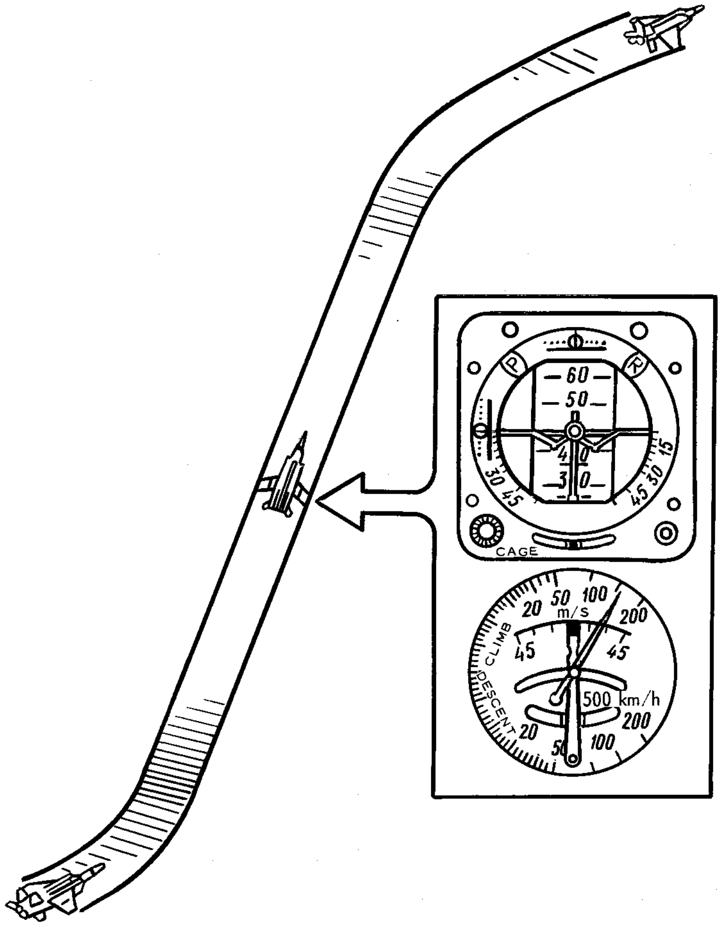


FIG. 44. ZOOMING PATTERN

The altitude gained in the course of the zoom depends on the airspeed, zoom entry altitude, engine power setting and a zoom angle. When executing the limit zoom from altitudes of 500 - 1000 m, the aircraft climbs to an altitude of 6000 to 6500 m, whereas from the altitudes of 17,000 - 17,500 m, the aircraft gains an altitude of 2500 - 3000 m. The limit zoom angles versus the flight altitude are presented in Fig. 45.

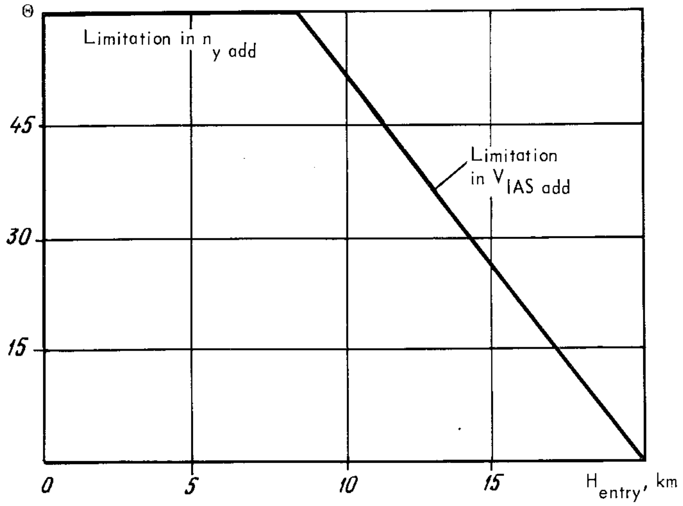


FIG. 45. ZOOM LIMIT ANGLES

For training purposes it is necessary to enter the zoom at an indicated airspeed of 850 to 900 km/h (Mach-number should not exceed 0.9) at the reheat power setting of the engines. It is advisible to accelerate the aircraft with a descent or ensure the attaining of the assigned airspeed on the descending leg of the maneuver which precedes the zoom.

After the assigned airspeed is reached, pull the control stick backward to apply the available or maximum permissible g-load for 3 to 5 s. Check the g-load against the movable sector of the ИП-155 g-load indicator.

When the zoom is entered at altitudes of 7000 to 8000 m and M = 0.97 to 1.2, the available vertical g-load decreases up to 2.5 - 3.5 g's.

Simultaneously deflecting the control stick backward, trim out the control stick in a coordinated manner by means of the stabilizer trimming mechanism.

In the course of entering the zoom it is recommended to distribute the attention in the following succession: indicator ИП-155 (g-load) - flight director indicator (climb angle, absence of banking) - airspeed indicator - altimeter.

As soon as the assigned climb angle is reached, slightly push the control stick forward to fix this angle.

After the assigned pitch angle is set on the gyro horizon of the flight director indicator, concentrate your attention to determining the moment of recovery initiation from the zoom. The greater the angle, the higher the airspeed of recovery initiation.

Recovery from the zoom at angles of less than 45° is accomplished with a turn through 90°. To recover from the zoom, upon achieving the recovery speed, bring the aircraft into a turn at a bank angle of up to 60° by deflecting the control stick and pedals in a coordinated manner and simultaneously lower the aircraft nose to the line of horizon. By the moment the aircraft recovers from the zoom the rate of the pitch angle decrease should amount to a value at which an airspeed is not less than 450 to 500 km/h.

As the aircraft nose approáches the horizon line, smoothly eliminate banking and bring the aircraft into the level flight.

To recover from the zoom at a pitch angle exceeding 45°, it is necessary to perform a half-roll. Then smoothly move the control stick backward to lower the aircraft nose to the horizon line and execute the second half-roll. When doing so, avoid stalling after executing the first half-roll.

At the pitch angles of less than 45° the aircraft may also be recovered from the zoom by deflecting the control stick forward. When doing so, avoid applying the negative g-load.

When the aircraft is brought into the level flight, cut off the afterburners and select the power setting corresponding to the further flight conditions.

A typical error committed during execution of the zoom is a delay in recovering the aircraft into level flight. In case of a considerable loss of the airspeed in zooming, in the course of recovery from the zoom do not be in a hurry to recover the aircraft from the bank completely. Bring the aircraft to descent attitude by decreasing the bank gradually. When doing so, pay special attention to coordinated manipulation of the controls. When the airspeed increases, roll out the aircraft, bring it into the level flight and cut off the afterburners.

4. CHANDELLE

The chandelle is performed at reheat power setting and at the maximum permissible vertical g-load read by the movable sector of the ИП-155 g-load indicator (Fig. 46). The aircraft may be entered into the chandelle at the maximum permissible airspeed at altitudes up to 10,000 m. The indicated airspeed of entry into the chandelle at low altitudes should not be less than 800 km/h.

When the aircraft carrying four missiles or without missiles is brought into the maneuver from altitudes of 500 to 1000 m at the maximum permissible airspeed, it will gain an altitude of 6500 to 7000 m.

For training purposes, enter the maneuver from the level flight at an indicated airspeed of 850 to 900 km/h (Mach-number should not exceed 0.9), with the engines running at reheat power setting.

Prior to entering the chandelle, cut in the reheat power setting, accelerate the aircraft up to the assigned airspeed in the level flight or during descending. During acceleration, memorize the flight course as read off the combined course indicator and look around.

As soon as an airspeed which is less than the assigned one by 30 - 50 km/h is achieved, apply the maximum permissible g-load (read by the movable sector of the ИП-155 g-load indicator) for 3 to 5 s and bank the aircraft through an angle of 10 to 15°.

When entering the chandelle, do not pull the control stick back abruptly, since it may result in exceeding the g-load limitations.

Then, continue climbing on an ascending spiral. When covering two thirds of the maneuver, do not permit the bank to exceed 60 - 65°.

When the aircraft turns through 120 to 130°, gradually decrease the bank and pitch by deflecting the control stick diagonally forward and sideways against the direction of the turn so as to complete the 180-degree turn at an airspeed of 400 km/h. When the aircraft is brought into level flight, cut off the afterburners.

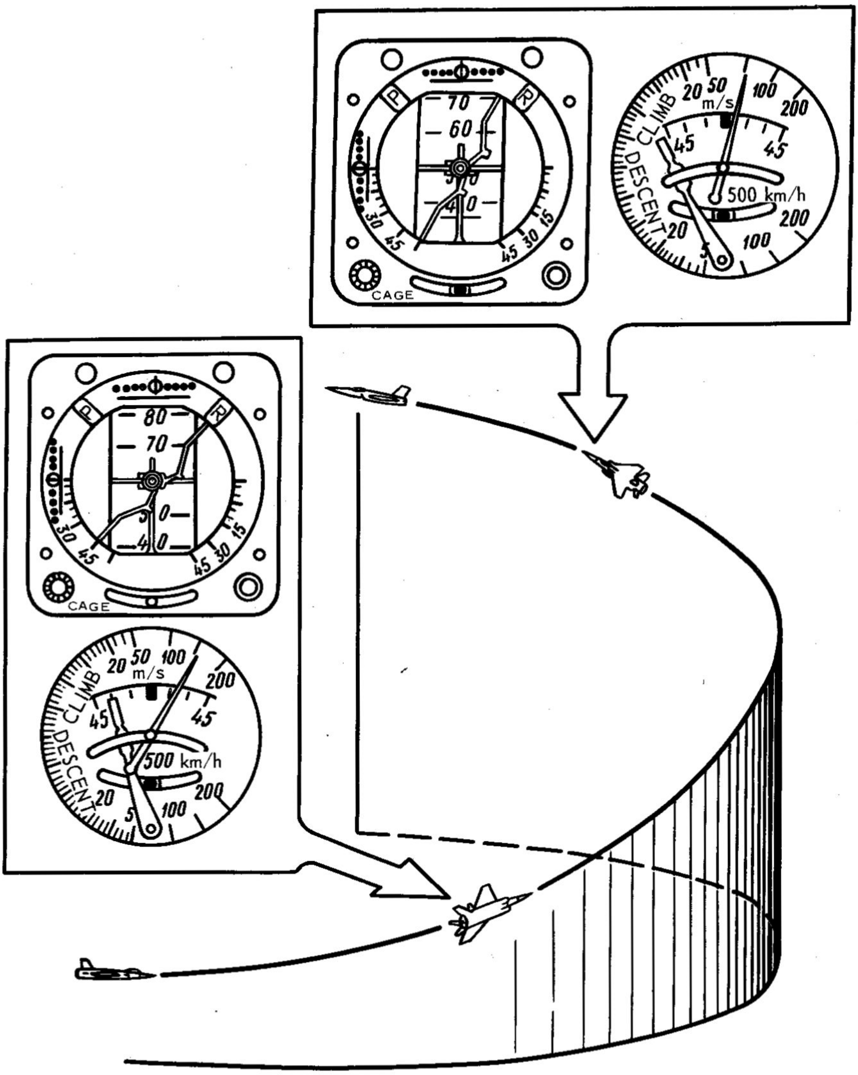


FIG. 46. CHANDELLE PATTERN

Remember that early increase of the bank angle results in that the 180° turn will be accomplished for a shorter time and the aircraft will gain a lesser altitude in the course of the chandelle. If the pilot starts increasing of the bank angle lately, the aircraft has no time to turn through 180°, since as altitude is being gained the flight speed decreases and the pilot has to recover the aircraft from the maneuver before achieving the assigned direction.

5. HORIZONTAL ROLL

Horizontal rolls may be performed on the МиГ-25П aircraft carrying four missiles or without missiles at an indicated airspeed of not less than 550 km/h, with the engines running at reheat and non-reheat power settings (Fig. 47).

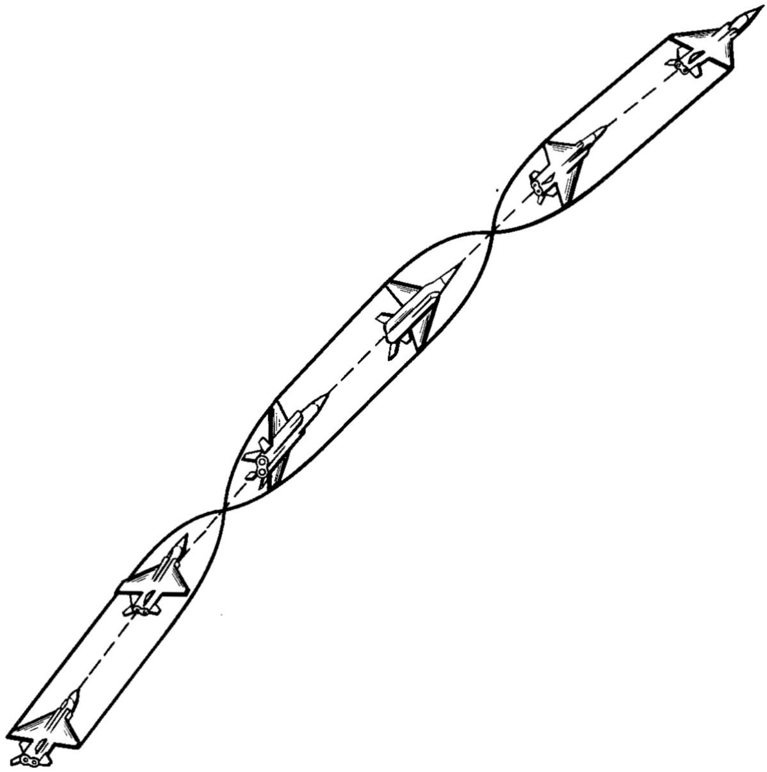


FIG. 47. HORIZONTAL ROLL PATTERN

In training flights, the horizontal rolls are executed at altitudes less than 8000 m and airspeed of 800 to 900 km/h.

For performing a roll, establish the assigned airspeed in the level flight, create a pitch-up angle of 10 to 15° and slightly move the control stick forward to fix this angle. Then, smoothly deflect the control stick as far as it goes in the direction of the roll to turn the aircraft about its longitudinal axis through 360° for 6 to 10 s, increasing the rate of roll by pedal application in the same direction.

To effect the roll correctly, as soon as the aircraft attains a bank angle of 45 - 50°, slightly deflect the control stick forward to counteract aircraft turning and then also to avoid lowering of the aircraft nose below the horizon line in the wheels-up attitude. The aircraft rolling rate in this case should be kept so as to counteract slowing down.

As the aircraft reaches a bank angle of 50 to 60°, ease the pedal to keep the aircraft nose against dropping. 60 to 70° before approaching the level flight attitude, increase the amount of pedal deflection to enter the maneuver, and 30 - 40° before completing the maneuver, smoothly deflect the control stick backward to keep the aircraft nose against dropping below the horizon, line.

When the aircraft turns through 330 to 340°, set the controls to recovery (somewhat behind the neutral position) in the direction opposite to the rotation. When rotation stops, place the pedals to neutral.

When performing the roll, pay special attention to the position of the aircraft nose relative to the horizon and the rate of aircraft rotation about its longitudinal axis. When rolling, direct your glance forward. It is not recommended to distract attention to instruments.

A typical error likely to be made when performing the roll consists in dropping of the aircraft nose below the horizon in inverted flight caused due to insufficient deflection of the control stick forward when entering the maneuver and backward when recovering from it.

6. SPIRAL

For training purposes, the spiral is accomplished at an airspeed of 600 to 700 km/h at a bank of 45° (Fig. 48).

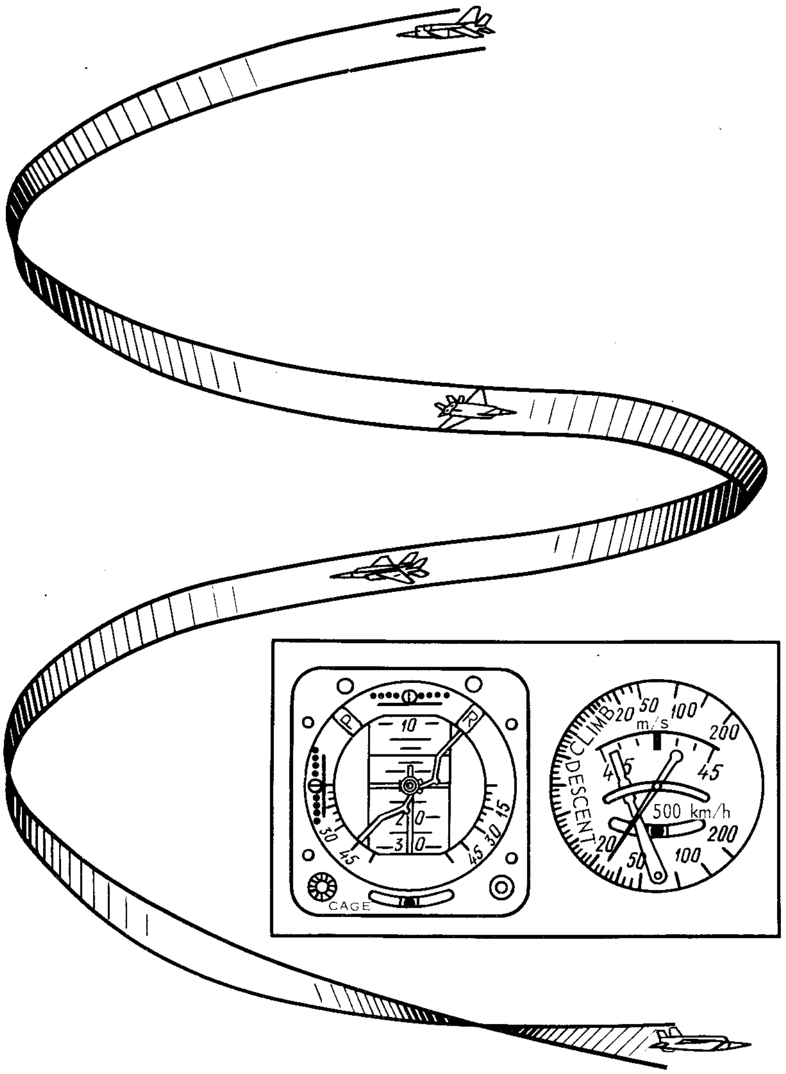


FIG. 48. DESCENDING SPIRAL

Prior to entering the spiral, it is necessary to look around, giving major attention to the lower hemisphere, establish the assigned airspeed, and then bring the aircraft into the turn by coordinated displacement of the control stick and pedals with simultaneously lowering the aircraft nose and selecting the engine speed to maintain the assigned airspeed on the trajectory.

Check the bank, vertical velocity and translational speed on the trajectory against the flight director indicator, ДА-200 combined instrument and УС-1600 airspeed indicator. If the spiral is executed correctly, the gyro horizon of the flight director indicator should read the assigned bank and pitch angles, and the ball should be located in the centre.

Increase or decrease of the airspeed on the spiral is effected by the appropriate variation of the vertical descent rate, whereas at the assigned vertical velocity, by the engine speed.

Recovery from the maneuver should be effected by coordinated deflection of the control stick and pedals, with simultaneous increase of the engine speed up to the required value to maintain the assigned airspeed in the level flight.

One of the typical errors likely to be made during execution of the spiral consists in excessive bank increase with nose lowering, which will result in airspeed increase. To correct this error, first eliminate the bank and then decrease the angle of descent.

7. PECULIARITIES INVOLVED IN FLYING AIRCRAFT AT LOW AND EXTREME LOW ALTITUDES

Flights in the maneuvering area at low and extreme low altitudes are intended for mastering firm habits of the pilots in flying and air navigation when performing combat operations under such conditions.

Flights at low and extreme low altitudes are characterized by a number of peculiarities involved. The main peculiarities are as follows:

- limited maneuvering possibilities due to ground proximity;
- weather conditions deteriorating flying conditions (bumpiness, ground haze);
- short time available for landmark detection and identification;
- decreased effective range of the electronic navigation aids, etc.

As a result of the long-time flying at low and extreme low altitudes clearness and rapidity of perception of the landmarks are hampered due to their rapid angular displacement, emotional stress of the pilot considerably increases. All this requires adequate physical and theoretical training, as well as regular practising the flights at low and extreme low altitudes on the part of the pilots.

Mastering flights at low and extreme low altitudes should be started after adequate mastering flying technique at medium and high altitudes by the pilot.

For training purposes, the flights at low and extreme low altitudes are performed at airspeeds of 700 to 800 km/h.

When flying the МиГ-25П aircraft it is necessary to take into account that the МиГ-25П aircraft possesses high acceleration characteristics, especially at altitudes less than 5000 m. With the engines running at the FULL REHEAT power setting and at an indicated airspeed of 1000 km/h, airspeed increment per one second amounts to 15 - 20 km/h. The rear possibility of exceeding airspeed limitations occurs.

To avoid exceeding the limitations, it is necessary to cut off the afterburners and bring the aircraft into the climb attitude at a g-load of 2.5 g's as soon as the LIMIT SPEED (ПРЕДЕЛЬНАЯ СКОРОСТЬ) voice information is received.

When deflecting the ailerons, the aircraft fitted with the stabilizer differential control experiences a bank accompanied simultaneously by a slight slip which does not hinder flying and does not affect the operation of the engines.

Energetic re-establishing of the bank at high subsonic airspeeds of flight at low and medium altitudes with the dampers engaged may result in slight oscillations in yaw at a frequency of about 1 Hz. Therefore, it is not recommended to engage damping mode at altitudes of less than 10,000 m due to possible deterioration of controllability.

At high indicated airspeeds (up to 1200 km/h) for maintaining the level flight practically full forward deflection of the control stick is required; but in this case, the forces on the control stick may be completely relieved by the trimming mechanism.

When flying the aircraft in the maneuvering area at low and extreme low altitudes, special attention should be paid to a coordinated manipulation of the controls and maintaining the flight conditions. Prior to starting maneuvering flights, it is necessary to trim out the aircraft with the aid of the trimming mechanisms of the stabilizer, ailerons and rudders.

At low and extreme low altitudes, trim out the aircraft by means of the stabilizer trimming mechanism so that an insignificant push force remains on the control stick. It ensures transferring the aircraft to climbing attitude in case of inadvertent distraction of attention and easing the forces applied to the control stick.

When performing turns and 360° turns it is necessary to take into account the aircraft tendency to lower the nose spontaneously during entry into the maneuver and to increase the pitch angle during recovery.

For instance, the aircraft may lose up to 100 m of altitude during entry into the 360° turn at a bank angle of 45° which is not permitted at low and extreme low altitude.

To counteract nose dropping during entering the turn or 360° turn, it is necessary to trim out the control stick by the trimming mechanism simultaneously with entry into the maneuver.

When performing vertical maneuvers take into consideration that the aircraft may easily exceed the airspeed and g-load limitations.

The vertical g-load should not exceed the maximum value indicated by the movable sector of the ИП-155 g-load indicator. It is necessary to continuously check the airspeed against the УС-1600 speed indicator.

Intensive air turbulence makes flying at low altitudes more complicated and it requires an increased attention, as well as counteraction of inadvertent deviations of the aircraft.

The VFR daylight flights at low altitudes, as a rule, are performed visually with a periodical check of the flight conditions against the instruments. It is necessary to gain the initial flight altitude gradually at small vertical velocities. When doing so, it is obligatory to check the altitude against the УВО-30К (УВО-М1) instrument and the radio altimeter. Before flight, set the altitude assigned by the mission on the indicator of the РВ-4 radio altimeter. When the aircraft descends below the assigned altitude, the LIMIT ALTITUDE (ОПАСНАЯ ВЫСОТА) warning signal is fed to the pilot's earphones.

It is prohibited to use the radio altimeter when flying over a mountainous terrain.

In addition to determining the altitude with the aid of the instruments, the pilot should be able to determine the flight altitude visually with an adequate accuracy. Visual determination and check of altitude are effected by referring to natural and artificial landmarks having vertical dimensions (trees, poles, separate buildings, etc.).

During the first flights the pilot may fail to evaluate visually the altitude of flight correctly due to a lack of adequate habits. But after two or three flights the pilot acquires enough habits both in visual evaluation of the altitude and in flying the aircraft at low altitudes as a whole.

Under conditions of good visibility of the ground surface and natural horizon, at low and extreme low altitudes the pilot should distribute his attention so that watching the instruments monitoring flight conditions, operation of the engines and various aircraft systems takes the minimum time. For this purpose, the pilot should perfectly know the arrangement of the instruments and units in the aircraft cabin.

Practical flights prove that the pilot satisfactorily trained in flying at low and extreme low altitudes spends 20 - 30% and 80 - 70% of the flight time for the in-cabin and outer-cabin inspection, respectively.

The pilot always determines and checks the flight speed by the instrument.

In case of a sudden decline of visibility or if the aircraft gets into a fog, rain or snowfall, immediately change over to instrument flying and climb to the safe altitude.

8. PECULIARITIES INVOLVED IN FLYING AIRCRAFT WITH USE OF AUTOMATIC FLIGHT CONTROL SYSTEM

When performing the flights for mastering flying technique, the САУ-155П automatic flight control system helps the pilot in handling the aircraft by releasing him from a number of actions as associated with controlling the aircraft.

When mastering the flight technique in the maneuvering area, the pilot may use the stabilization of the aircraft spatial attitudes, and at long-time straight-line flights he may use the levelling mode for stabilizing the flight altitude and heading.

In the course of flight with the attitude stabilization or levelling modes cut in, the pilot should check the aircraft attitude by referring to the flight and navigation instruments and visually. Should the САУ-155П automatic flight control system fail, immediately disengage the САУ system by depressing the AP DISENGAGE (ВЫКЛ. АП) button on the aircraft control stick.

When flying with the stabilization mode engaged, it should be borne in mind that when a force of 1.5 to 2 kgf is applied to the control stick in longitudinal or lateral direction, stabilization of the respective aircraft attitude is interrupted; as a result, the AUTO CONT (АВТ. УПР.) light-button goes out. In this case, the automatic flight control system follows the roll, pitch and yaw angles and, after relieving the control stick, the system stabilizes the aircraft attitude which was at the moment of the control stick relieving.

At the pitch angles of more than 80° the aircraft fails to be stabilized in roll, and at the pitch angles of more than 40°, in yaw.

Attitude stabilization mode is used in the level flight, climb and descent, as well as when executing the turns and 360° turns.

Level flight. For executing the level flight it is necessary to proceed as follows:

- at a preset altitude and at a bank of not more than 7°, set the COURSE SELECT AUTO - MAN (КУРС ЗАДАН. АВТОМ. - РУЧНОЙ) selector switch to the AUTO position;

- trim out the control stick with the help of the stabilizer and aileron trimming mechanisms;

- engage the stabilization mode by depressing the AUTO CONT light-button on the automatic flight control system panel; this done, the AUTO CONT and DAMPER (ДЕМПФ.) light-buttons light up thus indicating that the stabilization mode is engaged.

After selecting the stabilization mode, trim out the control stick. With the control stick trimmed out, the aircraft will be stabilized by the САУ system in the attitude which it has acquired at the moment of the control stick relieving.

If at the moment of control stick relieving the bank angle exceeds 7°, the angles of roll and pitch will be stabilized; should the bank angle be less than 7°, the angle of pitch and aircraft heading will be stabilized.

To change the aircraft heading with the stabilization mode engaged, by manipulating the control stick, turn the aircraft to a new course, recover it from the bank and trim out the control stick.

Execution of corrective turns in the stabilization mode may also be effected with the aid of the course selector (the CS knob) on the combined course indicator. To perform a corrective turn, move the COURSE SELECT AUTO - MAN selector switch to the MAN (РУЧН.) position, use the CS knob on the combined course indicator to set the required course and then shift the COURSE SELECT AUTO - MAN selector switch to the AUTO position. As a result, the aircraft will automatically turn to a new course.

The САУ-155П automatic flight control system provides for stabilization of the aircraft attitude in roll within $\pm 7 - 80^{\circ}$.

Climb and descent. Transition of the aircraft into the climb or descent with the stabilization mode engaged is effected by the appropriate deflections of the control stick without cutting off the mode.

To bring the aircraft into climb (descent), it is necessary to set the required vertical velocity (pitch angle), trim out the aircraft in the new attitude and relieve the control stick. In this case, this will cause stabilization of the vertical rate (pitch angle) which the aircraft acquires by the moment the control stick is relieved.

Minor corrections of the pitch angle for maintaining the assigned flight conditions are accomplished by short-time depression of the stabilizer trimming mechanism button with no force applied to the control stick.

While climbing or descending, check the airspeed and select the engine power setting in compliance with the assigned airspeed of flight.

The САУ-155П automatic flight control system provides for stabilization of the pitch angles within $\pm 85^{\circ}$.

360° turns and turns in horizontal plane. A 360° turn (turn) may be entered from the attitude stabilization mode or the manual control mode.

When entering a 360° turn (turn) from the attitude stabilization mode, apply a force of 1.5 to 2 kgf to the control stick in lateral direction to establish the required bank, trim out the aircraft in the new attitude by the trimming mechanisms and relieve the control stick. This will cause stabilization of the pitch and roll angles which the aircraft acquires by the moment the control stick is relieved.

When entering the 360° turn from the manual control mode, manipulate the control stick to create the assigned bank, trim the aircraft with the aid of the trimming mechanisms and depress the AUTO CONT light-button on the control panel of the CAУ automatic flight control system. With the stabilization mode engaged, relieve the control stick.

When performing the 360° turn (turn), check the airspeed by increasing or reducing the engine speed in due time.

Recover from the 360° turn (turn) manually.

Turns performed during climb and descent. For performing the turns in climb or descent, manually set the assigned bank and vertical climb or descent rate, trim the aircraft with the aid of the trimming mechanisms. After that depress the AUTO CONT light-button on the control panel of the CAУ automatic flight control system or relieve the control stick if the maneuver is entered with the aircraft attitude stabilization mode engaged.

The automatic flight control system ensures execution of the turns in climb and descent at bank angles of 7 to 80° and pitch angles of not more than 85°.

To disengage the attitude stabilization mode, depress the AP DISENGAGE button on the aircraft control stick. Disengagement is checked by referring to extinguishment of the AUTO CONT and DAMPER light-buttons on the control panel of the automatic flight control system.

Levelling mode. The levelling mode is engaged to bring the aircraft into level flight in case the pilot loses spatial orientation. Besides, it is recommended to use this mode in a prolonged straight and level flight for stabilizing the aircraft altitude and heading.

The levelling mode is engaged by depressing the LEVELLING ON (ВКЛ. ПРИВ. ГОРИЗ.) light-button on the aircraft control stick and check engagement of the mode by referring to lighting-up of the LEVELLING ON, AUTO CONT and DAMPER light-buttons on the CAУ system control panel.

Straight-and-level flight with the levelling mode engaged for stabilization of the altitude and heading is allowed to be performed at altitudes of not less than 300 m over the terrain. The levelling mode should be engaged within the pitch angle range of -2 to +10°. At larger angles of pitch the levelling mode is engaged with altitude variation.

The levelling mode is switched off by depressing the AP DISENGAGE button on the control stick; as a result, the LEVELLING ON, AUTO CONT and DAMPER light-buttons stop glowing.

FLIGHTS AT HIGH ALTITUDES AND IN STRATOSPHERE AT SUPERSONIC AIRSPEEDS

In compliance with the major purpose of the МиГ-25П interceptor, mastering supersonic flights at high altitudes and in stratosphere is one of the most important tasks of flight training of the units and subunits equipped with these interceptors.

During these flights the flying personnel should master climbing to the altitude of the non-reheat flight ceiling, acceleration and climbing to the service ceiling and zoom altitude of the aircraft, flying technique in stratosphere at supersonic airspeeds, as well as acquire firm habits in handling the cockpit interior with the high-altitude pressure suit on.

Acceleration and climbing to the aircraft service ceiling are effected according to the specified program. If the pilot fails to maintain this program, the climbing time, distance covered and fuel consumption will increase.

During acceleration and in flights at the maximum Mach-numbers the МиГ-25П aircraft features good stability and satisfactory controllability.

At high altitudes and supersonic airspeeds the damping of the aircraft oscillation slows down materially due to decrease of air density. With the dampers engaged, the lateral and longitudinal oscillations are damped more rapidly.

When flying at high altitudes and $M > 2.2$, with the dampers off and vertical g-loads amounting to 2.0 g's, the aircraft features increased bank response to deflection of the rudders (creation of slipping). In this case, the bank develops with a certain delay typical for high altitudes. As the g-load increases, effectiveness of the ailerons decreases. Therefore, when introducing the vertical g-loads, the aircraft energetically banks to the side which is opposite to the slip (the side which is opposite to deviation of the ball). In case of an asymmetrical thrust of the engines, the aircraft banks to the side of smaller thrust.

As the rate of the vertical g-load increases, the rate of roll also increases. Proceeding from this, the turns (360° turns), zooms and other maneuvers with g-loads should be performed in a coordinated manner, never permitting the aircraft to slip. Prior to performing the maneuver, trim out the aircraft in yaw attitude with the aid of the rudder trimming mechanism.

If the pilot fails to manipulate the controls in the coordinated manner when the aircraft performs the maneuver with the vertical g-load, this may result in failure to recover the aircraft from the bank and inadvertent nose dropping. If the aircraft fails to recover from the bank and lowers the nose, the pilot should proceed as follows:

(a) cut off the engine afterburners and decrease the vertical g-load up to 1.0;

(b) do not interfere with the aircraft nose dropping by pulling the control stick backward;

(c) eliminate slipping (bring the ball to the centre);

(d) as the g-load decreases, recover the aircraft from the bank.

When the dampers are engaged the aircraft roll response to slipping considerably decreases. Therefore, fly at high altitudes and $M > 2.2$ with the dampers engaged that considerably simplifies handling the aircraft.

Besides, flying the aircraft at high altitudes and in stratosphere is also characterized by a number of other peculiarities the most typical of which are:

- decrease of the airspeed range;
- decrease of the aircraft angles of attack;
- deterioration of the conditions of visual orientation and visibility of the natural horizon as a result of which the pilot has to perform air navigation and flying mainly with the aid of instruments;
- decrease of the aircraft capabilities with respect to g-load which results in considerable increase of the radius and time for performing turns (360° turns).

1. FLIGHT TO CEILING

Flights for gaining the aircraft ceiling are performed within the airfield area according to the preset pattern.

Fig. 49 presents a version of the pattern used for climbing to the service ceiling. When effecting the flights to ceiling with the use of the POLJOT-1M system, it is necessary to program the flight route.

When climbing to the service ceiling, the aircraft may be controlled manually and with the aid of the САУ-155П automatic flight control system in the director or automatic mode.

Prior to flying with the use of the director or automatic mode of the САУ-155П system, the pilot should proceed as follows:

- after having taken the seat in the cockpit, use the altitude and airspeed setter to select an altitude of 8000 to 9000 m and M = 0.8;

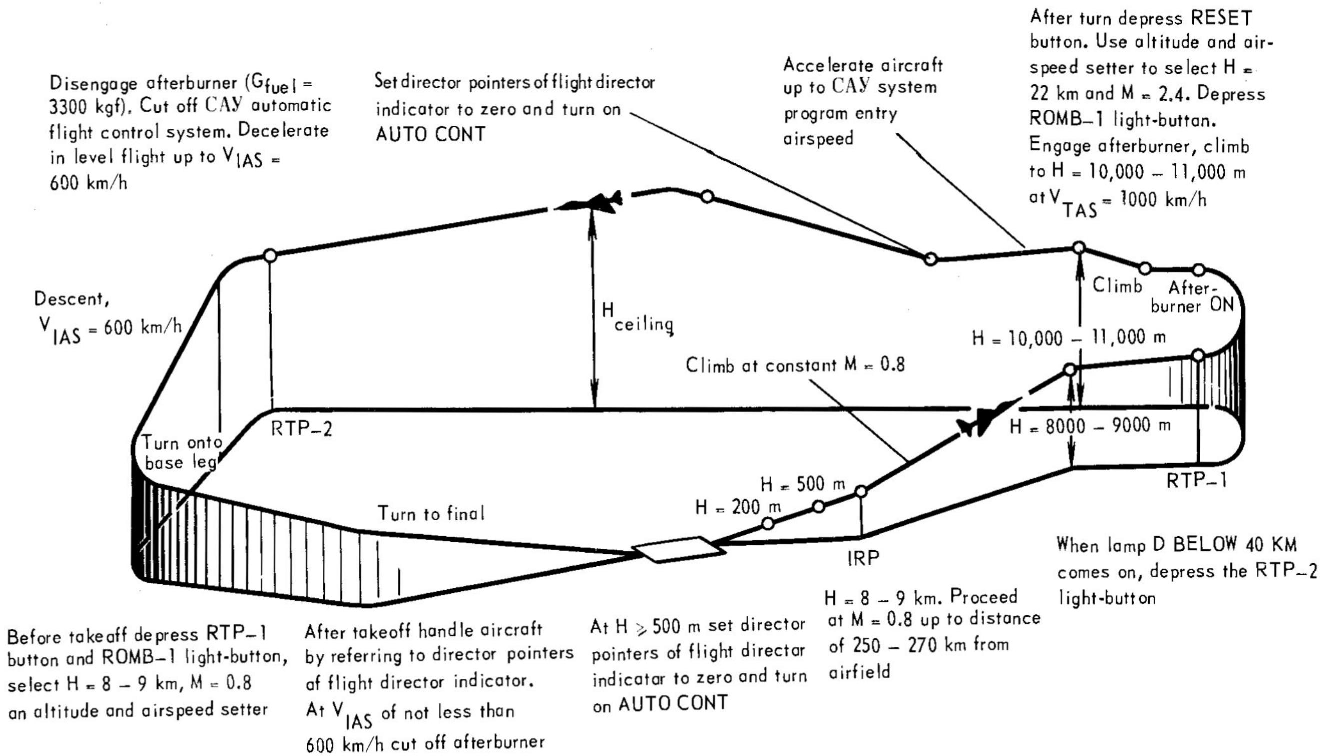


FIG. 49. FLIGHT TO SERVICE CEILING WITH USE OF AUTOMATIC MODE OF САУ–155П AUTOMATIC FLIGHT CONTROL SYSTEM

- on the РСБН-6С system control panel, depress the button of the first route turning point (ППМ-1);

- depress the ROMB-1 (РОМБ-1) light-button on the САУ system control panel.

Take off at the reheat power setting of the engines. After retracting the landing gear and flaps, fly the aircraft from an altitude of 200 m by referring to the command bars of the flight director indicator holding them within the circle (in case the climb and flight up to the RTP-1 (ППМ-1) are accomplished at a take-off heading or close to it).

If the initial route point (IRP) is a landmark and an additional maneuver should be performed to approach this landmark, execute this maneuver by controlling the aircraft manually. In this case, depress the ROMB-1 light-button on the САУ system control panel after flying over the initial route point (IRP).

At an altitude of 1000 m (at an airspeed of not less than 600 km/h) turn off the afterburners. Further climbing should be performed at the maximum power setting of the engines.

When using the automatic control mode of the САУ-155П system, at an altitude of not less than 300 m, with the control stick relieved and the command pointers of the flight director indicator zeroed, depress the AUTO CONT light-button on the САУ system control panel to cut in the automatic control mode and check lighting-up of the light-button. When doing so, it is necessary to remember that if the control stick is not relieved, the automatic control will not be cut in.

When the automatic control is cut in, the aircraft is flown automatically. In this case, the aircraft gains an altitude of about 2500 m with acceleration of up to M = 0.8, and further, at a constant Mach-number of M = 0.8.

In the director control mode, after passing the initial route point it is necessary to depress the ROMB-1 light-button on the САУ system control panel and climb by referring to the command pointers of the flight director indicator. When approaching the assigned altitude (8000 to 9000 m) the LEVELLING OFF TO H_{preset} (СХОД $H_{ЗАД}$) lamp lights up. When the lamp comes on, bring the aircraft into level flight (in the automatic control mode the aircraft is brought into the level flight automatically).

In the level flight, at an altitude of 8000 to 9000 m it is necessary to maintain M = 0.8, selecting the appropriate power setting of the engines.

At a distance of 40 km from the route turning point, D BELOW 40 KM (Д МЕНЬШЕ 40 КМ) lamp lights up on the РСБН-6С system control panel. After that, depress the light-button of the next RTP. The pilot may switch on the button of the next RTP also at an estimated distance from the initial route point by referring to the ППД-2 range indicator.

If the mission requires to fly over the RTP or cut in the next RTP not right after lighting-up of the D BELOW 40 KM light-button, at a distance of 25 km from the RTP change over to the manual control (cut off the САУ automatic flight control system by depressing the AP DISENGAGE button) and maintain the preset course.

If the pilot does not change over to the manual control, from a distance of less than 25 km oscillation of the preset course pointer, position bar and the command pointer of the lateral channel occur. This results in oscillation of the aircraft in bank within $\pm 5^{\circ}$. When passing the estimated distance values on the ППД-2 range indicator through zero, the preset course pointer turns through 180°.

With the next RTP button on the САУ automatic flight control system panel engaged, turn to the preset course in the director (manual) or automatic mode. When performing the turn in the automatic mode, make sure that the bank angle does not exceed 30°.

When the aircraft is turned to the preset course of the second RTP, depress the RESET (СБР. РЕЖ.) button on the САУ system control panel, select the altitude of 22 km and M = 2.4 on the altitude and airspeed setter, depress the ROMB-1 button and select the reheat power setting. Check ignition of the afterburners, establish an airspeed of 1000 km/h and climb to an altitude of 10,000 - 11,000 m at this airspeed.

At an altitude of 10,000 to 11,000 m bring the aircraft into level flight and accelerate the aircraft to an airspeed established by the program of the automatic flight control system (H = 10,000 m, program entry M = 1.58). At an airspeed which is less than the program entry indicated airspeed by 20 - 30 km/h (1120 km/h), bring the aircraft into climbing attitude by smoothly pulling the control stick backward.

Perform further climbing with acceleration up to M = 2.4. Then, with this Mach-number stabilized, climb to the service ceiling corresponding to M = 2.4.

In the course of climbing avoid decreasing of the Mach-number below 2.35.

When accelerating the aircraft up to M = 2.4 check engagement of the REHEAT II (II ФОРСАЖ) power setting. This power setting gets engaged at M = 1.4 to 1.6 and is determined by referring to increase of the engine speed up to 98.5 - 100% and increase of the exhaust gas temperature which should not exceed 820°C. Besides, at M = 1.5 - 1.7, check the initial moment of the air intake ramp extension.

For more gradual descent to the assigned altitude at supersonic speed, select the minimum reheat power setting as soon as the LEVELLING OFF TO H_{preset} lamp comes on. Proceeding in the level flight at supersonic airspeed, select an airspeed which corresponds to M = 2.4. The aircraft height oscillation may be within ±200 m.

When mastering flights for climbing to the aircraft service ceiling at supersonic airspeed in the manual control mode (without employing the САУ-155П system), take off at full reheat power setting.

At an indicated airspeed of not less than 600 km/h, successively cut off the afterburners of the engines by shifting the throttle levers to the MAXIMUM (МАКСИМАЛ) position.

If the flight is performed with four missiles carried, accelerate the aircraft up to a true airspeed of 920 km/h by an altitude of 1000 m, whereas without missiles, accelerate the aircraft up to a true airspeed of 960 km/h. Continue climbing at the above airspeeds, respectively.

To relieve the control stick in climbing, use the stabilizer trimming mechanism.

When the subsonic speed service ceiling is reached, bring the aircraft into level flight. Then, perform the cruising climb flight at M = 0.85 as the fuel is being consumed.

In the level flight at a distance of 250 to 270 km from the airfield,select full reheat power setting at an indicated airspeed of not less than 550 km/h and climb to an altitude of 10,000 - 11,000 m at a true airspeed of 1000 km/h.

At an altitude of 10,000 to 11,000 m bring the aircraft into level flight and accelerate it to an indicated airspeed of 1070 km/h. By the end of acceleration the fuel remainder should be not less than 6000 kgf.

Perform the climbing turn towards the airfield at a bank angle of 45°. When climbing, maintain an indicated airspeed of 1070 km/h until M = 2.5 is achieved.

Upon accelerating the aircraft to M = 2.5, shift the doors manually from the second to the third position by setting the DOORS (СТВОРКИ) selector switch to MAN 3RD PSN (РУЧН. 3-Е ПОЛОЖ.) in order to prevent "flopping" of the doors in response to Mach-number variation during climb.

With the fuel remainder being not less than 3300 kgf, cut off the afterburners. In this case the distance from the landing airfield should be not more than 200 km. If this distance is more than 200 km, cut off the afterburners earlier since it is required 700 kgf of fuel for each 100 km of the additional distance. Perform further climbing by maintaining M = 2.5 up to a vertical climb rate of 3 m/s.

2. FLIGHT FOR AIRCRAFT ACCELERATION TO MAXIMUM MACH NUMBER

The flight for aircraft acceleration to the maximum Mach-number should be planned after the pilot has accomplished the flight to service ceiling.

Fig. 50 presents an approximate pattern of the flight for aircraft acceleration to the maximum Mach-number.

The flight for aircraft acceleration to the maximum Mach-number is performed with the engines running at reheat power setting. After taking off, climb to an altitude of 1000 m with acceleration of the aircraft to a true airspeed of 1000 km/h. Perform further climbing to an altitude of 10,000 m at a constant true airspeed of 1000 km/h.

At an altitude of 10,000 m bring the aircraft into level flight, accelerate the aircraft up to an indicated airspeed of 1070 km/h, trim out the aircraft with the aid of the trimming mechanism and bring it into climbing attitude.

When climbing at M = 1.4 to 1.6, check engagement of the REHEAT II (II ФОРСАЖ) power setting by referring to increase of exhaust gas temperature (it should not exceed 820°C) and smooth increase of the engine speed up to 98.5 - 100%. Besides, at M = 1.5 to 1.7 the pilot checks the beginning of extension of the air intake ramps.

Check operation of the automatic control system of the air intakes and the position of the ramps by referring to the УПЭС-34 cone position indicator and two light signals AIR INTAKE CONTROL DUPLICATION (ДУБЛИР. УПР. ВХОД) on the annunciator. When the auto-

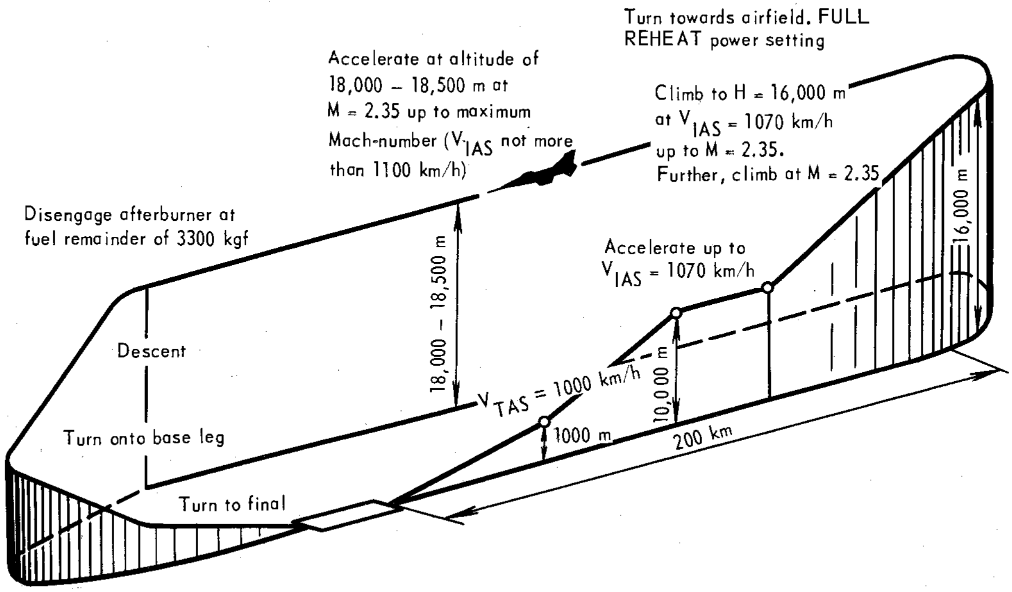


FIG. 50. PATTERN OF FLIGHT FOR ACCELERATION TO MAXIMUM MACH-NUMBER

matic control system operates normally, the above-mentioned lamps should be dead.

Gain an altitude of 16,000 m at an indicated airspeed of 1070 km/h until M = 2.35 is attained. In this case the distance from the airfield should be not more than 200 km.

At an altitude of 16,000 m start turning to the direction of the airfield. When turning, climb at M = 2.35.

If during the turn the Mach-number starts decreasing, reduce the vertical climb rate or turn even with a descent (especially when the aircraft carries four missiles), if necessary.

The aircraft attitude in climb is checked with the aid of the gyro horizon on the flight director indicator, whereas the flight conditions are checked by the Mach-number indicator, vertical speed indicator and altitude indicator.

After performing the turn, at an altitude of more than 16,000 m move the throttle levers to the position of partial reheat so that the exhaust gas temperature is by 20 to 30°C lower than the exhaust gas temperature at full reheat. This is required not to exceed the time of continuous operation of the engines at full reheat setting.

Wait for one minute and shift the throttle levers to the FULL REHEAT position and in the level flight at an altitude of 18,000 to 18,500 m continue accelerating the aircraft up to the maximum Mach-number.

In the course of acceleration, at M = 2.47 to 2.53 check the air-intake lower doors for change-over to the 3rd position by referring to the lighting-up of the 3RD PSN (3-Е ПОЛОЖ. СТВОРОК) light signals (two) on the annunciator or shift the doors to this position manually at M = 2.5.

In the course of acceleration follow indicated airspeed avoiding its increase in excess of 1100 km/h. Disengage the engine afterburners when the fuel remainder amounts to 3300 kgf.

When the РП-25 radar indicator starts blinking and the "Limit speed" voice information is sounded in the earphones, proceed as follows to avoid exceeding airspeed limitations:

(a) in performing level flight or climb, turn off the afterburners and bring the aircraft into climb (increase an angle of climb) at a g-load of up to 2.5 g;

(b) in descending, bring the aircraft into the level flight attitude at a g-load of up to 2.5 g, throttling the engines simultaneously.

3. FLIGHT AT MAXIMUM RATE OF CLIMB

Flight at a maximum rate of climb should be performed at full reheat power setting as follows. After taking off, climb to an altitude of 1000 m with aircraft acceleration to a true airspeed of 1000 km/h; then by changing the climb angle up to an altitude of 8000 m maintain a constant true airspeed of 1000 km/h.

At an altitude of 8000 m level off the aircraft and, without changing the engine power setting, establish an indicated airspeed of 1070 km/h. In the course of acceleration it is necessary to constantly check the airspeed increment rate, since in level flight at the reheat power setting and at an indicated airspeed of about 1000 km/h the airspeed increases approximately by 15 to 20 km/h per one second. Therefore, it is necessary to bring the aircraft into level flight with a certain preceding at an airspeed which is less than the assigned one by 20 to 30 km/h.

As an indicated airspeed of 1070 km/h is attained, bring the aircraft into climb attitude and maintain it until M = 2.35 is achieved. Climb to an altitude of 20,000 m at a constant Mach-number of M = 2.35. The time of climbing to an altitude of 20,000 m according to the specified profile decreases approximately by 30 s.

On the aircraft fitted with the stabilizer differential control system, flight at the maximum rate of climb should be performed in the following sequence:

- take off at the FULL REHEAT power setting of the engines;
- climb to an altitude of 1000 m with aircraft acceleration to a true airspeed of 1000 km/h and maintain this airspeed for attaining an altitude of 8000 m;
- at an altitude of 8000 m accelerate the aircraft up to an indicated airspeed of 1150 km/h;
- climb to an altitude of 13,000 m at an indicated airspeed of 1150 km/h;
- when approaching an altitude of 14,000 m, increase the climb angle to establish an indicated airspeed of 1070 km/h; further climb should be effected at the above airspeed until M = 2.35 is obtained;
- climb to an altitude of 20,000 m at a constant Mach-number of 2.35.

When performing training flights at a maximum rate of climb within the areas where transition to a supersonic flight at altitudes less than 10,000 m is prohibited, accelerate the aircraft to an indicated airspeed of 1070 km/h at an altitude of 10,000 m. Climb to an altitude of 10,000 m at a constant true airspeed of 1000 km/h.

4. FLIGHT TO DYNAMIC HEIGHTS

Flights to dynamic heights are performed according to the pattern specified for a particular airfield.

When an altitude of 18,000 to 18,500 m is reached, accelerate the aircraft with the engines running at the full reheat power setting until the maximum Mach-number is achieved and bring the aircraft into climb at a g-load of n_y = 1.5 - 1.75 g.

When climbing, to maintain n_y = 1.5, smoothly deflect the control stick backward. As an altitude of 22,000 to 22,500 m is reached, gradually decrease the g-load to 1.0 g. At n_y = 1.0 the aircraft continues climbing with the pitch angle decreasing. As soon as the pitch angle decreases up to 10 - 15°, apply back stick pressure again to avoid descending. When doing so, it is necessary to take into account that in case of premature deflection of the control stick backward, the aircraft rapidly loses its airspeed, lowers the nose with the control stick fully deflected backward and starts descending.

A late deflection of the control stick backward will result in the aircraft nose dropping and acceleration. Further deflection of the control stick backward slows down a rise of airspeed and results in energetic loss of altitude.

When at the dynamic height, proceed with level flight for 20 to 30 s decelerating the aircraft to an indicated airspeed of not less than 600 km/h.

When performing turns, deceleration increases and the time of flight at dynamic heights decreases. At great bank angles the airspeed energetically drops; therefore, it is necessary to bring the aircraft into descent and do not permit the airspeed to drop below the maneuvering one.

When the fuel remainder amounts to not less than 3300 kgf, it is necessary to cut off the afterburners and start descending. Cut off the afterburners at an airspeed not less than the maneuvering one.

The major flight parameters obtained as a result of the test flights performed to determine the maximum service altitude of the level flight of the МиГ-25П aircraft carrying four missiles Р-40 are presented in Table 6.

Table 6

Parameters of Flight to Dynamic Heights

Parameter	Value of parameter in time t, s						
	0	20	40	50	60	70	78.5
Mach number	2.75	2.66	2.45	2.37	2.33	2.30	2.28
V_{true}, km/h	2916	2626	2592	2520	2469	2437	2416
Altitude, m	18,000	19,000	22,000	23,700	24,800	25,400	25,600
G-load	1.5	1.5	1.5 to 0.5	0.5	0.5	0.5	-
V_y, m/s	0	50	150	170	114	55	20
L, km	0	15.6	30.4	37.3	44.1	50.9	56.6
Fuel consumption, kgf	0	176	312	354	390	422	443
Pitch angle	0°	0.7°	15°	11.4°	7.6°	3.5°	0°

The table shows that it takes 78.5 s for the aircraft to gain an altitude of 25,600 m beginning from an altitude of 18,000 m. By the end of the climb the Mach-number amounts to 2.28. In the level flight the aircraft is decelerated up to the maneuvering airspeed during 30 s. The afterburners are disengaged when the fuel remainder amounts to 3300 kgf.

5. AIRCRAFT DECELERATION AND DESCENT

In the level flight, after accomplishment of the mission, disengage the afterburners. To cut off the afterburners when flying at $M > 2.2$, proceed as follows:

- shift the throttle levers from the FULL REHEAT position to the MINIMUM REHEAT stop;
- then depress the latches and move the throttle levers to the MAXIMUM stop. Check disengagement of the afterburners by referring to extinguishment of the REHEAT light signals on the annunciator and decrease of the exhaust gas temperature.

In case of failure to cut off the afterburners by shifting the throttle levers to the MAXIMUM stop (the REHEAT light signal on the annunciator does not go out), disengage them using the appropriate switch labelled REHEAT located on the left-hand console.

When the afterburners are cut off, decelerate the aircraft in the level flight with the engines running at the 2ND MAXIMUM (II МАКСИМАЛ) up to M = 2.2. When decelerating the aircraft, at M = 2.5 check transition of the doors to the 2nd position by referring to extinguishment of the DOORS 3RD PSN light signals on the annunciator.

At M < 2.2, when the afterburner are cut off, throttle down the engines up to idle power setting by moving the throttle levers to the IDLE stop and continue decelerating the aircraft up to an indicated airspeed of 600 km/h. Shift the throttle levers in compliance with the position of the air intake ramps preventing them from extension more than 90% in the course of the engine throttling down.

Descend at an indicated airspeed of 600 km/h with the engines running at IDLE.

Effectiveness of the stabilizer during descent increases due to variation of nature of the airflow. It results in that at M = 0.97 to 0.95 the aircraft tends to increase the angle of attack (g-load), i.e. a "tuck-in" of the aircraft may occur.

Intensity of a "tuck-in" depends on a rate of deceleration: the aircraft increases the angle of attack more energetically in case of more abrupt deceleration.

At supersonic airspeeds the required deflection angles of the stabilizer are greater than at subsonic airspeeds. Therefore, at the transonic airspeed, with the stabilizer deflected for pitch-up, a short-time overload may occur.

In a straight-line descent, the aircraft experiences a slight "tuck-in" which practically appears as a slow nose-up of the aircraft. This phenomenon takes place due to a smooth deceleration.

At altitudes higher than 10,000 m a "tuck-in" is dangerous because of a possible increase of the g-load involving a loss of the airspeed, whereas at altitudes of less than 10,000 m the aircraft may attain the limit g-load.

When descending, it is necessary to trim out push forces by means of the stabilizer trimming mechanism in due time and move the control stick forward in case of a "tuck-in".

RECOMMENDATIONS TO COMMANDER (INSTRUCTOR) ON TRAINING AND MASTERING OF FLYING TECHNIQUE

The sequence of training and mastering the pilots in flying technique on the МиГ-25П aircraft is prescribed by the Combat Training Course.

Pilot training includes instruction, practising and mastering the skill in flying acquired in the course of training, as well as restoration of the habits lost due to long-time breaks in flying practice.

When training the flying personnel in flying technique, introductory circling flights and flights in maneuvering area are of great importance. The introductory flights are obligatory in the primary training, for restoring the habits lost due to long-time breaks in flying practice, as well as in case the pilot commits blunders or systematically repeated errors.

When performing the introductory flights, the instructor uses various methods and procedures of training of the pilot which are as follows:

(a) demonstration of the aircraft flying technique elements;

(b) practising in performing the demonstrated element, maneuver or the whole flight carried out under the supervision of the instructor;

(c) prompt, explanation, instructions and remarks over the intercom system in the course of performing an exercise;

(d) introduction of an improvised situation to the pilot for checking assimilation and skill of the trainee to handle the aircraft under adverse conditions.

Demonstration of the flying technique elements is used when the trainee practises this or that element of flight for the first time, when the instructor is not sure whether the trainee is able to perform this element independently or when the pilot fails to effect this or that element of the maneuver.

Demonstration flight is carried out either by the instructor himself or together with the trainee. When the demonstration is completed, the trainee should repeat obligatorily the flying technique element which has been demonstrated.

Practice is used for acquiring, consolidating and mastering the habits by the trainee in flying and handling the aircraft.

To create the adequate conditions for the trainee, which ensure effectiveness of his training, the instructor should not interfere with handling the aircraft if the trainee makes errors in piloting which are within the "satisfactory" mark, and if the trainee is able to notice and correct the error committed. In case when the trainee fails to fly the aircraft within the "satisfactory" mark limits and makes errors which do not provide flight safety, the instructor must immediately interfere with handling the aircraft and correct an error committed by the trainee.

Prompt, explanations, instructions and remarks over the intercom system are used for developing the correct sequence of actions of the trainee in distribution and transfer of attention during handling the aircraft, mastering coordinated manipulation of the controls when executing and maintaining the assigned flight conditions, handling the aircraft equipment and look-out.

Prompt should be instructive (i.e. how to act) without detailed analyzing the cause of this or that error committed by the pilot; a comprehensive analysis of the errors committed should take place after the flight. When performing the complex flight maneuvers (take-off, estimation, landing, landing approach with the use of navigation means), which require much attention, the directions of the instructor must be very brief. When prompting, the instructor should take into account that the trainee listening to the directions may distract his attention and aggravate the errors made. Therefore, a prompt should concentrate the pilot's attention on correcting the errors being committed at the given moment.

The pilot should repeat this or that element of the flight in the course of practising an exercise until the element is firmly mastered and the pilot is able to perform it independently without any help of the instructor.

The method used by the instructor during training depends on the flight training level of the trainee.

If during the primary training the instructor mostly demonstrates each new element to be practised, restoration of the lost habits includes training and prompting.

When performing introductory flights, the instructor should take into account that during the first flights for mastering new elements the pilot lacks enough attention due to which he may make blunders. Therefore, in these flights the instructor must concentrate the pilot's attention on the major, most important elements. In this case, it is good practice for the instructor to operate some equipment in the cockpit and conduct radio communication.

As the pilot acquires the appropriate habits, it is necessary to increase the volume of his actions; decrease the instructor's interference with the aircraft control, handling the cockpit equipment and prompting so that by the end of the introductory flights the trainee is able to perform independently the whole scope of operations required for handling the combat aircraft.

When performing introductory flights, besides the general flight training level of the trainee, the instructor should take into account the specific habits acquired by the pilot on the other type of the aircraft before conversion which may have a detrimental effect on handling the МиГ-25П aircraft.

After the pilot has accomplished the required number of introductory flights and acquired firm habits in performing the elements mastered, the commander examines him.

The check flights are performed to check the flying technique after the introductory flight program is finished or after a break in flights, correctness of the training method and determining causes of errors committed by the pilot during solo flights.

Only pilots who are able to conduct the solo training flights for performing the given type of training (according to the instructor's opinion) are admitted to the check flights. These flights should be performed as training ones: the inspector does not interfere with the aircraft control, follows the actions of the pilot, flight conditions and accuracy of executing the mission assigned for the flight.

As a rule, the check flights are performed under supervision of the commander who did not take part in training of the given pilot so as to evaluate the pilot's training level more unprejudicedly.

When checking the flying technique before the first solo flight, evaluate execution of the following flight elements:

- take-off;
- climb;
- route pattern;
- 360° turns at bank angles of 30 and 45°;
- divings and zooms at an angle of 20 to 30°;
- chandelles and spirals;
- landing approach and landing proper.

The pilot is certified for the solo flight and further training on the combat aircraft in case he has demonstrated firm habits in handling the aircraft in the maneuvering area and during circling flight.

Check readiness of the pilot for the solo flight on the day when the first flight on the combat aircraft is performed so that the pilot performs his first flight in the conditions under which he has been checked or under more simple weather conditions.

The cockpit drills with the ground power supply connected are of great importance in preparation for the first solo flight.

When preparing for the first solo flight, the instructor concentrates the pilot's attention on a strictly definite and required number of the flight elements and manipulations with the cockpit interior, as well as on the pilot's actions in emergency cases. Dealing with the cockpit equipment of minor importance for the given flight, watching the secondary instruments, as well as additional tasks and variations of the flight conditions differing from those of previous check flights may adversely affect the first solo flight.

A great moral and physical strain of the pilot in the first flight makes it inexpedient to perform more than two solo flights this day. Besides, an increased number of flights performed first day (solo flight and flight with assistance of the instructor) without detailed analysis of errors made during the flights may complicate the way of their elimination.

Before the solo flight of the pilot, the instructor should check preparation of the cockpit interior and the aircraft equipment, the sequence of the pilot's actions during preparation for the flight and help him in due time to analyze the errors committed.

A successful performance of the first solo flight depends on the level of the pilot's preparation for this flight as far as the flying technique is concerned and his morale. During the introductory flights the task of the instructor consists in that he should inculcate firm habits to the trainee in performing all the elements of the flight, teach him to correct the errors committed in due time and develop his firm confidence in successful execution of the flights on the МиГ-25П aircraft.

If the pilot has committed serious errors during the first flight, he should carry out additional introductory (check) flights on a combat trainer. In these flights special attention should be paid to mastering the elements of the flight which were performed with errors.

As the pilot acquires the habits in performing the simplest flying elements, the missions assigned for the flight specified by an exercise should be made more complicated so as to meet all the requirements of this exercise and to attain its aim.

Prior to performing the flights to the service ceiling and to the maximum Mach-number, it is necessary to check whether the pilot knows all limitations and nature of the aircraft behaviour at supersonic airspeed.

During the flight the instructor watches how the pilot operates the cockpit interior and aircraft equipment, draws his attention on variation of the control forces applied to the controls and sequence of the aircraft trimming with the aid of the trimming mechanisms, variation in the readings of the instrument when the aircraft transfers to the supersonic airspeed and the order of distribution of the pilot's attention at this moment, peculiarities involved in climbing to the service ceiling and flying at service ceiling, as well as during deceleration of the aircraft after disengagement of the afterburners.

CHAPTER III

AIR NAVIGATION

Air navigation is a complex of actions of the crew and teams of the ground-based flight control radio aids intended to ensure maximum accuracy in air navigation of the solo aircraft or a group of the aircraft during en-route flight for directing them with reference to area and time to the assigned objects (to the area of interception) and landing airfields.

Training in air navigation is aimed at forming firm habits of the pilots in use of all navigation aids in combination with visual orientation when performing the flights for interception of air targets within the full tactical radius or maximum range with landing on the maneuver airfields in daytime and at night in both VFR and IFR weather conditions.

The main peculiarities of air navigation of the МиГ-25П aircraft depend on the high airspeed of flight, wide range of altitudes, possibility of flying with an alternating profile, as well as possibility of complex employment of the flight-control and navigation equipment. Adequate knowledge of technical capabilities of this equipment and its efficient use in flight in combination with dead-reckoning and visual orientation ensure accurate target (the interception line) approach at the assigned time under various conditions of navigational and tactical situation.

As a rule, air navigation effected by the pilot in flight is supplemented by the control produced from the command and direction posts. For successful interception of air targets the pilot should exactly maintain the assigned flight conditions (course, airspeed and altitude), quickly and in due time execute the commands transmitted from the command post by voice or over the radio-telemetry line.

A great power-to-weight ratio of the МиГ-25П aircraft allows the pilot to perform the flights with alternating profile. Such a flight is accompanied by variation of the flight conditions which complicates air navigation. Besides, it makes the flying personnel to quickly transfer from air navigation effected with the help of radio aids to the visual air navigation and vice versa. During preparation for the flight, all this requires a thorough study of the procedure of complex employment of the airborne air navigation aids and methods of their use for each stage of the route depending on the flight conditions, navigational and tactical situation.

COMPLEX SYSTEM POLJOT-1И AND ITS EMPLOYMENT

1. GENERAL

The POLJOT-1И system is a complex of airborne interconnected flight-control and navigation equipment which incorporates the following systems:

- short-range navigation and landing system РСБН-6С;
- automatic flight control system САУ-155П (САУ-155П1);
- directional/vertical gyro system СКВ-2Н-2;
- air data computer system СВС-ПН-5.

The POLJOT-1И system operating in conjunction with the РСБН-2Н (РСБН-4Н) rho-theta radio beacon and the ПРМГ-4М landing radio beacon group (RBG) provides for execution of the following flight elements both in VFR and IFR conditions, during automatic and director control of the aircraft:

(1) programmed climb with subsequent levelling-off and stabilization of the assigned altitude or Mach-number;

(2) return to the airfield of departure or to one of the three programmed landing airfields;

(3) enroute flight involving three programmed route turning points and four airfields;

(4) break-through clouds from the cruising altitude up to the prelanding maneuver;

(5) execution of the prelanding maneuver;

(6) landing approach to a height of 50 m;

(7) missed approach procedure.

Throughout the flight, the pilot is able to check the position of the aircraft relative to the radio beacon of the selected airfield, determine aircraft attitude, check whether the assigned parameters of the flight are maintained and interfere with the automatic control, if necessary. The automatic control is disengaged when a force of 1 to 2 kgf is applied to the aircraft control stick; in this case, the director control commands are not cut off.

In case of failure of the САУ-155П (САУ-155П1) automatic flight control system, the POLJOT-1И system ensures execution of enroute flight, return to the landing airfield and landing approach during the manual control of the aircraft.

The POLJOT-1И system coupled with the АРЛ-СМ automatic radio line equipment and the БРЛС РП-25 radar sight provides for directing the aircraft into the target detection and lock-on area in response to the signals delivered from the direction post during automatic and director control, and into the missile launching area in response to the signals of the БРЛС РП-25 radar sight in case of independent guidance.

The system provides for approaching the programmed route point at a mean radial error of 3.75 km, maximum, when flying at an altitude of 10,000 m within the zone of radio correction and at a distance of 150 to 175 km from the РСБН-4Н rho-theta radio beacon.

Deviations of the aircraft from the equisignal zones of the ПРМГ-4М landing radio beacons (with the glide-slope beacon installed in front of the runway approach end at a distance of 130 m) at a distance of about 1000 m and altitude of 50 m during automatic and director control of the aircraft are:

- 1.5 to 4.5 m in the longitudinal channel;
- 8 to 15 m in the lateral channel.

The coverage zone of the POLJOT-1И system depends on the capabilities of the РСБН-6С equipment. In the radio correction mode the coverage zone is 500 km, while in the mode of independent dead-reckoning it amounts to ±3000 km from the origin of co-ordinates (the square on the sphere with sides of 6000 km).

For solving navigational problems the POLJOT-1И system uses the great-circle system of co-ordinates. This system is a spherical system of co-ordinates, but its poles do not coincide with the geographical poles of the Earth, due to this its meridians, equator and parallels are somewhat turned relatively to the geographic ones. The equator of the great-circle system of co-ordinates is called as the main great-circle course and conventionally it is assumed as axis Y. The parallels and meridians are referred to as conventional parallels and meridians.

The PCБН-6C system is provided with the modified great-circle system of co-ordinates (Fig. 51).

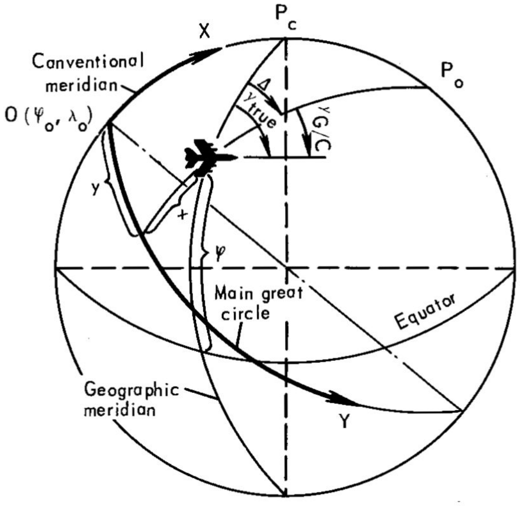


FIG. 51. GREAT-CIRCLE SYSTEM OF CO-ORDINATES
X – conventional meridian; Y – great-circle equator (main great circle); O – point of origin with co-ordinates: φ_o latitude; λ_o – longitude; x,y – great-circle co-ordinates of aircraft position; Δ – meridian convergence angle; γ_{true} – true course; $\gamma_{G/C}$ – great-circle course

In this system of co-ordinates the conventional meridian aligned with the geographical one and passing through the point of origin is assumed as axis X. The rules of readout of heading, conventional latitude (co-ordinate x) and conventional longitude (co-ordinate y) are given in compliance with the geographical system of co-ordinates. The positive direction of axis X is the north, whereas that of axis Y is the east.

Origin of co-ordinates O (φ_o, λ_o) is selected so that the system covers the flight area (the battle area). Sometimes, the point corresponding to the location of the home airfield is assumed as the point of origin. In this case, the point of origin should be at a distance of not less than 20 km (along the X and Y axes) from the place where the home airfield beacon is installed.

The position of the aircraft is determined by great-circle co-ordinates x and y, where: x is the distance from the aircraft to the main great-circle course along the conventional meridian, whereas y is the distance along the main great-circle course from the point of co-ordinate origin to the spherical perpendicular dropped from the point of the aircraft position.

Fig. 51 shows that the great-circle course (γ_0) differs from the true course (γ_{true}) by the m a p a n g l e . In the PCБH-6C equipment this angle is termed as the meridian c o n v e r g e n c e a n g l e which is marked with Δ. It is an angle between the North direction of the geographical meridian in the point where the PCБH beacon is installed and the North direction of axis X (great-circle meridian). Angle Δ is read out from the geographical meridian towards the great-circle meridian in the clockwise direction (Fig. 52).

If the radius of the flying area does not exceed 750 to 800 km the great-circle system of co-ordinates is plotted on the flight maps as interperpendicular straight lines as presented in Fig. 53.

2. EMPLOYMENT OF SYSTEM CBC-ПН-5

The CBC-ПН-5 air data computer system is designed for continuous computation and transmission of the parameters of the aircraft movement to the consumers.

The following parameters are delivered from the air data computer system to the PCБH, CPBMУ, CO-63Б, PП-25 and CAУ systems, as well as to the instruments arranged in the pilot's cockpit:

- Mach-number within 0 to 3.24;
- true airspeed within 0 to 3500 km/h;
- true barometric altitude ranging from -500 m to 30,000 m;
- relative barometric altitude ranging from 0 to 30,000 m;
- deviation of the true barometric altitude from the assigned value by $\Delta H = \pm(400 - 1500$ m).

The POLJOT-1И system uses the Mach-number for shaping the g-load limitation signals during manual flying, computation of the magnitude of deviation of the command course indicator pointers during director control, as well as for shaping the control signals during climb.

The true airspeed is used for dead-reckoning and controlling the flight conditions.

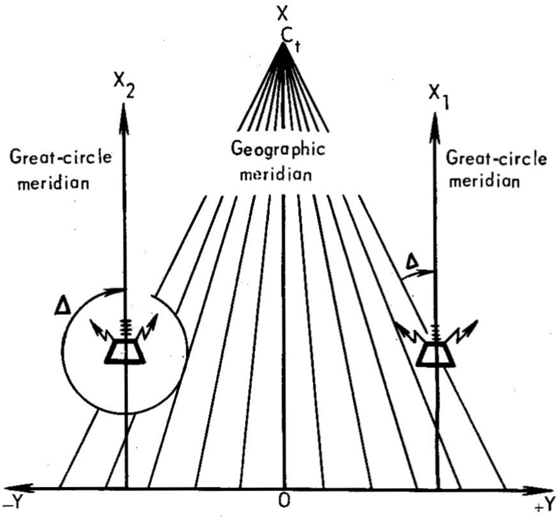


FIG. 52. DETERMINATION OF MERIDIAN CONVERGENCY ANGLE

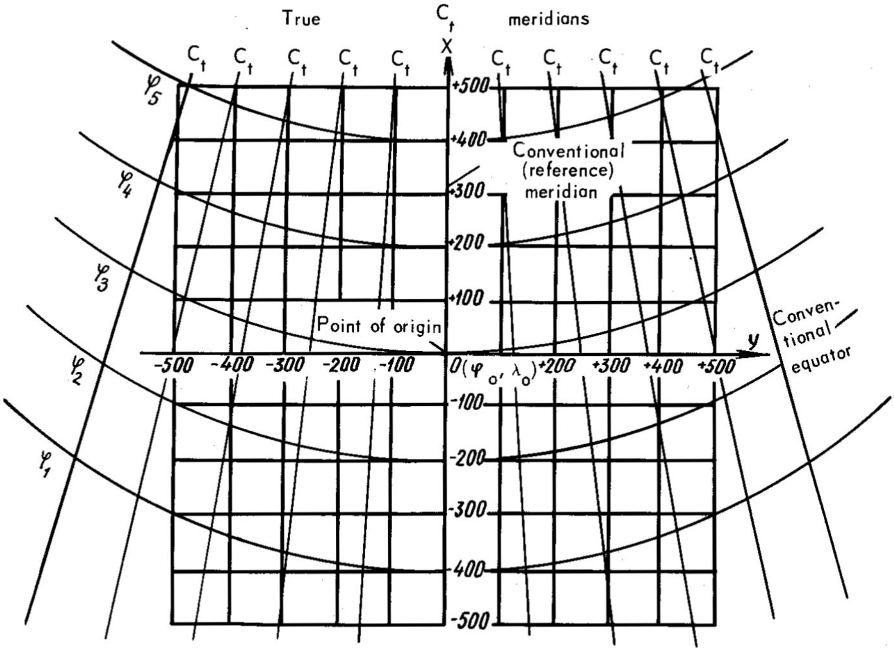


FIG. 53. EXAMPLE OF PLOTTING CO-ORDINATE GRID FOR FLYING AREA

The true barometric altitude is used for correcting the autopilot gain and obtaining the control signals during climb, while the relative barometric altitude is used for shaping the control signals in the clouds break-through conditions and for checking altitude at the ground command post.

The signals proportional to deviation of the true barometric altitude from the assigned value are used for stabilization of the aircraft altitude.

The СВС-ПН-5 air data computor system is engaged with the aid of two circuit breakers arranged on the right-hand console: AIR DATA COMPUTER (СВС) and AIR DATA COMPUTER HEAT (ОБОГРЕВ СВС). The readiness time of the system for operation after the AIR DATA COMPUTER HEAT circuit breaker is switched on is 5 minutes.

The pilot may judge the flight parameters by referring to the following two instruments: the true airspeed and Mach-number indicator (УСОК or УСО-М1) and the relative altitude indicator (УВО-30К or УВО-М1).

The УСОК (УСО-М1) true airspeed and Mach-number indicator reads the following:

- true airspeed within the range of 0 to 3500 km/h;
- Mach-number within the range of 0 to 3.24;
- preset Mach-number within the range of 0 to 3.0.

All the parameters are read off one scale numbered every 0.5 unity for the Mach-number with scale graduation value being equal to 0.05 unity. The scale of the УСО-М1 indicator is graduated every 0.2 unity with the scale graduation value being equal to 0.02 unity. When determining the readings of the true airspeed it is necessary to multiply the indicated values by 1000. The Mach-number is read by the broad pointer, the true airspeed is read by the slender pointer, whereas the assigned Mach-number, against the triangle index.

The upper part of the instrument scale is provided with an opening in which figures 0 and 3 are observed at true airspeed of less than 1500 km/h and more than 1500 km/h, respectively. It provides for continuation of the scale for reading out true airspeed of more than 3000 km/h and Mach-number in excess of 3.0.

The УВО-30К (УВО-М1) indicator has two scales and two counters. The outer scale is graduated in meters from 0 to 1000 every 100 m with the scale graduation value being 10 m. The altitude is read out against the tail of the large pointer. The inner scale is graduated in kilometers from 0 to 30 every 5 km with the scale graduation value being 0.5 km (1 km on the УВО-М1 indicator). The altitude is read against the tail of the small pointer. The integral number of kilometers read out against the inner scale is also indicated by the two-digit position counter located on the medium part of the scale. The values of the assigned altitude are read out against the triangle index of the inner scale.

The instrument is fitted with the setting knob arranged in its right-hand lower part. The knob is used for setting barometric pressure by referring to the indications of the four-digit position counter located in the lower part of the scale. When doing so, make sure that the indications of the altimeter is within ±30 m from the zero position.

3. EMPLOYMENT OF SYSTEM СКВ-2Н-2

The СКВ-2Н-2 directional/vertical gyro system is designed for determining and continuous transmission of roll and pitch angles and great-circle course, required for flying and solving navigational problems to the consumers.

