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[redacted] English translation of a Soviet manual on the MIG-21F-13 aircraft, containing 188 pages [redacted]

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AIRCRAFT MIG-21F-13 TECHNICAL DESCRIPTION

Book I

Flight Characteristics

SECRET

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THE MIG-21F-13 TECHNICAL DESCRIPTION

First Book

Flight Characteristics

Chapter 1

GENERAL DATA

The jet aircraft MiG-21F-13 is a tactical supersonic fighter.

The MiG-21F-13 aircraft is a single-engine fighter, with one turbojet engine, with delta wing and controllable stabilizer; it is armed with two self-guiding rockets K-13 and cannon NR-30.

The basic flight characteristics of the MiG-21F-13 are given in Table 1.

Table 1

Flight Characteristics of the Aircraft

1	Maximum speed in km/hr	2125 (at an altitude of 12.5 to 18.5 km)
2	Static ceiling in meters	19,000 (at M=1.85)
3	Time to climb to practical ceiling in minutes	up to 6
4	Time of climbing to static ceiling in minutes:	
	a) with afterburner turned on at the moment of takeoff (without turning during climb)	13.5
	b) With afterburner turned on at an altitude of 8000 m (with 180° turn during climb)	16.9

5 Maximum tactical range at an altitude of 11,000 m, in km (at fuel density = 0.83 gr/cm^3)	
without suspension tank	1400
with suspension tank	1670
6 Maximum tactical duration at an altitude 11,000 m in hr-min (at fuel density = 0.83 gr/cm^3)	
without suspension tank	1 hr 13 min
with suspension tank	2 hr 3 min
7 Takeoff run in meters with afterburner	800
8 Length of landing run in meters	
with brake parachute	900
without brake parachute	1200 to 1800
9 Takeoff speed in km/hr	315 to 330
10 Landing speed in km/hr	260 to 270

Remarks: Ranges and flight durations are given for a single aircraft with reserves of 7% of the initial fuel load, allowance for seven minutes of engine operation on the ground prior to takeoff, and with the external tank being jettisoned when empty.

The strength of the MiG-21F-13 is calculated in accordance with the following data:

Table 2

Structural Limitations of the Aircraft

Maximum operational load factor	7
Maximum indicated speed in km/hr	1250

2

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Maximum Mach nr of flight	2.35
Maximum head pressure in kg/m^2	7500

The suspension tank and its attachment is figured by the following limits (when flying with filled and empty suspension tank).

Maximum-permissible indicated speed km/hr	1000
Maximum permissible Mach nr	1.8
Maximum head pressure in kg/m^2	4830
Maximum operational load-factor	6

Table 3

Basic Weight and Centering Characteristics

of the MiG-21F-13 Aircraft

Initial weight kg	7370
Landing weight (minimum at 7% fuel supply in main tanks less K-13 rockets and cannon shells) kg	5217
Weight of fuel kg (at gamma = .83 gm/cm^3)	2080
Practical center of gravity travel in % MAC	31 to 35
Total center of gravity travel in % MAC	31.3 to 36.3

General view of the MiG-21F-13 aircraft is shown in Fig 1, 2, 3.

Table 4

Geometric Data of the MiG-21F-13

Wing area	23	m^2
Wing span	7.150	m

3

[redacted]

Mean aerodynamic chord of the wing	4.002	m
Angle of wing sweep-back along leading edge	57	deg
Angle of dihedral "V" of the wing	-2	deg
Area (overall) of two ailerons	1.18	m^2
Maximum angle of deflection of ailerons (perpendicular to the axis of rotation)	±20	deg
Length of trim tab (only on left aileron)	0.4	m
Width of trim tab (perpendicular to trailing edge)	0.01	m
Flap area (2)	1.87	m^2
Angle of flap deflection for takeoff and landing (from the streamline position)	24.5	deg
Total area of two forward speed brake panels	0.76	m^2
Area of rear speed brake panel	0.47	m^2
Maximum angle of deviation of two forward braking panels	25	deg
Maximum angle of deviation of one rear braking panel	40	deg
Area of horizontal empennage	3.94	m^2
Maximum angles of stabilizer deflection:		
Nose of stabilizer deflected upwards	7.5	deg
Nose of stabilizer deflected downwards	16.5	deg
Vertical stabilizer area	4.45	m^2
Maximum angle of deviation of rudder (perpendicular to the axis of rotation)	±25	deg
Length of aircraft (in line of flight)		
Without pitot tube	13.46	m
With pitot tube	15.76	m

4

Height of aircraft (when parked with non-compressed shock absorbers)	4.10	m
Width between landing gear wheels	2.69	m
Longitudinal base of landing gear	4.81	m
Standing angle of aircraft (with uncompressed shock absorber)	0°16	
Landing angle of aircraft (with shock absorbers uncompressed)	14°03	

Chapter 2

FLIGHT CHARACTERISTICS OF THE AIRCRAFT

The flight characteristics of the MiG-21F-13 aircraft include: maximum speeds at flight altitudes, ranges and flight durations, stability qualities, controllability and maneuverability as well as takeoff and landing qualities.

All data, with the exception of stability qualities, controllability and maneuverability are given for standard atmospheric conditions.

1 Speeds and Flight Altitudes

The MiG-21F-13 aircraft has a wide range of cruising speeds: from minimum V of the instrument = 215 km/hr to supersonic speed of 2125 km/hr at altitudes of more than 12,300*.

Maximum cruising speed is attained during accelerations, when the engine is working on afterburner, at altitudes ranging from 12,300m to 18,500m.

The aircraft, under power, has the ability of continuing acceleration to greater speeds.

The following maximum permissible operational speeds/Mach nrs of flight are established for the MiG-21F-13 aircraft both with and without the K-13 rockets:

a) With K-13 rockets suspended and without them (with pylons)

H=0-5000m - indicated speed Vind=1100 km/hr
(according to the wide arrow)

H=5000-12,300m - indicated speed Vind=1200 km/hr
(according to the wide arrow)

H=12,300m and above - Mach nr=2.0

b) With non-controllable missiles S-5M or S-5K (suspended instead of K-13 rockets)

H=0-13,500m - indicated speed Vind=1200 km/hr
(according to the wide arrow)

H=13,500m and over - Mach nr=1.8

c) With suspended fuel tanks (filled and empty), with K-13 rockets or with missiles S-5M or S-5K, as well as without rockets and missiles (with suspension tanks only)

H=0-12,000m - indicated speed Vind=1000 km/hr
(according to the wide arrow)

H=12,000 and over - Mach nr=1.6 Fig 4 and 5

Best operational speed for level flight and maneuver Vind=350 km/hr.

For the MiG-21F-13 aircraft with K-13 rockets the static ceiling at full afterburning, is best at M=1.8 to 1.86 and = 19,000m, and without K-13 rockets = 19,500m. For the MiG-21F-13 aircraft with K-13 rockets and with suspension tank the static ceiling equals 17,500m at M=1.6. The reduction in ceiling of 1500m is due to the additional drag of the suspension tank and a reduction of Mach number in climb to M=1.6.

6

Practical ceiling of the aircraft with two missiles S-5M or S-5K without suspension tank is 17 to 17.5 km depending on the fuel supply.

MiG-21F-13 aircraft possesses greater vertical climb velocities, the value of which at small altitudes with afterburner equals 130 to 140 m/sec and at maximum power without afterburner, 70 to 80 m/sec.

Depending upon the climbing profile and the mode of engine operation the static ceiling can be reached in various times and with the consumption of various quantities of fuel. One of the schedules concerning minimum fuel consumption in climbing to static ceiling recommends the following sequence:

- Takeoff and climb to 8000 m and at maximum non-afterburning power at true speed of 925 to 930 km/hr.

- At an altitude of 8000 m, the afterburner is cut in and the aircraft climbs to an altitude of 12,000 to 13,000 m, with an acceleration up to M=1.1 to 1.35, simultaneously with a 180° turn. After this the acceleration to M=1.8 to 1.85 and climb to the practical ceiling at a constant M=1.8 to 1.85 is accomplished.

The vertical velocities of the aircraft MiG-21F-13, Mach numbers in climb, and time of climb are shown in Fig 6, 7, and 8.

For the MiG-21F-13 aircraft with afterburning during climb, the time to climb to 5000 m = 2 min, 10,000 m = 3.2 min, 15,000 m = 5.5 min. When using maximum power to an altitude of 8000 m the time of climb to each indicated altitudes increases, for example for 10,000 m to 6.6 min. The time is indicated from the moment of takeoff.

<u>Remarks</u>: The time for takeoff run and acceleration to a climbing speed at maximum power equals 1.5 min and with afterburning equals 1 min.

7

The flight profile and operating mode of the engine when flying with suspended tank remain unchanged, but the time to climb to altitude with suspended tank increases by approximately 0.5 min for an altitude of 5000m, and correspondingly by 2.5 min for an altitude of 10,000m. To increase the rate of climb (to reduce the time of climb) the suspension tank can be released after the fuel from it has been consumed. With this available fuel system the fuel from the suspension tank is consumed completely when reaching an altitude of 11,000 to 12,000m.

In Fig 9 and 10 are given approximate practical consumptions of fuel for various altitude climbing schedules.

2 Range and Flight Duration

The MiG-21F-13, as well as any other supersonic aircraft, possesses various characteristics with respect to range and flight duration depending upon the speed and flight altitude.

When strictly adhering to the recommended flight profiles from the point of takeoff to reaching the ceiling, the amount of fuel consumed in the attainment of the practical ceiling of the MiG-21F-13 aircraft is 800 to 900 liters and the flight duration of the aircraft to the point of the ceiling is about 6 min.

The time of climbing to static ceiling can be reduced by 0.5 min with a simultaneous fuel saving of up to 100 liters through a preliminary acceleration to a speed of 2100 km/hr and then followed by deceleration of the aircraft during climb.

Maximum range and flight duration of the MiG-21F-13 aircraft is attained at an altitude of 11,000m at a cruising speed of flight. In table 5 are given data concerning the flight conditions for maximum range and flight duration.

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Table 5

MIG-21F-13 AIRCRAFT

Practical Range and Flight Duration of the Aircraft at an Altitude of 11,000m

with Reserve Fuel Equal to 7% of the Basic Amount

(At specific weight of fuel=0.83 g/cm^3)

a) With rockets K-13

Initial gross weight of aircraft - 7370 kg
Total fuel supply - 2080 kg
Supply of fuel for horizontal flight - 1330 kg

Flight condition	Speed of flight km/hr		Rev of low pressure engine rotor in %	km-consump of fuel kg/km	Hourly fuel consump kg/hr	Range km		Flight duration (hrs-min)	
	Instr	True				Hor	Pract	Hor	Pract
1	2	3	4	5	6	7	8	9	10
Max range	520	925	91	1.12	1040	1190	1400	1-17	1-37
Max flight duration	440	795	89	1.20	955	1110	1320	1-23	1-43

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b) Without rockets (with pylons AHY)

Initial gross weight - 7215 kg
Total fuel supply - 2080 kg
Supply of fuel for horizontal flight - 1410 kg

Flight condition	Speed of flight km/hr		Rev of low pressure engine rotor in %	km-consump of fuel kg/km	Hourly fuel consump kg/hr	Range km		Flight duration (hrs-min)	
	Instr	True				Hor	Pract	Hor	Pract
1	2	3	4	5	6	7	8	9	10
Max range	520	925	87	1.01	937	1400	1580	1-31	1-49
Max flight duration	440	795	85	1.10	885	1280	1460	1-36	1-54

c) With K-13 and suspension tank, ejectable after consumption

Gross flight weight - 7840 kg
Total fuel supply - 2480 kg
Fuel supply for horizontal flight - 1680 kg

1	2	3	4	5	6	7	8	9	10
Max range	520	925	92	1.17	1080	1440	1670	1-34	1-56
Max flight duration	440	795	90	1.26	1000	1840	1570	1-41	2-03

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Table 5a

Practical Range and Duration of Aircraft at an Altitude of 10,000m with S5M or S5K Missiles with 7% Fuel Remaining

(At a specific weight of fuel gamma = 0.83 gm/cm^3)

Flight condition	Speed of flight km/hr		Rev of low pressure engine rotor in %	km-consump of fuel kg/km	Hourly fuel consump kg/hr	Range km		Flight duration (hrs-min)	
	Instr	True				Hor	Pract	Hor	Pract
1	2	3	4	5	6	7	8	9	10
a) With two non-controllable reaction missiles S-5M or S-5K Initial gross weight - 7417 kg Total fuel supply - 2080 kg Fuel supply for horizontal flight - 1397 kg									
1	2	3	4	5	6	7	8	9	10
Max range	550	910	88.8	1.20	1090	1160	1320	1-17	1-35
Max flight duration	440	745	88.4	1.42	1060	985	1155	1-19	1-37
b) With two non-controllable reaction missiles S-5M or S-5K and suspension tank Initial gross weight - 7877 kg Total fuel supply - 2480 kg Fuel supply for horizontal flight - 1722 kg									
1	2	3	4	5	6	7	8	9	10
Max range	550	910	90	1.32	1200	1300	1490	1-26	1-46
Max flight duration	440	745	89.2	1.53	1140	1130	1320	1-30	1-50

-11-

S-E-C-R-E-T

S-E-C-R-E-T

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In calculating the range and flight duration of the aircraft the following factors were considered:

a) Fuel consumption during the operation of engine on the ground (starting and testing of engines and taxiing) for a period of 7 min = 60 kg

b) Fuel consumption, distance and time for takeoff and climb and during gliding in conformity with tables 6, 7, and 8

c) Fuel consumption when flying in circle before landing for a period of 4 min = 80 kg

d) Non-consumed supply of fuel = 30 kg

e) 7% of fuel supply of the basic supply at a specific weight gamma = 0.83 g/cm^3 = 145 kg.

In the table is given the value of range and flight duration without launching K-13 rockets during flight. With consideration of the launching of K-13 rockets during the horizontal flight the range and duration of the horizontal section increased by 5%.

Fuel consumption, time, and distance during takeoff and climb are taken at maximum operating condition of the engine.

12

Table 6

Fuel Consumption, Time, and Distance for Takeoff and Climb at Maximum Condition of Engine of MiG-21F-13 Aircraft

Flight Altitude in Meters	Without K-13 Rockets (With Pylons) V = 930 km/hr			With K-13 rockets V = 930 km/hr			With K-13 rockets and susp tank V = 930 km/hr		
	Fuel consump kg	Time min	Distance km	Fuel consump kg	Time min	Distance km	Fuel consump kg	Time min	Distance km
1	2	3	4	5	6	7	8	9	10
1,000	70	1.3	5	85	1.5	5	105	2.0	10
5,000	165	3.1	30	195	3.4	35	220	4.3	45
8,000	225	4.1	50	260	5.0	60	305	6.5	75
10,000	265	5.4	65	325	7.3	90	380	8.4	110
11,000	285	6.2	85	360	8.6	110	415	10.0	130

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Table 7

Fuel Consumption, Time, and Distance during Gliding of MiG-21F-13 Aircraft

(For all variants of external suspensions, including suspension tank)

Flight altitude m	Fuel consumption kg	Time min	Distance km
5,000	20	3.0	35
8,000	40	5.0	60
10,000	60	7.0	85
11,000	75	8.0	100
17,500	120	13.0	165
19,000	135	14.0	180

Remarks: 1 Gliding from all altitudes is done at Vins = 500-550 km/hr
2 Engine control lever on small gas
3 Brake panels in the retracted position

Table 8

Fuel Consumption, Time, and Distance during Takeoff and Climb at Maximum Operation of the MiG-21F-13 Aircraft

Flight Altitude in Meters	With S-5M or S-5K missiles and without suspension tank V = 900 km/hr			With suspension tank and S-5M or S-5K missiles V = 830 km/hr		
	Fuel cons kg	Time min	Distance km	Fuel cons kg	Time min	Distance km
1,000	85	1.35	10	90	1.5	10
5,000	180	3.0	35	210	3.7	40
10,000	320	7.0	90	390	9.3	115

[redacted]

3 Takeoff and Landing Characteristics of the Aircraft

For the MiG-21F-13 aircraft without suspension tank the speed of breaking from the ground with deflected flaps equals 315 to 320 km/hr (under standard atmospheric conditions in the absence of wind) at an angle of attack at takeoff of 9 to 10°.

To assure this speed of break away of the aircraft the beginning of lifting the nose wheel should be realized at a speed of not more than 210 to 220 km/hr. The time of climb at the takeoff angle of attack with afterburning should be 3 to 4 seconds, and at maximum power should be 5 to 6 seconds.

When the nose wheel is lifted off at higher speed or during slow attainment of the takeoff angle of attack the speed of separation of the MiG-21F-13 aircraft increases.

At normal rate of separation, V = 315 to 330 km/hr, the length of the takeoff run of the aircraft is: L takeoff run = 1150 to 1300m at maximum power; L takeoff run = 850 to 900 with afterburning.

With suspended tank and a rate of separation V = 330 to 340 km/hr, the length of the takeoff run is: L takeoff run = 1250 to 1350m at maximum power; L takeoff run = 900 to 1000m with afterburning.

In figure 11 is given an approximate dependence of the takeoff speed and length of takeoff run upon the angle of attack during takeoff.

In table 9 are given approximate fuel consumptions and times necessary for takeoff and for acceleration of the aircraft from the moment of lift-off to the beginning of climb.

The length of the landing run after touching ground depends upon the landing speed of the aircraft, timely application of the brakes of all three wheels, and upon the state of the surface of the landing strip, as well as upon timely deployment of the brake parachute.

Table 9

Engine Operation	Afterburning	Maximum
Time of takeoff run (sec)	17	25
Fuel consumption on takeoff run (kg)	55	26
Time of acceleration up to V climb = 1000 km/hr (sec)	32	50
Fuel consumption during acceleration to V climb = 1000 km/hr (kg)	110	60

Data concerning the length of landing run is given for a dry runway strip. The landing speed of MiG-21F-13 aircraft is equal to 260 to 270 km/hr at an angle of attack of 9 to 10°.

The length of the landing run of the MiG-21F-13 aircraft without brake parachute, but with braking of all three wheels, equals 1200 to 1300 m.

A reduction in landing run is attained to a large extent by applying the brake parachute.

With released brake parachute the length of the landing run of the MiG-21F-13 aircraft is reduced to 900 m. We must remember that, even when releasing the parachute at the moment the aircraft touches ground, the time between releasing the parachute and its inflation is 2 to 2.5 sec during which time the aircraft covers a distance on the ground of 150 to 200 m actually without the braking effect of the parachute.

The landing characteristics are listed in the following table:

	Without brake parachute	With brake parachute
Landing weight (kg)	5480	5480
Angle of flap deflection	24.5°	24.5°
Landing speed (at alpha = 9 to 10°) (km/hr)	260 to 270	260 to 270
Length of landing run (on dry runway) (m)	1200 to 1300	900
Length of landing distance (from an altitude H = 25m) (m)	2300 to 2400	1600

In figure 12 are given approximate dependence of the landing speed and length of landing run upon the angle of attack of the aircraft during landing.

Takeoff and landing distances are shown in figure 13 and 14.

Stability and Controllability

In this chapter are given the basic characteristics for longitudinal and lateral stability and controllability of the MiG-21F-13 aircraft, derived from flight tests.

The basic criterion of longitudinal stability of the aircraft appears to be the degree of longitudinal static stability in accordance with overload. On the MiG-21F-13 aircraft the centering was selected in such a way that under subsonic speed conditions the amount of longitudinal static stability appears to be optimum for light fighters. It constitutes on an average 3 to 5% MAC. The change in neutral centering of the aircraft by

17

the Mach number of flight, as given in figure 15, shows an increase in the amount of stability when changing over to supersonic speeds. When the engine is cut off the amount of longitudinal stability rises by 1 to 2% MAC. When launching K-13 rockets the stability is practically unchanged.

Longitudinal controllability of the aircraft is determined by the following parameters, felt directly by the pilot during flight, - overload of the aircraft, shifting of control stick, and by the forces affecting it. In figure 16 is given the required angle of deflection (φ^{n_y}) of the stabilizer for a 1 g overload versus the Mach number of flight for several flight altitudes. The relation of the angle of deflection of the stabilizer to the magnitude of overload, $\varphi = f(P_y)$, for all Mach numbers of flight in the case of the MiG-21F-13 aircraft is linear, which appears to be a positive quality of the aircraft. An automatic mechanism for changing the gear ratio between the control stick and the stabilizer (ARU-ZV) is installed in the longitudinal control system to provide good control characteristics - magnitude of stick movement (X^n) and stick force (R^n) required to produce a 1 g overload.

In figure 13 are given dependence of X^{nu} upon the Mach number and flight altitude, obtained during flight test. Mathematically the characteristics X^{nu} and P^{nu} are determined by formulas $X^{n_y} = \varphi^{n_y} \cdot X^{\varphi} \left[\frac{мм}{ед. перег.}\right]$, $P^{n_y} = X^{n_y} \cdot P^{x} \left[\frac{кг}{ед. перег.}\right]$

where: $X\varphi$ = the gear ratio between the movement of the handle and the deflection of stabilizer; P^x = gradient of change in forces on the control handle by its movement.

18

The values $X\varphi$ and P^x. which appear to be the characteristics of the ARU-ZV mechanism mounted on the aircraft do change in relation to the speed and flight altitude as shown in figures 18 and 19.

The balancing curves - dependence of the angles of stabilizer deflection, movement of control handle, forces on the handle in recti-linear flight (for a 1 g overload) upon the M nr of flight is given in figures 20, 21, and 22.

Balancing curves have a smooth character of change in accordance with the flight speed. In the range of near-sonic speeds there is a small instability with respect to speed, which does not deteriorate the technique of aircraft piloting. The balance of the MiG-21F-13 aircraft is such that the trimmer mechanism produces the effect of zero stick force when the stick is in the neutral position at flight speeds V ins = 750 km/hr under climbing conditions after takeoff at altitudes ranging from 0 to 3000 m.

The nature of changes in the forces against the control handle during a change in flight velocity depends considerably upon the magnitude of stabilizer "manipulation." "Manipulation" refers to the change in the angle of deflection of the stabilizer when shifting the rod of the operational mechanism of the ARU-ZU apparatus on the control handle and when the mechanism ARU is switched over from the larger to the smaller arm.

By changing the magnitude of stabilizer "manipulation" it is possible to balance the control forces by the air flow, attaining thereat a reduction in instability with respect to speed to a minimum.

In the chapter dealing in leveling and balancing of the aircraft is thoroughly discussed the method of changing the balancing on account of stabilizer "manipulation."

19

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The flight with 0 forces against the control handle is achieved by installing in the control system a trimmer effect mechanism, the operational range of which offers the possibility of such flight at practically all speeds and altitudes.

The extension of landing gears, wing flaps, brake flaps, change in operating conditions of engine, and the mounting of a suspension fuel tank have practically no effect on the change in stability and controllability characteristics.

The basic characteristic of lateral stability appears to be the degree of directional stability. On supersonic aircraft the degree of directional stability decreases, beginning with a Mach number and at subsonic flight velocities corresponds to the standard requirement;and in the range of Mach number = 1.2 to 1.6, it rises. When flying with suspended fuel tank the degree of directional stability corresponds to the standard requirement at Mach 1.6.

The characteristic of lateral control is determined by the magnitude of angular banking speed $(W_x^{\delta z})$ produced by one degree deflection of ailerons, and by the magnitude of forces acting against the control handle (R_z^{wx}) during the creation of an angular banking speed of 1 rad/sec as shown in figures 23, 24, and 25.

And so on the MiG-21F-13 aircraft the system of irreversible booster control of ailerons has a charging mechanism, and the value R_z^{Wx} can be determined: $P_3^{\omega_x} = \frac{P_3^{X_r} \cdot X_r^{\delta_z}}{\omega_x^{\delta_z}} \left[\frac{kg}{rad/sec}\right]$

The characteristic of the charging mechanism R_z^{Xr} is non-linear; also non-linear is the gear ratio from the handle to the ailerons X_r^{8z} (see

20

[redacted]

figure 26). The non-linear connections between the movement of the handle and the deflection of the ailerons on the aircraft are for the purpose of reducing the extreme effectiveness of ailerons, at greater instrument speeds (in a small range of aileron deflection angles).

Maneuverability

Maximum overloads of the aircraft (in the plane of symmetry) are determined in the range of subsonic Mach numbers.

Maximum lift is produced by the aircraft at angles of attack smaller than critical, and at supersonic speeds--with sufficient longitudinal stability and stabilizer effectiveness. In the range of Mach numbers from minimum to Mach 1.3 or 1.4 when, during overload conditions, the aircraft approaches a discontinuous angle of attack, there is felt a warning vibration in the aircraft. In figure 27 is shown a change in maximum-oriented overloads of the aircraft in the plane of its symmetry by the Mach number for a number of altitudes.

Maximum negative overloads are limited by the condition of continuous feeding of fuel into the engine. The fuel feeding system is intended for a 15 sec delivery for the engine under negative load conditions.

One of the important features, characterizing the maneuverability of the aircraft, is the ability of the aircraft to rapidly change the speed of flight. The characteristics of aircraft acceleration at various altitudes, time of acceleration, fuel consumption and length of path during accelerations are given in figures 28, 29, 30, and 31.

Braking characteristics of the aircraft with cutoff engine are shown in figures 32 and 33. In figure 34 is given the change in maximum overload of the aircraft, originating during the release of brake flaps versus Mach number of flight.

On the MiG-21F-13 aircraft it is quite simple with small deflections of control surfaces to execute an acrobatic figure, whereby all control surfaces retain their effectiveness at any evolution of the aircraft. The nature of spins is shown in figures 35, 36, and 37.

Chapter 3

WEIGHT AND CENTERING CHARACTERISTICS OF THE AIRCRAFT

In the chapter concerning weight and centering characteristics are given weight and centering characteristics of the MiG-21F-13 aircraft with K-13 rockets--a variant with normal load; with K-13 rockets and suspended fuel tank, with non-controllable missiles S-5M or S-5K, mounted instead of K-13 rockets, with non-controllable S-5M or S-5K missiles and with suspended fuel tank.

A calculation of the aircraft's centering is done in coordinate axes "X" and "Y". Axis "X" appears to be the longitudinal axis of the aircraft and is situated in the plane of structural horizontal. The axis "Y" is perpendicular to axis "X" and passes in vertical plane, situated at 600 mm toward the tail of the aircraft from bulkhead nr 16. The intersection of axes "X" and "Y" is the starting point for the reading of CG coordinates of the aircraft and its components.

The coordinates of the units, arranged in the direction of the aircraft's tail along the axis "X" and upwards along the axis "Y" have the plus sign, and toward the nose of the aircraft and below they have the minus sign.

The weight characteristics with respect to centering relative to the centering of axes "X" and "Y" of the aircraft at takeoff with normal load, and with normal load plus suspended fueltank and non-controllable missiles S-5M or S-5K are given in table 10.

The centering of the aircraft is given in %MAC of the wing relative to the point where the MAC (average aerodynamic shord of the wing) intersects the wing leading edge. The "X" coordinates of the CG of the aircraft in direction of axes "X" in %MAC are determined in the following manner:

$$\bar{X} = \frac{a + \lambda \cdot x}{b_A} \cdot 100, \text{ rze}$$

where: alpha X = 1.302 m = distance from the intersection point of the wing leading edge and the MAC to the centering axes "Y" (see disposition of MAC on figure 38)

X = distance of CG of the aircraft from the origin of the coordinates, which are taken with their own sign

b_A = 4.002 m = average aerodynamic wing chord (MAC).

Weight and centering characteristics of the aircraft with normal load and with K-13 rockets plus suspended fuel tank are given in table 11: with non-controllable missiles S-5M or S-5K and with non-controllable missiles S-5M or S-5K plus suspended fuel tank are given in table 12.

Centering of the aircraft in flight changes depending upon the consumption of fuel from the tanks and upon the operating conditions of the engine.

Consumption of fuel from the tanks during non-afterburning engine operation takes place in the following order:

1. From tanks 1, 2, 3, 4, 5, 6 until a special float valve opens the connection to the suspended tank.
2. From rear section of suspended tank.
3. From forward section of suspended tank.
4. From rear wing tanks.
5. From forward wing tanks.
6. From first group of tanks.
7. From third group of tanks.
8. From second group of tanks.

Small changes in aircraft centering during flight, depending on fuel consumption, occur when operating the engine with afterburner. The order of consuming the fuel in flight with afterburning operation of the engine differs from that during non-afterburning operation by combined consumption of fuel from wing tanks and partial consumption from fuselage tanks.

The change in aircraft centering during flight in the variant with normal load due to fuel consumption for afterburning are given in figure 39.

The change in aircraft centering in flight for the variant with K-13 rockets and with suspended fuel tank due to the consumption of fuel for afterburning is given in figure 40.

The change in aircraft centering in flight with non-controllable missiles S-5M or S-5K due to fuel consumption for afterburning is given in figure 41.

The change in aircraft centering in flight with non-controllable missiles S-5M or S-5K and suspended fuel tank due to fuel consumption for afterburning is given in figure 42.

A change in aircraft centering as a result of a change in weight or as a result of any other change or modification is permitted within limits of plus or minus 0.5%MAC of the maximum forward and maximum rear balancing limits mentioned in tables and shown in figures.

Table 10

WEIGHT AND CENTERING DATA ON THE MIG-21F-13 AIRCRAFT

Name	RX kg.m	X m	R kg	Y m	RY kg.m
Aircraft with normal load at takeoff (landing gear out)	47	0.006	7370	0.053	390
Empty aircraft	1020	0.205	4980	-0.021	-104
Normal load	-973	-0.407	2390	0.207	494
Normal load	-973	-0.407	2390	0.207	494
Pilot with parachute	-319	-3.19	100	0.39	39
Rockets, K-13 (2 units)	25	0.165	154	-0.52	-80
Rounds, NR-30 (60 units)	-100	-1.80	56	0	0
Fuel in Tank One	-482	-2.41	200	0.38	76
Fuel in Tank Two	-798	-1.33	600	0.35	210
Fuel in Tank Three	-51	-0.22	232	0.19	44
Fuel in Tank Four	90	0.52	174	0.34	59
Fuel in Tank Five	232	1.16	200	0.40	80
Fuel in Tank Six	384	1.92	200	0.40	80
Fuel in Rear wing tanks	205	1.18	174	-0.03	-5
Fuel in forward wing tanks	-159	-0.53	300	-0.03	-9
Retraction of landing gear	-196	-	-	-	278

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50X1-HUM

50X1

Name	RX kg.m	X m	R kg	Y m	RY kg.m
Installation of suspension fuel tank V = 500 liters	-132	-0.28	470	-0.96	-452
Suspension tank	-7	-0.146	46	-0.98	-45
Beam of suspension tank	-11	-0.485	24	-0.65	-15
Fuel in suspension tank V = 490 liters	-114	-0.285	400	-0.98	-392
Mounting of non-controllable missiles S-5M	61	0.22	277	-0.46	-127
Beams	17	0.39	43	-0.23	-10
Missiles S-5M (32 units)	20	0.158	124	-0.504	-62
Pods	24	0.22	110	-0.504	-55

Remarks: 1. Weight and centering with non-controllable missiles S-5M are no different than with non-controllable missiles S-5K.

2. When mounting non-controllable missiles S-5M instead of K-13 rockets the rocket installation is removed from the aircraft.

Mounting of K-13 rockets	46	0.19	237	-0.45	-106
Beams	17	0.39	42	-0.23	-10
Starting device, APU-13u	4	0.107	41	-0.40	-16
Rockets, K-13 (2 units)	25	0.165	154	-0.525	-80

-27-

50X1-HUM

Table 11

TABLE OF CENTERING VARIANTS OF THE MIG-21F-13 AIRCRAFT WITH K-13 ROCKETS

Loading Conditions	Acft with normal load	Acft with 50% fuel, w/o ammo	Acft with max fwd c.g.	Acft with max aft c.g.	Acft w/o fuel and ammo	Acft with ext fuel tank, V=500 liters
Weight of aircraft kg	7370	6120	7046	6086	5080	7840
c.g. location (gear down %MAC	32.7	36.0	32.1	36.3	36.1	32.3
on X axis (gear up %MAC	32.1	35.2	31.4	35.5	35.1	31.7
Empty aircraft weight kg	4980	4980	4980	4980	4980	4980
Useful load kg	2390	1140	2066	1106	100	2860
Pilot with chute kg	100	100	100	100	100	100
K-13 Rockets kg	154	-	154	-	-	154
Ammo (NR-30) kg	56	-	56	-	-	56
Total fuel weight* kg	2080	1040	1756	1006	-	2480
Tank #1 (V=241 l) kg	200	16	180	-	-	200
Tank #2 (V=720 l) kg	600	308	560	290	-	600
Tank #3 (V=277 l) kg	232	192	192	192	-	232
Tank #4 (V=208 l) kg	174	159	159	159	-	174
Tank #5 (V=241 l) kg	200	183	183	183	-	200
Tank #6 (V=241 l) kg	200	182	182	182	-	200
Fwd wing tanks (V=360 l) kg	300	-	300	-	-	300
Aft wing tanks (V=210 l) kg	174	-	-	-	-	174
External tank (V=490 l) kg	-	-	-	-	-	400
Wt of external tank installation without fuel kg	-	-	-	-	-	70

*Specific weight of fuel = γ = .83 gm/cm^3 throughout.