The above parameters are applied to the combined course indicator, flight director indicator, as well as to the САУ automatic flight control system, short-range navigation and landing system, РП-25 radar sight and the armament system. The roll and pitch angles and course are transmitted without limitations with an accuracy of not more than $\pm 2^{\circ}$.

To check serviceability of the directional/vertical gyro system, proceed as follows:

(1) connect the ground power source;

(2) cut in the EXT PWR BATT (АЭРОД. ПИТ. БОРТ. АКК.) selector switch;

(3) switch on the following circuit breakers arranged on the right-hand console: STBY D/V GYRO, D/VG, ДА-200 and D/VG, CCI, FDI (ЗАПАСН. КВ., СКВ, ДА-200 И СКВ, КПП, НПП);

(4) in 1 - 1.5 min slave the main and stand-by directional/vertical gyros by depressing the MAG HDG SLAVE (СОГЛАСОВ. М. КУРСА) button and make sure that when the main vertical gyro is changed over to the stand-by gyro and vice versa the indications of the system practically do not vary.

In all cases the indications of bank, pitch and course should correspond to the aircraft parking position.

If magnetic declination is introduced into the correcting mechanism, in flight the system generates the true great-circle course, i.e. the gyro heading relative to the geographic meridian of the departure airfield. If the magnetic declination is not introduced into the correcting mechanism, in flight the system generates the magnetic great-circle course, i.e. gyro heading relative to the magnetic meridian of the departure airfield.

When flying from the airfields located within the high (north) latitudes where the magnetic compass functions with great errors, slaving of the directional/vertical gyros with respect to the magnetic or geographical meridian may be accomplished with the aid of the 3K-4 course setter installed in the fuselage compartment, and the HSC (HBK) button arranged on the instrument board. For this purpose, place the CELESTIAL SLAVING - SET COURSE (AK - 3K) selector switch at the SET COURSE (3K) position and exactly set the aircraft course; after that depress the HSC button in the cockpit two times:

- for the first time depress the HSC button when the D/VG STBY - MAIN (KB. ЗАПАС. - OCHOBH.) selector switch is placed at the STBY (ЗАПАСН.) position;

- depress the button for the second time when the selector switch is set to the MAIN (OCHOBH.) position.

It is recommended to select the take-off heading (runway landing heading) on the 3K-4 course setter. In this case taxi the aircraft onto the runway and align it exactly with the runway centre line and slave the system with the aid of the HSC button: the readings of the course against the combined course indicator should correspond to the take-off heading (runway landing heading) at both positions of the D/VG STBY - MAIN selector switch.

After the system is slaved with the help of the MAG HDG SLAVE or HSC buttons the course processing part of the CKB-2H-2 system operates in the directional gyro mode. In this case, azimuth deviation of the gyroscope amounts to not more than 1.5° for one flying hour.

When slaving the system with the aid of the MAG HDG SLAVE button in the straight-and-level flight at a constant subsonic airspeed, slaving error does not exceed 2 to 3°. But at supersonic airspeeds the slaving error may amount to 20 - 30°; therefore, it is not recommended to slave the system in these conditions.

The direction and vertical system determines bank and pitch angles with an accuracy of ±0.5 in the straight level flight at the constant airspeed. An error after performing the 360° turn is within $\pm 2^{\circ}$, while an error after the aerobatic maneuvers does not exceed $\pm 4^{\circ}$.

Failure of the СКВ-2Н-2 directional vertical gyro system is indicated by illumination of the CAGE (АРРЕТИР.) pilot lamp arranged on the face part of the КПП-1 indicator.

4. EMPLOYMENT OF SHORT-RANGE NAVIGATION SYSTEM РСБН-6С

Purpose and problems solved. The РСБН-6С short-range navigation and landing system is the navigation and landing airborne equipment of the POLJOT-1И system.

The РСБН-6С airborne equipment is a conjugated complex of the radio-navigation and independent system of determining the co-ordinates used for shaping the trajectory of flight and control signals in compliance with the assigned program during automatic or director control of the aircraft.

The radio-navigational equipment of the РСБН-6С system operates in conjunction with the ground rho-theta radio beacons РСБН-2Н (РСБН-4Н), while at the landing mode it operates with the ПРМГ-4М landing radio beacon group which includes: the runway localizer (КРМ), glideslope beacon (ГРМ) and distance retransmitter (РД). The radio-navigational equipment serves for determining the polar co-ordinates of the aircraft, i.e. variation of azimuth and range with respect to the РСБН beacon, and on its basis it corrects the data of the independent system.

The self-contained equipment of the РСБН-6С system estimates the data for the flight using the present course of the aircraft and true airspeed.

The РСБН-6С short-range navigation and landing system provides for:

- shaping the control signal in compliance with the assigned course during performance of the en-route flights, supplying this signal to the automatic flight control system and for its indication on the НПП combined course indicator;

- forming the trajectory of return to the programmed airfield of landing at an altitude of 9500 m from distances of less than 250 km from the radio beacon;

- forming the break-through trajectory from the cruising altitude up to an altitude of the prelanding maneuver and trajectory of the prelanding maneuver at an altitude of 630 $\pm$30 m with generation of the control signals to the САУ automatic flight control system and for indication on the combined course indicator and flight director indicator;

- forming the landing path with a descent up to an altitude of 50 m with applying the control signals to the САУ automatic flight control system as well as to the combined course indicator and flight director indicator for indication;

- forming the trajectory of the repeated approach at an altitude of 630 m, with furnishing the control signals to the САУ automatic flight control system and to the combined course and flight director indicators for indication;

- measuring and indicating a range up to the radio beacon and distance retransmitter (ПРМГ-4М) on the ППД-2 range indicator, as well as the distance to a programmed route point;

- measuring and indicating the aircraft azimuth on the navigation and flight instrument with respect to the radio beacon;

- measuring and indicating the radio station relative bearing on the navigation and flight instrument;

- monitoring the call-signals of the РСБН-2Н (РСБН-4Н) rho-theta radio beacon by the pilot.

Basic Specifications of РСБН-6С System

(1) Range of action in the mode of independent dead-reckoning of rectangular co-ordinates (along axes X and Y) amounts to ±3000 km.

(2) Accuracy of independent dead-reckoning (with no radio correction) amounts to 5 km +0.03 D, where D is the distance covered with no wind taken into account.

(3) Range of action in the radio correction mode during operation of the РСБН-6С equipment in conjunction with the РСБН-2Н (РСБН-4Н) rho-theta radio beacon is as follows:

- not less than 320 km at an altitude of 8500 m;
- not less than 470 km at an altitude of not less than 20,000 m.

(4) Range of action during operation in conjunction with the ПРМГ-4М landing radio beacon group is:

- not less than 180 km at an altitude of 10,000 m;
- not less than 80 km at an altitude of 1000 m;
- not less than 20 km at an altitude of 300 m.

(5) Accuracy of measurement of the aircraft polar co-ordinates during operation in conjunction with the PCБH-2H (PCБH-4H) rho-theta radio beacon amounts to:

- ±0.25° in azimuth;
- better than ±300 m in distance.

(6) Accuracy of shaping of the cruising altitude of 9500 m amounts to not more than ±500 m.

(7) Accuracy in measuring the distance to the retransmitter of the ПPMГ-4M landing radio beacon group amounts to ±180 m.

(8) Accuracy of shaping an altitude of the prelanding maneuver (630 m) is equal to ±30 m.

(9) Instrument error in shaping the assigned course does not exceed 3°.

(10) Errors in determining the equisignal directions are as follows:

- not more than ±0.2° in heading;
- not more than ±0.3° in glide slope.

(11) Number of the frequency-code channels required for operation with the PCБH-2H rho-theta radio beacon and ПPMГ-4M landing radio beacon group is 40.

Principle of Operation of PCБH-6C. The navigational problems are solved by the PCБH-6C short-range navigation and landing system on the basis of the independent dead-reckoning of the co-ordinates of the aircraft position by the signals of the true airspeed and great-circle course corrected by the radio beacons.

The PCБH-6C short-range navigation and landing system possesses a high accuracy in determining the aircraft co-ordinates, but it is not protected against jamming and features a limited radius of action.

The self-contained system features a high reliability, has a great radius of action. Besides, it is not subjected to jamming but it has a low accuracy.

The combined operation of the radio navigation and self-contained systems ensures high accuracy in determining the co-ordinates, high reliability, antijamming capability and great radius of action.

The principle of operation of the self-contained equipment consists in continuous dead-reckoning of the true airspeed and great-circle course data applied to the PCБH-6C system from the CBC-ПH-5 air data computer system and CKB-2H-2 directional vertical gyro system, respectively.

On the basis of these data the БВН navigation computer unit computes the great-circle present co-ordinates of the aircraft (x_{pres}, y_{pres}). The data concerning the present co-ordinates of the aircraft and programmed co-ordinates of the route turning points are supplied from the navigation computer unit to the БВП landing computer unit where the distance to the turning point (airfield) and the assigned course of flight are determined 54).

The distance and assigned course are computed according to the following formulas:

$$D = \sqrt{(x_t - x_{pres})^2 + (y_t - y_{pres})^2};$$

$$\Psi_{assigned} = \text{arc tg}\,\frac{y_t - y_{pres}}{X_t - y_{pres}},$$

where:

X_t, y_t - co-ordinates of the route turning point;

x_{pres}, y_{pres} - present co-ordinates of the aircraft;

$\Psi_{assigned}$ - assigned course of flight.

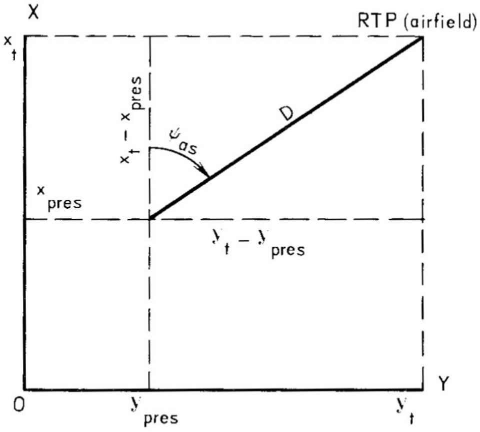


FIG. 54. PRINCIPLE OF ESTIMATION OF DISTANCE AND GREAT-CIRCLE COURSE

Distance to the route turning point (airfield) is displayed on the ППД-2 range indicator; its dial is fitted with two scales: 0 - 500 km and (0 - 500) x 10 km. The scales are changed over automatically. As the distance is decreased, the change-over is effected at indications of 40x10 km, i.e. at a distance of 400 km. If the distance increases, the change-over takes place at readings of 495 - 500 km.

The assigned course in the form of a synchronizing voltage is applied to the САУ automatic flight control system to be displayed on the combined course indicator and to generate the aircraft control signals.

The signal, proportional to the difference of the courses $\Delta\Psi = \Psi_{assigned} - \Psi_0$, is applied to the vertical position bar of the flight director indicator: it deflects in the direction of the corrective turn to be performed. Besides, the side channel director signal generated in the САУ automatic flight control system on the basis of an error in heading is applied to the vertical command pointer of the flight director indicator. It shows the direction and the bank angle of the corrective turn when the aircraft enters the desired course line. Make sure that the command pointer is always in the centre of the flight director indicator.

The radio-navigational equipment of the PCБH-6C system is designed for determining azimuth and distance of the aircraft with respect to the ground radio beacon with a high accuracy. These data are used for correcting the present co-ordinates of the aircraft within the coverage area of the PCБH-2H (4H) radio beacons.

For measuring the distance the use is made of the radar method with active response. The PCБH-6C short-range navigation and landing system radiates the interrogation signals through the PION-3П antenna system with circle radiation pattern. These signals are received by the ground receiving device and actuate the П-20Д distance retransmitter of the ground radio beacon. At the moment the signal transmitted by the distance retransmitter is received, the PCБH-6C system radiates a reply signal. Thus, the PCБH-6C system radiates two trains of pulses: interrogation and response pulses with a shift of time between them.

The slant distance of the aircraft from the ground radio beacon will correspond to one half of the time interval between the interrogation and response pulses. This distance will be used for correcting the data of the self-contained equipment of the PCБH-6C system.

For measuring the aircraft azimuth the PCБH-6C system uses the signal of the П-20A and П-200 transmitters of the ground radio beacon.

The П-200 transmitter operates in the continuous mode and radiates electro-magnetic energy through the azimuth parabolic-reflector aerial which has pencil-beam pattern in the horizontal plane. The antenna rotates at a speed of 100 r/min successively radiating the space. The aircraft equipment receives the azimuth signal as a pulse per one revolution of the antenna. When the azimuth antenna is directed right to the north, the П-20A transmitter radiates a code reference signal through a non-directional antenna. This signal is received by all the aircraft flying within the radius of coverage of the beacon, and the time reference circuit of the PCБH-6C system measuring unit is started.

At the moment when the azimuth antenna is directed to the given aircraft, the PCБH-6C system equipment receives the azimuth signal. A special circuit of the measuring unit determines the interval between the reference and azimuth signals as voltage proportional to the aircraft azimuth and applies it to the combined course indicator and for correcting the data of the self-contained equipment of the PCБH-6C system as well.

Controls of the PCБH-6C short-range navigation and landing system and indication of output parameters. The in-flight remote control of the PCБH-6C system in all modes is ensured from the control panel arranged on the starboard side of the cockpit. Arranged on the front side of the non-modified control panel are the following controls and indicating lamps (Fig. 55):

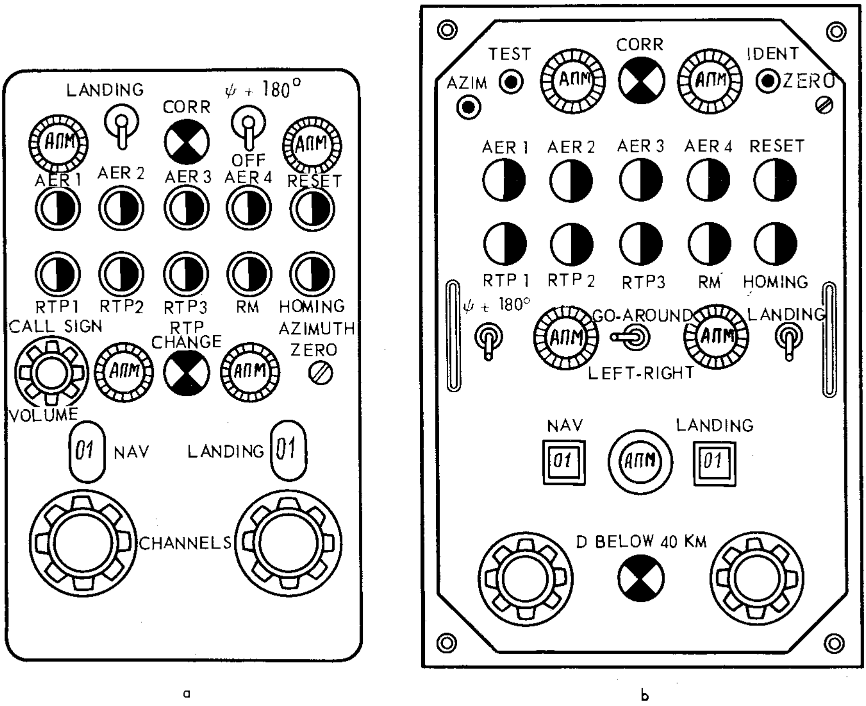


FIG. 55. SHORT-RANGE NAVIGATION SYSTEM PCБH-6C. CONTROL PANEL

a – non-modified; b – modified

- four button-lamps labelled AER1, AER2, AER3, and AER4 which are intended for the in-flight selection of the programmed aerodrome;

- three button-lamps labelled RTP1, RTP2, and RTP3 which serve as a means of selecting the programmed route turning point;

- the RADIO MARKER (PO) button-lamp which becomes energized in using any of the programmed radio beacon of the short-range navigation and landing system or aerodrome as a route turning point;

- the HOMING (ВОЗВРАТ) button-lamp which is intended for changing over of the navigation equipment so as to ensure interception of the desired course to the programmed aerodrome and landing;

- the RESET (СБРОС) button-lamp which serves for resetting the equipment from the previously furnished data on all the programmed radio beacons of the РСБН short-range navigation and landing system and the ПРМГ radio beacon group. Upon resetting, the equipment can be manually tuned in flight to the channels of the radio beacons of the РСБН system and the ПРМГ-4М radio beacon group of the non-programmed aerodromes;

- the LANDING (ПОСАДКА) selector switch which is intended for manually changing over the navigation equipment to the channel of the ПРМГ-4М radio beacon group during landing on a non-programmed aerodrome;

- $\Psi + 180^{\circ}$ - OFF ($\Psi + 180^{\circ}$ - ВЫКЛ.) selector switch which becomes energized (occupies the upper position) when the aircraft is going to land on the programmed aerodrome with a heading which is reverse to the programmed one;

- the CALL SIGN VOLUME (ГРОМК. ПОЗЫВН.) control which ensures volume control of the call signs transmitted by the radio beacons in the head-phones of the pilot;

- the AZIMUTH ZERO (УСТ. О АЗИМ.) control knob which is used for setting the zero azimuth during the ground adjustment of the equipment;

- the RTP CHANGE (СМЕНА ППМ) lamp which lights up at a distance of 40 km from the RTP, thus indicating the necessity in the change-over of another RTP;

- the CORR (КОРР.) lamp which warns the pilot that the РСБН-6С system operates in the correction mode. This lamp remains dead in the landing mode;

- the NAVIGATION (НАВИГАЦИЯ) channels selector switch which is used for the in-flight tuning of the required channel to a non-programmed aerodrome equipped with the РСБН short-range navigation and landing system radio beacon;

- the LANDING (ПОСАДКА) channels selector switch which is used for selecting the required channel during landing on a non-programmed aerodrome equipped with the ПРМГ-4М radio beacon group.

The modified control panel is shown in Fig. 55 (b). In addition, it mounts the following:

- the GO-AROUND L R (ПОВТ. ЗАХ. ЛЕВ. - ПРАВ.) selector switch which is used for selection of either RH or LH traffic circuit during repeated approach;

- the TEST (КОНТРОЛЬ) button which ensures monitoring of the serviceability of the РСБН-6С system. Pressing on this button must cause the combined course indicator and the ППД-2 distance indicator to reproduce the check azimuth and distance values, respectively. The check azimuth value accounts for 177°, and the value of the distance is equal to 291.5 km;

- the IDENTIFICATION (ОПОЗН.) button which is used to ensure individual identification of the aircraft displayed on the plan position indicator of the РСБН ground short-range navigation and landing system;

- the AZIMUTH (АЗ) button and ZERO slotted screw which are used for the equipment adjustment (setting of azimuth zero).

In addition, the inscription of the RTP CHANGE indicator lamp is replaced by the D BELOW 40 KM (Д МЕНЬШЕ 40 КМ) inscription.

The output parameters processed in the РСБН-6С system are displayed on the combined course indicator, flight director indicator, and distance indicator.

Both the combined course indicator (Fig. 56) and flight director indicator (Fig. 57) are integrated into the automatic flight control system.

The combined course indicator is intended to provide the pilot with the following information:

- present and pre-selected courses;

- relative bearings of the radio beacons or radio stations (RB);

- aircraft position relative to the equisignal zones of the localizer and glideslope radio beacons;

- entry into the zone of positive coverage of both the localizer and glideslope radio beacons (by means of warning flags) and sound operation of the localizer and glideslop channels of the radio equipment of the РСБН-6С system;

- departure from the desired course and glideslope.

Located on the front panel of the instrument are the following:

(a) outer fixed dial 6 indicating the relative bearings of the radio beacons or homing radio stations. This is numbered every 60°, each division being equal to 10°. With the SHORAN - ADF selector switch set to the SHORAN position, narrow pointer 3 of the fixed dial reads the relative bearings of the radio beacons (Fig. 56). With the above switch in the ADF position, the pointer reads the relative bearings of the homing radio stations;

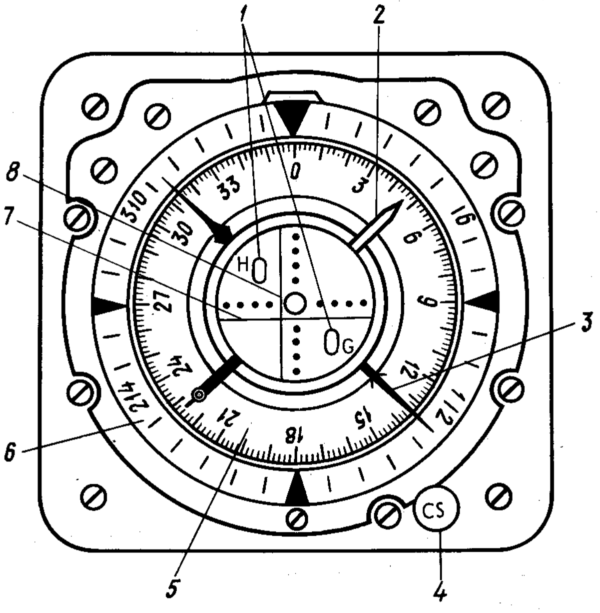


FIG. 56. COMBINED COURSE INDICATOR (НПП):

1 – localizer and glide-slope warning flags; 2 – course setter pointer; 3 – APK and РСБН azimuth pointer; 4 – course setter knob; 5 – course and azimuth movable dial; 6 – fixed dial of course angles; 7 – glide-slope bar; 8 – localizer bar

(b) inner (moving) course dial 5 numbered every 30°, each division being equal to 2°. The present heading indications are presented on the moving dial with respect to the triangular index marked on the upper portion of fixed dial 6;

(c) broad pointer 2 which is intended to read the preselected course against the moving heading dial. The pointer indicates the heading to the pre-selected RTP (aerodrome) in enroute flight or the pre-landing manoeuvre point when approaching the landing airfield. The pre-selected course is reproduced either automatically or manually depending on the position of the COURSE SELECT AUTO - MAN selector switch;

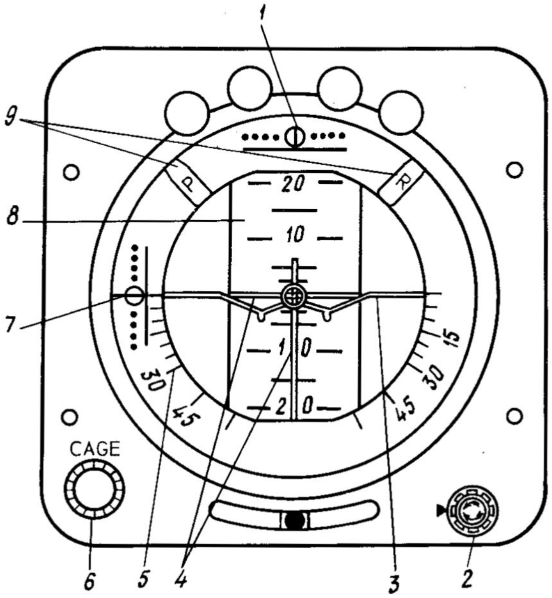


FIG. 57. FLIGHT DIRECTOR INDICATOR (KIIII):
1 – horizontal deviation bar; 2 – horizon zero setting knob; 3 – miniature aircraft; 4 – command pointers; 5– scale of bank angles; 6 – CAGE light-button; 7 – vertical deviation bar; 8 – strip scale of pitch angles; 9– pitch and roll warning flags

(d) CS knob 4 is used for setting the pre-selected course;

(e) H (left) and G (right) warning flags. The operation (closure) of the warning flags is indicative of the normal functioning of the heading and glideslope channels, respectively;

(f) bars 7 and 8 arranged in the centre portion of the instrument upon deflecting off the central circle indicate the position of the equisignal zones of both the localizer and glideslope radio beacons relative to the aircraft.

These bars become operative only during the performance of landing approach by reference to the ПРМГ-4М radio beacon group upon operation of the respective localizer and glideslope warning flags. During other flight stages these bars do not operate. The horizontal and vertical dotted scales are arranged symmetrically with respect to the central circle. The centre of the circle simulates the aircraft longitudinal axis, and the point of intersection of bars 7 and 8, the equisignal zone.

<u>The flight director indicator</u> is intended for representation of the following parameters:

(a) current values of both roll and pitch angles furnished by the СКВ-2Н-2 directional/vertical gyro system;

(b) position of the aircraft relative to the assigned trajectory both in azimuth and elevation;

(c) control signals by means of which the director control is ensured;

(d) warning by flags about cutting in of the САУ automatic flight control system to operate in conjunction with any of the outer systems.

Pitch angle readings are presented by pitch strip scale 8 (Fig. 57) against the central mark of miniature aeroplane 3. The pitch scale presents indications over a range of 0 to 80° both in the upward and downward directions. That portion of the scale which is above the horizon line is painted white, whereas the portion below the horizon line is painted black. The scale is numbered every 10°, each division equalling 5° within the range of 0 to 40° and 10° over the range extending from 40°.

Bank reading scale 5 presents indications against the lowered wing of the miniature aeroplane. The bank scale gives readings within the range of 0 to 60°. It is numbered every 15°, each division being equal to 5° within the range of 0 to 30° and 15° over the range of 30°.

The aircraft position relative to the prescribed flight path in the vertical plane is indicated by left-hand bar 7 which deflects with respect to the centre of the dotted scale.

The position of the aircraft relative to the prescribed flight path in the horizontal plane is determined by means of upper bar 1 which deflects with respect to the centre of the dotted scale.

The pilot is provided with the roll command to intercept the pre-selected trajectory by vertical director pointer 4 which deflects in either rightward or leftward direction relative to the centre circle of the miniature aeroplane.

The pitch command is provided to the pilot by horizontal director pointer 4 which deflects either upward or downward with respect to the miniature aeroplane centre circle.

Red-coloured warning flags R (roll) and P (pitch) inform a pilot about the cutting in of the САУ automatic flight control system for joint operation with any of the outer systems. With the channels properly functioning, the flags are out of the pilot's sight. Should either of the channels fail, the respective flag gets in the pilot's sight.

In addition, the instrument front panel carries the following:

- slip indicator;
- red-coloured CAGE button-lamp 6 which is intended to cut in and indicate the operation of the caging devices of the СКВ-2Н-2 gyro system;
- setting knob 2 which is needed for setting the horizon to zero. It is also may be used for introducing corrections of $\pm 12^{\circ}$ for the pitch angle readings.

The ППД-2 distance indicator is intended for the following:

(a) indication of a distance from the landing aerodrome radio beacon in the HOMING mode when operating the radio equipment of the РСБН system;

(b) indication of the distance from the pre-selected route point or aerodrome during joint operation with the self-contained computers;

(c) indication of the slant range to the landing range finder in the LANDING mode (upon operation of the H warning flag of the combined course indicator);

(d) generation of the signal which ensures the illumination of the D BELOW 40 KM or RTP CHANGE lamp located on the control panel of the РСБН-6С system.

Distance measurements are obtained from the instrument provided with the following two scales:

- the first scale giving readings within the range of 0 to 5000 km;
- the second scale which gives readings within the range of 0 to 500 km.

Should the distance exceed 495 km, the x10 warning flag of the ШПД-2 distance indicator drops out, thus causing the scale change-over. This also causes the change in the scale readings from 495 to 49 km. The diminishing of the distance to 495 km causes a reverse change-over of the scales and removal of the x10 warning flag.

5. PREPARATION FOR FLIGHT WITH USE OF POLJOT-1И SYSTEM

The preparation for flight should be effected in accordance with the general rules with due regard to the characteristic features of the POLJOT-1И system.

In the course of the preparation for flight the pilot should:

(a) plot the great-circle coordinate system;

(b) plot and calculate the flight route;

(c) determine the great-circle coordinates of the route turning points and the radio beacons of the РСБН short-range navigation and landing system, angular corrections, track angles, and the initial flight data for the automatic landing approach;

(d) make up a programme for enroute flight and landing on the main and alternate airdromes;

(e) introduce the initial data (programme) for the enroute flight and landing on the main and alternate airdromes.

Flight route selection and plotting should be effected with respect to the tactical and navigational situation as well as the capabilities of the POLJOT-1И system which makes it possible to programme seven route points, namely three route turning points and four radio beacons of the short-range navigation and landing system. The procedures for plotting the flight route are given in Fig.58. To be marked first are the basic route points, that is the initial route point, intermediate route point, target, and terminal route point. Then, these points, with due regard to the turning radius, should be connected with the geodetic lines which form the course line.

The geodetic lines marked on the modified polyconic projection maps having a scale of 1:1,000 000 and composed of nine sheets may be replaced by straight lines.

Upon completion of flight route plotting, make flight calculations involving determination of flying distance and time, track angles at each en-route flight stages, total flight endurance, flying time reserve, and takeoff time to ensure timely target interception, and fuel reserve.

The great-circle coordinates of the preselected route points and the radio beacons of the PCБH short-range navigation and landing system should be determined by way of measuring the distances along axes X and Y with the use of a scale rule. The distances are to be determined only within the limits of a single square of the great-circle coordinate system grid. Furtheron, the measured coordinate corrections should be added to the values of the basic scale marks. If the above grid is not available, the great-circle coordinates should be determined in accordance with the general procedures specified in the AIR NAVIGATION MANUAL.

When flying in an area the radius of which does not exceed 750 to 800 km, the great-circle coordinates may be replaced by rectangular cartographic coordinates which can be easily measured with the use of a protractor and scale rule. If axis X is in full alignment with the geographical meridian in the point of origin of coordinates, the great-circle coordinates of the preselected points in flight to a distance of more than 750 to 800 km should be calculated by the following formulae:

$$\sin x^{\circ} = \sin\varphi \cos\varphi_{o} - \cos\varphi \sin\varphi_{o} \cos(\lambda - \lambda_{o}) \quad \text{and}$$

$$\sin y^{\circ} = \frac{\cos\varphi \sin(\lambda - \lambda_{o})}{\cos X},$$

where: x°, y° - great-circle coordinates of the preselected points;

φ_{o}, λ_{o} - geographical coordinates of the point of origin;

φ, λ - geographical coordinates of the preselected points.

Values x and y expressed in degrees should be determined by reference to the table of trigonometric functions (accurate to a fourth decimal place) or with the aid of a slide (computer) rule.

The great-circle coordinates of the pre-selected points in terms of kilometres may be determined by the aid of the following formulae:

$$x = \frac{x^{\circ}}{57.3^{\circ}} \cdot 6372.9 \quad \text{and} \quad y = \frac{y^{\circ}}{57.3^{\circ}} \cdot 6372.9.$$

Determination of angular corrections and track angles. To perform an enroute flight with the use of the POLJOT-1И system, determine the following angular corrections:

(a) convergence angles Δ for the radio beacons of the short-range navigation and landing system;

(b) conventional magnetic declination ΔM_{conv}.

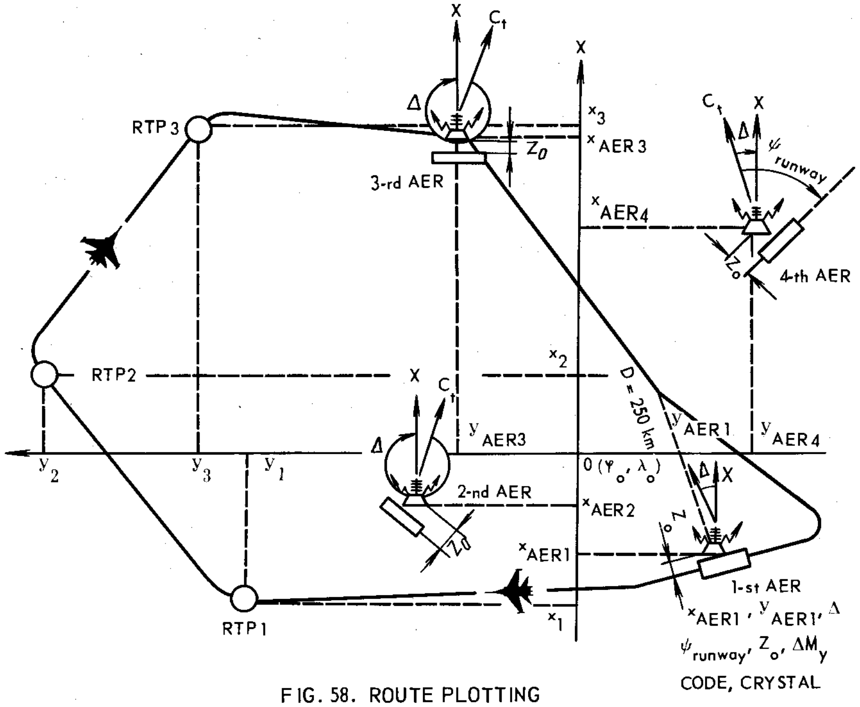


FIG. 58. ROUTE PLOTTING

The convergence (map) angle is the true track angle of axis X of the modified great-circle coordinate system in a given point.

With axis X being in alignment with the geographical meridian in the point of origin of coordinates, the convergence angle may be calculated with the aid of the following formula:

$$\sin \Delta = \frac{\sin \varphi_o}{\cos x^o} \sin (\lambda - \lambda_o), \text{ or}$$

$$\sin \Delta = \frac{\sin \varphi_o}{\cos \varphi^o} \sin y^o,$$

where: φ_o, λ_o - geographical coordinates of the point of origin;

φ, λ - geographical coordinates of the ground short-range navigation and landing system;

x^o, y^o - great-circle coordinates of the ground short-range navigation and landing system.

The convergence angle may also be measured with the use of a protractor and the map as it is clear from Fig. 59.

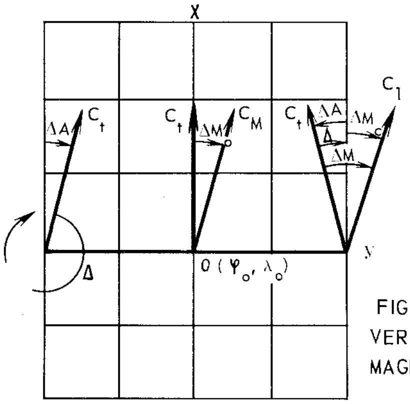


FIG. 59. DETERMINATION OF MERIDIAN CONVERGENCE ANGLES Δ AND CONVENTIONAL MAGNETIC DECLINATION ΔM_C (ΔA–AZIMUTH CORRECTION)

The convergence angle values are inserted into the navigation computor for the purpose of solving the following two problems:

(a) transformation of coordinates during the introduction of corrections;

(b) obtaining of the true course during the return to the airdrome from a point extending to a distance of 250 km and landing approach.

The conventional magnetic declination data are put into the KM-5 compensating mechanism of the directional/vertical gyro system to cause directional gyro erection. It is measured over the range of 0 to $\pm 180^o$ (positive sign stands for clockwise measurement and minus is for counterclockwise measurement). The magnitude and sign of the conventional magnetic convergence are an algebraic total resulting from the addition of azimuth correction ΔA and magnetic declination ΔM in a given point

$$\Delta M_c = \Delta A + \Delta M.$$

The magnetic declination is determined by reference to the map with the use of the isogonals marked on it.

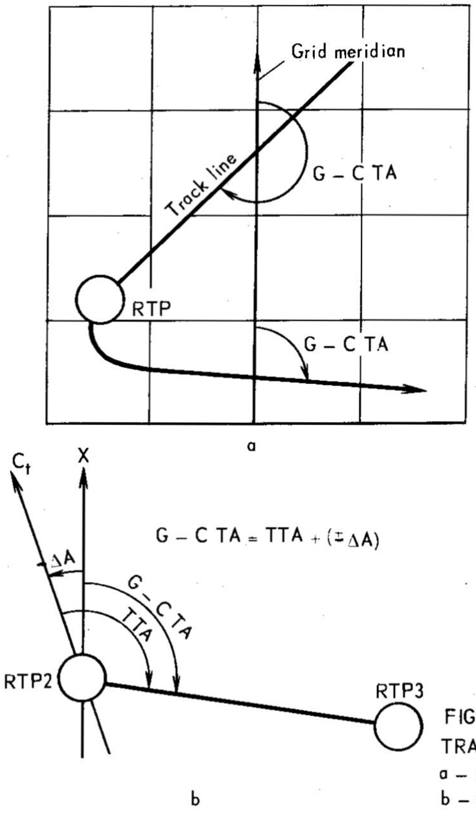


FIG. 60. DETERMINATION OF GREAT-CIRCLE TRACK ANGLE (G-CTA)
a – measurements taken with use of map;
b – calculation with reference to TTA and ΔA

The azimuth correction should be calculated within the range of 0 to $\pm 180^\circ$. In order to determine this correction, use the convergence angle with which the azimuth correction is associated through the following relationships:

$$\Delta A = -\Delta, \text{ if } \Delta < 180^\circ \text{ and } \Delta A = 360^\circ - \Delta, \text{ if } \Delta > 180^\circ.$$

When flying the aircraft in an area which is limited by a circumference having a radius of 750 to 800 km, with the difference between the longitudes not exceeding 10 to 12°, the azimuth correction may be calculated with the use of a simplified formula

$$\Delta A = (\lambda_0 - \lambda) \sin \varphi_0,$$

where: φ_0, λ_0 - geographical coordinates of the point of origin;
λ - longitude of the pre-selected point.

With the point of origin of coordinates aligned with the airdrome or a point extending at a distance of 20 to 30 km off the airfield, the conventional magnetic declination is equal to the airdrome magnetic declination if axis X is in coincidence with the geographical meridian in the point of origin.

The great-circle track angles (G-CTA) may be determined by way of direct measurement if the great-circle coordinate system grid is available on the map. Such being the case, it is necessary to measure the angle between the conventional meridian (axis X) and the track line with the use of a protractor (Fig. 60, a).

If a great-circle coordinate system grid is not marked, the great-circle track angles should be determined (Fig. 60, b) by the aid of the following formula:

$$\text{G-CTA} = \text{TTA} + (\pm\Delta A).$$

Determination of initial data for automatic landing approach. To insure automatic landing approach to a base and three alternate airdromes, determine the following initial data:

(a) true runway headings (Ψ_{runway});

(b) lateral offset of radio beacons with respect to the runway line (Z_o);

(c) frequency-code navigation and landing channels.

The true runway heading should be determined as a total of the magnetic runway heading and the magnetic declination of the programmed airdrome (Fig. 61)

$$\Psi_{runway} = MH_{runway} + \Delta M.$$

The runway magnetic heading should be selected from the Air Traffic and Airdrome Navigation Data Manuals and Radio Communication Means and Radio Support Lists and Schedules. The magnetic declination data is obtained by reference to the map.

It is necessary that the true runway heading data corresponding to the main landing direction be inserted into the landing computor.

The true headings ranging from 0 to 179° correspond to the main landing direction. The true headings within the limits of 180 to 359° correspond to the reverse direction.

Lateral offsets Z_o of the radio beacons of the short-range navigation and landing system with respect to the runway lines of the base and alternate airdromes should be selected from the Air Traffic and Airdrome Navigation Data Manuals, Radio Communication Means and Radio Support Lists and Schedules, or Flight Manuals and Instructions pertaining to a given aerodrome.

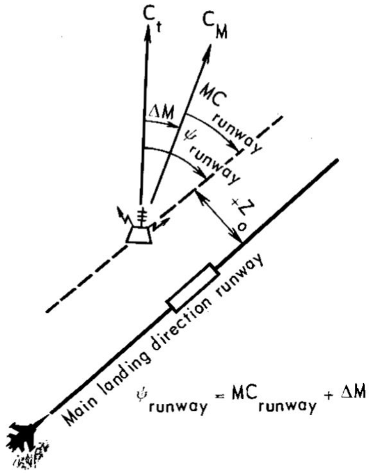


FIG. 61. DETERMINATION OF TRUE LANDING HEADING

If the radio beacon is located on the left side with respect to the runway line when landing in the main direction, the amount of the radio beacon lateral offset should be given with a positive sign. When the beacon is on the right side relative to the runway line, it should be taken with a negative sign. The values corresponding to the lateral offsets of the radio beacons should be inserted into the landing computor.

The frequency-code navigation and landing channels must be selected from the Air Traffic and Airdrome Navigation Data Manuals and Radio Communication Means and Radio Support Lists and Schedules. The information pertaining to the positions of the CRYSTAL (КВАРЦ) and CODE (КОД) selector switches can be obtained by reference to the tables available in the technical descriptions of the РСБН-6С airborne short-range navigation and landing system.

Knowing the numbers of the navigation and landing channels, one can find the CRYSTAL and CODE numbers without searching for them in the above-mentioned tables. If the channel number is less than 4, the crystal number will be equal to 1, and the code number is equal to the channel number. Should the channel number be equal or greater than 4, the crystal number should be determined by dividing the channel number by 4. The resulting quotient should be rounded off to the nearest greater integer. The code number is equal to the remainder of division. If the division produces an integer, the code number should be assumed equal to 4. Let us assume, for example, that the channel number is equal to 33. Hence, the crystal number will be equal to 9 and the code number, to 1.

<u>The programme for the enroute flight and landing on the main and alternate airdromes</u> should be worked out during the period of

preliminary preparation. To be included in the programme are the following initial data:

(a) great-circle coordinates of the four SHORAN beacons located at the airdromes and the three enroute turning points;

(b) convergence angles of the meridians for the four airdromes;

(c) great-circle coordinates origin latitude;

(d) true headings corresponding to the main direction of landing on the four airdromes;

(e) lateral offsets of the radio beacons for the four airdromes;

(f) numbers of the frequency-code channels for the radio beacons of the short-range navigation and landing system and the ПРМГ-4 radio beacon group at the main and alternate airdromes;

(g) medium latitude of flight area or the latitude of the takeoff airdrome (during local flights);

(h) takeoff airdrome conventional magnetic declination.

All these initial data are to be filled in on a special blank sheet which is used for flight programming. The initial data programme should be made up by the pilot under the supervision of the squadron navigator, and checked out for correctness by the chief navigator of the air regiment.

The initial data on the units of the PCБH-6C system are set by a radioelectronic equipment technician.

PERFORMING ENROUTE FLIGHT

1. PREPARATION FOR TAKEOFF

After climbing into a cockpit the pilot should turn on the electric power supply and carry out the following operations:

(1) turn on the circuit breakers labelled D/VG, FD, CRS IND; STBY D/V GYRO, D/VG, ДA-200; ADCS; ADCS HEAT; SHORAN, and AFCS. The turning on of the D/VG, FD, CRS IND circuit breakers results in the flashing-up of the CAGE button-lamp located on the flight director indicator panel and subsequent fading-out after 30 sec of glowing and the indicator showing the parking values of both the roll and pitch angles;

(2) depress the AER1 and RTP1 (1AЗP. и ППМ1) button-lamp to be found on the control panel of the shoran airborne system;

(3) set the SHORAN - ADF (PCБH - APK) selector switch to the SHORAN position;

(4) move the COURSE SELECT AUTO - MAN selector switch to the AUTO position;

(5) ascertain that the LANDING selector switch is in the OFF position and the $\Psi + 180^{o}$ - OFF selector switch is set to a position corresponding to the required takeoff heading;

(6) check to see that the distance to the RTP1 is indicated by the ППД-2 direct reading distance indicator and the CORR indicator lamp located on the control panel of the РСБН-6С short-range navigation and landing system is glowing;

(7) set the altitude and airspeed selector of the САУ-155П (САУ-155П1) automatic flight control system to the required altitude and Mach number.

Upon completion of engine start-up press on the ROMB-1 button-lamp located on the control panel of the automatic flight control system and check out whether the indications presented by the instruments correspond to the following positions of the bars and pointers:

(a) the pre-selected course pointer of the combined course indicator indicates the course (bearing) relative to the RTP-1;

(b) the RB pointer indicates the direction to the radio beacon at the takeoff airdrome;

(c) the flight director indicator side channel director pointer and position bar have deflected toward the RTP-1;

(d) the flight director indicator pitch channel director pointer has deflected downward relative to the circle;

(e) the pitch channel position bar has deflected upward relative to the circle.

Depress the TEST (КОНТРОЛЬ) button located on the modified control panel of the РСБН-6С shoran airborne system. With the above button depressed, the combined course indicator must show the azimuth reference value of 177^{o} and the ППД-2 direct reading distance indicator, the distance reference value of 291.5 km. On releasing the button the above indicators must indicate the previous values.

After taxiing the aircraft onto the runway ascertain that the present heading is equal to the true takeoff heading at a given airdrome.

The enroute flight involving the POLJOT-1И system may be performed in the automatic, or director, or manual control mode . The automatic control mode is the principle one. The director control mode should be used in the event of failure of the automatic control system or for the training purposes. The manual control mode shall be made use of provided that both the automatic and director control modes have failed.

2. PERFORMING ASSIGNED ENROUTE FLIGHT IN AUTOMATIC CONTROL MODE

Takeoff and climb to an altitude of 200 m shall be effected manually.

On attaining an altitude of 200 m the aircraft shall be piloted by reference to the director pointers of the flight director indicator. The roll channel director pointer shows the direction of turn and the roll channel position bar points to the prescribed path. The pitch channel director pointer will be found below the circle and the position bar, above the circle. As the aircraft climbs, the pitch channel director pointer will tend toward the centre of the circle. The pitch channel position bar indicates the position of the prescribed flight path.

On attaining an altitude of at least 500 m the pilot holding the director pointers within the limits of the circle should trim out the aircraft to zero stick force and enable the automatic control mode by way of pressing on the AUTO CTRL button-lamp located on the control panel of the automatic flight control system and ascertain that it has come to glow. After the automatic control mode has been enabled the aircraft in-flight control becomes automatic. Engine operation control shall be effected by the pilot himself.

The flight speed and the engine power setting will depend on which of the climb programmes the altitude and airspeed selector is set to.

In both the subsonic and supersonic climbing, when the aircraft approaches the prescribed altitude, the SELECT ALT LEVELLING-OFF (СХОД $H_{ЗАД}$) indicator lamp located on the instrument board comes to glow and remains on for 3 to 5-sec period upon expiration of which the aircraft is automatically reverted to level flight at the prescribed altitude and with the preset heading. Apart from this, the attainment of the prescribed altitude by the aircraft shall be checked out by reference to the pitch channel position bar which must cover the distance between the upper limit stop and the lower edge of the circle across the centre mark of the scale.

As emptiness in the fuel tanks grows in subsonic flight at a constant altitude, the pilot should maintain the airspeed corresponding to a Mach number of 0.8 by way of gradually diminishing the r.p.m. speed of the aircraft engines.

To insure a more smooth levelling-off after the attainment of the preset maximum supersonic altitude, on flashing-up of the SELECT ALT LEVELLING-OFF indicator lamp the pilot should place the throttle lever in the MINIMUM AUGMENTED power setting and in level flight establish an airspeed corresponding to a Mach number of 2.35.

In straight flight, both at sub- and supersonic speeds, the aircraft is steadily held on the prescribed path. The director pointers and position bars of the flight director indicator at the time must be within the limits of the respective circles.

The pre-selected course indicator pointer settles in the direction of the route turning point.

With the takeoff airdrome radio beacon up-dating insured, the CORR indicator lamp located on the control panel of the PCБH-6C system flashes up and the RB pointer on the combined course indicator will show the relative bearing of the radio station.

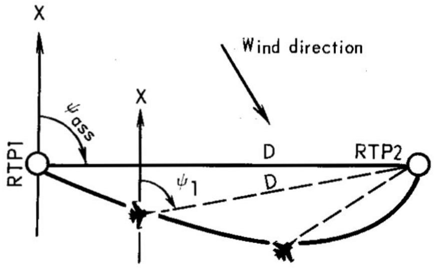


FIG. 62. AIRCRAFT TRAJECTORY WHEN FLYING TO ASSIGNED POINT BY DIRECTIONAL METHOD IN WIND AND RADIO CORRECTION CONDITIONS

Preset point (RTP) interception flight involving the command direction method under wind conditions, with the dead-reckoning up-dating ensured by the PCБH short-range navigation and landing system radio beacon, should be effected by the use of the command direction method involving radio beacon up-dating procedures, as shown in Fig. 62.

When flying the aircraft clear of the zone of coverage of the short-range navigation and landing system radio beacon in the independent dead-reckoning mode, the flight path is essentially a straight line as shown in Fig. 63.

When at a distance of 40 km to the RTP, the D BELOW 40 KM (Д МЕНЬШЕ 40 КМ) indicator lamp located on the control panel of the shoran airborne system comes to glow. Upon flashing up of this lamp or attaining a distance specified in the flight assignment, depress the button-lamp pertaining to the next RTP. Depressing of the above button results in the automatic turning of the aircraft, with the bank not exceeding 45° and 30° under supersonic and subsonic conditions, respectively.

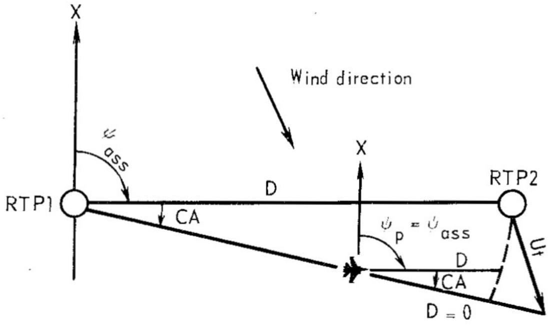


FIG. 63. AIRCRAFT TRAJECTORY IN INDEPENDENT DEAD-RECKONING AND WIND CONDITIONS

Upon illumination of the button-lamp referring to the next RTP the preselected course indicator pointer of the combined course indicator shows the heading relative to the subsequent RTP and the ППД-2 distance indicator indicates the distance to this RTP. The flight director indicator roll channel director pointer and position bar will deflect toward the preselected course.

It is recommended that the throttle lever be placed in the FULL REHEAT position when turning the aircraft at a supersonic speed and reversed to the original position upon completion of turning.

With the flight mission involving flying-over the route turning point, proceed as follows:

- at a distance of 25 km disable the automatic control mode by depressing the AP DISENGAGE button on the control stick;
- change over to manual control and maintain the present heading;
- when the distance readings presented by the ППД-2 distance indicator become equal to the flight altitude, turn on the button-lamp of the next RTP, start to manually turn the aircraft, set the director pointers in the centre of the circle, and cut in the automatic control mode.

Upon completion of turning the aircraft with the purpose of intercepting the pre-selected course, the director pointers and position bars should be within the limits of the respective circles.

In case the radio beacons of the PCБH short-range navigation and landing system, or enroute radio beacons, or beacons of the radio navigation points programmed in the system are used as the route turning points, depress the AER and RE button-lamps located on the PCБH system control panel. The subsequent procedures to be followed by the pilot are similar to those involved in flight to RTP.

On getting out of the zone of coverage of the takeoff airdrome short-range navigation and landing system radio beacon (the CORR indicator lamp located on the PCБH system control panel does not glow) or intercepting the points specified in the navigator's flight chart, press on the button-lamp relevant to the next programmed radio beacon into the operational zone of which the aircraft will enter.

When performing an enroute flight in the automatic control mode, a pilot must effect engine operational control, check the correctness of the present course indications, check the combined course indicator pointers and the flight director indicator position bars and director pointers for correct positioning, note the readings presented by the ППД-2 distance indicator, keep check on the flight director indicator for correct pitch and roll indications, and check the illumination of the ROMB-1 button-lamp located on the automatic flight control system panel.

The fading-out of the button-lamp results in the dropping-out of the R and P warning flags on the flight director indicator and causes the automatic flight control system to stabilize the aircraft attitude registered in the moment of the lamp fading-out. Such being the case, a pilot should change over to manual control without cutting off the automatic control system by the use of the AP DISENGAGE button, ascertain that the CORR lamp located on the shoran system control panel has come to glow, depress the ROMB-1 button-lamp, set the director pointers within the limits of the circle, and trim out the aircraft to zero stick force.

If the CORR lamp is dead, the return to the landing airdrome should be effected by the use of the APK-10 automatic direction finder by way of placing the SHORAN - ADF selector switch to the ADF position. Upon setting the switch to the required position ascertain that the combined course indicator RB pointer readings are within the variation tolerance of 6 to 8° at a distance of more than 40 km with respect to the landing airdrome.

Apart from what is said in the above, a pilot, when in doubt about the properness of functioning of the shoran equipment, must periodically check the flight direction with the use of the APK-10 automatic direction finder and the radio direction finder and the distance to the airdrome by using the information given from the control post during the performance of enroute flights and return to the programmed airdrome.

3. RETURN TO PROGRAMMED AIRFIELD

Upon completion of the mission assigned or upon the return-to-airdrome command from the control post, depress the AER and HOMING (BO3BPAT) button-lamps located on the shoran system control panel.

After the HOMING mode has been enabled ascertain that the position to which the $\Psi + 180^{\circ}$ - OFF selector switch has been set corresponds to the landing course at a given airdrome.

If the aircraft has been piloted at an altitude exceeding the cruising return one (9500 m) and distance to the airdrome of more than 250 km, a pilot should cut off the automatic control by depressing the AP DISENGAGE button on the control stick and press on the HOMING button-lamp.

Subsequent descent should be effected manually with the use of the roll channel by reference to the director pointer so as to be able to attain an altitude of 9500 m at a distance of 120 to 150 km with respect to the airdrome.

On attaining a cruising altitude of 9500 m establish the prescribed airspeed and cut in the automatic control system, with the director pointers of the flight director indicator being within the limits of the circle.

At a distance of 90 to 120 km notice the moment of cloud-break by the deflection of the flight director indicator glideslope bar and pitch channel director pointer from the midposition as well as by the automatic descent transition.

When descending along the cloud-break glideslope, the flight director indicator glideslope bar is held in position below the circle between the second and third points.

With the engine idling in descent to an altitude of 3000 m, the forward speed is maintained within the limits of 600 to 650 km/h at a rate of descent of 35 to 40 m/s.

Starting from an altitude of 3000 m the angle of descent diminishes. It is, therefore, necessary that a pilot accelerates the engines in approaching an altitude of 1000 m in order to maintain an airspeed of 600 km/h. Gradually level off the aircraft at an altitude of 600 m in the area of the turn onto base leg or final turn depending on the return and approach headings. In the course of descent set the altimeter to the landing airdrome pressure.

To effect a return from an altitude of below 9500 m, proceed as follows:

(1) cut off the automatic flight control system by depressing the AP DISENGAGE button;

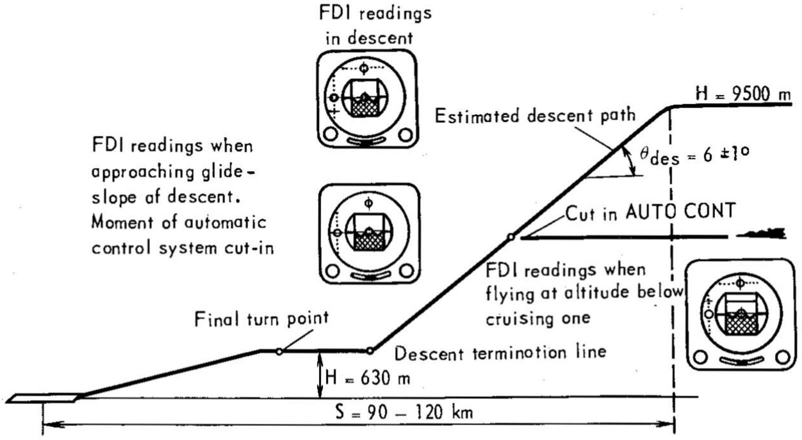


FIG. 64. BRINGING AIRCRAFT TO LANDING COURSE IN VERTICAL PLANE BY USE OF POLJOT-1M SYSTEM

(2) press on the AER and HOMING button-lamps;

(3) sustain level flight, holding the flight director indicator director pointer and roll channel position bar within the limits of the circles. The flight director indicator pitch channel position bar and director pointer are above the respective circles and move toward the centre as the aircraft reaches the preset descending path;

(4) as soon as the director pointer and pitch channel position bar attain the centres of the respective circles, cut in the automatic flight control system and furtheron monitor the aircraft descending along the preset path. Guide the aircraft on the landing course in the vertical plane by the aid of the POLJOT-1M system as illustrated in Fig. 64.

If an enroute flight has been performed beyond the radio updating zone, return the aircraft to the programmed airfield by following the procedures given below:

(1) cut off the automatic flight control system by pressing on the AP DISENGAGE button;

(2) depress the AER and HOMING button-lamps located on the shoran system control panel;

(3) depress the ROMB-1 button-lamp on the automatic flight control system panel;

(4) arrange the director pointers within the limits of the circle on the flight director indicator and change over to manual control;

(5) depress the AUTO CTRL button-lamp on the automatic flight control system panel and trim out the control forces.

As the distance to the landing airdrome diminishes, a pilot should monitor the radio updating by the illumination of the CORR lamp located on the control panel of the PCБH-6C system. Under zero updating conditions the combined course indicator will present the pre-selected course data relative to the short-range navigation and landing system beacon rather than the base-leg or final turn point. In these circumstances a pilot should cut off the automatic control system, set the SHORAN - ADF selector switch to the ADF position, and fly the pre-landing manoeuvre by reference to the APK-10 automatic direction finder.

Whenever the stabilized altitude is above 700 or below 550 m during the performance of the pre-landing manoeuvre, turn off the automatic flight control system by pressing on the AP DISENGAGE button.

Furtheron, prior to entering the glideslope effect roll channel control by reference to the director pointer of the flight director indicator and maintain the flight altitude by reference to the УВО-30К (УВО-М1) altitude indicator in accordance with the distance to the runway so as to insure glideslope interception with the landing heading. As soon as the combined course indicator position bar comes close to the upper edge of the circle, with the director pointers being serviceable, turn on the automatic flight control system by depressing the AUTO CTRL button-lamp located on the automatic flight control system panel and monitor the aircraft in flight along the glideslope.

4. PECULIARITIES OF PERFORMING ENROUTE FLIGHT IN DIRECTOR AND MANUAL CONTROL MODES

The director control mode is engaged by depressing the ROMB-1 button-lamp on the automatic flight control system panel. The aircraft should be piloted in the director control mode in accordance with the indications presented by the director pointers of the flight director indicator and by holding them within the limits of the circle.

When flying at altitudes above the level of 10,000 m, it is necessary to engage the damping mode by pressing on the DAMP button-lamp on the automatic flight control system panel in order to improve aircraft stability in flight.

The scope and sequence of operations involved in maintaining flight conditions, the system control, and checking the system serviceability in the director control mode are similar to those involved in the aircraft automatic control mode.

Manual control mode should be made use of in the event of failure of both the automatic and director control modes. To insure manual control mode, a pilot should use the selected course and radio beacon relative bearing readings presented by the combined course indicator. Upon depressing the ROMB-1 button-lamp on the automatic flight control system panel a pilot can also make use of the indications presented by the pitch channel or glide-slope bar of the flight director indicator operated in the HOMING mode in response to the commands from the PCБH-6C system.

During the performance of an enroute flight in the manual control mode the selected course indicator pointer of the combined course indicator must be set to the required position by the use of the SELECT COURSE knob and the SELECT COURSE AUTO-MAN selector switch,to the MAN position.

To maintain the prescribed flight altitude with the purpose of returning to the programmed landing airdrome, a pilot should hold the flight director indicator pitch channel bar in the centre of the circle.

When descending along the cloud-break path, the flight director indicator pitch channel bar must be held at the second lower point to insure smooth attainment of a minimum pre-landing manoeuvre altitude of 600 m.

The monitoring of the navigation parameters reproduced by the POLJOT-1M system and use of the equipment in the manual control mode should be effected in the same scope and sequence as during the aircraft operation in either the automatic or director control mode.

5. PECULIARITIES OF PERFORMING FLIGHT TO NON-PROGRAMMED AIRFIELD WITH USE OF POLJOT-1M SYSTEM

During the performance of an enroute flight there may arise a necessity in landing the aircraft on a non-programmed airfield.

When clear of the zone of coverage of the non-programmed airdrome navigation beacon, the aircraft should be flown on the pre-selected course. Upon entry into the zone of coverage of this beacon the aircraft must be piloted in the direction of the navigation beacon.

Upon receiving superior's command or making an independent decision on landing the aircraft on a non-programmed airdrome, the pilot must follow the procedures given below:

- when at long distances from the landing airdrome, that is when clear of the zone of coverage of the navigation beacon, approximately determine the aircraft position on the desired course and the distance to the next route turning point;
- visually determine the great-circle course to the landing airdrome by reference to the map;
- use the radio set to request the team at the control (observation) post for the present distance and inbound course data and report the amount of fuel remaining in the tanks;
- cut off the automatic flight control system by the aid of the AP DISENGAGE button;
- depress the RESET button and check to see the BOMB-1 button-lamp located on the automatic flight control system panel has faded out;
- perform a turn to intercept the desired course and climb to an altitude corresponding to the maximum flight range;
- set the SELECT COURSE AUTO - MAN switch to the MAN position; set the combined course indicator to the desired inbound course by the use of the SELECT COURSE knob; perform a corrective turn to align the pre-selected course indicator pointer with the fixed triangular index mark and fly the aircraft to the airdrome;
- depress the RESET and HOMING button-lamps on the shoran system control panel; engage the operating channels of the navigation beacon and radio beacon group by the aid of the NAVIG and LANDING channels selector switches;

- establish radio contact with landing airdrome control post and report the new control team about readiness to assume control to the previous command (direction) post;

- to start the airdrome beacon updating, set the SHORAN - ADF selector switch to the SHORAN position and check the combined course indicator for proper relative bearing indications and the ППД-2 distance indicator, for correct reading of distance to the radio beacon;

- set the ADF - COMPASS selector switch to the COMPASS position and listen to the landing airdrome navigation beacon call signs; ascertain that they are correct, revert the above selector switch to the ADF position, and perform an inbound flight;

- depress the ROMB-1 button-lamp on the automatic flight control system panel;

- proceed on an inbound course, holding the roll channel director pointer within the centre of the circle and checking the flight direction by reference to the relative bearing indicator pointer;

- at a distance of 120 to 100 km from the airdrome start manual descent so as to be able to pass the radio beacon at a flight pattern altitude; establish the landing airdrome pressure in advance;

- after flying past the radio beacon effect a landing approach in accordance with the flight pattern adopted at a given airdrome.

Under VFR weather conditions the inbound course should be intercepted at a circling flight altitude.

To land the aircraft on a non-programmed airdrome, follow the procedures given below:

(1) set the combined course indicator to the great-circle landing course with due regard to the conventional magnetic declination of the takeoff airdrome;

(2) when on a final leg or at a distance of 20 km from the airdrome with the view of performing a straight-in approach, turn on the LANDING switch on the shoran system control panel;

(3) check the combined course indicator localizer warning flag for closure and depress the LANDING button-lamp on the automatic flight control system panel;

(4) check to see the ROMB-1 button-lamp properly flashes up and the R and P flags on the flight director indicator get closed;

(5) set the director pointers within the limits of the circle of the flight director indicator and press on the AUTO CTRL button-lamp;

(6) keep watch of how the aircraft performs an automatic landing approach to a height of 50 m. On descending to this height, cut off the automatic flight control system and manually carry out the landing operations.

It should be borne in mind, that non-programmed aerodrome approach should be effected on the great-circle course reproduced by the directional/vertical gyro system. The true heading data is computed by the РСБН-6С system only in the mode of return to the programmed aerodrome.

6. USING POLJOT-1И SYSTEM DURING FLIGHT TO AIR ALERT AND INDEPENDENT SEARCH ZONES

During flight to the air alert zone or training flying area the POLJOT-1И comprehensive system is commonly used for only guiding the aircraft to above said areas, returning it home, and performing landing approach (Fig. 65).

To get into the zone, determine the great-circle coordinates of a definite point (manoeuvre point) and insert these data into the programme unit of the РСБН-6С system carrying a definite RTP number. Prior to takeoff depress the AER 1 button-lamp and that pertaining to the respective RTP on the РСБН system control panel. After takeoff proceed on the course to intercept the pre-established manoeuvring point in the same manner as in case of intercepting the pre-established route point.

Keep a constant check on the position of the aircraft in a given area by the aid of the pre-determined headings (bearings), flight time, and distance from a programmed point during the performance of zone mission.

Zone mission accomplished, a pilot can intercept the inbound course and perform landing in automatic control mode from any point. To this end, he should depress the AER 1 and HOMING button-lamps on the shoran system control panel.

In case an aircraft is expected to be landed on any programmed airfield other than the takeoff aerodrome, a pilot should press on that button-lamp which is pertinent to the respective aerodrome.

A pilot can guide the aircraft to the aerial target independent search area, fly the assigned manoeuvre in the preset area, and intercept the inbound course in the automatic control mode

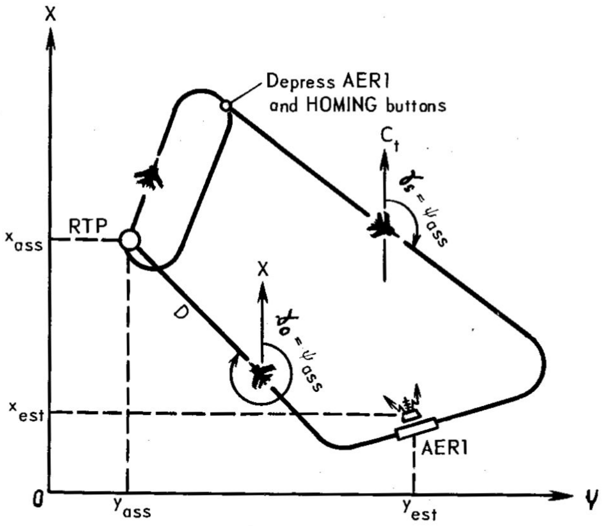


FIG. 65. EMPLOYMENT OF POLJOT-1И SYSTEM WHEN FLYING TO AIR ALERT ZONE (TRAINING FLYING AREA)

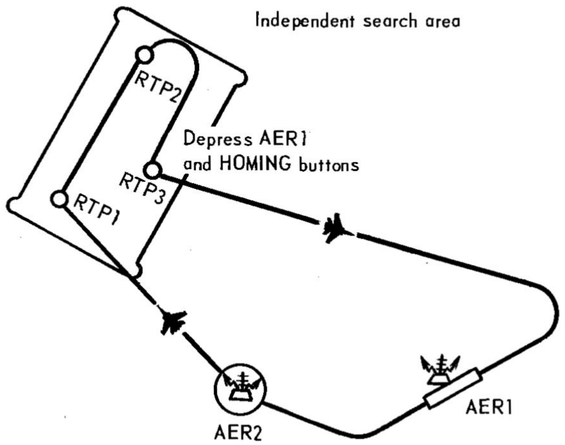


FIG. 66. PERFORMING MANEUVER IN INDEPENDENT SEARCH AREA WITH USE OF POLJOT-1И SYSTEM

with the use of the POLJOT-1И system at all stages of flight (Fig. 66). To accomplish the above procedures, determine the great-circle coordinates of the route turning points and insert these data into the programming unit of the PCБH-6C system.

7. EMPLOYMENT OF APK-10 AUTOMATIC DIRECTION FINDER FOR AIR NAVIGATION PURPOSES

The МиГ-25П interceptor-fighter is provided with the APK-10 automatic direction finder which is intended for the solution of the air navigation problems with the use of the homing and broadcasting radio stations,as well as the performance of aircraft landing with the use of the instrument landing system in the event of failure of either the ground or airborne short-range navigation and landing system. The APK-10 direction finder is kept ready in flight for emergency operation at all times.

The automatic direction finder is essentially an airborne radio direction finder which is used for determination of direction toward a homing or broadcasting radio station. It operates within the medium wave range of 120 to 1340 kilocycles and is tuned to nine fixed frequencies in advance. The call signs and operating frequencies of the homing radio stations are listed on a template arranged in the aircraft cockpit. The odd-numbered buttons on the control panel correspond to the tuning frequencies of the outer homing stations. The adjacent even-numbered buttons stand for the tuning frequencies of the inner homing beacons arranged at the same aerodromes. Such an arrangement insures the operation of the automatic selector switch upon the commands transmitted by the marker beacons when flying over the homing radio station what is indispensable during the performance of a landing approach with the use of the instrument landing system.

The automatic change-over of the automatic direction finder from the outer to the inner beacon takes place only after flying past the homing radio station with the landing gear down. Setting the wave remote-control selector switch to the number of the respective inner beacon is an indispensable condition for such an automatic change-over.

The operational range of the APK-10 automatic direction finder during the joint operation with the homing radio stations of the ПАР-8С type, with the aircraft being flown at an altitude of 10,000 m, amounts up to 350 km. At an altitude of 2000 m this range extends to at least 210 km. At greater distances from the aerodrome the direction finder functions unsteadily and the reading error of the RB indicator pointer fluctuates within the limits of $\pm 7^{\circ}$.

The APK-10 automatic direction finder makes it possible to effect as follows:

- perform both the inbound and outbound flights, with the combined course indicator presenting visual indications of the relative bearing of a certain radio station;
- determine the relative bearing of the radio station;
- perform landing planning and approach with the use of the instrument landing system;
- receive and reproduce the signals transmitted from the homing and broadcasting radio stations.

The direction finder under discussion is capable of operation in two modes, namely COMPASS and ANTENNA.

In the COMPASS mode the reception is simultaneously effected by the frame and non-directional antennas, thus the automatic finding of the direction to the radio station being insured. The relative bearing of the radio station is displayed on the combined course indicator scale.

To ensure monitoring of the homing radio station call signs, set the ADF - COMPASS selector switch to the COMPASS position and the ANTENNA - COMPASS selector switch,to the ANTENNA position.

If the aircraft is piloted with the use of the POLJOT-1M system, the ADF - SHORAN selector switch should be placed in the ADF position in order to make the APK-10 direction finder present the RB indications.

In the ANTENNA mode the reception is effected only by the non-directional antenna and the automatic direction finder operates as a conventional radio receiver. This property makes it possible to use the automatic direction finder as a means of reception of the flying control officer's commands in the event of failure of the radio receiver.

To ensure the reception of the flying control officer's command by the APK-10 automatic direction finder, follow the procedures given below:

(1) set the ADF - COMPASS selector switch located on the panel of the PCMУ-5 communication radio set to the COMPASS position;

(2) set the ANTENNA - COMPASS selector switch to the ANTENNA position; place the SHORAN - ADF selector switch to the ADF position.

Flying the aircraft on the inbound course with the use of the APK-10 automatic direction finder may involve passive, course stabilization or active methods.

In passive method of flight on an inbound course the indicator pointer of the direction finder should be held at zero.

Under cross-wind conditions the aircraft heading will vary. As a consequence of this, the aircraft will displace along a curve which is also known as a radio course line. An increase in the aircraft course is indicative of a left-hand drift while a decrease in the course is an evidence of a right-hand wind drift.

The course stabilization method is used when the aircraft is to take the inbound course under the conditions when the automatic direction finder fails to present steady readings and the distance from the aerodrome is great (up to 200 km).

To intercept the inbound course with the use of the course stabilization method, set the ADF pointer of the combined course indicator at zero, note the aircraft heading, and maintain it for a certain period of time. In the event of steady pointer deflection off the zero mark, perform a corrective turn to reset it at zero and maintain a new heading, etc. The direction of drift should be determined by a change in the heading, the same principle being involved in the passive method of flight on inbound course. Namely, an increase in the aircraft course indicates a left-hand drift. A decrease is indicative of a right-hand one.

The active method of flight on an inbound course is commonly used in enroute long-distance flights.

With this method being involved, it is necessary that a pilot maintains the heading and such a relative bearing of the radio station at which the desired inbound course interception will be ensured. Upon interception of the desired course, perform a corrective turn to take the course with due regard to the drift angle. As a result, the movable heading dial will present the course data with regard to the drift angle and the ADF indicator pointer will deflect from the zero mark in the opposite direction by the amount of the drift angle. Holding the combined course indicator pointers in the above positions ensures flight on a desired course, with the aircraft axis turned through an amount of the drift angle with respect to the course line.

Flight on an outbound course in the predetermined direction should be performed with the preselected heading. The position of the aircraft relative to the desired course line should be checked by reference to the automatic direction finder.

When proceeding on the desired course, the ADF pointer will indicate RB = 180° only at zero drift. In flight an aircraft is subject to wind drift practically at all times. The existence of drift can be determined by either the left-hand or right-hand deflection of the ADF pointer relative to the 180° mark. To intercept the desired course, perform a corrective turn by reference to the movable heading dial in the direction of the ADF pointer deflection. The amount of turn must be equal to double drift angles.

Upon completion of a corrective turn,the pilot will find the ADF pointer deflected by triple drift angle with respect to the position corresponding to an angle of 180°. It is further necessary that the course be constantly maintained until the pilot will be able to intercept the desired course. At the moment of the desired course interception the ADF indicator pointer will be deflected through double drift angle to a position corresponding to 180°. Furtheron, perform a corrective turn so as the course correction is equal to one drift angle.

Subsequently, keep check of the aircraft position by way of proper use of the entire airborne navigation equipment, visual orientation as well as the information furnished from the control (direction) post.

PECULIARITIES INVOLVED IN AIR NAVIGATION UNDER VARIOUS CONDITIONS

1. PECULIARITIES INVOLVED IN AIR NAVIGATION AT LOW ALTITUDES

The low-altitude flight is characterized by the following:

(1) decreased effective range of the radio navigation and communication aids;

(2) hampered visual orientation owing to high velocity of landmark displacement and short time available for landmark identification;

(3) considerable increase of fuel consumption;

(4) limited possibilities in using the aircraft maneuvering capabilities;

(5) increased emotional and psychological stress which results in rapid fatigue of the pilot;

(6) as a rule, there is no possibility of using the automatic control system in flight.

Difficulties in air navigation at low altitudes arise primarily due to a decrease in the effective range of the radio navigation and communication aids. When in flight at an altitude of 200 m, for example, the effective range of the PCБH-6C short-range navigational and landing system accounts up to 20 km, and that of the radio communication is equal to 50 km. Such a limitation generates a need for dead-reckoning versus airspeed and time in combination with a thorough visual orientation. The visual orientation is in turn considerably hampered.

Within the field of vision of the pilot there is a limited number of landmarks,the rate of displacement of which is so great that the pilot is provided with only a few seconds for identification of these landmarks. When flying the aircraft at a speed of 720 km/h, for example, the available visual orientation time at an altitude of 400 m accounts for 10 s, whereas at an altitude of 200 m this time amounts to 5 s. From the tactical considerations, it is practical that a low-altitude flight be performed at high indicated airspeeds. As a consequence, the possibilities of visual orientation are limited even more.

It is common knowledge that fuel consumption increases with decrease of the flight altitude. The minimum fuel consumption per kilometer in near-ground flight is approximately twice as great as that at an altitude of 8000 m. Such an intensive consumption rate considerably reduces the operational radius of the interceptor-fighter and flight endurance. It is,therefore,necessary that the pilot varies the flight profile, whenever possible, in order to successfully accomplish a combat mission assigned.

The maneuvering capabilities of the aircraft improve with decreasing altitude. The proximity of the ground (water) surface forces the pilot to limit the amount of vigorous turns, give constant attention to the flying altitude and coordinated manipulation of the controls in order to ensure flight safety. Such a condition prevents the pilot from making the best of the aircraft maneuvering capabilities at low and especially extreme low altitudes. The flying experience shows that even highly proficient pilots are capable of performing maneuvers at a bank of not more than 45 to 50° when flying the aircraft at low altitudes in daytime under VFR weather conditions. In so doing, the flight altitude maintaining accuracy accounts for ±50 - 70 m.

Proceeding from the above-mentioned peculiarities the aircraft should be routed for the training purposes during low-altitude flight along the characteristic landmarks, if possible, or along the reference lines, with the route having a minimum number of legs.

As a rule, the departure aerodrome (outer beacon) or a landmark which can be easily reached after takeoff is chosen as the initial route point.

With a characteristic reference line available, the aircraft should be routed in such a manner that it be flown in parallel with the linear landmark and at a distance at which this landmark can be clearly visible. For a flight altitude of 200 to 300 m such a distance accounts for 1 to 3 km.

Flight route shall be selected with due regard to the radio aids available in the flight area. The flight route should be plotted so as to ensure the effective range of the radio aids.

Prior to flight,it is necessary that the pilots thoroughly familiarize themselves with the configuration of the ground landmarks, terrain elevations of more than 50 m high, as well as the obstacles available within the flight strip of ±25 km in width. It is necessary that the hills marked on the map and existing within the above-mentioned strip be elevated and the flight path be divided in legs depending on the terrain irregularity. It is also necessary that a barometric flight altitude be determined for each leg so that the absolute altitude corresponds to the pre-established one. Safe altitude must also be calculated by means of the barometric altimeter.

It is expedient to use the map of 1:500,000 in scale to plot the flight route for low-altitude flight.

The most practical method for intercepting the desired course in the low-altitude flight should be considered a visual method of intercepting the course determined on the basis of the pilot-balloon wind data.

If the flight route begins in the area,where the PCБH short-range navigational and landing system beacon or homing beacon is located, the interception of the desired course should be effected with the use of the preset azimuth or radio bearing.

The distance covered by the aircraft is checked with reference to the reference line attained, target range (flying time), or reference landmark. The reference line attained must be determined by visual dead-reckoning with respect to the reference line which is at right angles to the course line, or when abeam the side landmark as well as by the bearing perpendicular to the track line.

Directional control is effected by maintaining the flight course and by determining the distance-off-track visually or by means of the radio aids.

Even insignificant departure from the selected course presents certain difficulties in reference landmark detection and identification which may lead to considerable errors in determining the aircraft location and loss of orientation which may occur in extraordinary conditions. For example, proceeding on the course with an error of 5° for 5 min at an altitude of 100 m and flying speed of 900 km/h may result in cross track error of 6.6 km, thus precluding the identification of the route turning point or a non-linear landmark.

The flight course is maintained primarily through accurate interception of the desired course line after crossing the initial route point and subsequent constant detailed visual orientation. In low-altitude flight the wind factor is usually taken into account by introducing corrections into the course on the basis of the actual amounts of distance-off-track upon completion of their visual determination.

Thus, the successful solution of the low-level air navigation problems can be obtained through a comprehensive employment of the radio aids and training personnel for methods of constant detailed visual orientation.

2. PECULIARITIES INVOLVED IN AIR NAVIGATION AT SUPERSONIC SPEEDS IN STRATOSPHERE

The stratosphere flight can be effected on the МиГ-25П aircraft with the engines running at augmented power settings only. Running the engines at augmented power settings results in increased fuel consumption rate and, as a consequence, decrease of flight range and endurance. Deterioration of the aircraft maneuvering capabilities, particularly in near-ceiling flight, causes a considerable increase in time required for turning and establishment of the preset flight conditions.

The stratosphere flight presents the most favourable conditions for the complete solution of the air navigation problems by means of the radio aids, as their effective range is maximum practically at these altitudes. The visual orientation in stratosphere, however, is considerably hampered by a haze which is particularly thick at dawn, late hours, and at night. As a result, conditions of navigation measurements are hampered and air navigation accuracy is decreased. Apart from this, the pilot performs the supersonic stratosphere flight in a high-altitude outfit which considerably limits the visual orientation range. Consequently, adequate air navigation in stratosphere can be ensured only by proper use of the capabilities of the airborne electronic navigation aids.

Considering the above-mentioned peculiarities, the stratosphere supersonic flight route should have the minimum number of legs and should be plotted so as to ensure flight safety during crossing of airways and corridors. When preparing for flight, one should calculate and plot on the map the preselected climb and descent lines, as well as the lines at which the engine afterburners must be cut in and turned off. The coordinates for each of these lines are computed by the PCБH-2H (PCБH-4H) rho-theta radio beacon.

The navigational calculations must be effected before each flight. Fuel consumption and remaining fuel data for each stage of flight should be marked on the flight map.

The instances of interception of the turning points or the pre-established lines are commonly determined with the use of the electronic navigation aids. The afterburners should be cut in and off and the engine power settings changed in accordance with the data calculated on the ground.

The en-route stratosphere flight in a general case consists of the following stages:

(a) takeoff and climb to the preset altitude;

(b) maximum-range level flight;

(c) acceleration to the pre-established Mach number during straight or turning climb at a constant indicated airspeed;

(d) straight or turning climb at a constant Mach number;

(e) return to the home aerodrome at a preset altitude with subsequent descent for landing.

In each separate case some of the above-mentioned flight stages may be omitted.

Interception of the terminal route point and the landing approach course is usually effected at a subsonic speed in the direction of the homing beacon, the РСБН-2Н (РСБН-4Н) rho-theta radio beacon or the landing approach estimated point.

3. PECULIARITIES OF AIR NAVIGATION AT NIGHT

Night air navigation involving visual orientation is complicated by poor visibility of the ground surface and zero illumination of many of the landmarks. Apart from this,the same landmarks differ considerably in configuration in daylight and at night.

In en-route night flight the visual orientation conditions are affected by the season of the year, moon phase, nature of the terrain, weather, and flight altitude.

A snow blanket enhances illuminance and makes uncovered landmarks such as unfrozen rivers and lakes, residential districts, forest outlines, etc. more contrast against the snow background. At the same time landmarks covered with snow converge with the terrain background.

Landmarks are not so clearly visible in summer time against a dark background of the terrain.

The most unfavourable conditions for visual orientation are obtainable in spring and autumn. This can be explained by the fact that a partial snow cover makes the underflying ground surface particoloured, thus distorting the customary outlines of the landmarks.

On a bright moonlit night, especially in full moon phase, rivers, lakes, forests, and even unlit built-up areas are rather easily distinguishable. Landmarks are most clearly visible when the moon is high above the horizon. A considerable deterioration of visibility conditions occurs at moon rise and set, and particularly in twilight. Clouds diminish the landmark visibility range, and the shades produced by separate clouds distort the shape of the landmarks.

At a dark night the landmark visibility conditions are considerably deteriorated. The visual orientation therefore is practically impossible during high-altitude and stratosphere flights with no large-size reference points available. At a dark night the outlines of the light landmarks are more distinct than in a moonlit night.

Large-size light landmarks facilitate visual orientation. It should however be taken into consideration that the outlines of the artificially lit landmarks are subject to distortion, that the illuminence of the same light landmarks varies with various night time periods, and that the visual ranging of these landmarks produces gross errors.

Visual orientation is also hampered when there is an excessive number of small-size light landmarks.

Light landmarks are identified by their relative dimensions and characteristic outlines. Intensive illumination and large lit areas are the characteristic features of cities. It should be borne in mind that small invisible in daylight landmarks under high ambient light conditions in night time may well serve as reference points.

In night en-route flight, the greatest part of the flying time is taken by instrument flying which limits the possibilities of visual orientation.

Particular attention should be given to selection of the turning and check points. It is practical that the homing beacon, light beacon, radio direction finder, or, when these are not available, some other artificially lit or clearly visible landmark be selected as initial and terminal route points.

To successfully complete the night en-route flight, the pilot must commit to memory the flight plan, en-route data, data on the location and operation of the electronic navigation aids, actual outlines of light landmarks and their characteristic features, and the distinguishable features of the light equipment installed at the home and alternate airfields.

A particular thorough study prior to night en-route flight should be to the weather data, for it is extremely difficult to estimate these data in flight.

During weather study particular attention must be given to the type of clouds, height of cloud base, and thickness of clouds. Weather conditions should be evaluated from the point of view of the necessity in preventing the aircraft from entering the conditions which endanger flight safety (thunderstorm charged clouds, icing hazard, etc.).

The initial route point may be intercepted by the heading and-time-hold method, flying the aircraft in the direction of the homing beacon (radio beacon) or radio direction finder, as well as by visual orientation provided that a light beacon or a landmark, well visible at night, is taken as the initial route point.

The en-route flight may be effected either in the automatic or director, or manual control mode in accordance with the pre-established turning point programme and involves mandatory visual orientation procedures (if landmarks are visible) for checking the aircraft track.

The terminal route point and landing airfield interception must be effected with the use of the electronic navigation aids.

The primary condition for the successful accomplishment of the night air navigation procedures is the capability of the pilot to maintain the pre-selected flight regime throughout the en-route flight stages as regards the heading, flying speed and altitude, banking, and turning as well as to skilfully combine visual orientation and operation of the electronic navigation aids for the track checking and correction purposes.

4. PECULIARITIES OF AIR NAVIGATION DURING AERIAL TARGET INTERCEPTION

It is customary that interceptor-fighter pilots take off with no plotted and estimated route data at hand, for in most cases flight missions are assigned when the aircraft is aloft, the flight regime is determined by the navigator at the command post and altered very frequently. Such a peculiarity demands high proficiency in air navigation from the flying personnel and command post controllers, necessitates the use of the simplest and sufficiently reliable methods of air navigation which make it possible to appropriately use both the airborne and ground electronic navigation aids. In intercept flight the pilot is sometimes deprived of the possibility for position finding. Upon completing the air combat, however, the pilot must rapidly find the position and intercept the landing airfield. This is dictated by a limited amount of the remaining fuel. Under such conditions a thorough ground training is a guarantee that the pilot will be able to find the position.

When training for interception, it is necessary that the pilot very thoroughly familiarize himself with the combat area, the data obtained by the aid of the radio-and-light navigational means and the procedures for their in-flight use, as well as train in cooperation with the team of the control (direction) post.

The airfield and combat areas should be given a careful study by the pilots until they are capable of unmistakably identifying characteristic landmarks from memory and without consulting the map from various altitudes and during target approach from various directions.

When studying a future combat area, the pilot should use large-scale maps and mockups.

Knowing the layout of the main radio-and-light navigational aids facilitates orientation when clear of the field of vision of ground landmarks. In the combat area the pilot must study the location and distance to the front line (frontier), nature of the terrain, the location of magnetic anomalies, arrangement of the airfield network, the operational data and layout of the radio-and-light navigational aids and broadcasting stations, as well as the procedures for position finding to be followed in a given area.

The flying personnel must irreproachably know the airfield network, as interception may be effected at maximum ranges and involve transfer of control to the command posts of the cooperating units and landing at the nearest aerodrome.

Satisfactory results in individual training for properly using the electronic navigation aids in air navigation and learning skill in making necessary navigational calculations from memory to a sufficient degree of accuracy and with minimum of time requirements can be obtained through systematic navigation drills during preliminary preparation.

The pilot must plot the axial routes with calm weather data and the track on the flight map. Tracks should be laid with respect to the characteristic landmarks located in the battle area. Route data available on the map is always a help to the pilot returning to the home airdrome.

Preparation of the flying personnel for flights is commonly performed together with the command post controllers. Joint preliminary preparation for flights, flight critique, critique of drills during which personnel get familiar with the basic direction rules and peculiarities involved in the aircraft direction post controller's work promotes mutual understanding between the pilot and the aircraft controller, facilitates revealing of the actual causes of errors and blunders committed during interception and makes the best of the experience gained by the pilots and direction post controllers.

Interceptor-fighters accomplish takeoff upon a command from the command post usually from the ground alert position. After takeoff each pilot should cut in the direction channel upon permission of the flight control officer and establish contact with the command post controller. Upon first guidance command received, the pilot must establish the assigned power setting and strictly maintain it. Timely fulfilment of commands given by the command post controller and strict maintaining of the prescribed flight regime are the primary conditions for successful air navigation during target interception.

When flying the aircraft in the automatic control mode, the pilot is very limited in time for consulting the flight map during guidance stage of flight. During flight in clouds he is deprived of that opportunity at all, for the entire pilot's attention is concentrated on maintaining the prescribed flight regime, keeping of the spatial attitude in operating the controls, armament system, as well as on the radio communication and solution of the tactical problems pertaining to the methods of destruction of aerial targets.

Under the ECM conditions, the position of the fighters can be determined by the aid of the radio direction finders, short-range navigational system, as well as the navigational triangle method.

The responsibility of the controller at the command (direction) post is to observe the process of closure between the interceptor-fighter and the target, warn the pilot about the changes in the air situation, and render the pilot help in flying the aircraft to the home airdrome.

Upon completion of the air battle the pilot should notice the time, determine the amount of the fuel remainder in minutes of flight with respect to the maximum endurance flight conditions. The controller at the command post must provide the pilot with the course and duration of flight to the landing airfield or commence directing the aircraft to another target in case of a sufficient fuel remainder.

The landing airfield interception is effected mostly upon the commands of the command post controller. The intercept flight conditions are so complicated and diverse, however, that the pilot may be forced to independently fly the aircraft to the home airfield. Therefore, on the ground the pilot has to study the problems of independent target interception, search, and destruction but in what regards the procedures for flying the aircraft to any of the airfields available in the battle area upon accomplishment of the combat mission assigned.

Only thorough preparation for each flight, profound knowledge of the general air navigation rules, and proficiency in proper employment of the air navigation means serve as a reliable guarantee of the successful accomplishment of orientation and the flight mission as a whole.

RECOMMENDATIONS TO COMMANDER (INSTRUCTOR) ON TRAINING PILOTS IN AIR NAVIGATION

The air navigation accuracy largely depends on the pilot proficiency, that is the skill in maintaining the predetermined course, flying speed, altitude, and banks during turns, as well as making the best of the comprehensive airborne flight and navigational equipment. En-route flights, therefore, must be preceded by learning the skill of piloting the aircraft in the definite conditions.

The learning and improvement of skill in air navigation are effected through cockpit drilling or by the use of the KTC-5 trainer and other training equipment and practice piloting of combat trainers and combat aircraft.

In the course of ground training pilots must acquire skill in air navigation which is indispensable in flight.

In flight a pilot is deprived of the opportunity to do graphical work on the map and to use navigational aids. He must be able to determine angles and distances by sight and make necessary dead-reckoning and mental flight data calculations. The accomplishment of this objective may be obtained by systematic cockpit drills and using the training equipment and studies in the navigational training classrooms.

The fact that the МиГ-25П aircraft is equipped with modern flight-and-navigation and radio-and-electronic equipment to a greater extent enhances the importance of the cockpit drills and those with the use of the training equipment. During cockpit drills pilots must acquire a profound skill in using the POLJOT-1И comprehensive outfit in various stages of flight. This, however, does not exclude the necessity in acquiring good skill in prompt and accurate determination of heading corrections by reference to the APK-10 automatic direction finder during flight off the beacon in the prescribed direction and power-on flight toward the beacon, as well as the skill in checking the correctness of the picked up heading by the aid of the combined course indicator, automatic direction finder, and the radio direction finder.

It is recommended that general cockpit drills involving the entire personnel be combined with individual drills with separate pilots in accordance with the individual plans for the purpose of acquiring skill in using separate air navigation means, navigational sighting, and doing mental arithmetic.

The initial stage of the air navigation training on a given type of aircraft should be commenced from medium-altitude en-route flights.

During medium-altitude navigation course a pilot must completely master the POLJOT-1И system to be able to perform en-route flights with the use of the programmed turning points (alternate airdromes), flight to the home airdrome, and landing approach both in the automatic and director control modes.

It is not wise to impose a great amount of work on a trainee when performing first en-route flights. A flight mission must be simple and involve those air navigation means in using of which a pilot keeps the best hand. As a pilot gains experience, i.e. as his skill improves, there arises a necessity in teaching a trainee how to comprehensively use all the navigational means installed on the aircraft, all the methods of intercepting the initial route point and course line, as well as the methods of track monitoring and correction.

First independent flights involving supersonic climb to the service ceiling should be performed in clear weather and good visibility weather, in order that favourable visual orientation conditions be provided for a pilot.

When preparing for maximum endurance flight involving landing on other than home airdromes, the flying personnel must be given a training course in accordance with the specially selected subject programme.

To be discussed in the first hand are such matters as the influence of flight altitude, speed, and external stores on the fuel consumption per kilometre and hour, peculiarities involved in air navigation when flying the aircraft at supersonic speeds, the methods of programming flight, the capabilities of both the ground and airborne short-range radio navigation and landing equipments, and the procedures for using the radio and electronic aids in en-route flight.

In the course of training for low-altitude en-route flights particular attention should be given to accurate maintaining of the pre-selected altitude and course, performance of visual orientation, and introduction of corrections into the course with the aim of intercepting the turning point to a definite degree of accuracy.

Low-altitude flights are always associated with an increase in the emotional and psychological stress sustained by the pilot. Such a load may result in an excessive stress and fatigue. The lower the flight altitude and the more scarce the experience in flying the aircraft under such conditions, the heavier the stress. It is therefore necessary that in introductory (check) flights the instructor should prevent the pilot from exerting excessive pressure on the control stick by reminding him of this from time to time.

Air navigation training should be commenced from flying a combat trainer at an altitude of 500 to 300 m above the terrain. A subsequent descent must be effected with due regard to the individual properties of a certain pilot.

Only those who are highly proficient in piloting the aircraft at low altitudes and medium-altitude air navigation can be permitted to perform independent low-altitude en-route flights.

Upon completion of the training course on the combat trainer, the instructor should allow a trainee to perform first en-route flights on the combat aircraft at an altitude of at least 500 m. The flight route should be plotted so as to enable the personnel on the ground to continuously follow the aircraft aloft by means of the electronic navigation aids available at an airdrome of departure. In further flights, gradually decrease the altitudes and increase the flying speeds.

When performing the flights beyond the effective range of the ground electronic navigation aids installed at the airdrome of departure, periodically increase the flying altitude to 1000 - 1500 m for 30 - 40 s to enter the zone of coverage of the above means and ensure flight control from the ground.

After acquiring the adequate skill in en-route flights at low altitudes and in handling the combat aircraft by the trainee, the instructor may start a training course in performing en-route flights at limit low altitudes.

CHAPTER IV

DAYLIGHT FLYING UNDER IFR CONDITIONS

1. PECULIARITIES INVOLVED IN INSTRUMENT FLIGHTS

Training flying personnel for performing flights under IFR weather conditions is one of the basic components of the combat training of the air defense interceptor-fighter pilots. The commanders of all ranks must treat this problem in a constructive manner and with due regard to the attained level of pilot proficiency and individual properties of each pilot.

Profound theoretical background and proper methods of training personnel for performing flights in clouds with subsequent landing approach at the predetermined weather minimum is a guarantee of future success in solving the problems of the combat employment of an interceptor-fighter under IFR weather conditions.

The major peculiarity involved in instrument flights is that over the entire or greater part of the flight time period the pilot flies the aircraft beyond the field of vision of landmarks and natural horizon, determining the spatial position of the aircraft by reference to the flight and navigation instruments, and the location according to the data obtained by means of the ground and airborne electronic navigation aids.

The difficulties involved in an instrument flight consists in that the pilot has to continuously consult the instruments, take the readings, analyze the data obtained, and bring the aircraft with the use of the controls into such a position which appropriately corresponds to the preselected flight conditions. During practically the entire instrument flight the pilot has to either maintain the preselected flight conditions or change them. The rarer the flight regime is altered and disturbed the easier it is for the pilot to fly the aircraft on instruments.

The flight regime change-over frequency is determined by the character of flight or mission. Any inadvertent change in the flight regime is associated with the properties of the aircraft (stability, controllability and balance), atmospheric conditions, and quality of piloting.

The quality of flying the aircraft on instruments is determined by such factors as the arrangement of the instruments on the instrument board and the necessity in operating the equipment installed in the aircraft cockpit, all this being of attention-diverting character.

The flight in clouds is one of the most complicated kind of the instrument flight. When flying under the hood, the pilot has no visual perception of ambient medium and concentrates his attention on the piloting procedures, while flying the aircraft in clouds the pilot's attention is partially diverted by the visible parts of the aircraft and the phenomena taking place in the ambient media, for example, the changing density and colour of clouds, rain, snow, icing, etc. The effects produced by the excitators may prove so strong that a definite disturbance of the attention distribution and transfer procedures to which the pilot has accustomed during hooded flights may occur. All this in the long run considerably decreases the quality of aircraft piloting. Under such conditions the pilot must do his best to concentrate his attention primarily on the flight and navigation instruments in order to be able to maintain the required flight regime.

In a hooded flight the pilot may remove the curtain and start visual flight at all times. When flying the aircraft in clouds, the pilot is deprived of such an opportunity and thus may find himself in an inconvenient situation if he is not sufficiently skilled in blind flying.

When flying in clouds there is no any possibility for visual orientation and look-out. It is therefore necessary to make the most of the airborne and ground radio aids and strictly maintain the prescribed airspeed, altitude, course, and time irrespective of flight nature. It is of primary importance that the pilot be able of timely locating a failure of an instrument or group of instruments and change over to piloting the aircraft by reference to the duplicating instruments. Apart from this a flight in clouds is frequently accompanied by bumpiness and icing conditions which require greater caution on the part of the pilot for maintaining the prescribed flight conditions. The existance of bumpiness in breaking to bottom of clouds, in clouds, or below clouds at low altitudes presents considerable difficulties for the pilot in maintaining the prescribed flight conditions and at the same time enhances the requirements for accurate maintaining the assigned flight conditions.

When flying the aircraft in clouds under ice hazard conditions, the pilot is forced to distract his attention, as he has to periodically inspect the canopy glazing and the visible parts of the aircraft. As soon as ice occurs on the aircraft surfaces, the pilot must immediately get clear of the ice zone.

When flying the aircraft under the hood on instruments, and especially in clouds, the pilot is subject to illusions associated with the vestibular apparatus excitation as regards the spatial attitude of the aircraft. A change of flying speed in level flight, for instance, particularly that involving energetic accelerations and decelerations, may give rise to the illusory perception of diving or pitching-up, and in climb, a decrease or increase in the angle of ascent. Presence of slipping during instrument flight may give rise to a false sense of roll.

Sensory illusions may be caused by prolonged intervals in instrument flights, incorrect distribution of attention during flight in clouds, mixed piloting involved both in visual and instrument flight, improper transfer from visual to instrument flying, a prolonged distraction of the attention from the artificial horizon, abrupt movements of the control surfaces, strain, etc.

Should sensory illusions occur, do not believe your feelings and cold-mindedly evaluate the situation. Relying on the instrument readings is the most important condition for overcoming illusions. The responsibility of the pilot is to calmly continue flight and concentrate his entire attention on the instrument readings, the artificial horizon being in the first place. The correctness of the readings taken from the artificial horizon should be checked by reference to the ДА-200 combined instrument.

If sensory illusions as to the aircraft attitude persist, the pilot should make use of the automatic modes of the САУ automatic flight control system, simplify the flight, whenever possible, to break on top or to bottom of clouds, compare the readings presented by the artificial horizon with those on the electronic horizon on the display screen of the radar sight. Apart from the above remedies, the pilot may take advantage of the already known practical methods of suppressing illusions, namely: vigorous head movements, inclination of body, relaxation of muscles, etc.

The above-mentioned peculiarities involved both in flying the aircraft on instruments and in clouds and affecting the quality of piloting of aircraft give rise to a necessity in placing the more stringent requirements on the training methods and the procedures for the admission of flying personnel for flights under such conditions.

Apart from the general pilot proficiency level, one shall take into account the self-command, quick thinking, neatness, reaction to changes in air situation, and physical training level of the pilot undergoing the test for permission to IFR flights. It is also of particular importance that the pilot be convinced in that the pilot shall be ready to give a true-to-fact and timely report on troubles occurred during flight, lack of confidence in self-properties, and illusions which may occur in flight. According to the pilot's report it is necessary to determine the causes of errors and blunders correctly and outline the further IFR flight training programme.

2. PRINCIPLES UNDERLYING PILOT'S ATTENTION DISTRIBUTION AND TRANSFER DURING INSTRUMENT FLIGHTS

The quality of instrument flight performance depends on the capability of the pilot to timely and proportionately apply stick force in accordance with the instrument readings, correctly distribute and transfer his attention with a view to receiving the information furnished by numerous flight and navigation instruments, engine instruments and various light and audio warning units.

One of the most important elements of the top-quality flying in clouds is the capability of correct distribution of attention to the flight and navigation instruments and transfer of attention from one instrument to another. In flying the aircraft on instruments it is beyond the pilot's capability to simultaneously evaluate the readings presented by several instruments at a time. This is explained by the physiological properties of a human organism. Proper evaluation of readings given by this or that instrument is possible when the pilot concentrates the entire attention on a given instrument. To correctly evaluate the readings presented by several instruments, the pilot should transfer his attention from one instrument to another in a certain consecutive order.

In order to determine the most practical sequence of distribution and transfer of attention in steady instrument level flight, it is necessary to determine the characteristic features of the given flight regime and how it is maintained by the pilot.

Level flight regime is characterized in maintaining of constant airspeed, altitude, and direction of flight. It is practically impossible, however, to maintain such flight conditions only with the use of the airspeed indicator, altimeter, and direction finder without reference to other instruments, or natural horizon line, or landmarks.

The point is that only definite spatial attitude of the three aircraft axes and amount of thrust developed by the engines, which is required for maintaining the assigned airspeed, correspond to level flight conditions. To maintain the assigned level flight conditions, in a general case, the pilot must keep at a constant level certain initial values, flying speed, altitude, and direction being derivatives thereof, rather than flight condition determining parameters.

When flying the aircraft at a constant altitude, for example, it is necessary to maintain the aircraft longitudinal axis (pitch angle) in such a position so as to ensure the horizontal direction of the speed vector, to maintain a constant direction of flight, to prevent the aircraft from rotating with respect to its vertical axis, that is to prevent aircraft rolling and slipping. Maintaining of speed at a constant level is ensured by the respective thrust developed by the engines.

Insofar as pitch and roll angles are determined by reference to the artificial horizon, in theory it will be sufficient to keep pitch angle constant at zero bank in view of maintaining the aircraft in level flight, with the engine power setting being in accordance with the prescribed airspeed. In practice, however, it is difficult to maintain the aircraft in level flight with a sufficient degree of accuracy by reference to the artificial horizon only, for its reading accuracy does not satisfy the requirements. The amount of roll and pitch angles may be determined with the maximum accuracy not exceeding 2 - 3°. If roll angle of such an amount causes an insignificant change in the flight direction over a short period of time, the change in the pitch angle, and consequently angle-of-attack, by 2 to 3° will result in a rather intensive descent or climb and the respective change in the flying speed.

Maintaining of the aircraft bank at a constant level of 2°, when flying at a true airspeed of 900 km/h, causes a change in the aircraft heading by 5° only for one minute of flight. The departure of the speed vector by 2° from the horizon for the above period of time causes a change by 500 m in the flying altitude. Such an accuracy in maintaining the flight altitude by the aid of the artificial horizon is not apparently sufficient at all. It is therefore recommended to use the rate-of-climb indicator which ensures a vertical speed measurement accuracy of up to 1 m/s for the purpose of maintaining the assigned flying altitude.

Thus, upon establishment of the engine power setting corresponding to the assigned level flight speed, the pilot must concentrate his attention on the artificial horizon and the rate-of-climb indicator and by applying the appropriate stick pressure try to hold the miniature aeroplane of the artificial horizon in the horizontal position and the pointer of the rate-of-climb indicator at zero to a maximum attainable degree of accuracy.

But maintaining the level flight only with the use of the above method can not guarantee high precision, as the roll and pitch angle reading errors with time give rise to the accumulation of a certain error in all the three parameters which determine the flight regime. In order to prevent or eliminate a considerable variation of the preset parameters in proper time, the pilot must from time to time check the flight regime by reference to the airspeed indicator, altimeter, and direction finder and bring the aircraft to the preset flight regime by premeditatedly varying the bank and pitch angles (vertical speed).

It is clear from the above example that the five instruments used for sustaining level flight fulfil different functions. The first two instruments, namely the artificial horizon and rate-of-climb indicator, serve to maintain the flight conditions, while the other three instruments, that is the airspeed indicator, altimeter and direction finder, are used for monitoring the assigned parameters of the flight conditions. It is also obvious that in order to maintain the prescribed flight conditions to the required degree of accuracy, one should give particular attention to the readings presented by the first two instruments. The latter three instruments should be referred to from time to time.

Thus, instrument flying comprises two parallel processes, namely maintaining flight conditions (piloting proper) and flight conditions monitoring. The process of piloting is of continuous character while the process of monitoring flight parameters is periodic in character. Such a sequence of distributing attention ensures precise maintaining of the assigned flight conditions with the minimum efforts on the part of the pilot.

The rate and sequence of transfer of attention from the flying instruments to the monitoring instruments will depend on the accuracy of flying regime holding. This accuracy depends on the flying skill of the pilot, aircraft trim, weather conditions (bumpiness, icing, clouds) and other factors. The smaller the amount of, the rarer and the shorter in time the deviations of the roll and pitch angles (vertical speed) from the initial values, the less frequently has the pilot to transfer his attention to the monitoring instruments and the greater the amount of time available for accomplishment of other operations in the aircraft cockpit.

The sequence of attention transfer is determined by the tendency in reading deviations of the instruments by the use of which the required flight conditions are maintained. If, for example, in maintaining flight regime a left-hand bank prevails and the rate-of-climb indicator pointer swings about the zero mark, it is necessary in the first place to check the aircraft heading. The pilot shall do it the sooner the more considerable and frequent the bank. And vice versa, when banks imposed on aircraft are insignificant and occur in both directions and the rate-of-climb indicator pointer deflects in the same direction, it is necessary first to draw attention to the altimeter. This shall be done the sooner, the greater the amount of and the longer in time the unidirectional deflection of the rate-of-climb indicator pointer.

It has not been said in the above example of instrument flying about at which altitude and for what purpose this type of flight has been performed. It is apparent that when performing a definite flight mission the nature of attention distribution and transfer to the instruments is affected by the peculiarities involved in the mission assigned. For example, in level flight at a medium or high altitude the pilot has to consult the altimeter much less frequently than when flying at lower altitudes, for the necessity in a more stringent monitoring of the flight altitude in the latter case arises directly from the requirements for flight safety.

Additionally, to ensure flight safety at a low altitude, the pilot has to alter the very flying technique. He should pilot the aircraft so as to eliminate the rate-of-climb indicator pointer tendency to indicate descent. To this end, it is advisable to trim the aircraft by means of the stabilizer trimming mechanism so as to sense insignificant push forces.

The sequence of attention distribution in maintaining one and the same flight regime may depend on the stage of flight as well. For example, there is no necessity in checking the flight time when performing an enroute flight at the very beginning of the straight leg, when there is a long distance from the route turning point. The rate of attention transfer to the clock and reading time increase as the aircraft approaches the route turning point.

It is also unnecessary in climb in the first stage of flight to frequently refer to the altimeter. As the aircraft approaches the assigned altitude level, the pilot should refer to the altimeter more frequently.

At transitional (unsteady) flying regimes, and also when correcting considerable deviations from the assigned flight conditions, the checking procedure for a short period of time becomes practically compatible, as the piloting procedure. As a consequence, the pilot has to exert considerable energy.

Proceeding from the above statements, it is possible to formulate the basic principles underlying the sequence of the pilot's attention distribution and transfer at any regime and phase of instrument flight.

1. Piloting the aircraft on instruments involve two parallel processes, i.e. the process of flying regime holding (flying proper) and the process of flying regime monitoring.

2. Under steady flying conditions, the process of piloting the aircraft is of continuous character while the regime monitoring is periodic. Under such conditions the emotional and psychological stress of the pilot is reduced to the minimum value in the given phase of flight.

3. The rate of attention transfer and the duration of the monitoring instrument reading period are mostly determined by the accuracy of flying and on the tendency of the flight instruments for deviation, as well as the nature of the mission assigned, the phase of the flight, and present weather conditions.

4. At transitional flying regimes and when correcting the considerable deviations of the aircraft from the assigned mode the process of instrument monitoring assumes continuous character. Such conditions cause an increase of the pilot's emotional and psychological stress.

Proceeding from the above basic principles it is possible by way of preliminary analysis to determine the general pattern of the pilot's attention distribution for any flight conditions. The pattern should answer the following questions: which of the instruments should be used for holding and monitoring the flying regime, and which of the monitoring instruments at the particular phase of flight should be given major attention with a view to ensuring greater accuracy of regime holding, executing the flying mission at this regime and providing safety of flight.

The sequence of attention transfer in each definite case should be based on the general pattern, with due consideration of the specific flying conditions:

(a) probability of use of the automatic flight control modes of the CAY system:

(b) spontaneous banking caused by poor trimming;

(c) condition of atmosphere;

(d) nature and rate of permissible deviations from the assigned flight regime;

(e) volume of additional information which may divert pilot's attention (operating the radar sight controls, radio communication, illumination of indicator lamps, etc.);

(f) psychological readiness of the pilot for flight.

The correctness of the selected attention transfer pattern to be followed during instrument flight in clouds may be judged by the flying regime holding accuracy throughout the entire flight, reserve of time required for accomplishment of the cockpit operations not associated with the aircraft piloting, and the degree of fatigue of the pilot upon completion of flight mission.

3. FLIGHTS IN MANEUVERING AREA FOR PRACTISING INSTRUMENT FLYING TECHNIQUE

Instrument flights under hooded flying conditions and in clouds should be initially performed in the instrument flying area where the pilot is to successively acquire skill in establishing and maintaining the level flight, climbing and descending conditions. A further step is to practise turns to intercept the assigned course and 360° turns at banks of up to 45° first in the horizontal plane and then in the vertical one, involving both climb and descent, as well as recovery of the aircraft from an abnormal attitude. Apart from the above techniques, the pilot should in parallel practise the procedures for upward and downward cloud penetration with subsequent performance of landing estimation and approach by the use of the established methods.

The final stage in the instrument flight training is practising to fly the aircraft when performing maneuvers at great roll and pitch angles.

Upon acquiring proper skill in flying the combat trainer on instruments under the hood and in clouds, the pilot can be admitted for flying the combat aircraft under IFR weather conditions.

Flight to maneuvering zone to practise the flying technique in clouds usually includes the following elements: a level flight, climbing, descent, turns, and 360° turns.

Level flight. To perform the level flight, it is necessary to establish the required air speed and accelerate the engine to the respective speed on attaining the assigned altitude and memorize the pitch angle by reference to the miniature aeroplane of the flight director indicator and the flight course.

The quality of performing the level flight largely depends on the correct selection of engine speed. It is necessary therefore during initial flight to establish the required engine speed and avoid changing it in the level flight, if possible.

The sequence of the pilot's attention transfer to the instruments in level flight is shown in Fig. 67. It is recommended to follow the attention distribution pattern given below:

(1) FDI - ДА-200 combined instrument;

(2) FDI - indicated airspeed indicator - altimeter;

(3) FDI - ДА-200 combined instrument - true airspeed indicator;

(4) FDI - CCI - FDI.

This pattern may be slightly altered depending on flight conditions. In certain cases it is unnecessary to refer to the indicated and true airspeed indicators at one and the same time. In high-altitude and stratosphere flights particular attention should be given to the true airspeed and Mach-number indicators, whereas at medium and low altitudes the major attention must be given to the indicated airspeed indicator.

In bumpy air conditions the rate-of-climb indicator will present unsteady readings, i.e. its pointer will continuously deflect in both directions from zero, although the position of the aircraft longitudinal axis remains unchanged. In this case particular attention should be given to the artificial horizon and airspeed indicator.

Aircraft equilibrium about pitching axis must be determined and restored by the pilot with reference to the artificial horizon

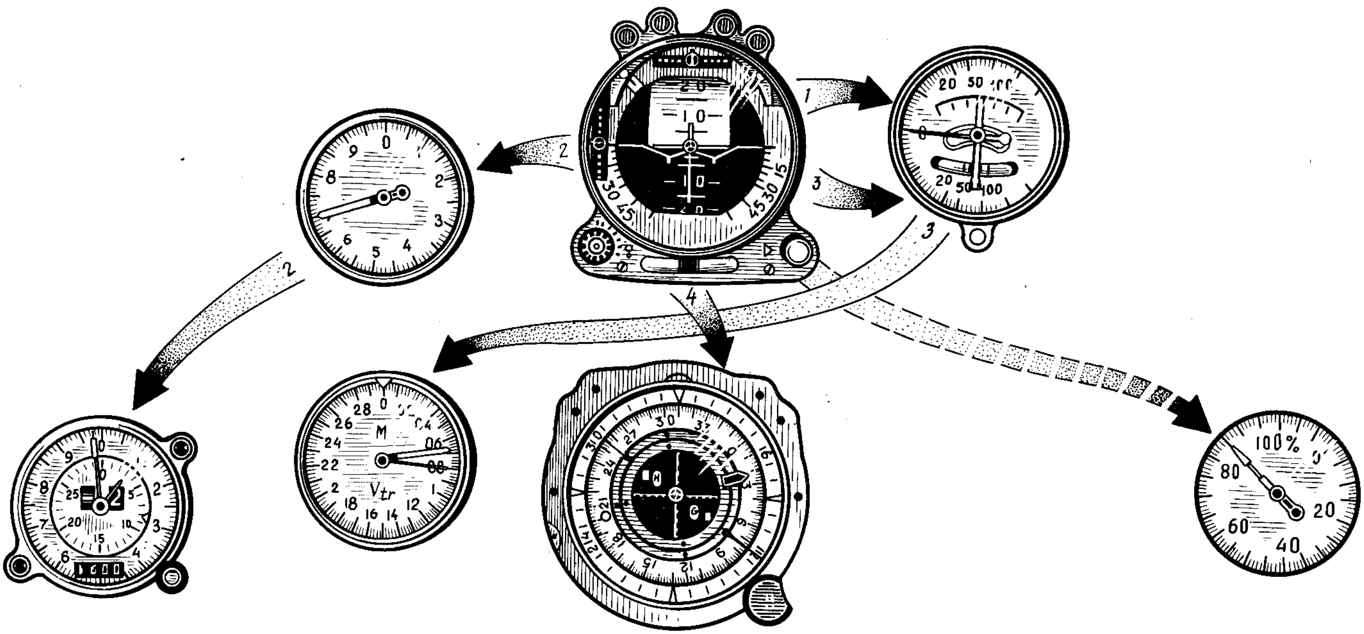


FIG. 67. ATTENTION DISTRIBUTION PATTERN IN LEVEL FLIGHT

and turn indicator. Aircraft equilibrium about yawing axis should be determined and restored by reference to the sideslip-and-turn indicator and checked in accordance with the readings presented by the combined course indicator.

Even during first instrument flights the pilot must practise checking the artificial horizon against the readings of the turn indicator. In the event of disagreement in the readings of the artificial horizon and the sideslip-and-turn indicator during flying the combat trainer under the hood, the pilot should remove the hood and determine the cause of this trouble. When flying in clouds, the pilot should ascertain by reference to the combined course indicator which of the instruments gives erroneous readings and make a decision on further continuation of the flight on the basis of the data obtained.

Level flight practice shall be alternated with practising in performing climb, descent, turns, and other elements of the flying technique.

Climb. Steady climb is characterized at the assigned engine power setting by constant vertical and translational speeds and flight direction.

When flying the МиГ-25П aircraft, climbing is to be performed at a true airspeed of 920 km/h, with the engines running at maximum power setting.

To perform climbing, it is necessary in level flight to set the throttle levers to the MAXIMUM position. Upon attaining an indicated airspeed of 750 km/h, bring the aircraft into climbing. On attaining a true airspeed of 920 km/h, continue climbing at this airspeed to the assigned altitude.

When maintaining and monitoring the climb, the pilot should adhere to the following sequence of referring to the instruments (Fig. 68):

(1) FDI - ДА-200 combined instrument - true airspeed indicator;

(2) FDI - indicated airspeed indicator - altimeter;

(3) FDI - CCI - FDI.

Periodically check the operation of the aircraft engines, systems, and equipment.

The movements of the control surfaces aimed at maintaining the climb should be smooth, short, and coordinated.

In level-flight transition (from 200 - 400 m to the assigned altitude), smoothly reduce the rate of climb to zero and set the

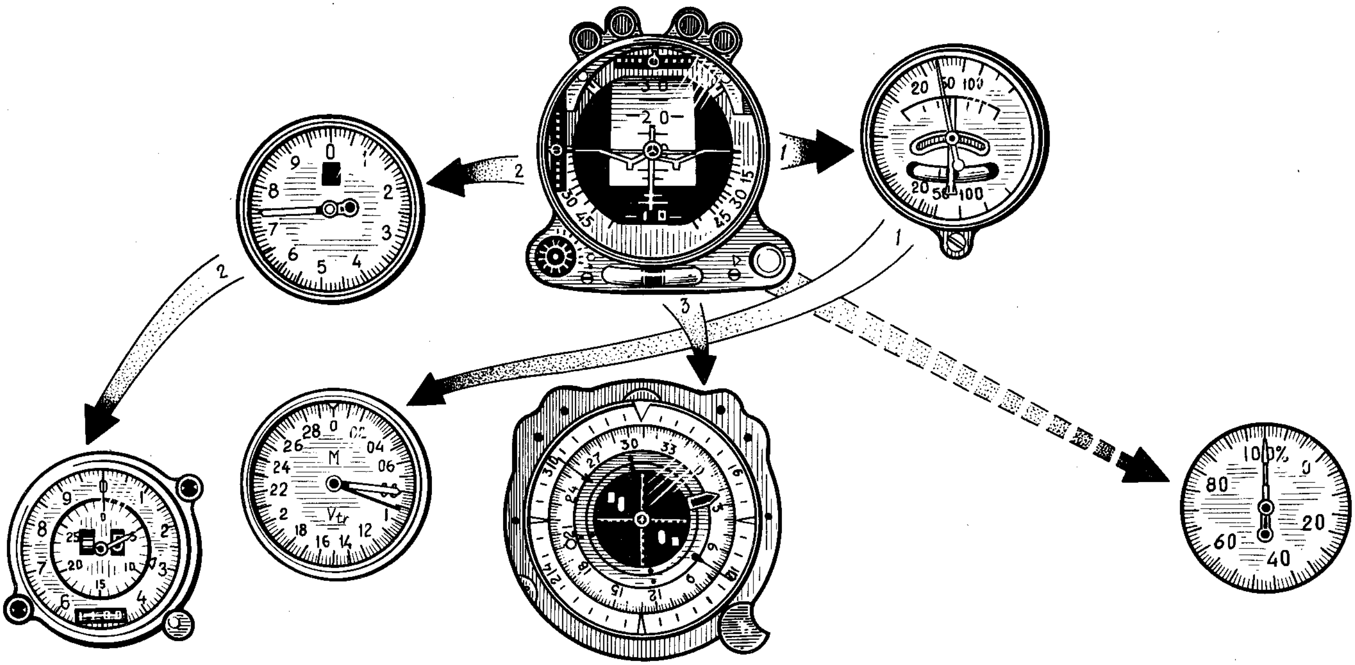


FIG. 68. ATTENTION DISTRIBUTION PATTERN IN CLIMB

flight director indicator miniature aeroplane to a position corresponding to level flight.

Descent. Descent should be effected at an indicated airspeed of 550 to 700 km/h. To perform a descent, bring the aircraft into level flight at an assigned altitude and establish the assigned airspeed. Then, smoothly deflecting the control stick forward, bring the aircraft into a descent and reduce the engine speed.

In descent, the pilot should keep watch of such instruments as the artificial horizon, indicated airspeed indicator, rate-of-climb indicator, engine instruments. As the aircraft approaches the assigned altitude, particular attention should be given to the readings of the artificial horizon and altimeter, with the aircraft maintaining the assigned translational speed and flight direction.

It is recommended to use the following attention distribution pattern in descent (Fig. 69):

(1) FDI - ДА-200 combined instrument;

(2) FDI - indicated airspeed indicator - true airspeed indicator;

(3) FDI - altimeter;

(4) FDI - ДА-200 combined instrument;

(5) FDI - CCI - FDI.

Periodically check operation of the aircraft engines, systems, and equipment.

To bring the aircraft to level flight, apply a smooth back-stick pressure at 200 - 300 m from the assigned altitude level to decrease the rate of descent and simultaneously accelerate the engines to maintain the translational speed and set the miniature aeroplane of the flight director indicator to a position corresponding to level flight.

Turns and 360° turns in clouds are recommended to be performed at banks up to 60° and indicated airspeed of 600 to 700 km/h.

To perform a turn or 360° turn, select and memorize the direction of entry into a turn (with respect to the heading or the relative bearing of the radio station). Establish the assigned altitude and speed by reference to the respective instrument and engine speed corresponding to the flying regime of the 360° turn, and bring the aircraft into the 360° turn by coordinated manipulation of the controls. The rate of entry into the 360° turn

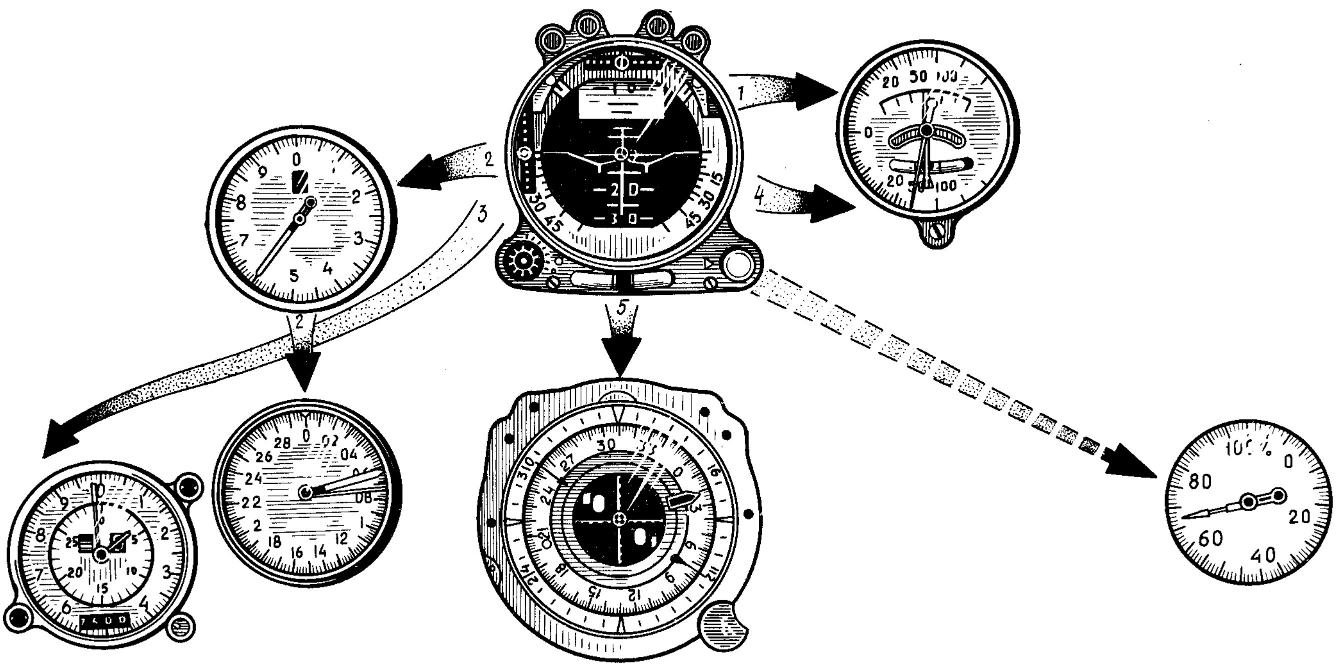


FIG. 69. ATTENTION DISTRIBUTION PATTERN IN DESCENT

and the amount of bank must be checked by referring to the artificial horizon, whereas the rate of descent or climb should be checked with the use of the rate-of-climb indicator.

On obtaining the assigned bank, keep it unchanged against the position of the miniature aeroplane of the flight director indicator. Check the coordinated movements of the controls by reference to the sideslip indicator of the ДА-200 combined instrument.

The quality of performance of the 360° turn largely depends on the accuracy of the 360° turn entry. If the rate of descent (climb) amounts to 10 - 15 m/s during entry into a 360° turn, never attempt to restore the assigned flight regime. It is necessary to bring the aircraft to level flight and repeat the 360°-turn entry.

In order to maintain the prescribed flying conditions when performing a 360° turn (turn), the pilot should refer primarily to such instruments as the flight director indicator, ДА-200 combined instrument, indicated airspeed indicator, altimeter, and combined course indicator. The degree of importance of each of the above instruments varies with various stages of a 360° turn (turn).

It is recommended to use the following attention distribution pattern during entry into a 360° turn (Fig. 70):

(1) FDI - ДА-200 combined instrument;
(2) FDI - airspeed indicator;
(3) FDI - CCI - ДА-200 combined instrument;
(4) FDI - airspeed indicator - altimeter.

Fig. 71 illustrates the attention distribution pattern to be followed when performing a 360° turn:

(1) FDI - ДА-200 combined instrument;
(2) FDI - airspeed indicator;
(3) FDI - altimeter;
(4) FDI - CCI.

The attention distribution pattern to be followed in recovery from a 360° turn is slightly different (Fig. 72):

(1) FDI - CCI;
(2) FDI - ДА-200 combined instrument;
(3) FDI - altimeter;
(4) FDI - airspeed indicator.

Do not fail to check the operation of the aircraft engines, systems, and equipment from time to time.

If during performance of a 360° turn the flight altitude has changed insignificantly, establish a vertical speed of 3 to 5 m/s

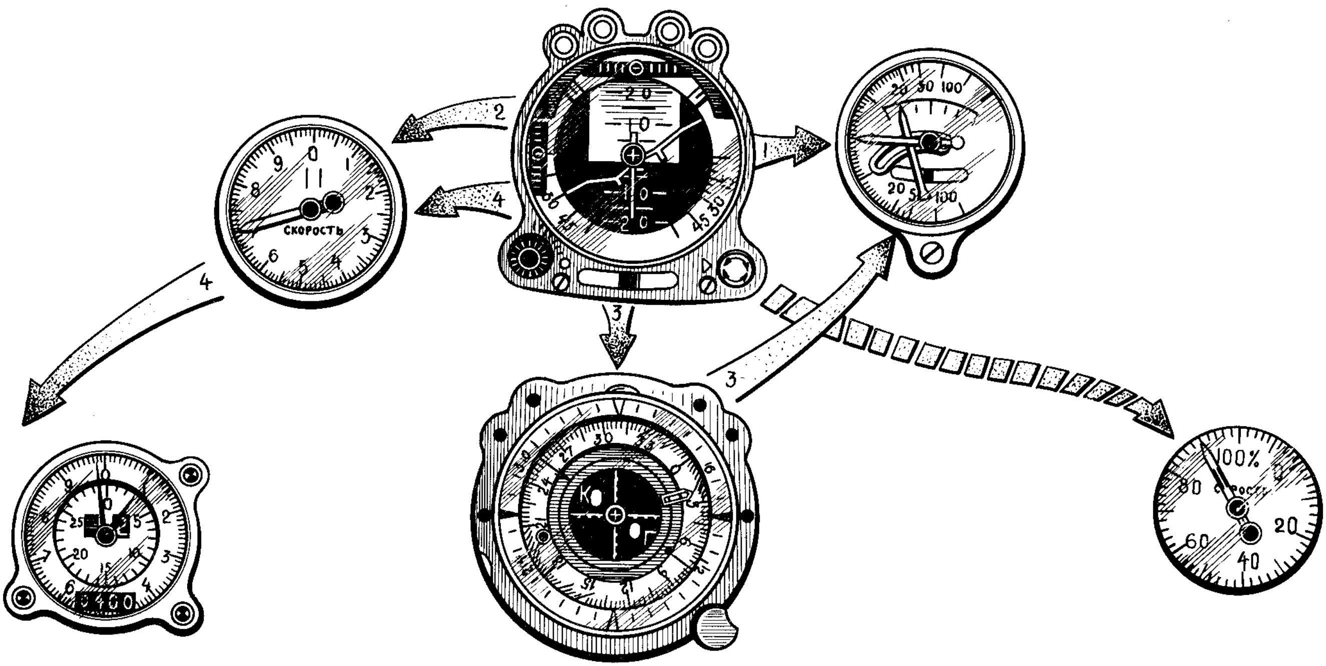


FIG. 70. ATTENTION DISTRIBUTION PATTERN WHEN ENTERING INTO 360° TURN

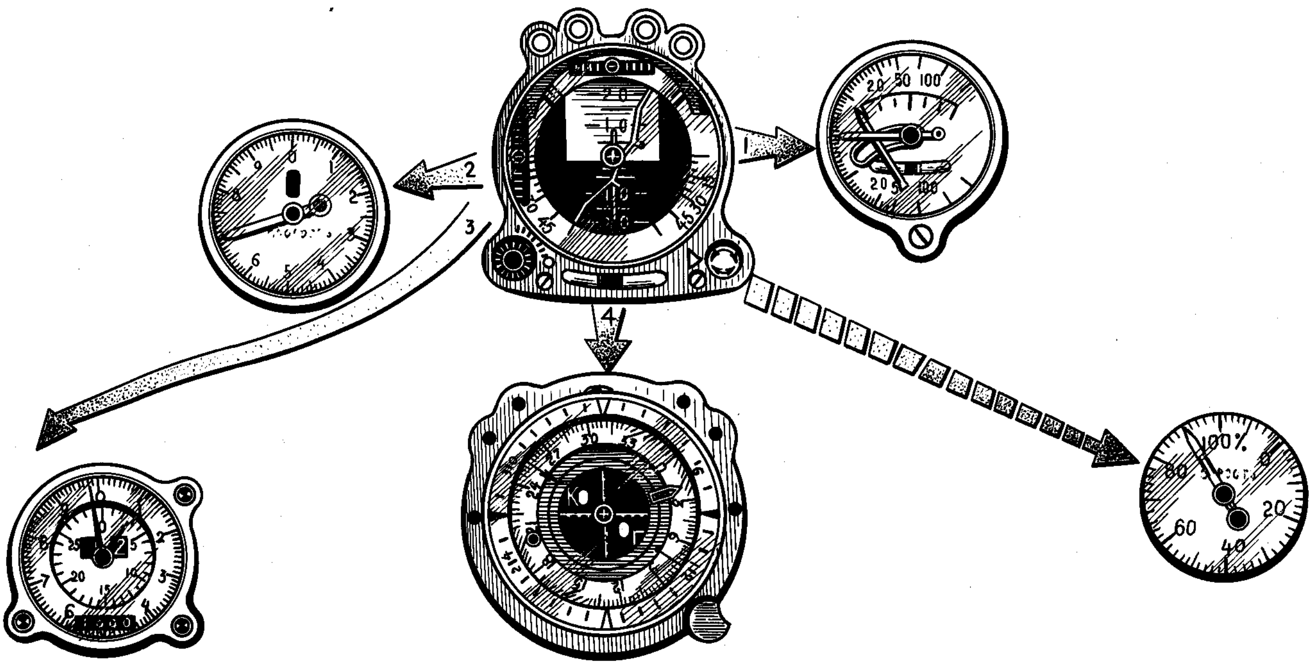


FIG. 71. ATTENTION DISTRIBUTION PATTERN WHEN PERFORMING 360° TURN

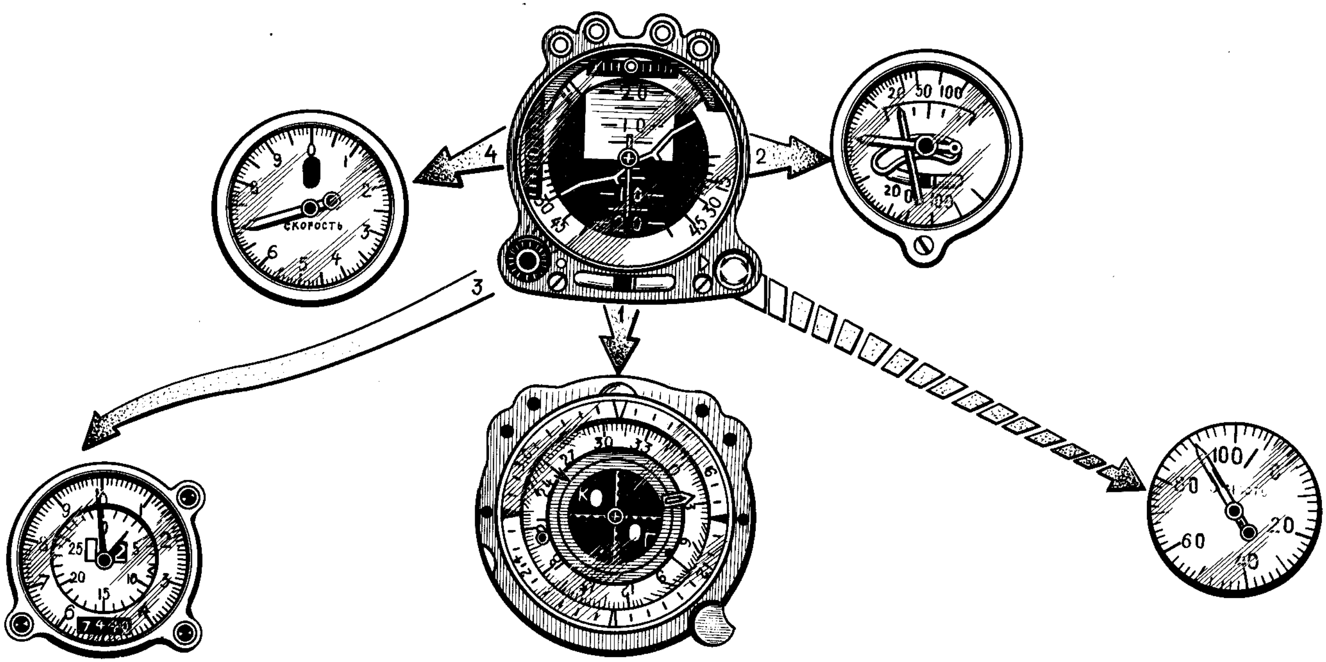


FIG. 72. ATTENTION DISTRIBUTION PATTERN DURING RECOVERY FROM 360°TURN

against the rate-of-climb indicator and maintain a new pitch angle by reference to the artificial horizon until the assigned altitude is attained. Should any change in the flying speed occur when performing a 360° turn at a constant flying altitude, restore the assigned airspeed by gradually varying the engine speed. Should a rapid change in the flight altitude occur, bring the aircraft to level flight as soon as possible.

During recovery from a 360° turn gradually decrease the bank, checking its changes by reference to the artificial horizon and keeping the rate-of-climb indicator in sight to prevent climbing or descending. When decreasing the bank, simultaneously check the heading (relative bearing of the radio station) so as to complete the recovery in the pre-selected direction. At the end of recovery, reduce the engine speed to a level which corresponds to the level flight regime at the assigned airspeed.

When performing a climbing or descending turn, first establish the assigned rate of climb or descent and then enter into a turn at a constant translational and vertical speeds. In so doing, particular attention must be given to maintaining the pitch and roll angles, as well as the assigned vertical and translational speeds.

The sequence of attention transfer to the instruments when performing either a climbing or descending turn are similar to those involved in performance of turns in the horizontal plane.

4. AIRCRAFT RECOVERY FROM ABNORMAL ATTITUDE

The automatic flight control system installed in the МиГ-25П aircraft makes it possible to perform recovery from abnormal attitude. In all cases of losing spatial orientation, the pilot must use the levelling mode to bring the aircraft into straight level flight.

It is recommended to bring the aircraft intentionally into abnormal attitude, with subsequent bringing the aircraft into level flight by the trainee, in order to provide the pilot with an opportunity to acquire profound skill in rapid determination of the aircraft attitude by reference to the flight and navigation instruments and in performing a recovery from abnormal attitude by the use of the most practical methods when practising hooded flights on the combat trainer.

The aircraft abnormal attitude is characterized by two parameters, i.e. by the roll and pitch angles. The aircraft heading is of no importance for aircraft recovery from abnormal attitude.

The aircraft attitude with respect to roll is characterized by the direction of the roll (right or left) and magnitude of the roll (the roll of less than 90° is associated with normal aircraft attitude, the roll over 90° being characteristic of aircraft inverted attitude).

The aircraft attitude with respect to pitch is also characterized by the direction of pitching (nose-down pitching and nose-up pitching) and by angle of pitch (less than 90° - normal position; over 90° - inverted position).

The entry of the aircraft into abnormal attitude in IFR flight is commonly associated with the diverting of a pilot's attention from the instruments, first of all from the artificial horizon. If the pilot's attention has been diverted for a short time, the aircraft deviation from the initial flying mode will be insignificant. The aircraft may take an extremely abnormal attitude when performing vertical maneuvers terminating in an abrupt entry into clouds.

Aircraft abnormal attitudes are usually characterized by high roll and pitch angles, energetic increase or decrease of the flight altitude and speed.

To recover from abnormal attitude, first determine the direction and amount of bank by reference to the artificial horizon and the sideslip-and-turn indicator and roll the aircraft out. Then bring the aircraft into level flight and establish the assigned flying regime by referring to the artificial horizon (pitch angle) and rate-of-climb indicator in conjunction with the airspeed indicator and altimeter.

In addition, when recovering the aircraft from abnormal position, the following peculiarities should be taken into account:

1. If the pitch-up angle is considerable, recovery from the zoom should be performed not through the straight line, but with a turn; particular attention should be paid to checking the translational speed.

2. If the diving angle and airspeed are great, decrease the engine speed and extend the air brackes for a short time in the course of recovery; if the pitch-up angle is great, and the engine speed is decreased, increase the engine speed to the maximum value.

3. When recovering the aircraft from a dive or pitch-up, watch the flight altitude and speed, never permitting the aircraft to exceed the g-load limitations.

5. PERFORMING FLIGHT ON DUPLICATING INSTRUMENTS

Duplicating instrument-flying training is intended to make personnel profoundly skilled in timely determination of failures and enable them to safely land the aircraft under such conditions.

In duplicating instrument-flying training it is necessary in the first place to familiarize the pilot with the symptoms of the probable failures of the САУ-155П (САУ-155П1) automatic flight control system and the likely behaviour of the aircraft in the events of failure of the above system in both the automatic and director control modes.

The responsibility of the pilot is to correctly determine the fault introduced into the automatic flight control system by the instructor, cut off the system by depressing the AP DISENGAGE button on the control stick, and report the nature of failure and the measures taken to the instructor.

What is peculiar about the МиГ-25П interceptor-fighter is the provision of this aircraft with the СВС-ПН-5 air data computer system and the СКВ-2Н-2М directional/vertical gyro system the failure of which will result in failure of the entire group of instruments. Therefore, a pilot must properly know the symptoms and nature of failures of the above systems and be capable of flying the aircraft on duplicating instruments.

The failure of the СВС-ПН-5 air data computer system may be determined by the following symptoms:

(1) fluctuation of pointers of the УСО-М1 and УВО-М1 indicators or the setting of separate pointers to extreme positions;

(2) considerable disagreement of the readings of either the УСО-М1 or УВО-М1 indicator with those presented by the УС-1600 airspeed indicator, the УВбСК duplicate pressure-altitude indicator, and the ДА-200 combined instrument, the power settings of the engines, and the aircraft flight profile.

If the aircraft was flown with the use of the САУ automatic flight control system, the pilot must press on the RESET button on the automatic flight control system panel and continue manually piloting the aircraft by reference to the УС-1600 and УВбСК indicators (at altitudes below 10,000 m).

Maintaining flight speed by reference to the УС-1600 airspeed indicator presents no difficulties.

Flying altitude should be determined by referring to the УВбСК duplicate pressure-altitude indicator only at altitudes exceeding 1000 m due to considerable reading errors and difficulties encountered in reading the instrument. The instrument reading error may amount up to 100 m. Every 1000 m division is numbered. The scale graduation value accounts for 100 m. Therefore, at altitudes below 1000 m as well as during landing approach, the pilot must use the readings of the PB-4 radio altimeter to determine flying altitude.

The failure of the CKB-2H-2M directional/vertical gyro system may be either partial or complete. At partial failure of the system only one component of the system fails to function. It should be noted that vertical gyro failure usually causes the failure of the directional part of the system.

The basic symptoms of failure of the CKB-2H-2M system directional component are as follows:

(1) the aircraft effects maneuvers not planned in the flight programme both in the automatic and director control modes;

(2) chaotic displacements or immobility of the combined course indicator heading dial during turns.

Failure of the directional component of the CKB-2H-2M directional/vertical gyro system determined, follow the procedures given below:

(1) cut off the CAУ automatic flight control system by depressing the AP DISENGAGE button located on the control stick and press on the RESET button on the CAУ system control panel;

(2) set the D/VG STBY - MAIN (KB. ЗAПAC. - OCHOBH.) selector switch to position D/VG STBY and ascertain that the roll and pitch readings of the flight director indicator remain practically unchanged;

(3) request over the radio the home flight course. Upon obtaining the required information check the combined course indicator for correct course indications.

Upon setting of the indicator pointer to present correct course readings, switch on the automatic flight control system, continue the accomplishment of the mission assigned or fly the aircraft to the landing aerodrome depending on the conditions which have been resulted from the change-over to the stand-by directional and vertical gyro.

Never turn on the CAУ automatic flight control system when in doubt about the correctness of the course indications.

To ensure landing approach, the pilot must take the readings from the automatic direction finder and periodically recheck flight direction by requesting ground-based radio direction finder data.

If the course indicator fails in flight and there is no possibility in using the automatic direction finder, the pilot may effect turns through the preselected angles with sufficient accuracy, maintaining roll and constant true flight speed. To succeed in this, one must know the angle through which the aircraft is turned per time unit during banked turn with the given parameters.

To accomplish a turn through the predetermined angle in the event of failure of the combined course indicator, the pilot must establish a constant flight speed and then put the aircraft into the required roll, and simultaneously count the time.

During turn at a true airspeed of 600 km/h and bank angle of 30° the angular rate will be equal to 2 deg/s and the time required for effecting a turn through any angle will be twice as less. Thus, the time required for effecting a turn through an angle of 30° will account for 15 seconds, 90° turn requires 45 seconds, and so forth.

The failure of the vertical gyro subsystem of the CKB-2H-2M system is testified by the following symptoms:

(1) changes in aircraft roll, pitch, and yaw attitudes not specified in the flight programme both in the automatic and director control modes;

(2) disagreement between the roll and pitch readings of the flight director indicator and the actual aircraft attitude;

(3) lighting-up of the CAGE (АРРЕТИР) button-lamp located on the front panel of the flight director indicator.

Failure of the vertical gyro subsystem of the CKB-2H-2M system determined, follow the procedures given below:

(1) cut off the САУ automatic flight control system by manipulating the button on the control stick and depress the RESET button located on the САУ system control panel (the moment the CAGE button-lamp lights up the САУ automatic flight control system switching-off and mode resetting are effected automatically);

(2) set the D/VG STBY - MAIN selector switch to position D/VG STBY;

(3) ascertain that the roll and pitch indicator presents correct reading;

(4) request the homing course over the radio and make sure that the combined course indicator course readings are correct.

If the flight director indicator and the combined course indicator present steady pitch/roll and course readings, respectively, switch on the CAУ automatic flight control system and, depending on the existing conditions, continue accomplishment of the flight mission assigned or fly the aircraft to the landing airdrome. If the above indicators fail to give stable roll/pitch and course readings, fly the aircraft by referring to the ДА-200 combined instrument in conjunction with the altitude and speed indicators and maintain the flight direction by reference to the radio compass, periodically requesting the heading from the direction finder. In this case the turn-and-slip indicator, airspeed indicator, and rate-of-climb indicator are the main instruments, while the rest of the instruments are of secondary importance. By reference to the respective instruments the pilot is capable of precisely determining the aircraft attitude and maintaining the preselected flight conditions.

Flying aircraft in the longitudinal direction with the gyro horizon failed is effected by reference to the rate-of-climb indicator and presents no difficulties for an experienced pilot.

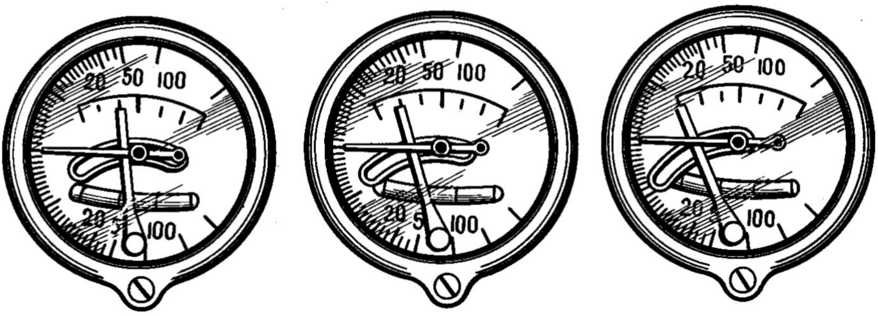
The existence and amount of roll in the event of failure of the gyro horizon may be judged by the angular rate of aircraft rotation about the vertical axis. The angular rate of aircraft rotation in this case is estimated with respect to the readings presented by the turn indicator of the ДА-200 combined instrument. The turn indicator dial has three divisions corresponding to the amounts of roll of 15, 30, and 45°. Nevertheless, the position of the indicator pointer being at one of the above said divisions will correspond to the respective amount of roll provided that TAS accounts for 500 km/h.

The aircraft turn angular rate is directly proportional to the bank angle tangent and inversely proportional to the flight speed, that is

$$\omega = \frac{g \, tg \gamma}{V} .$$

Therefore, the angular rate decreases with increasing flight speed and, consequently, the turn indicator pointer deflects by a shorter distance. An increase in the angular rate demands increasing the aircraft bank angle.

The readings presented by the turn indicator during turns at various banking angles are given in Fig. 73.



a b c

FIG. 73. READINGS OF TURN INDICATOR WHEN PERFORMING TURN AT TRUE AIRSPEED OF 650 – 700 km/h

a – at a bank of 15°; b – at a bank of 30°; c – at a bank of 45°;

6. LANDING APPROACH TO PROGRAMMED AIRFIELD WITH USE OF POLJOT-1И SYSTEM

The main method for landing approach on the МиГ-25П aircraft is considered to be the method of approach with the use of the POLJOT-1И system in the aircraft automatic control mode. However, it is recommended to train the personnel in piloting the МиГ-25П interceptor-fighter in emergency cases involving landing approach in the director and manual control modes. The training course involving landing approach with the use of the POLJOT-1И system shall be carried out in accordance with the special pattern established at a given airfield. The approach pattern must involve flight to the turning point, flight to the point of descent, and subsequent descent and interception of the point of turn onto a base leg and final turn point.

After attaining the descent termination line at an altitude of 600 m the above system continues to reproduce the true selected course towards the predicted point of turn onto a base leg and final turn depending on the direction of approach and landing course.

Fig. 74 illustrates the pattern of bringing the aircraft onto a runway landing course in azimuth. It is evident from Fig. 74 that the point of final turn A (21;0) is located on the line of the

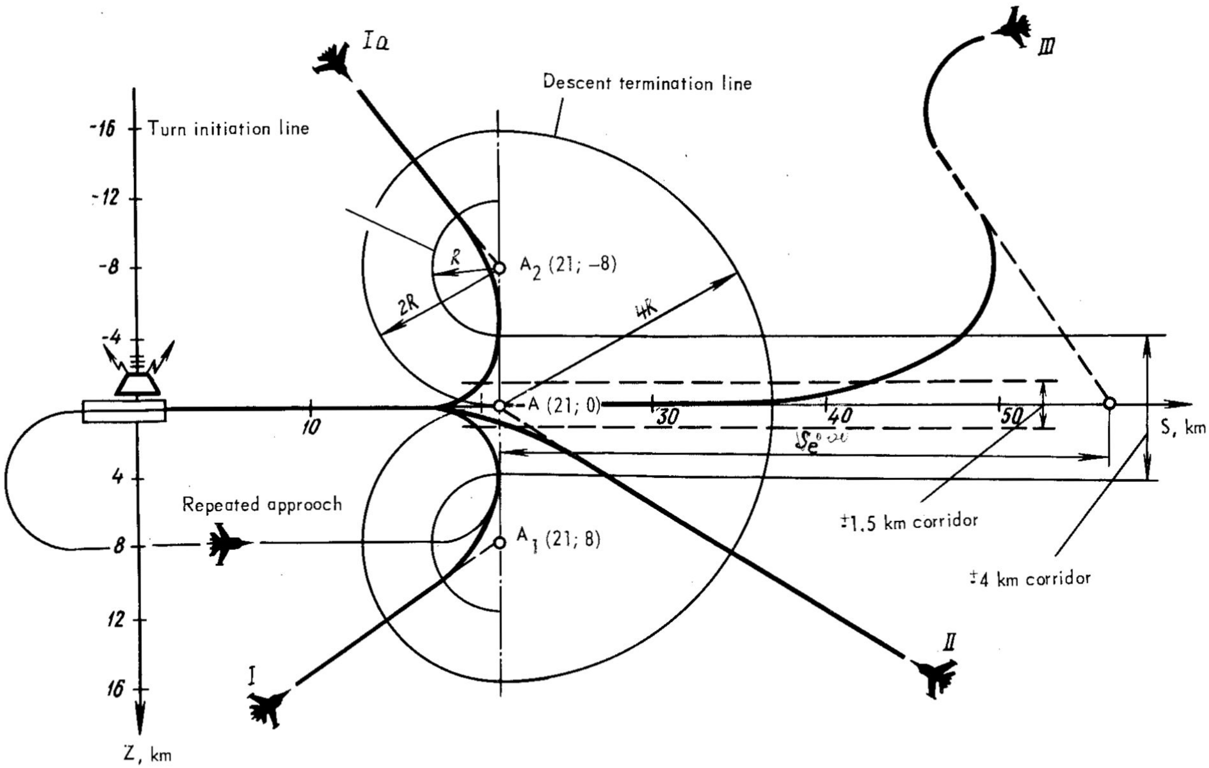


FIG. 74. INTERCEPTION OF LANDING COURSE BY AIRCRAFT IN HORIZONTAL PLANE

runway landing course and at a distance of 21 km from the runway centre.

Points A_1 (21; 8) and A_2 (21; -8) of entry into the turn on to a base leg are arranged symmetrically with respect to the line of landing course and lies on the perpendicular line intersecting point A. The radius of the aircraft turn at a banking angle of 30° is assumed to be equal to 4 km.

The aircraft is brought to the point of the final turn if the aircraft heading in the RETURN (ВОЗВРАТ) mode at a distance of less than 250 km differs from the runway landing course by less than 90° (positions II and III). If the aircraft heading differs from the runway landing course by more than 90°, the aircraft is brought to the point of turn on to a base leg (positions I and Ia).

The equipment is changed over to reproduce the selected course towards the predicted point of the final turn 4 km before the predicted point of the turn on to the base leg. During the changeover the preselected course pointer turns unevenly passing through 30° at a time.

On entering a corridor of ±4 km wide (with respect to the runway axis) the predicted point of the final turn in respect to which the selected course is effected starts to displace along the line of the landing course in the direction of the runway at such a speed that the distance between the aircraft and this point along axis S be equal to 2.5 km (Fig. 75). The aircraft moves along the "pursuit" curve to follow the moving point. Thus, the aircraft flight path is smoothly conjugated with the line of the landing course.

An aircraft entering a corridor of ±1.5 km in width (relative to the runway axis) brings about an automatic change-over of the equipment to operate in conjunction with the ПРМГ-4М radio beacon group. This change-over also causes the operation of the localizer blinker of the combined course indicator and the flashing-up of the LANDING (ПОСАДКА) button-lamp on the САУ automatic flight control system panel.

The ППД-2 range indicator reads the distance to the range finder retransmitter. Within a range of not less than 20 km the glide slope blinker of the flight director indicator closes and both bars of the combined course indicator begin to operate. The course bar of the combined course indicator deflects either to the left or to the right, thereby indicating the position of the localizer beacon equisignal line with respect to the aircraft, while the combined course indicator glide-slope bar deflects abruptly upward, thereby indicating the position of the glide-slope beacon equisignal line.

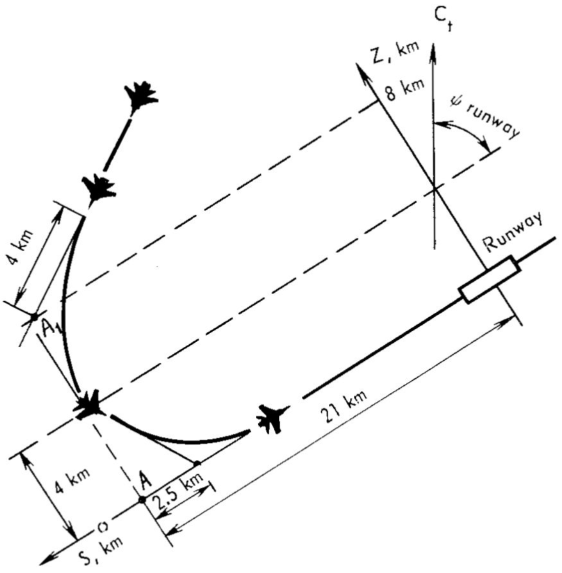


FIG. 75. DISPLACEMENT OF FINAL TURN POINT

The selected course pointer on the combined course indicator reads the true runway landing course.

In the automatic control mode, when approaching an altitude of 600 m, see that the aircraft is smoothly brought into level flight at a distance of 20 to 37 km from the runway. When in level flight, lower the landing gear, ascertain that the landing gear has actually been extended and report the matter to the flight control officer. Establish an airspeed of 500 km/h and, at a distance of 19 to 21 km from the runway, check the automatic entry of the aircraft into the turn at a bank angle of up to 30°.

During the turn on to a base leg maintain the airspeed of 500 km/h. Upon completion of the turn on to a base leg, gradually decrease the airspeed of 450 km/h and perform the final turn at this speed.

When accomplishing the final turn make sure that the landing mode has been automatically engaged by referring to lighting-up of the LANDING button-lamp located on the CAУ automatic flight control system panel. After engagement of the landing mode, deflection of the director pointers occurs for a period of 2 to 3 seconds.

Apart from the above, check automatic engagement of the landing mode by the following symptoms:

(1) the localizer blinker on the combined course indicator is closed and the combined course indicator localizer bar deflected from the centre of the circle either to the left or to the right, thereby indicating the position of the localizer beacon equisignal line with respect to the aircraft;

(2) at a distance of at least 20 km the glide-slope blinker of the combined course indicator closes and the glide-slope bar deflects abruptly upward, thereby indicating the position of the glide-slope beacon equisignal line;

(3) the director pointers of the flight director indicator are within the instrument circle;

(4) the selected course pointer on the combined course indicator reads the runway landing course.

Furtheron, the aircraft enters the glide-slope beacon equisignal zone what is evidenced by the following readings of the flight director and the combined course indicators:

(1) the director pointers of the flight director indicator are within the instrument circle;

(2) the flight director indicator glide-slope pointer settles within the limits of the instrument circle, thereby indicating that the aircraft is at the stabilization altitude or descends along the glide-slope on entering it within a range of 12 to 14 km;

(3) the combined course indicator glide-slope pointer smoothly displaces from top downward to the centre of the instrument and comes into alignment with the centre of the instrument circle after entering the glide-slope within a range of 12 to 14 km;

(4) the localizer pointer of the combined course indicator as well as that of the flight director indicator deflects from either the left or right side towards the instrument centre and comes into alignment with the instrument circle centre on aircraft entering the localizer beacon equisignal zone within a range of 12 to 14 km.

Extend the wing flaps at a distance of 15 to 16 km, report this to the flying control officer, and check the aircraft starting to descend at a vertical speed of 5 to 7 m/s after it has entered the glide-slope beacon equisignal zone. Maintain the desired flying speed by varying the engine power settings during descent.

During glide-slope descent maintain the following relationship between the flight altitude and the runway range:

H = 600 m - range of 12 to 14 km;

H = 400 m - range of 8 to 9 km;

H = 200 m - range of 4 km;

H = 100 m - range of 2 km;

H = 50 m - range of 1 km.

Switch off the automatic control system by depressing the AP DISENGAGE button on the control stick at an altitude of 50 m to the runway, change over to the manual control mode, visually verify approach and estimation for landing and perform landing.

If in the course of the prelanding maneuver, the altitude being stabilized is more than 700 m or less than 550 m, disengage the automatic control mode by pressing on the AP DISENGAGE button located on the control stick, and change over to manual control. Before entering the glide-slope beacon equisignal zone, effect the side channel control by reference to the flight director indicator director pointer, and the longitudinal channel control by reference to the УВО-30К (УВО-М1) altitude indicator.

Upon completion of the final turn and aircraft entry into the glide-slope beacon equisignal zone (the glide-slope bar of the combined course indicator has reached the upper edge of the instrument circle), provided that the director pointers deflect normally, switch on the automatic control system by depressing the AUTO CONT (АВТ. УПР.) button located on the САУ automatic flight control system panel.

If the return or repeated approach has been effected either in the director or manual control mode, upon closing of the combined course indicator localizer warning flag and lighting-up of the LANDING button-lamp on the САУ automatic flight control system panel, set the director pointers of the flight director indicator within the limits of the instrument circle and engage the automatic control mode by pressing on the AUTO CONT button on the САУ automatic flight control system panel.

If the landing mode fails to be automatically cut in (the warning flags of the combined course indicator not closed), manually engage the landing mode by using the LANDING selector switch on the control panel of the РСБН-6С short-range radio navigation and landing system, and then change over to the automatic control mode.

<u>In the director control mode</u> the aircraft shall be piloted in accordance with the position of the flight director indicator director pointers, maintaining them at the centre of the instrument circle.

Prior to landing approach to the programmed airfield ascertain that:

(1) button-lamps labelled HOMING and AERODROME pertaining to the airfield of landing are depressed;

(2) the CORR lamp is on;

(3) the $\Psi + 180^{\circ}$ selector switch is set to the position corresponding to the assigned landing course;

(4) the GO-AROUND L - R (ПОВТ. ЗАХ. ЛЕВ. - ПРАВ.) selector switch is set to position corresponding to the direction of approach;

(5) the ROMB-1 button-lamp is depressed;

(6) the readings presented by the flight director and combined course indicators are in compliance with the flight programme.

Perform the flight to the turn initiation point to intercept the landing course at a speed of 550 km/h, holding the director pointers of the flight director indicator in the centre of the instrument circle. Extend the landing gear at an altitude of 600 m, report the matter to the flying control officer, and establish an airspeed of 500 km/h.

By referring to deflection of the assigned course pointer on the combined course indicator and the position bar and side channel director pointer of the flight director indicator, bring the aircraft into the turn at a bank angle of 30° to intercept the landing course. During the turn hold the director pointers at the centre of the instrument circle.