Table 12

TABLE OF CENTERING VARIANTS OF THE MIG-21F-13 AIRCRAFT WITH S-5M MISSILES

Loading Conditions	Acft with normal load	Acft with 50% fuel, w/o ammo	Acft with max fwd c.g.	Acft with max aft c.g.	Acft w/o fuel and ammo	Acft with ext fuel tank, V=500 liters
Weight of aircraft kg	7410	6190	7086	6156	5150	7880
c.g. location (gear down %MAC	32.8	36.1	32.2	36.4	36.2	32.4
on X axis (gear up %MAC	32.2	35.3	31.5	35.6	35.2	31.8
Empty aircraft weight kg	5050	5050	5050	5050	5050	5050
Useful load kg	2360	1140	2036	1106	100	2830
Pilot with chute kg	100	100	100	100	100	100
S-5M missiles kg	124	-	124	-	-	124
Ammo (NR-30) kg	56	-	56	-	-	56
Total fuel weight* kg	2080	1040	1756	1006	-	2480
Tank #1 (V=241 l) kg	200	16	180	-	-	200
Tank #2 (V=720 l) kg	600	308	560	290	-	600
Tank #3 (V=277 l) kg	232	192	192	192	-	232
Tank #4 (V=208 l) kg	174	159	159	159	-	174
Tank #5 (V=241 l) kg	200	183	183	183	-	200
Tank #6 (V=241 l) kg	200	182	182	182	-	200
Fwd wing tanks (V=360 l) kg	300	-	300	-	-	300
Aft wing tanks (V=210 l) kg	174	-	-	-	-	174
External tank (V=490 l) kg	-	-	-	-	-	400
Wt of external tank installation without fuel kg	-	-	-	-	-	70

*Specific weight of fuel = γ = .83 gm/cm^3 throughout.

Chapter 4

ADDITIONAL DATA ON FLIGHT CHARACTERISTICS

I. Method of determining flight speed and altitude

On board the aircraft are installed instruments for determining speed of flight relative to the air flow and barometric altitude of flight. For this purpose an air pressure receiver, DUAS-8M, is mounted in the nose section of the aircraft fuselage.

The location of the receiver on board the aircraft has been selected with consideration that distortions in velocity and flight altitude indications on the cockpit instruments should be at a minimum.

Flight altitude is determined by instrument indications with introduction into same of instrumental and aerodynamic corrections.

The geometric altitude, i.e., flight altitude over the surface of the earth is determined as follows: $H_g = H + \text{delta } H_z$ where: H = barometric altitude and delta H_z = local altitude variation over or under relative to sea level. Delta H_z takes into consideration a correction for barometric altitude in connection with the difference in actual atmospheric pressure on the ground and standard pressure of 760 mm of mercury.

For example, at an actual pressure on the ground of 740 mm Hg, the magnitude of the correction delta H_z determined by a table of atmospheric standards equals +220m, and at a pressure of 780mm Hg the correction delta H_z is -220m.

The magnitude of barometric altitude H is determined by formula: $H_{pr} + \Delta H\ instr + \Delta H_a + \Delta H_B + \Delta H_{zap}$ where: H_{pr} = actual

30

altitude in accordance with instruments indication in the cockpit; Δ H instr = instrumental correction to altitude indicator obtained after callibration of instrument; ΔH_a = aerodynamic correction to the altitude indicator (altimeter); ΔH_B = altitude correction to altimeter.

The total of aerodynamic and wave corrections ($\Delta H_a + \Delta H_B$) depending upon the number M ind and the flight altitude are given in figure 43.

Remarks:

In figure 43 along the axis of the abscissa, M ind number is taken with the introduction of an instrumental correction Δ M instr, which is obtained during the calibration of the M nr indicator.

ΔH_{lag} = correction for the lag in altimeter indications.

The magnitude of correction for the lag in altimeter indication depends upon the rate of flight altitude change and upon the volume and length of wiring of the system for flight altitude measurements, PVD.

In the presence on the aircraft of board instruments only, i.e., in the absence of special recorders, the value of the correction for lagging is small.

The true rate of flight V (relative to the flow of air) is determined by $V = \frac{V_i}{\sqrt{\Delta}}$ where: V_i = indicated speed, i.e., the speed which would be indicated by the speed indicator, if it would not have any errors in the instrument and would be situated at an altitude of H = 0, i.e., under conditions for which it has been calibrated.

$\Delta = \frac{\rho_h}{\rho_o}$ = relative air density.

The magnitude of indicated speed V_i is determined by formula:

$V_i = V_{pr} + \delta V \text{ instr} + \delta V_a + \delta V_b + \delta V_{com} + \delta V_{lag}$ where: V_{pr} =

31

instrumental speed (according to the wide arrow); δV instr = instrumental correction to speed indicator, obtainable during the calibration of instrument; δV_a = aerodynamic correction of speed indicator, taking into consideration the distortion of static pressure at the point of installation of the air pressure indicator; δV_b = wave correction, taking into consideration the distortion of static pressure at the point of installation of the air pressure receiver, due to the effect of density jumps; the total of aerodynamic and wave corrections ($\delta V_a + \delta V_b$) depending upon Mach number and flight altitude is given in figure 44; δV_{lag} = correction for the lag of the speed indicator in time, practically equals 0; δV_{com} = correction for the difference in compressibility of air at given altitude and on zero altitude (for which instrument calibration was made).

The dependence of the correction δV_{com} upon air compressibility upon the indicated speed, $V_i = V_{pr\,cor} + \delta V_a + \delta V_b$, is given in figure 73.

where: $V_{pr_{cor}} = V_{pr} + \delta V$ instr

We want to point out that the correction δV instr is always negative. This leads to the fact that the speed indicator will always indicate a somewhat delayed speed. This explains the frequent misunderstandings when the pilot is convinced that he attained in flight a greater speed than in actuality.

One of the highly important parameters characterizing the speed of flight is the Mach number, indicating the ratio of true flight speed to the speed of sound, i.e., $M = \frac{V}{a}$.

The value $M = \frac{V}{a} = 1.0$ appears to be the boundary of the zone of subsonic speeds (M smaller than 1.0) and supersonic velocities (at M greater than 1.0).

32

The true Mach number of flight is determined by formula:

$M = \frac{V}{a} = M_{pr} + \delta M_{instr} + \delta M_a + \delta M_b + \delta M_{lag}$ where: M_{pr} = Mach number by instrument in the cockpit; δM_{instr} = instrumental correction to Mach number indicator; δM_a = aerodynamic correction to Mach number indicator; δM_b = wave correction to Mach number indicator.

The dependence of $(\delta M_a + \delta M_b)$ upon the number M_{pr} (with consideration of instrumental corrections) of flight is shown in figure 45.

It is evident from this figure that for Mach numbers greater than $M_{pr} = 1.08$ the air pressure receiver has no aerodynamic or wave correction, i.e., for flight Mach numbers of more than $M_{pr} = 1.08$ the speed indicators, indicators of Mach number and flight altitude give indications without distortions.

δM_{lag} = correction for lag to Mach number indicator.

Analogous to the correction δH_{lag} the correction M_{lag} is also small.

In addition it is also possible to employ the following ratio of connections between the Mach number and the speed of flight: $V = 72.2M\sqrt{T}$ where T = absolute temperature of outer air. $T = 273° + t°$ where $t°$ is the temperature in degrees Centigrade.

For practical utilization when changing instrumental speed into true speed and into Mach number of flight or when changing from true speed or Mach number of flight into instrumental speed are given graphs $V_{pr} = f(M;H)$ and $V_{pr} = f(V;H)$ in figure 74 and 75. On these graphs of V_{pr} values should be taken with the introduction of an instrumental correction δV_{instr}.

2 Bringing the Static Ceiling to Standard Conditions

The ceiling of the aircraft depends to a large extent upon the temperature of the outside air, because the thrust of the engine decreases with increase in temperature of outside air and increases during its reduction.

This leads to the fact that the static ceiling will depend upon the temperature of the outside air, and the higher the temperature the lower will be the static ceiling.

Evaluation of the obtained ceiling during afterburning operation of the engine and its conformity to the ceiling under standard conditions is given in figure 46, where the dependence of the static ceiling value is shown in the relationship to the actual temperature of the outside air.

The static ceiling value is also affected by the flight weight of the aircraft, therefore when evaluating the obtained ceiling at given actual temperature of the air it is necessary to bring in a correction for the weight.

If the flight weight of the aircraft of the aircraft at the ceiling differs from normal weight, then for each 100 kg the actual weight exceeds the normal one the value of the obtained altitude would be decreased by 100m, and for each 100 kg of reduction in actual weight, the obtained altitude would be increased by 100m.

Taking into consideration the production deviations in the role of aircraft manufacturing and a tolerance for engine thrust, a static ceiling tolerance has been established which reduces the static ceiling by 2% of the standard. In figure 46 the lower boundary of static ceiling is shown in relation to the actual outer temperature of air.

Chapter 5

LEVELING AND BALANCING OF THE AIRCRAFT

1 Ground Leveling and Balancing

Technical control over the position of outer contours of the aircraft and over dimensions of control systems is realized with the aid of a leveling arrangement.

When making flight tests and during flight operations some control dimensions can be changed. All these changes should be reflected in the leveling system. As has been established by many years of practice, a part of the leveling can be done during the process of flight operations, but only on certain selected aircraft. Consequently the leveling system is divided into two parts: a basic leveling system for each aircraft and an addition to it for selective aircraft.

Measurement by the leveling system should be carried out in accordance to methodical instructions (see Appendix 1 to Chapter 5).

Measurements by the leveling system and bythe addition to the leveling system are also carried out in the event repairs were made on the aircraft or when, in the process of flying, any kind of abnormalities in the behavior of the aircraft are detected (e.g., unusual, above normal turns, banks, etc.).

Given below are methodical instructions on the conduct of ground leveling and balancing of each aircraft in addition to the measurement carried out with this instrument for selective aircraft (see Appendix 1 to Chapter 5).

The leveling system of the MiG-21F-13 aircraft is shown in figures 48-61).

2 Balancing of Aircraft in Flight

Balancing of the aircraft in flight is realized in accordance with a program of flight tests in conformity with methodical instructions. Methodical instructions on the balancing of an aircraft in flight are given in the Appendix 2 to Chapter 5.

Appendix 1

METHODICAL INSTRUCTIONS ON LEVELING AND GROUND BALANCING

General Data

1. The leveling system dexcribed in this book and the auxilary graphs (Figures 47-61) represent a list of control and assembly dimensions for the aircraft airframe.

The balancing system is filled in during the assembly of the aircraft at the aircraft manufacturing plant and appears to be the only document giving the actual state of the aircraft after assembly and in its further exploitation.

The centering system records all changes in the adjustment of the control system and observed changes in the process of aircraft operation.

The filled-in form of the leveling system is then attached to the certificate of the aircraft.

Before flights begin the pilot should acquaint himself with the actual data concerned with aircraft control recorded in the leveling system.

2. Leveling of the aircraft and control systems is done for each aircraft in the entire process of leveling systems.

3. For selective aircraft are also carried additional measurements using the attachment to the leveling system for selective aircraft.

4. In figures 62-72 are given additional data pertaining to ground leveling of aircraft. This also constitutes a reference material on the characteristics of the control systems.

I. General Leveling of Object

5. Leveling of aircraft is done without fuel, pilot, and special loads with equipment installed onboard the aircraft.

6. When leveling, the aircraft is placed on support (horses) at bulkheads of the fuselage numbers 2 and 28 (weights to the nose of the fuselage are not suspended). See figure 47.

The aircraft retains stable position on the supports even during the application on the horizontal empennage of a load of 100 kg. In addition, are placed protective supports over the wing (at a distance of 2 meters from the axis of the aircraft) and under the fuselage along bulkhead number 35.

7. The axis of the main part of the fuselage is placed horizontally over reference points number 1 left and 2 left.

In the lateral respect the aircraft is placed horizontally over the reference points of the wing "8" lower left and "8" lower right (Figure 48).

Allowance for the difference along these points was set up at ±0.5 mm.

8. All leveling points are plotted in the figures up to the point of general leveling. The points on the wing and horizontal empennage are plotted only below and on the fin only to the left.

9. After filling in the cards with differences of the type "a-b" and "b-a" etc., the designations are engraved on the surface.

Remarks:

1. Leveling points number 3, 6, 22, and 18m are used when leveling selective aircraft.

2. Leveling points 6a, 40, 41, 46, 30, and 27 are used for unit leveling.

Wing

10. Measurements after mounting the wing are carried out for the right and left panels by three sections.

When determining the difference in excess of the leveling points, it is necessary to take into consideration the local contour deflections from the chart showing wing contour measurements, i.e., note in the tables the dimensions with addition (or subtraction) of local deflections. In the presence of local deflections along the reference points in the leveling system we make "remarks," -- "point is higher than the contour" or "point is lower than the contour."

After filling in the boxes in the leveling system with respect to differences in exceeding points of the right and left wing, for all points the measurement values of the left wing are subtracted from the measurement values of the right wing, i.e., "right" or "left." If "left" is greater than "right," then the difference is written in the table with the minus sight. The wedging angle of the right wing will be greater than that of the left one in the case where the sign of measurement differences "right-left" is as follows:

a) For points 8-9, 8-10, 12-18, 16-17 -- minus sign;

b) For points 7-9, 11-13, 15-17 -- plus sign.

In figure 49 is given the measurement arrangement along the wing.

Rudder

11. Measurements on the wedging of the rudder, figure 49, are carried out with respect to the axis of the main part of the fuselage (according to reference points 4-5).

39

Rudder tilting measurements with respect to height are made perpendicularly to the axes, passing over points 4-5.

Stabilizer

12. Stabilizer measurements are carried out when testing the control. (Mounting of stabilizer in lateral ratio is checked only on selective aircraft.)

Fuselage

13. Fuselage measurements are not carried out for each individual aircraft, but only on selective aircraft.

Brake Flaps

14. Measurements of angles of deflection of brake flaps (Figure 49) are carried out at maximum flap deflection with connected hydraulic system along the linear dimension according to points 33 and 34.

An angle of flap deflection of 24° corresponds to a nominal dimension M = 368 mm.

Flap Blades

16. "Blades" (plates) mounted on the rear edge of the flaps (Figure 49) are intended for flight adjustment of lateral stability of the aircraft during deflection of the hydraulic system in the process of delivery tests and are not deflected during operation.

Flap Gap

17. Flap gap is measured (Figure 49) by means of a ruler along points 33 and 34 at connected hydraulic system with flaps in retracted position.

When measuring the gap, a force of 2 kg is applied to the trailing edge of the flap.

Bar of Air Pressure Receiver

18. Measurements on the installation of the APR bar (Figure 49) are carried out with respect to any given axes of the leveling device in vertical and horizontal planes.

Ventral Fin

19. Measurement on the installation of ventral fin (Figure 50) is done relative to the leveling axes over points 4-5.

Suspension Tank

20. Measurements with respect to the installation of the suspension tank (Figure 50) are made from the axes of the main part of the fuselage (on the side) and relative to the axes of symmetry of the main part of the fuselage (in plan) according to leveling points 56a and 57a.

21. Leveling the pylon under the suspension tank (Figure 50) is carried out over points 61, 62, 63, and 64 relative to the axes of symmetry of the main part of the fuselage.

Pylon of Special Suspension on the Wing

22. Leveling of pylon (Figure 50) is done with respect to the line of the leveling device parallel to the axes of the main part of the fuselage according to points 56, 57, 58, and 59.

Cone

23. Cone measurements (Figure 51) are carried out for three positions--cone retracted, and cone extended in two and three positions-- in addition

is checked the beginning of cone outlet by the flashing of a signal light.

Testing cone installation with respect to the rim should be carried out in accordance with a special pattern; a schematic drawing of the pattern is shown in figure 52 where:

e_k = distance from leading edge of fuselage to tip of cone in its first position (retracted).

e_k^2 = distance from leading edge of fuselage to tip of cone in extended position.

e_k^3 = distance from leading edge of fuselage to tip of cone in third position (extreme extended).

The basic surface should be the plane of the forward edge and outer surface of the envelope.

Fuselage Flaps

24. Measuring the angles of deflection of fuselage flaps (front and rear) figure 51 is done in accordance with linear dimensions by points 53 and 56.

Nominal dimensions according to points 53 and 56 correspond to angles of deflection of the flaps: 20° for forward ones and 35° for rear ones.

Landing Gear

25. On each aircraft are measured the sizes of the base and wheels of the landing gear (Figure 48).

II. Testing Control Systems

26. Testing of control systems is carried out at the assembly plant in conformity with tolerances established for the assembly in the leveling system. When carrying out the receiver-delivering program at a series manufacturing plant it is permitted to readjust the control system with

expansion of the range of permissible installation dimensions, listed in the leveling system.

A. Longitudinal Control

Mounting of Stabilizer

27. The leveling point on the stabilizer is point 55. The leveling point in the stabilizer insert -- point 54 is applied on the left, as well as on the right stabilizer insert when mounting each half of it in accordance with leveling points 19 and 20 (Figure 53).

The dimension (L) in this case should be equal to 0 (i.e., points 54 and 55 on each side of the insert and stabilizer are combined). This corresponds to a height differential from the axes of the leveling device along points (19) and (20) i.e., the dimension b-a = 13mm (here "b" = distance from the axes of the leveler to point 20, "a" = distance to point 19).

Remarks:

At such a control arrangement, the "shears" of left and right halves of the stabilizer are equal to zero with a tolerance of ±1mm along points 19 and 20 or along points 54 and 55 (dimension D = 0 ±1mm).

The distance D between points 54 and 55 when checking the neutral position is measured in the projection of the vertical for the purpose of eliminating the effect of slot widths.

Stabilizer Shears

Stabilizer "shear" is defined as the angle of deflection (in degrees in accordance with the angle gauge or by the linear dimension "D", or by the difference "b-a") of the right half of the stabilizer during the mounting of its left half under a zero angle (see figure 53). When assembling the aircraft at the plant the "shears" of stabilizer halves should be equal to zero (allowance ±1mm).

43

28. Measuring the "shears" of left and right halves of the stabilizer are carried out with connected hydraulic system. Using the control stick it is necessary to place the left half of stabilizer along points 54 and 55 in zero position, D = 0. Measurement along points 54 and 55 of the dimension D of the right half of the stabilizer follows next.

In the case of presence of local contour deviations at measured points, the measurement should be corrected by a value of initial stages between stabilizer and insert.

Neutral Position of Handle

29. Checking the neutral of the control handle is done (see figure 53) in the following manner: with connected hydraulic system set control handle of the left half of the stabilizer by pulling it toward yourself from forward position according to points 54 and 55 by the dimension "left" = 0 mm, ARU should in this case be on the longer arm, the trimmer effect mechanism should be in neutral.

To measure the position of the handle from the instrument panel along the distance "K", the position of point "T" on the handle is fixed by means of a special collar.

"Adjustment" of Stabilizer when Switching over ARU from Greater to Smaller Arm

30. The check is made with the "trimmer effect" mechanism in neutral position with hydraulic system on (see figure 53).

By pulling the control handle toward yourself from the forward position set left stabilizer according to points 54 and 55 by a dimension left = 0 ±1mm on the larger ARU arm.

Fix handle in this position.

44

Switch over ARU from larger to smaller arm. On smaller arm of the ARU measure the dimension "K" left; when doing the adjustment the nose of the stabilizer should be lowered, i.e., point 55 will be lower than point 54. The dimension D, left = 18mm (up to points 54-55) corresponds to an angle of deflection of the stabilizer of 2°40' with nose down.

A change in the "lead-away" value of the stabilizer is utilized to change the nature of the balancing curve.

If at greater balancing speeds (V_{ins} = 900 to 1000 km/hr) pulling forces appear greater than the permissible ones by 3 to 4 kg, then the "lead-away" should be increased (lower nose of stabilizer even more down).

When changing the lead-away of the stabilizer (change in position of the ARU rod along the vertical) it is necessary to adjust the loading mechanism to zero forces on the larger arm, with the stabilizer fixed by the control handle in accordance with the actual position "DSR." In figure 54 is given a schematic drawing of the kinematic connection from the stabilizer to the ARU.

A change in "lead-away" of the stabilizer along the dimension D by 1 mm corresponds to a change in control handle forces of 2 to 3 kg at a speed V_{ins} = 900 to 1000 km/hr.

Neutral Position of the Trimmer Effect Mechanism

31. A check of the neutral position is made (Figure 53) in accordance with the dimension DSR determinable by the dimensions D_1 and D_2 of the stabilizer, as a mean value $\frac{D_1 + D_2}{2}$. Measuring the values D_1 and D_2 is done in the following manner: ARU is placed on the larger arm.

The trimmer effect mechanism is placed in neutral position by the signal of a flashing-on green light designating trimmer effect in neutral position, by shifting the switch on the control handle toward yourself. Before this is executed the light is put out by shifting the switch away from yourself.

We measure the distance D left between points 54 and 55 after the handle is turned into neutral position from position D_1 and from position D_2.

The turning of the handle into neutral position is done by first tilting it into extreme position, slowly at a rate of not more than 100mm of handle movement per 10 sec.

In this case the handle will stop at any distance from neutral position, thanks to the friction of the control system.

The dimensions D_1 and D_2 are placed in a formula with their own signs: Minus if point 55 is lower than point 54 (stabilizer nose is down); plus if point 55 is above point 54 (stabilizer nose upwards).

When balancing the aircraft, a change in neutral position of the trimmer effect mechanism is permitted. The change in neutral position of the trimmer effect mechanism is applied to assure balancing of the aircraft in flight at instrument speed of V_{ins} = 750 ±100 km/hr.

At a balancing rate of less than V_{ins} = 750 ±100 km/hr it is necessary to change the DSR by raising the nose of the stabilizer upwards (according to points 54 and 55), and at a speed greater than V_{ins} = 750 ±100 km/hr in direction of lowering the stabilizer nose downward. Adjustment of the DSR is done after the adjustment of the stabilizer lead-away.

To a dimension of DSR equaling plus 10 mm corresponds an angle of stabilizer deflection (perpendicular to the axes of rotation) of 1°30' nose upwards. In figure 55 is given the relationship between the dimension D and stabilizer angle for small angles.

Balancing the aircraft by the forces at a given lead-away D = 18mm will be assured at a V_{ins} = 750 ± km/hr at an altitude H = 0 to 3 km. ARU under these conditions will be situated in an intermediate position.

An increase in DSR (raising the stabilizer nose according to points 54 and 55 upwards) by 1 mm increases the balancing speed by approximately 10 km/hr.

The friction force and gap in the control system on the greater arm when the trimmer effect mechanism is in neutral position is determined by the difference between D_1 and D_2 along points 54 and 55 of the left half of the stabilizer.

The difference between D_1-D_2 = 10 mm corresponds to a friction force, applied to the handle, on the larger ARU arm equaling 0.6 kg at a 0 gap condition. Allowances for D_1 and D_2 are not set up and allowance is only made for their difference, i.e., D_1-D_2.

Maximum Movements of the Handle and Maximum Deflections of Stabilizer

32. On every aircraft are measured only the maximum movements of the handle and maximum angles of deflection of the stabilizer on the large and small arm of the ARU.

Measuring the movement of the handle is done by points listed in the schematic drawing shown in figure 53 and 56 during its total deflection toward yourself and away from yourself by the difference in the dimension "K-M" and "N-K," point "T"-conditional point of applying the force of the pilot's hand. Position of point "T" on the handle when measuring the movement of the handle is fixed by a special collar.

Measurements are carried out with hydraulic system connected with normal pressure and with trimmer effect mechanism in neutral position. The fixing and control of the ARU position is done by the indicator in the cockpit.

The angles of stabilizer deflection are measured by an angle gauge perpendicularly to the axes of rotation. The angle gauge is placed in zero position along points 19 and 20 on each half of the stabilizer. The reading of angles foreach half is done from zero (Figure 53).

When it is necessary to change the angle of inclination from perpendicular into a direction parallel to the flow it is necessary to use the following ratio: φ°_{st} in direction of flow = 0.559 φ°_{st} perpendicular to the axis of rotation.

Clearance along the Movement in the Control System

33. The clearance on the handle in longitudinal direction is measured (Figure 53) when the hydraulic system is disconnected and the loading mechanism on the small ARU arm is off. The clearance is measured in the chain running from the handle to the booster. The magnitude of clearance allowance includes the gap of the booster slide-valve. The booster is fixed automatically (thanks to a hydraulic lock). To the handle is applied a force of 2 kg pushing the handle forward and the movement of the handle is measured, when pulling the handle toward yourself we also measure the

movement of the handle. The sum of handle movements away from yourself and toward yourself appears to be the gap. The measurement is repeated twice but in a different sequence.

The mean value is inserted in a table.

B. Lateral Control

Neutral Position of Handle

34. Neutral position of the handle (i.e., at a force applied to it equaling zero (P = 0) should be in the plane of symmetry of the aircraft.

The hydraulic system is on, pressure normal. The shifting of the handle into neutral position during operation is controlled by the distance "from left" end of cabin (from reference point 21) to point T on the handle, measured when the airplane is leveled at the assembly plant and the handle is fixed according to a balance (see figure 57).

Aileron Shears

35. The "shears" of ailerons are the sum of angles of deflection of the left and right ailerons (in various directions) during neutral position of the handle. When the aircraft leaves the assembly plant the shears of the ailerons should be zero. The shears of ailerons are used for lateral balancing of the aircraft when carrying out the acceptance-delivery program.

The shears of ailerons (see figure 57) are measured in the following order:

- hydraulic system "on";
- handle in neutral position according to the leveling dimension "from the left."

49

It is unnecessary to fix the handle because it is held in neutral position by the friction force and by the force of the loading mechanism.

We measure the linear dimensions "N" according to points 38 and 38a along the left and right ailerons.

We determine the magnitudes of the shears of ailerons by the number of measurements of "N" (at a deflection of ailerons in various directions). The direction of shears is determined by the right aileron using terms--"right aileron up," "right aileron down," at a condition when points 38 and 38a of the left aileron coincide.

In the process of changing the shears of the aileron for the purpose of balancing the neutral position of the handle does not change.

When measuring the shears in the case of presence of local deviations of the contours at the measured points, the measurements should be corrected by a value of the initial stage between wing and aileron.

The shears of ailerons are used to eliminate the banking of the aircraft during flight with boosters on. The rules of applying aileron shears when balancing the aircraft with hydraulic system on are:

a) during left banking of the aircraft it is necessary, during neutral position of the handle (by the dimension "form the left") by adjusting the control cables, to deflect the left aileron downward and the right one upwards.

b) during right banking of the aircraft left aileron up and right one down.

The magnitude of aileron deviation along points 38-38a is evaluated by the following ratios: During banking, moving the handle 5 mm from neutral position (force against the handle approximately 0.3 to 0.4 kg) each aileron should be deflected by 5 mm along points 38-38a.

50

Maximum Movements of the Handle and Maximum Angles of Aileron Deflection

36. Maximum movements of the handle are checked with hydraulic system connected. The movement of the handle is measured by a ruler from neutral position (by the dimension "from the left") along point "T" on the handle (see figure 57 and 58).

37. The angles of aileron deflection are measured by an angle gauge with connected and disconnected hydraulic system perpendicularly to the axis of aileron rotation (Figure 57).

Zero position of the angle gauge is set up for each aileron by combining points 38-38a of the left and right sides (see figure 57).

Non-Linear Mechanisms

38. On each aircraft is made (figure 57) a check of the non-linearity of the kinematic bond between the handle and the ailerons with connected hydraulic system and one position of the handle.

To this condition corresponds a maximum coefficient of non-linearity. Measurements are conducted simultaneously with the measurements described in paragraph 36.

When entering into the table the angles of aileron deviations for a given handle movement from neutral, the obtained angle of deviation should be deducted from the value of the angle corresponding to the neutral position (with the existance of shears). Measurements are carried out for both left and right ailerons for handle deflections both left and right ±50 mm. A check of the nonlinearity of the kinematic coupling between the lever and aileron for the entire range of handle movements is made according to the additional instructions.

51

Knife (Plate) of Left Aileron

39. The knife of the left aileron serves for transverse balancing of the aircraft.

When the aircraft leaves the assembly plant of a series manufacturing plant and before the first flight, the angle of bending of the knife should be zero (see figure 57). The deflection of the knife is further used to assure lateral balancing of the aircraft with deflected aileron boosters.

The rule for bending the knife of the left aileron to assure lateral balancing with engaged hydraulic system is as follows:

a) If the aircraft banks to the left it is necessary to bend the knife of the left aileron upwards.

b) If the aircraft banks to the right the knife of the left aileron is bent downwards.

The bending of the knife by 1 mm against the banking reduces the control handle force by 4 to 8 kg at V_{ind} = 1000 to 1100 km/hr.

C. Path Control

Maximum Angles of Deflection of the Rudder and the Movement of Pedals

40. Angles of deflection of the rudder (Figure 57) is measured with an angle gauge perpendicularly to the axis of rotation. Zero position of the angle gauge corresponds to a coordination of points 47 on the rudder and 27 on the fin.

Movement of the pedals is measured from zero position of the rudder using a ruler.

Knife of Rudder

41. After assembling, the angle of bending of knife of the rudder should be equal to zero (see figure 57).

The bending of the knife is used to assure path balancing of the aircraft with respect to force.

Control of knife bending is carried out along two sections, lower and upper, using the following rule: if the aircraft turns to the right, the knife of the rudder is bent to the right (in direction of flight); during left turn--to left side.

For the turning of the aircraft (leadout of "pellet" of EUP-56):

a) up to subsonic speeds - bend knife in lower sections;

b) at supersonic speeds in upper section.

In the center section the knife should not be bent.

If the aircraft turns such that the leadout of the "pellet" is one diameter, the knife should be bent approximately 0.5 mm.

III. Measuring the Forces on the Handle and in Pedals

A. Longitudinal Control

Forces on the control Handle from the Loading Mechanism

42. The forces acting against the handle are measured on each aircraft when the ARU is on the small arm, when shifting toward yourself and away from yourself but only in direct movement.

The forces (Figure 59) are measured after a control check has been made, i.e., by the established values of Duvod and Dsr.

The measurements are made under the following conditions:

[redacted]

The forces against the handle are measured with a special dynamometer (of the "TOKAR" type).

When the handle is shifted away from yourself or toward yourself the axis of the dynamometer should be parallel to the axis of symmetry of the fuselage and perpendicular to the axis of the handle. The application of dynamometer forces to the handle should be at point "T".

The movements of the handle are measured with the aid of a special ruler installed in the cabin on a bracket. The reading of movements is done along the arc of the ruler with its radius of 605 mm.

The beginning of reading the handle movements is assumed to be the position of the handle, at a zero angle of deflection of the stabilizer, i.e., at a stabilizer position (left) by the dimension D = 0 (along points 54 and 55).

The measurements are made when the handle is shifted from position D = 0 into position toward yourself and away from yourself by 5 mm less than the maximum movements.

Selection of handle movement less than maximum is made for the purpose of eliminating inaccurate measurements of forces on account of handle resistance.

The forces are measured during direct movement of the handle, i.e., when it moves from neutral toward yourself, then from neutral away from yourself. In the force measurements will be included the magnitudes of friction forces in the control system and ±8% change in forces on account of the friction forces of the loading mechanism.

The forces during the movements from extreme positions into neutral (reverse movement) are not measured.

54

[redacted]

The forces are measured only in movement, i.e., other forces are not measured.

The measurements are carried out at neutral position of the trimmer effect.

The mechanism of the trimmer effect is placed in neutral position by the movement of the switch on the handle toward yourself, the signal light is put out by the movement of the switch away from yourself. The measurements are carried out at normal pressure of the hydraulic system.

The measurements are made at a temperature of the outer air within limits of the +10° to +20°C.

The measurements are carried out on the aircraft with fuselage hatches closed.

Prior to carrying out the measurements are made several movements of the stabilizer.

Number of points to be checked during measurements:

In the range of a rigid spring of the loading mechanism during the movement toward yourself - 6 to 8 points, away from yourself also 6 to 8 points.

In the range of a soft spring during the movement toward yourself - 10 to 15 points, away from yourself - 8 to 10 points.

The ARU is set on the small arm by the cabin indicator.

The forces are measured in the following manner:

a) Deflect handle into forward position and then, due to friction, lower it into neutral position with a speed of not more than 100 mm of handle movement per 10 sec, so as to assure the attainment of the neutral

[redacted]

position exactly. (This leads to the elimination of lags between the handle and loading mechanism.)

b) Measure the forces along the movement of the handle when shifted from this position into the direction away from yourself.

c) Having deflected the handle into position toward yourself,place it in neutral position, analogous to point "A".

d) Measure forces during movement toward yourself from this position. The force values by the measurements should be adjusted by the available sample, shown in figure 60.

In the table should be entered the maximum forces appearing during movement toward yourself and away from yourself.

After plotting the force points on the handle along its movement and after drawing a line along these points, check the gradient of changes in forces in the range of handle movement to points E-F.