Before placing the aircraft on the landing course, decrease the airspeed to 450 km/h, and ascertain that the landing mode has been automatically engaged by making use of the same symptoms involved in the automatic approach.

Insofar as the engagement of the landing approach mode is followed by oscillation of the flight director indicator director pointers for 2 - 3 s, it is necessary to continue turning at a previous bank angle until the aircraft is brought onto the landing course.

Director pointers settled, arrange them within the instrument circle, manipulating the aircraft controls. It should be borne in mind that the director pointers become more sensitive in the landing approach mode. Holding the longitudinal control channel pointer within the instrument circle requires particular smooth and precise stick movements. Dual movements of the control stick are not permissible. Apart from the above, in the events of the considerable departures of the aircraft from the equisignal zone, the director pointer becomes nearly insensitive to the insignificant displacements of the control stick.

Given in Fig. 76 are the readings of the flight director and combined course indicators in the horizontal plane after intercepting the landing course.

In level flight, the aircraft is on the right side to the line of the landing course in point a. The position of the landing course line with respect to the aircraft and the amount of deviation are indicated by the localizer position bars of the flight director and combined course indicators. The vertical director pointer of the flight director indicator is also deflected to the left, thereby indicating the necessity in a left bank turn to the landing course. In the director control mode, the aircraft must be brought into the turn at such a bank as to make the director pointer of the flight director indicator remain in the centre of the instrument circle (position b). As the aircraft approaches the line of the landing course, decrease the bank angle and, furtheron, completely roll out the aircraft (position c) to maintain the director pointer in the centre of the circle. Since the closure rate of the aircraft with respect to the course line is great for the given cross track error, the vertical director pointer of the flight director indicator starts to deflect rightward. To maintain it in the centre of the instrument circle, bring the aircraft into the right bank (position d). Furtheron, if the cross track error exists and the speed of closure of the aircraft with the course line decreases, the director pointer will deflect leftward, thereby indicating that the aircraft should be recovered from the right bank.

Transition to the steady straight flight without a bank, with the localizer bar and the director pointer being in the centre of the circle, means that the aircraft follows the course line (position e).

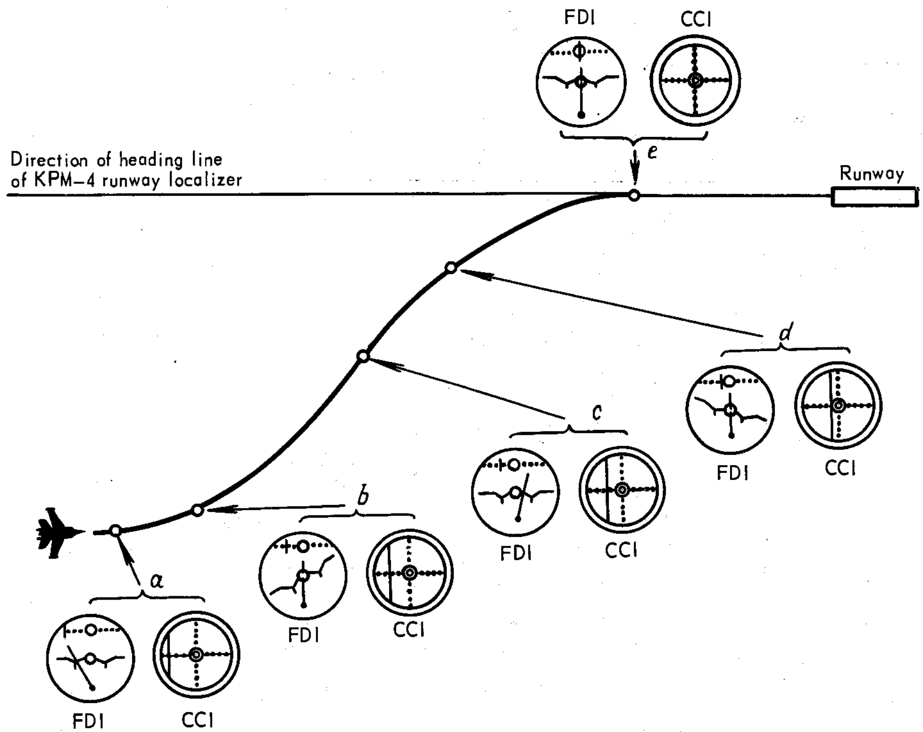


FIG. 76. READINGS OF FLIGHT DIRECTOR INDICATOR AND COMBINED COURSE INDICATOR AT INTERCEPTION OF LANDING COURSE IN HORIZONTAL PLANE

In the course of aircraft closing with the selected course line, the localizer position bars of the flight director and combined course indicators read the amount of the gradually diminishing cross track error. The reading in the longitudinal channel is similar.

Thus, the pilot should know the following:

(1) the director pointers of the flight director indicator never inform the pilot about the aircraft attitude in respect to the selected course line; for this purpose, there are the position bars on the flight director indicator;

(2) during flight to the selected course line the aircraft follows the path of a curved trajectory;

(3) the moment of aircraft approach to the selected course line is determined by reference to the flight director and combined course indicators, with the director pointers and the position bars of the flight director indicator being at the centres of the instrument circles and the localizer position bar of the combined course indicator being also in the instrument centre point. The glide-slope position bar settles against the instrument centre only at a distance of 12 to 14 km.

Manual control mode is made use of in the events of failures of the CAУ automatic flight control system, that is when the director pointers of the flight director indicator are inoperative. Flight to the estimated point of the turn to the landing course as well as the landing approach in the manual control mode are effected by reference to the position bars of the flight director indicator and the selected course pointer of the combined course indicator. After bringing the aircraft to an altitude of 600 m, establish the predetermined airspeed and extend the landing gear. As the combined course indicator selected course pointer starts deflecting, bring the aircraft into the turn at a bank of up to 30° for intercepting the landing course. When performing the turn, check to see that the landing mode has been automatically engaged by reference to lighting-up of the LANDING button-lamp, closure of the combined course indicator warning flags, and the assigned course pointer reading the landing course. If the LANDING button-lamp fails to light up, close the LANDING switch on the PCБН short-range radio navigation and landing system control panel. After intercepting the landing approach course, perform corrective turns for precise entry into the localizer beacon equisignal zone by placing the localizer position bar within the centre of the instrument circle. If the localizer position bar displaces off the instrument centre, perform a corrective turn through 3 - 5° in the direction of the bar offsetting and proceed on a new course until the bar starts moving toward the centre of the circle. Furtheron, select such a flight course at which the vertical position bar could be held within the circle center.

Maintain an altitude of 600 m until intercepting the glide-slope beam, by retaining the glide-slope bar on the flight director indicator within the centre of the circle.

As the range decreases the combined course indicator glide-slope position bar moves downward and settles at the instrument centre at a distance of 12 to 14 km. From this time it is necessary to bring the aircraft into descent at a vertical speed of 5 - 7 m/sec.

If the glide-slope position bar deflects from the instrument centre, select such a vertical descent speed as to bring it to its center position.

Check descent with reference to the glide-slope in the same sequence and within the same scope as when performing a landing approach in the director control mode.

<u>The repeated landing approach to the programmed airfield</u> is accomplished after a go-around or immediately after a takeoff if this is planned by the flight programme.

To accomplish a repeated landing approach when proceeding on the landing course, switch off the automatic control system by means of the AP DISENGAGE button (provided that the landing approach has been performed in the automatic control mode) and ascertain that the HOMING and AERODROME button-lamps of the landing airfield are depressed and the positions of the Ψ + 180° and GO AROUND L-R selector switches correspond to the landing course and the direction of landing approach.

When climbing and performing a turn at a bank of 30 to 40°, depress the GO AROUND button-lamp on the CAУ automatic flight control system panel and ascertain the respective mode has been engaged by reference to its lamp which must light up.

If the GO AROUND button-lamp fails to come on depress it for the second time after the CORR lamp on the control panel of the PCБН-6C short-range radio navigation and landing system lights up. Perform a turn at a bank of up to 30°.

Check to see that the course selector of the combined course indicator reads a reciprocal course.

After climbing to an altitude of 600 m, set the director pointers within the circle of the combined course indicator and proceed to the automatic control mode.

When proceeding from the second to the third turn, make sure that the selected course pointer indicates a reciprocal course and the position bars and the director pointers of the flight director indicator are within the circles. The flight course may differ from the assigned one by the amount of the drift angle. Sure that the CORR lamp on the short-range radio navigation and landing system control panel glows, check the flight altitude which must be within the limits of 550 to 700 m. Maintain an airspeed of 600 km/h prior to landing gear extension. Extend the landing gear when flying abeam the outer marker beacon and establish a flying speed of 500 km/h.

When performing a turn on to a base leg, at a distance of 19 to 21 km make sure that the selected course pointer of combined course indicator, the position bar and the director pointer of the side channel of the flight director indicator display entry into the turn, and the GO AROUND button-lamp on the CAУ automatic flight control system panel is dead.

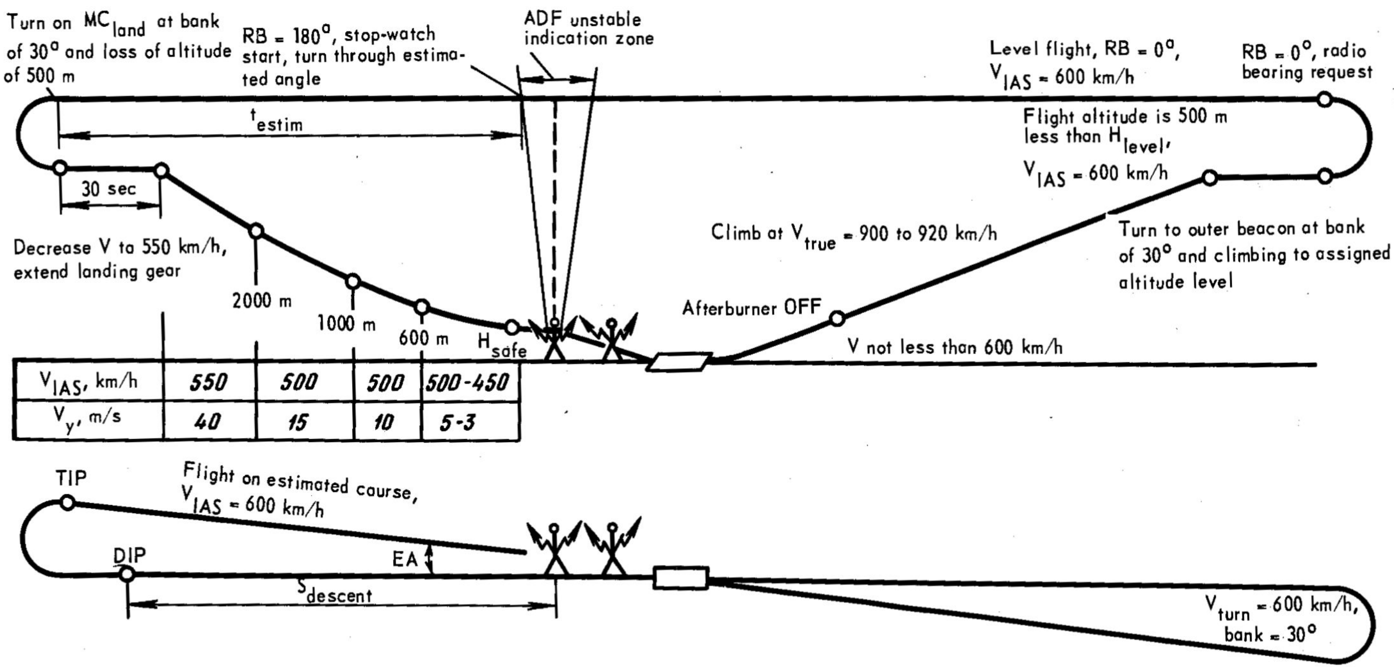
Upon recovery from the turn onto the base leg, establish a flying speed of 450 km/h. In 10 - 15 s a command for performing the final turn will be automatically given, at the end of which the landing mode will be automatically engaged (the LANDING button-lamp on the CAУ automatic flight control system flashes up).

Subsequent instrument readings and actions of the pilot are similar to those involved in the landing approach in either the automatic or director control mode.

7. INSTRUMENT APPROACH WITH USE OF APK-10 AUTOMATIC DIRECTOR FINDER

The APK-10 automatic direction finder ensures landing approach and estimation for landing under adverse meteorological conditions in the event of failure of the POLJOT-1M system components as well as landing on airdromes unequipped with the PCБH-2H (PCБH-4H) rho-theta radio beacons. Therefore, each pilot should be trained to perform landing approach under adverse meteorological conditions with the use of the APK-10 automatic direction finder.

Training flying personnel for performing landing approach and estimation for landing with the use of the APK-10 automatic direction finder should be carried out in accordance with the special



V_{IAS}, km/h	550	500	500	500-450
V_y, m/s	40	15	10	5-3

FIG. 77. STRAIGHT-IN LANDING APPROACH PATTERN

pattern established for a given airdrome. The principle method for performing landing approach with the use of the APK-10 automatic direction finder is the straight-in approach method.

Apart from the above method, the pilots must be well trained in such methods of landing approach as approach from estimated line (line of beginning of descent), approach by two 180-degree turns, and extended rectangular pattern approach.

Straight-in landing approach. The essence of this method consists in that the pilot brings the aircraft to the descent initiation point (DIP) located on the landing course line, and then within the 30-s level flight leg establishes the assigned speed, extends the landing gear, and brings the aircraft into descent at an assigned power setting towards the outer beacon. The straight-in landing approach pattern is shown in Fig. 77.

Flight to the descent initiation point involves the following maneuvers:

(a) turn to the estimated angle;

(b) 180-degree turn;

(c) circling over the radio beacon;

(d) turn in the direction of the least angle.

Turn to the estimated angle is effected during approach to the outer beacon with a heading which differs from the reciprocal landing course by not more than 30 to 45° (Fig. 78).

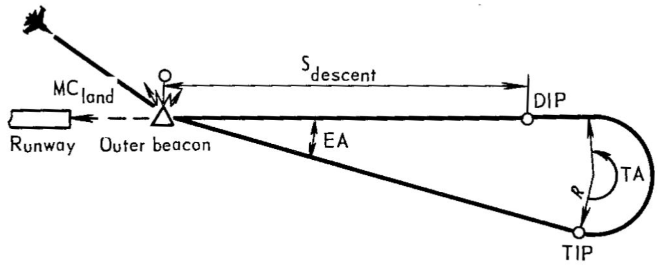


FIG.78. INTERCEPTION OF DESCENT INITIATION POINT BY TURNING TO ESTIMATED ANGLE

During landing approach by reference to the APK-10 automatic direction finder the aircraft may be piloted either manually or with the use of the automatic control system in the stabilization mode.

To change over the indicators from the POLJOT-1M system to the APK-10 automatic direction finder, follow the procedures given below:

(1) depress the RESET button on the automatic flight control system panel;

(2) press on the AUTO CONT button-lamp provided that the automatic flight control system is going to be used in the stabilization mode;

(3) set the SHORAN-ADF (PCБH-APK) selector switch to position ADF;

(4) move the COURSE SELECT AUTO - MAN selector switch to position MAN;

(5) manipulate the setting knob on the combined course indicator to set the selected course pointer to the landing course.

When flying the aircraft in the direction of the outer beacon, maintain RB = 0° and the assigned flight level. To check the correctness of the flying towards the outer beacon, request the relative bearing which must correspond to the flight course. Correct maintenance of the assigned inbound course shall be checked by reference to the airspeed indicator, altimeter, rate-of-climb indicator, radio compass, and the APK-10 automatic direction finder.

Being in the zone of unstable readings of the radio compass, the pilot must maintain the straight level flight without changing the course by reference to the combined course indicator. The moment of flying past the outer beacon is determined by the 180-degree deflection of the radio compass pointer.

On determining the moment of flying over the outer beacon, start the stop-watch, accomplish a corrective turn through the estimated angle and proceed to the turn initiation point at an indicated airspeed of 600 km/h.

The course and time of flight to the point of turn to the landing course are radioed to the pilot by the flying control officer according to Table 7.

Table 7

Straight-In Approach Flight Parameters

Level, m	Turn angle	Time of flight to turn initiation point, min
2,000	20°	2.40
3,000	21°	2.55
4,000	21°	3.00
5,000	23°	3.00

Level, m	Turn angle	Time of flight to turning point, min
6,000	26°	2.35
7,000	23°	2.51
8,000	20°	3.20

Given in Table 7 are the values of the estimated turn angles and the estimated flight time after crossing the outer beacon during straight-in approach.

If necessary, the estimated angle (EA) is determined by the navigator on duty at the control post with the aid of the following equation:

$$tgEA = \frac{2R}{W_{descent}\, t_{descent}},$$

where: R - aircraft turning radius;

$W_{descent}$ - average ground speed in descent;

$t_{descent}$ - time of descent.

The estimated flying time after flying over the outer beacon is determined with the use of the following equation:

$$t_{estim} = \frac{W_{descent}\, t_{descent} - r}{W} \pm \frac{U}{W}\, t_{turn},$$

where: W - ground speed before turn initiation point;

r - radius of zone of unstable radio compass readings; assumed as equal to 1.5 - 2 values of flight altitude;

U - wind speed component directed along landing course at maneuvering altitude (sign "+" is taken for tail wind, sign "-" stands for headwind when on landing course);

t_{turn} - time required for performing turn to landing course.

After intercepting the estimated course, the instrument reference procedures are the same as during interception the outer beacon. Of particular importance, however, during this stage of flight are the following two factors, i.e. flying time and speed which determine the distance between the outer beacon and the turn initiation point, and consequently, the descent initiation point.

Upon expiration of the estimated time, perform a turn to the landing course at a bank of 30° and with a loss of an altitude of 500 m. Aircraft turn to the landing course is one of most crucial stages of flight and requires greater caution on the part of the pilot. It is essential to not only consult the instruments which present constantly varying readings but evaluate the readings displayed as a whole and timely vary aircraft banking in order to ensure precise alignment of the aircraft to the runway. Aircraft banking should be varied in such a manner that upon recovery from the turn the radio compass pointer be zeroed and the course be equal to the landing one.

To ensure rapid evaluation of the course and automatic direction finder readings for correction of errors which may occur during flight to the landing course by varying a bank, the following rules are recommended:

(a) if the pointer of the automatic direction finder moves to zero faster than the selected course pointer deflecting towards the reading index, the bank should be decreased as it must be eliminated at all in automatic direction finder pointer approaching the zero mark;

(b) if the automatic direction finder pointer displaces toward the zero mark slower than the selected course pointer moving to the index line, bank should be increased.

Thus, it should be borne in mind that the automatic direction finder pointer "follows" the bank, i.e. the bank should be decreased if it is necessary to slow the pointer down and increased if faster pointer movement is required.

After intercepting the landing course fly level for a period of 30 s. During this time establish an airspeed of 550 km/h, extend the landing gear and bring the aircraft into descent on obtaining the respective permission of the flying control officer.

It is important that the vertical descent speed of 40 m/s at a translational speed of 550 km/h be maintained up to an altitude of 2000 m.

On attaining an altitude of 2200 m, start gradually decreasing the angle of descent so as to enable the aircraft to pass an altitude of 2000 m at a constant vertical speed of 15 m/s, with the translational speed of 500 km/h. Gradually decrease the vertical speed to 10 m/s at an altitude of 1100 m, maintaining the indicated airspeed at a level of 500 km/h. To this end, slightly increase the engine speed. Maintain this flight regime up to an altitude of 600 m. From an altitude of 600 m to the safe altitude, establish a vertical speed of 5 - 3 m/s, and gradually decrease the translational speed so that it is equal to 450 km/h on attaining a safe altitude.

Readings of instruments both in descent and level flight at a safe altitude are given in Figs 79 through 83.

Amongst the main instruments to be referred to in maintaining the descent mode are the gyro horizon on the flight director indicator, rate-of-climb indicator, airspeed indicator, and the combined course indicator (course and RB). Initially, watch the altimeter from time to time. The rate of glance to the altimeter must be increased as the aircraft descends to a descending mode change altitude.

During descent under cross-wind conditions it is vital that the pilot consult the combined course indicator (course, RB) more frequently in order to be constantly aware of the aircraft attitude with respect to the runway centre line and be able to eliminate departure from the landing course in proper time. Departures which may occur in descent are to be eliminated by making corrective turns in the respective direction at a bank angle of 15 to 30° (depending on the amount of departure) without changing the vertical and translational speeds.

The procedures for correcting course errors are illustrated in Fig. 84. If the present course is in excess of the landing one, with RB = 0°, this means that the aircraft is flown slightly to the left with respect to the runway centre line. To ensure strict alignment of the aircraft with the runway, perform a corrective turn to the right by the amount of double error. As the automatic direction finder pointer nears the selected course pointer (landing course), start a left turn, aligning the pointers at the index line.

The error is corrected identically when the present course is less than the landing one, i.e. the aircraft is flown to the right relative to the runway centre line, with RB = 0°. Corrective turns are effected in the leftward direction in this case.

Whenever the aircraft course is equal to the landing one and the radio compass pointer deflects to the left (right), it is necessary to perform a corrective turn in the direction of the automatic direction finder pointer deflection until it assumes the middle position between the selected course pointer and the triangular index. As the automatic direction finder pointer approaches

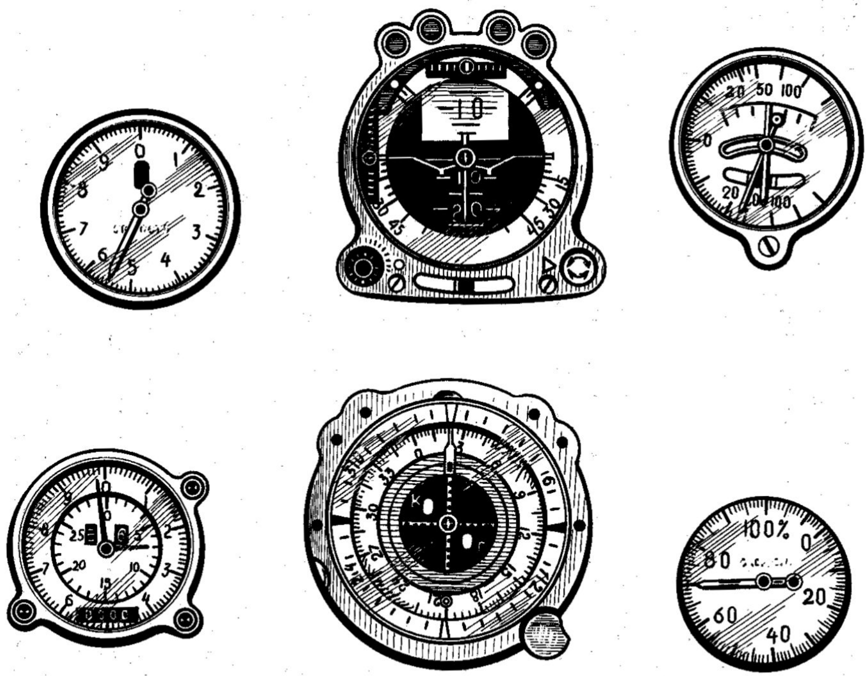


FIG. 79. INSTRUMENT READINGS CORRESPONDING TO GLIDESLOPE DESCENT TO ALTITUDE OF 2000 m WITH LANDING GEAR EXTENDED

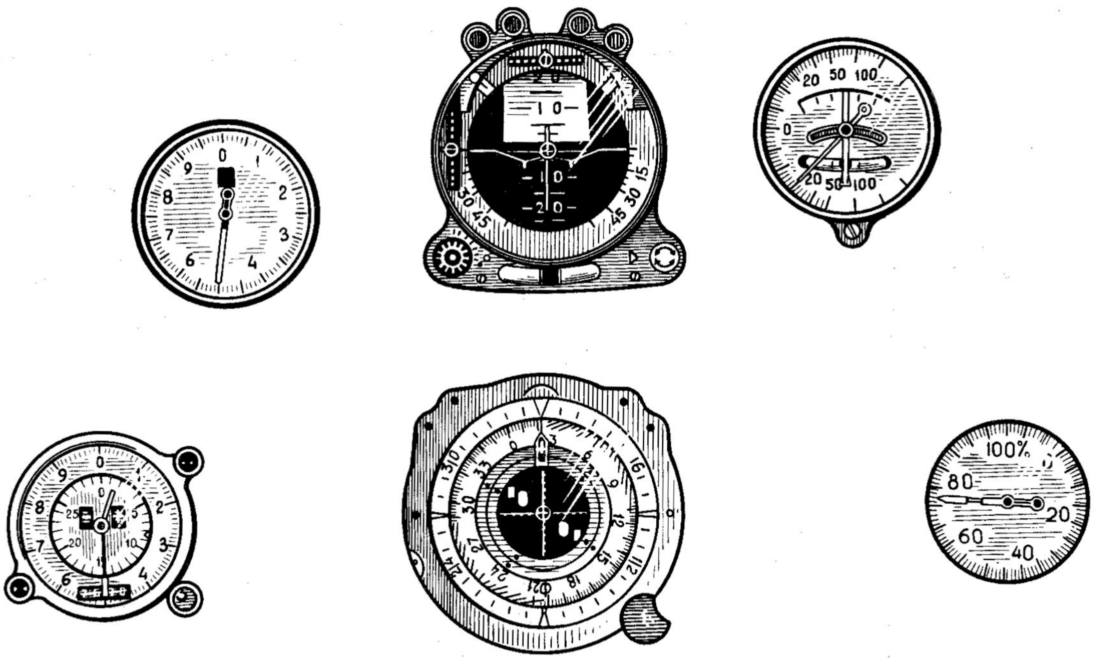


FIG. 80. INSTRUMENT READINGS CORRESPONDING TO GLIDESLOPE DESCENT FROM ALTITUDE OF 2000 m TO 1000 m WITH LANDING GEAR EXTENDED

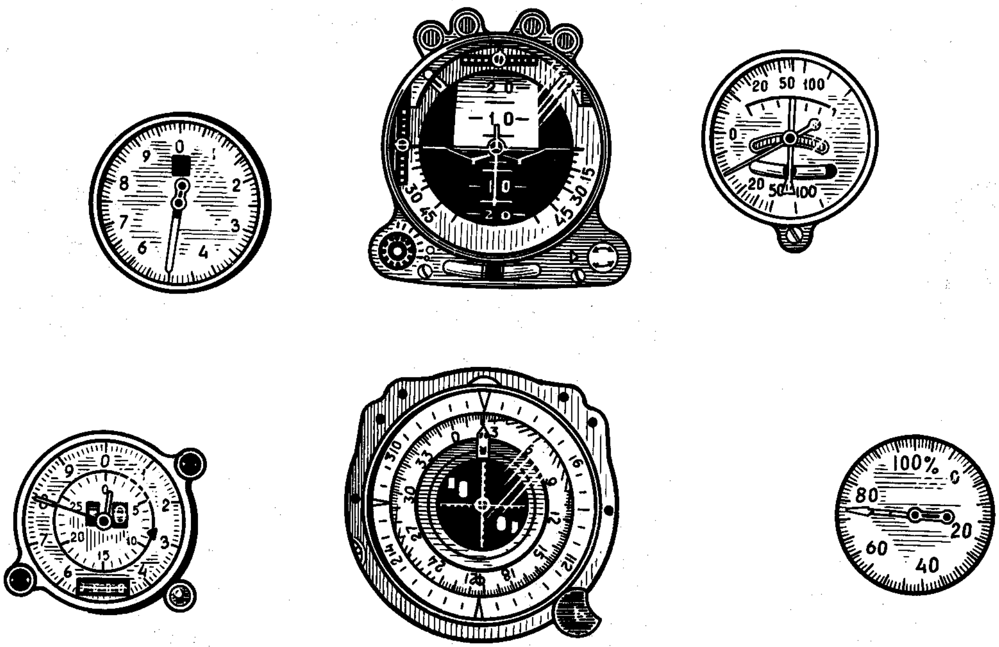


FIG. 81. INSTRUMENT READINGS CORRESPONDING TO GLIDESLOPE DESCENT FROM ALTITUDE OF 1000 m TO 600 m WITH LANDING GEAR EXTENDED

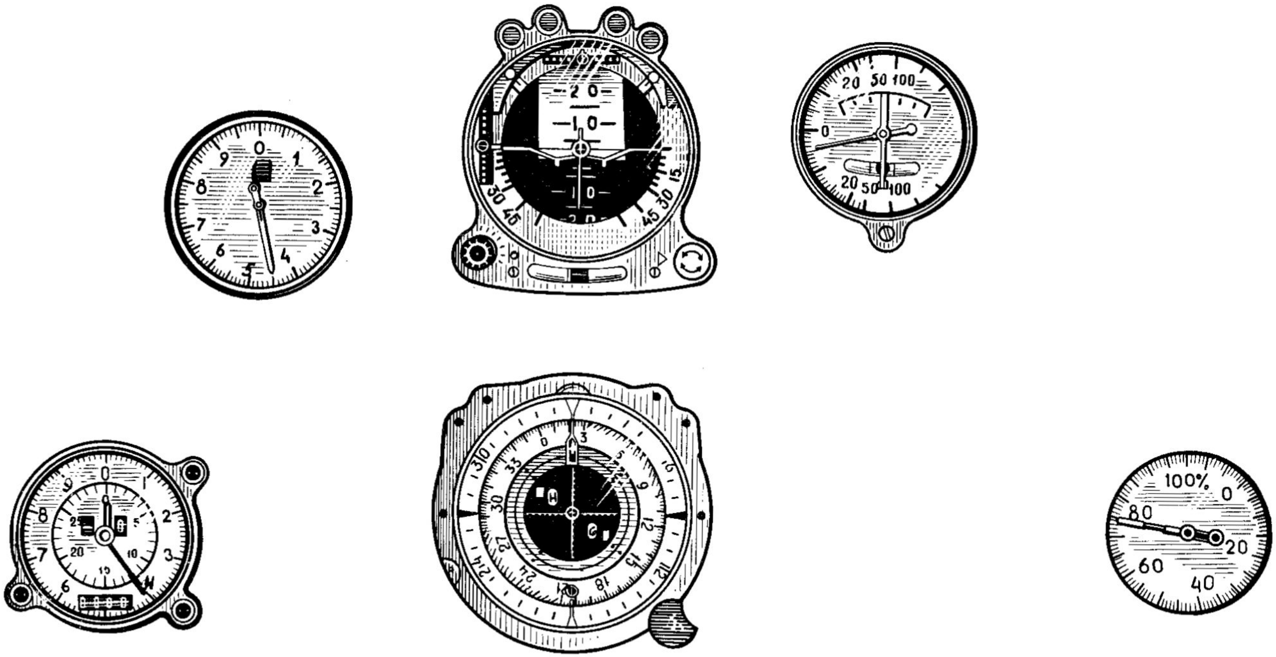


FIG. 82. INSTRUMENT READINGS CORRESPONDING TO GLIDESLOPE DESCENT FROM ALTITUDE OF 600 m TO SAFE ALTITUDE WITH LANDING GEAR EXTENDED

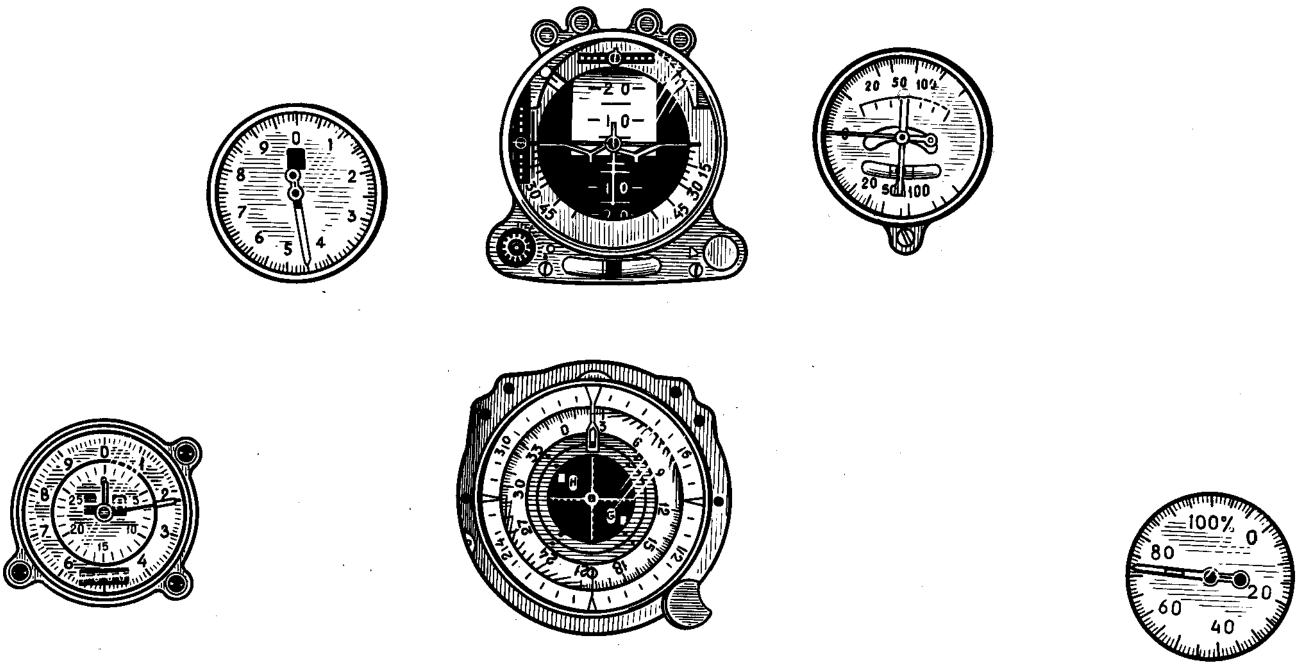


FIG. 83. INSTRUMENT READINGS CORRESPONDING TO LEVEL FLIGHT AT GLIDESLOPE SAFE ALTITUDE WITH LANDING GEAR AND FLAPS EXTENDED

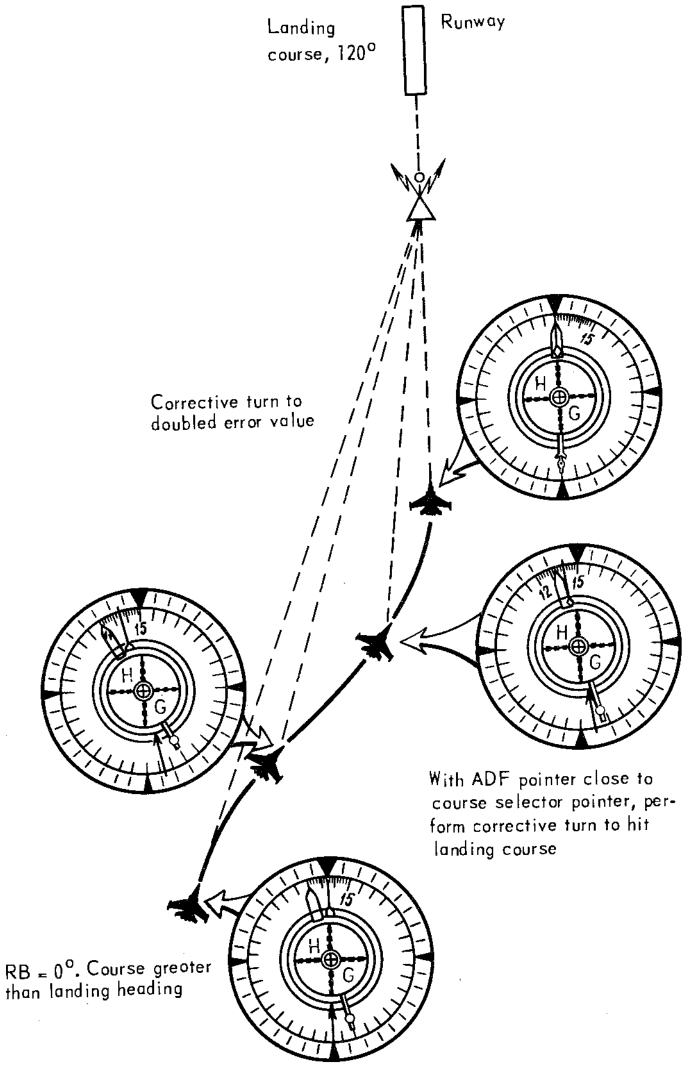


FIG. 84. CORRECTION OF ERROR WHEN HITTING LANDING APPROACH COURSE

the selected course pointer, perform a turn to the landing course, aligning the pointers below the index mark.

Aircraft descent on the landing course is effected in an active manner, i.e. on the course corrected by the amount of the drift angle. The direction of the landing course drift and its likely amount should be estimated well before takeoff on the basis of weather data and the report submitted by the weather reconnaissance officer. Insofar as flight conditions may vary even within a short period of time, the pilot must be well trained in determining the amount of drift angle directly in the course of descent. To this end, the pilot must decide whether the flight course increases or diminishes, with RB = 0°. An increase in the course, namely, the selected course pointer deflects rightward off the index mark causes an aircraft leftward drift. If the course decreases, an aircraft rightward drift takes place. The amount of drift may be judged approximately by the rate of change in the course.

In the event of leftward drift the automatic direction finder pointer must be maintained from the left-hand side with respect to the index mark by the amount of the drift angle, and the flight course must exceed the landing approach course by the drift angle. In the event of the rightward drift the automatic direction finder pointer should be maintained from the right to the index mark by the amount of drift angle. Accordingly, the flight course must be less than the landing approach one by the amount of drift angle.

To introduce corrections, try to obtain such a condition when the automatic direction finder and the selected course pointers be just opposite the index mark. At this moment, the aircraft will be within the runway plane and its longitudinal axis will be pointed at the outer beacon. Then, perform a break-off upwind turn through the drift angle. As a consequence, the automatic direction finder and the selected course pointers will simultaneously shift by the same angle but in the opposing directions with respect to the index mark. If the drift angle is selected correctly, the pointers will never change their position.

On attaining the safe altitude, stop counteracting the drift, establish RB = 0°, and maintain it strictly. Check the flight course from time to time in order that the direction of the corrective turn to the landing course after flying over the outer beacon could be determined in advance.

In the course of descent it is necessary to introduce corrections into the values of vertical speed and flight course in response to the commands delivered from the ground-controlled approach system.

At a distance of 15 to 16 km to the runway, extend the wing flaps, intercept the outer beacon at a speed of 420 to 400 km/h.

Particular attention should be given to strictly maintain the flight altitude, never permitting an altitude less than 200 m. Absence of bank will ensure a precise maintaining of flight direction at RB = 0°.

A premature transition to visual flying is not allowed, especially in cloud breaking at a long distance from the outer beacon, as the pilot attempting to detect the runway or familiar reference points distracts his attention from the instruments. All this gives rise to a risk of losing control over flight altitude and speed. This is of particular danger under uneven-cloud-bottom-edge and limited visibility. Therefore, in each case when the flight is performed under limited visibility minima, instrument flight shall be effected before reaching the outer beacon.

When flying over the outer beacon, check the automatic direction finder for change-over to the inner marker beacon, perform a corrective turn to RB = 0°, establish the required engine power setting, and bring the aircraft into descent. Furtheron, head the aircraft for the inner beacon, maintaining RB = 0°, recheck the direction of the landing approach, flight altitude and speed and proceed to the VFR flying with reference to the instruments.

The above described actions to be taken by the pilot beginning from the point of turn to the landing approach course and before reaching the inner beacon are pertinent to other types of maneuvers involved in straight-in approach.

Landing approach involving a maneuver of "estimated angle turn" is used as a main principle in the initial stage of training for performing a landing approach in IFR weather conditions.

A 180 - degree turn may be used in cases when the approach course to the homing beacon approximates the landing approach one (Fig. 85).

After determining the moment of flying by the outer beacon by reference to the automatic direction finder, bring the aircraft into the turn to the course reverse to the landing approach one at a bank of 30° and airspeed of 600 km/h.

Upon completion of the turn maintain the course reverse to the landing approach one after having made due corrections for drift angle.

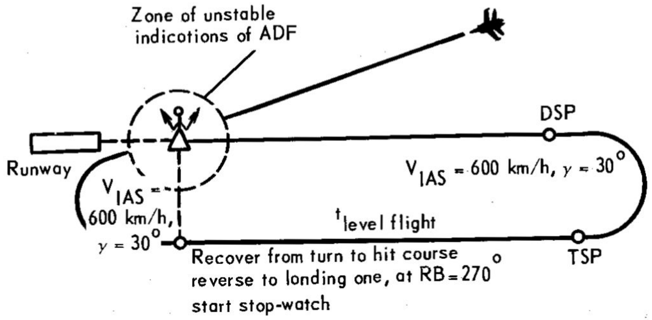


FIG. 85. 180-DEGREE TURN LANDING APPROACH PATTERN

When flying abeam the outer beacon (RB = 270° in left turn or RB = 90° in right turn), start the stop-watch, and proceed until the estimated time has expired. On expiration of the estimated time, carry out a 180-degree turn at a bank angle of 30° in view of intercepting the landing course. The turn should be performed at an airspeed of 600 km/h and loss of an altitude of 500 m.

After intercepting the landing course further procedures are similar to those involved in straight-in approach.

C i r c l i n g o v e r t h e h o m i n g b e a c o n is used in approach to the outer beacon at an angle approximating 90° with respect to the landing course (Fig. 86).

To accomplish a maneuver, having determined flying over the outer beacon, bring the aircraft into the turn at a bank of 30°, and watch the readings of the automatic direction finder pointer. As soon as the pointer comes close to mark RB = 270° (during left turn), reduce the bank angle to 15° and, maintaining the above-mentioned relative bearing, proceed in performing a turn for intercepting the course reverse to the landing course. After intercepting the reciprocal course make due correction for the drift angle, start the stop-watch, and proceed to the turning point.

Accomplish a turn to the landing approach course at a bank of 30° upon expiration of the estimated time or in response to command given by the officer of the ground-controlled approach system.

Further approach and estimation for landing are similar to those used in straight-in approach.

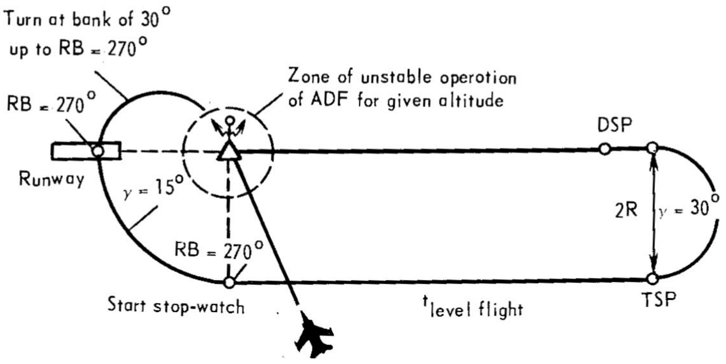


FIG. 86. LANDING APPROACH PATTERN INVOLVING METHOD OF "CIRCLE OVER HOMING STATION"

T u r n t o w a r d s m i n i m u m a n g l e is used in the same cases as circling over the radio beacon, but involves simpler maneuvering and takes shorter time required for the aircraft to reach the turning point (Fig. 87).

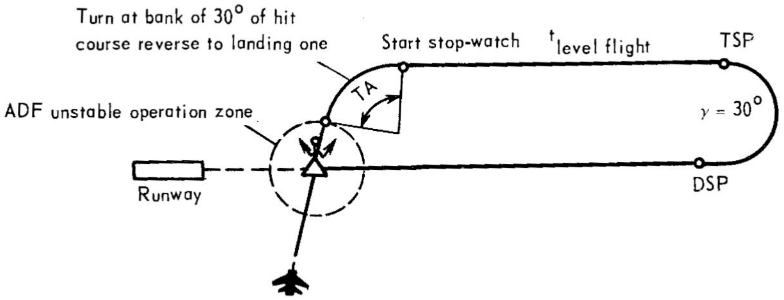


FIG. 87. LANDING APPROACH PATTERN INVOLVING METHOD OF "TURN TOWARDS LEAST ANGLE"

The essence of the maneuver consists in that once over the outer beacon the pilot must perform a turn which is reverse to the landing approach one towards the minimum angle, and proceed on this course to the turning point.

The time to the turning point is determined by the navigator on duty at the control tower. The turn for intercepting the landing course can also be carried out in response to the command given by the ground-controlled approach system officer.

Further approach and estimation for landing are similar to those involved in straight-in approach.

Landing approach from estimated line. The flight pattern in the landing approach from estimated line must be plotted on the shortest route and effected on the commands from the control post on the basis of the radar data.

Visualizing the aircraft blip displayed by the plan-position indicator and knowing the distance between the aircraft and the airdrome, the direction, speed, and altitude of flight, the controller at the command post makes calculations as to determine the line, from which the aircraft should be put into descent according to the most advantageous programme, with the use of special graphs and cards. The pilot is provided with such direction and vertical speed parameters as to enable the aircraft to attain an altitude of 2000 m at the point of turn to the landing approach course (Fig. 88).

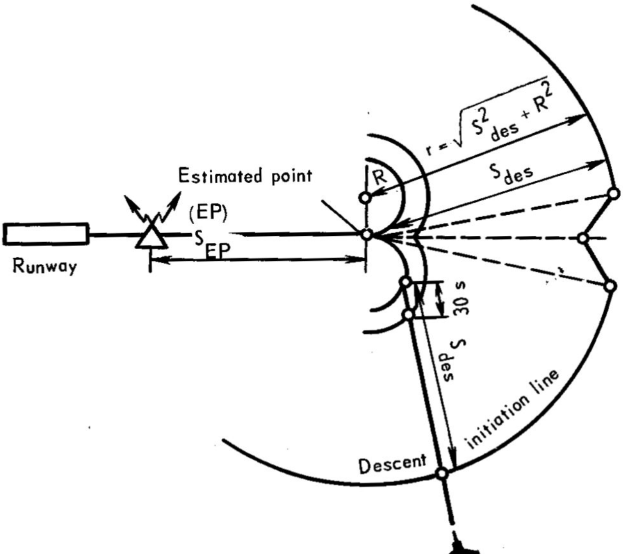


FIG. 88. PATTERN OF LANDING APPROACH FROM DESCENT INITIATION LINE

At long distances the pilot is provided with information pertaining the altitude and course of flight to the landing airdrome at such a time as to enable the pilot to fly the aircraft at an altitude and flight regime corresponding to the minimum fuel consumption per kilometre before attaining the estimated line of descent. On attaining the estimated line of descent the controller at the command post gives command ESTIMATED LINE (РУБЕЖ) and specifies the translational and vertical speeds as well as the distance to the point of turn to the landing course.

In the course of descent along the descending path to an altitude of 2000 m the pilot must maintain the assigned flight course and regime. The rate of descent may be varied, if necessary, upon commands from the command post or ground-controlled approach station. On attaining an altitude of 2000 m, bring the aircraft into level flight, establish an airspeed of 600 km/h, and perform a turn for intercepting the landing course at a bank of 30° on the command furnished from the ground-controlled approach station.

When on the landing approach course, reduce the speed to a level of 550 km/h, extend the landing gear and, on obtaining a permission for descent, let the aircraft down to perform landing approach.

Whenever the height of the bottom edge of cloud train exceeds 800 m and aircraft landing is planned to be performed from a circling maneuver, it is advisable that the descent from the estimated line be effected in the direction of the outer beacon. After breaking off in the region of the outer beacon, visually locate the airdrome, enter the traffic circuit, and carry out a circular approach.

<u>Landing approach by two reverse turns</u> is used after go-around and because of the errors committed in straight-in approach or approach from the estimated line in view of minimizing the time required for accomplishing a repeated approach. For training purposes the landing approach by two reverse turns may be performed immediately after either a takeoff or go-around.

The procedure for landing approach after go-around (Fig. 89) is as follows.

When gliding at an altitude of not less than 100 m, accelerate the engines to the maximum speed, smoothly put the aircraft into climbing, and retract the landing gear and flaps.

Climbing to an altitude of 600 m should be effected at an indicated airspeed of 600 km/h and rate of climb of 5 m/sec.

Start performing the first turn at a bank of 30°, altitude of 600 m, and airspeed of 600 km/h one and a half minute after flying over the outer beacon or a minute after flying over the inner beacon.

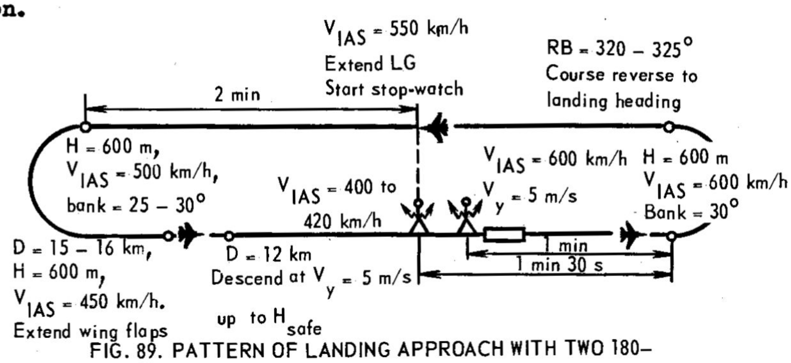


FIG. 89. PATTERN OF LANDING APPROACH WITH TWO 180-DEGREE TURNS

When performing the turn, most of the pilot's attention should be given to the readings presented by the gyro horizon and the rate-of-climb indicator. Particular attention should be given to the procedures for maintaining a bank of 30° and airspeed of 600 km/h, as any change in these parameters may disable the aircraft to intercept the estimated point of the turn on the downwind leg.

At the end of the turn on the cross-wind leg most of the pilot's attention should be given to the readings of the compass in order not to be late for taking a course reverse to the landing one.

If the turn on the cross-wind leg is performed correctly under calm-wind conditions, the relative bearing of the radio station, at the moment of aircraft taking the course reverse to the landing approach one, must be equal to 320 - 325° during LH turn or 35 to 40° during RH turn.

Once on the course reverse to the landing one, the pilot must strictly maintain the assigned flight regime. The aircraft should be piloted either manually or with the use of the automatic pilot operating in the stabilization mode.

When flying abeam the outer beacon, i.e. when the pointer of the automatic direction finder reads RB = 270° during LH circular approach or RB = 90° during RH circular approach, start the stopwatch, extend the landing gear, and establish an airspeed of 500 km/h.

Start the accomplishment of the turn on the downwind leg two minutes after flying abeam the outer beacon. Prior to entering the turn on the downwind leg request the control post for the radio bearing to recheck the aircraft attitude with respect to the estimated point.

Perform the turn on the downwind leg at a bank of 25 to 30°. During the second turn the procedures for changing aircraft roll attitude and landing approach estimation are similar to those involved in straight-in approach. The turn shall be performed without altitude loss.

After intercepting the landing course, at an altitude of 600 m extend the wing flaps and establish an airspeed of 450 km/h. To a distance of 12 km flight should be conducted at an altitude of 600 m and airspeed of 450 km/h. On attaining the distance of 12 km, bring the aircraft into descent at a vertical speed of 5 m/s. Further descent and landing procedure is similar to that used in straight-in approach.

<u>Extended rectangular pattern landing approach</u> may be carried out after a go-around (Fig. 90). Perform the first turn through an angle of 90° at a bank of 30°, airspeed of 600 km/h, and altitude of 600 m.

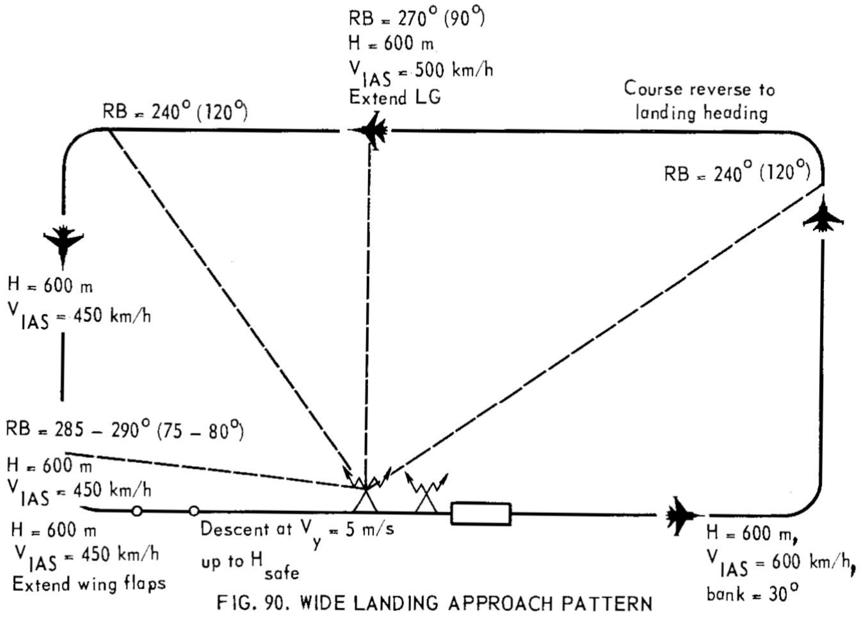


FIG. 90. WIDE LANDING APPROACH PATTERN

Upon completion of the turn on the cross-wind leg the course readings presented by the combined course indicator should differ from the landing approach course by 90°. This course should be maintained until the radio compass pointer reads RB = 240° during LH circling or RB = 120° in case of RH circling. Furtheron, perform the 90-degree turn at a bank of 30° and proceed on the course reverse to the landing one. As the aircraft comes closer to the position abeam the outer beacon, notice the readings of the automatic direction finder as frequently as possible.

When abeam the outer beacon (with RB = 270° during LH circling or RB = 90° during RH circling), extend the landing gear and establish an airspeed of 500 km/h.

With RB = 240° (in LH circling) or RB = 120° (RH circling), accomplish the turn onto base leg through an angle of 90°, reduce the airspeed to 450 km/h and, with RB = 285 to 290° (in LH circling) or RB = 75 to 80° (in RH circling) start performing a turn at a constant altitude to intercept the landing course. A precise interception of the landing course may be obtained through varying the amount of bank during turning.

In level flight at an altitude of 600 m extend the wing flaps and proceed to the point of a twelve-kilometre distance at an airspeed of 450 km/h. On attaining a distance of 12 km, bring the aircraft into descent at a vertical speed of 5 m/s, bring the aircraft on the course to the outer beacon, and perform landing.

8. LANDING APPROACH WITH USE OF GROUND-BASED RADIO DIRECTION FINDER

Landing approach with the use of the ground-based radio direction finder is to be performed for training purposes. Apart from this, the method for landing approach under discussion may be utilized in the events of failure of the PCБH-6C short-range radio navigation and landing system and the APK-10 automatic direction finder.

Having ascertained that the POLJOT-1M system and the APK-10 automatic direction finder can not be used for landing approach, report this to the flying control officer and request for the radio bearing to ensure a precise approach to the ground-based radio direction finder at the assigned altitude.

Place the aircraft on the course to the ground-based radio direction finder making use of the obtained radio bearings. In the course of flight request the radio bearings at an interval of 1.5 to 2 minutes to introduce due corrections into the flight course.

Flying over the radio direction finder is determined by the wireless operator who gives a FLY-OVER command or by the reversing of the radio bearings.

While flying over the radio direction finder, start the stopwatch, establish the course predetermined by the flying control officer, and proceed on this course for the estimated time. Flight course and time are estimated by the controller on duty at the takeoff control point with due allowance for the location of the radio direction finder.

After flying over the radio direction finder request for two or three times the direction finder bearing to maintain the correct turning angle.

On expiration of the estimated time, perform a turn to place the aircraft on the landing course. Request the finder bearing and correct the aircraft course with respect to the runway line in the second half of the turn. After intercepting the landing course within a 30-sec leg extend the landing gear and establish the required rate of descent.

As the aircraft descends, periodically request the radio bearing from the operator and introduce corrections into the landing course. The procedure for making landing course corrections is as follows. On obtaining data from the radio direction finder, detect the error and then determine the direction of aircraft departure from the runway line. Further, perform a corrective turn towards the runway line by the amount of doubled error. The corrective turn should be performed to the right, if the radio bearing is in excess of the landing course, and to the left, if the radio bearing is less than the landing course. When proceeding on a new course, request radio bearings. If the difference is from 2 to 3°, effect a corrective turn to intercept the landing course.

The tolerances for the translational and vertical speeds during landing approach with the use of the ground-based radio direction finder are the same as in the case of the straight-in approach with the use of the automatic direction finder.

RECOMMENDATIONS TO COMMANDER (INSTRUCTOR) ON TRAINING PILOTS FOR FLYING IN IFR CONDITIONS

Before proceeding to flights under IFR weather conditions, the regiment (squadron) commander must organize training of senior flying personnel as instructors.

Instructors are to be trained in the course of combat training plan flights or at special assemblies. A pilot-instructor undergoing a course of preparation for training flying personnel for flights under IFR weather conditions should be perfectly skilled in piloting the aircraft in cloudy weather for intercepting the landing course at a weather minima established for the combat aircraft and handling the combat trainer from the instructor's cabin under the respective meteorological conditions. To this end, the instructor must be qualified upon completion of the programme of the Combat Training Course.

The methods and techniques used by the instructor during training flying personnel for instrument flights are similar to those involved in flight training under VFR weather conditions.

What matters much during training for handling the aircraft under cloudy weather conditions is the sequence of the training exercises and maintaining a constant rate of advance. Training procedures demand strictly individual approach to each trainee, that is morale, physical properties, pilot proficiency, experience gained from piloting other types of aircraft, and the degree of actual readiness for accomplishment of missions assigned in IFR weather conditions must all be taken into consideration.

The responsibilities of the instructor to be observed during training flying personnel for instrument flights are as follows:

(1) capability to perfectly pilot the combat trainer from both of the cabins and readiness to demonstrate or precisely repeat any of the flight elements;

(2) willingness to study and knowledge of personal qualities and capabilities of trainees; strict adherence to the requirements of the individual approach to pilots under training;

(3) competence and readiness to explain every flight element to a trainee in a simple, definite, and object manner;

(4) adherence to the principle NEVER ORDER WHAT A PILOT CAN NOT CARRY OUT; strict observance of the principle of sequence of training exercises;

(5) adherence to the notion that best results are obtained through applied flying rather than a lecture;

(6) never interfere with aircraft control, if not necessary, for overassistance may nip pilot's initiative and inspire uncertainty;

(7) be exacting and considerate in respect of each charge; be able to determine the optimum "loading" for a flying shift to

be imposed on a trainee with due regard to his individual properties;

(8) be always ready to notice flight technique errors at proper time; be capable of determining the causes of troubles; help a trainee in correction of faults;

(9) constantly and systematically study and improve training methods and techniques on the basis of his personal experience and that gained by other instructors.

Flight training in IFR weather conditions,as well as flying training under VFR weather conditions comprises lectures, training with the view of keeping hand in aircraft flying, and improvement of flying skill acquired, and restoration of skill lost as a result of prolonged intervals.

Before proceeding to flights under IFR weather conditions, the commander must consider the degree of pilot proficiency of each trainee.

It is advisable that the pilots to be involved in instrument flight training for the first time start the training course from blind flights at medium altitudes. Such flights not associated with turbulence, variation in the illuminance and colour of clouds, flickering of breaks in clouds, raining or icing are easier to handle, do not divert attention from piloting,cause no nervous overstrain, and provide for the possibility of proper acquiring of the first instrument flight skill.

Design of the preparation of personnel for flights under IFR weather conditions must be conducted with strict adherence to the principle of individual approach.

Prior to flights,it is necessary that pilots be checked for knowledge of the subject and, if required, undergo a course of lectures on the following subjects:

(1) physical aspects of instrument flight;

(2) meteorological conditions of flight;

(3) principle of operation and readings of the flight-control and navigation instruments and other aircraft equipment which is indispensable in instrument flight;

(4) procedures for distribution and transfer of pilot's attention during instrument flight;

(5) flying technique to be involved in instrument flight;

(6) instrument flight radio aids and methods of handling aircraft with the use of the above-mentioned equipment with the landmarks being out of sight;

(7) ground and airborne equipment of the systems which ensure instrument landing approach;

(8) patterns and procedures for cloud breaking in the vertical direction established for a given type of aircraft in landing approach;

(9) errors probable in aircraft piloting during instrument flight and method of correction.

When taking the ground training course both in the pilot simulators and cabins, it is practical that trainees study the arrangement of the flight-control and navigation equipment, the peculiarities in the readings of newly introduced flight-control and navigation instruments, and the principles of distribution and transfer of the pilot's attention in flight. Sequence of handling the cabin equipment should also be mastered.

The effectiveness of the cockpit drill depends on what purposes are pursued, i.e. on its relevancy to the pilot's actions to be taken during each definite flight leg. Adequate organization of the ground preparation and use of all the trainer equipment make it possible to save efforts and resources during instrument flight training.

The course of training flying personnel for daylight flights in IFR weather conditions includes as follows: training for instrument flying in clouds (hooded flight), training for acquiring skill for performing landing approach with the use of the landing systems, training for breaking clouds, join-up and break-up of formations in over-the-top flights.

Insofar as the entire air defence aviation personnel are to a certain extent familiar with the instrument flight technique, the training for piloting aircraft in clouds (hooded flight) should be exercised in combination with the training for acquiring skill in instrument landing approach.

Preparation of flying personnel for flights under IFR weather conditions must be carried out in the most favourable time of the year. To ensure systematic training for flights under IFR weather conditions in the absence of such at a given period of time, it is necessary to schedule and carry out hooded flights which are an almost entirely simulation of flying aircraft in clouds.

Training personnel for flying aircraft in IFR weather conditions should be conducted to a sufficient degree of intensity in order to enable trainees to acquire stable skill for instrument flying. Starting from the first introductory flights in clouds (hooded flights) a trainee should be given all opportunities to show his best without any interference. An instructor should never interfere with the aircraft control unless a trainee fails to carry out a training exercise satisfactorily. A trainee should be provided with an opportunity to notice and correct mistakes by himself.

Keeping an attentive eye on the readings of the instruments and the trainee's actions, the instructor draws the pilot's attention to the persistent or neglected error, if the necessity arises. One of the responsibilities of the instructor is to demand from the trainee the strict observance of flight discipline, attendance to maintain the assigned flight regime, proper keeping of time intervals, observance of rules of radio communication, perfect handling of cabin equipment, all this being a guarantee of safety and success in accomplishment of flights in clouds.

Introductory flights in clouds can be also carried out at the weather minima determined by the instructor. Under such conditions the instructor must aid the trainee in descent and landing approach and, if necessary, take over aircraft control completely by himself.

Within the maneuvering area, the instructor usually confines himself to prompting and interferes with the control only in cases of emergency whenever a necessity in the immediate change in the flight regime arises.

During landing approach descent the instructor should explain both orally and practically to the trainee what he must do to maintain the assigned regime.

In response to the instructor's commands the trainee should memorize the readings presented by the flight-control and navigation instruments and those of the indicators which monitor the operation of the aircraft engines and systems, which correspond to the main flight regimes.

Another responsibility of the instructor is to deliver upon completion of each flight a brief postflight critique of a trainee's actions, point out the most serious errors committed during flight, and briefly note the actions to be taken by the trainee in order to prevent and eliminate these errors.

It is also practical sometimes that the trainee be given an opportunity to criticise himself and give an explanation as to the causes of the errors committed in flight. The instructor evaluates the correctness of the analysis made by the trainee and judges the degree of the mental and physical stress exerted by the trainee and the reserve of the pilot's attention during piloting the aircraft in clouds.

It is expedient that the first landing approach with the use of the landing system be accomplished visually so as to enable the trainee to compare the readings presented by the instruments and the actual position of the aircraft with respect to the runway. In subsequent flights, when the cloud ceiling is high, the instrument landing approach should be performed under the hood. As the trainee acquires appropriate skill, the hood should be removed at a lower altitude.

Initial training flights in clouds (above clouds) should be performed under the most favourable meteorological conditions, namely: absence of raining and icing conditions, calm cloud cover of moderate thickness, etc. The base of the clouds must be in excess of the predetermined weather minima by 400 to 600 m. The visibility should be within the limits of 5 to 6 km.

Proceeding from the concrete conditions, nature and height of clouds, degree of visibility under the clouds as well as the individual capabilities of the trainee and his experience gained during flights under IFR weather conditions on other types of aircraft, the squadron or regiment commander assigns each trainee a cloud base to practise piloting of the aircraft in clouds.

The most difficult stage of training pilots for flying aircraft under IFR weather conditions is training for performing a landing approach and estimation for landing at the predetermined weather minima. In order to prevent overexpanding of the training course due to the absence of real IFR weather conditions, it would be practical to conduct series of hooded introductory flights with the use of the combat trainer.

The hood must be removed during landing approach glide at an altitude of 100 to 150 m. Such substitution flights to a considerable extent reduce the required number of flights under real IFR weather conditions.

Pilots are allowed for flights under IFR weather conditions in the combat aircraft at a predetermined weather minima if they are well skilled in piloting the combat trainer at a weather minima under real IFR weather conditions.

<u>Training for the purpose of improving pilot proficiency</u> covers the greater part of the total of flying hours. It must involve repetitions of the earlier mastered drills.

The periodicity of pilot training should be such as to preclude losing of the acquired flying skill. The principle of determining the periodicity of flights should be based on the degree of complicacy of exercises. Instrument flying skill, for example, is likely to be lost quicker than that acquired during visual flights. During instrument flight intervals skill gained in flying aircraft on landing course during instrument landing approach is likely to be lost first of all, especially at the predetermined weather minima. As a consequence, training for adequate performance of flights or flight elements involving flying technique which are hard to keep hand in should be at a higher rate of repetition.

It should also be noted that the repetition of a more complex flight, as a rule, precludes the necessity in repeating the flight involving simpler operations.

To keep hand in performing landing approach with the use of the landing systems, trainees should be trained for instrument landing approach techniques with the use of both combat and combat trainer aircraft.

Flying skill restoration. Prolonged flying intervals in general and, especially, those in instrument flights, deteriorate pilot proficiency of trainees. Loss of instrument flying skill after an interval in the airwork manifests itself in the paralysis of the pilot's attention and concentration of his attention on the readings of a restricted number of instruments. The pilot's actions become disproportionate, sweeping, and abrupt. All this may result under certain circumstances in blunders in flying technique.

The duration of the intervals which may lead to a loss of flying skill depends on the personal psychological properties of the pilots, complicacy of flight programmes and aircraft under use. This relationship should be taken into consideration by commanding officers. Referring to the Flight Manual and Combat Training Course as a guide and taking into account the individual properties of each pilot, commanders are to determine the sequence of flying skill restoration exercises to be carried out after intervals between flights.

The flying skill restoration course as well as training must be conducted with high degree of intensity.

When accompanying the pilot in check flight after a prolonged interval, the instructor should bear in mind that the readings presented by the instruments are not always the evidence of loss of flying skill, especially when check flight is effected under simplified conditions. In order to avoid erroneous conclusions and admittance of the pilot for piloting the aircraft with unrestored flying skill, the pilot should be checked for pilot proficiency in instrument flying with the same degree of complexity involved in pilot training prior to intervals between flights.

The pilot must carry out, if necessary, at least two check flights with the instructor in order to enable the latter to most objectively evaluate the degree of flying skill available and contemplate the right ways of restoration of flying skill.

CHAPTER V

FORMATION FLIGHTS

The modern war experience shows that the aviation of the potential enemy effects combat operations in various tactical formations and groups rather than by means of solo aircraft which are also useful. The enemy broadly uses massing of forces in the decisive directions and periods of time.

In this connection it should be noted that interceptor-fighters will be also involved in formation combat actions in order to gain air superiority, ensure destruction of the enemy on the predetermined lines, and prevent enemy penetration to the assault objectives. Additionally, effecting ground control over a large number of solo aircraft within the limited airspace presents extreme difficulties. The ground control over aircraft formations is much more easier when the initiative of local control belongs to a formation commander. Bringing interceptor-fighters into action to gain a constant rate of advance is also facilitated. Interceptor-fighter formation operational use is also most probable whenever it is necessary to repel the attacks of the enemy tactical and deck-landing aviation, especially in daylight under VFR weather conditions.

The combat capabilities of interceptor-fighters and the flying skill of pilots as air fighters are most completely realized and the attack surprise and mutual protection are ensured, i.e. the combat mission assigned is most effectively accomplished during interceptor-fighter formation operations.

The interceptor-fighter formation in daylight under VFR weather conditions should be based on a constant visualization of friendly aircraft in operation. The basic element of the attack formation is a flight section of interceptor-fighters. Therefore, training of pilots for proper conducting of formation air fighting should be effected in two-plane elements and flight sections.

When friendly flying personnel for team flying of two-plane elements and flight sections, major attention must be given to conducting combat actions in loose formations which most fully satisfy the requirements of modern formation combat and ensure flight safety in maneuvering.

It is recommended that instructors follow the below-given sequence of methods of training flying personnel for the МиГ-25П interceptor-fighter formation flights:

(1) training for mastering pair echelon formation team flying with the following parameters: distance of 150 to 200 m, interval of 75 to 100 m, and vertical separation (elevation) of a wingman ranging from 10 to 30 m (Fig. 91, a);

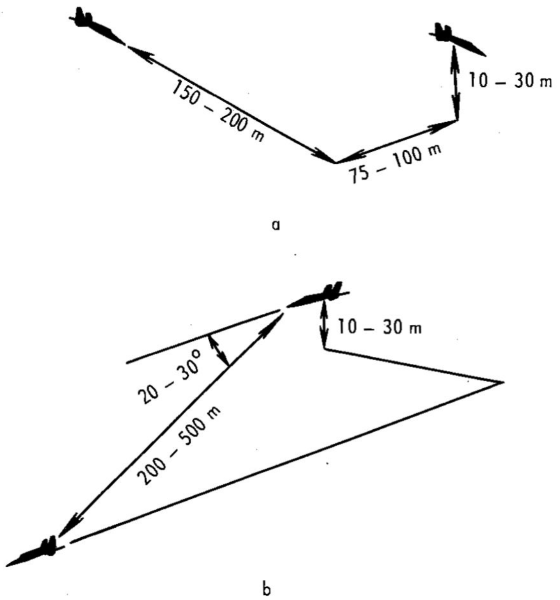


FIG. 91. PAIR ECHELON FORMATION
a – close; b – loose

(2) training for mastering pair echelon formation team flying at increased distances and intervals, with the distance between aircraft being from 200 to 500 m and at an angle of sight of 20 to 30° with respect to the leader (Fig. 91, b);

(3) training for mastering team flying in pair echelon and V-formation section flight with the following parameters: distance between pairs in the section is from 600 to 800 m at an angle of sight of 20 to 30° with respect to the leading pair (Fig. 92).

The consecutive order and number of flights depend to a large extent on the personal proficiency of the pilot for flying the МиГ-25П interceptor-fighter, experience gained during formation flights on other types of aircraft, and some other factors

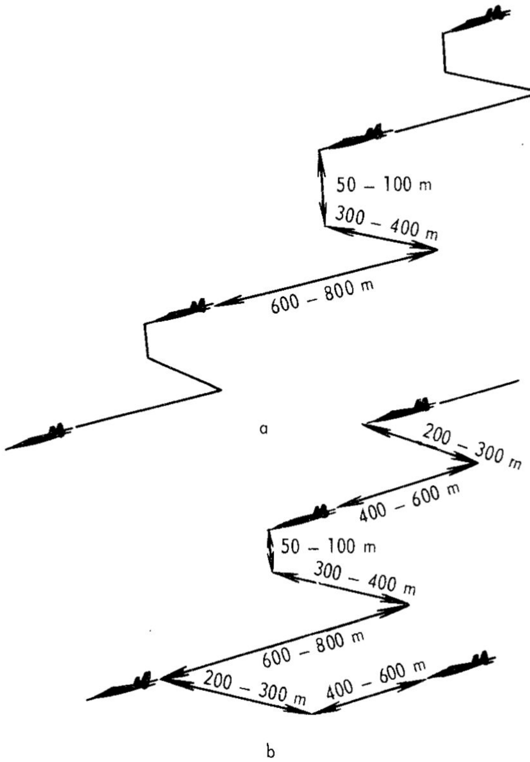


FIG. 92. SECTION FORMATIONS
a – pair echelon formation; b – V-formation

which must also be taken into consideration by senior flying personnel. The high level of team flying may be attained through the irreproachable individual flying skill of each pilot, mutual understanding and trust, experience gained by a formation leader, and strict flight discipline.

TWIN FLIGHT

Combat training experience shows that pilots which are highly skilled in performing twin flights are capable of easily mastering flying technique within combat formations comprising a great number of aircraft.

During twin flights with the aim of mastering the crew co-operation, the pilots should practise the following flight elements, i.e. takeoff, climb, maneuvering, regrouping, landing approach, and landing.

1. TAKEOFF

Prior to starting engines, the leader must establish communication with the wingman and report the pair's readiness for takeoff to the flying control officer. Engines are to be started simultaneously.

The sequence of taxiing is determined by the leader depending on the actual conditions and arrangement of aircraft. Particular attention should be given to the procedures for maintaining safe taxiing distances.

The quality of takeoff for the most part depends on the aircraft pretakeoff arrangement on the runway. Therefore, the responsibility of the leader (and the flying control officer, if necessary) is to give appropriate radio commands in order to ensure the correct arrangement of aircraft before takeoff. Aircraft properly arranged, the leader should report the readiness of the pair for takeoff to the flying control officer.

The aircraft may takeoff either in pairs or one by one at a safe time interval. Nevertheless, aircraft should be arranged on the runway in accordance with the parameters specified for the two-plane takeoff procedures.

Takeoff in single aircraft. After taxiing the aircraft over a distance of 5 to 10 m both the leader and the wingman stop thei aircraft on the runway. On ascertaining that all the aircraft ar properly arranged and the wingman is ready for takeoff, the le er requests a permission and performs takeoff. Upon completio takeoff and turning off the afterburners the leader selects engines speed of 85 to 88% which should be maintained until wingman joins him up. As the leader aircraft starts moving wingman, holding the aircraft on the brakes, increases th speeds and performs takeoff at the assigned time interval at the respective command of the flying control officer.

The amount of time interval depends upon the pilot proficiency, weather conditions, condition of the airfield, and the location of the join-up area assigned for the pair.

After turning off the afterburners the wingman should detect the position of the leader, estimate the distance to the leader, and establish such a power setting as to gain a speed reserve sufficient for overtaking the leader.

The wingman is to join up the leader while in straight flight either up to the turn on the cross-wind leg or after the turn on the downwind leg from either side and on obtaining the respective permission from the leader. As the wingman aircraft approaches the leader, the former first takes up the position at the assigned distance to the leader and increased interval and, further, smoothly diminishes the interval to the assigned one. The assigned distance between the wingman and the leader is attained by changing the engine power setting. The interval is established by applying pedal pressure in short movements in the direction of the leader. Should the interval be less than the assigned one, it must be increased by performing a coordinated turn at a bank angle of 5 to 10° off the leader.

The leader, as a rule, effects at straight flight and watches the wingman's join-up. On ascertaining that the wingman has occupied his position in the pair formation, the leader starts to perform the flight mission assigned.

Takeoff in pair. To attain the minimum of time required for the formation to join up, takeoff on the МиГ-25П interceptor-fighters may be effected in close pair formation if the runway width is sufficient.

Taxiing the aircraft over a straight line through a distance of 5 to 10 m completed, the wingman should position the aircraft at a distance of 30 to 50 m and interval of 15 to 20 m relative to the leader. In the event of left-hand side wind takeoff must be carried out in a left echelon. Under right-hand side wind conditions takeoff should be effected in a right echelon, thus preventing the wingman from getting into the wake produced by the leader aircraft.

The wingman arranges the aircraft at the assigned distance and interval, ascertains that the nose wheel is in the right position, holds the aircraft on the brakes, accelerates the engines to maximum power setting, and reports readiness for takeoff to the leader. The leader in turn ascertains that the aircraft are arranged correctly, receives the wingman's report on readiness for takeoff, and requests the flying control officer for takeoff permission.

On obtaining the respective permission the leader gives command TAKEOFF, TURN ON AFTERBURNER (ВЗЛЕТАЕМ, ФОРСАЖ); at this command, both the wingman and the leader simultaneously turn on the afterburners, check to see the afterburners have been actually turned on, gradually release the brakes, and start the takeoff run. During the takeoff run the wingman should maintain the direction of takeoff with reference to the leader, keeping in sight the runway side boundary.

The takeoff direction (prescribed interval) is maintained by the wingman by applying smooth pedal pressure. In the second half of the takeoff run the wingman gives particular attention to the amount of the nose-wheel lift-off so as to align the aircraft takeoff angle with that of the leader (Fig. 93).

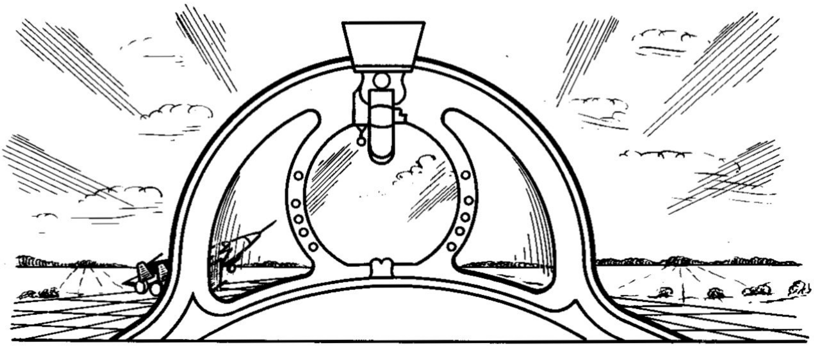


FIG. 93. POSITION OF LEADER IN SECOND HALF OF TAKEOFF RUN DURING TAKEOFF IN PAIR

If the running speed developed by the wingman aircraft is in excess of that of the leader, the wingman warns the leader about it over the radio and continues the takeoff, strictly following the required direction. Such being the case, the leader also maintains the takeoff direction, shifts glance to the wingman aircraft, and continues taking off as a wingman.

After the aircraft have cleared the ground the pilots establish the climbing angle and retract the landing gears and flaps. The wingman must follow the leader to retract the landing gear and flaps. The afterburners should be turned off after take-off at the leader's command. The wingman is the first to turn off the afterburners and then he establishes the distance of 150 to 200 m and interval of 75 to 100 m.

Climb. Twin climb is effected in loose formations at the most advantageous airspeed. Decreasing of the interval and distance to less than 50 m is not allowed. An r.p.m. speed reserve of at least 3 to 5% is left for the wingman by the leader.

The wingman maintains the assigned distance between the aircraft by varying the engine thrust, as well as by extending the air brakes. Insofar as the extension of the air brakes gives rise to a considerable pitching-up moment, their application with the view of maintaining the assigned formation should be restricted whenever possible and excluded on attaining the altitudes and Mach numbers specified in the pilot's instructions. The assigned interval is maintained by deflection of the pedal in the respective direction.

The assigned altitude gained, the leader brings the aircraft into level flight and establishes a speed required for accomplishment of the maneuvers specified by the mission.

2. MANEUVERING

Straight flight speed maneuvering is effected by varying the speed of the aircraft engines and, sometimes, applying the air brakes. In this case, the leader is to inform the wingman over the radio about extension or retraction of the air brakes.

On noticing an increase or decrease in the distance between the aircraft the wingman smoothly moves the throttle levers to respectively change the engine speed until the distance between aircraft commences to decrease or increase. As the distance nears the assigned level, the pilot moves throttle levers smoothly so that the aircraft assumes the initial position at a minimum rate of closure (lagging) with respect to the leader aircraft.

The wingman effects dual displacements of the throttle levers practically all the time. The rate of changing engine speed depends on the rate of change in the distance between two aircraft. Thus, the assigned distance between the aircraft is attained in an impulse manner. The less the difference between the current distance and the assigned one, the shorter the amount of the control impulse.

In the event of considerable lagging of the wingman aircraft with respect to the leader, the former should restrain himself from rushing in an immediate persuit by hastily and vigorously accelerating the engines, as this may result in an excessive acceleration of the aircraft.

If the leader is being overtaken by the wingman, the latter must warn the leader about it over the radio, increase the interval by turning away in the safe direction at a bank of 5 to 10°, decelerate the engines, and extend the air brakes, if permissible.

In this case, the leader again reassumes the position ahead of the wingman aircraft and the wingman joins up the leader on obtaining his permission by first establishing the assigned distance between the aircraft at a doubled interval to further set up the assigned interval.

The accuracy of maintaining the assigned distance and the time required for the aircraft to reassume the assigned distance for the most part depend on how rapidly the wingman responses to changes in the distance between the aircraft. When the wingman quickly notices a change in the distance between the aircraft and diminishes the speed of the engines in proper time, there is no need, as a rule, in applying the air brakes.

Level flight at altitudes above 1000 m should be performed with the vertical separation of 5 to 10 m with respect to the leader or at one and the same altitude. At altitudes below 1000 m the wingman should follow the leader at the same altitude or at elevation of 10 to 20 m relative to the leader aircraft. The visible positioning of the leader aircraft in level flight at low altitudes is shown in Fig. 94.

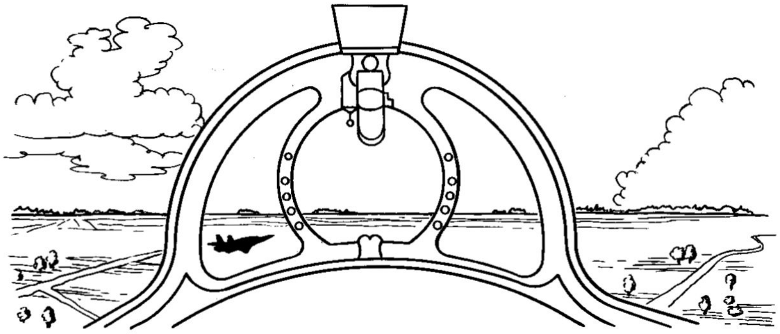


FIG. 94. POSITION OF LEADER IN LOW-ALTITUDE FLIGHT

When training for mastering the crew co-operation, intervals and distances are determined by the angle of sight and the apparent size of the leader aircraft. The amount of the angle of sight depends on the relationship between the distance and interval in respect to the leading aircraft (Fig. 95).

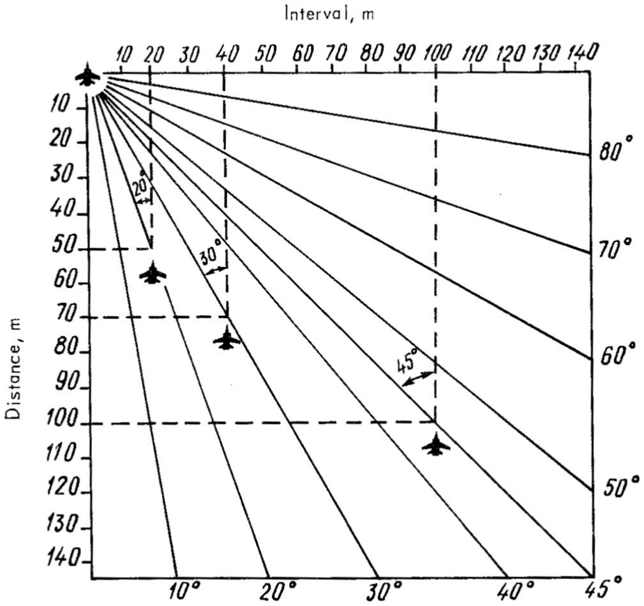


FIG. 95. SIGHTING ANGLE VERSUS RELATIONSHIP BETWEEN DISTANCE AND INTERVAL WITH RESPECT TO AIRCRAFT FLYING AHEAD

For example, with the angle of sight with respect to the leader aircraft approximately equal to 25°, the distance between the aircraft is twice as great as the interval. With the angle of sight of about 45°, the distance equals the interval. If the angle of sight approximates 65°, the distance is twice as less as the interval. The numerical value of the distance and interval at the assigned angle of sight can be determined only by the visible size of the leader aircraft or the degree of distinction of separate structural components of the aircraft. The ability to determine the above size and distinction between the aircraft components is obtained through systematic ground training and consolidation of the skill for determining the parameters of combat formation during flights for mastering crew co-operation.

<u>Turns (360° turns) towards the leader.</u> In the initial stage of the team flying, turns (360° turns) are to be first performed in close and then loose formations without changing the position by the wingman. The leader should effect turns with the throttle levers in such positions so that a speed reserve in either direction be left for the wingman. Furtheron, turns (360° turns) may be performed by the aircraft in the loose combat formations with changing the position by the wingman.

Prior to effecting a turn, the leader establishes the required speed, warns the wingman about the direction of turning, and smoothly brings the aircraft into a turn. At the leader's command, the wingman watches the actions of the leader and also carries out the turn, simultaneously increasing the bank angle to follow the leader. As the bank increases, the wingman increases the speed of the engines and occupies the position above the leader in one and the same plane (Fig. 96). In the course of the

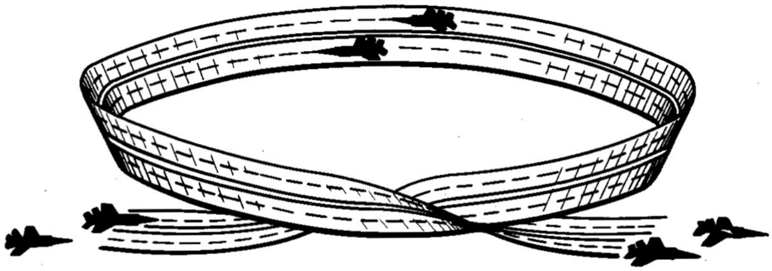


FIG. 96. DIAGRAM SHOWING EXECUTION OF 360° TURN IN PAIR

turn the wingman must maintain the interval by changing the amount of bank and deflecting the pedals. The distance between aircraft is maintained by varying the speed of the engines or extending the air brakes. The wingman aircraft is kept in its proper position in one and the same plane with the leader by increasing or diminishing the aircraft rotational speed.

To recover the aircraft from the turn, the leader first gives a respective command and then starts to smoothly recover the aircraft from the turn. The wingman follows the leader's maneuver by deflecting the control stick in the direction reverse to the banking motion and applying forward stick pressure to force the aircraft to follow the lowering wing of the leader aircraft. To maintain the assigned distance, slightly decrease the engine speed.

Recovery from the turn towards the wingman should be performed in a smooth manner. During fast recovery the wingman can lose the leader aircraft out of sight.

Should the leader aircraft be lost out of sight during the turn or when recovering from it, the wingman must perform a climbing break-off in the outer direction and report this to the leader. On noticing the leader aircraft and obtaining the respective permission, the wingman should join up the leader, following the established procedure.

Turns (360° turns) towards the wingman. Entry into a turn should be effected by the wingman with due reference to the leader aircraft by deflecting the control stick in the direction of the turn to obtain the required bank and applying forward stick pressure to make the aircraft follow the lowering wing of the leader aircraft. The procedures for maintaining the parameters of the combat formation are similar to those involved in performance of the turn towards the leader. On obtaining the leader's command for recovery from the turn, the wingman correspondingly diminishes the bank angle and simultaneously accelerates the engines proportionately to the displacement of the leader aircraft and assumes the stepped-down vertical separation with respect to the leader aircraft.

Regroupings are used when a rapid change in the interval and distance during turning is required, as well as to occupy a more advantageous attitude, for instance, when the sun prevents the wingman from observing the leader aircraft. For the training purposes, regrouping should be effected with the leader in straight flight.

To regroup the aircraft in a loose formation from the left echelon to the right one and vice versa, the leader gives a command for regrouping either over the radio or by changing aircraft attitude and continues flight at the pre-established speed.

The wingman slightly decelerates the engines, assumes the vertical separation of 20 to 30 m with respect to the leader aircraft, increases the distance between the aircraft, and gradually shifts to the other side by coordinatedly applying both stick and pedal pressure at a bank of 5 to 10°. When regrouping, the wingman should watch the leader aircraft at all times. Regrouping completed, the wingman increases the engine speed and establishes the assigned distance and then the interval (Fig. 97).

In all the cases getting into the wake produced by the leader aircraft must be avoided by the wingman during regrouping in formation.

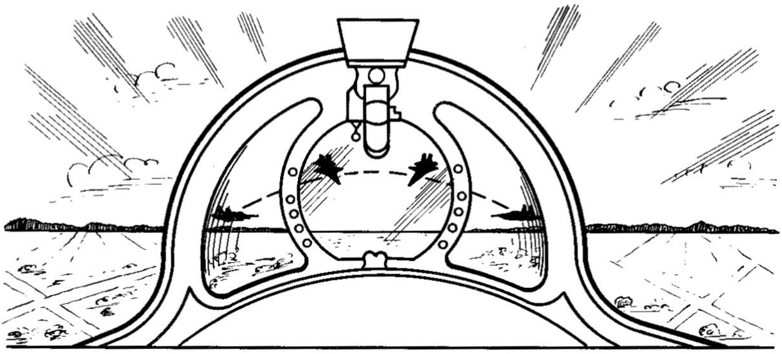


FIG. 97. CHANGE IN LEADER ATTITUDE DURING REGROUPING AT MEDIUM AND HIGH ALTITUDES

Regrouping at altitudes below 1000 m should be effected by the wingman with his aircraft elevated by 30 to 50 m with respect to the leader aircraft.

Diving. Twin entry into the dive (Fig. 98) is effected from the turn both with retracted and extended air brakes.

Initially, the flying personnel should be trained for entry into the dive by turning the aircraft off the wingman. Furtheron, the pilots should be trained for performing dive entry by turning the aircraft towards the wingman.

The assigned power setting established, the leader must bring the aircraft into a horizontal turn with subsequently bringing the aircraft into a descent by smoothly manipulating the controls. In the course of the turn the leader establishes the assigned dive angle. The wingman enters the dive following the leader and in the second half of the turn assumes a position 10 to 15 m below the leader aircraft.

At the end of the dive entry prior to bringing the aircraft into a straight leg of the dive, if recovery from the roll is rapidly effected by the leader, the wingman may fail to occupy the required vertical separation and lose the leader out of sight due to screening by the fore fuselage of the wingman aircraft.

The leader should take this probability into account and pilot the aircraft in a smooth manner so as to enable the wingman to effect the required vertical separation.

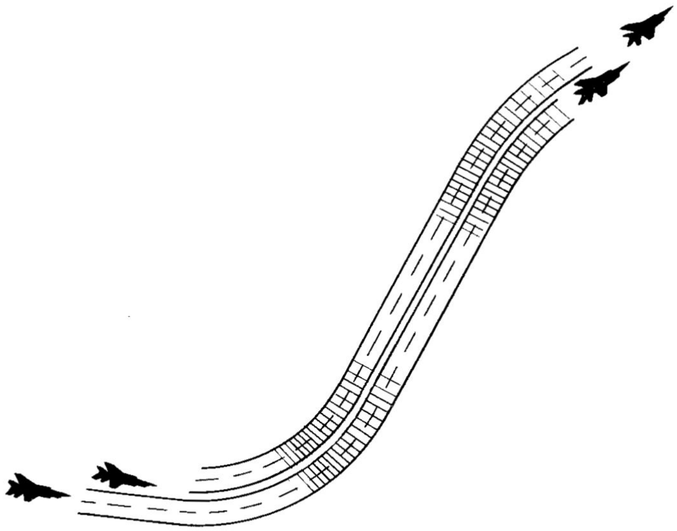


FIG. 98. DIAGRAM SHOWING EXECUTION OF DIVING IN PAIR

With the leader lost out of sight during dive entry, the wingman must abort dive entry, double look-out, break off the leader in the safe direction, and immediately report this to the leader.

Should the leader be lost out of sight in dive straight leg, the wingman must effect dive recovery without changing flight direction and report this to the leader in proper time. On entering level flight the wingman is to report the flight altitude to the leader.

In dive the wingman maintains the preset distance by varying the thrust developed by the engines. Maintaining the required interval is effected by deflecting ailerons and rudders.

Dive recovery should be completed at the assigned altitude and speed not exceeding the dive recovery maximum permissible speed. The wingman must effect dive recovery simultaneously with the leader. Lagging behind the leader and extreme vertical separation should be avoided in order to maintain the assigned distance between the aircraft and prevent the aircraft from exceeding the assigned speed and g-load limitations.

The leader must commence diver recovery with due regard to a possibility of wingman lagging in a dive recovery in order to prevent the wingman from failure to attain a safe altitude after dive recovery.

In the event of wingman lagging behind the leader in dive recovery, a join-up maneuver should be effected in the straight leg upon completion of dive recovery. Such an error may occur as a result of the wingman response lag to accelerate the engines. To prevent this error, the leader must give a command to increase engine speed in proper time.

Zoom. Twin zoom may be performed either at maximum or augmented power settings at a bank of 40 to 45° (Fig. 99). To perform a zoom at maximum power setting the leader smoothly brings the aircraft into climb at the assigned airspeed and warns the wingman about it over the radio. The leader sets the throttle levers not against the MAXIMUM stop but leaves the wingman a speed reserve of 3 to 5%. The wingman, keeping watch of the leader, enters the zoom maintaining a vertical separation of 10 to 15 m by varying the climb angle. The interval is maintained by the wingman by deflecting the ailerons and rudders, whereas the assigned distance is maintained by either smoothly moving the throttle levers or extending the air brakes for a short period of time.

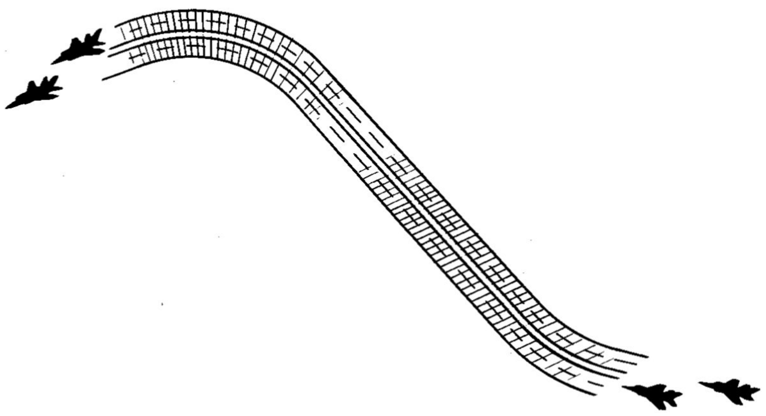


FIG. 99. DIAGRAM SHOWING EXECUTION OF ZOOMING IN PAIR

To perform a zoom at augmented power setting, the leader establishes the assigned speed, gives a command to turn on the afterburners, and brings the aircraft into climb. On ascertaining that the afterburners have been actually turned on, the leader selects partial augmented rating so as to leave a certain thrust reserve for the wingman. After the engine afterburners have been turned on the wingman performs a zoom entry, maintaining a vertical separation of 10 to 15 m with respect to the leader aircraft. The assigned distance is maintained by the insignificant displacement of the throttle levers from the FULL REHEAT stop or instantaneously depressing the air brake extension button without moving the throttle levers.

Recovery from the zoom is accomplished by turning the aircraft at an angle of 90°. The greater the zoom angle the greater the zoom recovery speed. In all cases the leader should recover from the zoom into a level flight so that the wingman aircraft flying speed be 100 to 150 km/h greater than the maneuvering speed.

When performing recovery from the zoom with turning the aircraft towards the wingman, the latter should carry out a turn together with the leader in one and the same plane. During performing the zoom recovery with turning the aircraft off the wingman, slightly reduce the interval, increase the vertical separation with respect to the leader up to 15 - 20 m, and perform the turn at the same radius as the leader. In case a zoom is performed at augmented rating, the afterburners must be turned off at the leader's command during zoom recovery in the second half of the turn.

Chandelle. A chandelle may be performed either at maximum or augmented power settings (Fig. 100).

To perform a chandelle at maximum power setting, the leader must establish the assigned airspeed, warn the wingman about it, and then establish gradually a climb angle of 10 to 15° to subsequently perform a turn. The aircraft bank angle should be gradually increased so that it may attain its maximum of 65 to 70° during the turn at an angle of 110 to 120°. The subsequent turn is performed by the leader at a continuously diminishing a bank and the leader smoothly brings the aircraft into level flight at an airspeed of at least 500 to 550 km/h. In the course of the entire maneuver the leader must leave a speed reserve of at least 3 to 5% for the wingman.

The wingman keeping watch of the leader also brings the aircraft into a chandelle, maintaining the distance between the aircraft by varying the engine thrust or extending the air brakes for a short period of time. The interval is maintained by changing the amount of bank and the rate of turning. When performing a chandelle towards the leader, the wingman on accomplishing a 90-degree turn directs the aircraft inwardly, if the thrust developed by the engines is insufficient for maintaining the assigned distance. The vertical separation with respect to the leader aircraft should be at least 20 to 25 m.

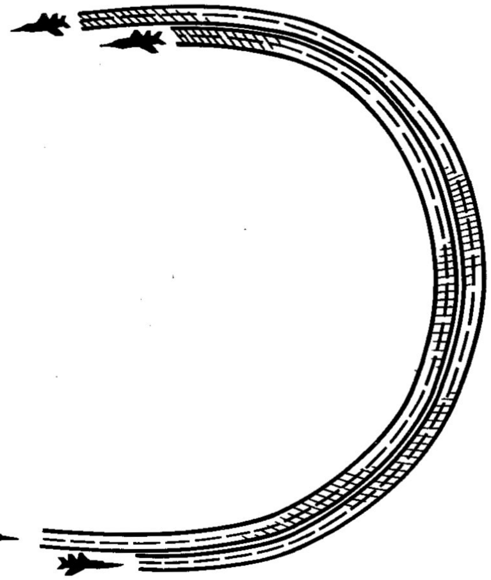


FIG. 100. DIAGRAM SHOWING EXECUTION OF CHANDELLE IN PAIR

To perform a chandelle at augmented rating, the leader gives a command to the wingman to turn on the afterburners prior to entering into chandelle. On turning on the afterburners the leader establishes partial reheat power setting, leaving a certain thrust reserve for the wingman. At the leader's command the wingman turns on the afterburners and brings the aircraft into chandelle with the stepped-down vertical separation of 10 to 15 m. The assigned distance between the aircraft is maintained by an insignificant displacement of the throttle levers from the FULL REHEAT stop or by instantaneously (1 to 2 s) depressing the air brake extension button.

The afterburners must be turned off on the command given by the leader after bringing the aircraft into level flight.

Spiral. To perform a spiral the leader in descent establishes an idle speed and gradually enters the spiral (Fig. 101). The wingman keeping watch of the leader must follow the leader and maintain the preset interval by varying the amount of bank. The distance established between the aircraft should be maintained either by varying the thrust developed by the engines or extending the air brakes for a short period of time.

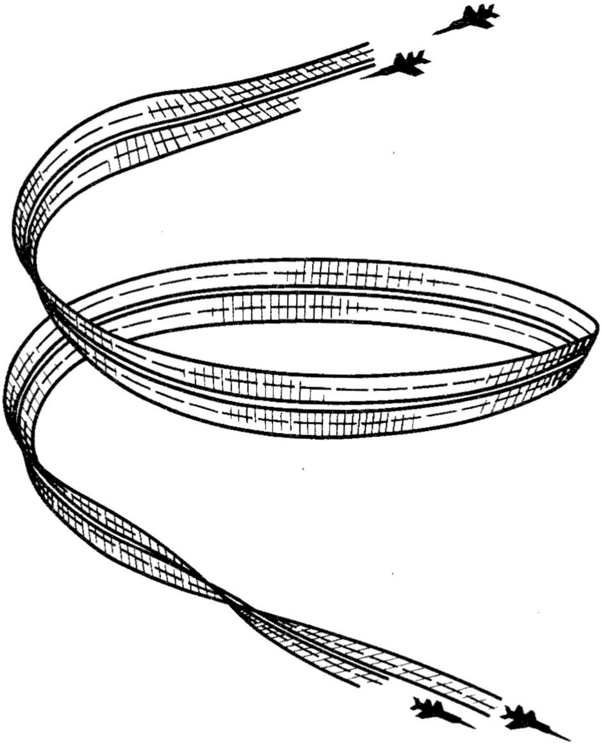


FIG. 101. DIAGRAM SHOWING EXECUTION OF DESCENDING SPIRAL IN PAIR

Should the wingman overtake the leader in spiral, the latter must slightly increase the engine speed and further continue performing the spiral at this power setting. To recover the aircraft from the spiral, the leader should first perform recovery from the roll, gradually increase the engine speed, and then bring the aircraft into level flight.

3. BREAK-UP FOR LANDING AND LANDING

The pair break-up is intended to ensure the assigned distance required for performing landing in single aircraft. The amount of this distance depends on meteorological conditions and the pilot proficiency in performance of landing at a minimum time interval. The landing interval is established by the commander. It must be selected with the view of precluding any possibility of getting into the aircraft wake, as well as ensuring safety during landing roll.

To break up for landing the leader must regroup the wingman either in the left or right echelon in advance depending on the traffic circuit. In case of the right traffic circuit the echelon should be left and vice versa. The leader brings the pair of aircraft slightly to the left or to the right with respect to the runway on the landing course at a traffic circuit altitude or at the altitude determined by the flying control officer. When approaching the runway the leader must request the flying control officer for permission to break up for landing. On obtaining the permission, the leader gives a command to break up, performs a 180-degree turn and proceeds towards the area of the turn onto base leg.

In the initial training stage, the leader ought not to perform a break-up for landing earlier than when abeam the beginning of the runway so as to give the wingman an opportunity to correctly estimate the route by referring to the runway.

After the leader has accomplished a turn-away the wingman continues a straight flight for the half of the safe time interval assigned for landing and then follows the leader. The wingman must give particular attention to other aircraft which may enter the traffic circuit on a tangent to the turn on the downwind or base leg.

Breaking-up completed, the pilots should independently proceed on the landing course and perform landing in single aircraft.

SECTION FLIGHTS

1. TAKEOFF AND JOIN-UP

Section takeoff may be accomplished either in single aircraft or in pairs depending on the width of the runway, meteorological conditions, and pilot proficiency of flying personnel.

Prior to takeoff the pilots of the section taxi the aircraft onto the runway and occupy the positions at the preestablished intervals and distances between aircraft (Fig. 102).

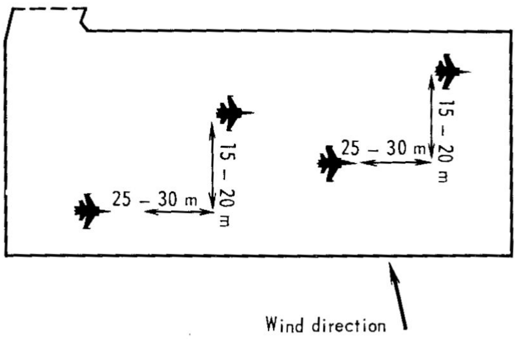


FIG. 102. ARRANGEMENT OF AIRCRAFT ON RUNWAY PREPARATORY TO TAKEOFF IN SECTION

All the pilots should report readiness for takeoff to the section commander in a consecutive order.

Takeoff in single aircraft. On obtaining the readiness report of the second pair wingman, the section commander requests takeoff clearance from the flying control officer. On obtaining the permission the section commander performs takeoff in accordance with the routine procedures. The wingman pilots start to increase the engine speed to the maximum value beginning from the moment of the fore aircraft starting a takeoff run and wait for the flying control officer to give a command for takeoff, holding the aircraft on the brakes. The flying control officer gives a command for takeoff of the next aircraft at the assigned time interval. On obtaining the command for takeoff given by the flying control officer, the wingman pilots perform takeoff in a consecutive order.

Join-up is effected first in pairs and then in the section. To this end, the leaders decrease the aircraft speed after takeoff and give an opportunity to the wingman pilots to join up. The section commander gains altitude at a small rate of climb, slightly extending the route towards the turn on the cross-wind leg so as to be able to effect it at an altitude of 1500 to 1800 m and bank of not more than 25 - 30°. Join-up of the pair completed, the leader of the second pair slightly increases the engine speed and joins up the leading pair. Should there be no possibility to join up the leading pair in straight flight up to the turn on the cross-wind leg, the leader of the second pair should increase a bank angle, take a short route, and join up the leading pair in straight flight leg upon completion of the turn on the cross-wind leg. In order not to lose the leading pair out of sight, the wingman pair should effect a turn with a stepped-down vertical separation of 75 to 100 m with respect to the landing pair.

Takeoff in pairs. On obtaining the respective permission the leading pair effects takeoff in accordance with the routine procedures. The pilots of the wingman pair hold the aircraft on the brakes and accelerate the engines to maximum power setting beginning from the moment the leading pair starts taking off. The flying control officer must give commands allowing takeoff at the assigned time interval. On these commands the wingman pair performs takeoff.

After takeoff the wingman pair pursuits the leading pair and joins it up.

After the specified position in the section formation has been taken the leader of the second pair reports this to the section commander.

2. MANEUVERING AND REGROUPING OF SECTION

Section flying is associated with certain difficulties which are most likely to be encountered by the wingman pair and consisting in that in order to keep ones place in the formation, the pilots should more frequently and vigorously vary the engine speed, use the air brakes and maintain the required vertical separation (elevation) in regrouping, maneuvering, etc.

Each wingman trying to maintain his position in the formation as correctly as possible frequently changes the direction of flight and moves the throttle levers. Therefore, outer wingmen should not react to all minor changes in the attitudes of the leading aircraft. Otherwise, they will have to continuously vary the engine power settings, manipulate pedals and use the air brakes. They are to react only to such changes in flight conditions that result in a considerable change in the assigned distances and intervals or endanger flight safety. All changes in attitude and maneuvers are to be effected by the section in the same manner as by the pair but more smoothly. Apart from the above said, the speed reserve left for the outer wingman should be more than that required for pair maneuvering in order to maintain the combat formation of the section in maneuvering.

When performing turns in the pair echelon combat formation, the wingman pilots should assume the positions either below or above the leader in one and the same plane depending on the direction of the turn to be performed. The responsibility of the wingmen is to carry out all the commands given by the leader in a precise and synchronous manner while being both on the right and left side relative to the leader. Therefore, when mastering team flying, it is essential that the wingman pilots (pairs) be trained for acquiring skill in regrouping and performing flight both on the left and right sides with respect to the leader (leading pair).

In training flights regrouping from one combat formation into another should be effected in a definite sequence and until each pilot has become skilful in performing the above maneuver.

The sequence for regrouping the aircraft in a combat V-formation, when the wingman pair is on the right side with respect to the section commander and his wingman is on the left side, into a right pair echelon is as follows. The wingman pair increases the distance and interval relative to the leader by 300 to 400 m leaving space for the section commander's wingman who assumes the required stepped-down vertical separation and brings the aircraft to the right side. This completed, the wingman pair establishes the prescribed distance and interval.

To regroup the aircraft from the combat V-formation into the left pair echelon formation, the leader of the second pair shifts to the left at a distance of at least 200 m and stepped-down vertical separation of 30 to 50 m with respect to the wingman of the first pair and assumes the position in the formation initially at increased distance and interval. His wingman also assumes the position with a stepped-down vertical separation of 30 to 50 m with respect to his leader. After the regrouping of the second pair wingman into the left echelon has been completed, the leader must take his place in the combat formation of the section.

Regrouping of aircraft from the left pair echelon into the right one is effected by shifting the aircraft to the right in a consecutive order beginning from the section commander's wingman. To regroup the aircraft, all the wingmen assume a distance of 200 to 500 m and then shift to the opposite side. When regrouping the aircraft from right pair echelon into a combat V-formation, the section commander's wingman only shifts to the left. The succeeding pair keeping to the right establishes the assigned distance and interval.

3. SECTION BREAK-UP FOR LANDING

The section landing is performed in single aircraft. Prior to a landing break-up, the section commander regroups the flight into either a right or left pair echelon in advance depending on the traffic circuit.

The section should approach the landing break-up point at either the traffic circuit altitude or altitude established by the flying control officer.

When approaching the runway boundary on a landing course, the section commander must request the flying control officer for permission to perform break-up for landing. On obtaining the respective permission the section commander gives a BREAK-UP (РОСПУСК) command and performs a 180-degree turn toward the area of the turn onto base leg. The wingman pilots proceed on the straight flight course for a half of the assigned time, interval for landing. On expiration of half of the time interval each pilot performs a 180-degree turn towards the area of the turn onto base leg, independently flies the route and performs landing.

In order to prevent the succeeding aircraft getting into the wake produced by the leading aircraft upon completion of the final turn as well as aircraft collision during landing roll, the section pilots performing landing in single aircraft at the minimum time intervals are advised to follow the procedure given below:

(a) under headwing conditions the leaders of both pairs are to glide along the left-hand side of the runway and their wingmen along the right side;

(b) in crosswind (left or right) conditions all the section aircraft must glide along the runway centre line;

(c) after touchdown each pilot must deploy drag chutes, decelerate the aircraft to a speed of 80 to 120 km/h, and start gradually shifting at this speed close to the centre line of that half of the runway from which the aircraft is going to be taxied out. Thus, the outer half of the runway is left clear to provide for the landing safety of the aircraft rolling at an increased speed as well as in the event of drag chute deployment failure or rupture.

4. PECULIARITIES INVOLVED IN TWIN AND SECTION FLIGHTS AT SUPERSONIC SPEEDS

Flights in stratosphere at supersonic speeds in the pair and section formations as compared to the flights at low, medium, and high altitudes present considerable difficulties which arise due to the following:

(1) deterioration of aircraft maneuverability;

(2) increase of aircraft sluggishness;

(3) existence of shock wave;

(4) limited thrust reserve for wingman pilots required for maintaining the assigned position in the combat formation;

(5) limited visibility for all the pilots of the formation when flying in pressure helmets;

(6) slightly increased excitability of pilots (as a rule);

(7) limited vertical visibility and deteriorated visual orientation conditions;

(8) increased fuel consumption and, as a consequence of this, the necessity in constantly checking fuel remainder.

In view of the limited maneuverability of the aircraft and increased aircraft sluggishness, the pilots of the succeeding aircraft should be more attentive in following the changes in the leader attitude and react to these changes in due time in order to maintain the position in the formation. The assigned interval must be maintained in formation flight at supersonic speed by coordinated movements of the ailerons and rudders. Turns at supersonic speed must be effected with a slight decrease in the preset intervals and, if necessary, changing ones place in the course of a maneuver.

Formation flights at supersonic speeds is characterized by the existence of shock waves following the aircraft. The strongest effect of the shock waves is sensed as shocks and "shaking" when overtaking the leading aircraft.

G-loads imposed on the aircraft and pilot as a consequence of the shock wave effect are insignificant. Shaking also has a neglegible effect on the aircraft control. Nevertheless, shock waves may deteriorate the steady operation of the powerplant. In this connection, overtaking of a fore flying aircraft at an interval of less than 200 m is not allowed.

When flying the aircraft in the pressure helmet the leader pilot is practically deprived of the opportunity to visualize the wingman. This places a stringent responsibility on the wingman in the sense of keeping the assigned position in the formation and providing for the formation flight safety.

Supersonic flights must be performed in accordance with the pattern adopted for a given aerodrome. The formation must enter the acceleration initiation point in loose formation at a non-reheat ceiling of the group. On attaining the point of acceleration starting the command post controller gives a command to turn on the afterburners. Having checked the group for maintaining the assigned combat formation, the leader gives command REHEAT. The wingmen turn on the afterburners at the command given by the section commander, not by the controller at the command post, and report the matter to the formation leader.

After the turning-on of the afterburners, the leader moves the throttle levers through about a quarter of the adjustable reheat travel in order to leave the wingman (wingmen) the thrust reserve required for maintaining the position in the combat formation. The wingman (wingmen) maintains the distance in the combat formation by moving the throttle levers within the limits of the partial augmented rating and extending the air brakes.

The assigned interval when flying at supersonic speeds is maintained by coordinated manipulation of the ailerons and rudders.

Afterburners should be turned off by the command of the leader. Afterburners cut off, the leader starts to descend, decreasing the indicated speed. The wingmen keep their places in the formation by varying the engine speed or applying the air brakes.

Thus, proceeding from the peculiarities of the formation flight, the combat formation parameters, i.e. the distance and interval, when flying the aircraft in the stratosphere at supersonic speeds, must be in excess of those pertaining to formation flights at medium and high altitudes. Such a requirement is dictated above all by the peculiarities involved in the combat employment of the interceptor-fighters in the stratosphere consisting in that missile launching is effected at maximum ranges to a target.

For these reasons, pilots will have to maintain considerably greater intervals as compared to those involved in flights at high and medium altitudes in order to succeed in individual aiming.

FORMATION FLIGHTS IN IFR CONDITIONS

From the viewpoint of both the methods of training and flying technique formation flights under IFR weather conditions present the greatest difficulties for those under combat training. To succeed in performing IFR formation flights, the flying personnel must be perfectly skilled in piloting aircraft in clouds as well as in the combat formation under VFR weather conditions.

Safety of formation flight under IFR weather conditions is ensured by the following:

(1) strict maintaining of takeoff and break-up time intervals;

(2) maintaining of the required speed, direction, and amount of bank during turns;

(3) maintaining assigned engine power settings during cloud break-through (upward);

(4) maintaining of vertical and translational speeds during downward cloud break-through;

(5) adequate condition of aircraft;

(6) proper actions of formation leaders and flying control officers;

(7) reliable operation of the airborne and ground equipment;

(8) high sense of responsibility of both the flying and command personnel for preparation and safety of flights.

Safety of flights under IFR weather conditions during the sequential breaking of clouds by a single aircraft or pairs along one and the same preset trajectories is ensured through maintaining the assigned time interval.

The safe time interval must preclude any possibility of overtaking the aircraft (pair) flying in clouds. The amount of the safe time interval t_{safe} is determined with the aid of the following equation:

$$t_{safe} = \frac{2\Delta V}{V} t,$$

where: ΔV - maximum possible deviation of the flight speed from the assigned speed, km/h;

V - translational speed of climb (descent), km/h;

t - time from the moment of takeoff (beginning of cloud break-through) till the moment of attaining the altitude of the assigned flight level or time from the moment of beginning of descent until reaching the outer beacon, s.

In calculating the safe time interval one should take into account not only the amount of mistakes made by the pilot but also make allowance for the airspeed indicator reading error which may exceed that committed by the pilot when flying at high speed. Considering this fact it is recommended for all categories of flying personnel that the amount of maximum deviation of flying speed from the assigned one be assumed as equal to 50 km/h in upward break-through and 35 km/h in downward break-through. Lower indicated speeds in descent correspond to lesser error values.

Table 8

Safe Time Intervals for Breaking Clouds, s

Flight altitude, m	t_{safe} (upward)	t_{safe} (downward)
1000	15	30
2000	20	30
3000	20	30
4000	20	40
5000	30	40
8000	40	50

Given in Table 8 are the values of the safe time intervals to be observed in both upward and downward cloud break-through. The figures given in the table are carried over to the nearest whole numbers for practice purposes.

For downward cloud break-through the above given values of the safe time interval between aircraft should be maintained in the event of break-up at the preselected line. In the event of the formation break-up on the course reverse to the landing one, each subsequent aircraft starts a turn to intercept the landing course on expiration of the time period equal to half the safe time interval.

1. TWIN FLIGHT

The upward cloud break-through on the МиГ-25П interceptor-fighters can be performed in pair subsequently in single aircraft or in pair in loose formation.

Upward cloud penetration subsequently in single aircraft is commonly conducted in the initial stage of training flying personnel for performing twin flights under IFR weather conditions as well as for performing takeoff under minima or below the assigned weather minima.

The wingman should start a takeoff run on the command of the flying control officer and on expiration of the assigned safe time interval beginning from the moment of the leader takeoff run start. Failure to maintain the assigned takeoff intervals is a typical mistake. On attaining an altitude of 1000 m both pilots turn off the afterburners and continue climbing at maximum power setting. When climbing, the pilots of the pair must maintain one and the same heading and translational speed.

On breaking through clouds and attaining an altitude of 500 m below the assigned join-up level, the pilots establish level flight conditions and report the matter over the radio. A typical mistake committed is failure to maintain the assigned speed and direction during upward cloud penetration. Wingmen sometimes intentionally decrease the translational speed to avoid overtaking of the leader or slightly depart from the cloud break-through course. This may result in a considerable increase in the time required for join-up.

Pair join-up in over-the-top flights is effected either in a loop or by varying the airspeed.

T o p e r f o r m j o i n - u p i n t h e l o o p, on receiving the report of the wingman about gaining an altitude 500 m below the assigned flight level, the leader gives command LEFT (RIGHT) TURN and starts to turn the aircraft to intercept the course to the outer beacon, climbing to the assigned flight level. The wingman must perform a turn towards the outer beacon on expiration of the time equal to a half of the safe time interval without gaining an altitude and counting the interval beginning from the moment of obtaining TURN command (Fig. 103).

In the course of the turn or upon completing it the wingman must detect the location of the leader and perform regrouping on a straight line.

Climbing to an altitude of the assigned flight level by the wingman is allowed only after the leader has been detected. Pair join-up should be reported by the leader to the flying control officer or the command post controller.

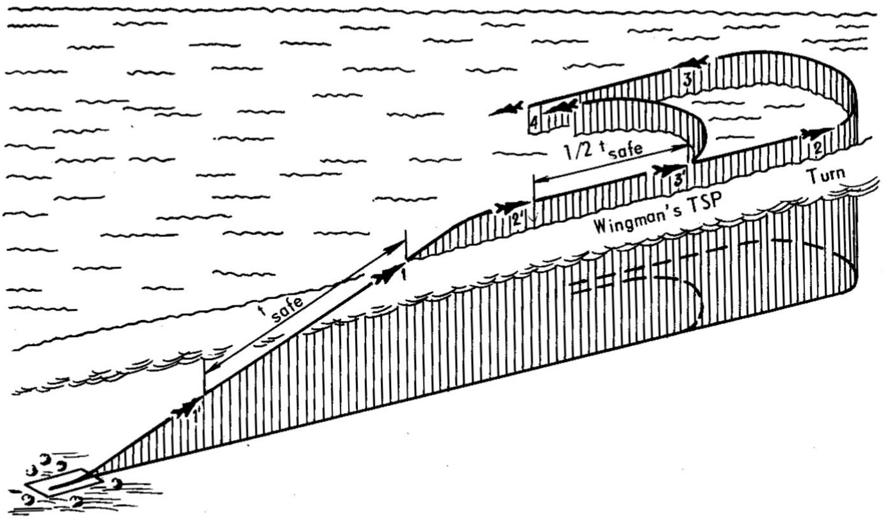


FIG. 103. PAIR JOIN-UP IN LOOP DURING UPWARD CLOUD PENETRATION SUCCESSIVELY IN SINGLE AIRCRAFT IN SAME DIRECTION

A typical error usually committed when performing join-up in a loop is wingman failure to maintain the assigned time interval on receiving the TURN command as well as failure to hold flight altitude due to the diversion of the wingman's attention while he is in search for the leader.

To join up by varying flight speed, on breaking through clouds and climbing to the assigned join-up level, the leader starts to fly level at an indicated speed of 500 to 550 km/h. On breaking through clouds the wingman starts to fly level at an altitude of 500 m below the assigned flight level and true airspeed of 900 km/h (with join-up level being less than 6000 m) or 1000 - 1100 km/h (with join-up level being above 6000 m). To detect the leader in performing join-up by varying the airspeed, the wingman may use the radar sight. On visually detecting the location of the leader, the wingman should decrease the flying speed and join him up. Pair join-up completed, the leader must report this to the flying control officer or the controller at the command post.

Cloud breaking in pair in loose formation is used provided that the pilots involved are sufficiently experienced in performing formation flights under IFR weather conditions and in weather not below the assigned minima. Perform takeoff in pair. On attaining an altitude of 150 to 200 m and retracting the landing gear and the wing flaps the wingman must perform an outside turn through an angle of 15° and report this to the leader. Climbing should be effected by both pilots at the assigned speed. On attaining an altitude of 1000 m the pilots must turn off the afterburners. At an altitude of 3000 m the wingman must perform a corrective turn to intercept the course parallel to that of the leader.

Breaking through clouds and attainment of the assigned altitude should be reported to the flying control officer. On making the report the pilots must level off the aircraft. In this case, the wingman should fly the aircraft at an altitude 500 m below the leader's flying altitude. On visually detecting the leader, the wingman must perform regrouping. Very thick clouds, bumpiness, and etc. considerably diminish the probability of join-up. In view of such conditions, the command post controller must always be ready to render help to the pilots to speed up their join-up by giving appropriate commands.

2. TWIN BREAK-UP BEYOND CLOUDS

The assigned mission accomplished, it is necessary to approach the line of descent or the outer beacon and fly the maneuver to ensure pair break-up and subsequent downward cloud penetration in single aircraft. Break-up of the pair of the МиГ-25П aircraft beyond clouds may be effected either in the loop or on the descent initiation line.

Break-up of pair when executing the loop is effected during landing approach by performing the maneuver "turn to the estimated angle" (Fig. 104). The outer beacon passed and the turn to the estimated angle completed, the leader should start the stop-watch and perform a joint flight to the point of turn to hit the landing course. On expiration of the estimated time, the leader should give the BREAK-UP command and further execute the assigned maneuver to perform a straight-in approach. The wingman performs the corrective turn together with the leader to intercept the course reverse to the landing one, starts the stop-watch on the BREAK-UP command and performs the turn to intercept the landing course on expiration of the time period equal to the half of the safe time interval. Landing course turn completed, the wingman should increase the duration of the level flight leg by the half of the safe time interval.

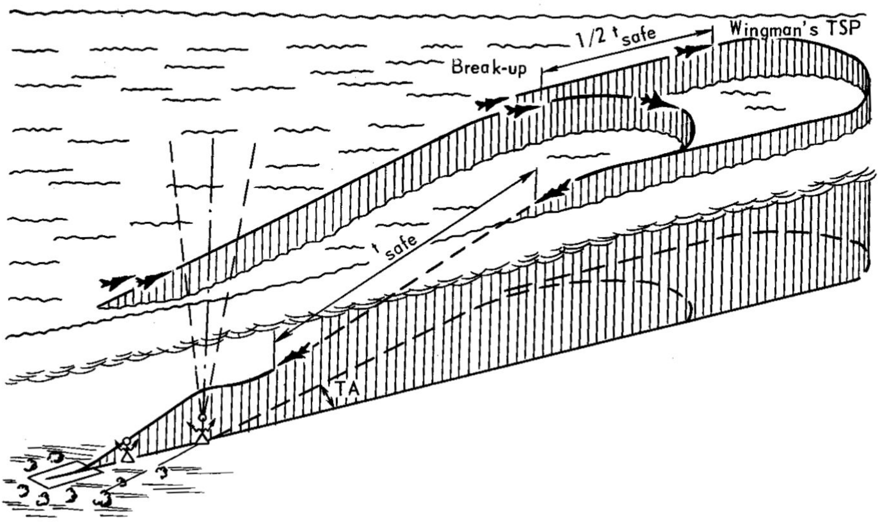


FIG. 104. PAIR BREAK-UP IN LOOP

The turn to intercept the landing course must be effected by both pilots at a bank of 30^{o}.

Break-up of pair on descent line may be effected for the purpose of breaking through clouds from any direction relative to the runway centre line or for break-through to hit the estimated glideslope point.

To ensure pair break-up for break-through from any direction with respect to the runway centre line, the command post controller must lead the pair to the break-up line after having ascertained that the pair proceeds in the combat formation appropriate for break-up (Fig. 105).

On obtaining the command to proceed to the break-up line, the leader establishes an indicated speed of 600 km/h. At a distance of 20 to 25 km to the break-up line the command post controller gives the pair a command to perform a turn to RB = 90° (270°) at a bank of 45°. On attaining RB = 90° (270°), the leader gives the BREAK-UP command, performs a corrective turn rightward (leftward) to take the course to the outer beacon and establishes the assigned descending mode, maintaining RB = 0°.

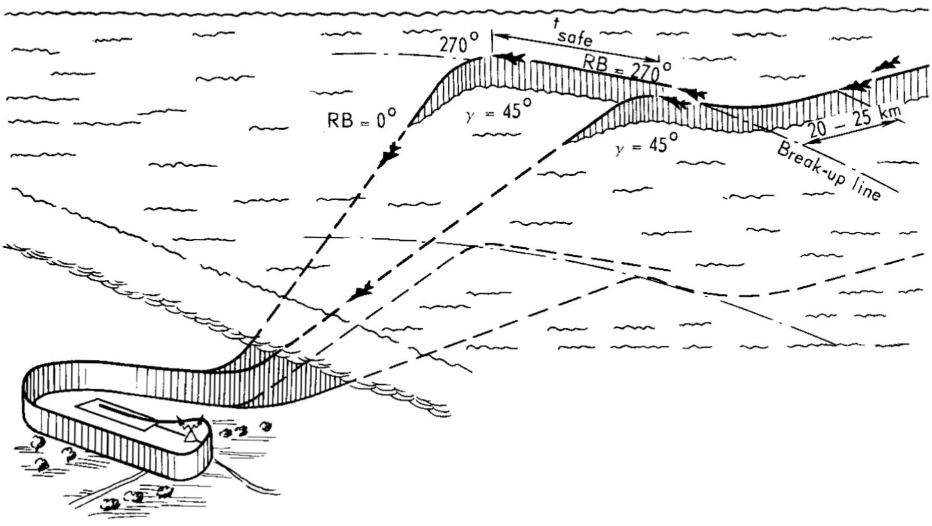


FIG. 105. PAIR BREAK-UP ON DESCENT LINE FOR DOWNWARD CLOUD PENETRATION FROM ANY DIRECTION

After downward cloud penetration the leader must visually detect the airdrome and join the circuit to hit the nearest turn. The wingman continues flying at RB = 90° (270°) for a period of time equal to the safe time interval and then repeats the actions of the leader.

This method is used in case of high cloud bottom with the maximum elevation of the terrain in the area of flights taken into consideration.

To ensure pair break-up for break-through to hit the estimated point of glideslope descent, at a distance of 20 to 25 km to the break-up line the command post controller gives the pair a command to perform the turn to hit the course perpendicular to that of descent upon completion of regrouping the pair into the respective echelon formation (Fig. 106). Further, the leader gives a BREAK-UP command, takes the assigned course and establishes the rate of descent. Breaking-up completed, the wingman proceeds along the straight line for a period of time equal to the safe time interval, and then performs a turn to intercept the break-through course assigned by the command post controller. Furtheron, the wingman repeats the actions of the leader.

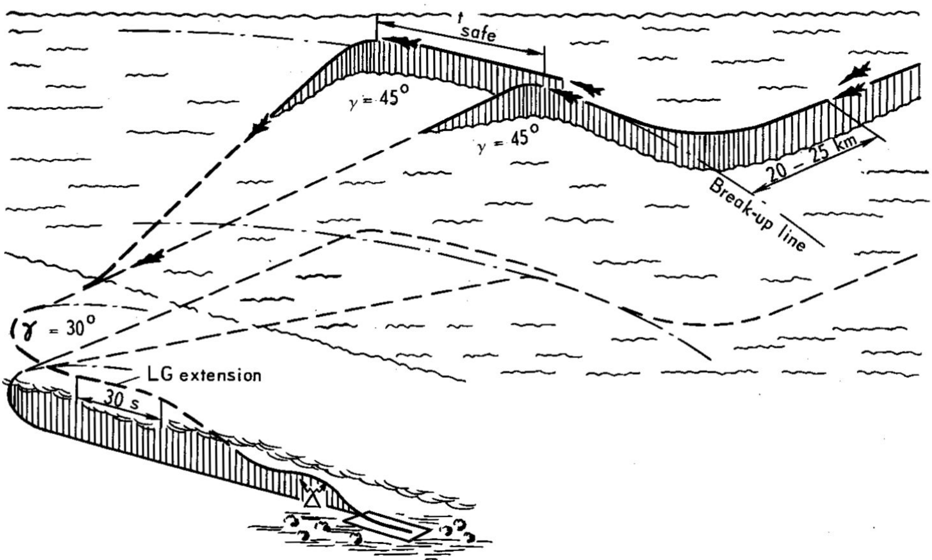


FIG. 106. PAIR BREAK-UP ON DESCENT LINE FOR DOWNWARD CLOUD PENETRATION TO HIT ESTIMATED POINT

As the pair descends the command post controller (ground-controlled approach team) should introduce corrections in the heading and rate of descent of the aircraft proceeding to the estimated point.

The landing gear should be extended after performing a turn to hit the landing course within a 30-sec leg.

3. SECTION FLIGHTS

Upward cloud penetration is effected by a section of the МиГ-25П aircraft successively in single aircraft or in pairs in the loose combat formation.

Upward cloud penetration successively in single aircraft is commonly made use of in takeoff under weather minima or below the weather minima, as well as under such circumstances when the condition of the runway makes it impossible to carry out takeoff in pairs. Such being the case, the section should take off in single aircraft at a safe time interval.

The wingmen start the takeoff run on the command of the flying control officer on expiration of the assigned time interval beginning from the moment of start of the preceeding aircraft. On attaining an altitude of 1000 m the pilots should turn off the afterburners and continue climbing at maximum power setting. After break-through beyond the clouds and gaining an altitude of 500 m below the assigned flight level the pilots bring their aircraft into level flight and report the matter over the radio.

When joining up in a loop, on obtaining the report from the wingman of the second pair on attainment of the assigned altitude, the section leader gives the LEFT (RIGHT) TURN command and performs a turn towards the outer beacon and climbs to the assigned flight level (Fig. 107). The wingman of the section leader performs a turn to the outer beacon on expiration of a time period equal to the half of the safe time interval. For the leader and his wingman of the second pair the waiting time is increased by 50% and the total safe time interval, respectively.

In the course of the turn or upon completion of the turn the wingmen must find the preceeding aircraft and join them up on the straight line successively.

Upward cloud penetration successively in pairs in loose formation is performed as follows. The section takeoff is performed in pairs at a safe time interval. When aloft, each pair performs cloud penetration in loose combat formation, with the wingman performing an outside turn through an angle of 15^{o}.

Section join-up beyond the clouds is initially effected in pairs. Furtheron, the succeeding pair should join up the preceeding pair in a loop or by varying the flight speed (Fig. 108).

To ensure the section join-up in the loop, the preceeding pair on attaining the assigned altitude continues flight over a period of time equal to the half of the safe time interval and then performs a turn to the outer beacon. The succeeding pair on climbing to an altitude 500 m below that of the preceeding pair performs a turn to the outer beacon in the horizontal plane. Upon completion or in the course of the turn the pilots of the succeeding pair must visually detect the preceeding pair and join them up on a straight line. Section join-up completed, the section leader reports this to the flying control officer or the command post controller.

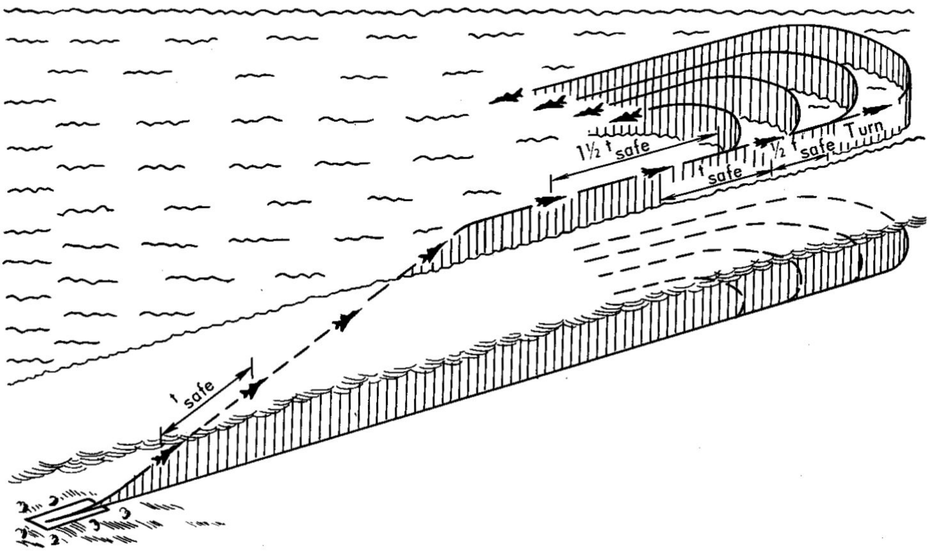


FIG. 107. SECTION JOIN-UP IN LOOP DURING UPWARD PENETRATION IN SINGLE AIRCRAFT IN CONSECUTIVE ORDER IN SAME DIRECTION

To ensure s e c t i o n j o i n - u p b y v a r y i n g f l y i n g s p e e d , the preceeding pair proceeds in level flight at an indicated speed of 500 to 550 km/h on breaking through the clouds and climbing to the assigned flight level. The succeeding pair must climb to an altitude 500 m below the preceeding pair establishes a true airspeed of 900 km/h in level flight (with the join-up level being less than 6000 m) or 1000 - 1100 km/h (with the join-up level established being above 6000 m).

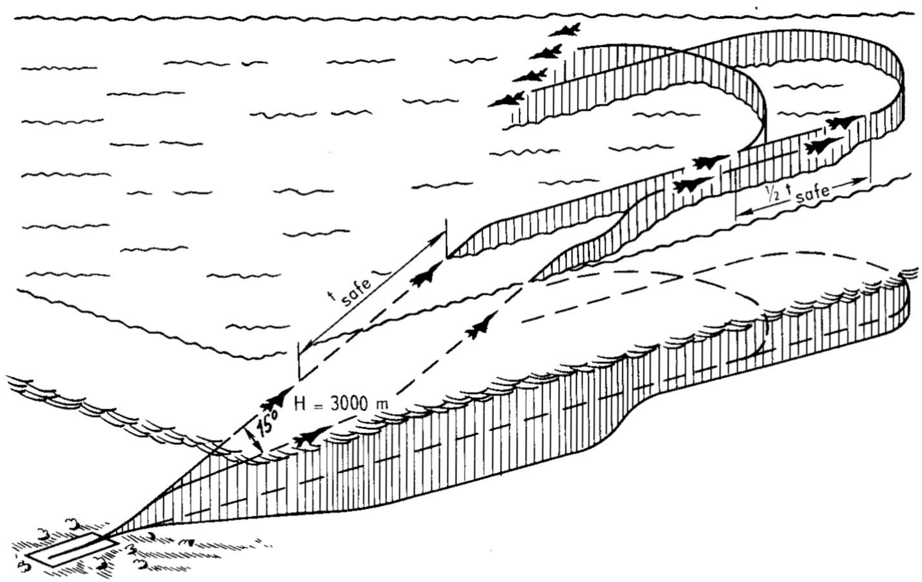


FIG. 108. SECTION JOIN-UP IN LOOP DURING UPWARD CLOUD PENETRATION SUCCESSIVELY IN PAIRS, IN LOOSE FORMATION AND IN SAME DIRECTION

The preceeding pair visually detected, the succeeding pair decreases the flying speed and joins up the preceeding pair. Section join-up completed, the section commander reports this to the flying control officer or the control post.

4. SECTION BREAK-UP BEYOND CLOUDS

The mission accomplished, the section commander leads the formation either to the descent initiation line or to the outer beacon and executes a maneuver to perform section break-up and further downward cloud penetration in single aircraft. The procedure for section break-up beyond the clouds is similar to that involved in the pair break-up in the loop or on the descent initiation line.

Section break-up in a loop is used during landing approach by performing maneuver "turn to estimated angle" (Fig. 109). On flying over the outer beacon and turning to the estimated angle, the section commander must start the stop-watch, perform a corrective turn to hit the course reverse to the landing one on the expiration of the estimated time and give the BREAK-UP command. Further-on, he performs the assigned maneuver to ensure straight-in approach.

The wingman of the section commander starts the stop-watch upon completion of the turn to hit the course reverse to the landing one and receiving the BREAK-UP command. On expiration of the half of the safe time interval he repeats the maneuver effected by the section commander.

The pilots of the succeeding pair should start the stop-watches at the moment of the preceeding aircraft turning to the landing course or on the BREAK-UP command. The pilots of the succeeding pair must always proceed on the course reverse to the landing one for a time equal to the half of the safe time interval relative to the preceeding aircraft and then perform a maneuver for straight-in approach.

To properly maintain the safe time interval in descent, all the pilots should perform a turn to hit the landing course at one and the same bank.

After completing a turn to the landing course, the wingman of the section commander proceeds flying in level flight for a period of time equalling the half of the safe time interval. The leader of the second pair should proceed in level flight for a period of time equal to the safe time interval, whereas his wingman,

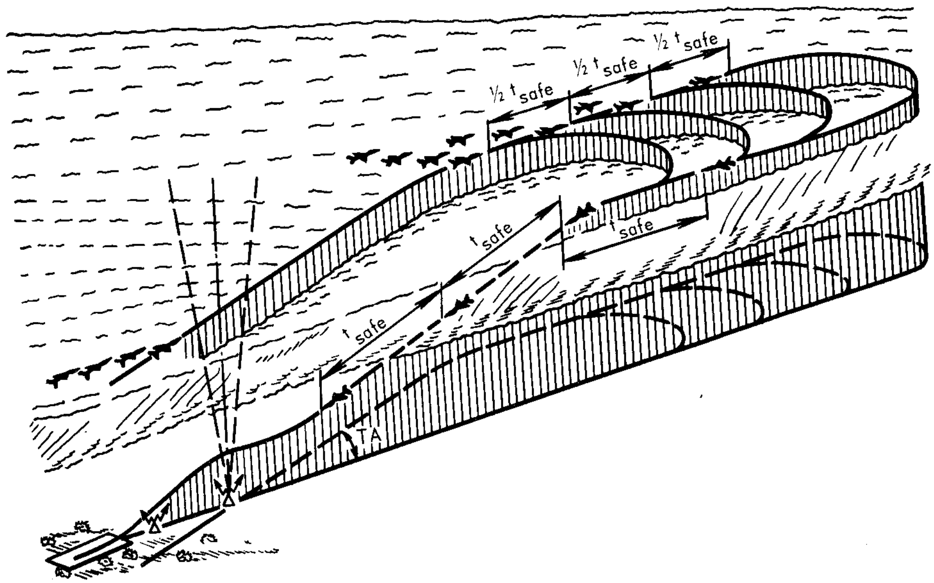


FIG. 109. SECTION BREAK-UP IN LOOP DURING LANDING APPROACH INVOLVING "TURN TO ESTIMATED ANGLE" MANEUVER

for a time equal to one and a half of the safe time interval. On expiration of the above said time the pilots must successively extend the landing gears, establish an airspeed of 550 km/h, and bring the aircraft into descent at the assigned flying regime.

Section break-up on the descent initiation line is performed to break clouds from any direction relative to the runway centre line or to break through clouds to hit the estimated point of glideslope descent.

To accomplish section break-up for breaking clouds from any direction with respect to the runway line, the command post controller gives a course to ensure section approach to the break-up line in an appropriate combat formation (Fig. 110). The section commander should regroup the section into the required echelon formation and establishes an indicated airspeed of 600 km/h.

At a distance of 20 to 25 km from the break-up line the controller at the command post gives command LEFT (RIGHT) TURN TO RB = 90° (270°). In response to this command the section must make a turn at a bank of 45°. With the instrument readings equal to RB = 90° (270°), the section commander gives the BREAK-UP command, makes a corrective turn towards the outer beacon and establishes the assigned rate of descent. On performing downward cloud penetration beyond the clouds the section commander should visually detect the airdrome and enter the traffic circuit to the nearest turn.

The wingman pilots proceeding on the course of RB = 90° (270°) successively perform turns towards the outer beacon at the safe time intervals with respect to the preceeding aircraft and then repeat the actions of the section commander.

This method is used when the cloud ceiling is high with due regard to the maximum terrain elevation in the flying area.

To accomplish section break-up for breaking through clouds to intercept the estimated point of glideslope descent, the controller at the command post brings the section to the break-up line. At a distance of 20 to 25 km from the break-up line the controller gives a command to the section to make a turn to hit the course perpendicular to the descent course. Further, the controller gives a command to break up and indicates the cloud penetration course (Fig. 111). Breaking up completed, the section commander performs a turn to intercept the assigned course and establishes the rate of descent. The wingman pilots proceed on the straight line for a period of time equal to the safe time interval with respect to the

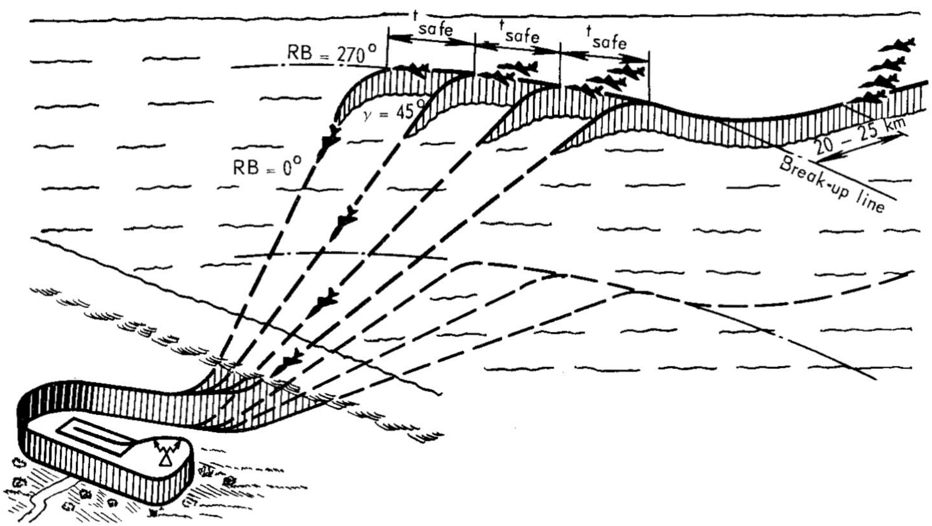


FIG. 110. SECTION BREAK-UP ON DESCENT LINE FOR DOWNWARD CLOUD PENETRATION FROM ANY DIRECTION

preceeding aircraft. On expiration of this period, the succeeding pilots successively perform a turn to hit the course assigned by the command post controller, and then repeat the actions of the section commander.

In view of the fact that in the course of formation flight at the break-up line the distance from the estimated point is commonly variable, the assigned flight courses and the vertical

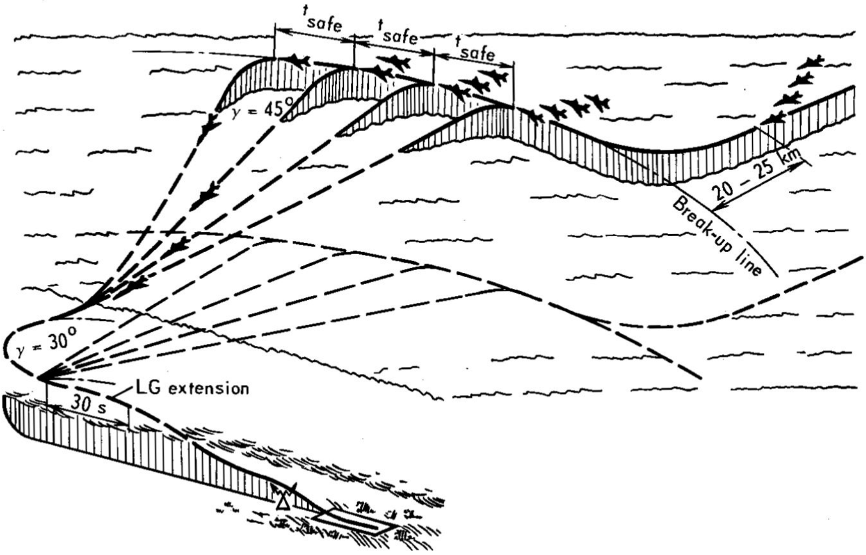


FIG. 111. SECTION BREAK-UP ON DESCENT LINE FOR DOWNWARD CLOUD PENETRATION TO HIT ESTIMATED POINT

speeds of descent to the estimated point may differ from each other. Therefore, the controller at the command post (ground-controlled approach post) must correct the flight course of each aircraft of the formation and the descent regime in the course of the formation descent to the estimated point.

RECOMMENDATIONS TO COMMANDER (INSTRUCTOR) ON TRAINING PILOTS IN FORMATION FLIGHTS

A successful accomplishment of a formation flight depends on the pilot proficiency of each pilot of the formation and the leadership of the formation leader.

The leader (commander) must:

(a) know the level of pilot proficiency of the wingman pilots and personally check their readiness to accomplish each formation flight;

(b) strictly maintain the assigned flight profile and regime; give distinct commands over the radio about changes in flight regime and maneuvers to be done prior to changing attitude;

(c) conduct continuous orientation, watch the actions of the wingmen and keep control over them;

(d) keep check of the fuel remainder in the aircraft of the formation;

(e) correctly evaluate the meteorological and air situation; take skilful decisions;

(f) carry out leadership during break-up and landing approach;

(g) effect thorough critique upon completion of the formation flight and point out all the mistakes committed during flight, especially those which have made the air situation more complicated or endangered the flight safety.

When training flying personnel for team flying, the task of the wingman pilots is reduced to obtaining skill in coordinated and purposeful actions corresponding to those of the leader. These actions will allow the pilot to maintain his position in the combat formation and maintain the assigned flight regime and to accomplish the required maneuver.

The successful accomplishment of formation flight is largely determined by a thorough ground drill in observing the procedures and sequence of performing all the flight elements.

The object of the combat formation flight training is to make each pilot properly know the following:

(a) the sequence of engine starting, taxiing procedure and arrangement of aircraft preparatory to takeoff;

(b) takeoff sequence, climbing (cloud penetration) and join-up procedure;

(c) sequence of carrying out the mission assigned and engine power settings with reference to the stages of formation flight;

(d) maneuvering and regrouping procedures during formation flight;

(e) procedure of look-out and distribution of observation zones in air;

(f) break-up procedure and landing sequence;

(g) organization of formation flight control and rules of radio communication;

(h) actions to be taken in formation flight under emergency conditions.

When preparing for formation flight particular attention should be given to the organization and ensurance of flight safety. Formation flight safety largely depends on the capability of each pilot to strictly maintain his position in the combat formation, rapidly response to the changes in the air situation, coordinate his actions with those of the rest of the pilots of the combat formation in order not to put them in an awkward situation.

Prior to training flights for acquiring skill in visually determining the assigned intervals and distances, it is necessary that the aircraft on the airfield be arranged in accordance with this or that combat formation. During training course the pilot should remember the position, linear dimensions, and angles of sight of the characteristic parts of the neighbouring aircraft with respect to the various points (lines) of the canopy of his own cabin.

It is recommended that the formation flight training be terminated by playing the flight in a "flying on foot" manner.

In formation flight the wingmen must give most of their attention to following the actions of the leader and visualization of the assigned air space. The time left for taking the readings off the instruments and manipulating the controls in the cabin is considerably reduced. Therefore, the pilot undergoing a formation flight training should systematically improve his skill in handling the equipment arranged in the cabin under the conditions when the greatest part of his attention must be given to the observation of the air space and the leader.

The methods of training flying personnel for piloting aircraft in pair (section) combat formations must be in compliance with the basic principle of training, that is a constant rate of advance should be maintained at all times. Experience and skill gained by the pilots in team flying on the previously mastered types of aircraft should also be taken into consideration.

Training of flying personnel who are going to master the combat formation flying technique for the first time should be commenced from twin flights with the use of a combat trainer.

The trainee is to be admitted for independent flights on a combat aircraft only after it has been established that the trainee has acquired perfect skill in joining up the leader and maintaining the assigned position in the formation at various flying speeds and stages with an accuracy sufficient to ensure flight safety.

In case of prolonged intervals in flights, training formation flights are allowed only after the pilots have restored their skill in solo flying. Check twin flights may also be performed, if necessary.

Skill in team flying at subsonic speeds acquired, the pilots may proceed to training for performing supersonic formation flights.

Only pilots who have successfully completed the supersonic solo flight training course may be allowed for supersonic twin (section) combat formation flights.

During flights in the pressure helmet the leader's field of vision of the wingman is limited. Apart from this the leader is too late to notice the mistakes committed by the wingman even during close formation flight. Therefore, the wingman must report his mistakes to the leader.

During first team flying the leader should correctly select the engine power setting, smoothly vary the flight regime, avoid abrupt movements of the throttle levers and out-of-place hastiness in changing aircraft attitude. All this being ensured, the wingman will cope with the first flights and acquire self-confidence. This will also enable him in future to cope with more complicated and vigorous maneuvers at great roll and pitch angles without difficulty.

In the initial stages of training flying personnel in team flying, ground and air control should be effected over the radio. Prior to effecting each maneuver and before recovery from this maneuver, the wingman must be warned about it by the leader. As the pilots acquire the team flying technique, the commander must do his best in training the wingmen to properly effect twin (section) combat formation flights by visual signals and use radio only in case of necessity.

It is permissible that radio commands be curtailed in flight to a certain degree provided that each pilot can unmistakably distinguish the commander's voice.

CHAPTER VI

INDIVIDUAL NIGHT FLYING UNDER VFR AND IFR CONDITIONS

1. PHYSIOLOGICAL PECULIARITIES INVOLVED IN NIGHT FLYING

Mastering night flight with the use of the МиГ-25П aircraft is one of the vital objectives of training.

A great number of instruments and controls demand from the pilot performing a night flight a profound skill in handling the aircraft equipment arranged in the cabin, distribution and transfer of attention, as well as effecting change-over from instrument to VFR flight and vice versa.

Prior to night flight training flying personnel must thoroughly study the aircraft night flying equipment in order to be able to properly handle it. To this end it is essential that personnel systematically conduct purposeful night cockpit drills. The cockpit drill should involve operating the equipment at all flight stages beginning from the engine starting before takeoff to engine shut-down after landing.

Particular attention must given to the procedures to be followed in cases of emergency.

The pilot must be trained to such an extent that he be able to manipulate the selector switches, levers, buttons, and other controls automatically.

Proceeding from the above said it is evident that night flight demands from the pilot a great amount of attention and high capacity for work.

At the same time the intensity of a human organism vital functions under daily routine conditions, i.e. when a person works in daylight and has a rest at night, normally varies with time of the day. The first half of a 24-hours requires maximum of human energy, and the second half demands only a minimum. It is important, therefore, that the daily regimen and regular diet be properly scheduled in order to maintain the maximum capacity for work of personnel for night flights. This problem should be solved by the joint efforts of the commander and medical officers.

An additional daylight rest is mandatory in order to maintain a sufficient capacity for work of personnel involved in night flights. It is essential that passive rest should be alternated with active relaxation which is expected to enhance the working tone.

A night flight, with light reference marks being visible, involves peculiarities associated with the fact that the pilot effecting instrument flight is forced to periodically check his attitude by referring to the light marks and, consequently, exerts considerably greater attention during the entire flight.

High flying speeds developed by modern aircraft give rise to the necessity in taking into consideration the capability of human eye to distinguish between objects located at different distances to the aircraft under night flight conditions.

The above process known as accommodation takes place as a consequence of the human crystalline lens ability to change the angles of refraction in variation with the extent of the contraction or relaxation of the accommodating muscle. When shifting eyes from a closer object towards an object located at a greater distance, the process of accommodation lasts for a shorter time as in the case when eyes are shifted from a farther object to a nearer one. In a general case, however, the accommodating time accounts for at most one second.

Apart from the above,it is important that eyes be adopted to percept objects under low ambient light conditions (adaptation) in order to ensure a successful accomplishment of night flight. In practice, this process takes about 20 sec. The least reduction in the night visual acuity is observed under red ambient light conditions. Therefore, it would be practical that all the waiting premises at the airfield should be lit red prior to night flights. The illuminence should be sufficient to ensure easy reading and writing without straining eye muscles. Such a condition reduces the time required for adaptation and causes no ocular fatigue.

The pilot cabin is lit red for the same reasons. The luminous intensity must be sufficient to enable the pilot to discern the readings presented by the instruments without straining eye muscles and, at the same time, be at minimum in order not to disable the pilot to discern the objects clear of the cabin under low ambient light conditions.

In bright moonlit night, the visual acuity is lowered to a level of 0.3 to 0.7. In dark cloudy night, it is decreased up to 0.03 to 0.05. At night, the acuity of colour vision is at zero. The ability to estimate distance (far vision ability) is also impaired in darkness. All this put together considerably decreases the possibilities for detecting ground reference marks.

In order to maintain and improve the night vision ability of personnel, they should regularly take vitamins of groups A and C. Fatigue, physical overstrain, improper organization of preflight relaxation, insufficient meals, liver and blood circulation organ diseases, and especially taking alcoholic drinks two or three days prior to flight, all this impairs the night vision ability of the pilot and deteriorates light adaptation under low ambient light conditions.

Strict observance of the routine of the day and regular diet, sufficient and deep sleeping, and regular physical training contribute to the pilot's ability for work, human endurance, and quality of flying technique.

During the initial stage of the night flying training, it is advised to ensure the most favourable conditions for night flying, namely:

(a) avoid complicating flight mission;

(b) avoid replacement of aircraft;

(c) do not postpone the takeoff time;

(d) avoid ungrounded substitution of instructors prior to introductory flights, etc.

It is desirable that the most important and complicated missions be planned for the first half of the shift.

2. PECULIARITIES OF CIRCLING FLIGHTS

Prior to night flight, check the serviceability of the cabin illumination facilities in addition to a routine checkout. The procedures for checking the lighting equipment with the ground power supply turned on are as follows:

(1) check position of the floodlights and set them to the required position;

(2) manipulate the integral and floodlight dimmer knobs to obtain the desired level of lighting (first, adjust the floodlights);

(3) check the serviceability of the white light with the use of a rheostat;

(4) set the screens of the indicator lamps on the instrument board and panels to the night flying position;

(5) switch on the position lights to operate at constant duty;

(6) check serviceability of the land/taxi lights. To this end, put the land/taxi lights selector switch to position LANDING (ПОСАДКА) and then to TAXI (РУЛЕЖ.); ascertain that the direction of the beam is correct; the checkup completed, set the selector switch to RETRD (УБРАНЫ) position;

(7) set the anti-dazzle screen in the operating position: (pull it towards yourself) and adjust the screen in height;

(8) close the side anti-dazzle screens on the hinged hood.

Engine starting and run-up should be carried out in the same sequence as in the daytime.

Prior to taxiing out,give command REMOVE CHOCKS (УБРАТЬ КОЛОДКИ) over the intercom system and duplicate it by blinking the position lights. After ascertaining that the wheel chocks have been removed and the technician has disconnected the intercom system wire, turn on the land/taxi lights and start taxiing out.

On taxiing out on the runway position the aircraft strictly in alignment with the runway centre line and switch off the land/taxi lights. Ascertain that the takeoff and side runway lights are projected at the same angle (left- and right-hand) with respect to the nose fuselage.

The takeoff procedures involved in night operation are similar to those to be followed in daylight. The direction of takeoff run should be maintained by reference to the runway lights. In bright night, the position of the fuselage nose during takeoff run is determined by reference to the horizon and the runway lights. In dark night,orientation is effected by reference to the runway and artificial horizon lights (takeoff lights).

The aircraft lift-off is determined by the pilot by the cessation of bumps of wheels against ground and the downward displacement of the runway lights.

When the wheels have cleared the ground, the pilot should continue climbing, checking the position of the aircraft by reference to the flight director indicator and rate-of-climb indicator without changing the position of the controls.

On attaining an altitude of 15 to 20 m, retract the landing gear, and retract the flaps after reaching an altitude of at least 100 m.

The night circling flight pattern is similar to that of the daylight flight but in addition involves considering the peculiarities of the outlines of ground reference marks in darkness.

It is essential in flight that the flight regime be strictly maintained and the moments of turning be determined in proper time.

Entry into the final turn should be effected at the moment when the angle of sight with respect to the runway entrance lights accounts for 20 to 25°.

It should be taken into account that determination of the right moment of the final turn in darkness presents certain difficulties and requires practical skill. Entry into the final turn, therefore, in first flights should be effected a little bit earlier in order to correct the direction of landing approach by decreasing bank rather than by increasing it.

Upon recovery from the final turn and flying over the outer beacon, set such a glide angle so as to enable the aircraft to descend in the beam of the second (along the direction of landing approach) runway floodlight.

The glide angle shall be maintained by reference to the runway lights. To properly maintain the required glideslope, use the inner marker beacon or the code neon beacon (CNB) commonly located in the vicinity of the inner marker beacon. In all the cases the rate of descent should not exceed 5 to 6 m/s.

The procedures of night landing on the runway lit by floodlights have no differences with those used in daylight landing but require excessive look-out. In darkness the distance to the runway or any other lit reference mark seems to be considerably smaller in size than in daylight. Under such circumstances the pilot may experience a desire for premature descent. In this connection it needs to be said that the pilot should check the rate of descent by referring to the instruments as frequently as possible. On attaining an altitude of 30 to 20 m, the pilot must shift his eyes towards the flare-out initiation point.

When above the runway lit by the second floodlight at an altitude of 8 to 10 m, diminish the angle of descent by applying smooth back stick pressure so as to cease descent at a height of not more than 1 m.

At the end of flare-out, smoothly move the throttle levers to IDLE position. As the aircraft descends, apply a back stick pressure to enable the aircraft to assume such a position for landing that it could land on two main L.G. wheels.

On touching down the ground, shift your glance forward in the direction of landing roll, check deployment of the drag chute or manually allow it to deploy, and start applying the brakes. The direction of landing roll should be maintained by reference to the side runway lights. Taxiing operations must be carried out with the land/taxi lights on.

3. PECULIARITIES INVOLVED IN LANDING ON NON-FLOODLIGHTED RUNWAY, WITH LAND/TAXI LIGHTS SWITCHED ON

The procedures for landing on a non-floodlighted runway with the land/taxi lights switched on present considerable difficulties and requires concentration of attention in determining an appropriate flare-out and holding-off altitude.

The procedures for effecting landing approach with the use of the land/taxi lights are to be followed in the same sequence as in case of landing on the floodlighted runway, the only difference lying in that the gliding and flare-out initiation speed must be by 10 km/h higher.