The gradient of force changes is called the ratio of force gain to the gain in the movement of the handle, i.e., $R^x = \frac{\Delta R}{\Delta K}$.

The gradient of force change R^x is determined for the small (rigid) spring;in this case the gradient is determined conditionally by the forces at points A, F, and A_2E (see figure 60).

The values of the force gradients R^x should be determined during the movement of the handle away from yourself by: $R^x = \frac{\Delta R}{\Delta X} = \frac{R_E}{K_E - X_{A_2}}$ and toward yourself by: $R^x = \frac{\Delta R}{\Delta K} = \frac{R_F}{X_F - X_{A_1}}$.

On the graph of the leveling scheme the nominal forces are plotted with consideration of the friction force and ±8% allowance for forces from the loading mechanism. Differences in forces allow for nominal values of leadout and Dsr of the stabilizer.

56

[redacted]

Range of Operation of the "Trimmer Effect" Mechanism

43. The range of the operation of the trimmer effect mechanism, Figure 59, is checked under the following conditions: Hydraulic system connected; ARU in two position--larger and smaller arm.

Movement of the handle is measured by a ruler in the cabin from the position of the handle at neutral position of the trimmer effect mechanism.

To measure the range of operation of the trimmer effect mechanism it is necessary to fix the trimmer effect mechanism in neutral position (by the flashing of green light) using switch during movement toward yourself; shift handle into extreme position away from yourself, applying pressure to the trimmer effect switch; measure maximum movement of handle; repeat measurement with handle deflected toward yourself.

B. Lateral Control

Forces Against Aileron Control Handle

44. The forces against the handle in relation to the movement of the handle are measured only on selective aircraft.

On each aircraft are checked the nominal values of forces acting against the handle from the loading mechanism with an allowance of ±8% for change in forces on account of the loading mechanism and friction forces only at extreme deflections of the handle (see figure 59).

The measurements are made with a special dynamometer (of the "TOKAR" type).

The application of dynamometer forces should be at point "T" on the control handle (see figure 58).

The axis of the dynamometer should be perpendicular to the axis of the handle.

When measuring the forces the handle should not be moved within 5 mm of the extreme position to avoid inaccuracy when measuring because of the handle stop.

Measurements are made with connected and disconnected hydraulic system.

Before measuring it is necessary to move the handle several times into extreme position.

Measurements are made at an outside temperature ranging from +10° to +20°C.

The forces are measured for a smooth deflection of dynamometer control handle to the left and right.

Measurement of forces during reverse movement is not made.

In the obtained force values (and in the nominal values) are included friction force values of control systems and ±8% for change in forces on account of the friction forces in the loading mechanism). When the hydraulic system is off the forces against the handle increase sharply due to the higher friction forces of the boosters.

C. Path Control

Forces Against the Pedals

45. The forces against the pedals (Figure 59) are measured by means of a special dynamometer with pedals in extreme positions, but not nearer than 10 mm to the point of rest during the movement of left pedal away from yourself and toward yourself. The force of the dynamometer is applied at the point of conditional application of the pilot's foot force, i.e., at a distance of 200 mm from the axis of rotation of the pedal.

In Figure 61 is given a schematic drawing of pedal movement.

Supplement to Methodical Instructions on Leveling and Ground Balancing for Selective Aircraft

General Data

Measurements by the "supplement" on leveling system is carried out only on selective aircraft or in the case abnormalities in the behavior of the aircraft are revealed in the process of carrying out the acceptance-delivery program (banking, unusual turns, etc.).

Prior to carrying out leveling by the "supplement" the aircraft should be leveled in conformity with methodical instructions previously explained.

In figures 62-72 is given supplementary material necessary for the checking of leveling data and the control systems of selective aircraft.

I. General Leveling of an Aircraft

Wing

1. The fixing of lateral "V" of the wing is checked by points 18a-8a. When looking in plan view the bend of the wing relative to the axes of the main part of the fuselage is checked in accordance with points T.1 and T.2 by dimensions "A left," and "A right."

The curving of the wing relative to the axes of the tail section of the fuselage is checked along points T.3 and T.18a, by dimensions "B right" and "B left" (see figure 62).

A nominal dimension E = 22 mm corresponds to an angle of lateral V = 2°.

Landing Gear

2. We measure the angle of landing gear collapse by the dimension E (Figure 62).

59

Fuselage

3. When checking the curving of the fuselage are measured the displacements of point 3 relative to the axis of the main part of the fuselage (the fuselage is located along points T.1 and T.2) by the dimension "L". When viewed in the plan the displacement of the axis of the tail section relative to the axis of the main section of the fuselage is measured by the dimension "V" between the axis of the main part over points T.4 and T.5 and point 6 on the tail section of the fuselage (Figure 62).

The twist of the fuselage is checked by sections. Measurement of fuselage twist is done when it is placed over points 1 left and 2 left along the length and over points 8a left and 8a right in width, by the differences between the measurements on the left and right halves of the fuselage (Figures 62 and 63).

Stabilizer

4. The mounting of the stabilizer and its curviture, relative to the main part of the fuselage, is checked along point T.2 on the main part of the fuselage and along point T.22 on the stabilizer by the dimension "R" (see figure 62).

Checking the lateral "V" of the left and right halves of stabilizer is done along points 20-22 by setting the stabilizer by the dimension "v-a." A check of the stabilizer at a height relative to the axes of the main part is made by the dimension "a" by placing the stabilizer at a zero angle by the difference in "b-a" between points 19 and 20 (see figure 63).

To the nominal dimension $e = u_{22} \cdot u_{po} = 412$ corresponds the lateral angle of the stabilizer "V = 0."

60

Flaps

5. The flap slots are measured by the dimension "n" (Figure 63) during flap deflection at the maximum angle with connected hydraulic system for left and right flaps.

Brake Flaps

6. Measurements of the angles of deflection of the brake flaps (Figure 62) are made during maximum deflection of brake flaps with hydraulic system on: (a) Forward (left and right brake flap) by the linear dimensions "Kshch" over points 57-57; (b) rear one by the dimension "Kshch" over points 51-51.

To the nominal dimension Kshch = 446 corresponds an angle of deflection of the forward brake flaps of 25°.

To a nominal dimension Kshch = 672 corresponds an angle of deflection of the rear brake flap of 40°.

Wing Fence

7. A check of the fence installation relative to the axes of the main part of the fuselage (along points 4 and 5) (see figure 63) is made by measuring the distance from the axis of the fuselage to the nose of the fence "G_p^{gr}" and by the distance of the nose of the fence and the tail of the fence "$G_p^{gr} - G_z^{gr}$" for the right and left fence.

II. Checking the Control System

A. Longitudinal Control

8. A check of the angles of stabilizer deflection. The stabilizer angles are measured in the same way as in paragraph 32 "Methodical Instructions on Leveling for Left and Right Halves of Stabilizer at Various Positions of the ARU rod" (see figure 64).

In figure 18 is shown a change in the stabilizer angles by the movement of the handle in relation to the instrument speed and flight altitude.

In figure 65 is shown the arm change of the ARU-3V automat in relation to the instrument speed and flight altitude.

A change in arm of the ARU-3V with flight altitude (altitude correction) takes place automatically to an altitude of 10,000 m. At an altitude of 10,000 m the ARU-3V changes into the larger arm which at altitude of 10,000 m and over remains constant at all flight velocities.

In figure 64 are given complete characteristics of the forces acting against the handle of the stabilizer mechanism when the ARU is in working position and the trimmer effect mechanism is in neutral position, and the booster is on.

The forces affecting the handle during its movement as shown in figure 19 are given without consideration of friction in the control system..

The angles of stabilizer deflection when ARU is in positions corresponding to altitudes of 5 km, 7.5 and 10 km, are checked at a speed of V_{ins} = 1100 km/hr (Figure 18).

When doing measurements we write into the tables of the leveling system (Figure 64) the actual speed values, V_{ins}, at the beginning of ARU operation and V_{ins} at the end of ARU operation (corresponding to a displacement) and with ARU in position of small and larger arms.

For the given speeds have been established tolerances.

In an analogous manner are checked the altitudes at the beginning of the correction after the connection of the ARU automat.

The actual altitude values at the beginning of corrections and the end of corrections are entered into the very same table.

In addition to angle measurement, is also measured the dimension D (along points 54 and 55) of the nominal dimensions. The norm for the D dimension is not given.

The instrumental speed (rated speed) and the altitude when measuring stabilizer deflection angles is produced by KPU-3 instrument. For this purpose one KPU-3 instrument is connected to the dynamic aperture DUAS-8M; (KPU-3) is connected to the static aperture DUAS-8M.

The pressure in the dynamic line of the ARU sensing element controls the indicated speed instrument (according to the wide arrow)--V_{ins}; and the pressure in the static line controls the altitude indicator--H_{ins}.

It is necessary to set the altimeter dial on the altitude value which is shown by the instrument in standard atmosphere at a barometric pressure while the aircraft is parked (this assures the realization of measurements in accordance with standard conditions).

To do this it is necessary: (a) to tighten the fastening clamp and set the pressure in the little window at 760 mm Hg; (b) to consider the instrument errors of the speed indicator and altimeter.

When setting the necessary gear ratio, the values V_{ins} and H_{ins} must be given accurately, starting with small values of V_{ins} and H_{ins}.

Remark: The control gear ratio is the ratio of increase in handle movement to the increase in stabilizer movement, i.e., $\frac{\Delta X}{\Delta \varphi}$.

The relative gear ratio K_φ of the control is the ratio of values $\frac{\Delta X}{\Delta \varphi}$ at given altitude and flight speed to the value $\frac{\Delta X}{\Delta \varphi}$ at H = 0 and $V_{ins} = 0$. In Figure 60 is shown the value $K_\varphi = \frac{\frac{\Delta X}{\Delta \varphi}_{H, V}}{\frac{\Delta X}{\Delta \varphi}_{H=0, V=0}}$ depending upon the altitude indicated by flight speed instrument.

Warning: at a constant V_{ins} it is necessary to keep in mind that exceeding a V_{ins} of 1250 km/hr may lead to a stoppage of the ARU automat.

63

[redacted]

B. Lateral Control

Non-Linear Aileron Mechanisms

9. A check of the non-linearity of kinematic coupling between control handle and ailerons is also done as described in paragraph 38, "Methodical Information," but only in forward and reverse movement of the handle and within 20 mm of the neutral handle position (see figure 67). On figure 67 is shown the angles of aileron deflection for movement of the handle to the right and left with boosters connected for the entire range of handle movement.

Play of the Control Handle

10. The play of the aileron control handle is measured with hydraulic system off, see figure 67. When measuring the amount of play the left aileron should be secured in the neutral position. The handle should then be moved sideways with a pressure of 2 kg and the position of the handle should be noted, then the handle should be moved toward the opposite side with pressure of 2 kg and this position of the handle should be noted. The full displacement of the handle in this range is the amount of play. Then repeat handle movement measurement again under the very same effects but in reverse sequence.

In the square of figure 67 write in the mean value.

III. Measuring the Forces Acting against the Handle and Pedals

A. Longitudinal Control

Forces against the Control Handle from the Charging Mechanism

11. The forces against the handle are measured in the same way as described in paragraph 42, "Methodical Instructions," for three positions

[redacted]

of the ARU rod on the small, large, and medium arm, during forward and reverse movements of the handle (see figure 64).

The number of points to be measured with the fixed spring of charging mechanism for movement toward yourself is 6 to 8 and away from yourself is 6 to 8 points; and with the flexible spring for movement toward yourself it is 10 to 15 points, and away from yourself it is 8 to 10 points.

If, after measurement of forces at each condition of V_{ins} and H_{ins}, there is a noticeable discrepancy of points, it is necessary to measure again.

The values of force measurements are plotted for forward and reverse movements under various conditions using the same designations as in figure 68.

When measuring the forces the handle should not be moved within 5 mm of extreme position in order to avoid distortions due to the point of handle rest.

The allowable force value includes an allowance of ±8% for spring forces of the charging mechanism and for friction.

The forces during forward and reverse movements differ by the value of double friction force.

The control characteristic is considered satisfactory if the force measuring points are situated within the tolerances, and in addition an allowance for the force gradient should be maintained.

Determining the Force Change Gradient on the Handle from the Stabilizer

12. The force change gradient in accordance with movement of the handle is determined only on the small ARU arm during forward movement.

65

The force change gradient according to the fixed spring is checked on every aircraft as mentioned in paragraph 42 "Methodical Instructions."

After plotting a force dependence for the handle in accordance with its movement and after drawing a line along these points, as is shown in figure 69, it is necessary to check the force change gradient for the hollow sections (according to points F--toward yourself, and E--away from yourself) $R^x = \frac{\Delta R}{\Delta X} = \frac{R_{E_2} - R_E}{X_{E_2} - X_E}$.

The gradient R^x of the hollow sections is checked only for selective aircraft.

Measuring the Friction Forces of Longitudinal Control

13. The friction forces are determined after plotting on the graph, figure 64, the force measurement results on the handle in accordance with its movement from the charging mechanism in forward and reverse movements.

The friction forces are determined with the handle in neutral position and in extreme positions on the greater and smaller ARU arms ($H = 0$; $V_{ins} = 0$ and $V_{ins} = 1100$ km/hr).

The friction force in the control system is determined from the ratios of forces acting during forward and reverse movements, e.g., if the force against the handle during forward movement equals 22 kg and during reverse movement of the handle only 20 kg, then the value of the friction force will be equal to $T = \frac{22-20}{2} = 1$ kg.

In figure 68 is shown a picture of plotting the results of measurements during direct and reverse movements of the handle.

66

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Play (According to Forces) on the
Longitudinal Control Handle

14. Play measurements are carried out in two positions of the ARU on the greater and smaller arms. The play of the stabilizer handle is determined by figure 64,plotted in accordance with measurement results.

The play should be checked between the center lines of actual force measurements regarding forward and reverse movements of the handle (handle "toward yourself" and "away from yourself") at P = 0 as mentioned in figure 68.

B. Lateral Control

Forces against Aileron Control Handle

15. The forces against the aileron handle are measured both during right and left movements and during forward and reverse movements (Figure 67).

The number of points during measurement is 6 to 8 during left and right movements in the range of action of rigid spring of the charging mechanism and 8 to 10 during left and right movement in the range of action of flexible spring of charging mechanism.

In figure 70 is given a sample of plotting force measurement results on the handle for its right and left movements. The value of the force should be plotted for the forward and reverse movements with various conditional signs.

When measuring handle forces the handle should not be moved within 5 mm of the extreme position in order to avoid inaccuracy due to the handle stops.

67

[redacted]

The force allowance value includes allowances for the spring of the charging mechanism equaling ±8% and the friction force. The forces during forward and reverse movements differ by the value of double friction force. The control characteristic is considered satisfactory, if the force measurement points are within allowances; and in addition it is necessary to maintain an allowance for the gradient of forces in accordance with the rigid spring.

In figure 71 is given a theoretical dependence of the change in forces on the handle upon its right and left movements. The forces are given without consideration of the friction force effect in the system of aileron control.

Measuring Friction Forces of Lateral Control

16. The friction forces are determined after plotting on the graph (see figure 67) the force measurement results on the handle from the charging mechanism during forward and reverse movements.

Friction forces are determined during neutral position of the handle and with the handle in extreme positions. The friction force in the aileron control system is determined from ratios of forces, acting during forward and reverse movements, e.g., if the force against the handle during forward movement equals 6 kg and during reverse movement 4 kg, then the friction force value equals $T = \frac{6-4}{2} = 1$ kg.

Play (in Accordance to Forces) on the Aileron Control Handle

17. The force play on the aileron control handle is measured from graphs (figure 67) as distances between the center lines of actual force

measurements for the movement of the handle during forward and reverse movements (handle "to the left" and handle "to the right") at P = 0, as it is shown in figure 70.

Forces against the Pedals

18. The forces acting against the pedals are measured for each aircraft (paragraph 45).

Determining the Gradient of Force Change on the Aileron Control Handle

19. The gradients of force change on the aileron control handle are determined along the section of the rigid spring during forward movement of the handle to the right and left (figure 67).

In a similar way are determined the forces acting against the handle of longitudinal control (paragraph 12).

C. Directional Control

Non-Linear Rudder Mechanism

20. A check of the non-linearity of kinematic coupling between pedals and the rudder is done during forward and reverse movements of the pedals within 20 mm from neutral position (see figure 72).

In figure 72 is given the change in the angles of rudder deflection to the right and left for the entire range of pedal movements.

Methodical Instructions on Balancing the Aircraft in Flight

General Data

1. The present methodical instructions on balancing the aircraft in flight have been compiled in conformity with the methodical instructions

69

[redacted]

governing the leveling and ground balancing of aircraft, described in appendix 1 to chapter 5 of this report.

2. Methodical instructions contain no allowances. All allowances are listed only in the leveling system.

3. The sequence of flights for aircraft balancing is given below.

I. Instructions for Flight Crew

A. Pre-Flight Control Test

Before flying for aircraft balancing the pilot should become acquainted with the leveling system, and as he makes a pre-flight inspection of the aircraft in conformity with instructions governing the operation he should check: (a) arrangement of ARU, which should be on the greater arm; (b) arrangement of trimmer effect mechanism in neutral position; (c) shears of stabilizer (difference in setting angles of right and left halves of stabilizer) according to lines 54 and 55 from the left (see figure 53) should be 0 ±1 mm when combining lines 54 and 55 of the left stabilizer half; (d) the correctness of the position of the rear stabilizer adges, rudder, ailerons, and flaps. The position of the rear edges should be as follows: The knife on the trailing edge of stabilizer tilted upward by 4°; knives of trailing edges of rudder and ailerons should be: before the first flight during acceptance-delivery tests at the series manufacturing plant in zero position. In subsequent flights they are controlled in conformity with the flight results for balancing.

B. Longitudinal Balancing of Aircraft in Flight

The purpose of this task is to balance the aircraft with the trimmer effect mechanism during climb to an altitude of 3,000 m (in rectilinear climb without overloads) during maximum operational condition of the engine

[redacted]

by instrument speed showing 750 ±100 km/hr (by the wide arrow) with retracted landing gear, flaps, brake flaps, and without suspension tank.

Make sure that the balancing mechanism of the trimmer effect is set in the neutral position according to the signal lamp prior to takeoff.

The order of carrying out the balancing--the balancing should be carried out in rectilinear flight after reaching an instrument speed of 750 ±100 km/hr, and then not using the trimmer effect mechanism speeding up to an instrument speed of 1000 km/hr he must check the nature of changes in forces affecting the handle.

At speeds greater than the balancing speed (V_{ins} = 900 to 1000 km/hr) pulling forces against the control handle of up to 3 to 4 kg are permitted. In figure 20a is given a typical graph of a balancing curve $P = f(V)$, i.e., a change in handle forces in relation to the speed of flight according to instruments when climbing to an altitude from H = 0 to H = 3,000 m.

Remarks: If to secure longitudinal balancing of the aircraft at an instrument speed of 750 ±100 km/hr the pilot has to utilize the trimmer effect mechanism and the illumination of the signal light has not corresponded with the balancing speed, then the pilot should determine the balancing speed at which the signal light does go on.

If after the balancing flight it is necessary to adjust the trimmer effect mechanism or to adjust the "lead-out" of the stabilizer, then it is necessary to make a control check of the balancing in the next flight.

C. Lateral Balancing of Aircraft in Flight

When doing lateral balancing evaluate the lateral balancing of the aircraft with aileron boosters on in accordance with an instrument speed

71

[redacted]

showing 1000 ±50 km/hr. If for the purpose of balancing aircraft banking the movement of the handle, in this case does not exceed 1/4 of the total movement of the handle (which corresponds to an aileron deflection angle of 2.5°) then it is possible to begin checking the lateral balancing of the aircraft.

<u>Remark</u>: If to balance banking we need more than 1/4 of handle movement, then after the flight it is necessary to adjust the "shears" of the ailerons.

The purpose of the mission is to assure lateral balancing of the aircraft over the entire range of speed operations.

Balancing is assured when the boosters of ailerons (adjusters of shears) are in "on" position, and when aileron boosters are "off", by tilting the knife on the trailing edge of the left aileron.

<u>Remark</u>: When checking lateral balancing the aircraft should fly without slip. If in heading ratio the aircraft is still not balanced, it is allowed to eliminate slip by tilting the rudder pedals.

<u>Balancing when Aileron Boosters are Off</u>

The purpose of the mission is to assure balancing of the aircraft up to an instrument speed of 1000 ±50 km/hr at an altitude of 2000 to 2,500 m. The order of carrying out the balancing at an altitude of 4000 to 5000 m at instrument speed of 600 km/hr cut off the aileron boosters and then in slanting descent from that altitude to a height of 2000 to 2,500 m at maximum engine operation accelerate to an instrument speed of 1000 ±50 km/hr, then decelerate to an instrument speed of 750 km/hr after which the aileron boosters are connected again.

72

[redacted]

[redacted]

Up to an instrument speed of 800 km/hr is permitted a slight banking, balanced by the deflection of the handle with a force of not more than 4 kg, and as the speed increases these forces can be smoothly increased to change the sign but at the end of the acceleration to an instrument speed of 1000 ±50 km/hr (Mach number = 0.89 to 0.92) should not accede 15 kg.

In the event the forces against the control handle reach a value of 15 to 20 kg at lower speeds, it is necessary to discontinue the acceleration, to decelerate and again cut in the aileron boosters.

Fix the speed, flight altitude, direction of bank, approximate value of the force against the handle and handle movement, necessary to eliminate bank.

Remark: If after the flight it was necessary to unbend the knife on the aileron, then in the next flight it is necessary to check the lateral balancing with aileron boosters shut off.

Balancing with Aileron Boosters On

The puspose of the mission is to check the balancing of the aircraft in acceleration to a maximum permissible Mach number at an altitude of 13,000 m.

Special attention should be devoted to lateral balancing during acceleration to a maximum permissible Mach number. In case the aircraft is not balanced at any given condition, the pilot should fix the instrument speed or Mach number, flight altitude, direction of banking, approximate force values and movements of the handle, necessary to eliminate bank.

73

[redacted]

50X1-HUM
50X1

At near-sonic Mach numbers (0.89 to 0.92) and up to maximum permissible Mach numbers (or at an instrument speed of more than 1000 km/hr and up to V_{ins} maximum) is permitted a smooth increase in control handle deflection of the aileron handle in order to eliminate bank up to 1/4 of the movement.

<u>Remark</u>: If after the flight it was necessary to adjust shears of the ailerons, then in the next flight it is necessary to check the lateral balancing with aileron boosters on.

D. <u>Directional Balancing of Aircraft in Flight</u>

The purpose of the mission is to assure directional balancing of the aircraft over the entire range of operational speeds.

The balancing is assured by bending the knife of the rudder.

For directional balancing it is necessary to pay attention to the bahavior of the aircraft when flying up to maximum permissible instrument speeds and maximum permissible Mach number.

In case of non-balancing of the aircraft at any given flight condition, the pilot should fix instrument speed or Mach number, flight altitude, direction and magnitude of deflection of the pellet of the EUP-56 indicator with free pedals and the approximate force value on the pedals necessary to eliminate turn.

At an instrument flight speed of more than 1000 km/hr (according to the wide arrow) and at a Mach number of more than 0.89 to 0.92 is permitted a smooth lead-out of the pellet of the EUP-56 indicator by ±1 diameter with free pedals in rectilinear flight without overload.

50X1-HUM

For a lead-out of the pellet of up to ±1.0 diameter the pilot should have the ability to balance the turn by rudder pedal deflections operating under acceptable forces. Sharp spontaneous aircraft turns are not permitted. The accuracy in determining the position of the pellet in various flights is 0.5 diameter.

Remark: If after the flight balancing was done by bending the knife on the rudder, the next flight it is necessary to check directional balancing.

E. Filling out the Leveling System

The pilot together with the LIS engineer should record in the flight log book the speed values of longitudinal and lateral balancing.

Remark: After adjusting balancing data the pilot, prior to the next flight, should be acquainted with the introduced changes in control data.

II. Instructions for the Technical Crew

Post-Flight Control Adjustment

Post flight aircraft control adjustment is done on the ground provided the adjustment data applied before the first flight have not provided the necessary conditions for balancing in conformity with chapter "A" of the present methodical instructions.

A. Longitudinal Control

If the pilot in the flight has not used the trimmer effect mechanism and the balancing was found to be proper, then the test of the balancing is considered complete; and if he did use it, then after landing it is necessary to adjust the neutral position of the trimmer effect mechanism.

[redacted]

To do this it is necessary to adjust the flashing of the signal light during neutral position of the trimmer effect mechanism, fixed by the pilot when flying for balancing.

If the pilot reports that at speeds greater than the balancing speed (V_{ins} = 900 to 1000 km/hr) pulling forces appear of more than 4 kg, then it is necessary to increase the lead-out of the stabilizer (to increase the lowering of stabilizer nose). The lead-out of the stabilizer is adjusted at Der = 0 (along points 54 and 55).

Adjustment of the lead-out of the stabilizer is done by dimensioned change of the ARU by changing the length of the cable running to the ARU from the pilot and the length of cables running from the ARU to the booster.

To increase the lead-out of the stabilizer (to lower stabilizer nose) it is necessary to tilt the ARU mechanism in clockwise direction (as viewed from the left side). The lead-out of the stabilizer from the greater arm of the ARU to the smaller one must be checked with stabilizer control handle arrested and away from Der = 0 (combining points 54 and 55 of the left stabilizer half).

The adjustment is made in accordance with methodical instructions listed in appendix 1 to chapter 5, paragraph 30.

During ground adjustment of longitudinal control it is necessary to keep in mind the dimension Der = 10 mm (stabilizer nose along points 54 and 55 tilted upwards) corresponds with the angle of stabilizer deflection (perpendicular to the axis of rotation) 1°30 nose upwards (see figure 55).

The increase (lifting stabilizer nose upwards) of Der (along points 54 and 55) by 1 mm raises the balancing speed by approximately 16 km/hr.

[redacted]

An increase (lowering stabilizer nose) (or deduction) of the lead-out of the stabilizer when switching over the ARU from larger arm to the smaller one by 1 mm decreases (increases) the traction (compression) forces at speeds V_{ins} = 900 to 1000 km/hr by 2 to 3 kg.

Remark: The knives on the trailing edge of the stabilizer are not a means for longitudinal balancing of the aircraft, but they serve to assure minimum hinge moments of the stabilizer.

The unbending of the knives of the stabilizer is prohibited.

B. Lateral Control

For Aileron Booster Deflections

Lateral balancing of the aircraft with aileron boosters deflected is assured by unbending the knife on the left aileron. If according to the pilot's report during flight with deflected boosters the forces against the handle necessary for balancing aircraft bank during acceleration to V_{ins} = 1000 ±50 km/hr and the deceleration to V_{ins} = 750 km/hr, were more than 15 kg, then it is necessary to unbend the knife of the left aileron.

For left bank the knife of left aileron is tilted upwards.

For right bank the knife of left aileron is tilted downwards.

Adjustment is donw in conformity with paragraph 35 of the leveling scheme.

The bending of the knife of the left aileron in opposite direction of the bank by 1 mm removes from the control handle a force equaling 4 to 8 kg at V_{ins} = 1000 to 1100 km/hr.

With Aileron Boosters Turned On

Lateral balancing with connected boosters is assured by shears of ailerons. If according to pilot's report when flying with connected aileron boosters a lateral unbalancing of the aircraft is observed, then it is necessary to adjust the shears of the ailerons.

During left bank it is necessary (at neutral position of handle), by adjusting the control cables, to deflect the left aileron downwards and the right one upwards.

At a right bank--left aileron up and right down.

In the process of changing the shears of the ailerons the neutral position of the handle should not be changed.

The adjustment should be carried out in conformity with methodical instructions governing the leveling and balancing.

The magnitude of the necessary deviation of shears of ailerons along points 38 and 38a is evaluated by the following ratio: during banking for equal 5 mm movements of the handle from neutral (the force against the handle in this case equals approximately 0.4 kg) each aileron should be deflected along points 38 and 38a by ±5 mm.

C. Path Control

Path unbalancing of the aircraft is eliminated by tilting the knife on the trailing edge of the rudder.

When tilting the knife it is necessary to use the following rule: For right turn of the aircraft in flight the knife of the rudder should be tilted to the right (in direction of flight); for left it should be to the left. When the aircraft is making a turn at subsonic speeds the knife of the rudder is tilted in the lower section; at supersonic speeds it is in upper section.

[redacted]

In the center section the knife is not tilted. If when making a turn we evaluate the lead-out of the pellet to be 1 diameter, the knife should be bent approximately 0.5 mm.

Adjustment is made in conformity with methodical instructions governing leveling and balancing.

Filling out the Leveling Documents by the Mechanic

The aircraft mechanic, after completing ground adjustments concerning the control to assure the balancing of the aircraft, has to fill out the leveling diagram.