Accomplishment of night landing on a non-floodlighted runway, with the land/taxi lights switched on, is considerably complicated by the fact that it becomes more difficult to estimate the flare-out point and maintain the glide-slope in gliding after flying over the outer beacon. Under such conditions,it is particularly difficult to determine the flare-out initiation height.

Upon completion of the final turn,the glide-slope must be the same as in landing approach onto the runway lit by the floodlights.

Switch on the land/taxi lights by setting the above selector switch to LANDING position after flying past the outer beacon.

Upon extension of the land/taxi lights, the luminous flux does not reach the ground surface, yet and creates a light screen in front of the aircraft, thus impeding the visual control over the accuracy of landing approach and flight altitude.

After passing over the inner beacon, descend the aircraft to the flare-out point, taking the runway threshold lights as such. When gliding to a height of 30 m, the aircraft should be piloted by reference to the instruments, checking the direction of landing approach and flight altitude visually by reference to the threshold lights. On reaching a height of 30 to 20 m, shift your glance towards the runway lit by the land/taxi lights and concentrate your attention on determining the flare-out initiation altitude.

As the aircraft descends along a normal glideslope,the luminous intensity of the land/taxi lights grows. At a height of 8 to 10 m,start aircraft flare-out by applying a smooth back stick pressure so as to cease it at a height of 1 m. At the moment of flare-out initiation,the light spot on the ground produced by the land/taxi lights is still weak and blurry. Therefore, in order to determine the height, the pilot must use the left-hand row of the runway lights. In the course of flare-out the brilliancy of the light spot on the ground grows to become perfectly sufficient for the visual determination of height. At the end of flare-out, set the throttle lever against the idle rating limit stops. The procedure for holding-off and landing are similar to those involved in landing on the floodlighted runway.

When performing landing with the land/taxi lights switched on, it is important to maintain the assigned glideslope. Premature descent and pull-up at a low altitude at a small glide angle must be avoided at all times, for the light beam produced by the land/taxi lights in this case is parallel to the surface of the ground and does not illuminate it almost.

It is not recommended to effect landing on the non-floodlighted runway with the land/taxi lights switched on when the force of the cross wind (particularly from the left side) exceeds 7 m/s as the wind drift encountered in gliding and landing till touch-down is combatted by varying the course. Under such conditions,the pilot turns the aircraft into the wind, thus deteriorating the conditions for visualization of the runway lights and visual determination of the flying altitude. The luminous flux produced by the land/taxi lights as a result will be directed to the side. All this considerably decreases the possibilities of correctly determining the flare-out initiation altitude and makes landing a more difficult task.

If the necessity in going around arises, the pilot should make the respective decision well before reaching an altitude of 50 m. Before go-around, retract the land/taxi lights after bringing the aircraft into climb.

In dense haze, rain, or snowfall, landing with the land/taxi lights switched on shall be avoided, as an intense light screen in front of the aircraft impedes spatial orientation, perception of the runway lights and landing approach, and thus the flight safety is endangered.

4. PECULIARITIES INVOLVED IN NIGHT MANEUVERING, LOW-ALTITUDE AND STRATOSPHERE FLIGHTS

The flying technique in the maneuvering area and the procedures for distribution and transfer of attention in maneuvering are similar to those used in daylight flight, except that the night flight regime is maintained and checked fully by reference to the instruments.

When flying the aircraft at a bright night, when the horizon is visible, it can be periodically used as a reference for checking the aircraft attitude.

Finding the position of the aircraft in darkness is more complicated due to the difficulties encountered during the estimation of the distance to the light reference marks. Therefore, upon completion of each maneuver, it is necessary to recheck the position in the area by determining the aircraft attitude relative to well distinguishable reference points which are visible in various azimuths.

Radio aids are the primary means used for finding the position of the aircraft in flight. The position of the aircraft in the maneuvering area is determined to the highest degree of accuracy with the use of the PCБH-6C short-range radio navigation and landing system by the distance to the ground radio beacon and the current azimuth. In addition, the pilot should use the automatic direction finder and the information furnished from the command post (ground-controlled approach system) for the purpose.

Prior to each maneuver, it is highly important to establish the assigned flight regime and ensure the appropriate trim of the aircraft. Entry into and recovery from the maneuver should be effected in the direction of the bright side of the horizon, illuminated reference point or the marker beacon (the PCБH beacon).

During high-altitude night maneuvering flight,it is highly important that the peculiarities associated with the deterioration of the aircraft maneuverability should be taken into consideration.

When flying various maneuvers, it is necessary that the pilot should do his best to attain maximum accuracy in coordinating the movements of the control surfaces and bear in mind that it is much more difficult to correct pilot blunders at night than in daylight.

A comparatively poor or zero vision of the ground, horizon, and sky in night flight considerably complicates visual flying and sometimes makes it completely impossible. Visual determination of the aircraft attitude and flight altitude and direction therefore becomes an extremely difficult matter.

In night flight at low altitude,it is very difficult and even impossible, with no illuminated reference points provided, to carry out visual orientation.

In order to prevent spontaneous loss of height, trim the aircraft with the use of the stabilizer trimming mechanism making allowance for an insignificant pitch-up so as to enable the aircraft to further climb in the event of decrease of the stick pressure.

It is important that the pilot fly the aircraft by consulting the instruments and periodically checking the aircraft position by reference to the natural horizon, if possible. Prior to transition to visual observation,it is necessary that the pilot settle down level flight conditions by reference to the instruments and only after this shift his glance beyond the cockpit, checking the aircraft attitude by referring to the instruments.

It is an extremely difficult task to visually determine the flight altitude and angle of pitch during night flight. These flight parameters should be determined only with the use of the altimeter and artificial horizon.

To bring the aircraft into a glide, smoothly perform double movements of the control stick, strictly checking the readings of the altimeter and rate-of-climb indicator.

When flying the aircraft at altitudes below 600 m, check the above parameters by reference to the УВО-30К (УВО-М1) altitude indicator and the РВ-4 radio altimeter. Prior to flight, set the radio altimeter indicator to the lowest permissible altitude.

In night flight,the pilot provided with a high-altitude output has to face considerable difficulties in operating the equipment installed in the cockpit. In addition, the very preparation and testing of the cockpit equipment by the pilot equipped for a high-altitude flight in darkness takes much more time than in daylight. This should be taken into account when planning night stratosphere supersonic flights.

When climbing at a subsonic speed, particularly at augmented power setting, the aircraft has such a pitch angle that the natural horizon is screened from the pilot by the nose fuselage. Such a condition demands that even in bright moonlit night the aircraft should be flown on instruments. Check the attitude of the climbing aircraft by reference to the artificial horizon, rate-of-climb indicator, altimeter, and airspeed indicator. The pilot can visualize light reference points in climb only at a high angle with respect to the longitudinal axis of the aircraft. To ensure track monitoring, therefore, it is necessary to select characteristic well illuminated landmarks located off the track line.

When climbing at a supersonic speed, visual orientation is practically impossible. The pilot can check the aircraft attitude only by referring to the instruments. It is not recommended that the pilot divert his attention off the instruments even for a short period of time.

5. PECULIARITIES INVOLVED IN NIGHT FLIGHTS UNDER IFR CONDITIONS

Night flights in clouds, beyond clouds and in low visibility conditions are the most complicated elements of flying technique demanding profound skill in prolonged instrument flying. From these considerations only pilots skilled in daylight IFR and night VFR flying may be permitted for night flights under IFR weather conditions.

Upward and downward cloud penetration regimes, maneuvering to hit the landing course are the same as in daylight flight. Night flying under IFR weather conditions as compared to daylight flights has some peculiarities.

Under low visibility conditions the outlines of clouds are undistinguishable at night and the surrounding terrain is blurred against the dark background of clouds. The natural horizon is therefore invisible, visual determination of the distance to the ground is impossible, and the pilot is confronted with difficulties in determining the moment of the aircraft approaching to clouds, as well as the moment of entry into and recovery from the clouds.

In a common case,cloud entry almost always takes the pilot by surprise. Therefore, just after bringing the aircraft into climb and retraction of the landing gear and flaps,the pilot should fly the aircraft only on instruments and be ready for flight in clouds at all times. Determination of the nature of clouds and processes taking place in clouds is commonly impossible.

Flight in clouds may be accompanied by diverting side effects. Bluish intermittent lines and separate splashes aroused due to the emergence of an electrostatic charge may appear on the surfaces of the aircraft canopy. During engine operation at augmented power setting there arises a rather big light screen which expands with growing density of clouds. Insignificant light screen may be produced by the aircraft position lights.

The presence of precipitation in clouds in the form of rain drops may be detected by the water runs on the cockpit glazing. It is practically impossible to visualize ice formation on the canopy glazing.

Due to the above-mentioned peculiarities the pilot is forced to carry out practically the entire night flight under IFR weather conditions only on instruments. An exception is the flight beyond the clouds in a bright moonlit night when it is possible to visually check the aircraft attitude by reference to the natural horizon provided that the top edge of the clouds is even.

The moment of cloud entry in upward cloud penetration is determined by deterioration, and further, by a complete invisibility of the light landmarks, as well as by occurring the light screen produced by the position lights.

Upward cloud penetration is recommended to be carried out in straight flight, especially in the initial stage of the training course. In this case prior to cloud entry, it is necessary whenever possible to ascertain that the flight and navigation instruments are functioning properly and that the artificial horizon presents correct readings. The latter should be done in the first place. It is necessary that during night flight under IFR conditions the pilot check the airspeed, altitude, and flight course more frequently than it is usually done in daylight. This is of particular importance after lift-off, in maneuvering, and descent during downward cloud penetration.

In flight at high altitudes and in stratosphere beyond the clouds a starry sky may become reflected against the background of cirrus clouds, thus misleading the pilot as to the actual attitude of the aircraft. The flight even beyond the clouds, therefore, shall be conducted only on instruments. Generally, the pilot flying the aircraft in night clouds may encounter illusions the nature and manifestation of which are identical with those commonly faced during daylight flight in clouds.

In breaking dense clouds to the bottom, especially in a bright night and dusk, the ambient illuminance clear of the cockpit varies as the flight altitude diminishes.

One must give his attention to the fact that the light beams from reference points which are large in area are capable of breaking through even dense clouds and emerge in the form of light spots. Diverting one's attention and waiting for cloud exit in this case shall be avoided. Only when in full confidence that the aircraft has broken clouds to the bottom, should the pilot visually check the direction of landing approach by reference to the light landmarks and runway lights. If the pilot is going to land at the predetermined weather minimum, he should not divert from the instruments until the very outer beacon approach and strictly maintain the preselected flight regime until the runway lights are distinctly visible. Flight altitude and speed must be checked prior to attaining the flare-out altitude.

The above-mentioned peculiarities involved in night flight under IFR conditions require additional psycological stress which may affect the quality of flight performance and air navigation. Night flight under IFR conditions is the finishing and most important stage of instrument flight training.

RECOMMENDATIONS TO COMMANDER (INSTRUCTOR) ON TRAINING PILOTS IN NIGHT FLYING

Timely and high-quality grounding of instructors guarantees adequate training of personnel for night flying. Instructors should be trained in the course of combat training in accordance with the programme of the Combat Training Manual.

Instructor personnel assigned to train the pilots for night flying must be perfectly skilled in piloting aircraft, using radio and navigational equipment to correctly lead out the aircraft onto the airdrome, performing instrument approach with the use of the navigational and landing system. In addition, an instructor must be competent as a teacher if he desires to succeed in training pilots for night flying.

Difficulties which may be encountered in night flight may cause nervous overstrain which may adversely affect the quality of piloting. This shall be well understood by the instructors in order that the quality of piloting the aircraft in darkness be ensured and the possibility of its deterioration be reduced to a minimum. Apart from this,an instructor should take into consideration the individual properties of the pilot in deciding whether he is fit for night training flight or not.

In training personnel an instructor must strictly adhere to the approved methods and procedures and maintain a constant rate of advance.

The course of training personnel for night flying aircraft under VFR conditions involves circling flights for acquiring skill performing takeoff, approach estimation and landing, maneuvering flight aimed at acquiring skill in performing turns, banked turns, climbing, descent, spiral, and level flight during acceleration and deceleration. Further improvement of night flying skill is expected during intercept and en-route flights.

Night flights with the use of a combat trainer and combat fighter-interceptor should be preceded by ground training within the scope sufficient to ensure successful accomplishment of future flying missions. Particular attention must be given to training personnel for cockpit equipment. Cockpit drill must be conducted in darkness with the ground power supply turned on.

Night flight training involves introductory and test flights with the use of a combat trainer and training flights with the use of a combat aircraft.

Introductory flights are a very important period of training. The quality of the flying skill and experience gained during introductory flights to maneuver area and circling flights determines the success of subsequent training flights with the use of a combat aircraft. It is practical that the pilots who lack experience in night flights over a given aerodrome fly the aircraft over the area to familiarize themselves with the light landmarks prior to introductory flights.

First introductory flight to maneuvering area is intended for familiarizing the pilots with the peculiarities involved in night flight.

Considering the peculiarities of night flying which make piloting more difficult, the instructor must be particularly exact in evaluating the actions of the pilot in maintaining the preselected flight regimes. In the course of training, it is of particular importance to reveal flying technique blunders committed by the pilot and their causes.

During introductory flight the instructor must prompt the pilot by the interphone system the correct procedures for arranging the aircraft for takeoff, draw the pilot's attention to the proper methods for maintaining the required direction during takeoff and after the wheels clear the ground, remind the pilot of the sequence in which his attention must be distributed. During climb transition the pilot must be instructed on how to correctly establish the pitch angle and handle the cockpit equipment.

When within the maneuvering area, the instructor should draw the pilot's attention to the necessity of maintaining the preselected flight regimes, the sequence of the look-out procedures, and orientation. Should the pilot commit errors during the accomplishment of certain maneuver elements, the instructor must draw the pilot's attention to these errors, determine the causes of these errors, and demonstrate, if necessary, how to correctly carry out this or that element of the flight mission assigned.

In planning the landing approach route the instructor must show the trainee the initial point of all the turns to be made, drawing his attention to the readings presented by the combined course indicator pointers and the angles of viewing the runway landing light marker line.

When proceeding on the landing approach course, the instructor should demonstrate the pilot how to project the levelling-off point in descent during the precision approach planning and how to project the line of the runway landing lights in order to maintain the required direction in descent and ensure accurate touch-down within the landing strip.

If the pilot succeeds in avoiding blunders during aircraft piloting and timely notices and skilfully corrects the revealed errors in the event departure from the preselected flight regime, this means that this trainee may be considered as fit for check flight in the company of the commander empowered with the authority to permit independent night flight.

In check flight,the commander in charge of the pilot must provide for an unbiased checking and evaluation of the quality with which the pilot has carried out all the elements of flight to maneuvering area and circling flight, the efficiency of the pilot's look-out both on the ground and aloft, trainee's proficiency in handling aircraft, and skill for properly conducting radio communication.

During test flight the instructor should give the pilot a free hand and avoid prompting and interfering with the aircraft control. Should the instructor be forced to take over control to correct blunders beyond the satisfactory mark on endangering flight safety, this means that the trainee is not yet prepared for independent flights.

In such a case,it is necessary that introductory flights be continued in order to eliminate piloting errors and the pilot be once again checked for preparedness for solo flights.

First night training flights should be performed in favourable meteorological conditions, that is in bright moonlit nights and when the natural horizon is clearly visible. Never permit the pilot to carry out a solo flight under conditions which are more complicated than those under which the trainee has completed the introductory flying programme with the use of the combat trainer.

It is customary that first solo flight be accomplished by the pilot in the very night in which a trainee has been fly-tested in the combat trainer. Should for any reason a solo flight have not been performed in the approved time, the pilot must carry out the check flight under supervision of the instructor prior to a sortie on the following night.

Upon accumulation of the approved circling flight hours, provided that the trainee's proficiency has been proved, the pilot can be allowed to commence training in the maneuvering area and then proceed to acquiring skill in air navigation and combat employment.

Night flying under IFR conditions should be preceded by training for night flying the aircraft under VFR conditions. Should the pilot fail to keep his hand in flying aircraft or in the event of forced intervals in flights under both VFR and IFR conditions, it is necessary that the pilot first restore his skill in night flying the aircraft under VFR conditions and then proceed to training for flying the aircraft under IFR conditions.

The IFR flight training course should be started with introductory flights in clouds with the use of combat trainer, provided that the pilot is sufficiently skilful in performing both daylight and night hooded flights, as well as in flying the aircraft in clouds with the use of the landing systems.

The significance of night introductory flights in clouds is, therefore and for the most part, reduced to training the pilot under the supervision of the instructor for the purpose of objectively determining the possibility of approving the pilot for night training flights in clouds.

First night training flights under IFR weather conditions should be performed under the most favourable visibility and illuminence conditions. When choosing the time for the above flights, cloud ceiling and thickness must also be taken into consideration. As the pilot acquires the habits, the flight conditions must constantly be complicated so as to enable the pilot by the end of the training course to perform combat mission flights at the assigned weather minimum with the use of the entire scope of the aircraft radio aids.

Before starting to train for flying the aircraft at low altitudes, the pilot should be qualified as fit for flying the aircraft at medium altitudes.

When training for flying the aircraft in the maneuvering area at low altitudes, the instructor must always draw the pilot's attention to the principles of distribution and transfer of his attention, maintaining the assigned flight regimes (flight altitude and speed in particular), and peculiarities involved in orientation.

Circling training flights are performed either with the use of the radio aids or without them. To enable the pilot to carry out landing approach without using the radio aids, the instructor must teach the pilot how to plot the route by reference to the runway lights and characteristic light landmarks in the area of the aerodrome.

When approaching the airfield, the instructor must also draw the pilot's attention to how to use the approach lights for checking gliding altitude and determining the distance to the runway.

Training of the pilot for landing the aircraft on the non-floodlighted runway with the land/taxi lights switched on should be planned to be mastered upon completion of training in night flying under VFR flights. Only proficient pilots who experience perfect flying technique and regularly perform night flying on this type of aircraft are involved in performing aircraft landing with the land/taxi lights switched on.

In the course of introductory flights aimed at enabling the pilot to acquire skill in landing the aircraft with the land/taxi lights switched on, the commander (instructor) must draw the trainee's attention to the peculiarities involved in gliding after flying over the outer beacon, determination of land/taxi lights cut-in altitude, flare-out initiation altitude, and landing.

Upon completion of introductory flights involving landing the aircraft on the non-floodlighted runway with the land/taxi lights switched on and checking the trainee for pilot proficiency in flying the combat trainer, the pilot is allowed for training flights.

When performing training flights involving landing on the non-floodlighted runway, the landing lights system of the aerodrome must be fully engaged. It is mandatory that an experienced flying control officer capable of giving a help to the pilot should he commit a mistake during estimation for landing and landing proper.

Proceeding from the individual properties and proficiency of the pilot, it is necessary to establish the maximum permissible terms of intervals for each pilot trained for landing the aircraft with the land/taxi lights switched on. If the aircraft exceeds the established time limits, the restoration of the lost flying skill should be commenced from the check flights on the combat trainer.

The instructor should bear in mind that flight safety in night flying under IFR conditions largely depends on the strict maintaining of the assigned flight regime and, especially, flight altitude. Therefore, the instructor must be exact to the pilot in the sense of maintaining the assigned flight regimes both during training on the combat trainer and solo training on the combat aircraft, using the data obtained by the flight data recording equipment, aircraft directing pattern at the command post, remarks made by the flying control officer and the landing signal officer.

CHAPTER I

BRIEF DESCRIPTION OF ARMAMENT AND COMBAT CAPABILITIES OF INTERCEPTOR-FIGHTER

The armament system of the МиГ-25П interceptor-fighter is intended to hit air targets, primarily high-altitude and high-speed targets, both in daylight and at night and VFR and IFR conditions when performing rear-cone and forward-cone attacks as well as high aspect angle-off attacks. The aircraft armament system incorporates the following:

(1) airborne radar РП-25;

(2) four air-to-air missiles of the Р-40 type;

(3) missile launching system;

(4) К-10Т collimating sight.

The aircraft may employ the following organic versions of external stores:

(a) two missiles provided with infra-red homing heads (inner) and two missiles equipped with radar homing heads (outer);

(b) four missiles fitted with radar homing heads.

The Р-40 missiles provided with infra-red homing heads are not to be used from the outer launchers due to great errors in target indicating by the homing heads.

AIRBORNE RADAR РП-25

1. PURPOSE AND BASIC PERFORMANCE OF РП-25 RADAR

The РП-25 radar is intended to ensure air target interception and makes it possible to solve the following main missions:

(1) air target search and detection;

(2) target identification in joint operation with the СРЗО-2 interrogator-responder;

(3) target lock-on and its automatic tracking with respect to the angular coordinates and range;

(4) issue of commands into the automatic control system;

(5) furnishing of signals and commands required at the stages of the interceptor-fighter-to-target approach, aiming, and missile launching;

(6) shaping and generation of signals of missile launch preparation, launch clearance, illumination of a target when launching the missiles provided with radar homing heads;

(7) indication of the moment and direction of break-off.

The air target detection range at detection probability of 0.5 with effective reflecting surface and equivalent reflecting surface of the B-52 aircraft at high altitudes accounts for 90 km.

Air target lock-on range (target of the B-52 aircraft type) with the detection probability of 0.9 at high altitudes amounts to 60 km.

The scanning zone, with the aircraft radar operating in the automatic control mode, is as follows:

30° in azimuth with the possibility of smooth automatic displacement through $\pm 55^{\circ}$;

11.6° in elevation with the possibility of smooth automatic displacement upward from 0 to 10°.

With the airborne radar operating in the manual control mode, the scanning zone in azimuth accounts for 60° with the possibility of discrete displacement through $\pm 40^{\circ}$. The scanning zone in elevation accounts for 11.6° with the possibility of discrete displacement upward through 30° and downward by 10° (in the LOW ALTITUDE (MB) mode only, upward up to 3°).

Time required for completion of a single scanning cycle accounts for 3.5 s.

The position of the scanning zone is stabilized in space:
in pitch within the limits of +70 to -30°;

in roll within the limits of $\pm 70^{\circ}$.

The target lock-on zone:

13.5 km in automatic gating mode;

8.25 km in manual gating mode;

3.75 km in the LOW ALTITUDE mode.

Zone of target lock-on in azimuth:

$\pm 15^{\circ}$ in automatic gating mode;

9° in manual gating mode.

Zone of target automatic tracking:

± 70 in azimuth;

from -30 to $+75^{\circ}$ in elevation.

The resolving power in azimuth:

3^{o} in scanning mode;

2^{o} in automatic tracking mode.

Resolving power in range:

2 km in scanning mode;

750 m in automatic tracking mode.

The dead reception zone is 2 000 m.

The airborne radar readiness time after switching-on is 3 to 5 minutes.

The mass of the radar accounts for 600 kg.

2. INDICATING AND WARNING UNITS AND CONTROLS

The indicator (Fig. 112) is installed above the instrument board in the aircraft cockpit. Marked on the protective glass panel in the centre of the indicator screen is a cross-hair with a ring the radius of which corresponds to the limit angle (45^{o}) of the antenna beam mark deflection during missile launching.

On the right-hand side of the indicator screen, there is a range scale with 20, 40, 60, 80, and 100 division marks for the

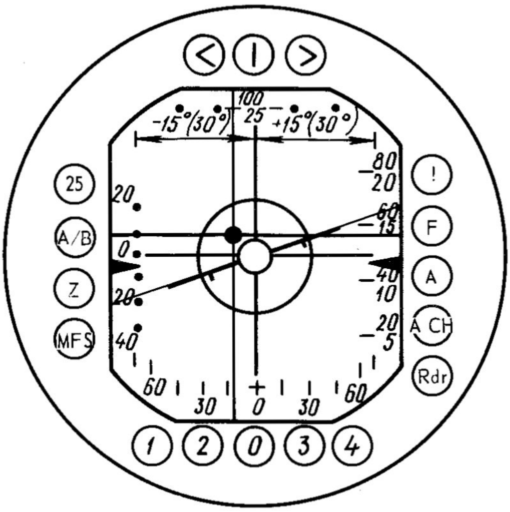


FIG. 112. РП–25 RADAR INDICATOR

"100 km" scale and 5, 10, 15, 20, 25 for the "25 km" scale (in the LOW ALTITUDE mode).

Pitch angle indications are given by two triangular indexes arranged both on the right and left sides of the indicator screen. The pitch indicator scale is only on the left side of the screen and has divisions from -20 to $+40^{\circ}$.

The bank indicator having a form of a miniature airplane is located in the centre of the screen. A bank indicator scale is omitted. The amount of bank is determined by the pilot approximately.

The position of a target in azimuth with respect to the centre of the scanning zone is determined by reference to the upper dial having divisions: at an interval of 5° within the limits of $\pm 15^{\circ}$ for the airborne radar operating in the automatic control mode; at an interval of 10° within the limits of $\pm 30^{\circ}$, with the airborne radar operating in the manual control mode.

The position of the scanning zone centre relative to the aircraft longitudinal axis is to be determined by reference to the lower azimuth scale having divisions which are spaced at an interval of 15° within the limits of $\pm 60^{\circ}$.

Aircraft control is effected by reference to the director mark ("bead") which receives director signals from the automatic flight control system. The amount of displacement of the director mark on the indicator screen is proportional to the difference between the assigned and present values of bank and g-load.

In front of the indicator screen there is an attitude - command marks unit. The circular display of the attitude - command marks unit is composed of seventeen lamps associated with the ground guidance, armament, and radar systems.

The indicator lamps of the ground guidance system are the following:

(<) - turn to left;

(|) - fly straight;

(>) - turn to right;

(A/B) - afterburner;

(!) - reaiming.

The armament system indicator lamps are the following:

(F) - filament to missiles;

(1) (2) (3) (4) - launch permitted for respective missiles.

The airborne radar incorporates the following indicator lamps:

- (A) - attack;
- (Z) - zoom;
- (ACH) - auxiliary channel on;
- (25) - "25 km" scale on display screen (for low altitudes);
- (B) - break-away;
- (Rdr) - turn off radar;
- (MFS) - no control of main channel transmitter frequency.

The brilliancy of the indicator screen and circular display lamps is adjusted by rotating the polaroid glass panels of the tube by the use of the special knob.

The indicator display screen photographing is effected by the ПАУ-473 gun camera which is automatically cut in if the airborne radar emission is ensured.

The radar control panel (Fig. 113) is arranged on the cockpit instrument board and intended for effecting the main control of the sight. The controls arranged on the radar control panel are intended for the following purposes:

- the EQUIPMENT CONTROL (УПР. АППАР.) selector switch which is used for cutting in the airborne radar control means to operate either in manual or automatic control mode;

- the EMISSION (ИЗЛУЧ.) selector switch which is used for cutting in the emitter;

- the INTERROGATION (ЗАПРОС) selector switch which is used for turning on the СРЗО-2 interrogator-responder to ensure target identification;

- the ZONE (ЗОНА) selector switch which is used for shifting the scanning zone in azimuth either to the left or to the right in airborne radar manual control mode;

- the SCANNING ZONE (ЗОНА ОБЗ.) selector switch which is used for manually shifting the scanning zone in elevation. The selector switch may be placed in the following positions: 10° (downward) and 0°; 1.5°; 2°; 2.5°; 10°; 20°; 30°) (upward);

- the ATMOSPHERICS (МЕТЕОПОМЕХИ) selector switch which is intended to cut in the atmospherics protection circuit of the airborne radar;

- the PASSIVE JAMMING (ПАСС. ПОМЕХА) selector switch which is used for cutting in the airborne radar passive jamming protection circuit;

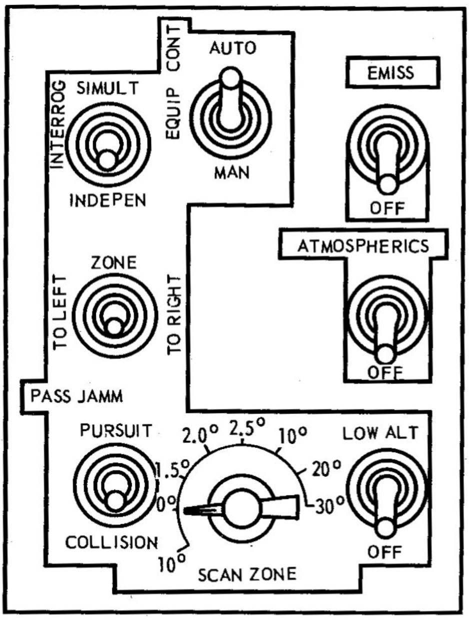


FIG. 113. AIRBORNE RADAR CONTROL PANEL

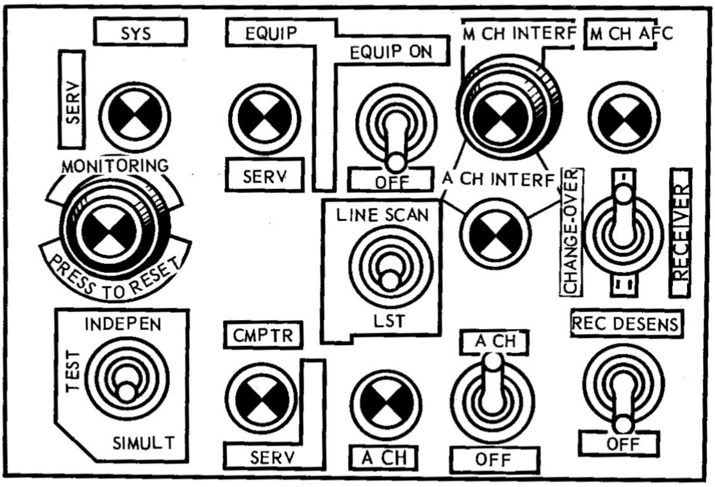


FIG. 114. CONTROL AND MONITORING PANEL

- the LOW ALTITUDE (МАЛ. ВЫСОТА) selector switch which is used for cutting in the LOW ALTITUDE mode.

The airborne radar control and monitoring panel (Fig. 114) is arranged on the starboard side in the cockpit and is intended to ensure control and monitoring of the airborne radar. The controls arranged on the control and monitoring panel are intended for the following purposes:

- the CH AFC (MAIN CHANNEL AUTOMATIC FREQUENCY CONTROL) (АПЧ ОК) lamp comes on in the event of failure of the automatic frequency control system. If this lamp flashes up, this means that the target detection is impossible or the target detection range is sharply reduced;

- the M CH INTRF (MAIN CHANNEL INTERFERENCE) (ПОМЕХА ОК) button light is intended to indicate the occurrence of active jamming in the main channel. Target lock-on in angular coordinates completed, the pilot can cut in the auxiliary channel emitter by depressing the button light;

- the EQUIPMENT ON (ВКЛ. АППАР.) selector switch which is used for turning on the airborne radar. As soon as this selector switch is closed, the airborne radar becomes ready for operation in 3 to 4 min;

- the A CH INTRF (AUXILIARY CHANNEL INTERFERENCE) (ПОМЕХА ДК) lamp which comes to glow if active jamming occurs at the first frequency of the auxiliary channel;

- the RECEIVER SELECTION (ПЕРЕКЛ. ПРИЕМН.) selector switch which is intended for cutting in either receiver I or receiver II of the main channel to operate in the scanning mode. Both the receivers are identical, but only one of them is engaged in scanning mode. The necessity in changing over the receivers may arise when the pilot is in doubt whether it is serviceable or not (no blip on the screen). The target detection is possible with the use of the second receiver if the first one is faulty, but the target lock-on is impossible in this case;

- the LINE SCAN - LST (ОБЗОР СТР. - МСЦ) selector switch which is used for cutting in the single-line scanning mode (LINE SCAN position), as well as for de-energizing the speed selection circuit (LST position), in performing an attack on a low-speed target and attacking at aspect angles above 2/4;

- the RECEIVER DESENS (ЗАГР. ПР-МА) selector switch is intended for manually switching on the main channel receiver desensitization circuit in the event of active jamming. With the desensitization circuit energized, the target detection range is diminished one and a half or two times;

- the A CH - OFF (ДК - ВЫКЛ.) is used for cutting off the auxiliary channel receiver;

- the A CH lamp is intended to indicate the deterioration of the auxiliary channel receiver thermal conditions. When the A CH lamp flashes up, it is necessary to turn off the auxiliary channel with the use of the A CH - OFF selector switch;

- the pressure-type MONITORING - INDEPENDENT - SIMULTANEOUS (КОНТР. - АВТОН. - СОВМЕС.) selector switch is intended for switching on either the independent or simultaneous monitoring system. During the simultaneous monitoring, airborne radar, computer automatic flight control system, and armament system are checked for serviceability. The simultaneous testing equipment is to be used during ground testing of the systems only. It is permissible that the independent monitoring be switched on in flight too. In the independent monitoring only the airborne radar and the computor are checked for serviceability. The proper functioning of the airborne radar which is checked by the built-in monitoring system is indicated by the illumination of the EQUIPMENT SERVICEABLE (АППАР. ИСПР.) lamp. The serviceability of the computor is testified by the illumination of the COMPUTOR SERVICEABLE lamp. The serviceable condition of the armament system and automatic flight control system is evidenced by the flashing-up of the SYSTEM SERVICEABLE (СИСТ. ИСПР.) lamp. The switching-on of the built-in monitoring system is indicated by the MONITOR ON - DEPRESS TO RESET (КОНТРОЛЬ ИДЕТ - СБРОС НАЖАТЬ) button light. As soon as the button light is depressed, the monitoring is reset.

The guidance panel arranged on the port side of the cockpit is intended for manual guidance of the target lock-on zone (gate pulses), as well as for resetting target lock-on.

MISSILE P-40

1. PURPOSE AND BASIC PERFORMANCE

The P-40 airborne homing missile is designed for hitting various air targets (aircraft and winged missiles). The missile is essentially a winged flying vehicle having a canard configuration, that is the control surfaces are arranged ahead of the wings.

For the purposes of enhancing the missile antijamming capability with respect to jamming and natural noise the missile is manufactured in two versions:

with radar homing head (missile of the P-40P type);

with infra-red homing head (the P-40T missile).

The P-40 missile has the following basic performance:

(1) Flying altitude of targets to be intercepted:

from 0.5 to 27 km in rear-cone (rear hemisphere) attack;

from 2.5 to 27 km in forward-cone (forward hemisphere) attack.

(2) Maximum flying speed of targets to be hit during attack:

up to 2400 km/h in rear hemisphere attack;

up to 3250 km/h in forward hemisphere attack.

(3) Maximum elevation of a target over the interceptor-fighter ΔH_{max} is determined from the following equation

$$\Delta H_{max} = 2000 + 0.2H_i ,$$

where H_i - interceptor-fighter flying altitude at the moment of missile launching, m.

(4) Permissible aiming error $\Delta\varepsilon_{permis}$ is determined from the following equation

$$\Delta\varepsilon_{permis} = 40^{o}K \frac{R_{launch}}{R_{permis.\ max}},$$

where K - coefficient which takes account of missile launching conditions;

R_{launch} - target range at the moment of missile launch;

$R_{permis.\ max}$ - maximum permissible launching range calculated by the computor of the PП-25 radar sight.

(5) Controlled flight maximum time accounts for 40 s.

(6) Maximum available g-load factor in the missile control channels accounts for 15.

(7) Maximum additional missile flying speed in variation with the launching altitude and speed ranges from 540 to 720 m/s.

(8) Minimum permissible missile-to-target approach speed depending on the fuze operation amounts up to 200 m/s.

(9) Operational radius of the proximity fuze, with the probability close to the unit:

10 to 20 m against large-size targets;

6 to 7 m against pinpoint targets.

(10) missile starting mass is 470 kg.

(11) Warhead mass is 38 kg.

(12) Number of fragments accounts for 1800 pcs.

(13) Mass of a single fragment equals 7 g.

(14) Rocket engine operating time is from 4 to 6.7 s.

(15) Time of missile flight from the moment of launching till the moment of self-destruction ranges from 40 to 60 s.

2. MAJOR COMPONENTS AND SYSTEMS OF MISSILE

The P-40 missile comprises the following major accessories and systems:

- missile body with wings and control surfaces;
- powder rocket engine;
- armament;
- missile control equipment;
- electrical equipment;
- gas system;
- cooling system;
- pneumatic system (for the P-40P missiles only).

A tracer may be fitted to the tail portion of a missile to provide conveniency for observing a missile in flight during the firing practice.

The body is intended for housing the missile equipment. Together with the wings and control surfaces it forms the missile aerodynamic system with required aerodynamic characteristics.

The powder rocket engine imparts a required speed to the missile for target interception. Propellant grain is initiated by means of a couple of squibs and an igniter. Powder gases rush out through two side nozzles to create jet thrust.

The armament of a missile consists of a fragmentation warhead, a combined radio-optical proximity fuze, contact electromagnetic sensors, and an actuator-and-safety mechanism.

Some missiles P-40 are equipped with electronic fuzes instead of the combined radio-optical proximity fuzes. An additional warhead of 17 kg in mass and an actuator-and-safety mechanism are also provided.

The missile control equipment comprises an infra-red or radar homing head and automatic pilot which ensure missile guidance and stabilization in flight. A homing head is intended to generate electric control signals depending on the relative motion of a missile and a target into the missile control system.

The infra-red homing head incorporates a liquid nitrogen power pack which is intended for cooling the photo-detector of the head with liquid nitrogen.

The automatic pilot composed of control units and sensing devices is used for stabilizing a missile relative to the centre of masses and converting the electric control signals furnished by the homing head into the required angular deflection of the control surfaces and ailerons in accordance with the common guidance law.

The missile electrical equipment provides for the electric power supply and interaction of the missile accessories. The electrical equipment comprises a power pack, automatic control unit, conversion unit, and electric wire bundle network with plug connectors.

The gas equipment (gas system) is intended to provide hot gas to the turbogenerator of the power pack and the servo units of the autopilot. The gas equipment comprises a solid-propellant not gas generator, filter, and pipe-line system with fittings.

The cooling equipment (cooling system) is used for maintaining the inner temperature inside the missile compartments within the prescribed limits to ensure proper functioning of the missile equipment. The missile cooling equipment incorporates a temperature pick-up, an airborne freon pneumatic connector, and a pipe line system with fittings.

The pneumatic equipment ensures operation of the radar homing head drive. The pneumatic equipment (pneumatic system) comprises an air package, a freon pneumatic connector, test connections, connections used for charging the air bottle which is integrated in the air package, and a pipe line system with fittings.

MISSILE LAUNCHING SYSTEM

The missile launching system provides for:

- secure locking of missiles on launchers at any change in aircraft attitude;
- reliable electric power and compressed air supply and cooling of missile sections with freon;
- preparation of missiles for launching;

- launching missiles in series by two or by one;

- emergency jettisoning of missiles.

The missile launching system comprises the launching electrical automatic equipment, four launchers АПУ-40, controls and indication system.

The electrical automatic equipment is essentially a package of separate units arranged in compartment No. 5 of the aircraft fuselage.

The launchers house a pneumatic system containing an amount of compressed air sufficient for 7-min continuous operation (for the P-40P missiles), missile emergency jettison pneumatic system, cooling system with freon content sufficient for 30-min operation, as well as locking, connect-release, warning, and interlocking mechanisms.

Controls and indication system are located on the starboard and port sides of the cockpit, on the upper left-hand panel of the instrument board, and the instrument board annunciator.

Arranged on the cockpit port side is the MR SIMULATION - MSL, LG (ИМИТАЦИЯ МР - СС, ШАССИ) selector switch which is intended for switching off the interlock with respect to the position of the extended landing gear when checking the electrical automatic equipment on the ground.

The following circuit breakers are arranged on the cockpit starboard side:

- the MSL INBD (СС ВНУТРЕН.) and MSL OUTBD (СС ВНЕШН.) circuit breakers which are used for energizing the electric circuits of the inboard and outboard missiles;

- the EMERG INBD MSL JETTIS (АВАРИЙНЫЙ СБРОС СС ВНУТРЕН.) and EMERG OUTBD MSL JETTIS (АВАРИЙНЫЙ СБРОС СС ВНЕШН.) circuit breakers which are intended for switching on the inboard and outboard missile emergency jettison systems.

The upper left-hand panel of the instrument board accommodates the following:

- the MSL LNCH (ПУСК СС) circuit breaker which is used for energizing the missile launch circuits;

- the φ_b - + RDR - φ_o ($\varphi_Л$ - С РЛС - φ_o) three-position selector switch which is used for changing over the electric circuitry to the automatic or semiautomatic (manual) mode of operation;

- the FH - RH (ПП - ЗП) selector switch which is used for final preparation of missiles for launching during operation in the semiautomatic mode depending on the hemisphere of attack;

- the SMALL - LARGE (МАЛАЯ - БОЛЬШАЯ) selector switch which is used for selecting the optimum amount of the proximity fuze action delay depending on the target size;

- the TERRAIN - AIR (ЗЕМЛЯ - ВОЗДУХ) switch which is used in the TERRAIN position for de-energizing the proximity fuze when launcing the missiles against ground targets;

- the SERIES - SINGLE (СЕРИЯ - ОДИН) selector switch which is used for selecting the firing version;

- the EMERG MSL JETTIS (АВАР. СБРОС СС) switch which is used for the missile emergency jettisoning.

The annunciator on the instrument board comprises the LH OUTBD MSL, (СС ВНЕШН. ЛЕВ.), RH OUTBD MSL (СС ВНЕШН. ПРАВ.), LH INBD MSL (СС ВНУТР. ЛЕВ.) RH INBD MSL (СС ВНУТР. ПРАВ.) lamps intended for indicating the presence of the missiles on the respective launchers.

The lamps located on the radar sight indicator edging indicate the actual passage of the FILAMENT (НАКАЛ) signal at least to one of the missiles (lamp F) and readiness of the missiles for launching (lamps ①, ②, ③ and ④).

The firing button by means of which the airborne missiles are launched is arranged on the aircraft control stick.

COLLIMATING SIGHT K-10T

The K-10T collimating sight is a simplest optical sight and is intended for aiming the missiles on visible targets in modes "φ_o" and "φ_b".

Basic data:

- the angular amount of the large circle radius equals 120 mils (6°53');
- the angular amount of the small circle radius equals 80 mils (4°36');
- the large division of the reticle equals 20 mils (1°09');
- the small division of the reticle equals 10 mils (0°34.5');
- the angular size of the large line is 11.4 mils (0°39.5');
- the angular size of the small line is 5.7 mils (0°19.7').

The collimating sight incorporates:

an optical system with a back-folding light filter;

a lamp with a brilliance adjustment potentiometer;

a mechanical duplicator.

CHAPTER II

INTERCEPTION FLIGHTS

1. GENERAL

The intercept flight is essentially a continuous process performed for the purpose of destroying hostile air targets. This process involves the following three main stages:

- ground guidance;
- airborne guidance (homing guidance) followed by missile launching and break-away;
- return to the landing aerodrome, landing approach, and landing.

The first stage is intended for solving the mission of ground guidance. The objective of this stage is to bring an interceptor-fighter into an area which is advantageous in the tactical sense to detect, lock-on and attack a target with due regard to the flight altitude, assigned aspect angle, and capabilities of the interceptor-fighter armament.

During instrument guidance the interceptor-fighter systems receive control commands, information on the mutual position of the interceptor-fighter and a target, as well as commands for switching on separate components of the armament system from the instrument guidance equipment through the АРЛ-НМ automatic telemetering radar system line. In response to these commands the interceptor-fighter is automatically controlled in the horizontal plane, the airborne radar scanning zone is automatically controlled in azimuth and elevation, the airborne radar emission is started, and the missile filament is cut in.

In the vertical plane the aircraft is controlled by the signals furnished by the programming device of the САУ-155П (САУ-155П1) automatic flight control system. The required flight parameters are set by the pilot on the speed and altitude selector.

The air target interception flight is effected in accordance with the standard speed and altitude gaining programmes realized in the programme devices of the automatic flight control system. There are three speed and altitude gaining programmes for the МиГ-25П aircraft:

- reheat programme is used in the short-range intercept version;
- combination programme is used in the long-range intercept version;
- cruising programme is used in the interception of targets flying at altitudes from 10 to 13 km at speeds below or equal to 1100 km/h, as well as during interception of low-altitude targets flying at long distances to the aircraft.

When performing a flight in accordance with the first programme the speed and altitude gain is effected during operation of the engines at the FULL REHEAT (ПОЛНЫЙ ФОРСАЖ) power setting. The flight is performed with a constant increase in climb and speed. Transition to a supersonic speed flight regime takes place at an altitude of 4000 to 4500 m. Therefore, the above said programme can be effected only in combat conditions or in areas where there are no limitations in the supersonic speed transition altitude.

The second programme involves the operation of the aircraft engines at reheat and non-reheat power settings.

This programme includes the following components:

(1) takeoff with the engines running at the FULL REHEAT power setting;

(2) cruising climb to an altitude of 7500 m at a Mach number of 0.8, with the engines running at a maximum power setting and the aircraft subsequently flying at a cruising altitude and Mach number of 0.8;

(3) acceleration of the aircraft in level flight to a speed suitable for the completion of the automatic flight control system programme (M_{entry} = 1.3), with the engines running at a reheat power setting;

(4) the further climb with the increase of a Mach number to the assigned value.

When performing the flight in accordance with the second programme in the areas where the supersonic transition at an altitude of 7500 m is not allowed, first climb to an altitude of 10,000 m at a reheat power setting and true airspeed of 1000 km/h to further accelerate the aircraft to M_{entry} = 1.58.

The flight in accordance with the third programme at non-reheat power setting is performed as in the case of the second programme.

The homing guidance stage commences with the detection of a target displayed on the airborne radar screen and its lock-on for automatic tracking. The target lock-on completed, the aircraft control in the horizontal plane is effected in response to the signals obtained by the automatic flight control system from the airborne radar. In the vertical plane the aircraft control is effected in response to the signals generated by the programme device of the automatic flight control system. In view of the fact that by the moment of the target lock-on the interceptor-fighter usually is at a reference altitude, the programme device of the automatic flight control system ensures the aircraft flight at this altitude by its signals. Upon reception of the ZOOM (ГОРКА) signal, the interceptor-fighter is controlled in the vertical and horizontal planes in response to the commands given by the airborne readar computor.

As soon as the interceptor-fighter enters the zone of possible launching of missiles, the pilot launches the missiles. The airborne radar computor calculates the required target illumination time and upon expiration of this time generates the BREAK-OFF (ОТВОРОТ) command in response to which the aircraft should break away.

The third stage involves the interceptor-fighter return to the landing aerodrome. This stage commences from the moment of completion of the break-away. Flight to the aerodrome is effected by the commands from the ground flight control aids.

The aircraft control may be effected throughout the three stages in director, automatic, and manual control modes.

In the course of the ground and homing guidance stages the automatic control mode is allowed only on the МиГ-25П aircraft provided with the САУ-155П1 automatic flight control system when used for interception of targets flying at altitudes of 3000 m and higher.

It should be borne in mind, however, that missile launching in the automatic homing guidance mode is temporarily suspended. In order to avoid an uninterntional violation of the above limitation the pilot is provided with the TM - CM (TRAINING MODE - COMBAT MODE) (УР - БР) selector switch arranged on the cockpit starboard side. With the selector switch set in the CM position, depressing the firing button switches off the automatic control mode. As a consequence, the breakaway maneuver, is flown in the director control mode.

2. INTERCEPTION OF AIR TARGET WITH REAR, CONE ATTACK AT HIGH AND MEDIUM ALTITUDES

The principle method of guiding the МиГ-25П interceptor-fighter against air targets is the instrument guidance method involving the application of the automatic control systems (ACS). Interception with the use of the automatic flight control system is the most effective application of the fighter.

Air target intercept flights with the use of the automatic control systems and the aircraft automatic flight control system must be preceded by thorough preparation of the pilot and the controller at the command post who is responsible for guidance operations.

During joint training of the pilot personnel and the team of the command post (direction post) the following subjects should be mastered and specified:

(a) procedures for checking the АРЛ-СМ automatic telemetering radar system for passage of commands;

(b) procedures for reaching the initial guidance point by the interceptor-fighter and chosing the moment of beginning of issue of guidance commands;

(c) radio communication procedures to be followed during instrument guidance;

(d) procedures for checking the guidance commands for passage to the aircraft systems and supervising the actions taken by the pilot and controller in the event of the non-passage of commands.

In the course of preparation for the instrument guidance intercept flight the pilot on entering the cockpit must set the aircraft armament system controls to the following positions:

- the FH - RH selector switch to mid-position;
- the φ_b - + RDR - φ_o selector switch to position + RDR;
- the MSL LNCH circuit breaker to the lower position;
- the SMALL - LARGE selector switch to position SMALL (when attacking a fighter) or to position LARGE (when attacking a bomber);
- the GROUND - AIR selector switch to position AIR;

- the SERIES - SINGLE selector switch to position corresponding to the flight mission.

To operate the РП-25 attack radar in the automatic mode, set the selector switches located on the panels to the following positions:

- the AUTO EQPMT CTRL - MAN (УПР. АППАР. АВТОМ. - РУЧН.) selector switch to position AUTO;
- the EMISSION - OFF switch to position OFF;
- the ATMOSPHERICS - OFF switch to position OFF;
- the LOW ALTITUDE (МАЛ. ВЫСОТА) - OFF selector switch to position OFF;
- the SCAN ZONE (ЗОНА ОБЗ) switch to zero position;
- the SIMULT INTERROG INDEP (ЗАПРОС СОВМ. - АВТОН.) selector switch to position INDEP;
- the PASSIVE JAM PURSUIT - COLLISION (ПАСС. ПОМЕХА ДОГОН - ВСТРЕЧА) selector switch to neutral;
- the ZONE - LH, RH (ЗОНА ВЛЕВО - ВПРАВО) selector switch to neutral;
- the ON EQUIPMENT OFF selector switch to position OFF;
- the LINE SCAN - LST (ОБЗОР СТР. - МСЦ) selector switch to neutral;
- the CHANGE-OVER OF RECEIVER I - II (ПЕРЕКЛ. ПРИЕМН. I - II) selector switch to position I or II;
- the A CH - OFF selector switch to position A CH;
- the RECEIVER DESENS - OFF (ЗАГР. ПР - МА - ВЫКЛ.) selector switch to position OFF.

After performing the above operations, prepare the cockpit for engine start, turn on the circuit breaker, wait for one or two minutes until the equipment becomes ready for operation, and set the assigned wave, code, and offset by manipulating the respective knobs on the control panel. Momentarily depress the MANUAL (РУЧН.) button and ascertain that the respective lamps of wave, code, and offset light up.

Establish radio communication with the command post controller and check the АРЛ-СМ automatic telemetering system for serviceability by checking the course, speed, and altitude indications for correspondence with the commands being prescribed.

Errors in the indications of the course, speed and altitude in relation to the assigned values must not exceed $\pm 6^{\circ}$, ± 50 km/h, and ± 300 m, respectively.

After starting the engines, set values of altitude and levelling-off Mach number (prescribed by the command post) on the altitude and speed setter provided that the intercept flight is going to be performed in accordance with the first programme.

When performing an intercept flight in accordance with the second or third programme, the pilot should set on the altitude and speed setter a levelling-off altitude of 7500 m (or 10,000 m when performing a maximum range intercept flight) and a levelling-off Mach number of 0.8.

After the initial values of altitude and levelling-off Mach number are set on the altitude and speed setter, depress the GUIDANCE (НАВЕД.) button light located on the control panel of the automatic flight control system and set the ON EQUIPMENT-OFF (ВКЛ. АППАР. - ВЫКЛ.) selector switch arranged on the control and monitoring panel of the РП-25 radar to position EQUIPMENT ON.

Wait for 3 to 4 minutes until the MFS lamp on the circular display of the attitude-command marks unit comes on to glow for a short period of time (1 s), thus being indicative of the readiness of the РП-25 radar for operation.

After takeoff and transition to the guidance channel ascertain that the commands and control signals properly pass through АРЛ - СМ. Commence instrument guidance on receiving the command from the guidance controller.

Automatic ground guidance. The aircraft automatic control mode is enabled at an altitude of 300 to 500 m and indicated airspeed of at least 650 km/h, with Mach number equalling or being more than 0.55.

Prior to cutting in the automatic control system, fly the required maneuver to zero the director pointers and position indicating bars of the flight director indicator. Further, depress on the AUTO CTRL button-light on the control panel of the automatic flight control system. This must be done only after zeroing is completed. Hold your hand on the aircraft control stick without applying any pressure.

If the director pointers and the position indicating bars of the flight director indicator are clear of the circles at the moment of cutting in the automatic control system, this means that the aircraft may enter the assigned trajectory at large roll and pitch angles. This may cause the pilot to be in doubt as to the serviceability of the aircraft automatic flight control system and to cut it off without proof.

The correctness of the automatic ground guidance should be checked by reference to the director pointers of the flight director indicator, the combined course indicator, and the indicated airspeed, Mach-number, and flight altitude indicators. If the interceptor-fighter flight is performed along the assigned trajectory, the director pointers of the flight director indicator are within the circle of the bank indicator and the position indicating bars are in close proximity to the zero marks.

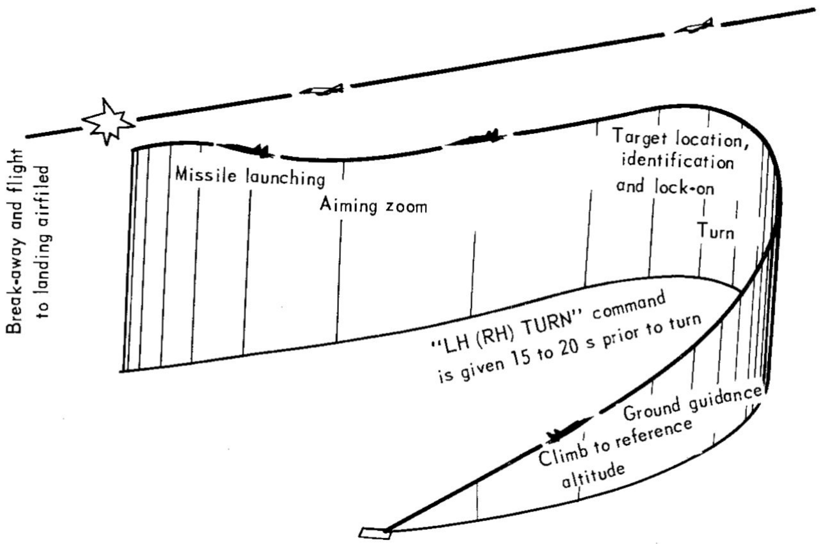


FIG. 115. AIR TARGET INTERCEPT FLIGHT PATTERN INVOLVING PURSUIT ATTACK AT MEDIUM AND HIGH ALTITUDES

The intercept flight pattern is given in Fig. 115. Prior to attaining the assigned reference altitude in climbing at a Mach number corresponding to the maximum range, the proper selection of the engine power setting and maintaining of the assigned flying speed are of particular importance. If the flying speed is below the programmed one, the climbing is discontinued and the aircraft descends with acceleration to the programmed airspeed. This may lead to an increase in the climbing time and, in the long run, may fail the interception.

It is essential that the pilot remember Mach number values in several points of the flight trajectory in order to be able to check that the programmed rate of climb is properly maintained (Fig. 116).

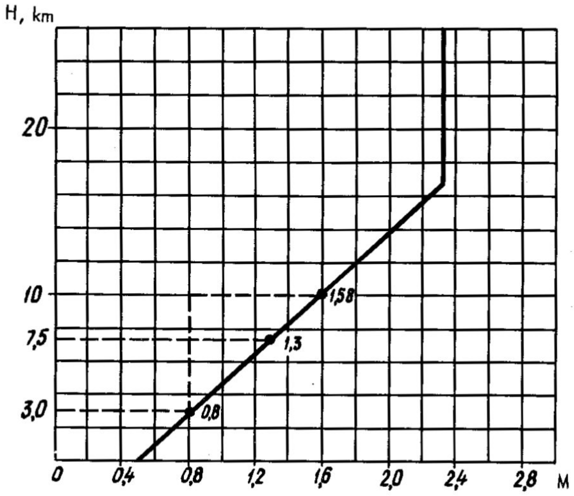


FIG. 116. DIAGRAM OF CLIMBING IN AUTOMATIC AND DIRECTOR CONTROL MODES

—— in accordance with programme realized in CAY automatic flight control system;

––– during target interception at maximum distance to interception line

It is clear from the graph that in climbing along the programmed trajectory the values of the airspeed in Mach number terms must be as follows:

- M = 0.55 at an altitude of 500 m;
- M = 0.8 at an altitude of 2700 to 3000 m;
- M = 1.3 at an altitude of 7500 m;
- M = 1.58 at an altitude of 10,000 m.

When performing flight in accordance with the second programme, climb to a cruising flight altitude of 7500 m (10,000 m) should be effected at an airspeed corresponding to a Mach number of 0.8 though flying the aircraft in accordance with the automatic flight control programme is planned to be performed at this altitude with a Mach number of 1.3 (1.58).

Such a conspicuous disagreement of the airspeeds makes it impossible to accelerate the aircraft in the automatic control mode. Therefore, after attaining the cruising flight altitude of 7500 m (10,000 m) it is necessary to perform the flight at Mach number of 0.8 with the flying altitude being stabilized. In the initial point of acceleration after the AFTERBURNER ON command has passed, turn off the automatic control system by depressing the AP DISENGAGE button and switch off the guidance mode by depressing the RESET button. During aircraft acceleration when the engines are running at the FULL REHEAT power setting, the pilot must set new altitude and speed values on the altitude and speed setter, depress the GUIDANCE button light, and continue acceleration of the aircraft in level flight to an airspeed enabling the aircraft to start the automatic flight control programme. The director pointers and the position indicating bars of the flight director indicator zeroed, depress the AUTO CTRL button-light and trim out the control forces.

It is recommended that the pilot follow the procedures of distributing attention in climbing given below:

(1) flight director indicator (the director pointers are within the circle of the bank indicator);

(2) combined course indicator (the flight course corresponds to the assigned one);

(3) altitude indicator;

(4) rate-of-climb indicator;

(5) engine and aircraft systems monitoring instruments.

Maintaining of the Mach-number in accordance with the climbing programme is checked periodically.

On attaining the altitude established on the altitude and airspeed setter the interceptor-fighter is automatically brought into level flight and the H_{preset} LEVELLING OFF lamp comes to glow. Levelling off to the assigned altitude in the automatic control mode may take place with an error of up to 500 m above the altitude established on the altitude and speed setter. In order to diminish the reference altitude interception error, select the partial augmented power setting 300 to 500 m prior to altitude levelling off. The constant airspeed (Mach number) is maintained by throttling the engines and referring to the H_{preset} LEVELLING OFF lamp which must come on.

<u>Director ground guidance.</u> In the director control mode the aircraft control is effected manually with reference to the

director pointers of the flight director indicator. (No pressure should be applied to the AUTO CONT button). By referring to deflection of the director pointers the pilot determines the direction and the amount of pressure to be applied to the controls to bring the aircraft to the assigned trajectory and to maintain it. Should the vertical director pointer of the flight director indicator deflect, the pilot must apply stick pressure in the direction of the pointer deflection, that is bank the aircraft. As the pilot introduces the required amount of bank, the pointer moves toward the centre of the circle. The control stick should also be returned to neutral. In the course of flight at the assigned bank the aircraft approximates the estimated trajectory and the director pointer starts to deflect in the opposite direction, thus indicating the necessity in diminishing the bank.

Aircraft piloting in the vertical plane is effected in a similar manner and in accordance with the amount and direction of deflection of the horizontal director pointer of the flight director indicator.

The procedure for climbing to the assigned altitude and attaining the required flight speed in accordance with the first and second programmes in the director control mode are similar to those involved in flying the aircraft in the automatic control mode. After passing of discrete command LEFT TURN or RIGHT TURN (lamp (<) or (>) on the attitude - command marks unit flashes up) the pilot must be ready for performing a turn in the respective direction. The turn should be started only at the moment the vertical pointer of the flight director indicator begins to deflect. Changing of the assigned course should be checked by reference to the combined course indicator.

The FILAMENT command passes through the automatic telemetering radar system to energize the missile heater circuits four minutes before ground guidance terminates. The passage of the FILAMENT command is indicated by the (F) lamp on the circular display of the attitude and command marks unit. The FILAMENT command is duplicated, in addition, by switching on the airborne radar to operate in the emission mode.

At a distance of 36 km to a target the airborne radar is automatically cut in to operate in the emission mode upon the command from the automatic heater control unit. The enabling of the emission mode causes the indicator display screen to illuminate and ensures the illumination of the radar azimuth and range scales.

Upon attaining the reference altitude and switching on the radar emission, the maximum attention should be given to the target detection. It is more practical, therefore, at this stage that the aircraft be piloted in the automatic control mode. Checking of the aircraft attitude must be effected by reference to the director mark or "bead", as well as the pitch and roll indicator on the attitude and command marks unit. The director mark on the attitude and command marks unit receives from the automatic flight control system the same signals that are furnished to the director pointers of the flight director indicator.

When performing flight involving missile launching, it is necessary that the MSL LNCH circuit breaker be cut in after the radar has been switched on for emission.

The recommended procedures for distributing attention after cutting in the radar to operate in the emission mode are as follows:

(1) the display screen of the РП-25 radar (the position of the director mark and the centre mark of the scanning zone, availability of target marks, pitch and roll);

(2) flight director indicator (correspondance of the roll and pitch readings to those presented on the display screen of the РП-25 radar);

(3) altitude indicator (ascertain that the flying altitude corresponds to that established on the altitude and speed setter);

(4) true airspeed and Mach-number indicator (check to see the flying speed is in conformity with the assigned one);

(5) instruments monitoring operation of the engines and aircraft systems.

The scanning zone in azimuth and elevation and the lock-on zone in range are controlled upon cutting in radar radiation on the commands delivered from the automatic heater control unit.

When the scanning zone is precisely controlled in azimuth, a target must be on the zero azimuth line on the same level with the gate mark (a descrepancy of $\pm 6^{\circ}$ is permissible).

The azimuth of the scanning zone center mark is determined by reference to the position of the gate mark relative to the lower scale. The target azimuth with respect to the scanning zone centre mark is determined by reference to the upper scale. Thus, the azimuth of the target with respect to the aircraft longitudinal axis is determined as the algebraic total of the scanning zone centre mark azimuth with reference to the lower scale and the target azimuth with reference to the upper scale (Fig. 117).

Upon cutting in radar emission at a distance of 36 km to the targets the process of detection of all the targets having effective reflection surface area δ_{eff} of more than 0.5 m^2 takes place practically at one and the same time. The mark of a target with δ_{eff} = 10 to 20 m^2 has a width of 5 to 6 mm and appears on the display screen during each scanning cycle. The marks of a target with $\delta_{eff} \leq$ 2 to 3 m^2 are 2 to 3 mm wide and may appear on the display screen every other scanning cycle. The minimum time required for effecting target location accounts for 6 to 7 s (double scanning cycle).

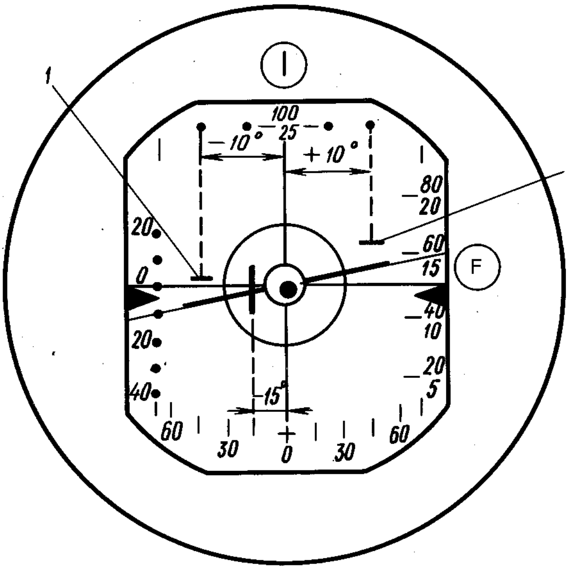


FIG. 117. DETERMINING TARGET AZIMUTH

1 – target azimuth equals 25°; 2 – target azimuth equals 5°

Target detection completed, it must be identified. To this end, the INTERROG selector switch should be set to the INDEP position. As a consequence, the other identification mark will appear above the mark indicating a friendly aircraft at a distance of 3 to 4 mm (Fig. 118). If the identification mark is not available, this means that the target is an enemy aircraft.

Whenever a friendly aircraft and an enemy aircraft are within one and the same range but in different azimuths, the identification mark may appear above the enemy aircraft identification mark as well. In this case it is necessary to set the INTERROG selector switch to position SIMULT (COBM.).

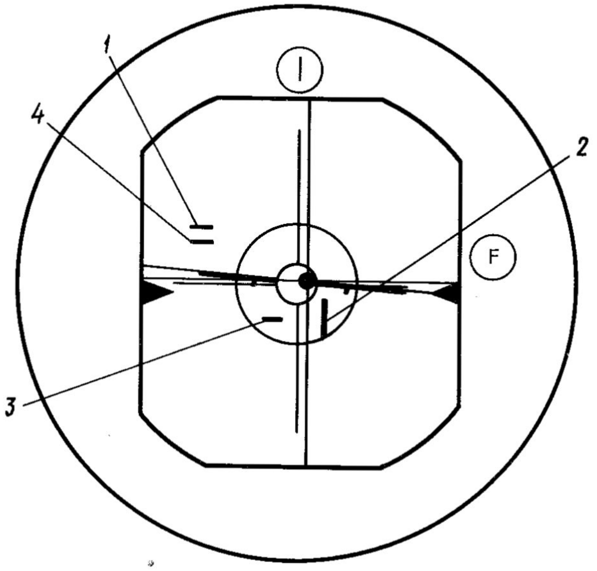


FIG. 118. RADAR SIGHT DISPLAY IN TARGET DETECTION AND IDENTIFICATION

1 – identification mark; 2 – azimuth and range scanning zone centre mark (gate); 3 – target mark; 4 – friendly aircraft mark;

If several marks are displayed on the sight indicator screen prior to attack, the pilot should ascertain that the equipment has selected the very target at which the aircraft has been guided.

If a target to be attacked is properly selected, the target mark should be on the same level with the range gate mark and displacement of the very gate mark must correspond to displacement of the target range mark. In case several targets are on the level with the gate mark, the pilot must inform the command post about the coordinates of the target to be attacked and receive the acknowledgement for lock-on.

If a single target mark is on the same level with the range gate mark, the target lock-on is effected by depressing the LOCK-ON (ЗАХВАТ) button and holding in this position for 3 to 5 s.

Should it be clear from the screen that the radar sustains interference or several target marks emerge at the same level with the gate mark, it is necessary prior to the target lock-on to manually gate the target by depressing the homing guidance lever, superimpose the lock-on zone confined by the two vertical gates on the selected target and then depress the LOCK-ON button.

During the rear-cone attack and after switching on the emission mode at a distance of 36 km, the pilot is provided with plenty of time from the moment of the target detection to the moment of the missile launching. The long-range target lock-on usually results in the enemy, vigorous maneuvering for the purpose of escaping from the interceptor-fighter attack and resorting to application of the available means of electronic countermeasures. Therefore, it should be considered tactically wise to lock on the targets within the ranges close to the maximum permissible missile launching ranges.

The target lock-on (the transition of the РП-25 radar from the scanning mode to the target automatic tracking mode) is checked by the change-over of the indicators from the presentation of the scanning information to that of the sighting one and by reference to the (A) lamp (attack) on the attitude - command marks unit which must light up (Fig. 119).

Immediately upon completion of the target lock-on, the pilot must ascertain that not a false target has been locked on (atmospherics, signals reflected by the ground, etc.). The simplest method of identifying a false target is to determine the mutual position of the marks designating the speed of approach and the flying speed of the interceptor-fighter, as well as by the target angular coordinates which are determined by the position of the beam mark. If a true target is locked on, the approach speed mark will be below the interceptor-fighter flying speed mark and, the beam mark is on the edge of the small circle. Should a false target be locked on, the pilot must depress the homing guidance lever and move it backward as far as it will go, and repeatedly gate and lock on the target.

The minimum time required for the repeated lock-on accounts for 5 to 6 s in the automatic gating mode and 9 to 11 s in the manual gating mode.

Homing guidance stage. This stage commences from the moment of flashing-up of the (A) lamp on the attitude-command marks unit. This lamp indicates that the transient processes taking place during the target lock-on are terminated and the automatic flight control system starts receiving the control signals and commands from the computor.

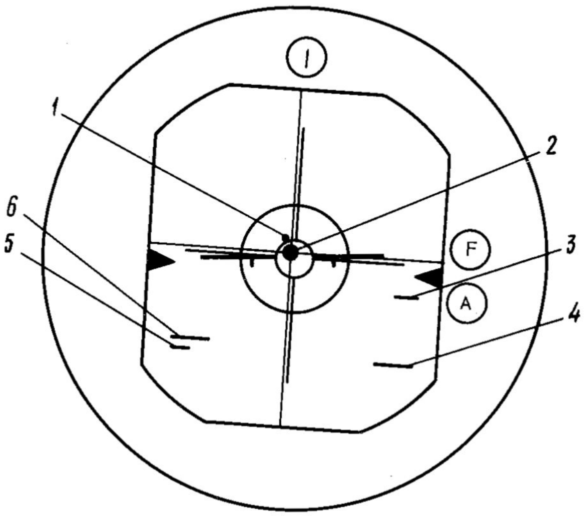


FIG. 119. RADAR SIGHT DISPLAY UPON COMPLETION OF TARGET LOCK-ON

1 – beam mark; 2 – director mark (bead); 3 – current range mark; 4 – missile launch maximum permissible range mark; 5 – closure speed mark; 6 – interceptor-fighter relative speed mark

The transition from the ground guidance stage to the homing guidance in the aircraft automatic control mode is commonly smooth in progress. Vigorous corrective turns are possible only during lock-on of false targets, gross errors of guidance, and failure of the automatic flight control system.

It is recommended that the pilot should follow the procedures for distributing attention upon completion of the target lock-on presented herein below:

(1) the display screen of the indicator of the РП-25 attack radar (roll, pitch, position of the director mark, mutual position of the current range mark and the $D_{m\ max}$, the interceptor-

fighter flying speed mark and the mark indicating the speed of approach);

(2) flight director indicator (pitch and roll);

(3) airspeed and Mach-number indicator (flying speed corresponds to the prescribed one);

(4) altitude indicator (flying altitude corresponds to the assigned one);

(5) instruments to monitor operation of the aircraft engines and systems.

In the director control mode upon completion of the target lock-on it is necessary to continuously hold the director mark within the centre of the small ring of the display screen. Prolonged piloting with the director mark set off the centre of the ring even at a constant amount of its departure leads to gross errors in aiming which may prove impossible even after bringing the director mark into the small ring of the display screen directly before the missile launch.

22 seconds before reaching the maximum missile launching range the computor generates a ZOOM (ГОРКА) command. In response to this command the (Z) indicator lamp on the circular display of the attitude and command marks unit flashes up and the director mark displaces upward in a step manner.

In the automatic control mode the aircraft automatically enters into climb following the "bead". This saves time for the pilot who is enabled to give greater attention to checking the flying speed, g-load and flight altitude.

In the director control mode upon the ZOOM command the pilot should manually bring the aircraft into the climb maneuver following the deflection of the "bead". Under these conditions the maneuver speed will depend on the rate of the director mark displacement. If the director mark moves upward vigorously, the zoom entry must be accomplished by the pilot rather energetically, introducing a g-load for a period of 3 to 5 s and without exceeding the assigned limitations. When rforming a zoom, the director mark should be brought into the small ring.

When performing a zoom the pilot is recommended to follow the procedures of distributing attention given below:

(1) the ИП-155 g-indicator (correspondance of the g-load developed with the maximum permissible one indicated by the moving sector of the indicator);

(2) the display screen of the РП-25 radar (the rate of displacement of the director mark towards the centre of the display screen and pitch angle);

(3) flight director indicator (pitch angle and bank);

(4) airspeed indicator (rate of decrease in flying speed);

(5) altitude indicator (current stepped-down vertical separation check).

In order to prevent loss of speed in performing a zoom it is necessary that the engine should be accelerated to the maximum speed. In the event of a sharp decrease in the flying speed, turn on the afterburner. In so doing, it is necessary to frequently change over attention to the airspeed indicator in order to prevent the exceeding of the maximum (assigned) speed for the given flight conditions and to turn off the afterburner in a proper time.

To prevent the speed loss beyond the handling speed during the target interception at altitudes of 3000 to 7000 m, the zoom entry flying speed should be not less than 750 km/h and the stepped-up vertical separation of the target with respect to the interceptor-fighter should not exceed 2500 m.

Failure to keep within the limits of the permissible g-load or angles of attack is indicated by the generation of the LIMIT MANEUVER (МАНЕВР ПРЕДЕЛЬНЫЙ) voice information command and the blinking of two red lamps on the g-load indicator.

Should the permissible g-load or angles of attack be exceeded, move the control stick forward to diminish g-load (angle of attack) or backward (at negative g-load) until the indicator lamps fade out.

The ATTENTION, MSL LAUNCH (ВНИМАНИЕ, ПУСК) voice information is given one second prior to attainment of the maximum missile launch range.

Missiles are launched by depressing the firing button and holding it in this position for 2 s (until the missiles lift-off). In this case the following requirements should be observed:

(1) one of the lamps ①, ②, ③, ④ is glowing (the lamps light up at the moment the current range mark is aligned with the $R_{max.\ perm}$ mark; missiles are ready for launching; target sight angle does not exceed 45°);

(2) the director signal mark is within the limits of the small mechanical ring;

(3) the speed, g-load, and sideslip requirements for missile launching are observed.

The view of the indicator display screen at the moment of missile launching is shown in Fig. 120.

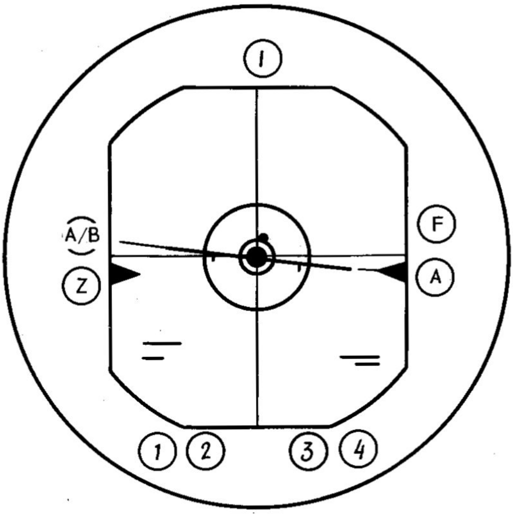


FIG. 120. RADAR SIGHT DISPLAY AT MOMENT OF MISSILE LAUNCHING

On the aircraft provided with the tail unit differential control means and inboard missile asymmetric lift-off automatic compensating unit it is allowed to perform the launching within the entire range of operational flight altitudes and airspeeds at positive vertical g-loads of 0.2 to 3 g and ball sliding deflection of not more than one ball diameter with $V_{IAS} < 700$ km/h and not more than by one and a half ball diameter with $V_{IAS} > 700$ km/h. In order to ensure missile flight stability after lift-off from the launchers, the minimum true airspeed during missile launching should equal 700 km/h.

The most kill probability in the rear-cone attack will be during the missile launching in the centre of the probable missile launch area. Missile launching from shorter distances imposes more stringent requirements upon the aiming accuracy. Since the pilot is not provided with the information about the permissible aiming error, he is forced to hold the director mark in the centre of the display screen prior to the missile launching for a longer period of time (at least 5 s) in order to ensure the assigned aiming accuracy.

Missile lift-off may be checked both visually and by reference to the respective MSL LAUNCH (ПУСК РАКЕТ) indicator lamps which fade out, as well as by reference to the annunciator signals which indicate that the missiles are suspended from the pylons. The automatic missile launch system ensures the following sequence of missile lift-off: No. 2, No. 4, No. 3, and No. 1 (all the LAUNCH PERMITTED (ПР) lamps flash up). If a missile to be launched is not ready (the MSL LAUNCH command has not been received) then comes the turn of the next missile ready for launching. Launching of two missiles from one and the same outer wing is impossible provided that the other two missiles remain on the opposite outer wing.

Symmetric missile launching (in series) does not practically affect the aircraft behaviour. Insofar as at medium and high altitudes the asymmetric inboard missile lift-off automatic compensating unit is inoperative (Mach-number is less than 2.4), the asymmetric missile launching (single missile launch) may cause the aircraft rolling and turning in the direction of the attached missile which can be counteracted with the aid of the rudders and ailerons under any flying conditions.

After depressing the firing button in the automatic control mode the aircraft automatic control system is switched off, and it is necessary to change over to the director control mode (the CM - TM (COMBAT MODE - TRAINING MODE) selector switch is set to the CM position).

If there is time for a repeated launching of another missile upon estimation of the first launch results, continue target approach, holding the director mark in the centre of the display screen. In case it is decided not to perform the repeated launching, withdraw from the attack at a bank of 60 to 70° immediately after the missiles provided with heat seekers (ТГС) have been launched and at a bank of 30 to 40° after launching the missiles fitted with radar seekers (РГС).

In all the cases withdraw from the attack at the BREAK-AWAY command (the BREAK-AWAY voice information is obtained and the Ⓑ lamp located on the attitude and command marks unit lights up) in the direction of the director mark deflection and hold this mark in the centre of the display screen (in this case the aircraft bank will be 60 to 70°).

In training flights (the CM - TM selector switch is set to the TM position) the aircraft automatic control is maintained during break-away as well. Insofar as the aircraft maintains a constant rate of climb upon the ZOOM command, the interceptor-fighter may attain an altitude of the target flight at the moment of the (B) lamp coming to glow. In this case the automatic control system should not be switched off for the distance at which the BREAK-AWAY command is generated ensures safe interval between the interceptor-fighter and the target.

An attack on a target without launching missiles in the automatic control mode is terminated by bringing the aircraft into level flight. To switch off the levelling-off mode, depress the AP OFF (ВЫКЛ. АП) button arranged on the control stick and check to see that the AUTO CONT, DAMP, and LEVELLING-OFF ON (АВТ. УПР., ДЕМПФ. И ВКЛ. ПРИВ. ГОРИЗ.) button lights have faded out.

After the levelling-off mode has been switched off, perform a turn to the assigned course and proceed to the landing aerodrome in the prescribed manner.

3. PECULIARITIES OF AIR TARGET INTERCEPT FLIGHT INVOLVING FORWARD-CONE ATTACK

The procedures and scope of preparation for the air target intercept flight involving forward-cone attack are identical to those involved in rear-cone attack intercept flight. The take-off, climb, and ground guidance procedures are also similar.

The major peculiarity of the intercept flight involving forward-cone attack is a high rate of the interceptor-fighter closing with the target and, as a consequence of this, a certain shortage of time required for the accomplishment of the attack. Therefore, in all the stages of interception the pilot should act particularly accurately and the time required for the successful performance of the target detection, identification, lock-on, and aiming operations should be reduced to the minimum. Meeting of these requirements is of particular importance in interception of point targets and high-speed targets.

In order to succeed in performing the forward-cone attack at a strong shortage of time, the pilot is advised to proceed as follows:

(1) make use of the aircraft instrument guidance and automatic control systems;

(2) select the optimum stepped-down vertical separation with respect to the target;

(3) turn on the target identification system in advance;

(4) automatically gate the target;

(5) depress the firing button immediately after the target lock-on has been completed.

Using the instrument guidance means diminishes the aiming error at the moment of locking on the target. In this case generally the aiming error does not exceed the permissible value, thus enabling the missiles to be launched without expenditure of time for aiming. Apart from this, the РП-25 airborne radar is automatically controlled in instrument guidance. This saves time through diminishing the number of operations with the radar controls and through automatic gating of the target.

The aircraft automatic control enables the pilot to pay most of the attention on target search and detection. Besides, the correction of the aiming errors upon completion of the target lock-on (in the automatic control mode) progresses considerably faster than in the director control mode.

In the forward-cone attack the maximum stepped-up vertical separation of the target over the interceptor-fighter depends on the target flying atlitude and may amount up to 7 km in the stratosphere. But, the optimum stepped-up vertical separation equals 1 to 2 km. At such a stepped-up vertical separation the vertical aiming errors are insignificant and the time required for their correction is little.

In target interception involving the forward-cone attack the radar emission mode is enabled in instrument guidance at a distance of 100 km (with the interceptor-fighter flying at an altitude of more than 8000 m) or 60 km (with the aircraft flying at an altitude below 8000 m).

The target detection range depends on the target effective reflective surface. Targets having an effective reflective surface of more than 20 m^2 can be detected at a distance of 90 km. The detection ranges of targets having an effective reflective area of less than 1 m^2 are given in Fig. 121.

It should be noted that the target lock-on zone mark limit displacement range both in the automatic and manual gating accounts for 75 km. Therefore a target can be detected in instrument guidance at a distance greater than the target lock-on zone range. Closing with a target in this case should be continued without making any attempt to lock on the target while the target mark

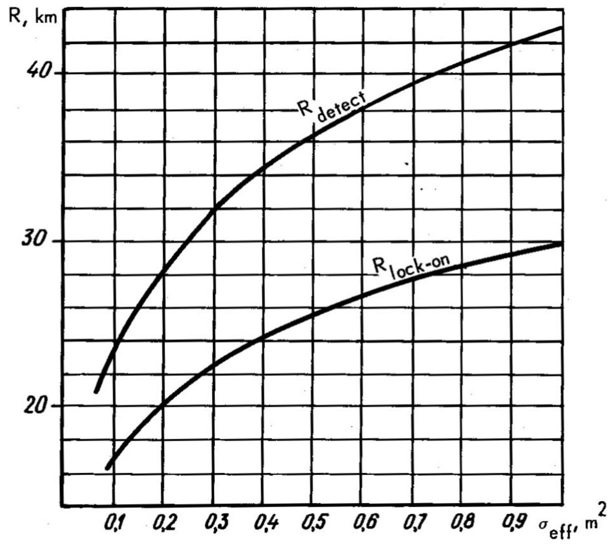


FIG. 121. TARGET DETECTION RANGE R_{detect} AND LOCK-ON RANGE $R_{lock-on}$ (BY MEANS OF RADAR PП–25) VERSUS TARGET EFFECTIVE REFLECTIVE SURFACE σ_{eff}

is not on the same range level with the target lock-on zone (Fig. 122).

In attack on high-speed and point targets depress the firing button immediately upon completion of target lock-on.

Every time when performing a forward-cone attack, it is necessary to launch missiles at a maximum permissible range. In this case the kill probability is increased and the aiming accuracy requirements are minimized.

The pilot's actions after missile launching are similar to the actions in the rear-cone attack.

The forward-cone attack at the lower limit of the combat altitude (H_{tgt} = 2500 m) has a number of peculiarities associated with the ground effect on the airborne radar.

Ground return gives rise to the ground clutter on the indicator display screen which in turn diminishes the target detection range and increases the probability of false target lock-on. Particularly strong clutter occurs during flight over marshy and wooded country.

The intensity of undersirable clutter can be diminished with the aid of the interference protection means. It should be remembered, however, that turning on the ATMOSPHERICS selector switch

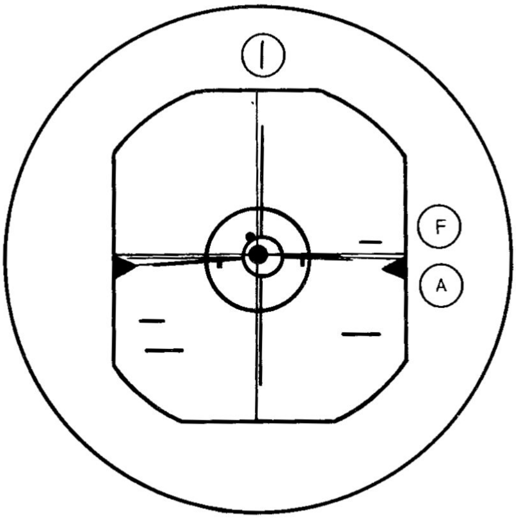


FIG. 122. RADAR SIGHT DISPLAY UPON COMPLETION OF TARGET LOCK-ON DURING FORWARD-CONE ATTACK

results in a decrease (approximately two-fold) in the target detection range. Therefore it is necessary to turn on the switch only when ground clutter makes it impossible to detect a target within a range of above 30 km.

The LOW ALT selector switch during the forward-cone attack should not be switched on for target lock-on failure may result due to the operation of the passive jamming protection system.

The target locked on, pay particular attention to the closing speed marks and interceptor-fighter flying speed marks and ascertain that a true target has been locked on.

In target interception at altitudes below 3000 m the aircraft handling is permitted in the director control mode only.

4. PECULIARITIES OF INTERCEPT FLIGHT WHEN PERFORMING GUIDANCE BY VOICE WITH USE OF RADAR PLAN POSITION INDICATOR

The intercept flight when performing guidance by voice with the use of the radar plan position indicator has certain peculiarities. They are associated with the fact that the scope of operations to be carried out by the pilot is largely increased. The switching-on of the airborne radar emission, control of the scan zone in azimuth and elevation, and the target gating before lock-on should be performed by the pilot manually with the use of the controls arranged on the control panels in the aircraft cockpit. The initial position of the selector switches located on the control panels during no-instrument-guidance intercept flight should be the same as in the automatic control mode, except for the EQPMT CONT selector switch which must be placed in the MAN position.

The intercept flight should be performed in strict compliance with the commands given by the controller at the command post (direction post) and transmitted by radio. During the ground guidance stage the aircraft should be piloted in the manual control mode.

When performing flight in accordance with the first programme the attainment of the prescribed flying altitudes and speeds should be effected at the FULL REHEAT engine power setting. In this case the flying speed is close to the maximum permissible value, i.e. an indicated airspeed of 970 to 1000 km/h should be maintained up to an altitude of 5000 m, and an indicated airspeed of 1000 to 1070 km/h should be further maintained up to the altitude of beginning of limitation by the maximum permissible Mach-number.

When performing flight in accordance with the second and third programmes the attainment of the cruising altitude is effected at a true airspeed of 900 to 920 km/h, with the engines running at a maximum power setting. The subsequent flight altitude and speed should be attained with the engines running at the FULL REHEAT power setting and with the indicated airspeed maintained at a level of 1070 km/h.

If climbing is effected without frequent corrective turns to the assigned course, the aircraft may be piloted either in the automatic or in the director control mode with the assigned course manually set on the combined course indicator. To this end, press on the GUIDANCE button-light, set the COURSE SELECT AUTO-MAN selector switch to position MAN, and using the knob set the combined course indicator to the course assigned by the command post (observation post). Prior to switching on the automatic control mode, set the director pointers within the limits of the small circle on the flight director indicator.

In case of descrepancy between the actual course and the assigned one upon switching on the automatic control mode, the aircraft should be turned to the assigned course at a bank of up to 60°.

During guidance by voice with the use of radar plan position indicator the scope of operations to be carried out by the pilot may be reduced by applying the automatic flight control system in the stabilization mode. Prior to switching on the stabilization mode, set the COURSE SELECT AUTO-MAN selector switch to the AUTO position, trim out the roll and pitch trimming mechanism control stick forces, and depress the AUTO CONT button light. After the stabilization mode has been switched on, trim out the stick forces. To carry out the altitude and heading commands given by the controller, apply the stick force to obtain the required roll and pitch angle under the stabilization mode conditions (as during the usual control) and trim the aircraft and trim out the stick forces.

Radar emission is cut in on the controller command by manipulating the EMISSION (ИЗЛУЧ) selector switch. Simultaneously, the FILAMENT (НАКАЛ) command is furnished to the missiles. The FILAMENT command should be given no later than 40 s prior to launching to ensure normal preparation of the missiles for launching. Consequently, the airborne radar emission must be switched on with due regard to the missile preparation time requirements.

Radar emission mode switched on, manually adjust the scanning zone in the optimum position to provide for the assured detection of the target. The shift of the scanning zone in azimuth in the respective direction is effected with the use of the SCAN ZONE LH - RH selector switch upon the controller's command or at a sight angle of 20 to 25°. The scanning zone is adjusted in elevation with the use of the SCAN ZONE selector switch depending on the stepped-up vertical separation of the target and the target range. The division marks on the selector switch correspond to the angle of deflection (in degrees) of the scanning zone lower boundary on the slope with respect to the horizon. The wrong setting of the selector switch may result in the failure to detect the target or in decrease of the target detection range.

Depending on the stepped-down vertical separation of the interceptor-fighter relative to the target, the SCAN ZONE selector switch should be placed in the following positions:

0.5° with ΔH = 1000 m;

2° with ΔH = 2000 to 3000 m;

3° with ΔH = 4000 to 5000 m;

5° with ΔH = 6000 to 7000 m.

The target gating should be effected manually with the use of the guidance lever. Prior to applying pressure to the guidance lever, the azimuth scanning zone center mark (gate) may be at any range depending on the position in which the guidance lever has been left.

The target locked on, ascertain that the GUIDANCE button light is in the depressed position and continue piloting the aircraft in the automatic or director control mode by reference to the director mark on the attitude and command marks unit. It should be borne in mind that the director mark is motionless in the centre of the display screen while the GUIDANCE button light is not depressed.

The indications presented by the РП-25 radar and the actions of the pilot upon completion of the target lock-on are the same as in the instrument guidance.

5. PECULIARITIES INVOLVED IN LOW-ALTITUDE AIR TARGET INTERCEPT FLIGHT

The major peculiarities involved in low-altitude air target interception are as follows:

(1) sharp decreases in the target detection and lock-on ranges as a consequence of a considerable interference with the airborne radar operation due to ground return;

(2) maximum missile launch ranges do not exceed 4 to 4.5 km owing to the limitations in the power/ballistic characteristics of the missile head and lock-on range. As a result, the time of presence of the interceptor-fighter in the permissible missile launch area is considerably diminished;

(3) more stringent requirements for piloting aircraft. Limitations imposed on the interceptor-fighter maneuverability due to ground collision hazard. Such a condition causes a drastic increase in the emotional stress imposed on the pilot;

(4) decreased capabilities of the target detection and control means. As a result, the automatic guidance of the interceptor-fighter is considerably impeded.

Target interception at low altitudes is possible only from the rear hemisphere at aspect angles of 0/4 to 2/4. The airborne radar can be effectively used only at altitudes of 500 m and above.

The guidance of the interceptor-fighter on a low-altitude target may be either instrument or by voice with reference to the plan position indicator of the airborne radar. The aircraft control mode may be either director or manual.

Flight to the target area should be performed at an altitude assigned by the controller at the command (direction) post. Altitude selection is effected in accordance with the assigned interception line and target detection range, i.e. flight to the target area may be performed at a cruising altitude. In this case climb to the cruising altitude should be effected either in the automatic or director control mode in accordance with any of three programmes. The further flight is carried out with stabilization of the assigned altitude or cruising altitude flight is performed at a constant Mach-number during instrument guidance.

Descent to the assigned attack altitude should be performed at the following rates of descent:

- 40 to 50 m/s from an altitude of 8000 m to an altitude of 5000 m;
- 25 to 30 m/s from an altitude of 5000 m to an altitude of 1000 m;
- 10 to 15 m/s from an altitude to 1000 m to an altitude of 300 m.

When flying the aircraft at the assigned reference altitude of interception below or equalling 1000 m, set the LOW ALT selector switch to OFF and ascertain that the required mode has been engaged by referring to lighting-up of indicator lamp (25) on the circular display of the attitude and command marks unit. Set the SCAN ZONE selector switch to a position corresponding to $+2^{\circ}$ (upwards) and set the radio altimeter indicator to the required critical altitude (solid index line).

Engagement of the LOW ALT mode causes the airborne radar to sustain the following changes:

(1) range scale is changed over (the entire scale corresponds to a range of 25 km);

(2) the lock-on zone decreases to 3.75 km in range;

(3) during instrument guidance the airborne radar scanning zone automatic control is ensured only in azimuth. In elevation the scanning zone is controlled manually within the limits of 0 to 3° (upward);

(4) compulsory energizing of the passive jamming protection circuit to operate in the PURSUIT mode irrespective of the position of the PASS JAMM PURSUIT-COLLISION slector switch.

The airborne radar is automatically cut in to operate in the radiation mode during instrument guidance (upon the "36 km" command) or manually, with the airborne radar operated in the manual control mode. Upon cutting in the radar emission, evaluate the nature of the ground clutter indicated on the display screen. The intensity of ground return depends on the interceptor-fighter flying altitude, the position of the scanning zone in elevation, and the kind of the underlying surface.

The interference (clutter) intensity decreases with increasing interceptor-fighter flying altitude and antenna elevation. When delivering an attack against a low-altitude target, the optimum stepped-down vertical separation should be 200 to 300 m. A decrease of the vertical separation relative to the target results in increase of the interference intensity on the display screen (owing to decrease in the antenna inclination) and increases probability of the interceptor-fighter getting into the wake produced by the target.

When flying the aircraft at low altitudes, the indicator display screen sustains a continuous clutter in its upper portion (Fig. 123). A change in the position of the scanning zone in elevation may result in the offset of the lower boundary of the clutter. It is necessary, therefore, to use the SCAN ZONE selector switch to select such an antenna elevation at which ground clutter appears at a distance of 7 to 15 km, depending on the flight altitude and regime and the nature of the underlying surface. However, an excessive elevation of the scanning zone (the ground clutter edge is at a distance of more than 15 km or no clutter at all) causes the target detection range to diminish.

Target search and location should be effected in the area which is free from interference. At low altitudes the target detection range does not practically depend on the target effective reflection area and accounts for 9 to 12 km.

A target detected, identify it. To this end, set the INTERROG selector switch to the SIMULT position.

To diminish the probability of locking on a false target, the gating operations should be carried out manually even if the airborne radar is in the automatic control mode. Upon completion of target lock-on, check to see once again that a real target has been locked on, not a false one.

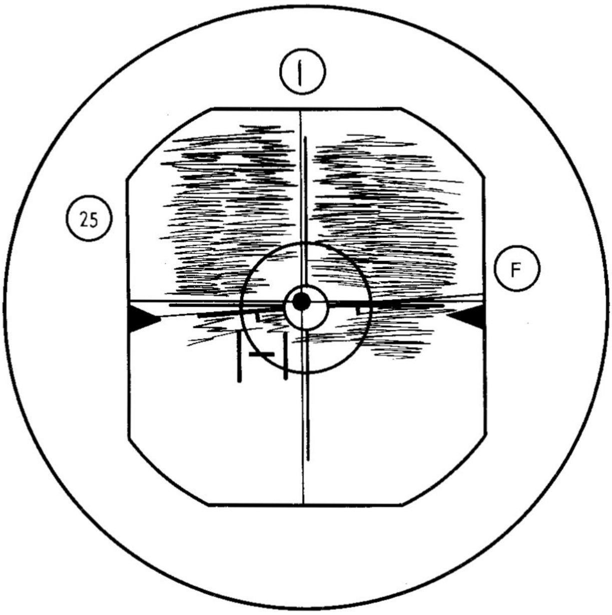


FIG. 123. TARGET DETECTION WHEN PERFORMING ATTACK AT LOW ALTITUDES

The symptoms of locking on a false target during low-altitude interception are as follows:

(1) unsteady position of the current range and $R_{max.\ perm}$ marks;

(2) the closure speed mark displaces in a skipping manner or coincides with the interceptor-fighter speed mark;

(3) the M CH INTRF or A CH INTRF indicator lamp lights up;

(4) chaotic displacement of the director mark on the screen;

(5) chaotic lighting-up of the (B), (Z), (A CH), (25) indicator lamps.

Should a false target be locked on, reset the lock-on, detect the target once again and repeatedly effect the target lock-on.

Upon completion of target lock-on pilot the aircraft in the horizontal plane by reference to the director mark. In the vertical plane, the reference altitude should be maintained by referring to the PB-4 radio altimeter and the УВО-30К altitude indicator. Descent to the critical altitude should be checked in accordance with the CRITICAL ALTITUDE voice information.

The subsequent actions to be taken by the pilot are similar to those used in an intercept flight at medium and high altitudes.

6. PECULIARITIES OF INTERCEPT FLIGHT IN CLOUDS

The peculiarities of an intercept flight in clouds are dictated by the necessity in constantly piloting the aircraft by referring to the instruments and the adverse effects of clouds on operation of the airborne radar.

When mastering flying technique in clouds the pilot has to concentrate all his attention to the flight and navigation instruments. In intercept flight, the pilot has, apart from what has been stated above, to operate the radar sight controls, attentively listen to or timely read off the guidance commands, timely change the flight regime and carry out all the armament system control operations prescribed for a given phase of interception in accordance with the readings of the instruments, radar sight display, the commands received and the air situation. In the target search and detection phase, for instance, the display screen of the radar sight becomes the primary object of the pilot's attention.

Attempting to detect the target, the pilot should at the same time periodically check the aircraft attitude and the flight regime to be maintained. The roll and pitch indicators on the display screen make it possible to approximately determine the aircraft attitude. It is necessary, therefore, to periodically consult the readings presented by the flight director indicator and other flight and navigation instruments in order to more accurately determine the actual aircraft attitude.

On making a decision to change the aircraft attitude, transfer your attention to the flight director indicator and then create the required roll or pitch angle. In maneuvering, handle the aircraft by reference to the flight and navigation instruments, periodically transferring attention to the display screen of the radar sight.

The automatic control system greatly helps the pilot in performing an intercept flight in clouds. The application of the CAУ automatic flight control system makes it possible to considerably reduce the scope of work to be done by the pilot. If the system is used, the pilot has only to check the flight regime. Besides, he is provided with an opportunity to spare more time to watch the display screen.

During intercept flight in clouds the ground guidance phase should be, as a rule, automatic, and the aircraft should be controlled either in the automatic or director control mode. In case the interceptor-fighter is controlled by voice over the radio with the use of the airborne radar plan position indicator in the ground guidance phase, it is expedient to use the aircraft attitude stabilization mode. This will contribute to mastering the intercept flights in clouds, especially in the initial stage of training.

The interference of clouds with the operation of the airborne radar consists in absorption and reflection of the energy of the radio waves. The tendency of the clouds to absorb the energy of the radio waves emitted by the airborne radar results in attenuation of the return signal, thus causing the reduction of the air target detection and lock-on ranges. A certain portion of the energy of the radio waves reflected by clouds is received by the airborne radar receiver and displayed on the radar sight display screen in the form of clutter which blurrs the target mark, thus impeding its detection, identification, and lock-on.

Clouds of various sheets and forms have various radio contrast which depends on the moisture content, density of clouds, and the character of the atmospheric processes which take place in them.

High-level clouds (cirrus, cirrostratus, cirrocumulus) have low radio contrast, the water content in them and their density are insignificant, and the optical visibility in these clouds accounts for 500 to 2000 m. Such clouds, therefore, commonly have no adverse effect on operation of the airborne radar. The target mark when performing flight in such clouds is clearly visible and no clutter occurs.

Medium-level clouds (alto-stratus and alto-cumulus) have stronger radio contrast and their water content is from 10 to 15 times as high as that of the cirrus. These clouds possess higher density and the range of visibility in them accounts for

100 to 300 m. Clouds of this type are capable of considerably interfering with operation of the airborne radar. During flight in these clouds the clutters displayed on the radar sight display screen have a form of separate large spots which make it more difficult to identify the target mark.

Dense low-level clouds (stratonimbus, fractostratus, stratus, stratocumulus) possess the highest radio contrast. Such clouds have considerable moisture content and density. The visibility range in these clouds does not exceed 15 to 30 m. During flight in these clouds there appear on the display screen continuous clutters which strongly impede target detection and lock-on (Fig. 124).

The mutual positioning of the target and the interceptor-fighter relative to clouds also strongly interfere with the normal functioning of the airborne radar. The intensity of clutter displayed on the display screen reaches its maximum when the target is flying in the clouds and the interceptor-fighter is below the clouds. Clutter intensity diminishes after interceptor-fighter entering clouds, with the target proceeding in the clouds.

During intercept flight in clouds, lock-on and automatic tracking of cloud returns may occur. Failure to identify a false target in due time may result in the attack failure.

To succeed in performing intercept flight in clouds, one should prior to flight familiarize himself with the character of clouds and the nature of their possible interference with the airborne radar operation.

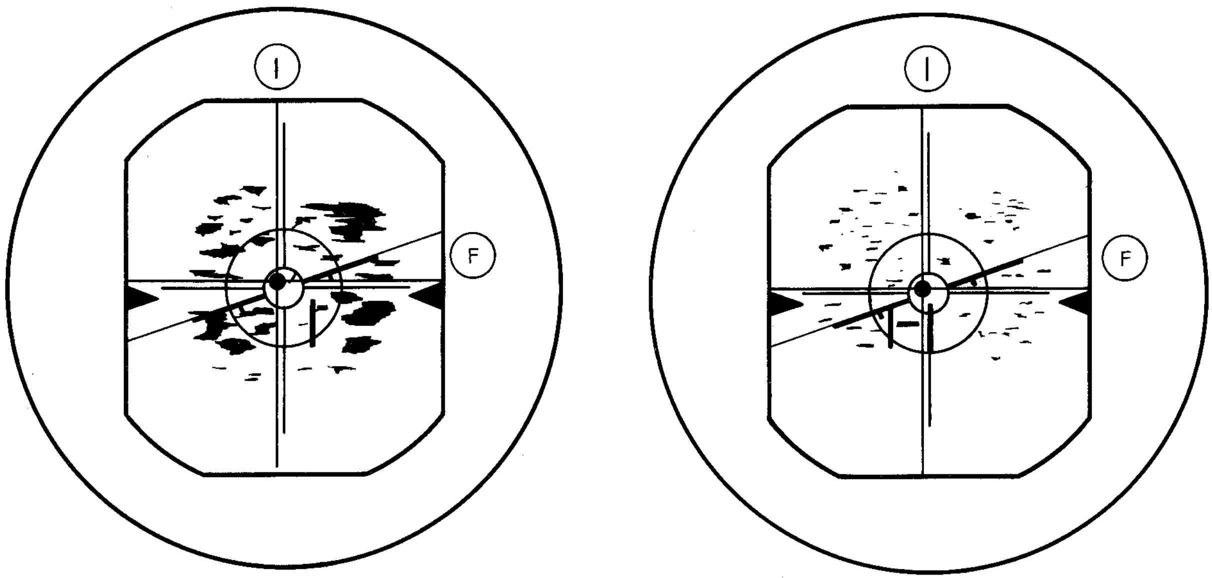
The instrument guidance in intercept flight is the most effective measure against intensive atmospherics, as in this case it is possible to determine the approximate position of the target by reference to the lock-on range mark (gate) which facilitates target detection under cloud clutter conditions.

The direction of attack should be selected so, if possible, as to prevent getting of the scanning zone of the airborne radar into dense cloud area.

After cutting in the airborne radar to operate in the emission mode, estimate the intensity of cloud clutters and possibility of detection of the target against the clutter background.

If the target flies in clouds, the closure shall also be performed in clouds. In this case the intensity of cloud clutters displayed on the radar screen is lower than in undercloud closure.

The blurring effect of the cloud clutters may be diminished by periodically pressing on the MAGN CANCEL (МГН. СТИР.) button. The indicator display screen brightening time length should be



a b

FIG. 124. TARGET DETECTION UNDER ATMOSPHERICS CONDITIONS

a – selector switch ATMOSPHERICS is in OFF position; b – selector switch ATMOSPHERICS is in ON position adjusted so that the rate of clutter accumulation be reduced to an ever possible minimum, with the target mark normal brightness being preserved.

Should the clutter intensity be great and the target cannot be detected against clutter background, cut in the ATMOSPHERICS switch. As a consequence, the clutter displayed on the radar screen becomes disintegrated into dots against the background of which it is possible to distinguish the target mark by its regular emergence on the display screen and the manner of displacement (Fig. 124). The target detection range at medium and high altitudes, with the ATMOSPHERICS switch cut in, becomes diminished 2 - 2.5 times due to attenuation of the signal strength.

At low altitudes, employment of the anti-atmospherics protection system does not practically result in decrease of the target detection range, as the maximum target detection range at these altitudes is limited by the adversely affecting ground return. The intercept flight at low altitudes in clouds, therefore, should be performed with the ATMOSPHERICS selector switch in the ON position at all times.

Target lock-on under conditions of intensive clutters on the radar sight display screen should be accompanied by manual target gating irrespective of the position of the EQUIPMENT CONT selector switch. Manual gating preceding target lock-on diminishes the probability of locking on a false target.

Since the probability of lock-on and relock-on of the false targets during intercept flight in radio contrast clouds is high, it is expedient when flying the aircraft in the automatic control mode to change over to the director control mode before target lock-on.

Target lock-on completed, ascertain that the airborne radar tracks a real target, not a false one. Steady target lock-on is characterized by the following features:

(1) the mark indicating the rate of clousure during forward-cone attack is above the interceptor-fighter flying speed mark, whereas in rear-cone attack, the rate-of-closure mark is below the aircraft flying speed mark;

(2) the angular position of the locked on target, target range, and rate of closure correspond to information furnished from the command (direction) post;

(3) the target current range mark gradually moves towards a shorter range.

The lock-on of a false target in clouds may be characterized by the following features:

(1) uneven displacement of the rate-of-closure mark or coincidence of the mark with the interceptor-fighter flying speed mark;

(2) unstable position of the current and $R_{max.\ perm}$ marks;

(3) lighting-up of the M CH INTRF and A CH INTRF indicator lamps;

(4) chaotic displacement of the director mark ("bead");

(5) chaotic lighting-up of the (A) and (ACH) indicator lamps.

It should be borne in mind that not only a false target lock-on is possible but a recapture of a clutter in place of a true target during automatic tracking (recapture). Therefore, the pilot should constantly watch indication of the display screen throughout the entire attack.

If the symptoms of the lock-on (recapture) of false targets occur, change over the aircraft control to the director control mode (if the flight is performed in the automatic control mode), reset lock-on, approach a target closer and then carry out the repeated gating and lock-on.

7. PECULIARITIES INVOLVED IN MULTIPLE TARGET INTERCEPT FLIGHT

In the ground guidance phase (until radar radiation mode cut-in) the multiple target intercept flight for the most part does not differ from the single-target intercept flight. After switching on the airborne radar emission mode, during performing the multiple target attack the intercept flight is characterized by a number of peculiarities associated with the capabilities of the airborne radar and the homing heads of the missiles in selecting (discriminating) a single target out of the entire group of targets.

Separate indication of targets on the display screen of the PП-25 radar is possible when the distance between them exceeds 2000 m or their azimuths differ by at least 3°. In the automatic tracking mode the discriminating capability of the PП-25 radar is higher than in the scanning mode. The independent tracking of a separate aircraft of the group is possible if the distance exceeds 750 m or the difference of angular coordinates is not less than 2°. The intervals and distances of target discrimination by the radar sight and the heads of the missiles versus the range are given in Fig. 125.

If the intervals and distances between the targets are less than the azimuth and range discriminating capability of the radar in the automatic tracking mode, the airborne radar will track not a single aircraft but the power mid-point which is the result of

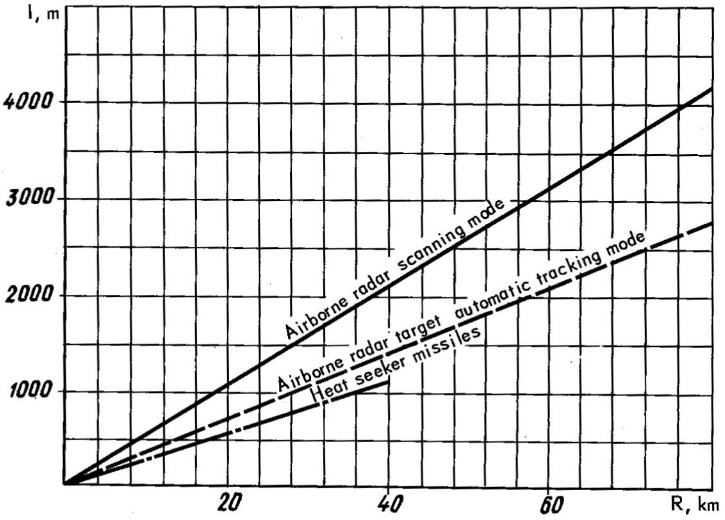


FIG. 125. MULTIPLE TARGET DISCRIMINATION INTERVALS

the composition of the signals returned from all aircraft of the group. In this case, performing an attack against the target in the automatic tracking mode is hampered and the probability of hitting the target by missiles is sharply reduced.

The timely identification of a multiple target enables the pilot to select the tactically correct method of attacking on a target with due regard to the capabilities of the airborne radar and missile armament. The character of a target (either multiple or single) may be determined on the basis of the information furnished from the command (direction) post, as well as by reference to the target mark displayed on the airborne radar display screen.

The detection range for a single target is somewhat less than that for a multiple target consisting of the same type of aircraft as the single target.

With the distances and intervals between the targets in the group approximating to those which are within the airborne radar discriminating capability, the target mark becomes wider, the brightness of this mark becomes somewhat less intensive. In this case it is possible to determine the composition of the multiple target.

The lock-on of the assigned target of the group is possible if the distance between the target marks displayed on the РП-25 radar screen is greater than the half of the lock-on zone (half of the distance between the gates) or if the distance between the targets is at least 2000 m. The target azimuth gating in this case should be accomplished in such a manner that the mark of the selected target be inbetween the gates, and the neighbouring marks be beyond the gates. The target selection with respect to its range is effected in the following manner:

(1) when launching a rear-cone attack against the aircraft of the group target, which is the closest to the interceptor-fighter, apply gates to the selected mark so that it is in the upper portion of the lock-on zone;

(2) when launching a rear-cone attack against the farthest aircraft of the group target, arrange the target mark in the lower portion of the lock-on zone;

(3) when delivering a forward-cone attack against the farthest aircraft of the group target, it is practically difficult to fulfil the mission in the first attempt. It is therefore recommended to attack the closest target. In this case, bring the gates close to the selected mark from a shorter distance so that it is in the upper portion of the lock-on zone.

Should a multiple target be displayed on the display screen in the form of a single target mark, the gating and the lock-on operations should be carried out in the same manner as in case of a single target. The selection of the target to be attacked will be hampered in this case. As a rule, the closest target lock-on and tracking occur. This is explained by the fact that the target search in range is started by the airborne radar from a shorter range to the longer one. When performing a rear-cone attack the lock-on and automatic tracking of the target which is the farthest with respect to the interceptor-fighter can be effected by placing the PASS JAMM PURSUIT - COLLISION (ПАСС. ПОМЕХА ДОГОН - ВСТРЕЧА) selector switch to position PURSUIT.

With a single target out of a group steadily locked on and tracked, the subsequent attack procedures are similar to those involved in delivering an attack against a single target.

Faster displacements of the beam and director marks and the skipping movements of the current range mark are indicative of the fact that the airborne radar is following several targets at a time (power mid-point). The unsteady tracking of the target by the airborne radar results in unsteady tracking of the target by the heads of the missiles. While the beam mark is moving faster than before or the current range mark is skipping, the MSL LAUNCH lamps ((1), (2), (3), (4)) are flickering. It is expedient under such conditions to continue approaching the target without resetting the lock-on mode. As the distance to the multiple target becomes shorter, the discrimination of the target is effected by the radar sight at shorter intervals. As a result, the radar may perform a steady tracking of the single target.

The aircraft automatic control mode should be engaged in delivering an attack against the multiple target only upon ascertaining that the target tracking is effected steadly. In the event of unsteady target tracking the aircraft will sustain rolling and pitching oscillation in synchronism with the oscillating director mark.

The missile launching variant should be selected from the actual tactical air situation. It should also be taken into consideration that the missiles provided with heat seekers ensure higher hit probability as compared with those fitted with radar seekers.

If the combat formation of a multiple target makes it imposi-impossible to obtain a steady lock-on and tracking of a single aircraft, it is necessary to continue closing to the target until it is detected visually and deliver an attack in the "φ_0" mode, aiming at the target by means of the K-10T collimating sight.

The pilot will succeed in delivering an attack against a single aircraft selected from a multiple target in the "φ_0" mode provided that the interval between the aircraft in the group is equal or in excess of that at which heat seekers are capable of discriminating the target.

If enemy aircraft are performing flight in a close formation, that is at intervals shorter than those at which heat seekers are capable of discriminating the target, aiming should be performed at one of the aircraft of the group and the missile is launched as the MSL LAUNCH lamps light up. When approaching the multiple target, the heat seeker selects a target which irradiates heat most intensively. The pilot in this case is incapable of predicting which aircraft of the multiple target will be hitted. Nevertheless, it should be expected that after even a single aircraft has been hitted, the enemy aircraft will be forced to assume a loose combat formation and start maneuvering, thus creating favourable conditions for the attacking interceptor-fighters to individually select the target.

8. INTERCEPTION AND SIMULTANEOUS ATTACK OF SINGLE TARGET BY PAIR OF INTERCEPTOR-FIGHTERS

Interception and simultaneous attack of single target by a pair of interceptor-fighters may be accomplished only in daylight under VFR conditions or beyond the clouds. In the course of the entire intercept flight the wingman should visually watch the leader at all times. In the homing guidance phase, the visual observation in a pair formation must be mutual.

In order to prevent mutual interference in practice flight (without launching missiles) it will be sufficient that the airborne radars of the interceptor-fighters operate at different repetition frequencies even at a single letter frequency. In flights involving missile launching, it is necessary that the airborne radars of both interceptor-fighters operate at different letter frequencies and repetition frequencies. Under otherwise conditions the emission produced by the airborne radar of one interceptor-fighter may adversely affect the missile launched from the other interceptor-fighter. Such an interference may result in missing a target due to a homing head "losing" the target.

The combat formation of the pair is determined by an interception phase. The basic requirements to be met by the combat formation in the ground guidance phase are as follows:

(1) relative easiness of maintaining of the assigned flight regime with simultaneous holding the combat formation;

(2) freedom of maneuverability of both the wingman and the leader;

(3) accurate direction of the pair to the probable attack zone.

In delivering a simultaneous attack against a target the pair combat formation must ensure the following:

(1) safety of interceptor-fighters against missiles simultaneously launched from the friendly aircraft;

(2) maneuvering freedom for the leader during aiming;

(3) individual target lock-on by each pilot and missile launching with minimum aiming errors;

(4) safe performance of an aiming zoom and break-away.

Proceeding from the above-mentioned requirements, the following combat formations are recommended for the pair of the interceptor-fighters:

(1) ground guidance phase: echelon formation at intervals of 70 to 100 m and distances of 150 to 200 m;

(2) simultaneous attack phase: line abreast formation at intervals of 200 to 250 m and distances of 50 to 70 m.

When performing the intercept flight by the pair of the interceptor-fighters in the instrument guidance mode, the same assigned radio data (wave, code, separation) are set on the АРЛ-СМ automatic telemetring system control panel.

After takeoff the pair of aircraft should perform flight in the preset combat formation.

Instrument guidance commands are received by both interceptor-fighters. The wingman can therefore judge the future maneuver by the guidance commands. Radio communication is effected only by the leader. Should the leader aircraft radio set fail, the wingman should assume the position ahead of the leader to fulfil the functions of the latter. The wingman should report this to the command (direction) post in advance.

The aircraft automatic control mode is engaged by the leader only. The wingman must hold his position in the combat formation visually.

When the pair has intercepted the closure leg, regrouping into the line abreast formation should be effected only on the command of the guidance controller. Target search is effected individually by each pilot, holding the assigned combat formation. With the target detected, the pilots independently identify and lock on the target.

Target lock-on completed, the wingman should report this to the leader. If the leader has been the first to complete target lock-on, he performs a maneuver to ensure accurate aiming, and the wingman, holding the combat formation, operates the airborne radar to lock on the target. The wingman follows the leader in performing an aiming zoom regardless of whether the respective command has been given or not.

Upon completion of precision aiming and receiving the LAUNCH PERMITTED command, the leader gives the LAUNCH command over the radio and presses on the firing button. On receiving the LAUNCH command given by the leader, the wingman, holding his position in the combat formation, also depresses the firing button.

Missile lift-off completed, smoothly break away the target at a bank of not more than 30°. On giving the BREAK-AWAY command, increase the break-away bank up to 60°. The leader must perform break-away maneuver off the wingman.

In case the wingman has been the first to accomplish target lock-on, upon the leader's command he performs a maneuver to ensure precision aiming, and the leader follows the wingman in performing the maneuver and carries out necessary operations to ensure steady target lock-on. If the leader fails to accomplish target lock-on, the leader's functions in the course of attack shall be taken over by the wingman.

To ensure flight safety during the attack, the wingman should never attempt to independently perform a maneuver for precision aiming without the leader's command.

Break-away completed, the wingman assumes his position in the combat formation. In case of losing of the leader during recovery from the attack, join-up is performed upon the commands from the command (direction) post. Join-up accomplished, the pair proceeds to the landing airfield or performs a maneuver for a repeated attack.

9. PECULIARITIES OF INTERCEPTION OF AIR TARGET AT GREAT ASPECT ANGLES

When launching an attack on a target its aspect angle exerts a considerable effect upon the detection and lock-on ranges, probability of employment of defensive weapon by the enemy, and setting up of jamming against the airborne radar. A high angle-off attack is particularly effective whenever its direction has been selected with due regard to the most vulnerable sections surrounding a target, namely blind spots in the cone of coverage of the enemy ECM aids, beyond the airborne radar detection zone, areas beyond the limits of the active defensive means destruction zones, etc.

The target aspect angle is relationship between the visible fuselage size and the actual one expressed in fourth and eighth fractions. The relative bearing of a target is an angle between the target speed vector and the interceptor-fighter - target sighting line (Fig. 126).

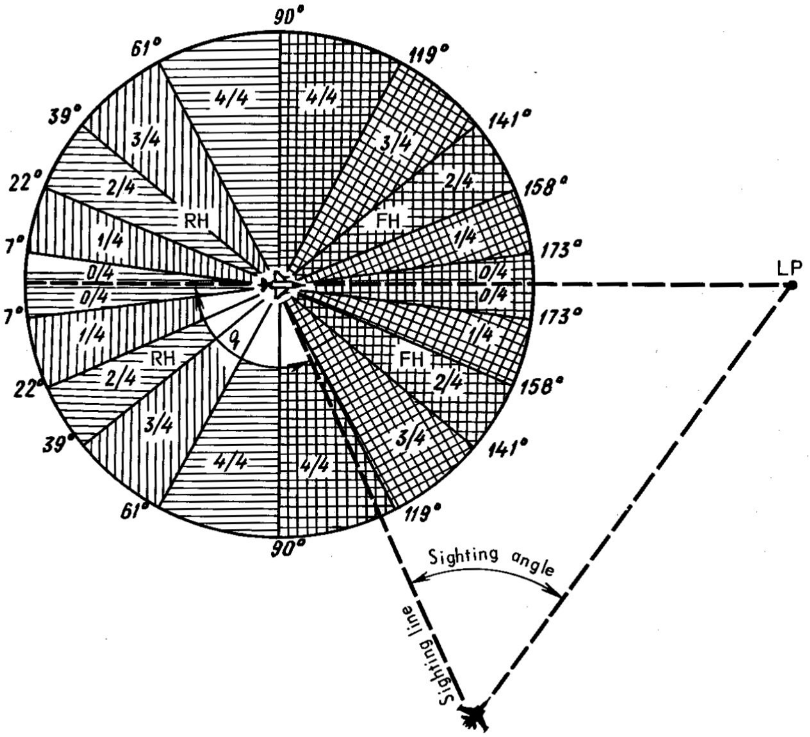


FIG. 126. RELATIVE BEARING VERSUS TARGET ASPECT ANGLE

Consequently, the apparent dimensions of the fuselage depend on the relative bearing of the target:

$$R_{tgt} = \sin q,$$

where: R_{tgt} - target aspect angle;
q - target relative bearing.

When delivering a rear-cone attack, the relative bearings of the target are within the limits of 0 to 90°, whereas in a forward-cone attack these are within the limits of 180 to 90°.

The target relative bearings corresponding to the target aspect angles expressed in the fourth fractions are as follows:

0/4 - 0 to 7^{o} (180 to 173^{o});
1/4 - 7 to 22^{o} (173 to 158^{o});
2/4 - 22 to 39^{o} (158 to 141^{o});
3/4 - 39 to 61^{o} (141 to 119^{o});
4/4 - 61 to 90^{o} (119 to 90^{o}).

The peculiarities involved in high angle-off attacks are determined by the following factors:

(a) high target angular velocities;

(b) increase in aircraft g-load required for precision aiming;

(c) short time of presence of the interceptor-fighter in the probable missile launch zone.

The angular velocity of target displacement with respect to the interceptor-fighter increases with decreasing the range and increasing the relative bearing (aspect angle) of the target. At short ranges the target angular velocity may be considerably high, i.e. the target by-passes the interceptor-fighter quickly.

Upon completion of target lock-on the flight path of the interceptor-fighter coincides with the "lead pursuit" attack curve the characteristic feature of which is a continuous change in the interceptor-fighter heading. If the pilot constantly ensures precision aiming, the aircraft is actually found in a continuous turn at a variable angular velocity which depends on the target displacement rate. Flight along the aiming curve is possible provided that the required g-load does not exceed the available one.

Since the rate of target displacement has a tendency to grow with diminishing the target range, the required g-load will also increase with decreasing the target range. Within a certain target range the available g-load imposed on the aircraft (with the g-load limitations taken into account) may become insufficient for the elimination of aiming errors. When the interceptor-fighter flying speed is high, the target range is in excess of the safe break-away range. It is necessary therefore that the missiles be used within the ranges approximating the maximum permissible missile launch range.

The duration of the interceptor-fighter presence in the zone of probable missile launching is determined by the limits of the permissible missile launching ranges and the rate of closure of the interceptor-fighter relative to the target. As the maximum permissible missile launch range and the safety break-away range increase with increasing the target aspect angle, the maximum permissible missile launch range at an aspect angle of 4/4 only

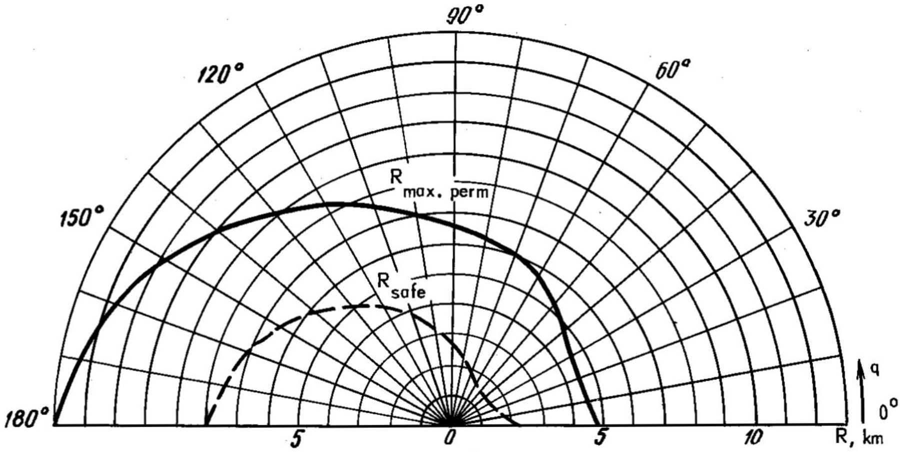


FIG. 127. RELATIONSHIP BETWEEN MISSILE POSSIBLE LAUNCHING AREA AND TARGET RELATIVE BEARING (H_{launch} = 6000 m, V_{launch} = 280 m/s, V_{target} = 230 m/s, H_{target} = 8000 m)

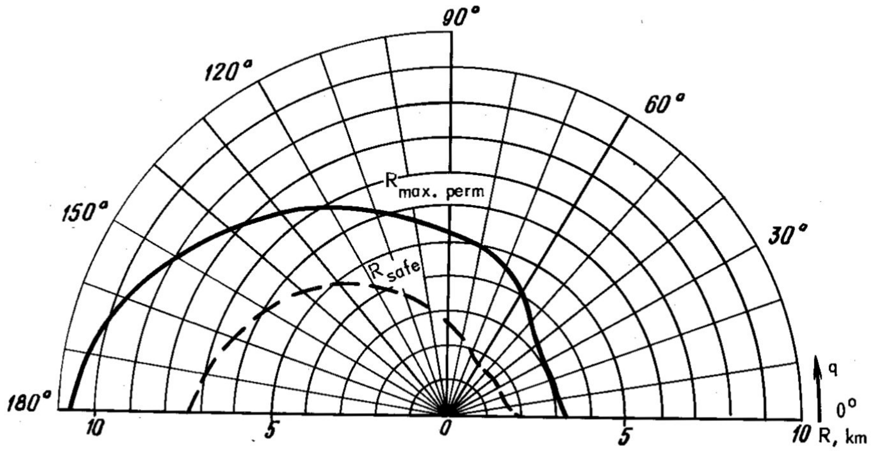


FIG. 128. RELATIONSHIP BETWEEN MISSILE POSSIBLE LAUNCH AREA AND TARGET RELATIVE BEARING (H_{launch} = 1500 m, V_{launch} = 250 m/s, V_{target} = 208 m/s, H_{target} = 2500 m)

slightly exceeds the launching range of the rear-cone attack performed at an aspect angle of 0/4 (Figs 127 and 128). At the same time the rate of closure considerably increases with increasing the aspect angle (at aspect angles of 3/4 to 4/4 the rate of closure approximates the interceptor-fighter flight speed). Consequently, the time of the interceptor-fighter presence in the probable missile launch zone sharply decreases with increasing the aspect angle.

Certain difficulties are encountered during performing an attack strictly at the assigned aspect angle, that is when the pilot should maintain the target relative bearing at a constant level over the entire guidance and closure period or approach the target and occupy the pre-determined position with respect to it.

The peculiarities involved in attacking on a target at the assigned aspect angle are characterized by an essential difference between the methods of ground and airborne guidance.

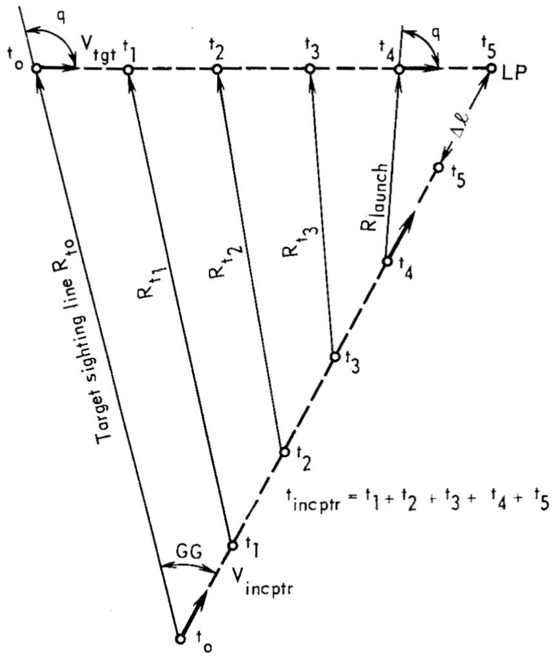


FIG. 129. INTERCEPTOR-FIGHTER FLIGHT TRAJECTORY DURING GUIDANCE WITH USE OF "INTERCEPTION" METHOD

During the third phase of ground guidance the interceptor-fighter flight path coincides with the straight trajectory. The flight is conducted with the use of the "interception" method (Fig. 129). With this method used the lead angle is determined with the aid of the following formula:

$$\sin \varepsilon_{GG} = \frac{V_{tgt}}{V_{incptr} + \frac{\Delta l_o}{t_{incptr}}} \sin q,$$

where: ε_{GG} - lead angle during ground guidance phase;

t_{incptr} - interceptor-fighter flight time;

Δl_o - magnitude characterizing the estimated moment of airborne homing guidance transition; it is set by the controller and calculated with the use of the following formula:

$$\Delta l_o = R_{launch} + V_{closure}\ t_{aiming}.$$

Upon completion of target lock-on the interceptor-fighter, as it has been mentioned above, proceeds along the "lead pursuit" attack curve to intercept the lead point of the missile impact with the target. The lead angle is computed by the airborne radar computor with the use of the following formula:

$$\sin \varepsilon_{incptr} = \frac{V_{tgt}}{V_{incptr} + \Delta V_{av}} \sin q,$$

where: ε_{incptr} - lead angle during homing guidance phase;

ΔV_{av} - average velocity of the missile proper (V_{av} = 450 m/s).

With the two lead angles being equal ($\varepsilon_{incptr} = \varepsilon_{GG}$), there will be no aiming error at the moment of target lock-on. As a result, the transition from the ground guidance phase to the homing guidance one will be smooth. Due to the difference in the methods of guidance the smooth transition from the ground guidance to the homing guidance may be ensured only within a single definite range. The maximum permissible missile launch range is usually taken for such a range. In this case, if target lock-on is completed at a distance exceeding the maximum permissible missile launch range, overlead occurs, that is the actual lead angle will be greater than the required one. In this case, the aiming error in the horizontal plane (ΔH) will be increasing with the increase in the difference between the lock-on range and the maximum missile launch range (Fig. 130). The dynamics of flight of the target and the interceptor-fighter at a certain aspect angle is such that during approach to the target upon the commands from the command post after the target has been locked on the aiming error has a tendency to diminish and within the maximum missile launch range will be equal to zero.

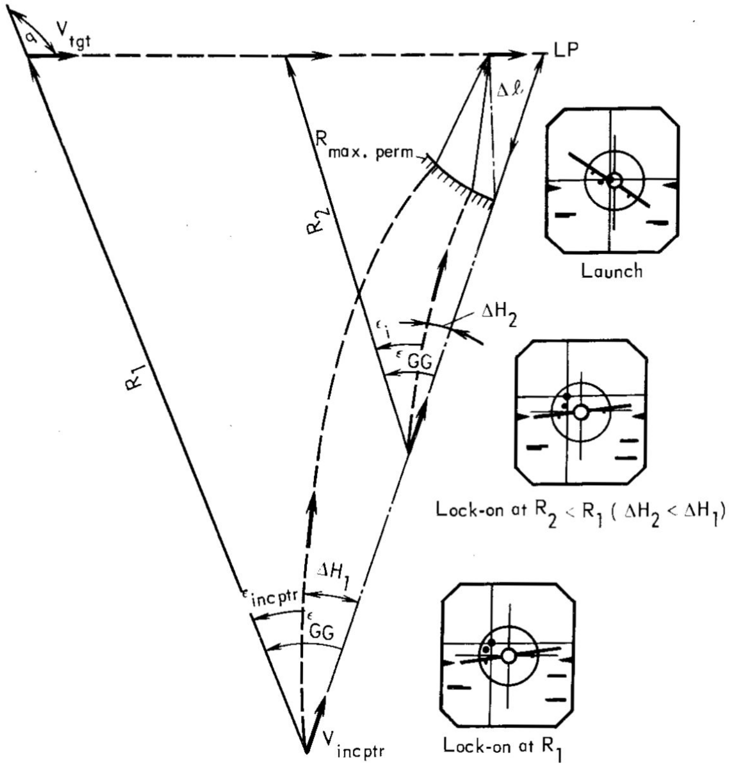


FIG. 130. VARIATION OF INTERCEPTOR-FIGHTER FLIGHT TRAJECTORY AND ASPECT ANGLE DEPENDING ON LOCK-ON RANGE DURING GUIDANCE EMPLOYING "LEAD PURSUIT" METHOD

Whenever the pilot succeeds to accomplish precision aiming immediately upon completion of target lock-on, the interceptor-fighter will proceed along the attack curve, with the target relative bearing being continuously diminished. At long lock-on ranges, the attack may be completed with the entry into the target rear hemisphere.

The МиГ-25П interceptor-fighter is capable of attacking the target at any aspect angle within the altitude range of 2.5 to 27 km, with the relationship between the flight speeds of the aircraft and the target being equal to 1.2. The relative bearing range within which an attack on a target is possible decreases with the above relationship diminishing. When this relationship equals 0.8, for instance, the attack on a target is possible from the forward hemisphere only within a relative bearing range of 180 to 120° which corresponds to an aspect angle of 0/4 to 3/4.

During interception of a passive jammer the maximum aspect angle is limited and does not exceed 2/4. This is explained by the fact that the airborne radar is provided with a circuit of target selection with respect to the closing speed which is intended to protect the radar against passive jamming. At a rate of closure approximating the flying speed of the interceptor-fighter, the target range lock-on mode is reset and the airborne radar is changed over to operate in the target search mode, thus ensuring the lock-on of the jammer rather than the chaff cloud. At the same time, when attacking on the target at high aspect angles, the closing speed is also approximating the flight speed of the interceptor-fighter proper, thus making it impossible to carry out an attack at aspect angles exceeding 2/4, with the passive jamming protection circuit energized.

The procedure to be followed by the pilot during intercept flight involving high angle-off attack in the ground guidance phase are similar to the actions to be taken by the pilot during intercept flight involving either rear-cone or forward-cone attack.

The interceptor-fighter is brought to the probable missile launch zone to the highest degree of effectiveness at the preset aspect angle during instrument guidance and with the aircraft operated in the automatic control mode.

The range at which the radar emission is automatically cut in depends on the selected direction of attack. In case of a forward-cone high angle-off attack, the radar starts emission at a range of 100 km (60 km at H < 8000 m). When the relative bearings of the target are less than 90°, the radar emission mode is engaged at a distance of 36 km.

In case of a rear-cone high angle-off attack involving instrument guidance, the target speed selection circuit is automatically cut in. Should this circuit not be cut off in proper time, a periodic target range lock-on reset will take place during target lock-on. The symptoms of operation of the target speed selection circuit are the following: flickering of the (A) (attack) indicator lamp on the УКПО attitude and command marks unit with a frequency of 1.5 to 2 s^{-1}, display of a horizontal line on the radar screen at the moment of the (A) indicator lamp extinguishing, and fluctuation of the director mark ("bead"). Such being the case, the pilot should set the LINE SCAN - LST selector switch to position LST either independently or upon a command from the controller.

The target detection range in high angle-off attacks is slightly in excess of that during rear-cone or forward-cone attack. It should however be taken into account that the target sighting angles at a range of 40 to 50 km may amount up to 30 - 50°. To keep the target within the scanning zone, with the airborne radar operating in the manual control mode, the pilot should change over the scanning zone in azimuth in the appropriate direction at a target sighting angle of 20 to 25° (upon the controller's command).

The target mark on the display screen displaces in azimuth and range simultaneously (Fig. 131). By completing several scanning cycles, one may determine the target flight direction with respect to the interceptor-fighter the knowledge of which will subsequently facilitate performing an attack.

Great aiming errors may occur during target lock-on, particularly at long ranges. The automatic flight control system eliminates these errors in a vigorous manner at high banking angles. This may result in a speed loss and aircraft rolling oscillation. It is therefore recommended before target lock-on to switch off the aircraft automatic control mode and eliminate the aiming errors in the director control mode.

The view of the display screen during target lock-on at an aspect angle of 4/4 is shown in Fig. 132. The mutual position of the closing speed and interceptor-fighter flight speed marks depends on a target relative bearing (attack direction and aspect angle), namely: at a target relative bearing of more than 90° the closing speed mark is slightly above the interceptor-fighter flight speed mark; at a target relative bearing equalling 90° the above marks merge; at a target relative bearing below 90° the closing speed mark is beyond the interceptor-fighter flight speed mark.

As the aircraft comes closer to the target, the relative bearing of the latter is changed. As a consequence, the closing

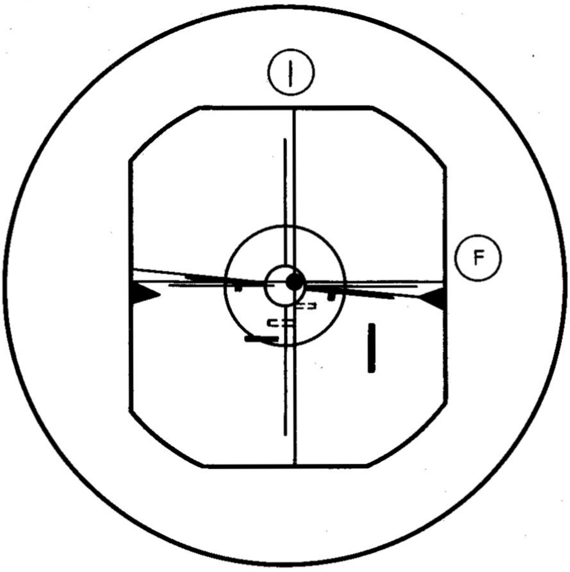


FIG. 131. TARGET DETECTION AT GREAT ASPECT ANGLES OF ATTACK

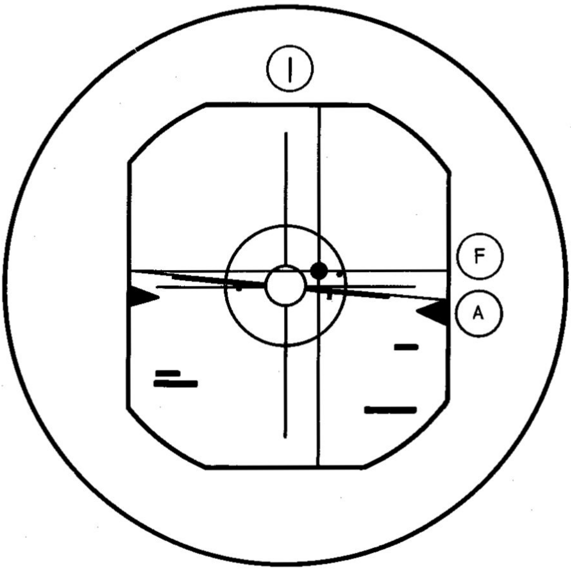


FIG. 132. VIEW OF INDICATOR SCREEN DISPLAY DURING TARGET LOCK-ON AT ASPECT ANGLE OF 4/4

speed mark will displace relative to the interceptor-fighter flight speed mark. At low magnitudes of the relationship between the target and interceptor-fighter flying speeds ($\frac{V_{incptr}}{V_{tgt}} \leqslant 1.0$), as well as at long lock-on ranges the beam mark may beyond the large mechanical ring.

If by the moment of the target lock-on the interceptor-fighter is directed with overlead, the beam mark will approach the zero azimuth line as the aircraft comes closer to the target. Precision aiming ensured, the lead angle will be equal to the target sighting angle and the beam mark will be beyond the zero azimuth line at a distance proportional to this angle (displacement of the beam mark by 1 mm corresponds to the target sighting angle of 3°).

It is recommended that target lock-on be effected at distances approximating the maximum permissible missile launch range in order to maintain the assigned attack aspect angle. If target lock-on has been effected at a long range, continue closing with the target at the course assigned by the controller at the command post until the director mark approaches the small circle. Further aiming operations should be carried out by reference to the director mark either in the automatic or director control mode.

An aiming zoom shall be performed by referring to lighting-up of the (Z) (zoom) indicator lamp located on the attitude and command marks unit. Before performing a zoom, select minimum or full augmented power setting in order to prevent flying speed loss. When performing a zoom, specify aiming in the horizontal plane and ascertain that the requirements for missile launching with respect to g-load, speed, and sideslip are satisfied. Particular attention must be given to the position of the beam mark relative to the large mechanical ring, that is, when the beam mark is beyond the large ring, the LAUNCH PERMITTED commands will not pass to the missiles.

It is necessary that the missiles be launched immediately upon lighting-up of at least one of the LAUNCH PERMITTED indicator lamps. It should be taken into consideration that the missiles may be shaded by the aircraft fuselage due to great target sighting angles. Missile shading takes place at the target sighting angles of more than 15 to 17°, especially at short ranges.

The view of the radar screen during missile launch at an aspect angle of 4/4 is shown in Fig. 133.

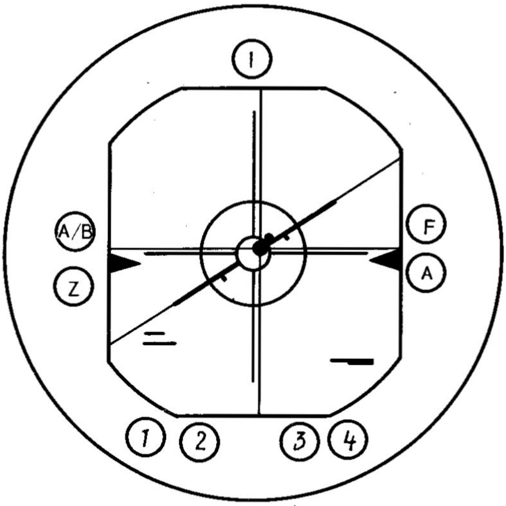


FIG. 133. RADAR SIGHT DISPLAY WHEN MISSILE LAUNCHING AT ASPECT ANGLE OF 4/4

The missiles launched, hold the director mark within the small ring in order to ensure target illumination.

Break off the attack upon the BREAK-AWAY command towards the director mark deflection at a bank of 60 to 70° and maximum possible g-load.

In case of failure to hit the target and the interceptor-fighter has a missile reserve, get ready to perform a repeated rear-cone attack just after break-away.

10. PERFORMING ATTACK AGAINST AIR TARGETS INVOLVING VISUAL SIGHTING

The main version of employment of the МиГ-25П aircraft armament system is realized when performing an attack involving the airborne radar operation in the automatic tracking mode and launch of the missiles, as a rule, under conditions of absence of visual target visibility. In certain cases, however, this version may prove ineffective.

Jamming set up against the airborne radar may result in deterioration of the target automatic tracking conditions or even radar failure to track the target. Apart from this, employment of the airborne radar may reveal the interceptor-fighter. With the airborne radar switched on in the emission mode, the enemy using the illumination warning equipment, may employ a defensive maneuver or ECM aids in due time. This will result in decrease of effectiveness of the attack.

The in-flight failure of the airborne radar also makes it impossible to use the main version of the armament system use.

In certain cases, when delivering an attack against a multiple target, for example, a single target selected out of the multiple target may be destroyed only by means of the missiles provided with heat seekers under visual sighting conditions, i.e. in the "φ " mode.

In the "φ_0" mode, the МиГ-25П aircraft may be used for performing a rear-cone attack with the use of the missiles provided with only heat seekers and under conditions of visual target visibility.

The guidance of the interceptor-fighter into the rear hemisphere of the target to the target visual detection range is performed by the controller at the command post. The target visual detection range at medium and high altitudes and in stratosphere depends on the transparency of the atmosphere, presence or absence of clouds, the attitude of the sun relative to the target and the interceptor-fighter, and the pilot's visual search proficiency. The average visual detection range accounts for 6 to 8 km.

The target visual detection range at low and extreme low altitudes is less than at medium and high altitudes. The shortening of the visual detection range at low altitudes is explained by deterioration of transparency of the near-ground atmosphere layers. Apart from this, the terrain background rapidly displacing before the pilot's eyes diverst his attention from searching an air target.

The average visual detection range at low and extreme low altitudes accounts for 4 to 6 km.

In sunny weather the surfaces of air targets may produce gleams, thus increasing the detection range up to 10 - 12 km. To detect the target, the pilot may use the shades produced by the target on the ground, which are considerably more distinguishable than the target iteself with respect to its contrast.

In cloudy weather the target visual detection range against the terrain background is reduced to 3 - 4 km. In broken clouds, greater caution on the part of the pilot is required to detect the target against the background of the shades produced by clouds.

With the target flying over a built-up area or particoloured terrain having a predominant green colour, the average visual detection range diminishes to 2 - 3 km.

Air target search in early or late hours is complicated due to the low position of the sun above the horizon and the distortion of shades. With the sun located above the horizon at angles of 20 to 30° and less, conduct the target search downsun. Whenever the sun is at high angles with respect to the horizon, it is expedient to perform target search upsun. In this case, gleams may occur from the target, thus facilitating target detection at an increased range.

The best conditions for the visual detection of the target flying at a low or extreme low altitude are ensured when the interceptor-fighter is flown at a stepped-up vertical separation of 800 to 1200 m relative to the expected target flight altitude.

When the target is detected visually, assume an initial position for attack. In doing so, it should be borne in mind that the target lock-on range for the heat seeker may exceed the maximum possible missile launch range. Therefore, the target range, with the aircraft being in the attack position, must correspond to the maximum possible missile launch range in order to preclude the possibility of launching missiles beyond the missile possible launch zone.

The target range is determined on the basis of the information furnished from the commandpost and visually with the use of the K-10T collimating sight. To visually determine the target range one must know its size (Fig. 134).

The pilot may deliver a low or high astern attack depending on the target flying altitude. It is recommended to deliver a low astern attack against a target flying at an altitude above 500 m. If the target flies at an altitude of below 500 m, perform a high astern attack. If the target flies over the top of clouds, it is expedient in the "φ_0" mode to perform a high astern attack.

To launch the above-mentioned attacks, assume the initial position with the stepped-down vertical separation of 200 to 500 m or stepped-up vertical separation of 400 to 1200 m relative to the target. The amount of the stepped-down (stepped-up) vertical separation depends on the target range and flight altitude.

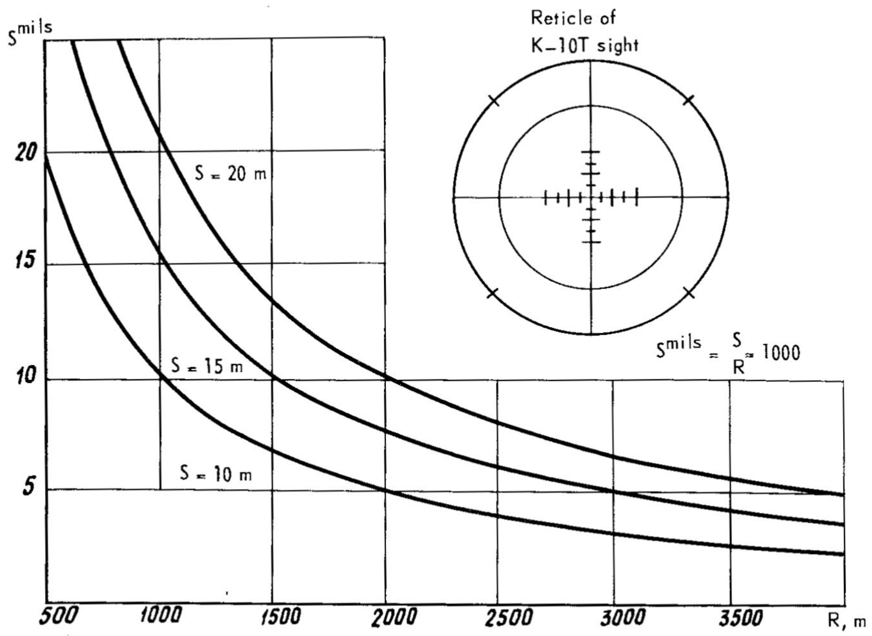


FIG. 134. TARGET ANGULAR SIZE IN MILS A^{mil} VERSUS TARGET RANGE R AND SPAN S

In this case, take into account the following peculiarities of using missiles equipped with heat seekers:

- deliver an attack against the target so that the target is projected on a clear background;
- launch missiles on the target which is against the background of the clouds lit with the sun at a minimum range and aspect angle of about 0/4;
- launching missiles when the target is at the same altitude with the aircraft may result in a miss, as in this case a more thermally contrast natural horizon line will be in the sight of the heat seeker;
- the maximum effectiveness of the missiles provided with heat seekers is achieved at low altitudes when they are launched at pitch-up or dive angles of 5 to 10°;

- when launching attacks at descent over industrial and built-up areas, as well as over the coast line the heat seekers of the missiles may lock on irrelevant heat irradiation sources.

Missiles must be launched only on displaying the LAUNCH PERMITTED commands (lighting-up of the (2) or (3) indicator lamp) and fulfilment of the following requirements:

- at altitudes below 500 m the target range does not exceed 3.5 km;
- at altitudes of 500 to 5000 m the target range does not exceed 3.5 to 5 km, respectively;
- at altitudes in excess of 5000 m the target range does not exceed the interceptor-fighter flight altitude.

The minimum missile launch range at altitudes below 500 m accounts for 1 km, and at altitudes above 500 m this range accounts for 2 km.

Discussed below are the possible variants of delivering an attack against the air target in the "φ_0" mode.

Low astern attack. The respective attack position is as follows:

- target range is 4 to 6 km;
- target sighting angle is from 20 to 30°;
- stepped-down vertical separation relative to a target is 200 to 500 m.

The procedures for manipulating the aircraft armament system controls are as follows:

(1) set the φ_0 - + RADAR - φ_0 three-position selector switch to the $_0$ position not later than one minute prior to missile launch. A missile receives the FILAMENT II command for checking the safety circuits, the filament circuits of the missile equipment and the $_0$ potentiometers become energized, the heat seeker photoresistor cooling system is cut in, the heat seeker is set to neutral, and the autopilot gyro motors are spinned up. The passage of the FILAMENT II command to at least one of the missiles can be checked by reference to lighting-up of the (F) indicator lamp on the indicator framing;

(2) turn on the MSL LAUNCH circuit breaker through which the missile launch circuits are energized;

(3) move the FH - RH selector switch to the RH position not earlier than 30 s after the "φ_0" mode has been enabled. The PREPARATION command is supplied to the missiles. The heat seeker is changed over to operate in the target search mode within the

limits of angle $3^{\circ}x3^{\circ}$. The predicted rate-of-closure command is furnished to the missile. Upon this command the fuze is set to the required delay time and the autopilot to the preset gain control coefficient;

(4) perform a maneuver to apply the centre of the collimating sight to a target. The sighting accuracy is ± 20 mils;

(5) upon the LAUNCH PERMITTED command launch the missiles within the permissible ranges.

High astern attack (on a target flying at limit low altitudes). The attack position should be as follows: target range is 4 to 4.5 km; target sight angle is from 20 to 30°; stepped-up vertical separation relative to the target is 400 to 1200 m.

The attack position taken and the armament system prepared for missile launch in the "φ_0" mode, perform a corrective turn to the target at a bank of 30 to 40°, simultaneously bringing the aircraft into descent. Accomplish the aiming with the use of the K-10T collimating sight providing for an accuracy of ± 20 mils.

When aiming, visually determine the target range. Launch a missile (missiles) on flashing-up of the ② or ③ indicator lamp within a range of 3.5 to 1 km.

Missiles launched, break away climbing to an altitude of 800 to 1000 m.

PERFORMANCE OF INTERCEPT FLIGHTS AT SUPERSONIC SPEEDS AND MAXIMUM REFERENCE ALTITUDE

Air target interception at supersonic speeds and maximum reference altitude is characterized by the following peculiarities:

(a) transience of closure between the interceptor-fighter and a target during ground guidance and performance of an attack, especially in a forward-cone attack;

(b) attainment of dynamic altitudes by the aircraft with great stepped-up vertical separation of the target;

(c) deterioration of the aircraft maneuver characteristics when flying it in stratosphere;

(d) the pilot's constraint actions when flying in a pressure suit.

In principle, the procedures of preparing the aircraft cockpit for a high-altitude intercept flight are similar to those used in intercept flights at high and medium altitudes. In order to minimize the time required for manipulating the controls of

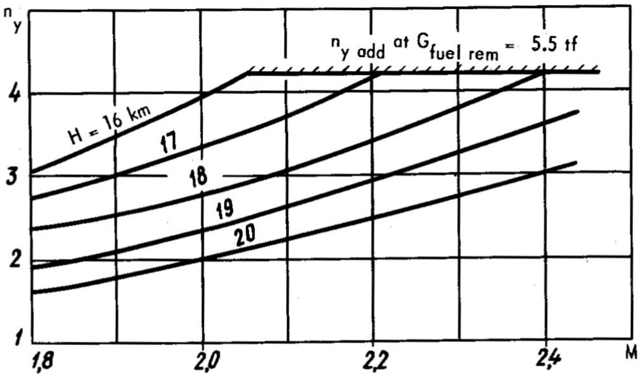


FIG. 135. AVAILABLE VERTICAL G-LOAD N_Y VERSUS MACH-NUMBER M AND FLIGHT ALTITUDE H

the airborne radar and the armament system in flight, it would be wise to set certain selector switches in the required positions beforehand on the ground. For instance, the SCAN ZONE selector switch should be placed in the position corresponding to the expected stepped-up vertical separation of the target even if the airborne radar control is automatic. This excludes the excess operation in the event of change over to the manual control. The SERIES - SINGLE selector switch may as well be put to the required position on the ground in advance.

Climb to the reference altitude and attainment of the respective speed are to be effected in accordance with the first or second programme. If the flight is performed in accordance with the second programme, the missile lift-off altitude should be set on the ground. The assigned Mach number only is to be set upon the A/B command.

It is recommended that a reference altitude should be selected within the limits of 17,000 to 18,000 m during interception of targets flying at altitudes of 21,000 to 23,000 m. It is also recommended that flight at a maximum reference altitude be effected only during interception of targets flying at altitudes of 25,000 to 27,000 m. When in flight at a reference altitude of 17,000 to 18,000 m at an airspeed of 2500 km/h, the interceptor-fighter proves to have sufficient maneuverability and speed margin required for performance of a zoom (Fig. 135). Apart from this, the acceleration characteristics at an altitude of 17,000 m are better than those shown at high altitudes.

During intercept flights at supersonic speeds and maximum reference altitudes the advantages of the aircraft automatic control mode are most fully realized, especially when the programmed speed and altitude gain modes are used. Therefore it is recommended that the pilot conduct the entire flight in the automatic control mode even during guidance by voice with the use of the plan position indicator. In the latter case at the ground guidance stage the assigned course is to be set by the aid of the knob located on the combined course indicator and setting the COURSE SELECT selector switch to the MAN position.

Upon attainment of the reference altitude and switching on the airborne radar emission mode the pilot should routinely carry out the target search, identification, and lock-on operations.

The sequence of the pilot's actions in the forward-cone attack is similar to that in an attack at high and medium altitudes provided that the target has been located at a distance of 70 to 75 km.

To succeed in delivering a forward-cone attack against a point target as well as in cases when for certain reasons a target has not been detected at distances up to 60 to 70 km, it is necessary to accomplish a preliminary zoom (until a target is detected). This requirement is dictated by the fact that the time of flying in the missile launch zone accounts for only 5 to 10 s due to a high rate of closure with the target at short lock on ranges and long break-away ranges required. If an aiming zoom is performed upon completion of target lock-on, the pilot usually can not manage the aiming errors in elevation during this period of time. At the same time, the permissible aiming errors diminish as the range decreases.

The complication of performing a preliminary zoom consists in that the pilot himself has to determine the zooming beginning range and vertical g-load the knowledge of which ensures accurate aiming in the vertical plane (the above parameters are computed by the airborne computor only upon completion of target lock-on).

The zoom entry range may be determined by the pilot from the formula realized in the computor ($R_z = R_{m.\ max} + 22\ V_{closure}$). In the forward-cone attack at $V_{closure}$ = 1000 m/s and $R_{m.\ max}$ = 35 to 40 km the zoom beginning, range accounts for 57 to 62 km.

The vertical g-loads ensuring accurate aiming are determined by the required aircraft trajectory angles in the vertical plane

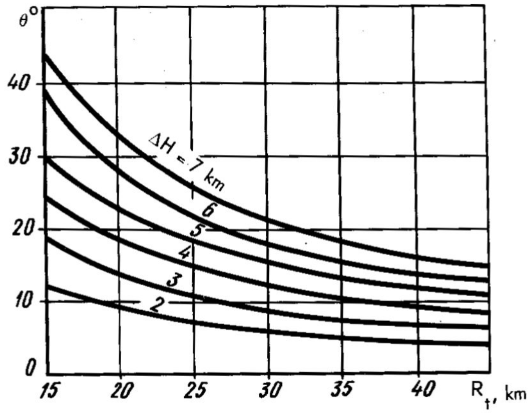


FIG. 136. ZOOM ANGLES Θ REQUIRED FOR MISSILE LAUNCHING WITH ZERO AIMING ERRORS IN VERTICAL PLANE VERSUS TARGET ELEVATION ΔH AND RANGE R_{TARGET}

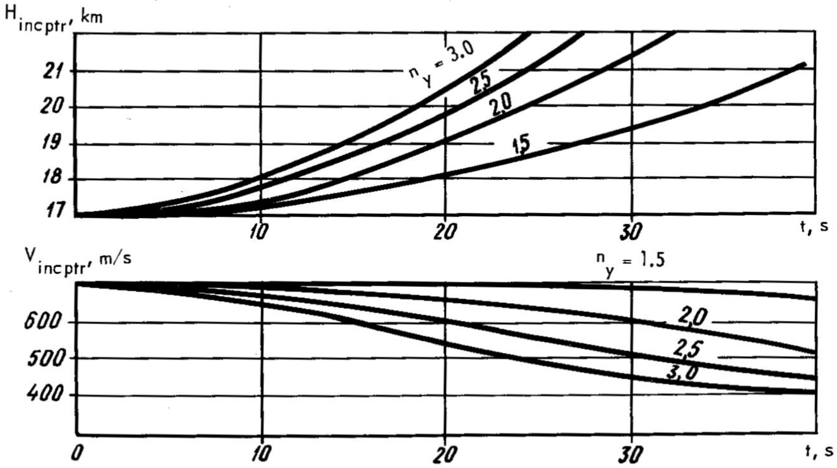


FIG. 137. VARIATION OF INTERCEPTOR-FIGHTER FLIGHT ALTITUDE AND SPEED WHEN PERFORMING PRELIMINARY ZOOM AT VARIOUS VERTICAL G-LOAD (H_{refer} = 17 km, M = 2.35, G = 28.5 tf, γ = 0)

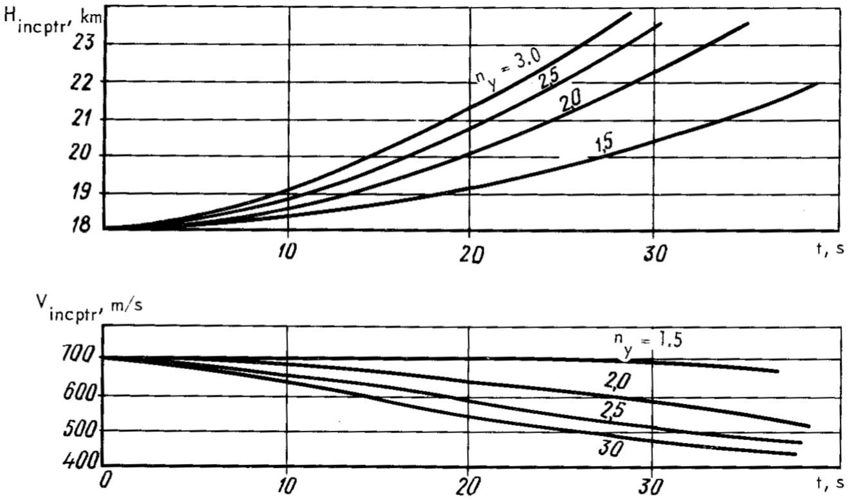


FIG. 138. VARIATION OF INTERCEPTOR-FIGHTER FLIGHT ALTITUDE AND SPEED WHEN PERFORMING PRELIMINARY ZOOM AT VARIOUS VERTICAL G-LOAD

(H_{refer} = 18 km, M = 2.25, G = 28.5 tf, γ = 0)

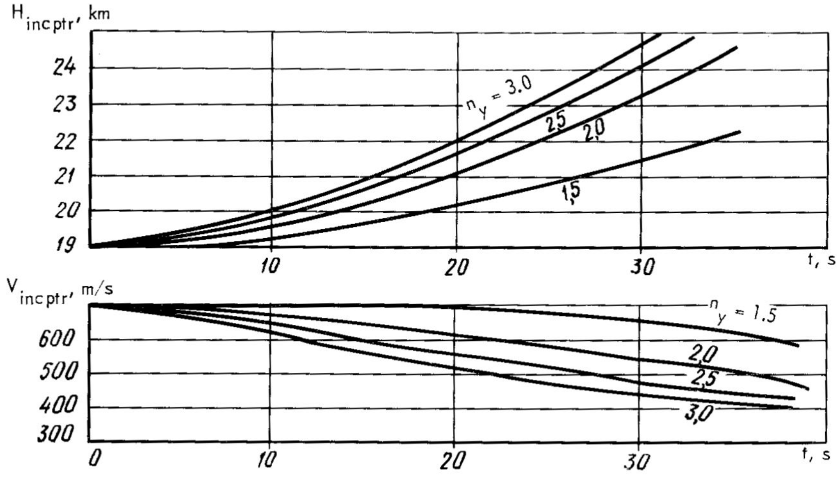


FIG. 139. VARIATION OF INTERCEPTOR-FIGHTER FLIGHT ALTITUDE AND SPEED WHEN PERFORMING PRELIMINARY ZOOM AT VARIOUS VERTICAL G-LOAD

(H_{refer} = 19 km, M = 2.35, G = 28.5 tf, γ = 0) which depend on the target elevation over the interceptor-fighter and target range (Fig. 136).