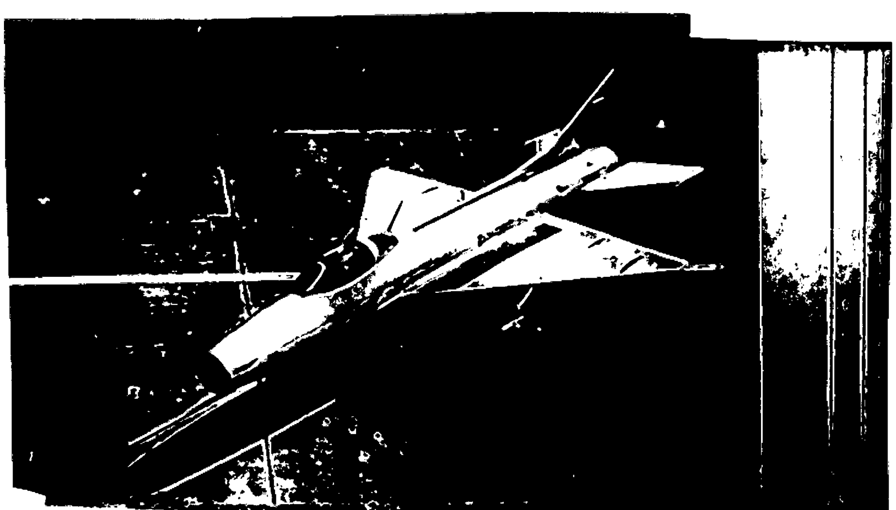
[redacted]

50X1-HUM

50X1-HUM

-80

S-E-C-R-E-T



Фиг. 1. Самолет МиГ-21Ф-13 (вид 3/4 спереди)

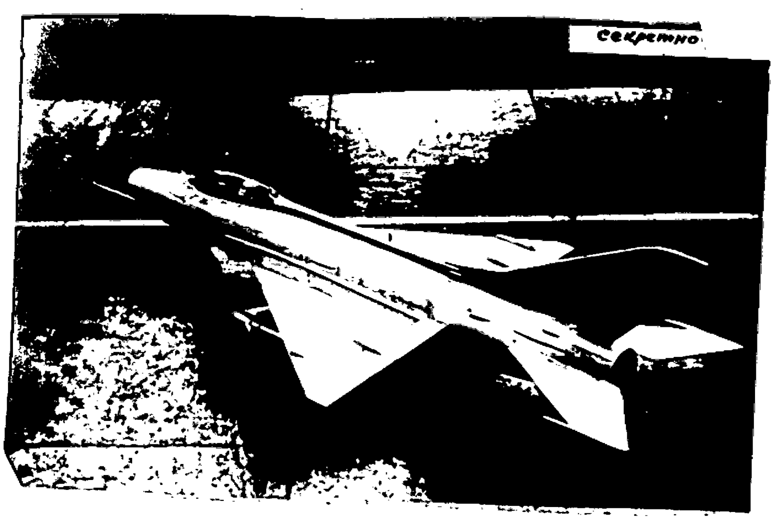
S-E-C-R-E-T

50X1

50X1-HUM

50X1-HUM

S-E-C-R-E-T



[illegible] Самолет [illegible]

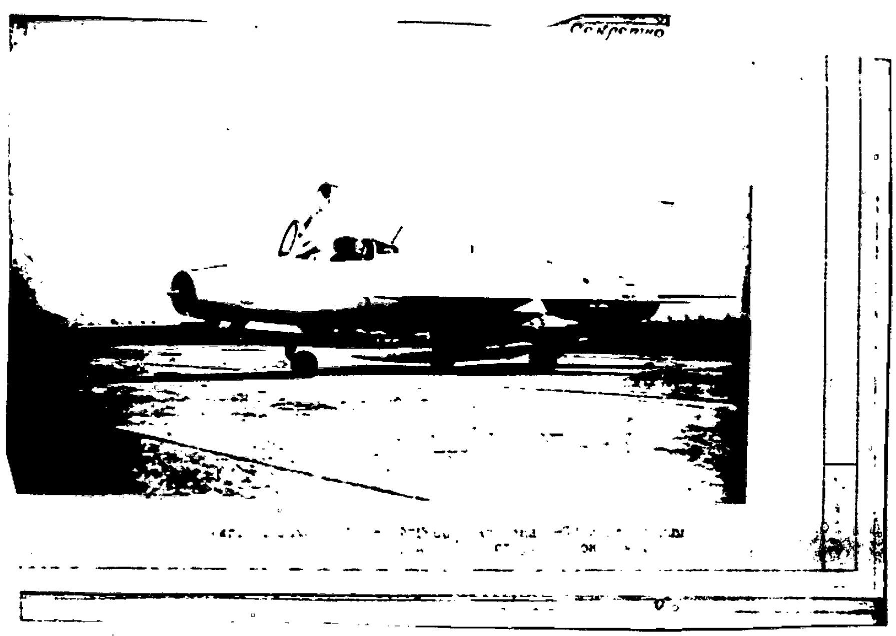
S-E-C-R-E-T

50X1

50X1-HUM

50X1-HUM

S-E-C-R-E-T



50X1

S-E-C-R-E-T

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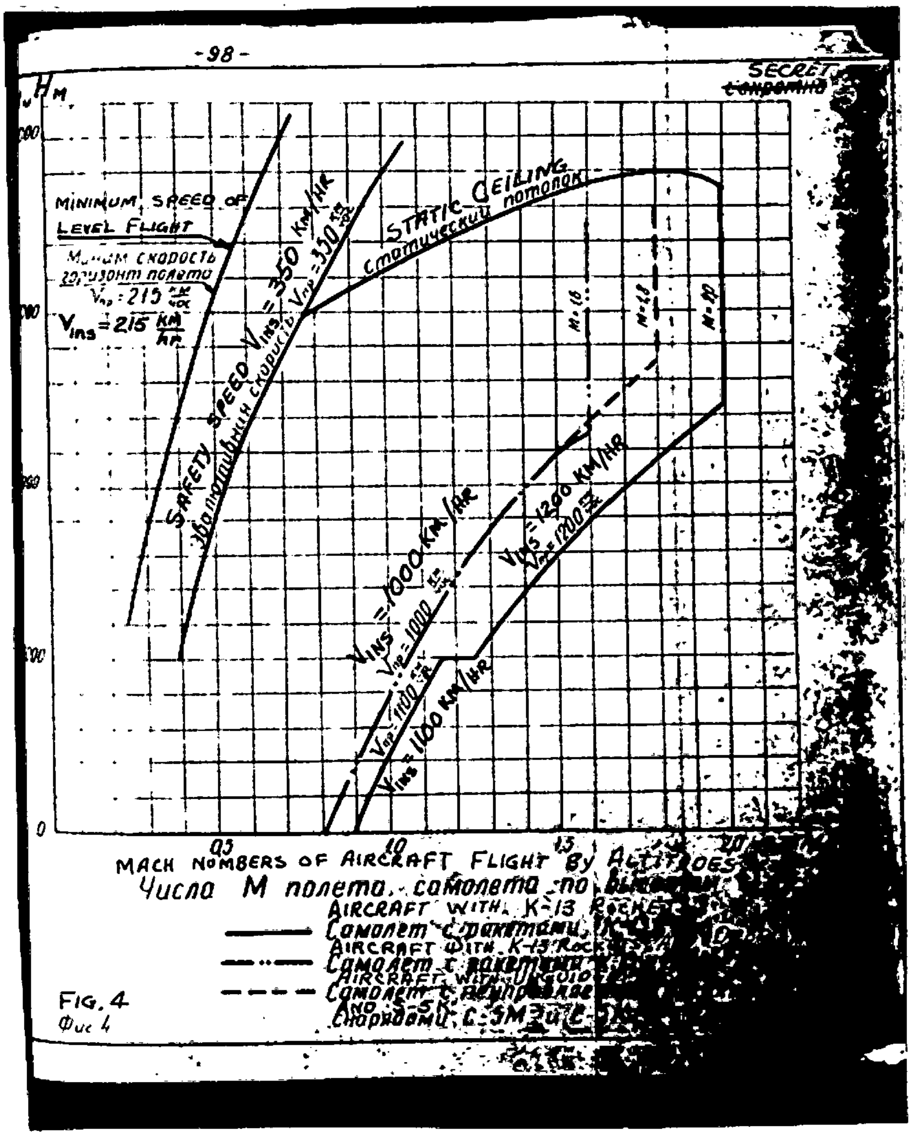
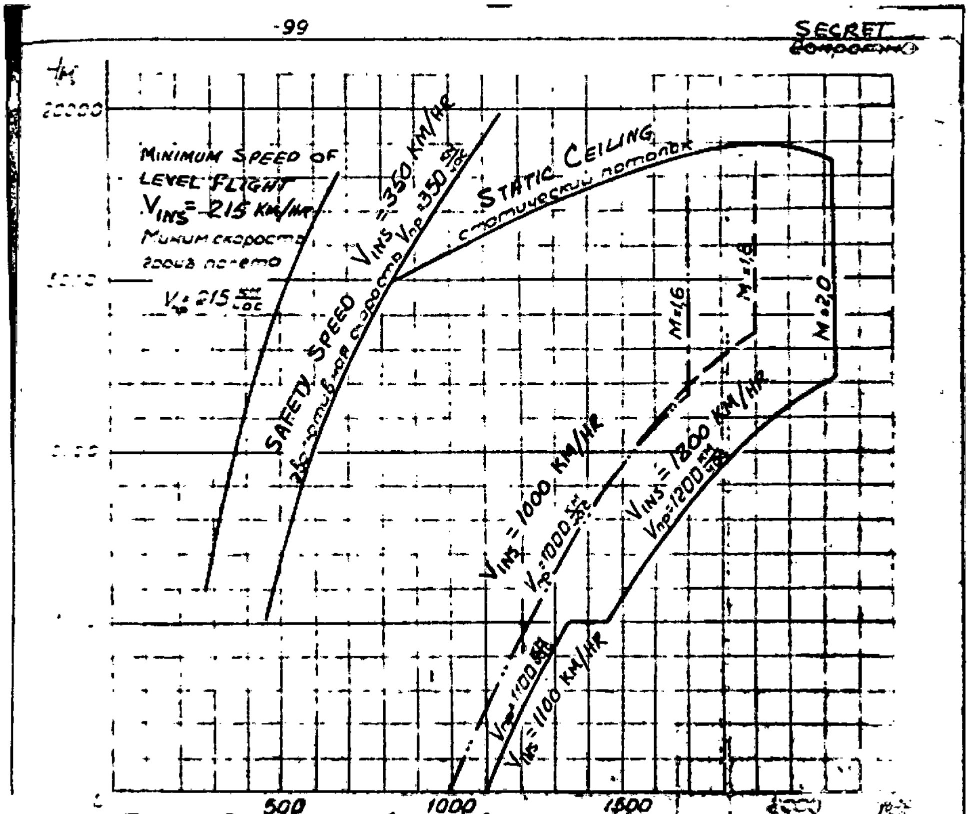
50X1-HUM

50X1



50X1-HUM



FLIGHT SPEEDS OF AIRCRAFT BY ALTITUDES
Скорости полета самолета по высотам.

AIRCRAFT WITH K-13 ROCKETS
Самолет с ракетами К-13

AIRCRAFT WITH K-13 ROCKETS AND DROP TANK

AIRCRAFT WITH UNGUIDED ROCKETS S-5M AND S-5K

Рис 5
FIG. 5

50X1-HUM

50X1

Секретно

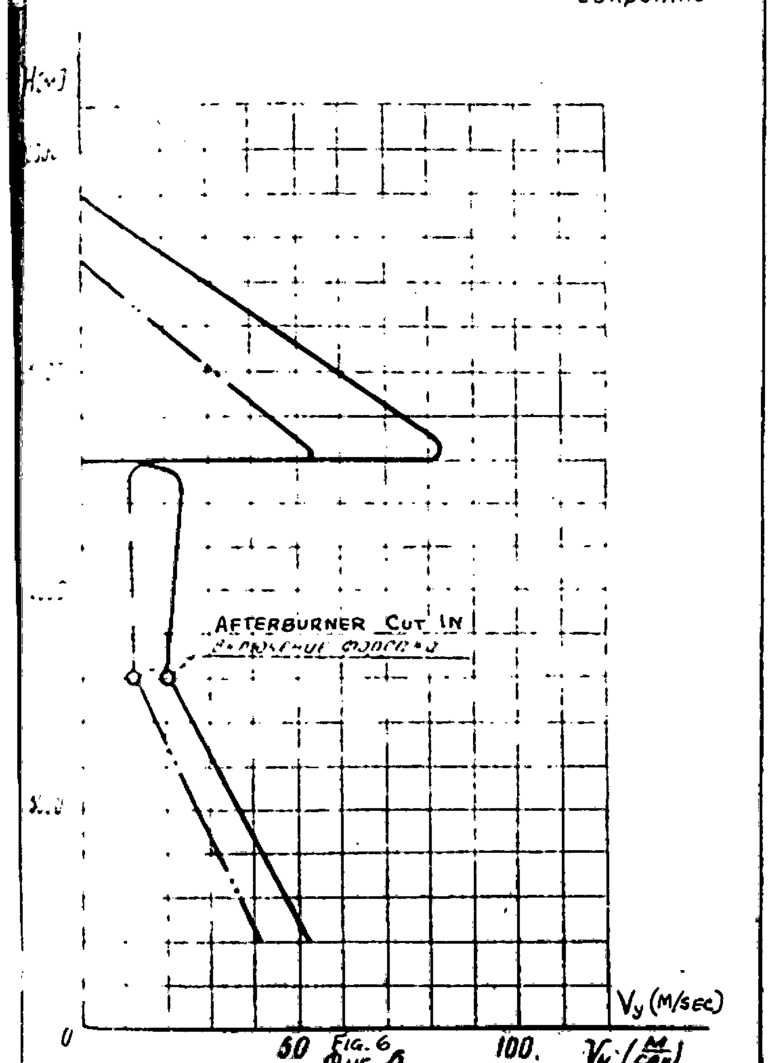


FIG. 6
Фиг. 6

RATES OF CLIMB VERSUS ALTITUDE
Вертикальные скорости полета при наборе высоты.

—— AIRCRAFT WITH K-13 ROCKETS
Самолеты с ракетами К-13;

—·— AIRCRAFT WITH K-13 ROCKETS AND DROP TANK
Самолет с ракетами К-13 и подвесным баком

50X1-HUM

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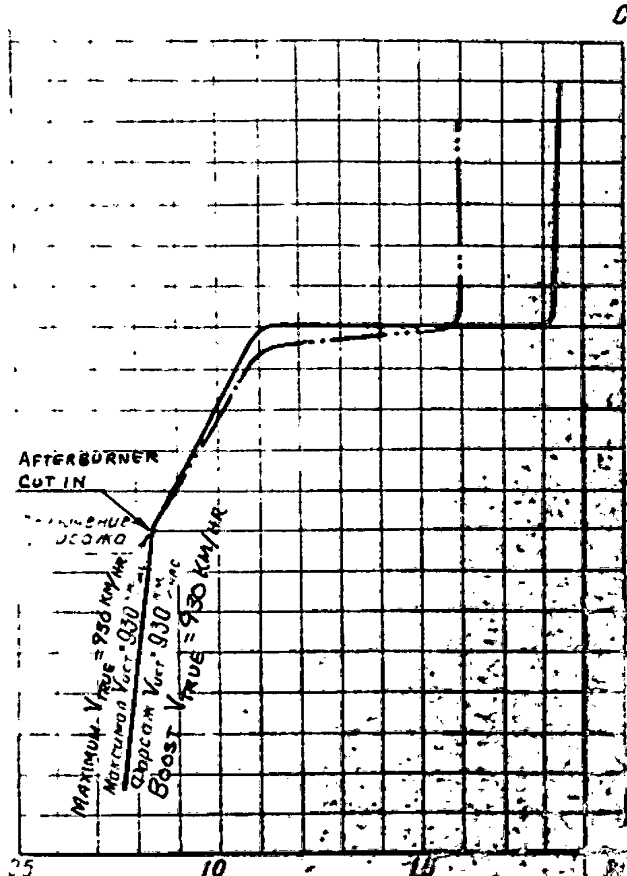
Секретно



MACH NUMBERS OF CLIMB

Числа М набора высоты

——— AIRCRAFT WITH K-13 ROCKETS
самолет с ракетами К-13

—·—·— AIRCRAFT WITH K-13 ROCKETS AND DROP TANK
самолет с ракетами К-13 и подвесным баком

FIG. 7

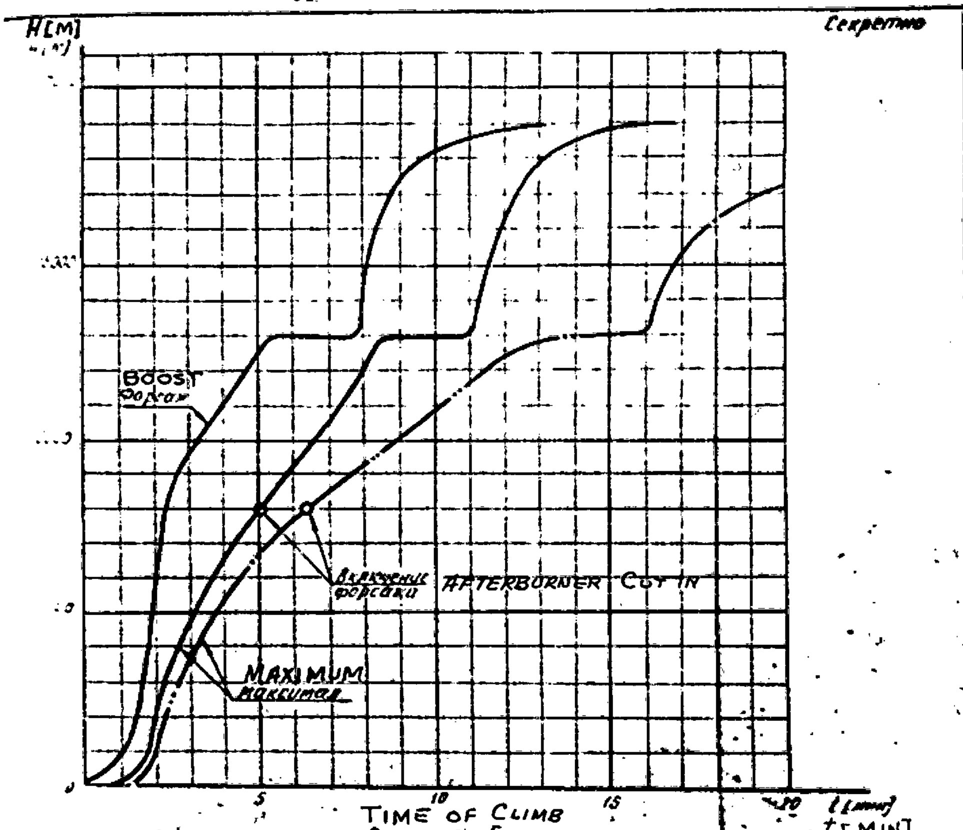
Фиг. 7

50X1-HUM

50X1

S-E-C-R-E-T

Секретно



AIRCRAFT WITH K-13 ROCKETS
Самолет с ракетами К-13
AIRCRAFT WITH K-13 ROCKETS AND DROP TANK
Самолет с ракетами К-13 и подвесным баком

NOTE: TIME OF CLIMB GIVEN FROM MOMENT OF TAKE-OFF
Примечание. Время набора высоты дано с момента старта

Фиг. 8

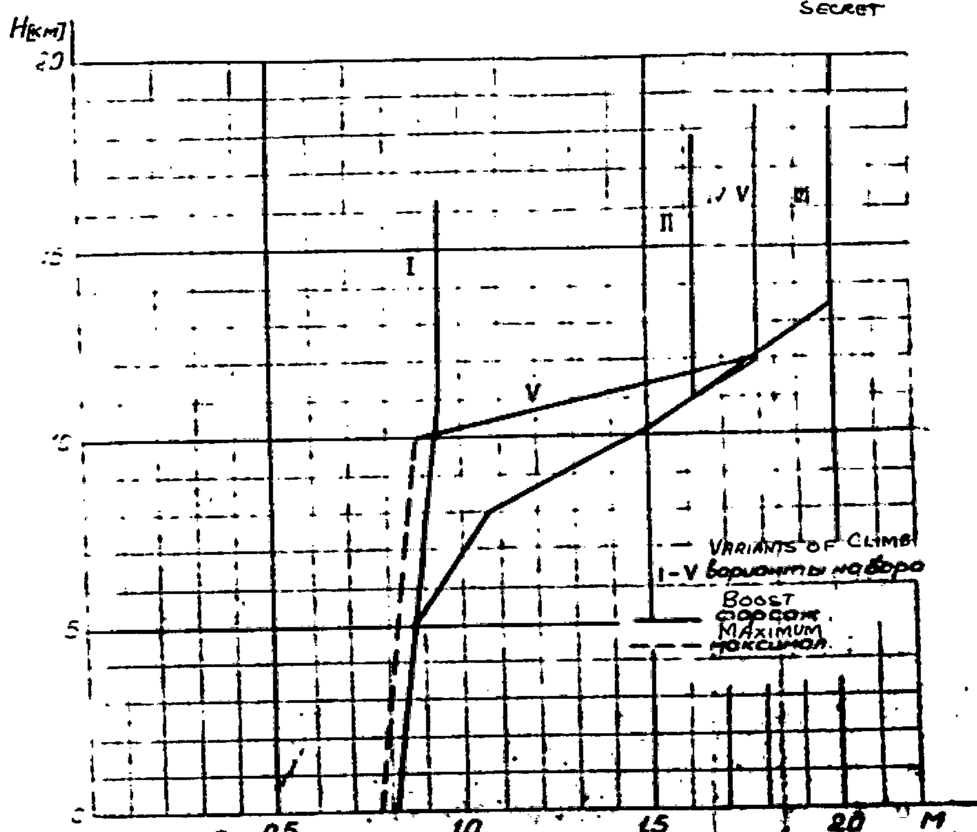
FIG. 8

S-E-C-R-E-T

50X1-HUM

[redacted]

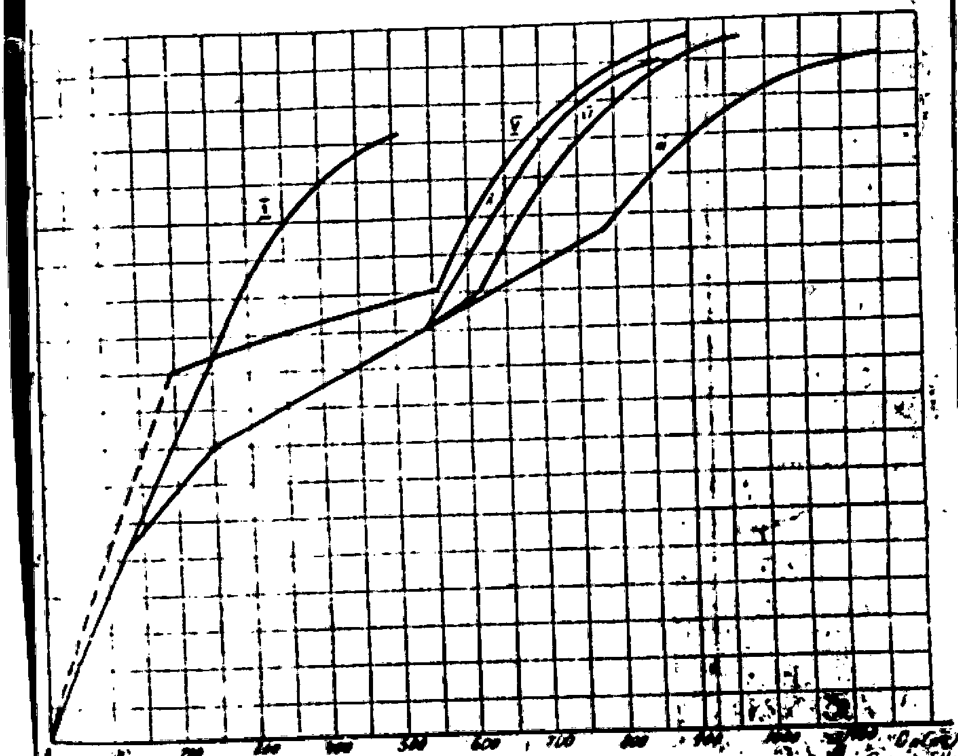
Секретно
Secret



MACH NUMBERS IN CLIMBING
Числа M при наборе высоты.

FIG. 9
Фиг.9

[redacted]

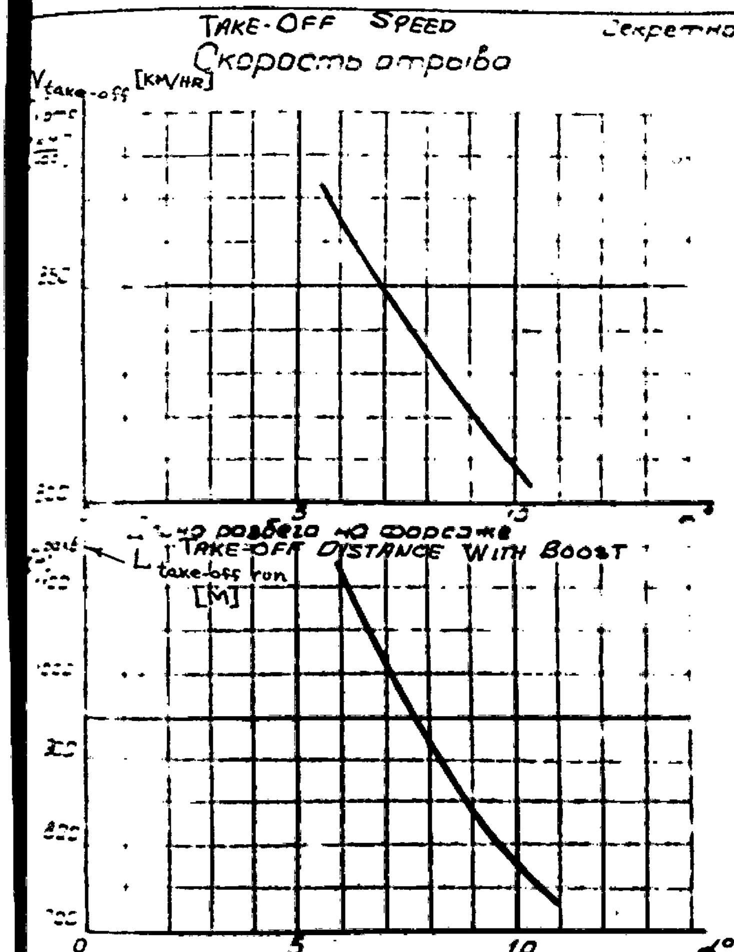


FUEL CONSUMPTION IN CLIMBING
Расход топлива при наборе высоты

FIG. 10
Фиг. 10

S-E-C-R-E-T

Секретно



TAKE-OFF SPEED AND TAKE-OFF DISTANCE AS A FUNCTION OF THE ANGLE OF ATTACK IN TAKE-OFF

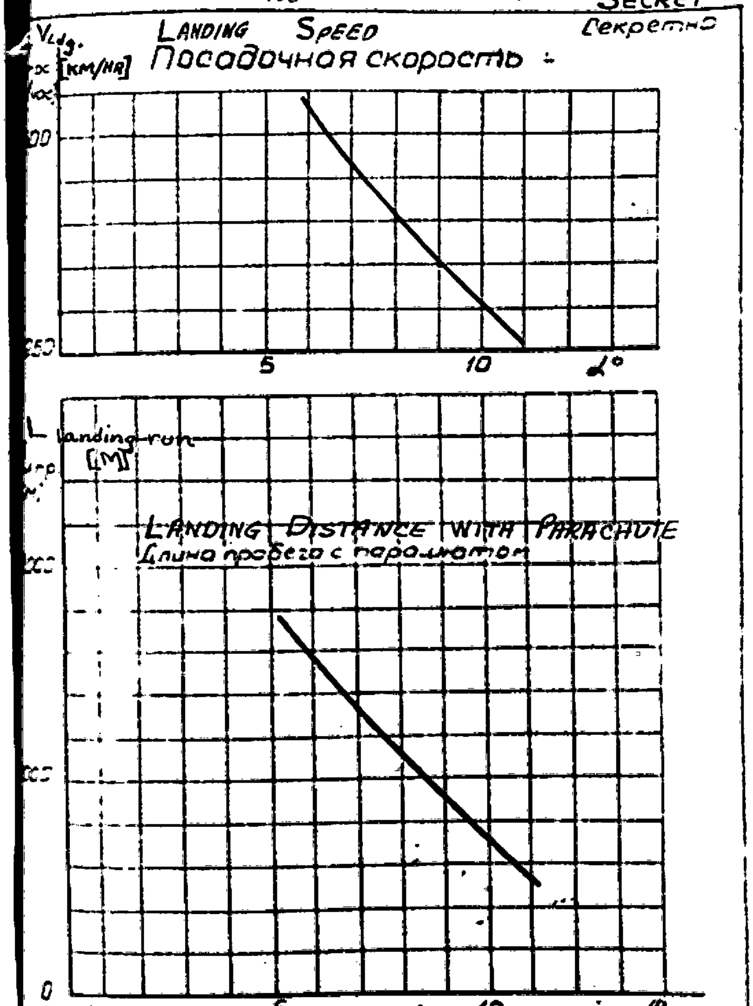
Зависимость скорости отрыва и длины разбега от угла атаки на взлете.

FIG. 11
Фиг. 11

S-E-C-R-E-T

[redacted]

SECRET
Секретно

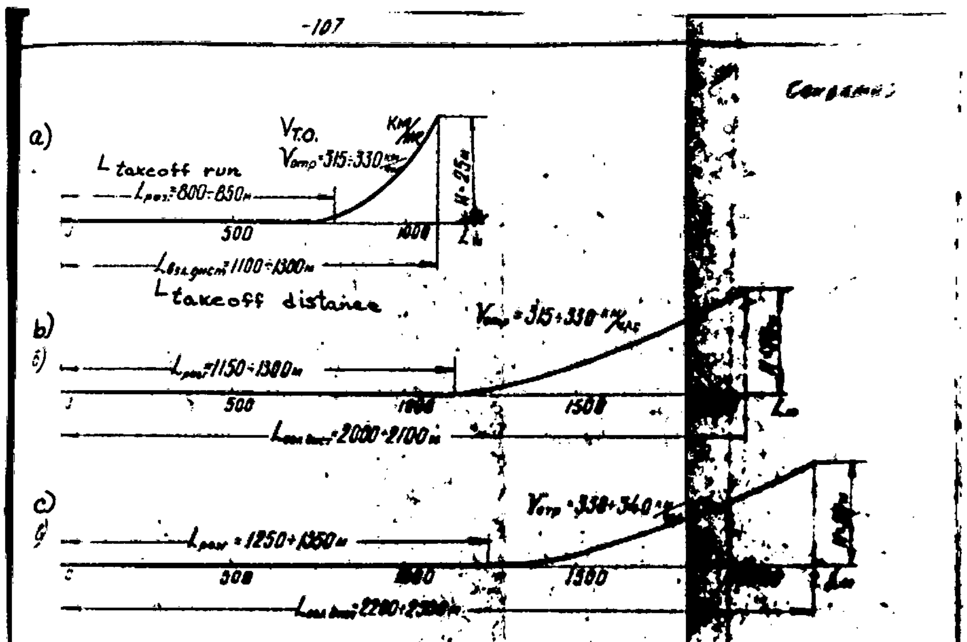


LANDING SPEED AND LANDING DISTANCE AS A FUNCTION OF THE ANGLE OF ATTACK ON LANDING
Зависимость посадочной скорости и длины пробега от угла атаки на посадке.

FIG. 12
Фиг. 12

[redacted]

[redacted]



DATA ON AIRCRAFT TAKE-OFF DISTANCE
Данные взлетной дистанции самолета

AT MAXIMUM REHEAT RATING OF THE ENGINE
a) а) на форсажном режиме работы двигателя
FLAP ANGLE = δ_3 = 24.5° $G_{взл}$ = 7310 кг = TAKE-OFF WEIGHT, Kg

AT MAXIMUM RATING OF THE ENGINE
b) б) на максимальном режиме работы двигателя
FLAP ANGLE = δ_3 = 24.5° $G_{взл}$ = 7310 кг = TAKE-OFF WEIGHT, Kg

AT MAXIMUM RATING OF THE ENGINE WITH DROP TANK
c) в) на максимальном режиме работы двигателя с подвесными баками
FLAP ANGLE = δ_3 = 24.5° $G_{взл}$ = 7780 кг = TAKE-OFF WEIGHT, Kg

Fig. 13
Фиг. 13

[redacted]

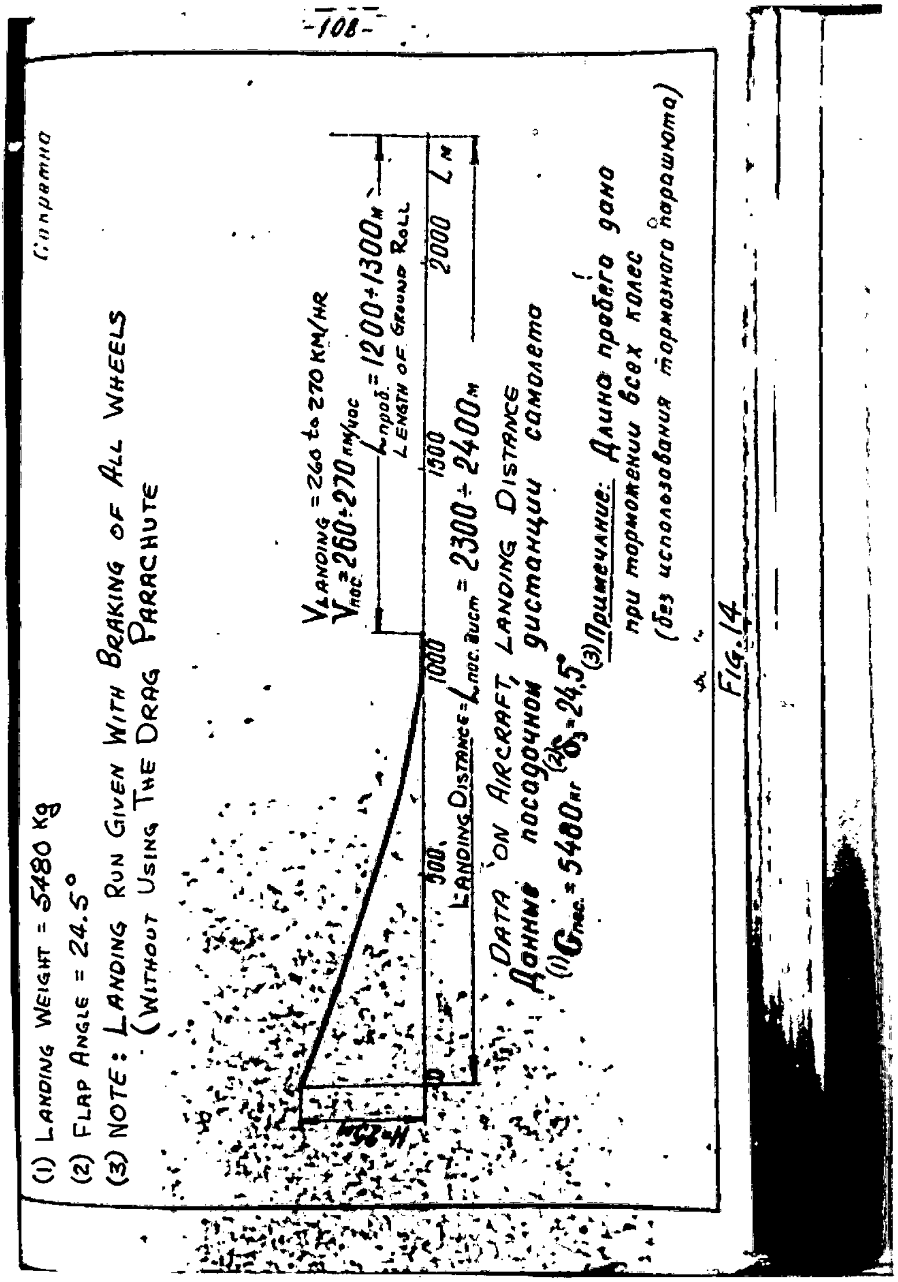
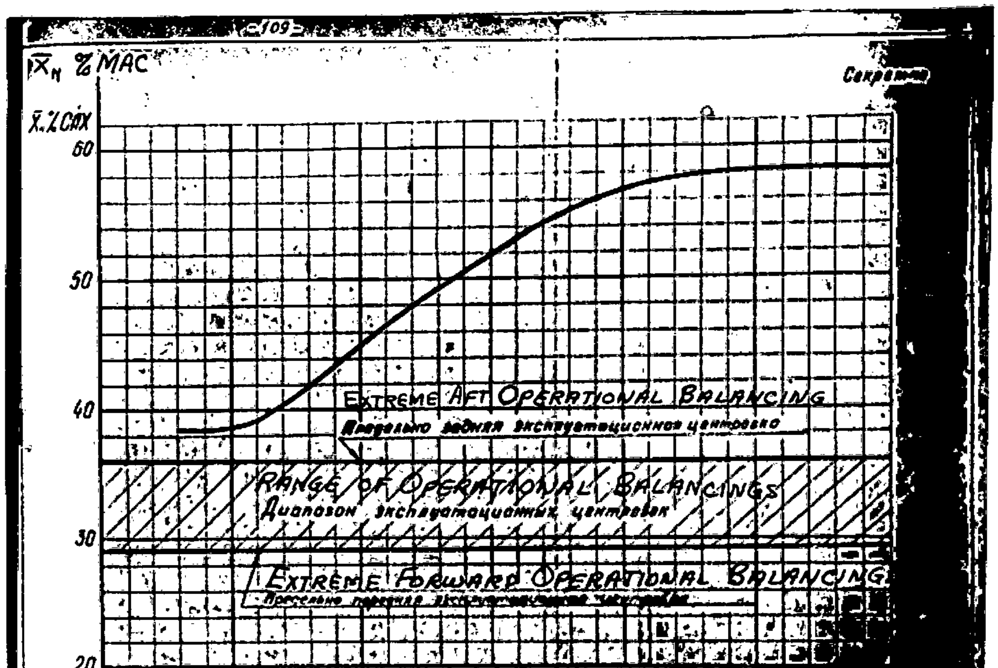

-108-
Секретно
(1) LANDING WEIGHT = 5480 Kg
(2) FLAP ANGLE = 24.5°
(3) NOTE: LANDING RUN GIVEN WITH BRAKING OF ALL WHEELS (WITHOUT USING THE DRAG PARACHUTE
V LANDING = 260 to 270 KM/HR
Vпос = 260÷270 км/час
Lпроб = 1200÷1300м
LENGTH OF GROUND ROLL
0
500
1000
1500
2000
L м
LANDING DISTANCE = Lпос.дист = 2300 ÷ 2400м
DATA ON AIRCRAFT, LANDING DISTANCE
Данные посадочной дистанции самолета
(1) Gпос = 5480кг (2) δз = 24,5°
(3) Примечание: Длина пробега дана при торможении всех колес (без использования тормозного парашюта)

Fig. 14

S-E-C-R-E-T

[redacted]

50X1-HUM
50X1



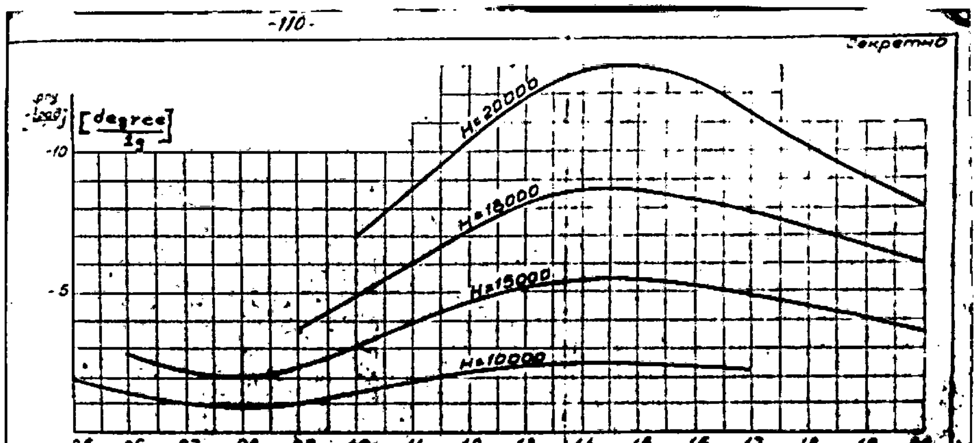
NEUTRAL BALANCING OF AIRCRAFT WITH RUNNING ENGINES
Зависимость нейтральной центровки самолета
FLIGHT MACH NUMBER
числа M полета

Фиг. 15
FIG. 15

S-E-C-R-E-T

[redacted]

50X1-HUM

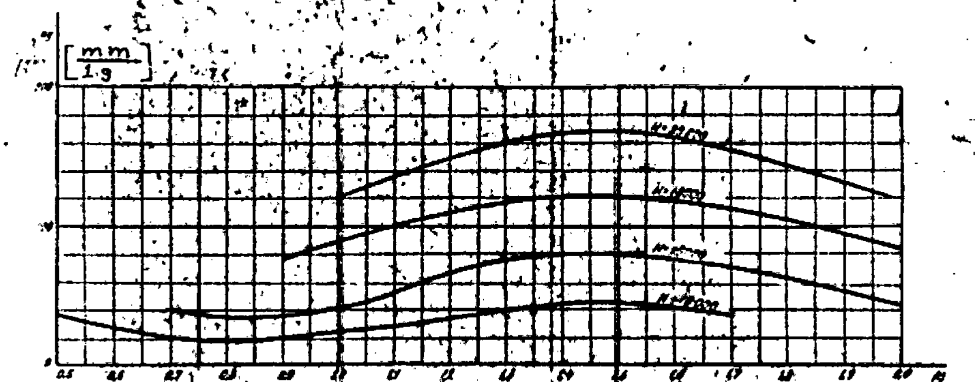


STABILIZER DEFLECTION ANGLES NECESSARY TO PRODUCE A UNIT OVERLOAD

Углы отклонения стабилизатора, потребные для создания единичной перегрузки

x_T = 30.5 ÷ 32.5% CAX (MAC); G/S = 260 ÷ 280 kg/m², KG/M²

FIG. 16



DISPLACEMENT OF CONTROL STICK REQUIRED FOR A UNIT OVERLOAD

MAC KG/M²

FIG. 17

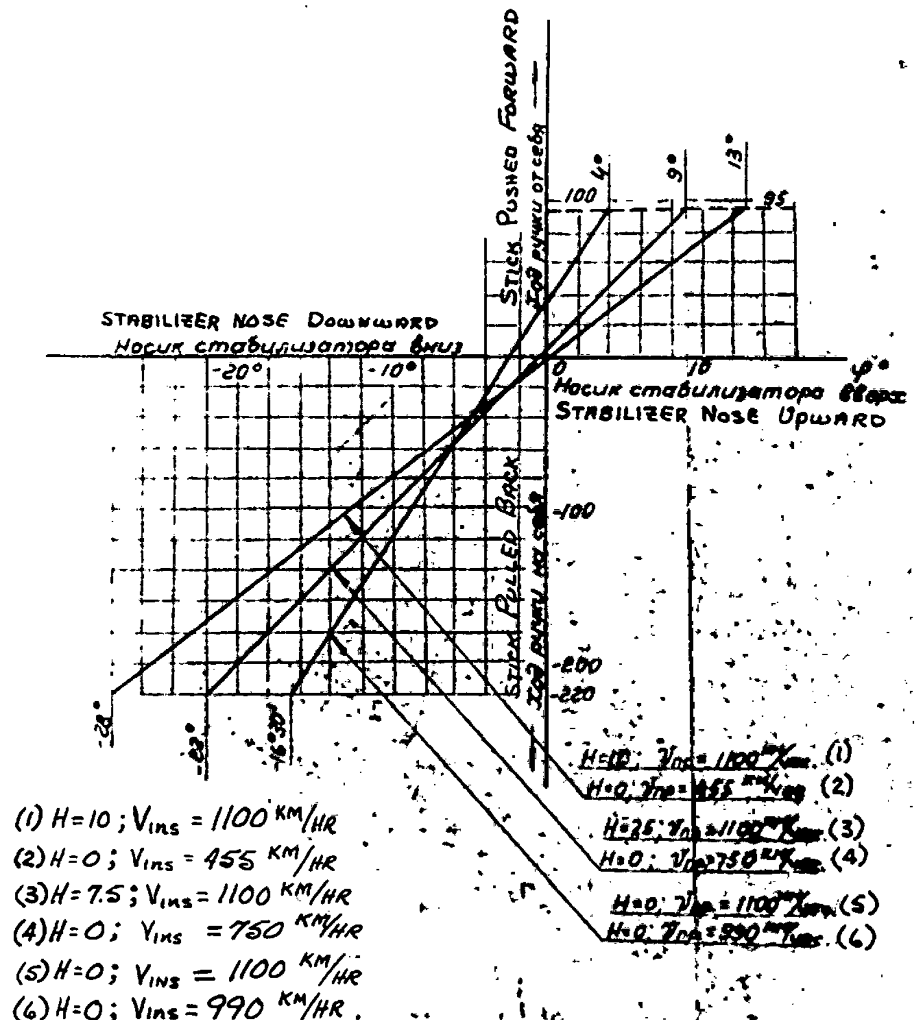
S-E-C-R-E-T

50X1-HUM

50X1

CHANGE IN STABILIZER DEFLECTION ANGLES ACCORDING TO STICK MOVEMENT IN RELATION TO INDICATED SPEED AND FLIGHT ALTITUDE

Изменение углов отклонения стабилизатора по ходу ручки в зависимости от приборной скорости и высоты полёта.

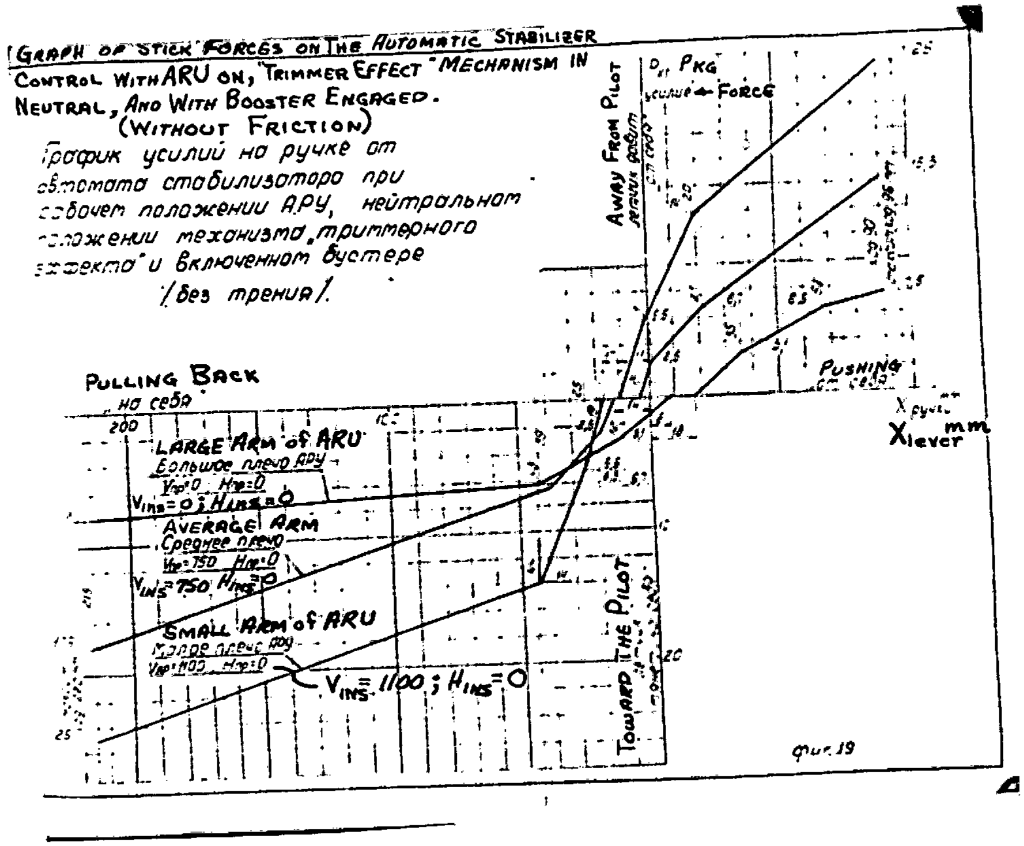


Фиг. 18

FIG. 18

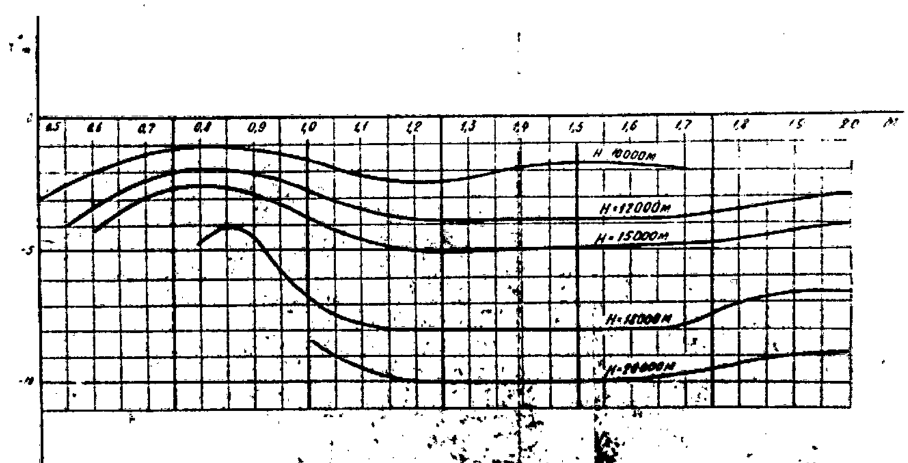
S-E-C-R-E-T

50X1-HUM


GRAPH OF STICK FORCES ON THE AUTOMATIC STABILIZER CONTROL WITH ARU ON, TRIMMER EFFECT MECHANISM IN NEUTRAL, AND WITH BOOSTER ENGAGED. (WITHOUT FRICTION)
График усилий на ручке от автомата стабилизатора при рабочем положении АРУ, нейтральном положении механизма триммерного эффекта и включенном бустере /без трения/.
AWAY FROM PILOT
PKG
FORCE
PULLING BACK
на себя
PUSHING
от себя
200
LARGE ARM OF ARU
Большое плечо АРУ
$V_{INS}=0$; $H_{INS}=0$
AVERAGE ARM
Среднее плечо
$V_{INS}=750$ $H_{INS}=0$
SMALL ARM OF ARU
Малое плечо АРУ
$V_{INS}=1100$; $H_{INS}=0$
TOWARD THE PILOT
X_{lever} mm
фиг.19

[redacted]

50X1-HUM
50X1



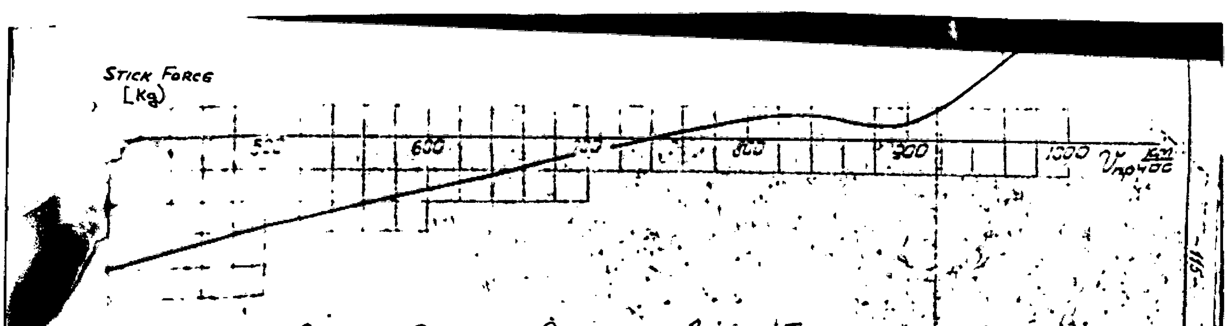
STABILIZER DEFLECTION ANGLES IN STRAIGHT AND LEVEL FLIGHT

$\bar{X}_T$ = 30.5 to 32.5 % MAC ; G/S = 250 to 280 Kg/M²

FIG. 20

[redacted]

50X1-HUM



Forces on Control Stick in Climbing After Take-Off

[illegible]ия на ручке управления при наборе высоты после взлета

Фиг 20а

Fig. 20a

50X1-HUM

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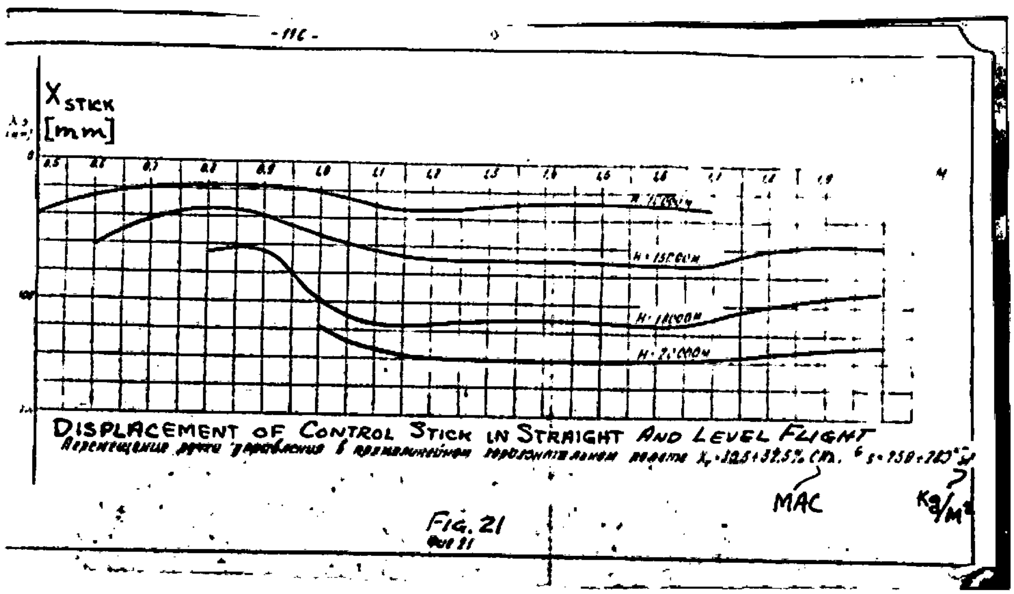
[redacted]

50X1-HUM

50X1

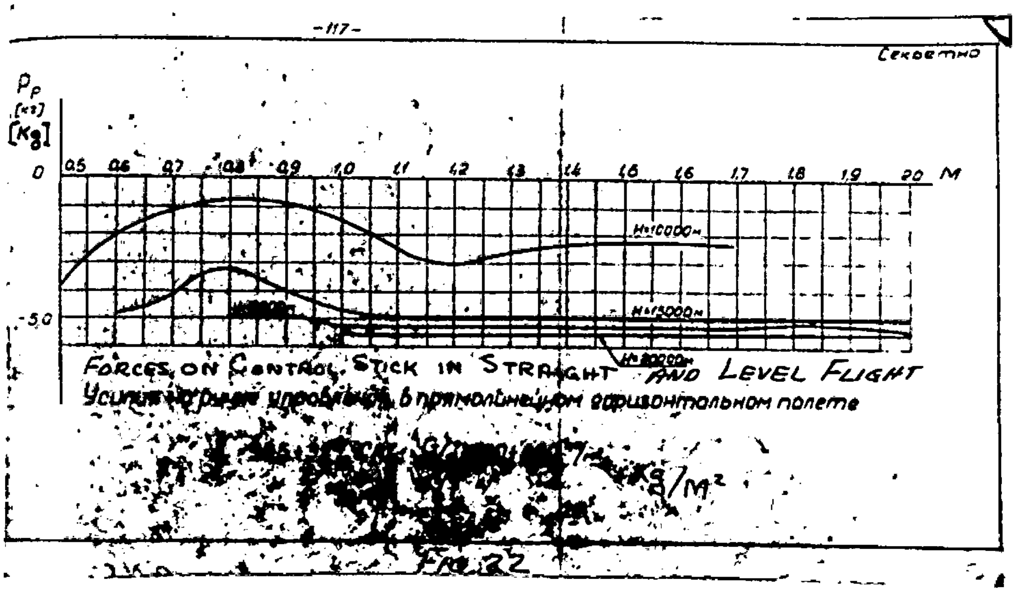


DISPLACEMENT OF CONTROL STICK IN STRAIGHT AND LEVEL FLIGHT

MAC

Kg/M²

FIG. 21



FORCES ON CONTROL STICK IN STRAIGHT AND LEVEL FLIGHT

Усилия на ручке управления в прямолинейном горизонтальном полете

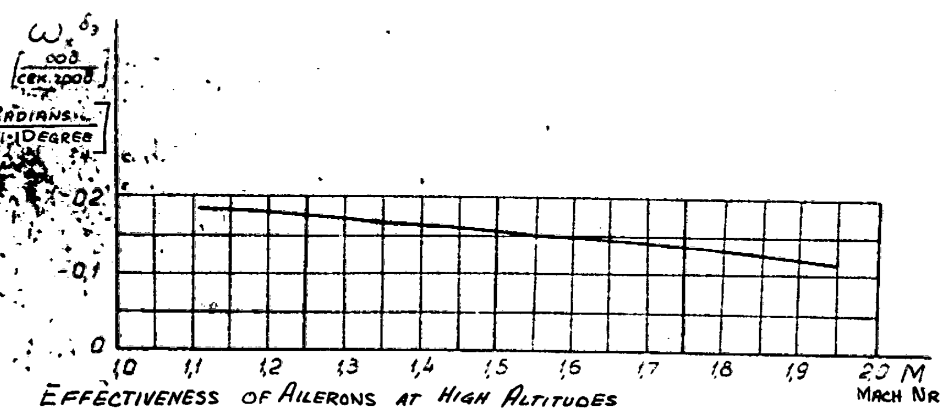
Kg/M²

FIG. 22

[redacted]

50X1-HUM

50X1-HUM



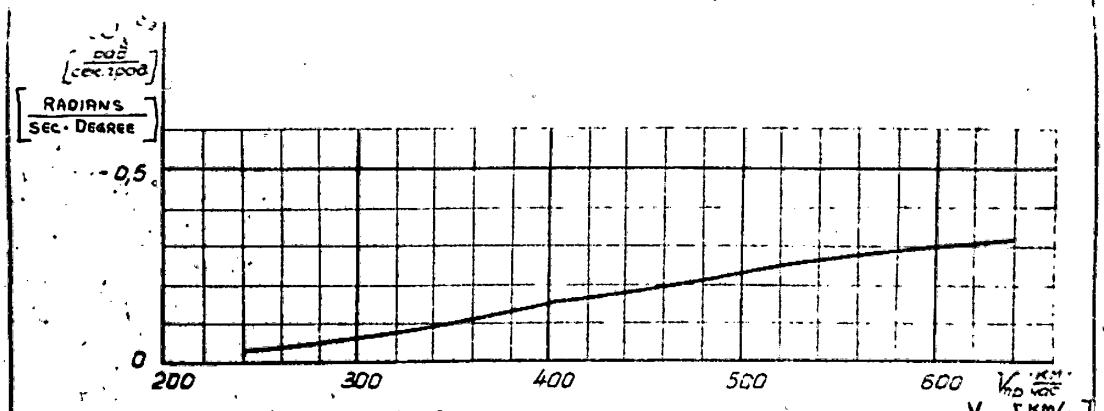
Effectiveness of Ailerons at High Altitudes

Эффективность элеронов на больших высотах ($H \geq 11000$ м)

Fig. 23

S-E-C-R-E-T

50X1-HUM



EFFECTIVENESS OF AILERONS AT 5000 m ALTITUDE

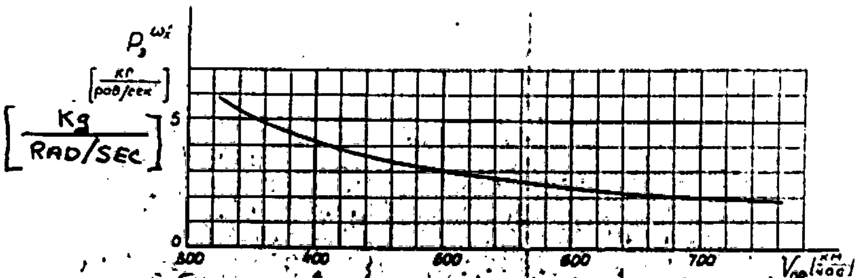
Эффективность элеронов на высоте H=5000 м

FIG. 24

Фиг 24

-120-

(1) FORCES ON STICK NECESSARY TO PRODUCE A RATE OF ROLL OF 1 RAD/SEC AT AN ALTITUDE OF 5000 m.



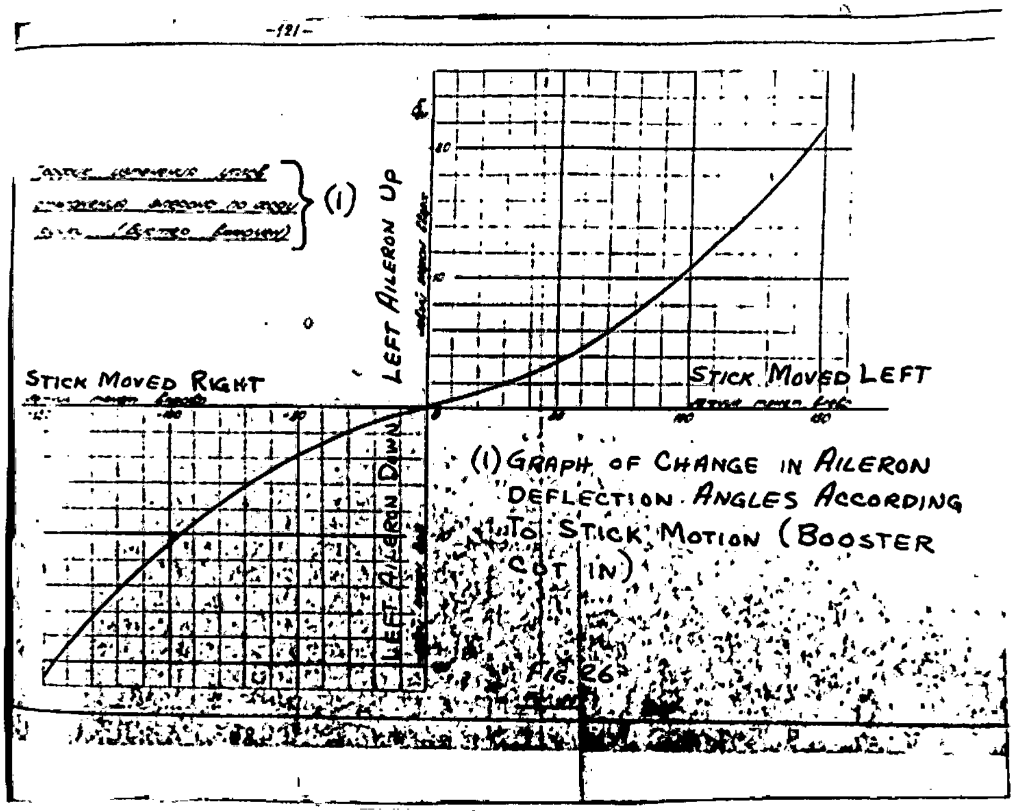
(1) {Усилия на ручке, потребные для создания угловой скорости крена в 1 рад/сек на высоте 5000 м.

FIG. 25

Фиг. 25

 50X1-HUM

[redacted] 50X1



(1) Graph of Change in Aileron Deflection Angles According To Stick Motion (Booster Cut In)

Fig. 26

[redacted] 50X1-HUM

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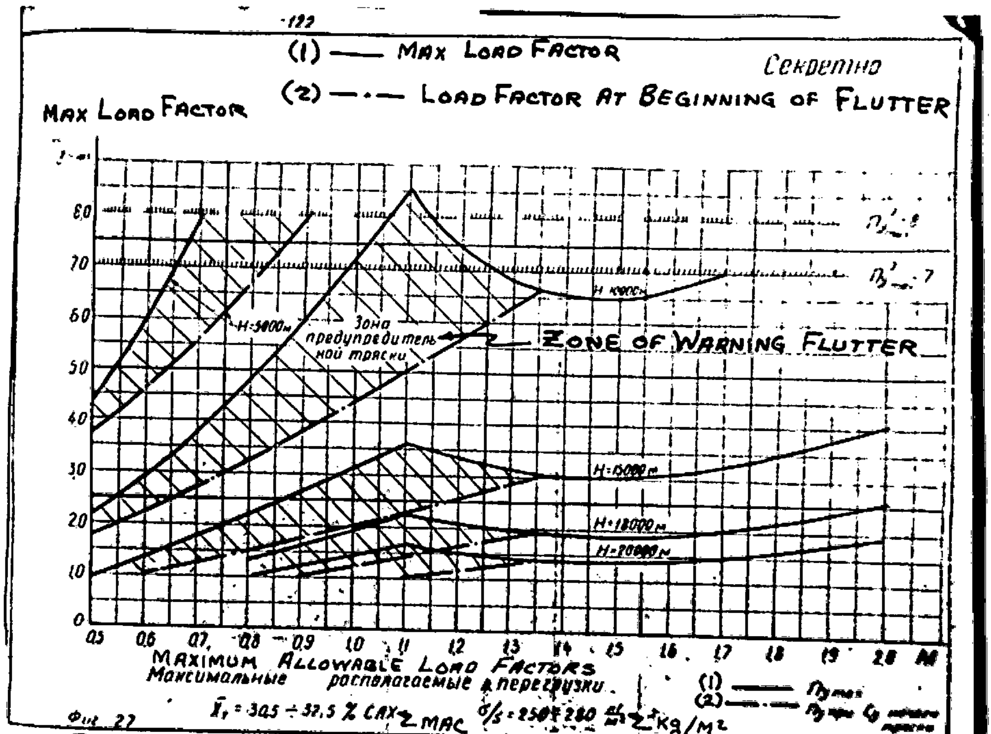

-122
(1) —— MAX LOAD FACTOR
(2) —·— LOAD FACTOR AT BEGINNING OF FLUTTER
Секретно
MAX LOAD FACTOR
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0
H:5000м
H 10000м
Зона предупредительной тряски
ZONE OF WARNING FLUTTER
H:15000м
H:18000м
H:20000м
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
1,3
1,4
1,5
1,6
1,7
1,8
1,9
2,0
M
MAXIMUM ALLOWABLE LOAD FACTORS
Максимальные располагаемые перегрузки.
$\bar{X}_T$ = 30,5 ÷ 32,5 % CAX = MAC
G/S = 250 ÷ 280 кг/м² = Kg/M²
Фиг. 27

FIG. 27

[redacted] 50X1-HUM

[redacted] 50X1

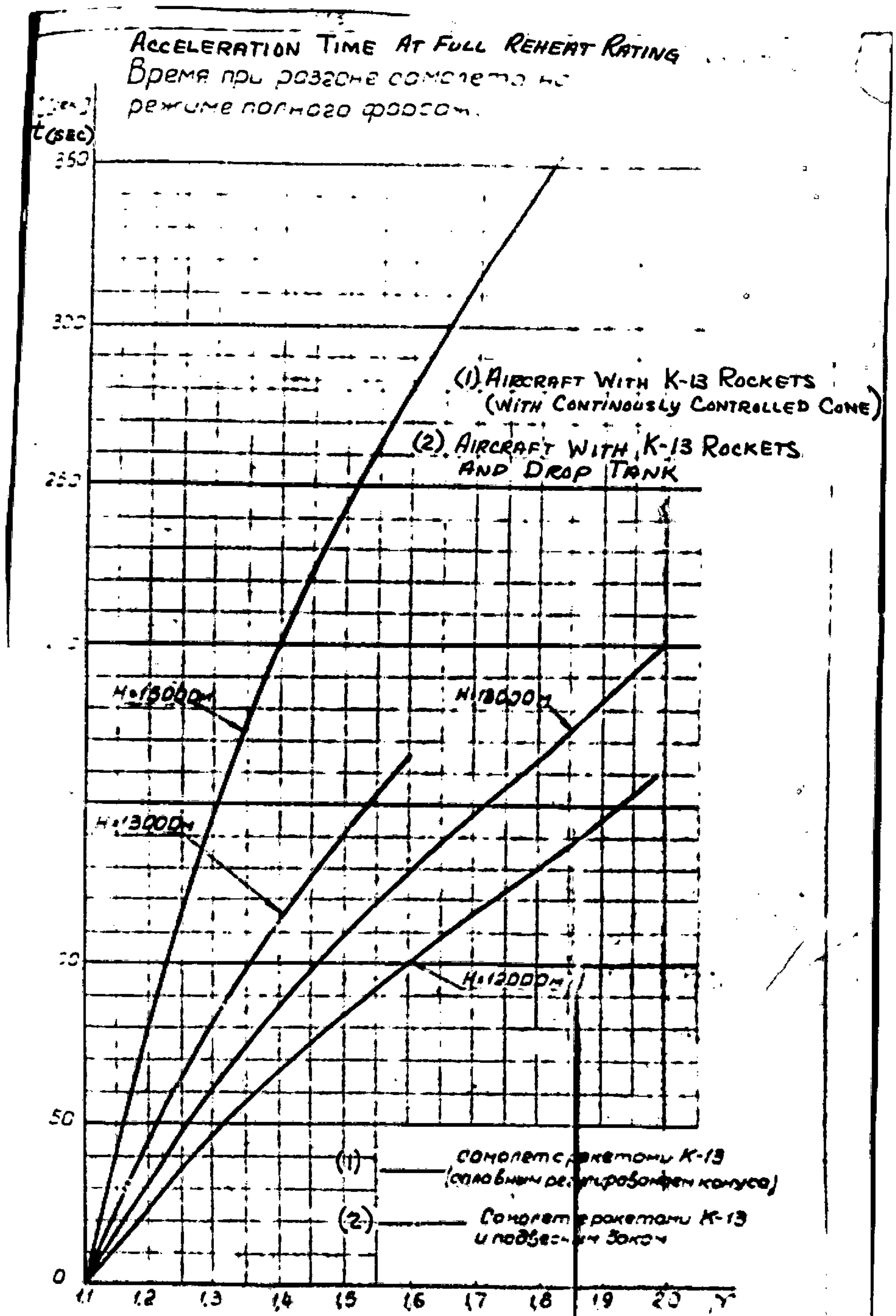


FIG. 28
Фиг 28

[redacted] 50X1-HUM

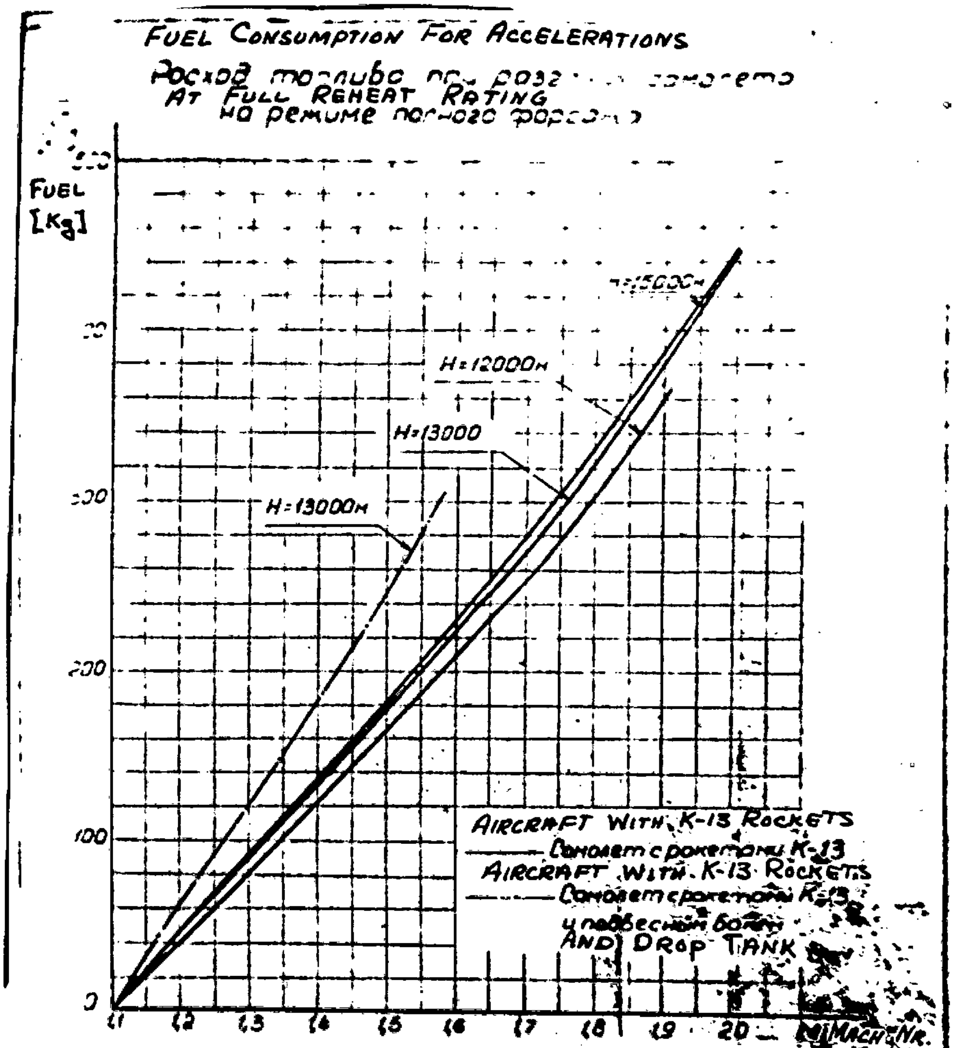

FUEL CONSUMPTION FOR ACCELERATIONS
AT FULL REHEAT RATING
FUEL [Kg]
H=15000м
H=12000м
H=13000
H=13000м
AIRCRAFT WITH K-13 ROCKETS
Самолет с ракетами K-13
AIRCRAFT WITH K-13 ROCKETS
Самолет с ракетами K-13
и подвесным баком
AND DROP TANK
0
100
200
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
M MACH NR.