The required vertical g-load will be minimum when performing a zoom without banking. A bank exceeding 45° built up to correct the aiming errors in azimuth may result in deterioration of the conditions for elimination of elevation errors and additional deceleration of the aircraft due to the expenditure of the vertical g-load for compensating the roll.

The relationship between the amount of the vertical g-load and aircraft deceleration in zooms performed at reference altitudes of 17 to 19 km is shown in Figs 137 to 139.

Accurate estimation of the required vertical g-load presents certain difficulties for the pilot.

If a zoom is performed at an altitude of 17,000 to 18,000 m at M = 2.35 to 2.5, a satisfactory aiming accuracy at the moment of missile launching is ensured at a g-load of 1.5 g and zero bank and a g-load of 2 to 2.2 and bank of up to 45°.

When performing a zoom, particular attention must be given to checking of the flying speed. In order to preclude an impermissible flying speed loss, the zoom should be performed with the engines operating at a FULL REHEAT power setting only. Should the flying speed of the aircraft on a zoom at a given climb angle be less than the permissible one realized in the maneuver computor (Fig. 140), the pilot must be given the LIMIT PITCH (ТАНГАЖ ПРЕДЕЛЬНЫЙ) command. Upon this command the pilot should diminish the pitch angle to a safe level immediately. If it is impossible

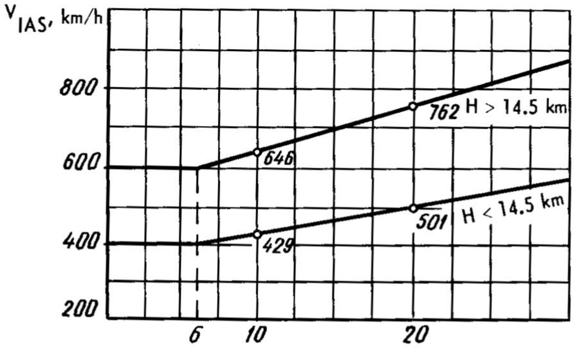


FIG. 140. INDICATED AIRSPEED MINIMUM LIMIT VALUES REALIZED IN MANEUVER DATA COMPUTOR

to finish an attack due to gross aiming errors, it is necessary to break away from the target at a bank of 50 to 60°, maintaining the recovery g-load at a level of 0.2 to 0.4 g, or break away upon completion of two half-rolls.

It should be taken into consideration that in certain cases when performing a zoom there may arise such a phenomenon as "vortex sheet" which may cause a decrease in the effective thrust developed by the power plant. At flying speeds corresponding to M = 2.5 ±0.3 this phenomenon can be prevented by the automatic change-over of the air intake doors. Whenever the "vortex sheet" phenomenon takes place at lower speeds, the pilot has to change over the air intake doors manually. In order to avoid loss of time required for accomplishment of this operation upon completion of target lock-on, it is recommended that the air intake doors be set to position III prior to the zoom performance.

Thus, the sequence of actions to be taken by the pilot during performance of the preliminary zoom for the forward-cone attack on the target should be as follows:

(1) turn off the aircraft automatic flight control system (if the flight has been performed in the automatic mode) by depressing the AP OFF button on the control stick and cut in the dampers by depressing the DAMP button-light on the control panel of the automatic flight control system;

(2) switch on the full reheat;

(3) move the DOORS (СТВОРКИ) selector switch to the MAN 3-rd POSITION (РУЧН. 3-е ПОЛОЖ.);

(4) accomplish a preliminary zoom at a g-load of 1.5 with a zero bank or a g-load of 2 to 2.2 g at a bank of up to 45°;

(5) carry out accurate aiming in a horizontal plane by reference to the director mark if the required bank does not exceed 45°. When in attempting to correct the horizontal error in aiming the required bank exceeds 45°, it is necessary to hold on the bank of 45° and use the director signals for the determination of direction of turn.

Accomplish the target lock-on in the automatic gating mode. It is recommended that the LOCK-ON button be depressed prior to target lock-on when delivering a forward-cone attack against point targets.

If the target indication errors are gross, target gating must be effected manually. To save time in manual target gating, it is practical that the GUIDANCE knob in advance be set to such a position that the gates be arranged on the zero azimuth line at a range of the expected target location (40 to 50 km).

In the forward-cone attack the missiles should be launched immediately upon the target lock-on (the firing button can be depressed together with the LOCK-ON button). It is recommended that the launching version selector switch be placed in the SERIES position. The definite speed, g-load, and slipping requirements must be met during missile launch.

Perform a break-away maneuver in the director control mode at a bank of 60 to 70° upon flashing-up of the (B) (break-away)lamp and reception of voice information.

The attack completed, reset the DOORS selector switch to the initial position.

CHAPTER III

INTERCEPTION OF AIR TARGETS UNDER JAMMING CONDITIONS

1. INTERCEPT FLIGHTS UNDER CONDITIONS OF ACTIVE JAMMING AGAINST INTERCEPTOR-FIGHTER ARMAMENT SYSTEM

Active camouflage noise has found broad application owing to its multi-purpose use. The airborne radar is sensitive to this type of jamming when operated both in the scanning and target automatic tracking modes.

In the scanning mode continuous noise causes the flare spotting of the display screen vertical band the width of which depends on the jamming intensity. If jamming is weak, the flare light band is narrow and the target may be visible against the background of the flare spots. Target lock-on and automatic tracking may be steady even in the main channel. When the intensity of jamming is at a medium or high level the flare light band is much wider and brighter and as a consequence of this a target is not visible against the jamming background (Fig. 141).

To compute the lead angle, maximum permissible range of missile launching, and other signals and commands indispensable for the effective application of the aircraft missile armament, it is necessary that the airborne radar computor be continuously provided with the information dealing with the present angular coordinates and target range. This is attained by automatic tracking of a target with respect to its angular coordinates and range.

The angle tracking channel of the РП-25 radar is highly immune against jamming and ensures the lock-on and steady automatic tracking of a high-intensity active jamming source. It is important that a jammer might not be locked on by the side lobes of the radar. To this end, the receiving channel must be desensitized. The desensitization is effected automatically or switched on by the pilot manually.

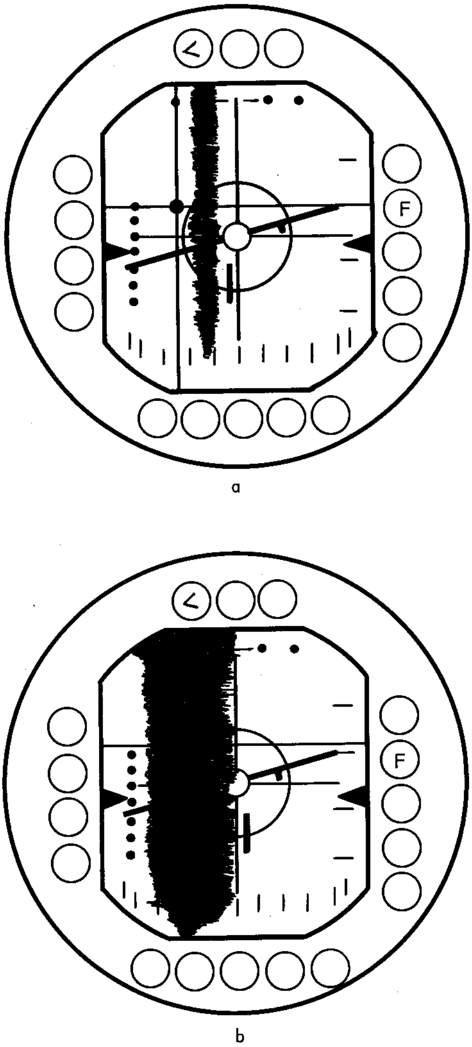


FIG. 141. VIEW OF DISPLAY SCREEN OF PII–25 AIRBORNE RADAR UNDER ACTIVE JAMMING CONDITIONS

a – weak jamming; b – strong jamming

The range finder channel is the most sensitive to noise. It is incapable of ensuring steady automatic tracking (in range) of the source of intensive noise. The main anti-jamming protection means provided to the airborne radar are therefore intended for protection of the range finder against noise and providing the radar computer with the information on the target range under conditions when the range finder cannot operate.

The information on the target range and rate of closure can be furnished by the following sources:

(1) a radar range finder upon the target lock-on through the main frequency channel;

(2) a radar range finder upon the target lock-on through auxiliary frequency channel;

(3) a range finder storage circuit;

(4) an automatic telemetering system АРЛ with the airborne radar operating in the automatic mode.

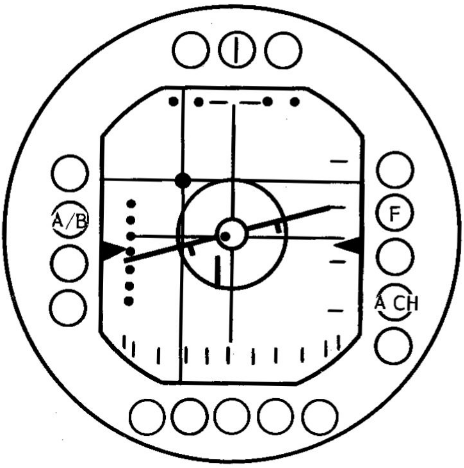
All these information sources are automatically linked with the computer. The procedures of connections and the pilot's actions during attack on an active jammer consist in the following.

The setting up of active noise causes the receiver desensitization device to operate. As a consequence, the flare spot on the display screen of the РП-25 radar becomes narrower. The receiver may be desensitized manually as well as with the use of the RECEIVER DESENS.(ЗАГРУБЛЕНИЕ ПР-МА).

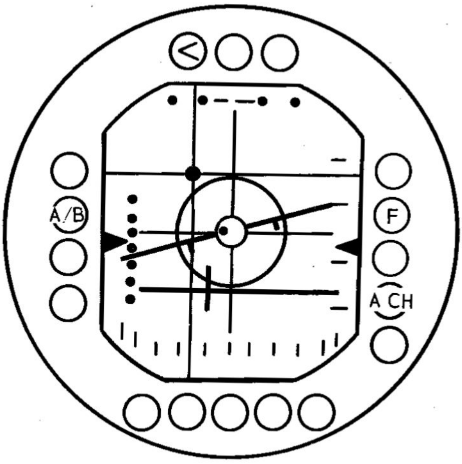
If the equipment operates in the automatic mode, the jammer lock-on upon completion of the receiver desensitization should be effected by depressing the LOCK-ON button. In the manual mode, it is necessary first to apply the lock-on zone marks to the vertical flare spot at any range.

Upon lock on of the jammer by angular coordinates, the M CH INTRF button-light on the control and monitoring panel of the РП-25 radar and the A CH lamp on the circular display of the attitude and command marks unit will come on. This is the evidence of the auxiliary channel cutting in to operate for emission.

If the distance from a target locked on in the main channel by angular coordinates does not exceed the operational range of the auxiliary channel, the display screen will display a target mark in the form of a horizontal line running across the entire display screen. In the automatic control mode a target is immediately locked on in range and the indications presented on the display screen are in full compliance with the sighting mode. With the equipment being operated in the manual control mode, it is



a



b

FIG. 142. VIEW OF DISPLAY SCREEN OF РП–25 AIRBORNE RADAR AT ACTIVE JAMMING SOURCE LOCK-ON

a – target range is in excess of auxiliary frequency channel; b – target detection with use of auxiliary frequency channel necessary to apply the lock-on zone marks to the target mark (horizontal line) and then effect the target lock-on in range by depressing the LOCK-ON button.

If the distance from the target exceeds the maximum range of the auxiliary channel operation to the target of a given type, the screen does not display a horizontal line at all (Fig. 142).

Further, upon entry into the operational range of the auxiliary channel a target mark appears in the form of a horizontal line. The procedures for lock-on in range are similar to those described the above (Fig. 143).

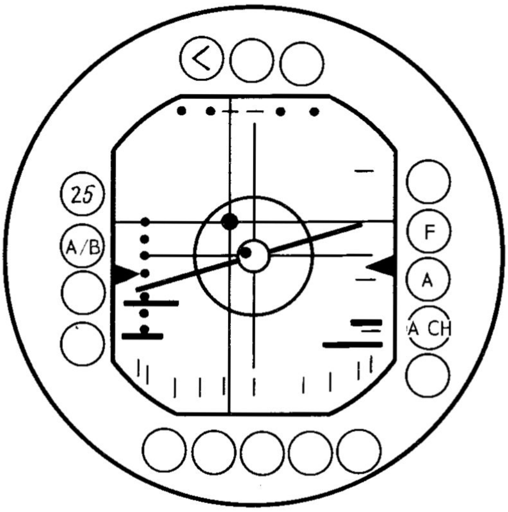


FIG. 143. VIEW OF DISPLAY SCREEN OF РП-25 AIRBORNE RADAR UPON COMPLETION OF RANGE TARGET LOCK-ON WITH USE OF AUXILIARY FREQUENCY CHANNEL

The setting up of active jamming on the first working frequency of the auxiliary channel is indicated by the flashing up of the indicator lamp located on the control and monitoring panel M CH INTRF (ПОМЕХА ДК). If a target has been positively locked on in range prior to the setting up of jamming in the auxiliary channel, the retuning of the auxiliary channel to the second working frequency does not take place. The target automatic tracking in range is effected with the use of the rate-of-closure data kept in storage. The indications presented on the display screen of the РП-25 radar remain unchanged and correspond to the sighting mode.

If jamming has been imposed on the auxiliary channel prior to the target lock-on in range, the A CH INTRF lamp comes to glow and the equipment automatically retunes the auxiliary channel to the second working frequency. If the second frequency is free from jamming, a target lock-on in range will take place. The indications on the display screen will correspond to the sighting mode.

If the target lock-on in range is impossible due to jamming even on the second working frequency of the auxiliary channel, the auxiliary channel is changed over to the dummy and the A CH lamp on the attitude and command marks unit dies out. The equipment is automatically switched over to operate with the use of the target range and rate of closure information transmitted to the aircraft from the ground over the telemetering system АРЛ-СМ link.

If the airborne radar is operated in the automatic control mode at this time, the display screen presents indications corresponding to the sighting mode, and an attack on a target shall be delivered by the usual method. With the radar equipment being operated in the manual control mode, the indicator screen displays the beam and lock-on zone marks only. In this case an attack on a target can be performed by launching missiles provided with radar seekers in the "φ_b" mode (Fig. 144).

If the enemy uses multiple return pulse jamming, a series of marks similar to the target mark appears on the jammer azimuth. Flare spots caused by this type of jamming (a column of marks) are always in parallel to the range scale. Their width remains unchanged with distance variation.

Flare spots initiated by the uncovering jamming are arranged at distances which are greater than the target range. If covering jamming is set up, the target mark is within the limits of the flare spots and thus it is undistinguishable amongst the flares. The use of multiple pulse jamming of high intensity gives rise to flare spots at two or three azimuth angles. The intensity and width of the flare spots on the jammer azimuth mark will be greater (Fig. 145).

To lock on a jammer producing noncovering multiple pulse jamming, perform gating of the nearest target mark by the aid of the guidance knob so that the target mark be in the upper portion of the zone of lock-on in range and depress the LOCK-ON button.

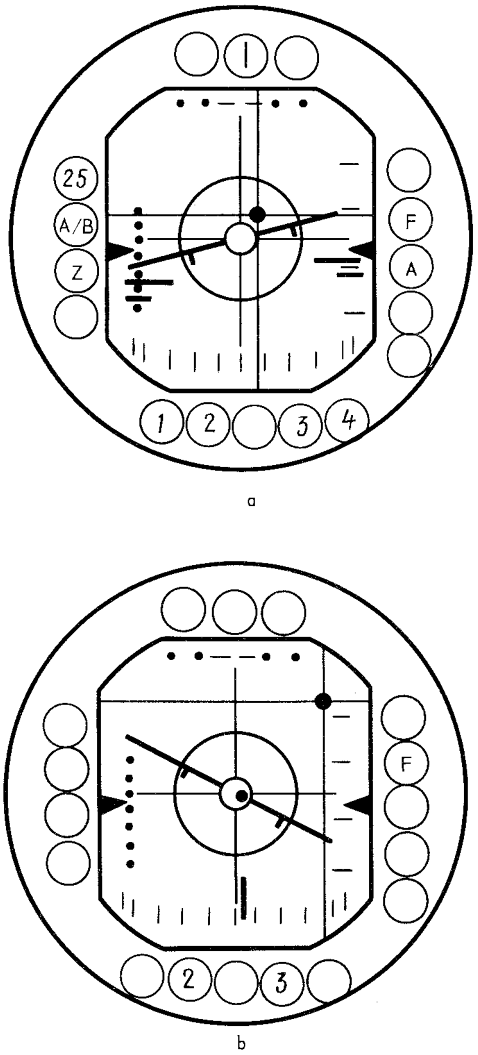


FIG. 144. VIEW OF DISPLAY SCREEN OF PII–25 AIRBORNE RADAR WITH BOTH FREQUENCY CHANNELS SUBJECTED TO ACTIVE JAMMING

a – automatic control mode; b – manual control mode

Upon completion of the target lock-on, the multiple return pulse jamming has no affect on the airborne radar operation.

In order to lock on a jammer generating covering jamming, apply the lock-on gates to the most intensive column of flare spots and depress the LOCK-ON button. To get rid of the jamming upon completion of the target lock-on, manually engage the auxiliary channel, depressing the M CH INTRF button-light from time to time until the (A) lamp on the attitude and command marks unit starts to glow steadily.

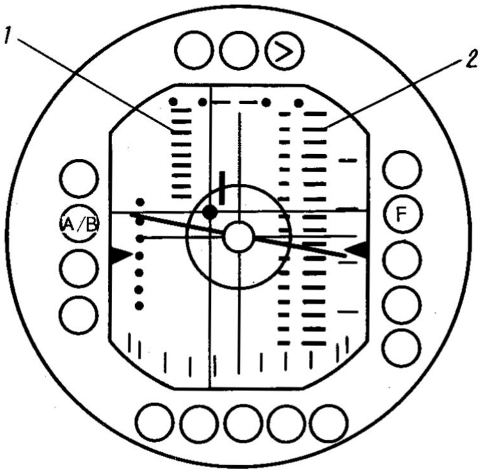


FIG. 145. VIEW OF DISPLAY SCREEN OF РП-25 AIRBORNE RADAR SUBJECTED TO RETURN NON-COVERING MULTIPLE PULSE JAMMING

1 – medium power; 2 – high power

Further, an attack is performed in the ordinary way.

Jamming which pulls off in range is used by the enemy to divert the interceptor-fighter radar automatic tracking system in range from the target and subsequently put the lock-on in failure. The principle of producing pull-off jamming in range consists in the following.

A jamming pulse is first radiated at the moment a main pulse emitted by the airborne radar transmitter reaches the target. The jamming pulse delay interval is further gradually extended. Since its power is considerably greater than that of the signal returned from the target, the jamming proves to be strong to divert the automatic tracking system in range. The emission of jamming pulses terminates, thus forcing the interceptor-fighter airborne radar changing over to operate in the mode of the target search in range. This process is repeated over and over again. During this process the airborne radar indicator screen displays the jamming pulse mark which separates from the present range mark. Next, resetting of lock-on in range takes place. After this, the indications presented will correspond to the target lock-on in angular coordinates. The target lock-on in range may take place once again. These changes in indication will periodically occur in synchronism with the jamming cycle.

The auxiliary channel is the most effective remedy against such a type of jamming. To switch on this channel, depress from time to time the M CH INTRF button-light on the control and monitoring panel until the A CH lamp on the circular display of the attitude and command marks unit lights up.

After the A CH lamp has come to glow and a horizontal line has passed across the entire display screen (target detection by auxiliary channel) lock on the target in range as described above. With the radar equipment operating in the automatic control mode, a target will be locked on in range automatically. Further, the attack on the target is performed in the way similar to the attack performed under no-jamming conditions. It should be borne in mind that the maximum operating range of the auxiliary channel is within the limits of 30 km.

The interceptor-fighter missile armament system will be subjected to active jamming which may be produced not only by attacked aircraft but also by special flying jammers which provide cover for their friendly strike groups from the air alert zones. The air alert zones are located along the directions of approach of strike groups to objectives of strike.

Under the above conditions, continuous or intermittent jamming, return noise and multiple pulse jamming are the major kinds of jamming.

A success in delivering an attack against air targets operating under the cover of jamming can be achieved provided the interceptor-fighter heading differs from the direction to the jammer as greatly as possible. In this case, the jamming set up by the jammer will affect only the side lobes of the radar antenna radiation pattern and the jamming effectiveness will be low.

Proper selection of the direction of attack delivered against enemy aircraft operating under the cover of special jammers from the air alert zones makes it possible to perform intercept flights involving not only a rear-cone attacks but also high angle-off attacks.

2. INTERCEPT FLIGHTS UNDER CONDITIONS OF PASSIVE JAMMING AGAINST INTERCEPTOR-FIGHTER ARMAMENT SYSTEM

When intercepting the enemy aircraft under conditions of passive jamming set up by the enemy the interceptor-fighters may be assigned a mission to destroy the passive jammers and aircraft flying under the cover of passing jamming set up in advance.

The РП-25 radar is provided with protective facilities which makes it possible to successfully attack the passive jammers. The principle of operation employed by these aids consists in the following.

The airborne radar range finder system provides for target search from shorter distances to longer ones. During a forward-cone attack on a passive jammer this makes it possible to lock on a target and not passive jamming as the return signal will be the first to enter the range finder lock-on zone. When delivering a rear-cone attack on a target the direction of the range finder search remains unchanged but the inhibitor is switched on for operation to ensure the lock-on and tracking in range of the remotest pulse in the passive jamming train which is essentially a signal returned from the target.

Special unbalance of the range automatic tracking circuit ensures tracking of the return signal with respect to its leading edge in the forward-cone attack and its trailing edge in the rear-cone attack. Such an arrangement diminishes the probability of the range finder change-over from tracking of the return signal to tracking of jamming.

In the event of the range finder locks on the passive jamming, the rate-of-closure selection circuit will ensure automatic re-setting of the lock-on mode and the range finder change-over to the target search mode. The selection circuit operates if the rate of closure with the locked-on target approximates the proper flying speed of the interceptor-fighter. This corresponds to the chaff cloud lock-on. In this case a pilot will observe the alignment of marks of rate-of-closure and interceptor-fighter speed on the display screen.

Use of the manual method of the target gating prior to lock-on also contributes to the process of passive jamming detuning.

Chaffs jettisoned by a jammer into the rear hemisphere produce on the airborne radar display screen a train of flare spots in the form of a loop originating from the target mark. The enemy aircraft detection range considerably increases, for the effective area of a chaff cloud is much greater than that of a single aircraft.

Chaff packs may be jettisoned at long time intervals. The marks of such separate chaff clouds are similar in shape to the target mark (Fig. 146).

Upon locating the source of passive jamming, prior to the target lock-on, the pilot should set the PASS JAMM PURSUIT - COLLISION (ПАСС. ПОМЕХА ДОГОН - ВСТРЕЧА) selector switch to the PURSUIT (ДОГОН) position in the rear-cone attack and to the COLLISION (ВСТРЕЧА) position in the forward-cone attack. Rear hemisphere entry instrument guidance ensures automatic passage of the PURSUIT mode switching on command with the selector switch set to neutral. During the forward-cone attack, however, with the radar equipment operating in the automatic control mode, it is necessary to set the above selector switch in the COLLISION position.

Target mark gating prior to lock-on shall be effected manually. The gates should be arranged in such a manner that the target mark (top of loop) be in the upper portion of the lock-on zone in case of the forward-cone attack and in the lower portion of the lock-on zone in case of the rear-cone attack. The target lock-on will take place after depressing the LOCK-ON button.

After the target lock-on, from time to time a horizontal line extends throughout the entire display screen which is indicative of the fact that the range finder has locked on a chaff cloud and that the rate selection system has been activated, as a result of which the rate-of-closure and interceptor-fighter flying speed marks come into alignment. In this case the pilot must reset the lock-on, then must gate again and lock on the target.

Use of passive jamming upon the target lock-on is discovered by the pilot with reference to alignment of the rate-of-closure and interceptor-fighter flying speed marks. If the rate-of-closure mark in a jump approaches the interceptor-fighter flying speed mark from above, set the PASS JAMM PURSUIT - COLLISION selector

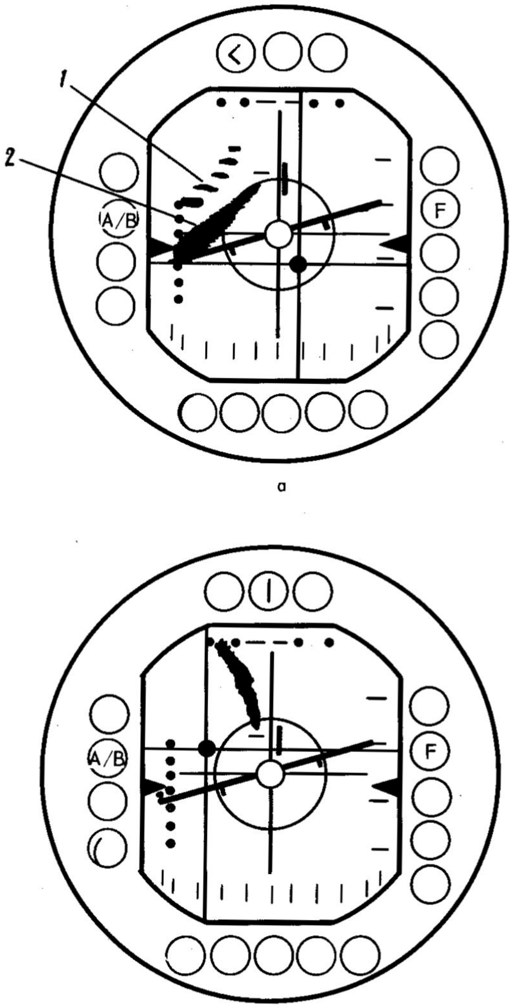


FIG. 146. VIEW OF DISPLAY SCREEN OF PII–25 AIRBORNE RADAR DURING ATTACK AGAINST PASSIVE JAMMER

a – rear-cone attack; b – forward-cone attack; 1 – discrete jamming; 2 – continuous jamming switch to the COLLISION position. If it nears the speed mark from below, the above selector switch should be placed in the PURSUIT position.

If using of chaffs is expected from a target to be attacked, it is wise that the passive jamming protection aids be switched on in advance, that is prior to lock-on, in order to decrease the time required to perform the attack.

3. INTERCEPT FLIGHTS UNDER CONDITIONS OF COMBINED JAMMING AGAINST INTERCEPTOR-FIGHTER

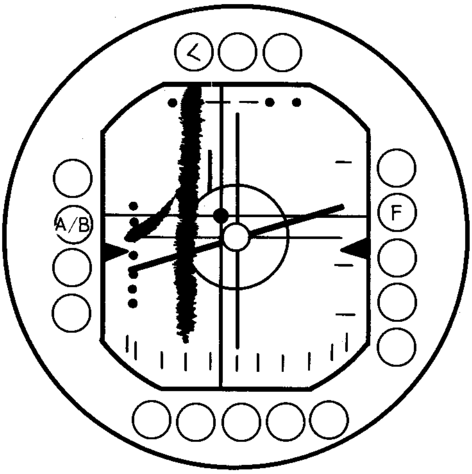
It should be expected that the enemy attempt to frustrate interceptor-fighter attacks with the use of not only separate types of jamming but various combinations of jamming.

The enemy may use combined jamming which presents a successive radiation of various kinds of jamming. Simultaneous setting up of active noise in combination with range and angular-coordinates pull-off jamming is practised. Various kinds of active noise jamming may be simultaneously used by an enemy in combination with passive jamming.

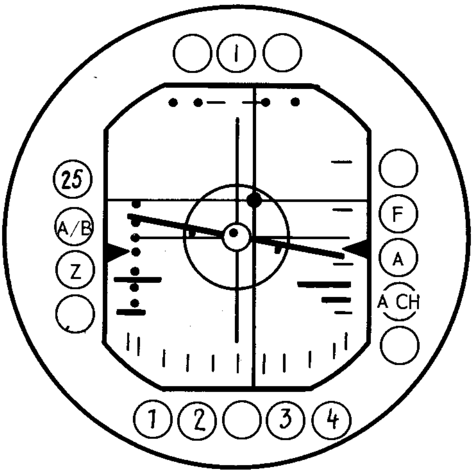
When an enemy being attacked uses active noise jamming in combination with chaffs, with the airborne radar operating in the scanning mode, the view of flare spots presented on the indicator display screen is the same as in the case of using noise jamming only, because the flare spots originated by noise jamming commonly serve as camouflage for the flares originated by chaffs. Nevertheless, if an attack is delivered at aspect angles of 1/4 to 2/4 and more, a passive jamming loop can be visible under weak active jamming conditions or upon switching on the desensitization of receivers. This makes it possible to determine the target range with the aid of the airborne radar operating in the scanning mode (Fig. 147).

On detecting the flare spots caused by both active noise and chaffs (upon obtaining information from the ground about the use of combined jamming by the enemy) turn on the passive jamming protection system by the PASS JAMM PURSUIT - COLLISION selector switch and perform lock-on of the target in the same manner as lock-on of the active jammer.

In case the airborne radar operates in the manual control mode, upon completion of target lock-on with respect to the angular coordinates and switching-on of the auxiliary channel, the display screen will present a horizontal strip the width of



a



b

FIG. 147. VIEW OF DISPLAY SCREEN OF PII–25 AIRBORNE RADAR DURING ATTACK AGAINST ACTIVE AND PASSIVE JAMMER (at aspect angles of 2/4 – 3/4)

a – search mode; b – target lock-on

which (size in range) depends on the length of the passive jamming loop. If use is made of intermittent jamming, the display screen will display several such strips. To effect range target lock-on under such conditions, apply the lock-on zone marks to the nearest portion of the flare strip when delivering the forward-cone attack on a target and to the remotest portion of the flare strip during the rear-cone attack. The above marks applied, depress the LOCK-ON button.

If the enemy uses the range pull-off active return jamming in combination with passive jamming, upon completion of the target lock-on, a horizontal line may appear for a short time throughout the entire display screen (range lock-on failure due to pull-off jamming) or one can see convergence of the rate-of-closure and interceptor-fighter flying speed marks (passive jamming lock-on). A complete target lock-on failure is also possible. In this case to preclude the affect of passive jamming,it is necessary to switch on the passive jamming protection system by the PASS JAMM PURSUIT - COLLISION selector switch. In order to tune off the range pull-off jamming upon completion of the target lock-on with respect to the angular coordinates, engage the auxiliary channel by periodically depressing the M CH INTRF button light until the (A CH) lamp on the circular display of the attitude and command marks unit flashes up. Upon completion of the target range lock-on in the auxiliary channel deliver an attack in the same way as under no jamming conditions.

4. ATTACK INVOLVING MISSILE LAUNCH IN "φ_o" ("φ_b") MODE

If the enemy sets up intensive jamming imposed on the airborne radar main and auxiliary frequency channels thus making it impossible to lock on the target in range and no information is transmitted to the interceptor-fighter over automatic telemetering system АРЛ, the pilot must perform an attack in the "φ_b" mode as in the event of failure of the radar computer. In this case the display screen represents only a beam mark which indicates the attitude of a target locked on by the angular coordinates relative to the interceptor-fighter. Launch of missiles provided with either heat seekers or radar seekers is possible.

To perform the missile launch in the "φ_b" mode, proceed as follows:

(1) change over to the aircraft manual control mode;

(2) set the three-position selector switch φ_b - +RADAR - φ_o to the "φ_b" position not later than one minute prior to missile launching;

(3) set the FH - RH selector switch to the RH or FH position upon the information furnished from the ground not earlier than 30 s after switching on the "φ_b" mode;

(4) perform target homing by reference to the antenna beam mark, holding it within the limits of a small mechanical ring on the radar display screen;

(5) launch the missiles on flashing up of the ①, ②, ③, ④ lamps and attaining permissible distance;

(6) missile lift-off completed, break off from the attack, never permitting lock-on collapse before missiles impacts on a target.

In this mode missiles can be launched either into the rear or forward hemisphere.

In the rear-cone attack at altitudes of 500 to 5000 m launch missiles at distances not exceeding 3.5 to 5 km, respectively. When flying at altitudes above 5000 m, the missile launch distance must not exceed the flying altitude of the interceptor-fighter.

In the forward-cone attack at altitudes of 5000 to 15,000 m, the missile launch is possible over a range of maximum to minimum distances which can be determined from the following equations

$$D_{l\ max.} = H_i + 10\ km;$$

$$D_{l\ min.} = H_i + 4\ km.$$

In the forward-cone attack at altitudes above 15,000 m the missile launch shall be effected at steady illumination of the ①, ②, ③, ④ lamps.

If it is impossible to deliver an attack on a target with the use of the airborne radar, launch missiles at the enemy with the armament system operating in the "φ_o" mode. Application of this mode is possible provided a target can be visually detected only when delivering a rear-cone attack on the target.

After the aircraft has approached a target on the commands furnished from the command post and a target has been visually detected, the pilot should proceed as follows:

(1) set the φ_b - + RADAR - φ_o three-position selector switch to the φ_o position not later than one minute prior to missile launch;

(2) turn on the MSL LNCH circuit breaker;

(3) change over to the aircraft manual control;

(4) set the FH - RH to the RH position not earlier than 30 s after the above selector switch has been set to the φ_0 position;

(5) keeping control over the aircraft, align the centre of the cross-hair of the K-10T optical sight with a target and depress the firing button upon flashing up of lamps (lamp) (1), (2), (3), and (4) at the same ranges as in the "φ_b" mode;

(6) missiles (missile) lift-off completed, break off from the attack and switch off the MSL LNCH circuit breaker.

Target identification in this case shall be effected by the controller or visually by the pilot.

Modern concepts suggest that aerial combat will be accompanied in most cases by the application of intensive radar jamming in view of interfering with the operation of the interceptor-fighter airborne radar and the entire missile armament system of the interceptor-fighter. The operation of the airborne radar and missiles under intensive jamming conditions is therefore considered as something normal and not extraordinary case. Success in an aerial combat largely depends on a pilot's skill to give a rapid evaluation of the jamming situation and skilfully use the anti-jamming protection aids available and the most practical tactical methods.

RECOMMENDATIONS TO COMMANDERS ON METHODS OF COMBAT TRAINING OF PILOT PERSONNEL

The primary purpose of combat training is to make a pilot skilful in destroying enemy piloted and pilotless air attack vehicles by day and night under various weather conditions throughout the entire range of flying altitudes and speeds.

The fact that the interceptor-fighter is provided with various complex radar sights and armament systems necessitates that the pilots be highly skilful in using the above-mentioned equipment and have profound theoretical knowledge. Satisfactory results can be obtained through systematic ground training and flying practice, teamwork of the command post (direction post) personnel and pilots on fulfilment of the assigned combat mission. As a result of training exercises the pilots should perfectly master the procedure and rules of employment the airborne radar and the armament system of the aircraft as a whole.

It is practical that intercept flights involving missile launch simulation and photographic control of the results of interception form a basis of the pilots' combat training. Particular attention should be given to performing the high supersonic stratosphere flights involving the attainment of dynamic altitudes to deliver the rear-cone and forward-cone attacks as well as high-angle-off attacks.

A constant rate of advance shall be maintained throughout the entire period of combat training. It is recommended therefore that the following sequence of performing intercept excercises be observed:

(a) in the daytime under VFR conditions (over the top of clouds) first at medium and high altitudes and then at low and maximum reference altitudes;

(b) in the daytime in clouds first at medium and high altitudes and then at low altitudes;

(c) in the night-time under VFR conditions (over the top of clouds) first at medium and high altitudes and then at low and maximum reference altitudes;

(d) in the night-time in clouds first at medium and high altitudes and then at low altitudes.

Training of the pilots for fulfilment of complicated kinds of combat employment (intercept flights involving a forward-cone attack and a high-angle-off attack, flights at low altitudes in clouds, flying under conditions of active and passive jamming, formation intercept flights, firing practice) should be preceded by practice flying both in the daytime and night-time. A more detailed sequence of the combat training exercises is given in the Combat Training Manual.

Combat flying exercises shall be started only after practising the aircraft piloting and air navigation under various weather conditions and at respective altitudes.

In order to become familiar with the nature of target marks displayed on the display screen and acquire proper skill in handling the radar sight, it is practical that a pilot undertakes a series of ground cockpit drills with the РП-25 airborne radar or installed for operation on the stand, making use of a transport aircraft or helicopter as a target. Particular attention in this case should be given to the variation in the antenna elevation with change in the target stepped-up vertical separation and range to the target.

The first intercept flight is aimed at acquiring skill in properly executing commands given over the automatic telemetering system АРЛ. To this end, an interceptor-fighter must enter the zone. Upon acquiring the skill by the pilot in piloting the aircraft in the zone in accordance with the commands transmitted over the automatic telemetering system, the controller must guide the interceptor-fighter to a real target. During first flights entry into the area should be effected by directing the aircraft into the target rear hemisphere at an aspect angle close to 0/4, with stepped-down vertical separation of 1000 to 2000 m relative to the target flying altitude, and to a distance of 20 to 25 km from the target at a rate of closure of 100 to 150 km/h. As the pilot becomes more skilful in flying the aircraft, the guidance parameters should be made more complicated and adjusted to the requirements of exercises described in the Combat Training Manual.

When practising maneuvering aerial target intercept flying, the pilot usually faces great difficulties, especially if a target vigorously maneuvers not only in respect to the heading but also in flying altitude and speed. Therefore, the first maneuvering air target intercept flights have to deal with a target the maneuver of which has been in advance limited and described. The nature of maneuver and the order of its accomplishment shall be assigned in the process of preliminary preparation. In flight a maneuver shall be performed only on the controller's command. The maneuvering target intercept flight is one of the most difficult-to-perform kinds of flying training as the maneuverability of the МиГ-25П aircraft is limited. The maneuvering target intercept flights shall be repeated from time to time. Flying training conditions should correspondingly be made more complicated. It is also important that the performing of intercept flight components be thoroughly checked with the use of the test-and-record equipment. Particular attention should be given to the meeting of the requirement for preventing surpassing of g-load and flying speed limitations.

Besides, after training the pilots to perform air target intercept flights involving the use of the radar sight in the automatic tracking mode it is necessary that the pilot practises techniques in target visual search and detection followed by an attack in the "φ_0" mode.

Upon completion of practising the target intercept flying at medium and high altitudes, proceed to intercept flights at maximum reference altitudes, in clouds at medium and high altitudes as well at low altitudes under VFR condition and in clouds. It is highly practical that the leading pilots of a unit being real experts of their job who are capable of hitting the enemy from a single run share their experience with the rest of personnel.

When performing intercept flights at maximum reference altitudes, it is necessary to take into account the following peculiarities:

(1) flying the aircraft at reheat power settings and supersonic speeds demands proper checking of fuel consumption on the part of a pilot, as well as on the part of a controller;

(2) complicacy of flying the aircraft in stratosphere at supersonic speeds; necessity in additional control over the operation of aircraft engines and inlet devices of the air intakes; necessity in preventing the aircraft from going beyond the flying speed limits (Mach number);

(3) high-altitude pressure outfit presents certain difficulties in operating the radar sight, and armament system and restricts a pilot's field of vision;

(4) impossibility of performing repeated guidance and attack due to a limited fuel reserve. This requires from the pilot proper and timely actions in all phases of flight to gain full victory over the enemy.

One of the major problems of combat training is to make pilots skilful in performing interception in clouds. Intercept flights in clouds must be preceded by check and training flights under the hood with the use of combat trainers in order to acquire skill in piloting the aircraft at high roll and pitch angles as well as to master techniques in piloting the combat aircraft in clouds in the zone. Besides prior to performing the intercept flight in clouds, the pilot must learn the following points:

(1) procedures for distributing attention in instrument flying and by reference to the electronic artificial horizon in delivering an attack in clouds;

(2) radar sight operating procedures;

(3) effect of various kinds of clouds on the target detection and lock-on;

(4) expected ranges of target detection and lock-on by the radar sight at various altitudes;

(5) symptoms of false targets lock-on;

(6) air target destruction probability in the event of failure of separate components of the airborne radar sight and armament system.

It is practical that first intercept flights in clouds be performed in the area of mid- and upper-level cirrus and stratus clouds. Subsequent flights should be performed in clouds which may produce highly adverse effects on the operation of the airborne radar. It is mandatory that in the course of preparation and when practising the intercept flights in clouds the pilots should keep their skill in instrument flying at all times.

Upon completion of practising the intercept flights at medium and high altitudes, proceed to training for intercept flights at low altitudes. Preparation of pilots in this field of combat employment is the major responsibility of commanders who must always take into consideration the individual capabilities of each pilot. Prior to performing the intercept flights at a low altitude a pilot should master the required piloting techniques and attention distribution procedures and acquire profound skill in piloting aircraft at low altitudes.

During the ground preparation for performing the intercept flights at low altitudes the pilot personnel must study the following points:

(1) peculiarities of terrain in flying area;

(2) peculiarities involved in intercept flight and procedures for operating radar sight at low altitudes;

(3) expected target detection and positive lock-on ranges;

(4) spreading of target-aircraft wake and actions to be taken by a pilot on hitting a target;

(5) procedures for checking a safe flying altitude;

(6) operational limitations of the aircraft at low altitudes;

(7) safety precautions to be taken during target detection and lock-on, as well as during missile launch and breaking off.

Upon completion of practising the intercept flying at low altitudes under VFR conditions and in clouds at medium and high altitudes proceed to practising the interception of targets flying in clouds at low altitudes. This kind of combat employment is one of the most complicated and demands from a pilot to perfect his skill in piloting the aircraft with the use of instruments at a low altitude.

During preparation for the intercept flight in clouds at a low altitude a pilot must study the following points:

(1) procedures for distributing attention when flying the aircraft in clouds;

(2) peculiarities of performing an attack in clouds at a low altitude and procedures of operating the airborne radar sight and armament system;

(3) expected target detection ranges and the most advantageous target positive lock-on ranges;

(4) actions in cases of emergency in flight at a low altitude and safety precautions.

First training intercept flights in clouds at low altitudes shall be performed when the cloud base is at least 600 to 700 m above the terrain, with a target flying at an altitude of 1300 to 1500 m.

Night combat training in VFR and IFR conditions shall be started upon completion of the respective type of daytime combat training. The principles and methods of practising the night intercept flights are similar to those involved in the daytime training, with the peculiarities involved in night flying being taken into consideration.

A night flight, especially in clouds, is accompanied by abnormal strain of the pilot which may adversely affect the aircraft piloting quality. Therefore, when checking the fitness of pilots for night combat flying, the commanding personnel take into account both individual proficiency level of each pilot and the concrete meteorological conditions in which the mission will be carried out.

It is wise that the training of the pilot personnel to perform interception of air targets with a forward-cone attack and a high-angle-off attack be started from flying at high altitudes at subsonic speeds. Upon completion of this programme proceed to practising the supersonic stratosphere intercept flights over a range of altitudes terminated by maximum reference altitudes. Practising the interception of targets flying in clouds involving a forward-cone attack and a high-angle-off attack shall be started only upon completion of practising the intercept flights involving a forward-cone attack and a high-angle-off attack under VFR conditions.

Practising the interception of air targets under conditions of active and passive jamming is one of the most complicated and at the same time exceptionally important problem of pilots' combat training because the aircraft of the potential enemy are equipped with various jamming facilities.

In combat operations intercept flights under conditions of jamming will be ordinary event. Therefore, in the course of combat training pilot personnel should be properly trained in operating radar sight under conditions of active and passive jamming.

During preparation for performing air target intercept flight under conditions of jamming the pilot personnel must study the following points:

(1) nature of active and passive jamming affecting airborne radar sight in scanning and lock-on modes of operation;

(2) peculiarities of detecting, approaching, and attacking a target which is setting up jamming or it is flying under the cover of jamming;

(3) tactical methods of diminishing the effectiveness of jamming;

(4) safety precautions to be taken in delivering an attack against a jammer.

During lay-offs personnel must restore flying skill in accordance with the procedures specified in the Combat Training Manual with due regard to the present pilot proficiency level and individual properties.

In order to obtain satisfactory results in the pilot personnel combat training, instructional pamphlets are compiled for identical exercises stipulated by the Combat Training Manual. These pamphlets contain graphical representation of target and interceptor-fighter flight paths and actions of a pilot in all phases of flight from the moment of takeoff till landing. In addition, during the preliminary preparation the pilot must make a detailed analysis of the procedures to be followed in all phases of flight in cooperation with the crew of a target aircraft and command post team. Particular attention should be given to observance of safety precautions.

Each combat training flight must be thoroughly analysed by an immediate commander, mandatorily analysing the data obtained by the test and recording equipment. On the basis of analysis it is possible to reveal the errors committed by the pilot and aircraft controller and find the remedies to ensure in future success in combat training.

CHAPTER IV

FLIGHT ANALYSIS WITH USE OF FLIGHT DATA RECORDING EQUIPMENT

1. METHODS OF INTERPRETING OBJECTIVE CHECK-OUT RECORDINGS

Objective evaluation of the flying mission performed and current check of serviceability of the МиГ-25П aircraft main systems are carried out by reference to the oscillograms of the К9-51Б flight data recording system.

The СРП-9М recorder (the major component of the К9-51Б flight data recording system) is intended for optical and mechanical recording of the flight parameters under normal and emergency conditions on the photographic film and storing the recorded information in case of impact or thermal action.

Flight Data Recording System К9-51Б Basic Specifications

The СРП-9М automatic flight data recorder is designed for measuring and recording the flight parameters by both mechanical and optical methods.

The mechanical method (photographic film scratching) is used for recording the following parameters:

(1) barometric flight altitude ranging from 0 to 25 km;
(2) indicated airspeed ranging from 200 to 1600 km/h;
(3) vertical g-load within the limits of -2 to +10;
(4) time intervals.

The optical method is used for recording the following flight parameters:

(1) longitudinal g-load from -1.5 to +1.5;
(2) left engine speed;
(3) right engine speed;
(4) aileron deflection angles;
(5) stabilizer deflection angles;
(6) time mark;

(7) discrete commands (by way of altering the left and right engine speed recording ordinate).

The alteration of the left engine speed recording ordinate takes place upon the following discrete commands:

(a) booster hydraulic system failure;

(b) main hydraulic system failure.

The alteration of the right engine speed recording ordinate is effected upon the following discrete commands:

(a) change-over to RH unit 1046 (fuel pump);

(b) cutting in of the САУ automatic flight control system.

The alteration of the time data optical recording ordinate follows upon the following discrete commands:

(a) change-over to LH unit 1046;

(b) firing button engagement.

The information carrier is a white-and-black non-perforated photographic film of 35 mm in width and photosensitivity of at least 250.

Reserve of a film in a spool is 14 $\pm$1 m.

The system provides for two film transporting speeds, namely: 0.85 mm/s and 3.5 mm/s $\pm$10%.

With the film transported at a speed of 0.85 mm/s, the time mark is scratched every 10 s; at a speed of 3.5 mm/s, every 3.5 s.

Flight parameters recording basic error is equal to $\pm$5% for the optical method and $\pm$4% for the mechanical method with respect to the measuring range of the respective parameter.

The K9-51Б system is powered from a DC generator. In the event of failure of the generators the system is supplied from the storage batteries. Flight parameters registered by the СРП-9М recorder are given in Table 9.

Table 9

Flight Parameters Registered by СРП-9М Recorder

Recording channel designation and No.	Flight parameter to be recorded	Type of recording	Discrete command No.
MRD	Mechanical reference datum	Mechanical	
TM	Time mark	Same	
n_y	Vertical g-load	Same	
H	Altitude	Same	

Table 9, continued

Recording channel designation and No.	Flight parameter to be recorded	Type of recording	Discrete command No.
V	Speed	Mechanical	
ORD	Optical reference datum	Optical	
1	Longitudinal g-load (is measured from -1.5 to +1.5)	Same	
2	Right engine speed:	Same	
	(a) unit 1046, right	Same	3
	(b) AFCS cut-in	Same	4
3	Left engine speed:		
	(a) booster hydraulic system failure	Same	1
	(b) main hydraulic system failure	Same	2
4	Port stabilizer deflection angle	Same	
5	Port aileron deflection angle	Same	
6	Time mark (TM):		
	(a) unit 1046, left	Same	5
	(b) firing button engagement	Same	6

To obtain full information covering the total flight time and the time of takeoff and takeoff run, provision is made for remote switching on the K9-51Б system from the БИА airborne measuring equipment switch located on the RH console. With the БИА equipment switch in the OFF position, the flight data recording system is put into operation automatically due to the dynamic pressure on attaining an airspeed of 100 - 200 km/h.

Discrete commands registered by the K9-51Б system are furnished by the aircraft systems in emergency cases. For instance, in case of drop of pressure in the main and booster hydraulic systems to a value of 160^{+5}_{-10} kgf/cm^2, simultaneously with lighting-up of the WATCH MAIN HYD SYS PRESSURE and WATCH BOOST HYD SYS PRESSURE indicator lamps, the electric signals are fed to the automatic recorder and registered on the film by a method of applying onto the left engine speed data (trail No. 3). The passage of a discrete or two discrete commands at a time results in an upward surge of trail No. 3.

Engagement of the CAY automatic flight control system in the DAMPING, LEVELLING-OFF, and AUTO CONT modes causes lighting-up of the AFCS DAMPING and AUTO CONT button-lamps located on the control panel and LEVELLING ON button-lamp on the control stick. An electric signal is furnished to the recorder and registered on the film carrying the right engine speed information by the superposition method (trail No. 2). The passage of the above signal gives rise to an upward surge of trail No. 2.

When changing over of the main automatic engine fuel control system to the duplicating system the DUPLICATING ENGINE FUEL AUTO CONT SYS indicator lamps come on and electric signals are furnished to trails Nos 2 and 6 of the recorder. The RH UNIT 1046 discrete command signal is recorded on the film carrying the right engine speed data by the superposition method. The passage of the command signal gives rise to an upward surge of trail No. 2. The LH UNIT 1046 discrete command signal is recorded on trail No. 6. The application of the firing button cut-in or LH UNIT 1046 discrete command signals to vibrator No. 6 results in an upward surge of trail No. 6.

In the course of interpretation of the objective check-out recordings the absolute magnitudes of the recorded parameters in separate sections of the oscillogram, as well as the rate of variation of the flight parameters at certain flight phases are determined.

The preliminary preparation of the oscillograms of the K9-51Б system for interpretation includes the following:

- marking the oscillogram in time;
- identification of recordings and discrete command signal lines for pertaining to definite parameters;
- qualitative interpretation of recordings for the purpose of selecting the sections and portions of oscillograms for determination of absolute values of parameters which make it possible to evaluate maintaining flight conditions;
- introduction of corrections into calibration charts and templates with due regard to misalignment of electrical and mechanical zeroes.

On the oscillograms presented by the recording system, time marks have a form of trapezoidal pulses. The duration of one time interval t_{int} is determined by the distance between the leading edges of two neighbouring pulses (Fig. 148). Each tenth time mark is characterized by longer pulse duration.

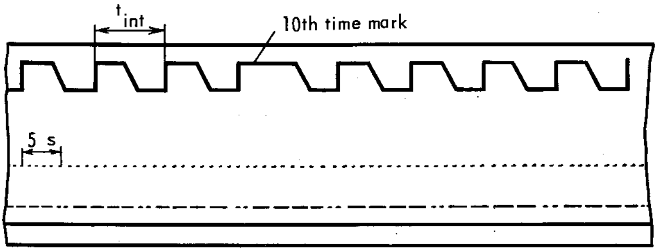


FIG. 148. RECORDING OF TIME MARKS ON OSCILLOGRAM OF K9-51Б FLIGHT DATA RECORDING SYSTEM

The marks of time measured by the МЧ-62 electromagnetic master clock are also registered on the oscillogram. These time marks are shaped as short pulses on the line of the sixth optical recording channel (tops of time pulses are registered on the photographic film). Each fifth second mark is characterized by a more pronounced contrast.

The lines of flight parameters recorded by way of scratching are identified by their interposition on the oscillogram (Fig. 149). With increasing the flight altitude and speed the record lines deflect in the directions indicated by arrows in the figure.

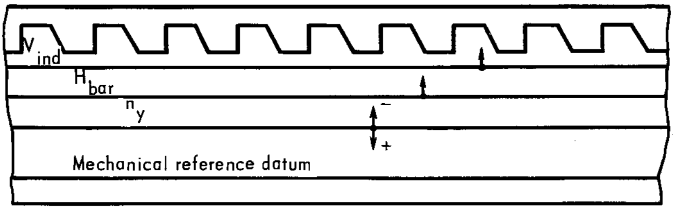


FIG. 149. SWITCHING OF CHANNEL RECORDING LINES REGISTERED MECHANICALLY ON OSCILLOGRAM OF K9-51Б FLIGHT DATA RECORDING SYSTEM

The sign and amount of g-load are determined by the use of the calibration graph. The lines designating flight data recorded by optical means are identified by determining the sequence of ruptures on the record lines. In the K9-51Б recording system

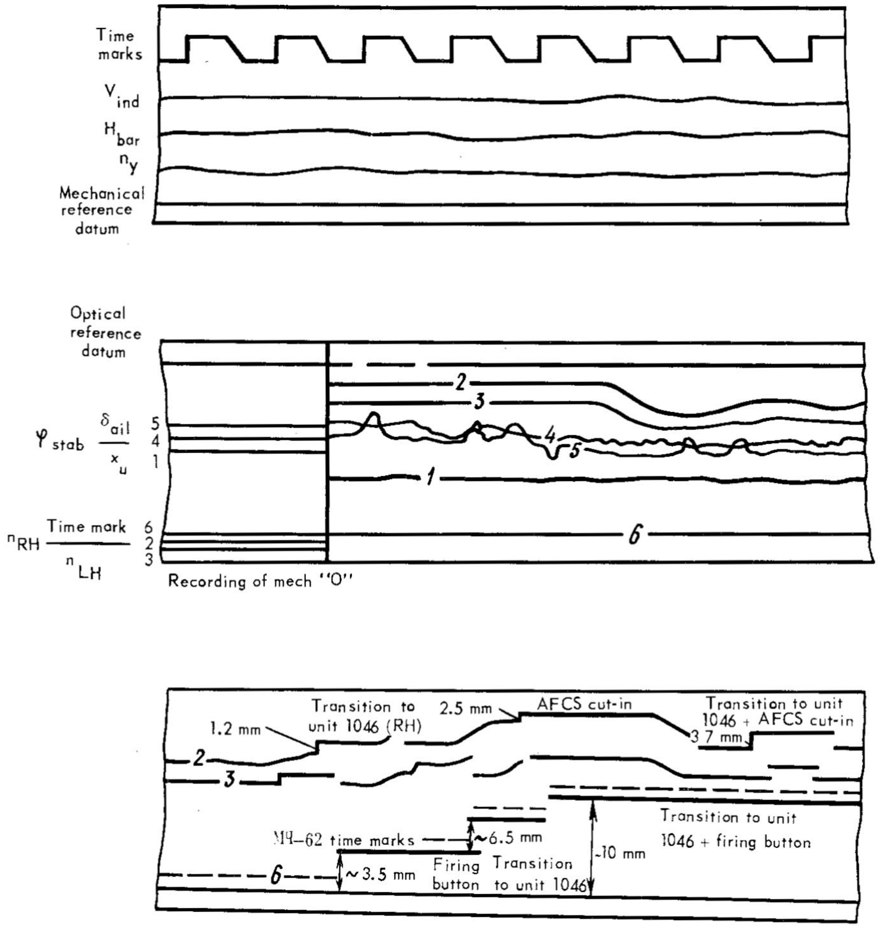


FIG. 150. ARRANGEMENT OF DISCRETE COMMANDS AND MECHANICAL ZEROES OF CHANNELS ON OSCILLOGRAMS OF K9–51Б FLIGHT DATA RECORDING SYSTEM

discrete command signals are presented in the form of a stepped displacement of the record line of the optical channel to which discrete command signals are supplied (Fig. 150).

The process of determining the absolute values of a certain parameter is started with adjusting the calibration graph (template) relative to the given mechanical zeroes of the record. The adjustment is effected by aligning the zero mark on a template with the zero-position mark of the respective trail in the beginning of the film. It is further necessary to determine the discrepancy between the datum line on the template and the datum line on the film itself. Should this discrepancy exist, it is necessary to plot a new datum line on the template, which is aligned with the datum line on the photographic film. The absolute value of the required parameter can be determined by aligning this new datum line on the template with that on the film at the required moment of time. The magnitude of a prameter will be equal to the ordinate of the respective recording channel calculated with the use of the template.

2. USE OF FLIGHT DATA RECORDINGS FOR ANALYSIS AND EVALUATION OF FLYING TECHNIQUE

The qualitative analysis of the oscillograms made by the flight data recording system makes it possible to determine the following:

(1) completeness of flight mission performed;

(2) maintaining the assigned parameters at separate flight stages;

(3) observance of flight safety;

(4) serviceability of the main aircraft systems.

The oscillogram portion preceding the flight parameters recording carries a record of the mechanical zeroes of all channels. This record makes it possible to perform current adjustment of the calibration graphs (due consideration shall be given to a displacement of mechanical zeroes). The position of the channel mechanical zero line is determined by the air pressure at the takeoff aerodrome at the moment of recording of mechanical zeroes.

Analysis of performing takeoff. The beginning of the takeoff run is determined by the existence of characteristic oscillation on the lines of the normal (n_y) and longitudinal (n_x) g-loads (Fig. 151). Straightening-out of the lines usually takes place at the moment of lift-off. An intensive displacement of the stabilizer deflection angle record line off neutral indicates the moment of the nose wheel light-off. The intensity of oscillation of this line characterizes the value of the aircraft longitudinal swing during takeoff run.

The moment of retraction of the landing gear is determined by a short-time alteration of the longitudinal g-load. The moment of disengagement of the engine afterburners is determined by the characteristic oscillation of the engine speed record lines and a rapid upward deflection of the longitudinal g-load record line. The flying speed at this moment must be at least 600 km/h.

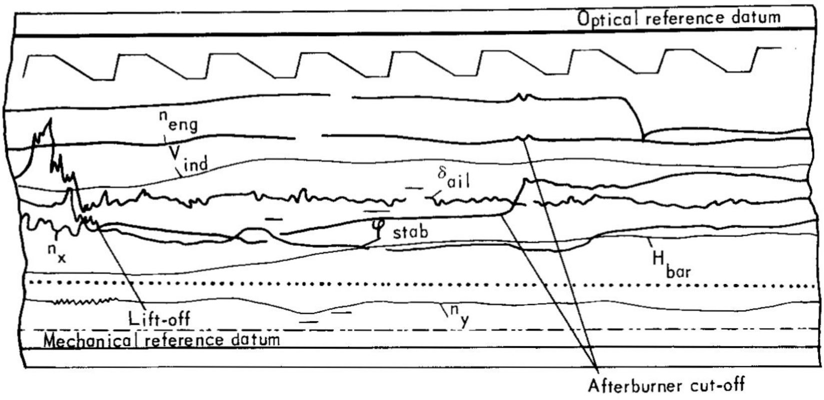


FIG. 151. TAKEOFF AND CLIMB PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51Б FLIGHT DATA RECORDING SYSTEM

<u>Analysis of performing a 360° turn.</u> A correct 360° turn is characterized by constant flying altitude and speed throughout the entire maneuver. The record lines pertaining to these parameters must, therefore, be in parallel to the datum line. Apart from this, the vertical g-load is more than 1 g throughout the entire turn and must correspond to the amount of bank. The beginning of a 360° turn is determined by a drastic change in the normal g-load and deflection of the stabilizer for creating a pitch-up moment with the purpose of compensating for the altitude loss sustained in banking. On the oscillograms made by the K9-51Б system, this moment can also be determined by deflection of the ailerons and their return to the initial position after the required bank is obtained (Fig. 152). In this case, a characteristic impulse occurs on the aileron deflection angle record line. The 360° turn direction is determined by the sign of the aileron deflection.

The moment of bringing the aircraft into level flight is determined by deflection of the ailerons in the direction of smaller bank. The average normal g-load in the 360° turn corresponds to the average bank which is maintained throughout the entire maneuver. With the correctly performed 360° turn, a bank is determined from the following relationship:

$$n_y = \frac{1}{\cos\gamma},$$

where: n_y - normal g-load in a 360° turn;
γ - bank angle.

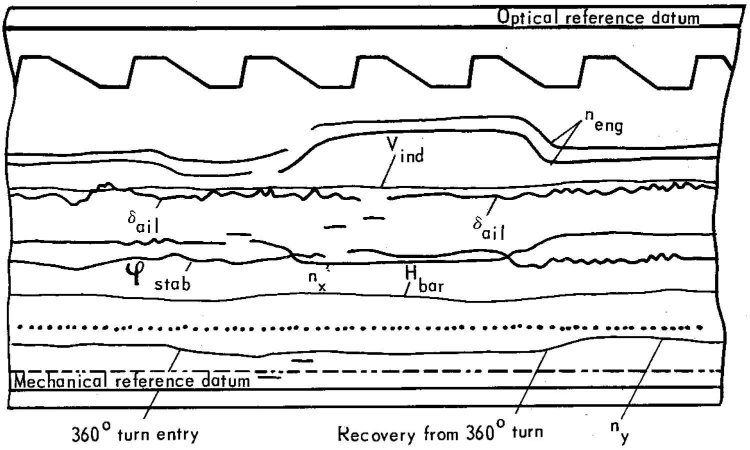


FIG. 152. 360° TURN PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51Б FLIGHT DATA RECORDING SYSTEM

This relationship for separate banks is given in Table 1.

When analysing the quality of performing a 360° turn, apart from the vertical g-load, an additional important information can be derived from such parameters as the engine speed, longitudinal g-load, flight altitude and speed.

By the nature of change in the engine speed one can judge the proficiency of the pilot in selecting the required engine power setting. Constant normal g-load and stabilizer deflection angles are characterizing the degree of skill of the pilot in performing a 360° turn. By the nature of the longitudinal g-load record presented on the oscillograms made by the K9-51Б system one can determine the moments of extension of the air brakes, selection of augmented power settings, and changes in the augmented power settings.

Analysis of performing vertical flight maneuvers. The character of the normal g-load record and the nature of the mutual alteration of the flight altitude and speed records are the major symptoms for identification of vertical maneuvers. The beginning of performing ascending maneuvers is characterized by a vigorous growth of g-load and further increase of flying altitude and decrease of flight speed.

Z o o m is characterized by an intensive growth of g-load in zoom entry and decrease of g-load to below 1 g in the middle portion of the maneuver (Fig. 153). Further change in g-load depends on the method of recovery, namely:

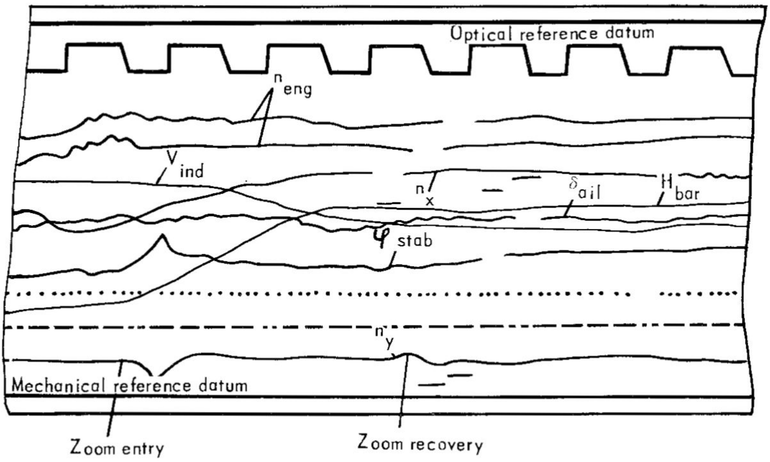


FIG. 153. ZOOM PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51B FLIGHT DATA RECORDING SYSTEM

- g-load may tend to diminish if the zoom recovery is performed without bank, i.e. by applying forward stick pressure;
- normal g-load may increase to 1 - 1.5 in zoom recovery involving a turn at a bank of less than 90^{o} and to 2 - 4 g in zoom recovery involving a half-wingover or wingover.

When on a straight leg of the zoom path, $n_y = \cos \Theta$, where Θ is the trajectory angle.

The values of the normal g-load in zoom for separate trajectory angles are given in Table 10.

T a b l e 10

Zoom Trajectory Angle Versus G-Load

Trajectory angle θ^{o}	20	30	40	50	60	70
G-load n_y	0.94	0.87	0.77	0.64	0.5	0.34

In zooming, the flying speed constantly diminishes, and the altitude increases. In zoom recovery the rate of decrease in flying speed and increase in flight altitude diminishes. Subsequently, these parameters remain nearly unchanged.

By the maximum and minimum values of the speed and normal g-load one can judge how the respective limitations are observed. The zoom angle may be determined by referring to the rate of flying speed decrease during a certain period of time.

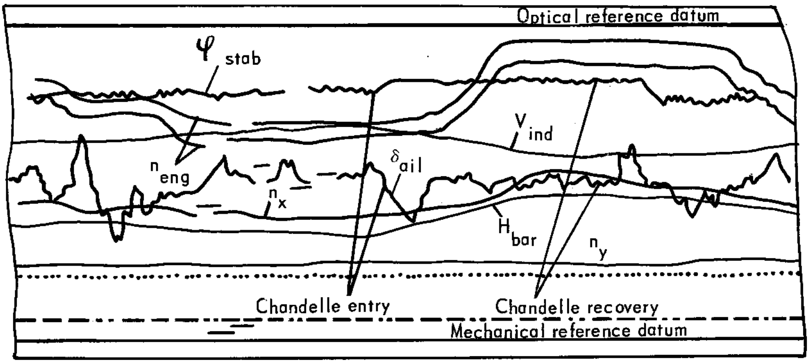


FIG. 154. CHANDELLE PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51Б FLIGHT DATA RECORDING SYSTEM

C h a n d e l l e is characterized by an intensive increase in the normal g-load in the initial phase and the linear change in this g-load to 1 g throughout the entire chandelle, i.e. the normal g-load must not be less than 1 g throughout the entire period of performing chandelle (Fig. 154). The direction of chandelle as indicated on the oscillograms produced by the K9-51Б recording system can be determined by the sign of aileron deflection.

When analysing the vertical ascending maneuvers (chandelle, zoom) for correct execution, one should consider the rate of change (gradient) of the normal g-load at the entry into the vertical maneuver. The g-load gradient must not exceed 1.5 g per second. An increase in the rate of g-load growth may give rise to an unintentional pitch-up in some flight regimes which is characterized by an inadvertent increase in the g-load at a constant stabilizer deflection angle. Practice flying calculations and data show that the optimum entry into vertical ascending maneuvers should be made at a rate of g-load growth of 1 to 1.5 g per second.

D i v e registered on the oscillogram is identified by an intensive increase in flying speed, with the engines running at a speed approximating flight idle power setting, and energetic altitude loss, with the normal g-load being equal or slightly below 1 g (Fig. 155).

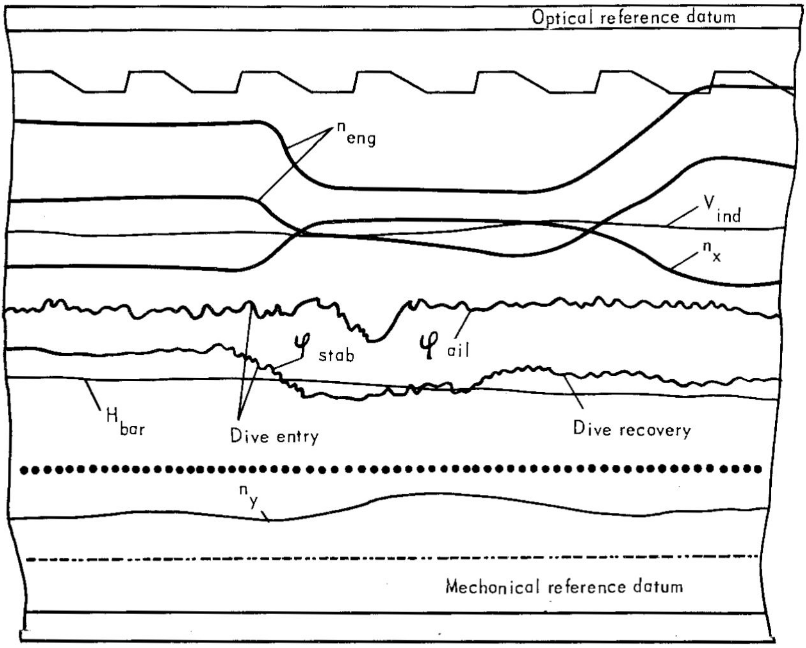


FIG. 155. DIVING PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51B FLIGHT DATA RECORDING SYSTEM

In dive recovery the g-load rapidly increases. The respective recording has a form of a surge lasting for 4 to 10 s. When analysing this maneuver from the point of view of flight safety, one should consider the amount of altitude loss ΔH taken from the moment of dive recovery to the moment of levelling-off as the main criterion. The moment of starting dive recovery can be determined by a characteristic stabilizer deflection and increase in normal g-load.

L a n d i n g is one of the most important stages of flight. Therefore, performing of landing should be analysed in detail with the use of the respective data recordings (Fig. 156). The moments of extension of the landing gear and flaps are determined by the following symptoms:

(1) change in longitudinal g-load;

(2) increase in engine speed;

(3) stabilizer deflection for compensation of aerodynamic moments.

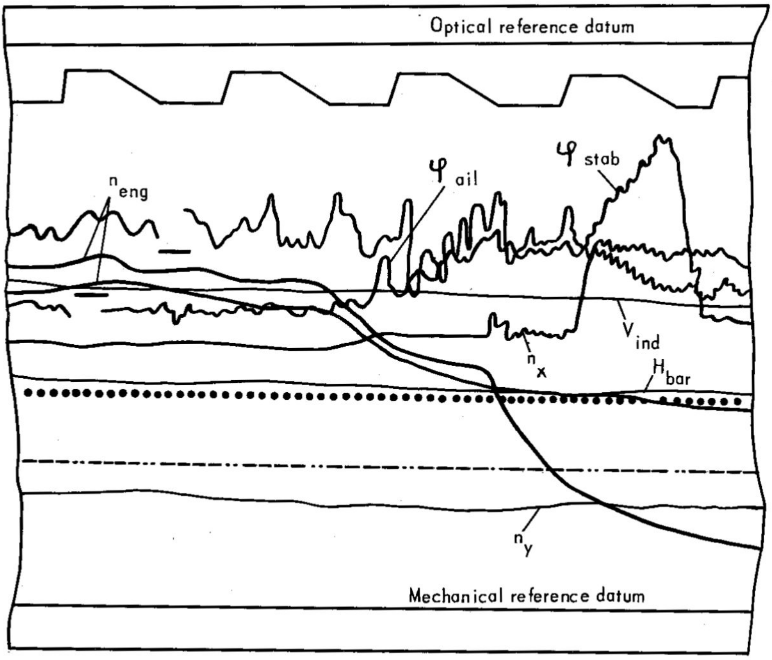


FIG. 156. LANDING PARAMETERS RECORDED ON OSCILLOGRAM OF K9-51B FLIGHT DATA RECORDING SYSTEM

In landing approach glide the flying speed and altitude change very smoothly and the normal g-load remains unchanged and approximates 1 g. A considerable change in the engine speed is indicative of an incorrect maintaining of the glide speed caused due to an insufficient control, diverting an attention from the instruments or improper distribution of attention.

Decrease in speed usually corresponds to fluctuation of the stabilizer deflection angle.

A thorough analysis of the oscillograms makes it possible to reveal the main cause of mistakes committed by the pilot in landing approach gliding and enhance flight safety.

The moment of touchdown is determined by oscillation of the normal g-load record line. The moment of deployment of the drag chute is determined by an intensive increase in the absolute value of the longitudinal g-load.

3. EVALUATION OF INTERCEPT FLIGHT RESULTS BY USE OF FLIGHT DATA RECORDINGS

The ПАУ-473 camera gun is an instrument which is intended for photographing the display screen of the airborne radar. The camera gun uses perphorated photo film of 16 mm wide for the purpose.

To switch on the ПАУ-473 camera gun, set the AUTO - OFF - MAN selector switch to the AUTO position. The camera gun is put into operation automatically, with the airborne radar starting operation in the emission mode. The MAN position of the above selector switch is used for ground testing of the camera gun only.

The rate of operation of the camera gun depends on the mode of operation of the airborne radar. With the radar operating in the SCAN mode, the ПАУ-473 camera gun is cut in by the pulses furnished by the synchronizer of unit 38 with respect to the fifth and tenth lines of the display screen of the radar, i.e. the display screen is photographed twice during each scanning cycle. With the radar operating in the AUTOTRACKING mode, the ПАУ-473 camera gun is cut into operation every 2 - 3 s.

In the SCAN mode of the radar the camera gun registers the following data:

(1) range and moment of target detection;
(2) target identification range;
(3) target azimuth relative to interceptor-fighter;
(4) airborne radar control mode and lock-on zone position;

(5) roll and pitch angles;

(6) piloting and sighting errors by reference to the position of the director mark of the attitude and command marks unit;

(7) passage of discrete command signals over the АРЛ system.

The target detection range is determined by the position of the target mark with respect to the range scale. The scale graduation value of the range scale is equal to 20 km at high and medium altitudes and 5 km, at low altitudes. The target azimuthal position within the scanning zone is determined by the position of the target mark relative to the upper scale.

The position of the scanning zone centre mark is determined by reference to the lower scale having a scale graduation value of 15°. The manual and automatic guidance modes are identified by the nature of lock-on zone indication. Roll and pitch angles are determined by the position of the respective indicators. The division of the pitch scale located in the LH portion of the display screen is 10°. The target identification range is determined by reference to the ПАУ-473 camera gun shot marked as FRIENDLY AIRCRAFT above the target mark.

In the AUTOTRACKING mode of the radar, the ПАУ-473 camera gun registers the following data:

(1) steady target lock-on range;

(2) ZOOM command generation range;

(3) maximum permissible missile launch range;

(4) director mark coordinates;

(5) beam mark position;

(6) moment and range of LAUNCH PERMITTED command signal generation;

(7) BREAK-AWAY command signal generation moment and range.

The lock-on range is determined by reference to the first shot carrying the information on steady target lock-on. The present range mark is displayed at the RH edge of the display screen. The maximum permissible missile launch range mark is also displayed at the RH edge of the screen. The moment of target lock-on is indicated by lighting-up of the (A) (attack) indicator lamp.

At the moment of generation of the ZOOM command signal the respective indicator lamp lights up at the framing of the airborne radar display screen and the attitude and command marks unit director mark deflects upward.

With the LAUNCH PERMITTED command displayed, the (1), (2), (3), and (4) lamps light up on the attitude and command marks unit.

The generation of the LAUNCH PERMITTED command signal is possible when:

(1) steady target lock-on by the homing heads of missiles;

(2) the range mark attains the value of the maximum permissible missile launch range (in this case, the present range short mark on the shot of the ПАУ-473 camera gun comes into alignment with the longer mark of the maximum permissible missile launch range);

(3) the airborne radar antenna beam mark is inside the great diameter ring ($\varphi_b = 45^{\circ}$).

The director mark should be within the limits of the small mechanical ring.

The moment of depressing the firing button is determined by passage of a discrete command signal in the 6th channel of the K9-51Б system. The barometric altitude and indicated airspeed pertaining to this moment are determined by reference to the oscillogram of the K9-51Б system.

The BREAK-AWAY command signal generation range is determined on the shot by the position of the present range mark at the moment of lighting-up of the (B) lamp at the framing of the display screen. The actual break-away range is determined by increase of bank (position of the bank line on the attitude and command marks unit).

The target captured, there appear a short closing speed mark and a long interceptor-fighter speed mark which are displayed at the LH edge of the display screen. The attack direction is determined by mutual arrangement of these marks with respect to the display screen vertical scale.

If the closing speed mark is above the interceptor-fighter speed mark, it means that the forward-cone attack has been launched. The reverse arrangement of the above-mentioned marks corresponds to the rear-cone attack.

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