FIG. 29
Фиг 29

50X1-HUM

50X1

Секретно

DISTANCE DURING ACCELERATION
Путь при разгоне самолета
AT FULL REHEAT RATING
на режиме полного форсажа

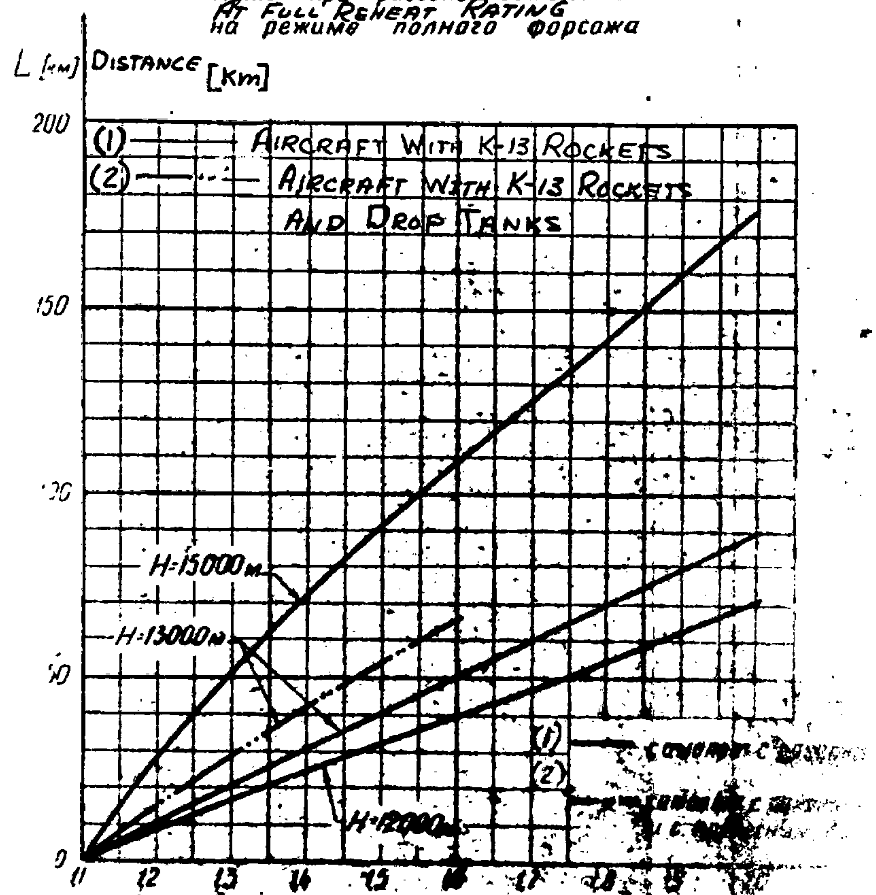
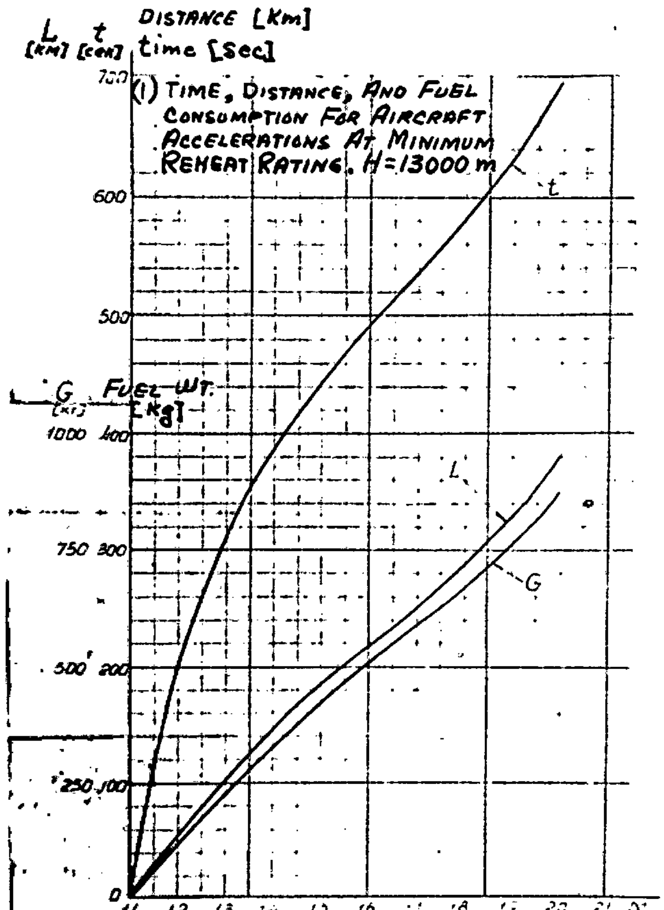


FIG. 30
Фиг. 30

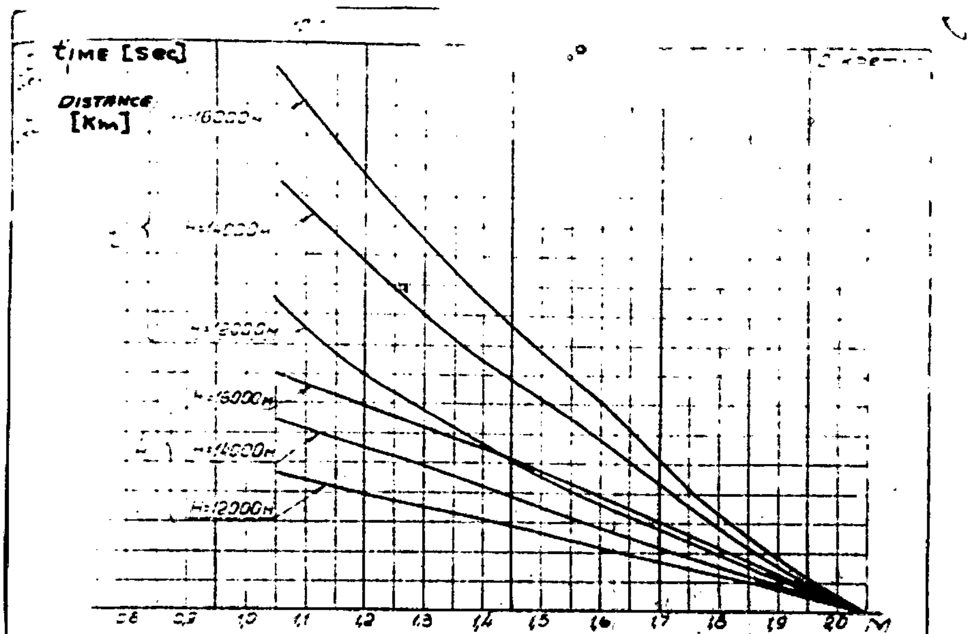
50X1-HUM



(I) Время, путь и расход топлива при разгонах самолета на режиме минимального форсажа H=13000 м

Фиг. 31

FIG. 31



TIME AND DISTANCE FOR AIRCRAFT BRAKING

Время и путь при торможении самолета

(до M=1,5 на максимале, далее на малом газе)

(TO M=1.5 AT MAXIMUM, FURTHER AT IDLING SPEED)

FIG. 32

Фиг.32

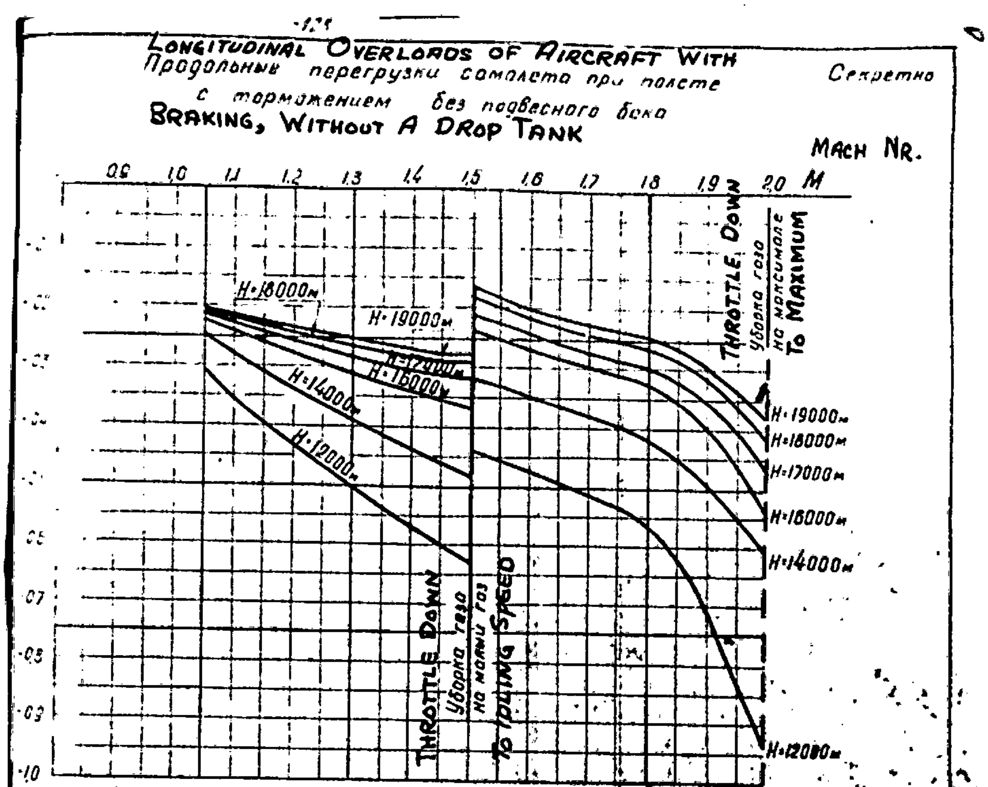
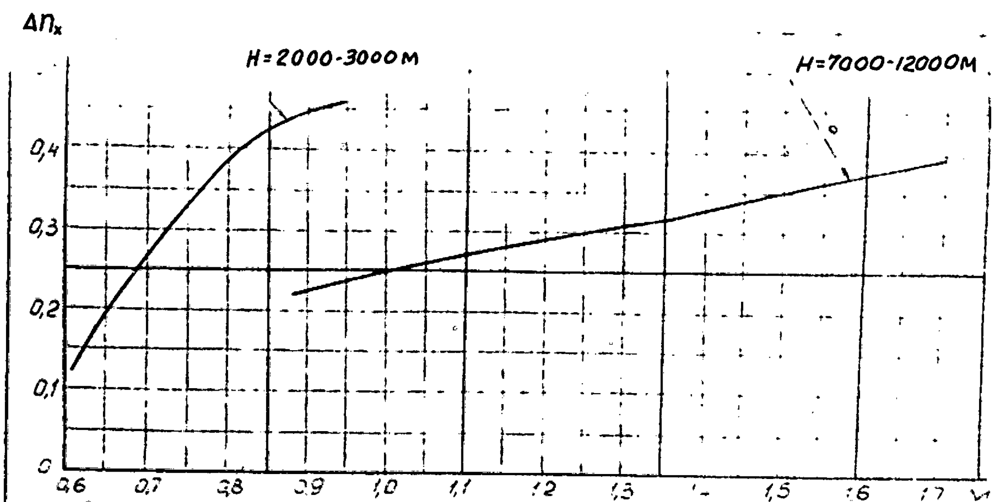

LONGITUDINAL OVERLOADS OF AIRCRAFT WITH
Продольные перегрузки самолета при полете
с торможением без подвесного бака
BRAKING, WITHOUT A DROP TANK
Секретно
MACH NR.
M
H=18000м
H=19000м
H=17000м
H=16000м
H=14000м
H=12000м
THROTTLE DOWN
Уборка газа на малый газ
TO IDLING SPEED
THROTTLE DOWN
Уборка газа на максимале
TO MAXIMUM
H=19000м
H=18000м
H=17000м
H=16000м
H=14000м
H=12000м
n_x

FIG. 33
Фиг. 33

50X1-HUM

50X1-HUM



Зависимость изменения продольной перегрузки при выпуске

CHANGE IN LONGITUDINAL OVERLOAD ON RELEASE OF AIRBRAKES
IN RELATION TO FLIGHT MACH NUMBER

FIG. 34

S-E-C-R-E-T

50X1

S-E-C-R-E-T

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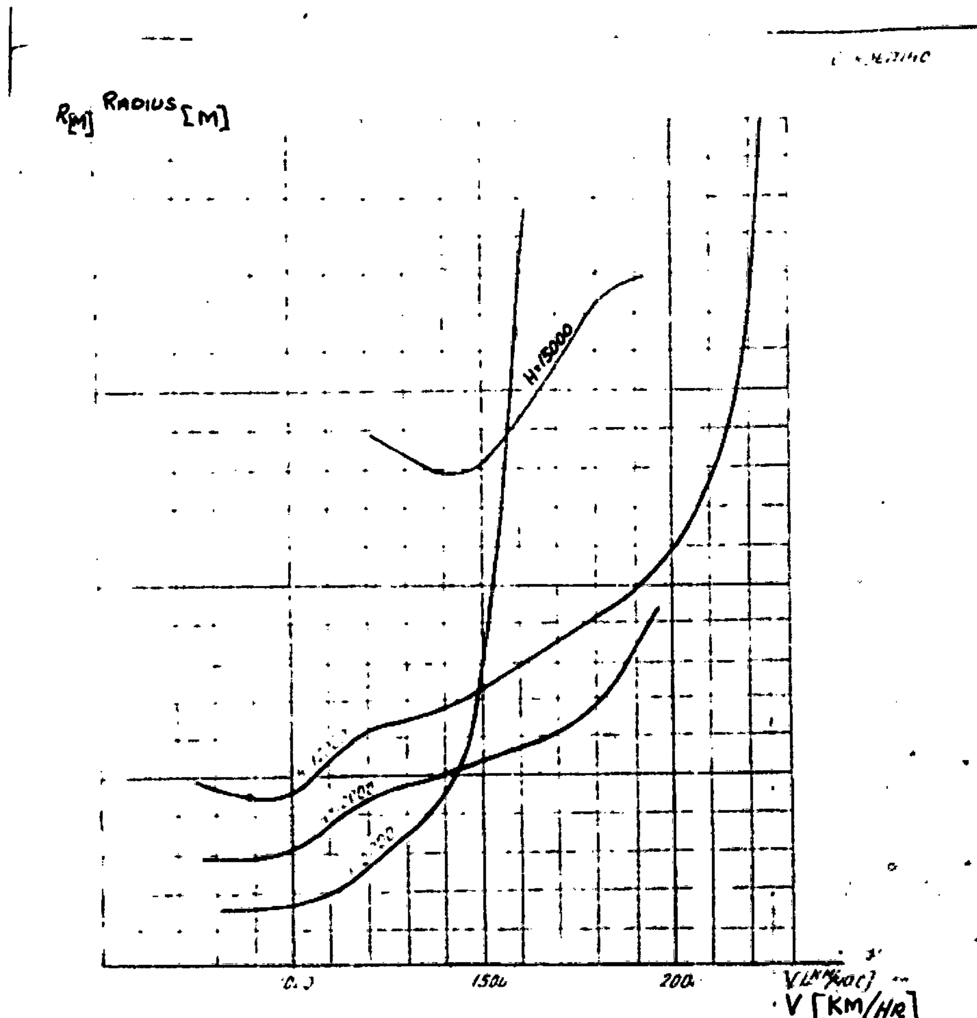
[redacted] 50X1-HUM

[redacted] 50X1



радиус установившегося виража на режиме полного форсажа

RADIUS OF STEADY TURN AT FULL REHEAT RATING

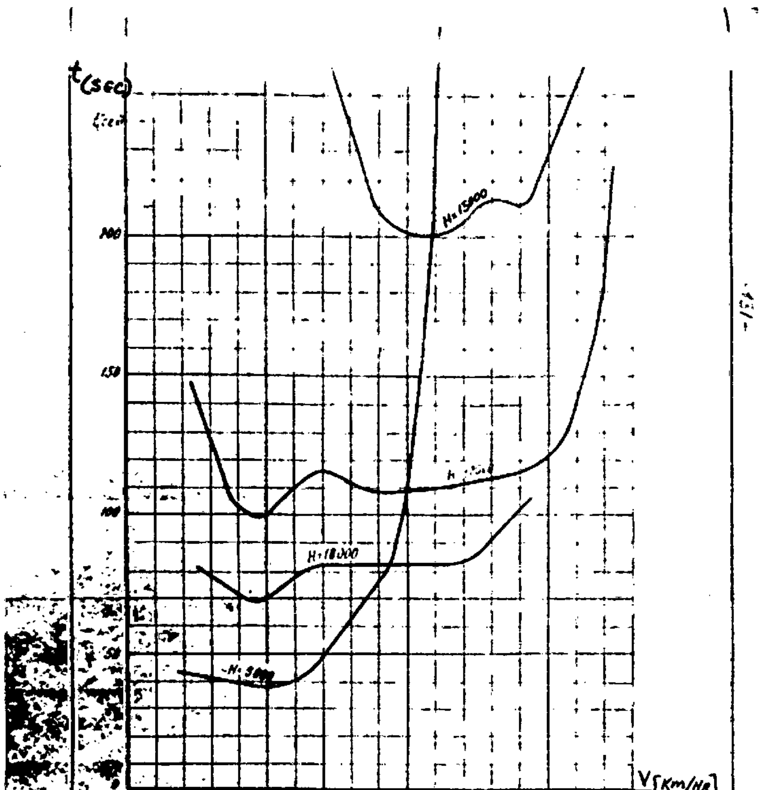
фиг 35

FIG. 35

[redacted] 50X1-HUM

50X1-HUM

50X1



TIME OF STEADY TURN AT FULL REHEAT RATING

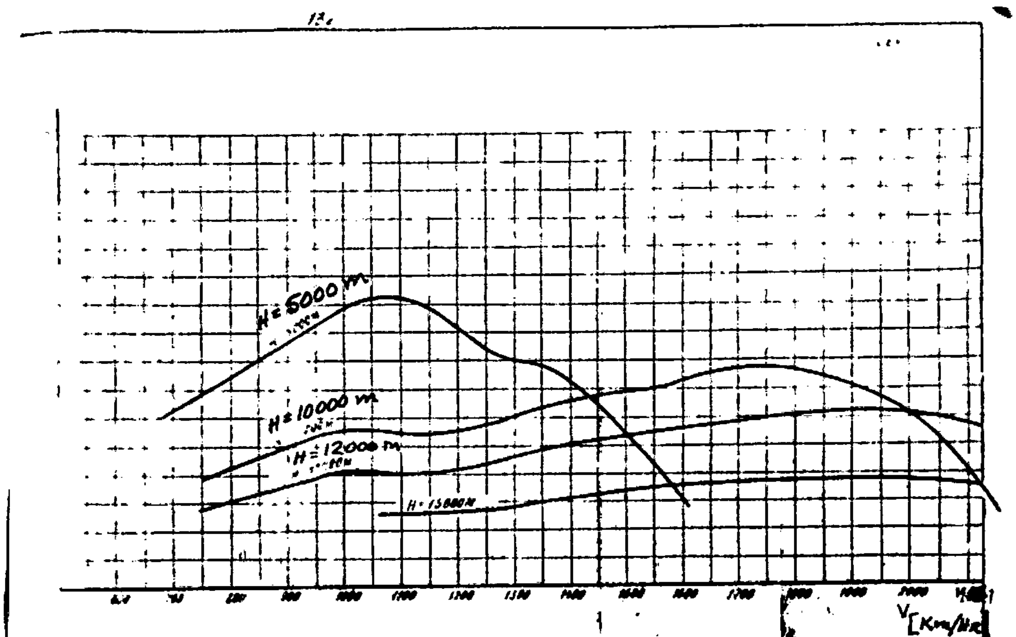
Время установившегося

FIG. 36

50X1-HUM

50X1-HUM

50X1



Установившаяся перегрузка на виражах при полёте на [illegible]

STEADY OVERLOAD ON TURNS IN FLIGHT AT FULL REHEAT RATING.

FIG. 37

50X1-HUM

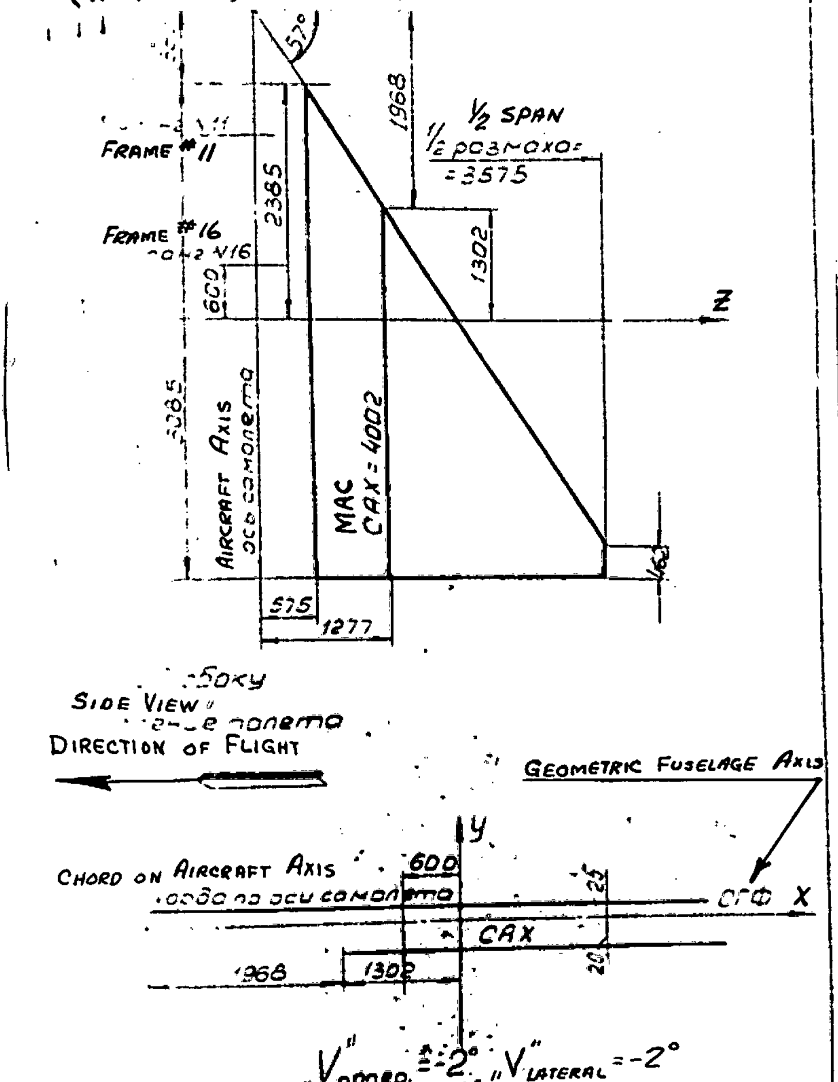
50X1-HUM

50X1

LOCATION OF MEAN AERODYNAMIC CHORD

Расположение САХ

(WING IN FLYING POSITION)



„V" попер. = -2°, „V" LATERAL = -2°

(LATERAL DIHEDRAL)

Фиг. 38

FIG. 38

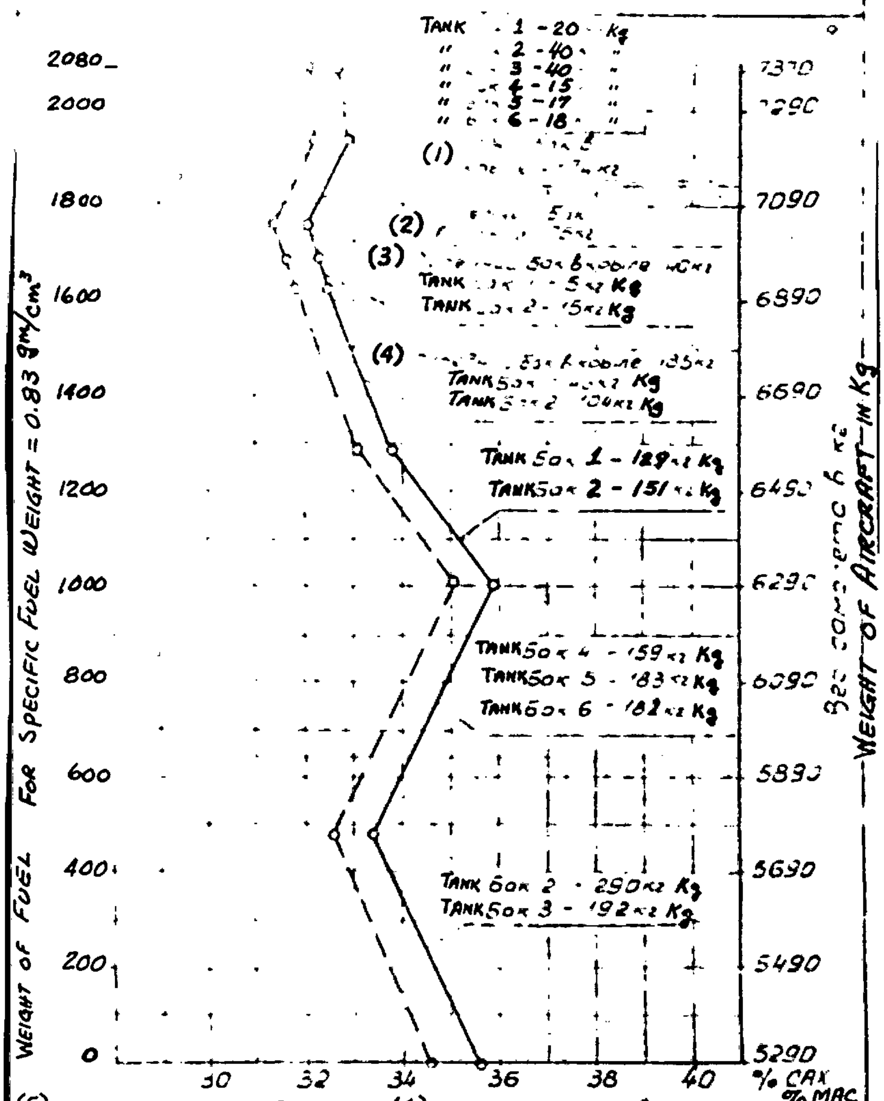
50X1-HUM

[redacted]

[redacted]

50X1-HUM
50X1

CHANGE IN BALANCING OF MIG-21F-13 DUE TO FUEL EXPENDITURE IN FLIGHT WITH NORMAL LOAD.



(5) — — шасси убрано (6) ——— шасси выпущено

(7) К-13, 2шт) смещает центровку вперед на 0,1% САХ

(8) смещает центровку назад на 0,4-0,5% САХ

FIG. 39

[redacted]

50X1-HUM

KEY TO FIGURE 39

(1) Rear wing tank - 174 kg

(2) Front wing tank - 75 kg

(3) Front wing tank - 40 kg

(4) Front wing tank - 185 kg

(5) - - - Landing gear retracted

(6) —— Landing gear extended

(7) Expenditure of K-13 rockets (2 ea) shifts the c.g. position forward by 0.1% MAC

(8) Expenditure of ammo of the NR-30 gun shifts the c.g. position rearward by 0.4 to 0.5% MAC

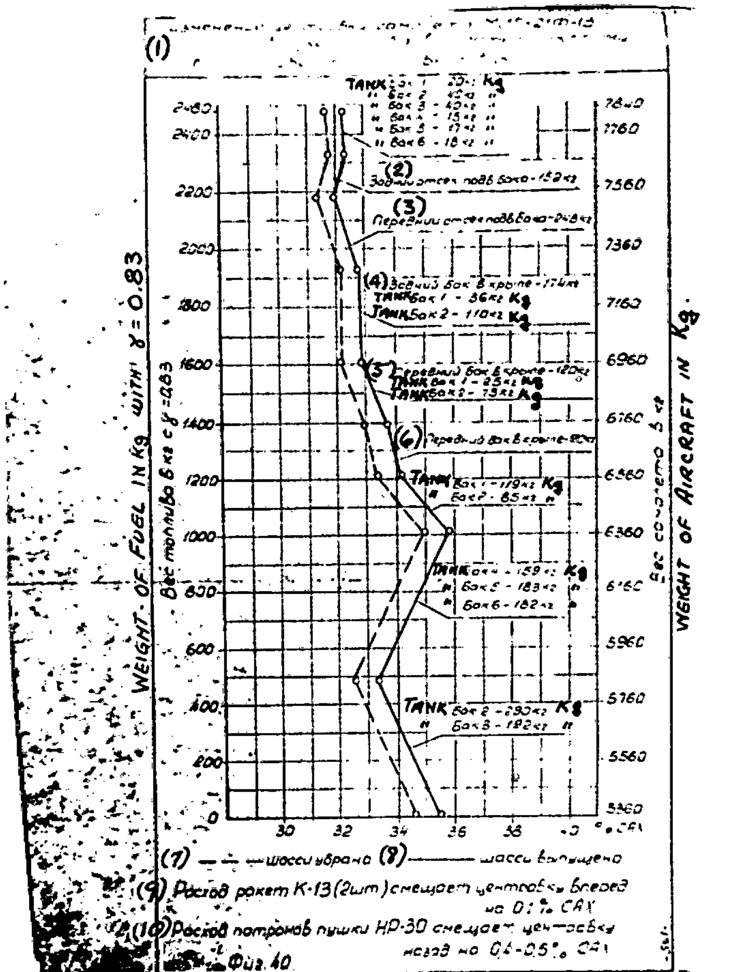

WEIGHT OF FUEL IN Kg. WITH γ = 0.83
WEIGHT OF AIRCRAFT IN Kg.
(7) шасси убрано (8) шасси выпущено
(9) Расход ракет К-13 (2шт) смещает центровку вперед на 0.1% САХ
(10) Расход патронов пушки НР-30 смещает центровку назад на 0.4-0.5% САХ
Фиг. 40

FIG. 40

KEY TO FIGURE 40

(1) Change in balancing of MiG-21F-13 due to expenditure of fuel in flight with K-13 rockets and drop tank

(2) Rear compartment of drop tank - 152 kg

(3) Front compartment of drop tank - 248 kg

(4) Rear wing tank - 174 kg

(5) Front wing tank - 120 kg

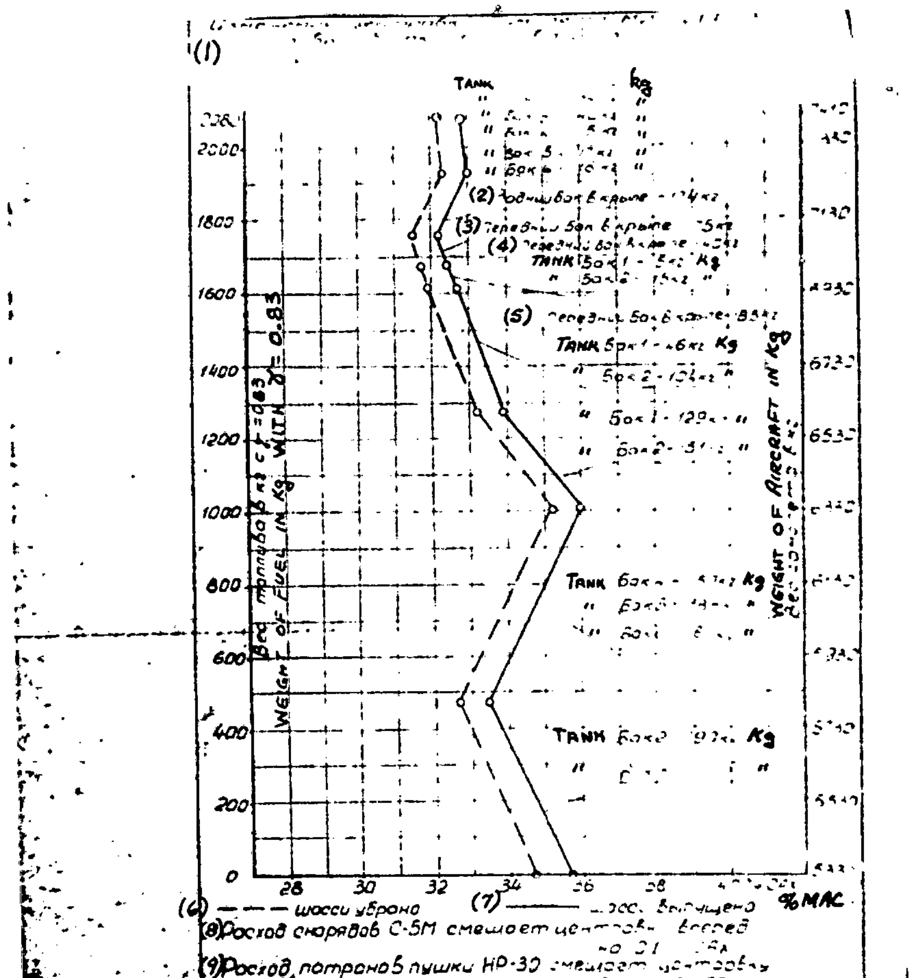
(6) Front wing tank - 180 kg

(7) - - - Landing gear retracted

(8) ——— Landing gear extended

(9) Expenditure of K-13 rockets (2 ea) shifts the c.g. forward by 0.1% MAC

(10) Expenditure of ammo of NR-30 gun shifts the c.g. rearward by 0.4 to 0.5% MAC


(1)
TANK
Kg
(2)
(3)
(4)
(5)
TANK
TANK
TANK
Вес топлива в кг с γ=0.83
WEIGHT OF FUEL IN Kg WITH γ=0.83
WEIGHT OF AIRCRAFT IN Kg
2000
1800
1600
1400
1200
1000
800
600
400
200
0
28
30
32
34
36
38
%MAC
(6) шасси убрано
(7) шасси выпущено
(8) Расход снарядов С-5М смещает центровку вперед
(9) Расход патронов пушки НР-30 смещает центровку назад на 0,4÷0,5% САХ
Фиг. 41
FIG. 41

KEY TO FIGURE 41

(1) Change in balancing of MiG-21F-13 due to expenditure of fuel in flight with unguided missiles S-5M.

(2) Rear wing tank - 174 kg

(3) Front wing tank - 75 kg

(4) Front wing tank - 40 kg

(5) Front wing tank - 185 kg

(6) - - - Landing gear retracted

(7) ——— Landing gear extended

(8) Expenditure of S-5M missiles shifts the c.g. forward by 0.1% MAC

(9) Expenditure of ammo of the NR-30 gun shifts the c.g. rearward by 0.4 to 0.5% MAC

[redacted]

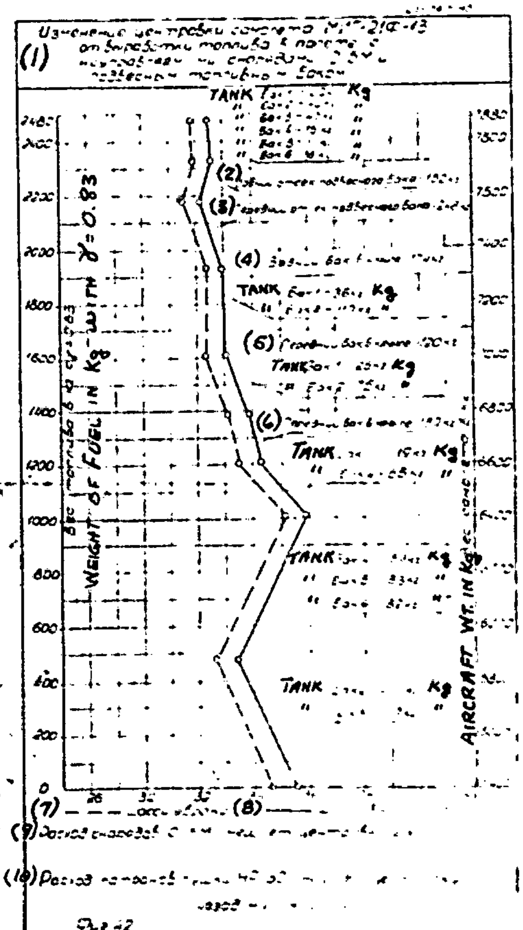


FIG. 42

[redacted]

KEY TO FIGURE 42

(1) Change in balancing of MiG-21F-13 due to expenditure of fuel in flight with unguided missiles S-5M and drop tank

(2) Rear compartment of drop tank - 152 kg

(3) Front compartment of drop tank - 248 kg

(4) Rear wing tank - 174 kg

(5) Front wing tank - 120 kg

(6) Front wing tank - 180 kg

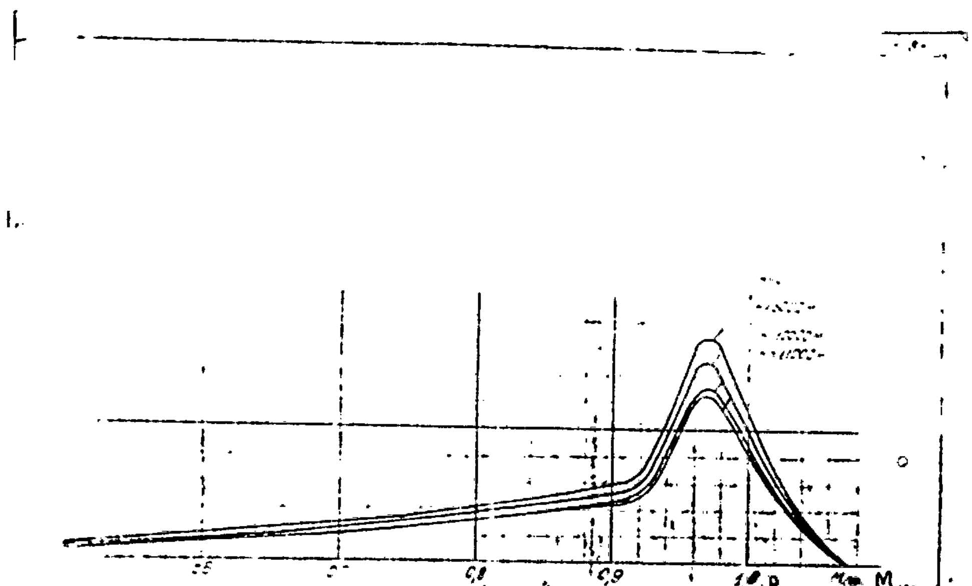
(7) - - - Landing gear retracted

(8) ——— Landing gear extended

(9) Expenditure of S-5M missiles shifts the c.g. forward by 0.1% MAC

(10) Expenditure of ammo of the NR-30 gun shifts the c.g. rearward by 0.4 to 0.5% MAC

[redacted]



TOTAL POSITION ERROR AND SHOCK WAVE CORRECTIONS TO ALTITUDE INDICATOR

FIG. 43

[redacted]

[redacted]

TOTAL POSITION ERROR AND SHOCK WAVE CORRECTIONS TO SPEED INDICATOR

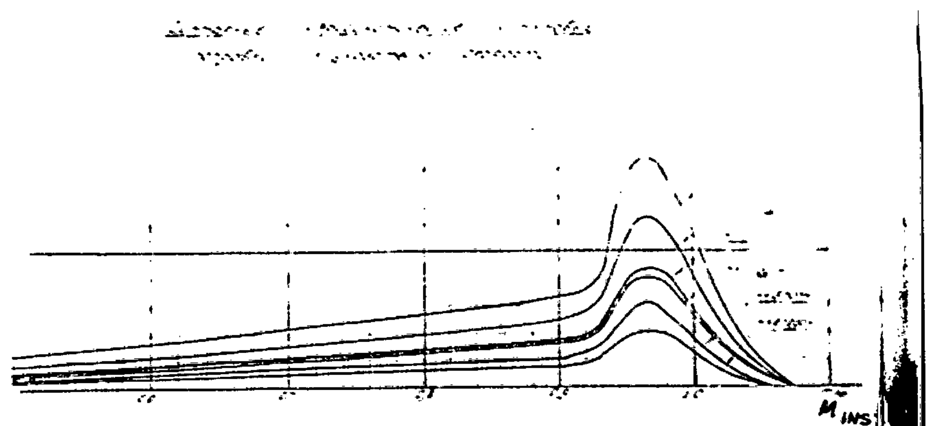
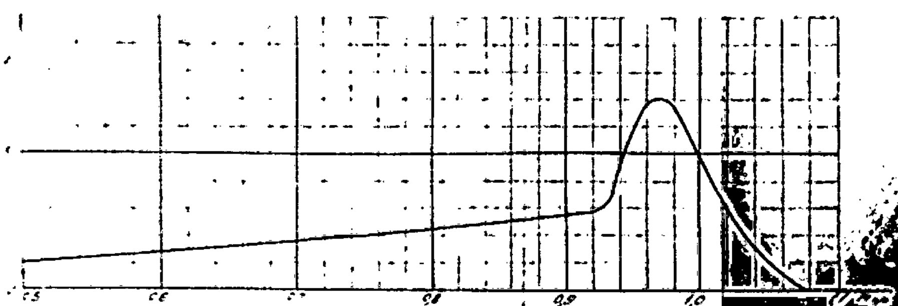


FIG. 44

[redacted]

NO [redacted]

[redacted]

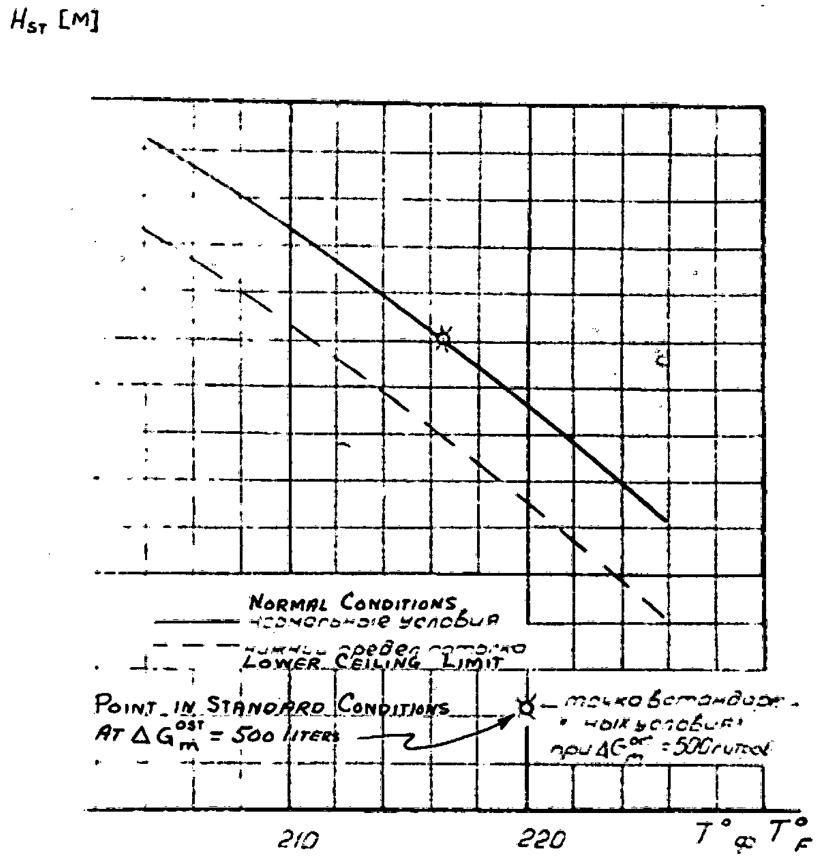


TOTAL POSITION ERROR AND SHOCK WAVE CORRECTION TO MACH NR. INDICATOR

FIG. 45

[redacted]

Секретно



STATIC CEILING VERSUS TEMPERATURE OF OUTER AIR

зависимость статического потолка от температуры наружного воздуха

$$H_{cm} = f(T^\circ_\phi)$$

$$H_{sm} = f(T^\circ_F)$$

Фиг. 46

FIG. 46

DIAGRAM FOR INSTALLATION OF SAFETY SUPPORTS

Схема установки предохранительных опор

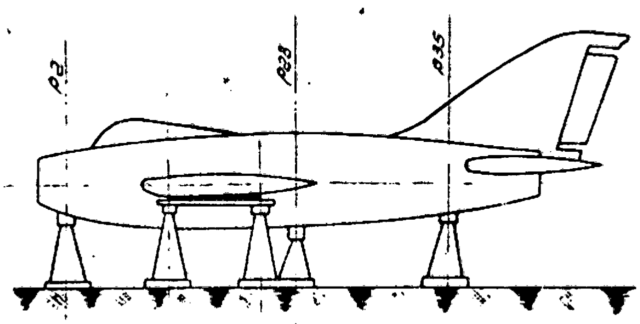


FIG. 47

S-E-C-R-E-T

50X1-HUM

50X1

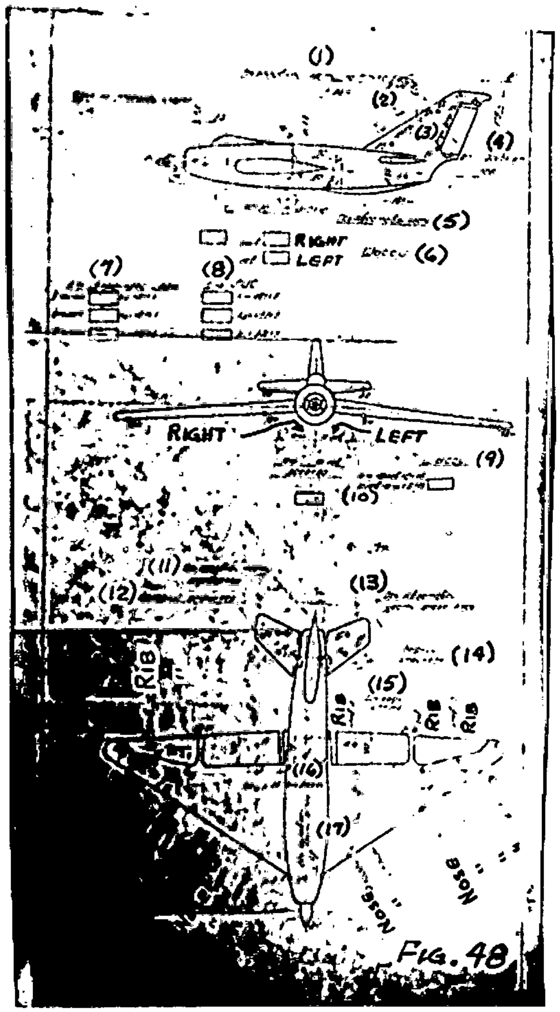


FIG. 48

S-E-C-R-E-T

50X1-HUM

KEY TO FIGURE 48

(1) Axis of the nose section (on point 1 left and 2 left)

(2) Longitudinal front stringer

(3) Longitudinal rear stringer

(4) Rudder axis of rotation

(5) Axis of the rear section

(6) Landing gear (

(7) For the assembling shop

(8) For LIS (probably flight-test personnel [Translator's note])

(9) Landing gear

(10) A right - a left = 0 + 15
A left - a right = 0 + 15

(11) Axis of the nose section of fuselage

(12) Longitudinal front stringer

(13) Axis of the rear section of fuselage

(14) Longitudinal rear stringer

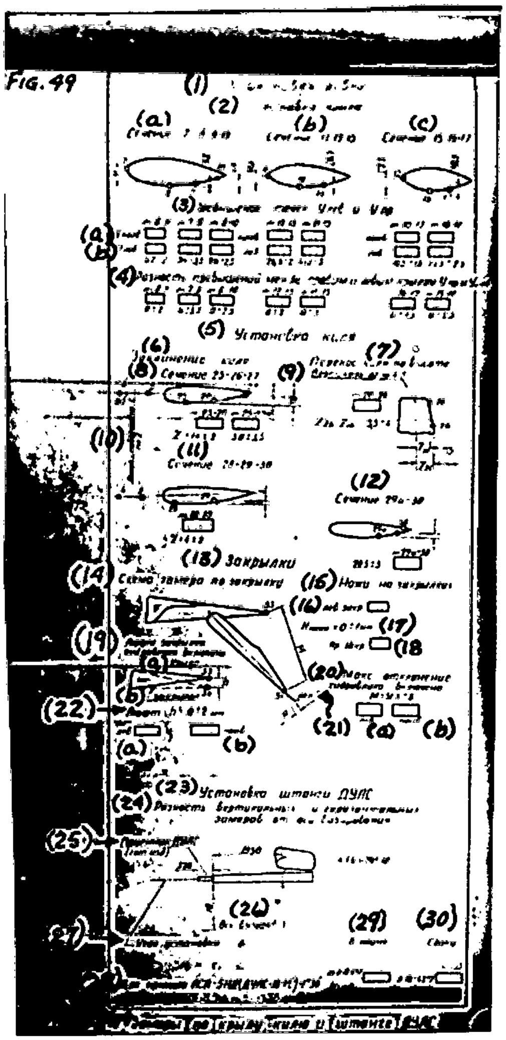
(15) Axis of the rear stringer

(16) Axis of the beam

(17) Axis of the nose section of fuselage

[redacted]

50X1-HUM
50X1



[redacted]

50X1-HUM

[redacted]

KEY TO FIGURE 49

(1) Overall leveling

(2) Wing setting
(a) to (c): section

(3) Exceeding of points Y Left and Y Right
(a): right
(d): left

(4) Difference of excesses between right and left wing Y right and Y left

(5) Setting of rudder fin

(6) Wedging of rudder fin

(7) Shift of vertical fin by altitude

(8) Section 25-26-27

(9) Vertical on p 4-5

(10) Line of leveling on Z

(11) Section 28-29-30

(12) Section 29a-30

(13) Flaps

(14) Diagram of measurement on flap

(15) Blades on flaps

(16) Left flap

(17) $H_{blade} = 0 \pm 1$ mm

(18) Right flap

(19) Play of flap - hydraulics engaged
(a) wing; (b) flap

(20) Maximum deflection - hydraulics engaged
(a) left; (b) right

[redacted]

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[redacted] 50X1-HUM

[redacted] 50X1

KEY TO FIGURE 49 (cont)

(21) "Blade"

(22) Play h = 0 ±2 mm
(a) left; (b) right

(23) Setting of DUAS sight bar

(24) Difference of vertical and horizontal measurements from axis of sighting

(25) DUAS head (ready-made item)

(26) Axis of sighting

(27) Angle of setting

(28) For the airborne gun sight ASP-5ND (DUAS 8 M) -1°30'

(29) In the plan

(30) From the side

(31) Figure 49. Measurements on the wing, vertical fin and DUAS bar

[redacted] 50X1-HUM

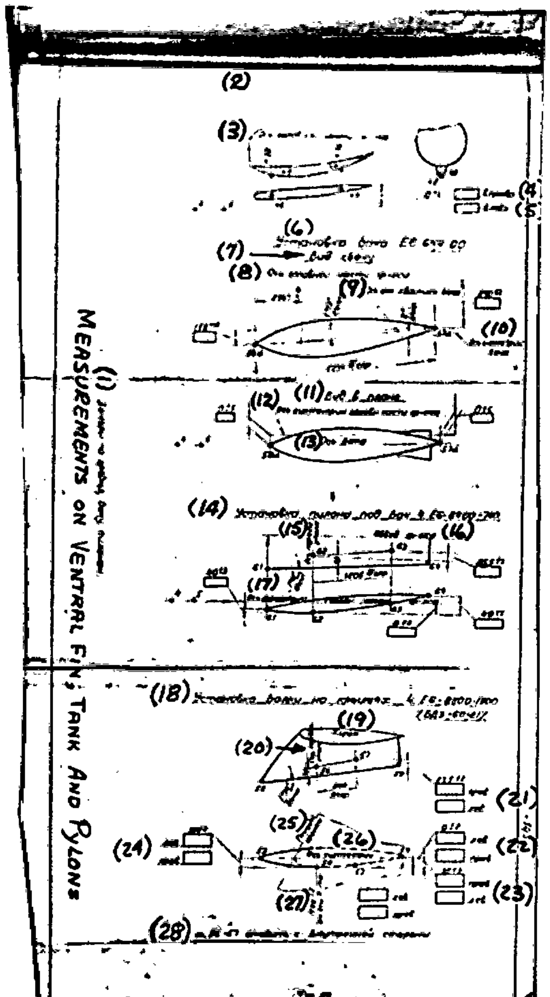

(1) MEASUREMENTS ON VENTRAL FIN, TANK AND PYLONS
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)
(16)
(17)
(18)
(19)
(20)
(21)
(22)
(23)
(24)
(25)
(26)
(27)
(28)

FIG. 50

[redacted]

KEY TO FIGURE 50

(1) Measurements on the ventral fin, tank and pylons

(2) Wedging of ventral fin

(3) Axis of fuselage nose section

(4) Rightward; (5) Leftward

(6) Setting of tank E6-6114-00

(7) Side view

(8) Axis of fuselage nose section

(9) Symmetry axis of tank tail

(10) Tank symmetry axis

(11) View in the plan

(12) Symmetry axis of fuselage nose section

(13) Tank axis

(14) Setting of pylon for tank 4 E6-8400-700

(15) Axis of front rest

(16) Fuselage outline

(17) Symmetry axis of fuselage nose section

(18) Setting of girder on wings

(19) Chord

(20) Axis of front rest

(21) Right; left

(22) Left; right

(23) Right; left

(24) Left; right

(25) Leading edge

(26) Axis of symmetry

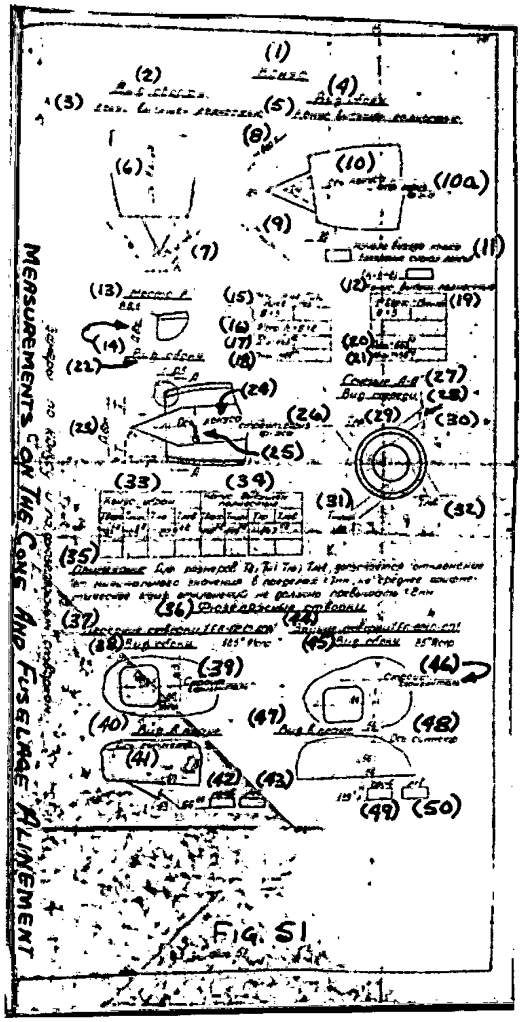
(27) From aircraft axis

(28) P. 56 - 57 set from inside

[redacted]

50X1-HUM

50X1



MEASUREMENTS ON THE CONE AND FUSELAGE ALINEMENT

FIG. 51

50X1-HUM

KEY TO FIGURE 51

(1) Cone

(2) View from above

(3) Cone fully released

(4) Side view

(5) Cone fully released

(6) Axis of entry

(7) M left

(8) M upper

(9) M lower

(10) Axis of cone

(10A) Horizontal datum line of fuselage

(11) Beginning of the cone release (signal lamp lights up)

(12) Cone fully released

(13) Place "K"

(14) D inlet

(15) M right - M left, or M left - M right

(16) 9/right h = 0 ±2

(17) Inlet D plan = 663 ±2

(18) α cone = 456 ±1

(19) M upper - M lower

(20) D side = 663 ±2

(21) α cone = 456 ±1

(22) Side view

(23) D side

(24) Cone axis

KEY TO FIGURE 51 (cont)

(25) α cone

(26) Horizontal datum line of fuselage

(27) "A-A" section

(28) Front view

(29) T right

(30) T upper

(31) T lower

(32) T left

(33) Cone retracted
T upper; T lower; T right; T left

(34) Cone fully released
T upper; T lower; T right; T left

(35) NOTE: Deviation of ±7 mm from the minimum value is permissible for dimensions T upper; T lower; T right and T left; however, the arithmetic mean of these deviations should not exceed ±2 mm

(36) Fuselage petals

(37) Front petals

(38) Side view

(39) Horizontal datum line

(40) View in the plan

(41) Axis of symmetry

(42) Right; (43) Left

(44) Rear petals /E6-0210-00/

(45) Side view 35°9/right

(46) Horizontal datum line

(47) View in the plan

(48) Axis of symmetry

(49) Right; (50) left

S-E-C-R-E-T

-141-

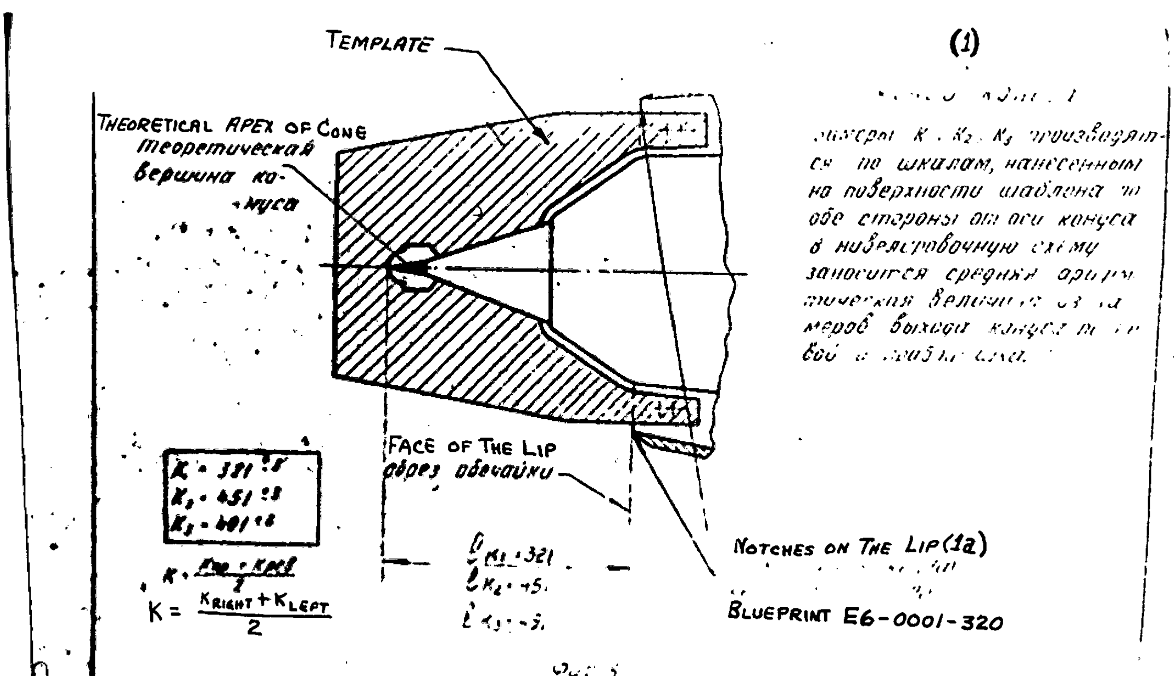


FIG. 52

S-E-C-R-E-T

50X1

KEY TO FIGURE 52

(1) Diagram for measurement of cone positions

Measurements of K_1, K_2, and K_3 are carried out by scales drawn on the surface of master form on both sides from the cone axis. Mean arithmetic from measurements of cone release by the left and right scale is entered in the leveling diagram.

[redacted]

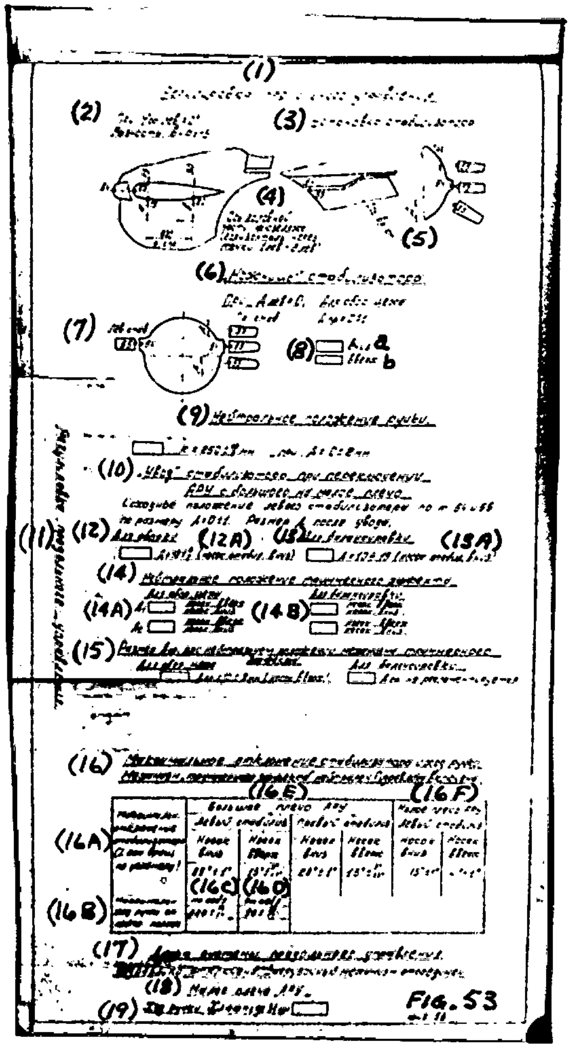


FIG. 53

[redacted]

KEY TO FIGURE 53

(1) Adjustment of longitudinal control

(2) At φ stab. left = 0°
difference b-a=13

(3) Setting of stabilizer

(4) Axis of fuselage nose section (Horizontal through points
1 left - 2 left)

(5) Axis of rotation of the stabilizer

(6) "Shears" of stabilizer, for the assembling shop
At D left = 0; right stabilizer D right = 0 ±1

(7) Left stabilizer

(8) a - down; b - up

(9) Neutral position of the lever

(10) "Tilt" of stabilizer upon switching of automatic stick control
from the large arm to the small one

(11) Adjustment of longitudinal control

(12) For assembling

(12A) Stabilizer nose down

(13) For balancing

(13A) Stabilizer nose down

(14) Neutral position of trimmer effect

(14A) For assembling shop
Nose up
Nose down
Nose up
Nose down

(14B) For balancing
Nose up
Nose down
Nose up
Nose down

KEY TO FIGURE 53 (cont)

(15) Dimension D_m at neutral position of trimmer effect mechanism
For assembling shop — For balancing
D_m=10 ±2 mm (nose up) — D_m not regulated

(16) Maximum deflection of stabilizer and motion of lever "Trimer effect" mechanism is neutral. Hydraulics engaged

(16A) Maximum deflection of stabilizer
(⊥ of the rotation axis by the angle gage)

(16B) Maximum motion of the lever from neutral position

(16C) Pulling back

(16D) Pushing forward

(16E) Large arm of automatic stick control
Left stabilizer — Right stabilizer
Nose down nose up — Nose down nose up

(17) Play of longitudinal control system hydraulics disengaged. Load mechanism disconnected

(18) Small arm of automatic stick control

(19) Travel of stick. T_{play}= up to 31 mm

50X1-HUM

50X1-HUM

S-E-C-R-E-T

-14-

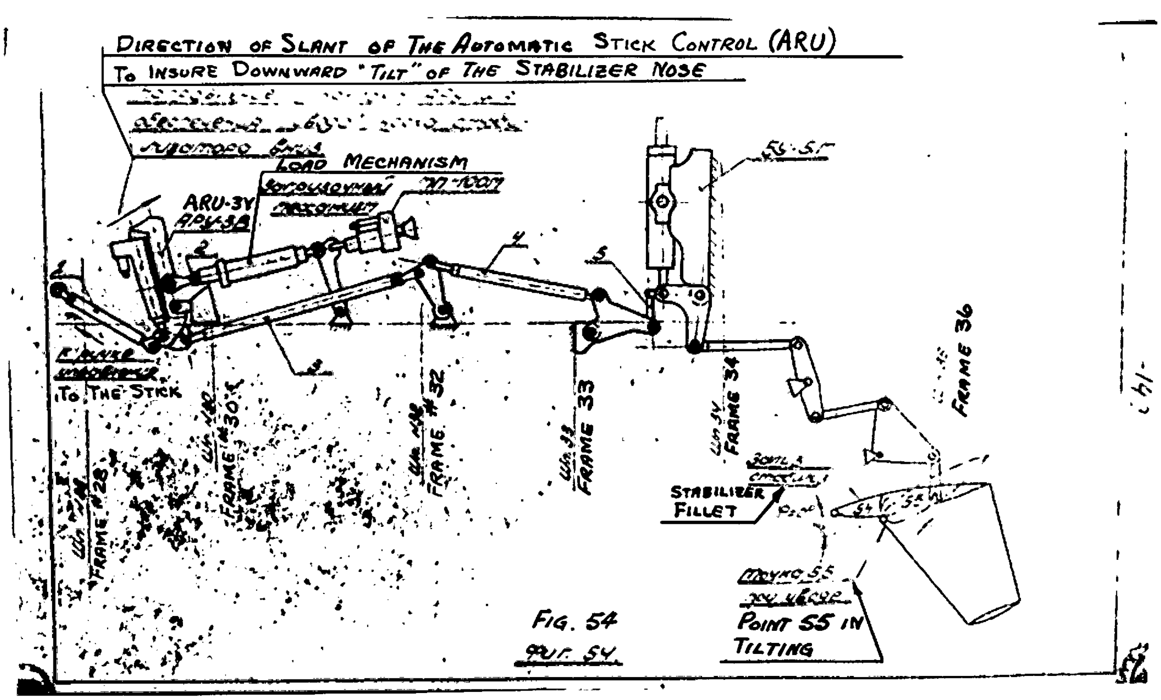


FIG. 54

50X1

S-E-C-R-E-T

50X1-HUM

50X1-HUM

STABILIZER DEFLECTION ANGLE AS A FUNCTION OF DIMENSION "D" (ON POINTS 54 & 55)

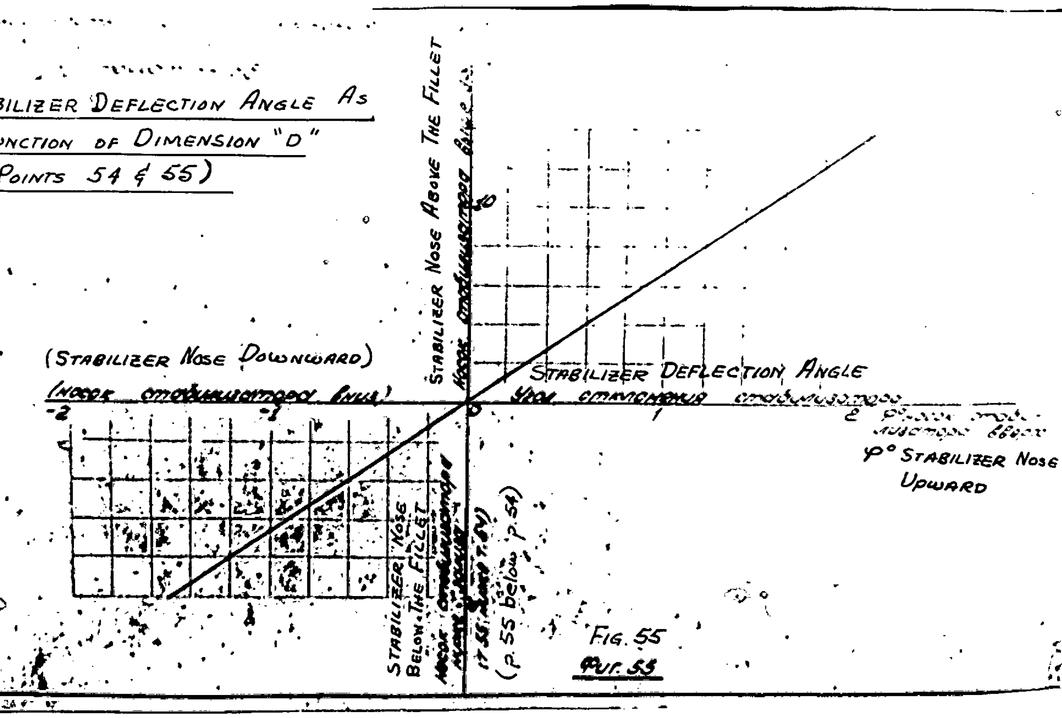


FIG. 55

50X1

S-E-C-R-E-T

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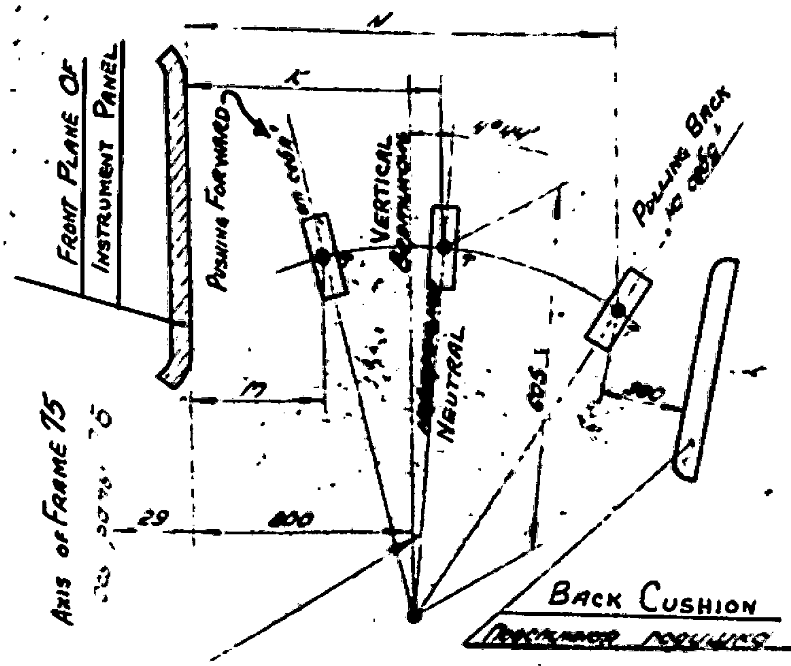
[redacted]

DIAGRAM FOR TRAVEL OF STABILIZER CONTROL LEVER

TRAVEL OF LEVER AWAY FROM PILOT = K-M
ход ручки от себя равен К-М
TRAVEL OF LEVER TOWARD PILOT = N-K
ход ручки на себя равен N-K

K=250



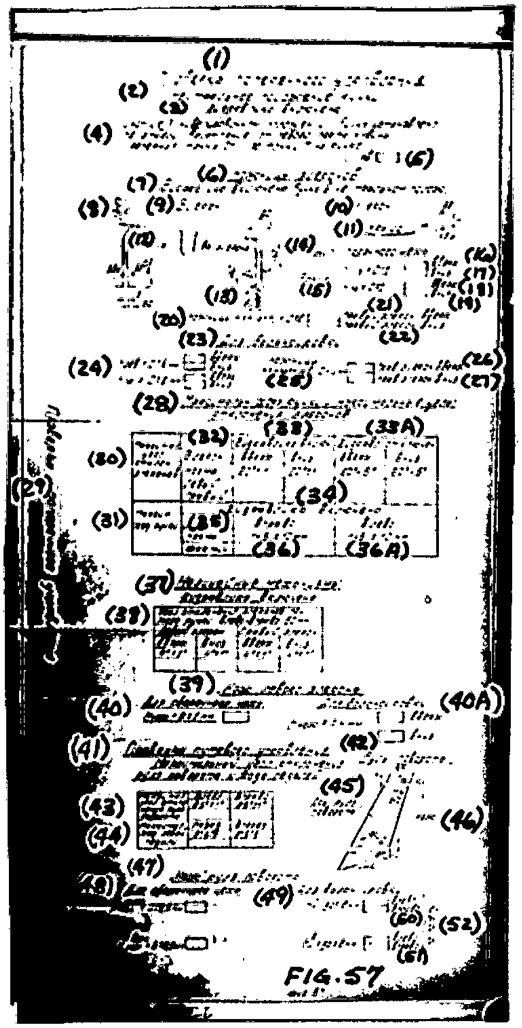
THE LINE OF READING LEVER TRAVEL CORRESPONDING TO THE STABILIZER ANGLE $\varphi = 0°$

FIG. 56

[redacted]

50X1-HUM

50X1



50X1-HUM

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KEY TO FIGURE 57

(1) Verification of transverse control

(2) Neutral position of the lever

(3) Hydraulics engaged

(4) Item in the leveling position. Lever positioned by plumb line. Distance from the left side of cabin (reference point 217 to point T on the lever)

(5) C left

(6) "Shears" of ailerons

(7) Hydraulics engaged. Lever in neutral position

(8) Face, section 1

(9) Aileron

(10) Aileron

(11) Wing

(12) Aileron's axis of rotation

(13) Section 14, face

(14) For the assembling shop
H left = 0 ±1

(15) Dimensions
H right = 0 ±1

(16) Up

(17) Down

(18) Up

(19) Down

(20) Shears H=H right + H left=0 ±2

(21) Right aileron up

(22) Right aileron down

(23) For balancing

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KEY TO FIGURE 57 (cont)

(24) H left = 0 ±8 mm up/down
H right = 0 ±8 mm up/down

(25) Shears H=H right + H left=0 ±16 mm

(26) Right aileron up

(27) Right aileron down

(28) Maximum travel of lever and maximum angles of aileron deflection

(29) Verification of transverse control

(30) Maximum angle of aileron deflection

(31) Maximum travel of the lever

(32) Aileron
Standard
Left
Right

(33) Hydraulics engaged
Up Down

(33A) Hydraulics disengaged
Up Down

(34) Hydraulics engaged

(35) Standard
Actual

(36) Rightward

(36A) Leftward

(37) Nonlinear mechanisms. Hydraulics engaged

(38) Aileron deflection angle at left-to-right lever travel of 50 mm
Left aileron Right aileron
Up Down Up Down

(39) "Blade" of left aileron

(40) For the assembling shop
$H_{blade} = 0 \pm 1$ mm

KEY TO FIGURE 57 (cont)

(40A) For balancing
$H_{blade} = \pm 4$ mm
up
down

(41) Verification of path control
Maximum deflection angle of rudder and pedal travel

(42) Rudder

(43) Maximum deflection angle of rudder left right

(44) Maximum travel of left pedal rearward forward

(45) Rudder axis

(46) Blade

(47) "Blade" of rudder

(48) For the assembling shop
$H_{blade}^{lower} = 0 \pm 0.5$ mm

$H_{blade}^{upper} = 0 \pm 0.5$ mm

(49) For balancing

(50) Left -- right

(51) Left -- right

(52) According to flight left
right

DIAGRAM FOR TRAVEL OF AILERON CONTROL LEVER

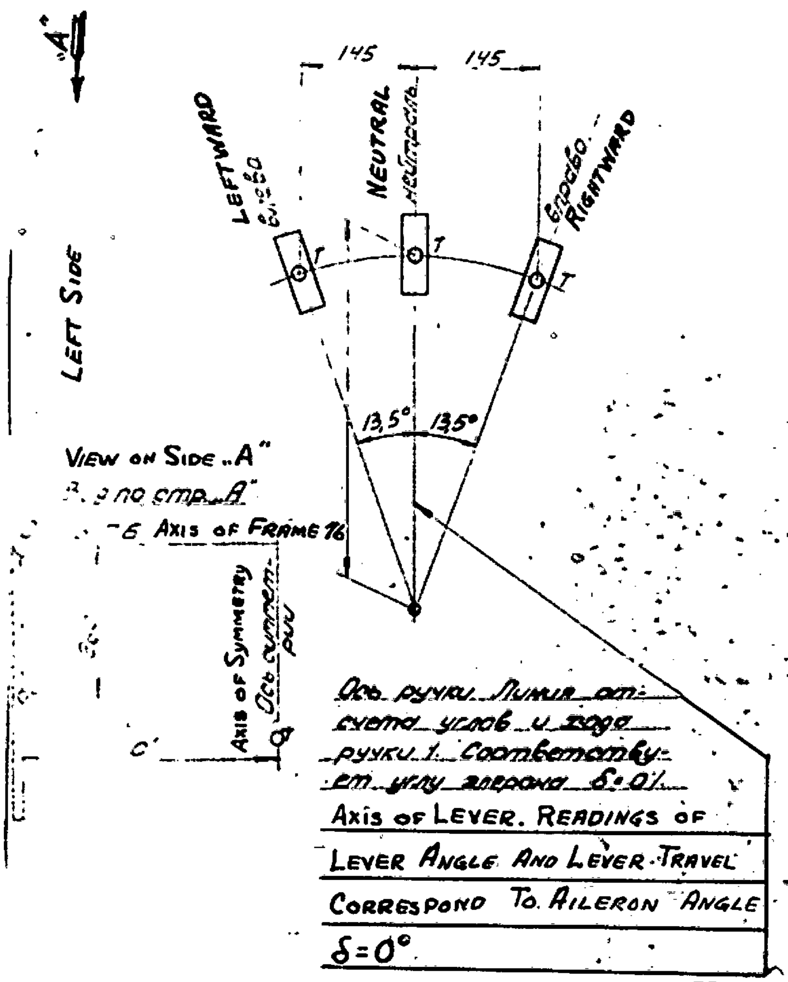


FIG. 58
Фиг. 58

[redacted] 50X1-HUM

[redacted] 50X1

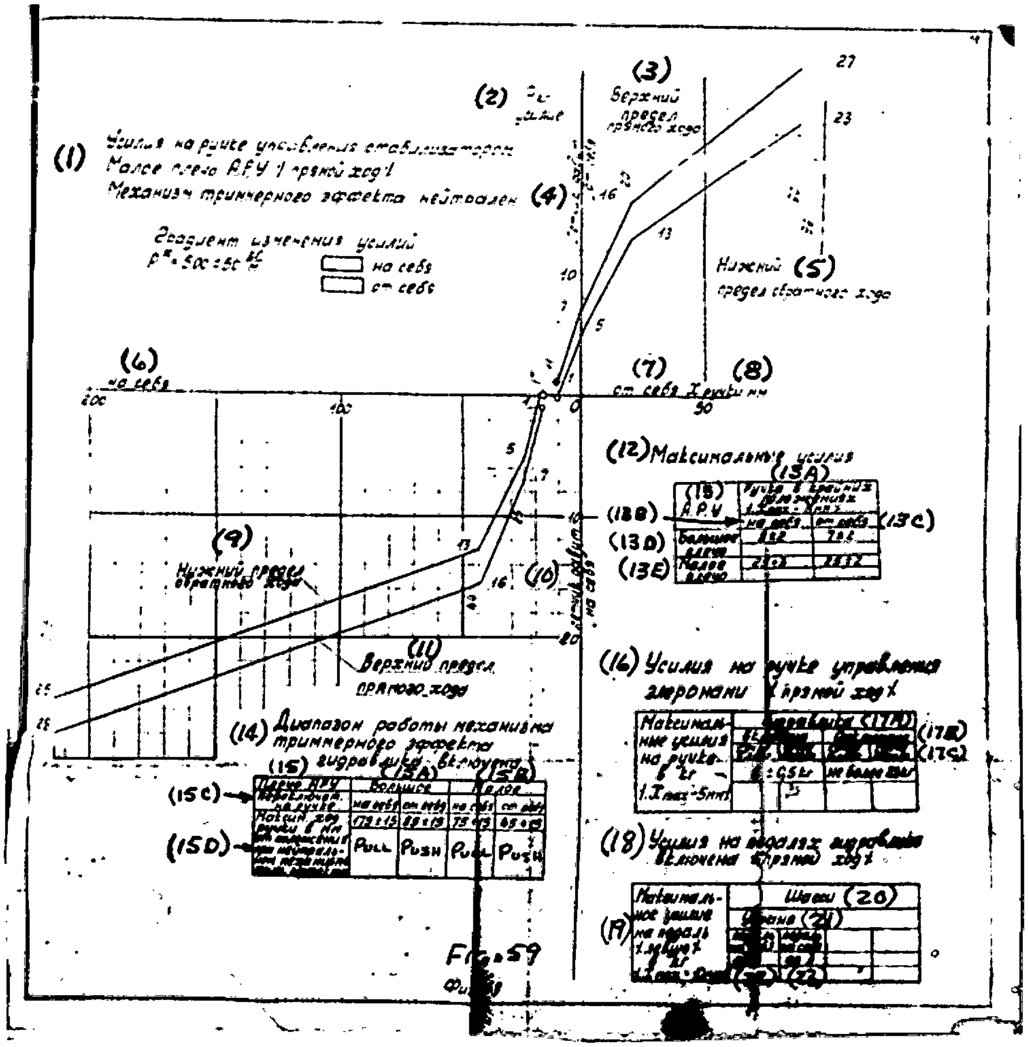


Fig. 59

[redacted] 50X1-HUM

KEY TO FIGURE 59

(1) Forces on stabilizer control lever
Small arm of automatic stick control (forward motion)
Trimmer effect mechanism in neutral

Cradient of the change of forces

pulling back
pushing forward

(2) P kg force

(3) Upper limit of the forward motion

(4) Pilot presses "away from himself"

(5) Lower limit of reverse motion

(6) Pulling back

(7) Pushing forward

(8) M lever mm

(9) Lower limit of reverse motion

(10) Pilot presses "toward himself"

(11) Upper limit of forward motion

(12) Maximum forces

(13) Automatic stick control

(13A) Lever in extreme positions
(M_{max} 5 mm)

(13B) Pulling back

(13C) Pushing forward

(13D) Large arm

(13E) Small arm

(14) Operational range of trimmer effect mechanism.
Hydraulics engaged

KEY TO FIGURE 59 (cont)

(15) Arm of automatic stick control

(15A) Large

(15B) Small

(15C) Switch on lever

(15D) Maximum travel of lever in mm from position with neutral trimmer effect mechanism

(16) Forces on aileron control lever (forward motion)

(17) Maximum forces on lever in kg
(M_{max} - 5 mm)

(17A) Hydraulics

(17B) Engaged -- Disengaged

(17C) Lever left -- lever right

(18) Forces on pedals. Hydraulics engaged (forward motion)

(19) Maximum force on pedal (left) in kg
(M_{max} - 10 mm)

(20) Landing gear

(21) Retracted

(22) Pedal pulled back

(23) Pedal pushed forward

[redacted]

50X1-HUM

50X1

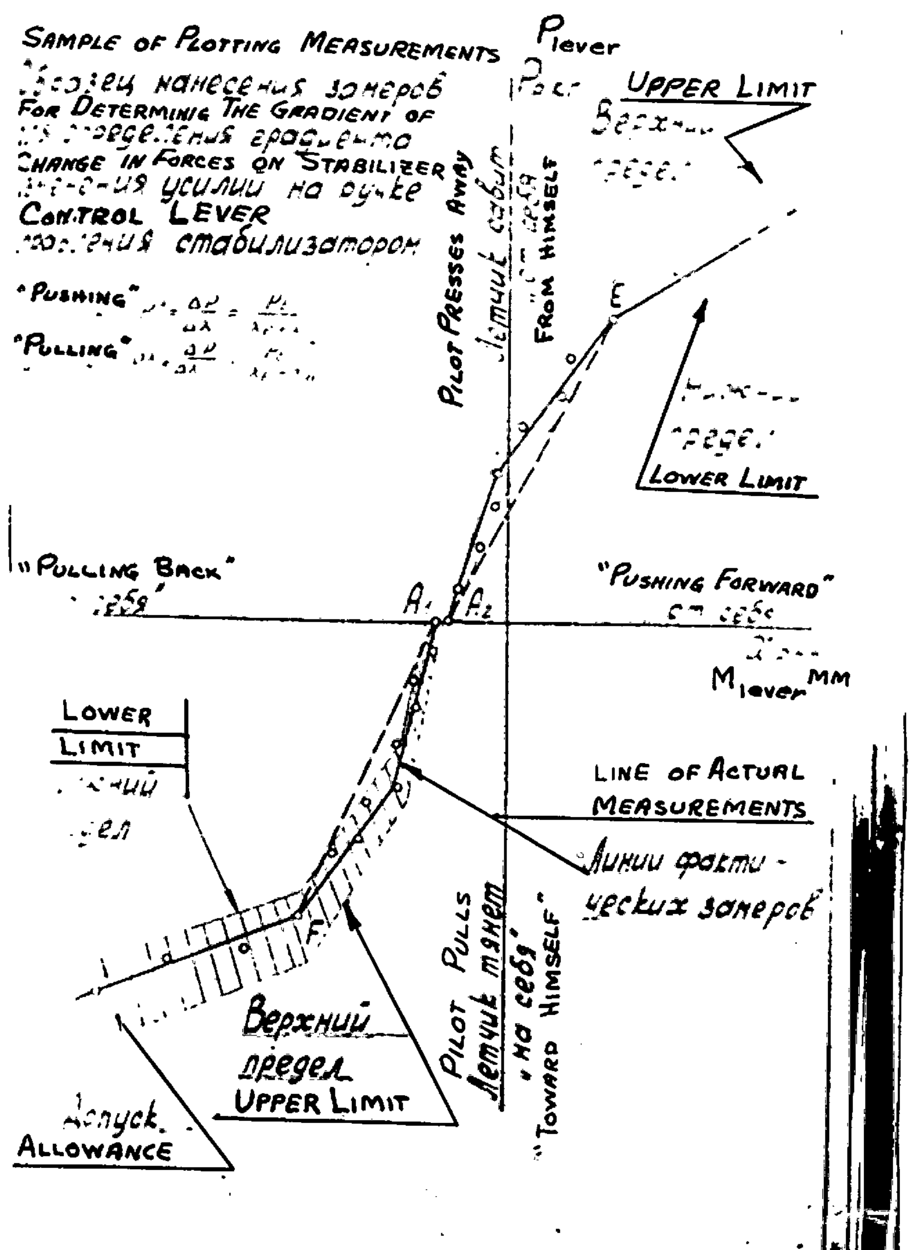


Fig. 60
Фиг. 60

[redacted]

50X1-HUM

MOTION DIAGRAM OF RUDDER PEDALS

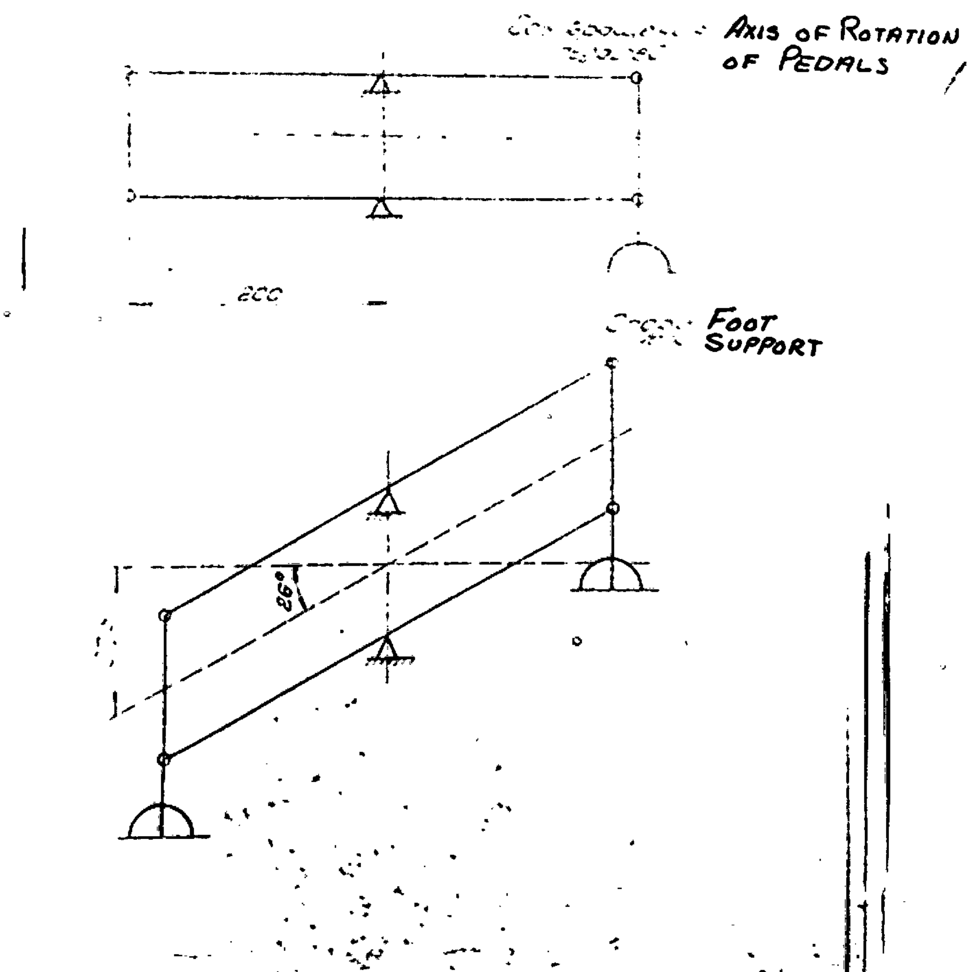


FIG. 61
Фиг. 61

50X1-HUM

50X1

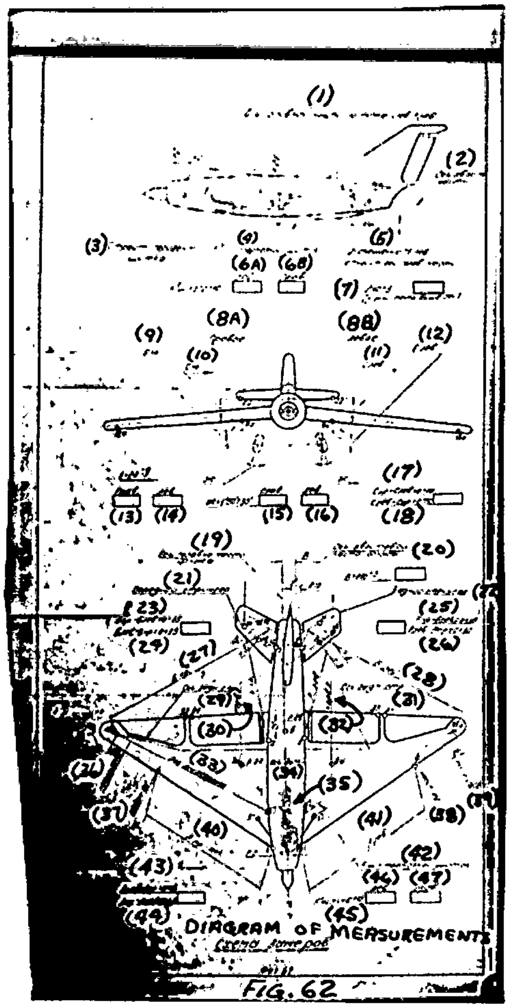


DIAGRAM OF MEASUREMENTS

FIG. 62

50X1-HUM

KEY TO FIGURE 62

(1) Axis of the nose section (on the point 1 left - 2 left)

(2) Axis of the rear section

(3) Horizontal datum line of the flap

(4) K^2_{a-b} - air brake

(5) L-displacement T.3 left relative to the axis of nose section

(6A) - left

(6B) - right

(7) L = 0 ±3 (if the point is above the axis)

(8A) - right

(8B) - left

(9) E right

(10) C right

(11) C left

(12) E left

(13) right

(14) left

(15) right

(16) left

(17) C right - C left = 0 + 10

(18) C left - C right = 0 + 10

(19) Axis of the nose section of fuselage

(20) Axis of the rear section of fuselage

(21) Longitudinal front stringer

(22) Longitudinal rear stringer

KEY TO FIGURE 62 (cont)

(23) B right - B left = 0 + 15

(24) B left - B right = 0 + 15

(25) R right - R left = 0 + 10

(26) R left - R right = 0 + 10

(27) B right

(28) B left

(29) Axis of longitudinal rear stringer

(30) Rib 2

(31) Axis of longitudinal rear stringer

(32) Rib 2

(33) Axis of spar

(34) Axis of beam

(35) Axis of the nose section of fuselage

(36) Nose 25

(37) Nose 21

(38) Nose 21

(39) Nose 25

(40) A right

(41) A left

(42) K^{1}_{a-b} - air brake

(43) A left - A right = 0 + 5

(44) A right - A left = 0 + 5

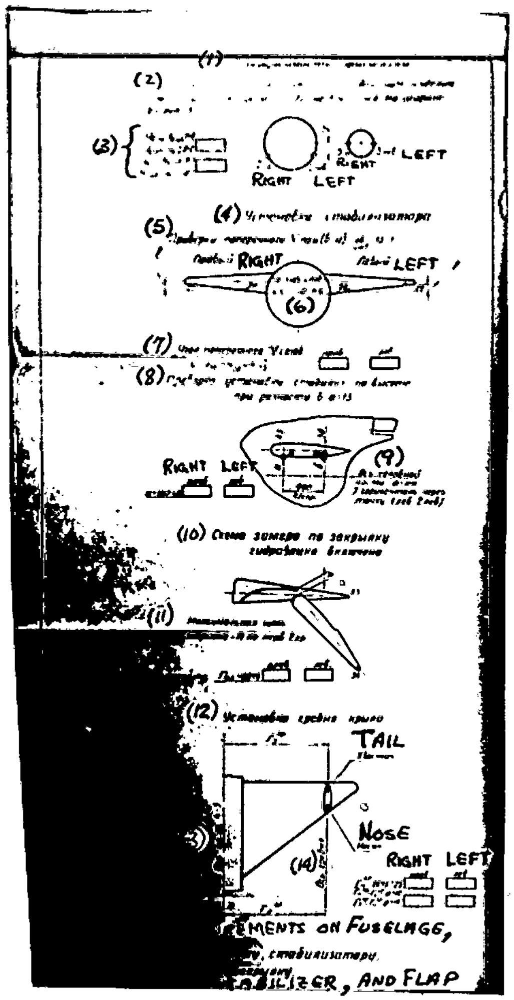
(45) K^{1}_{a-b} = 446 ±10

(46) Left

(47) Right

[redacted]

50X1-HUM
50X1



[redacted]

50X1-HUM

KEY TO FIGURE 63

(1) Twist of fuselage

(2) Leveling of fuselage on assembled product (setting by points; in length - 1 left - 2 left; in width - 8a left - 8a right)

(3) Y_2 right - Y_2 left = 0 + 2

Y_2 left - Y_2 right = 0 + 2

Y_3 right - Y_3 left = 0 + 3

Y_3 left - Y_3 right = 0 + 3

(4) Setting of stabilizer

(5) Verification of lateral dihedral at (b - a)
Left = 13 ±1
Right

(6) Section chord of stabilizer from nose section of fuselage

(7) Angle of lateral dihedral of stabilizer

(8) Verification of stabilizer setting by altitude at the difference
b - a = 13

(9) Axis of the nose section of fuselage
(Horizontal through the point 1 left - 2 left)

(10) Diagram of measurement on flap
Hydraulics engaged

(11) Maximum slot of the flap - P on the rib 2 (wing)

(12) Setting of wing fence

(13) Axis on p. 4-5

(14) Axis of fence

50X1-HUM

50X1

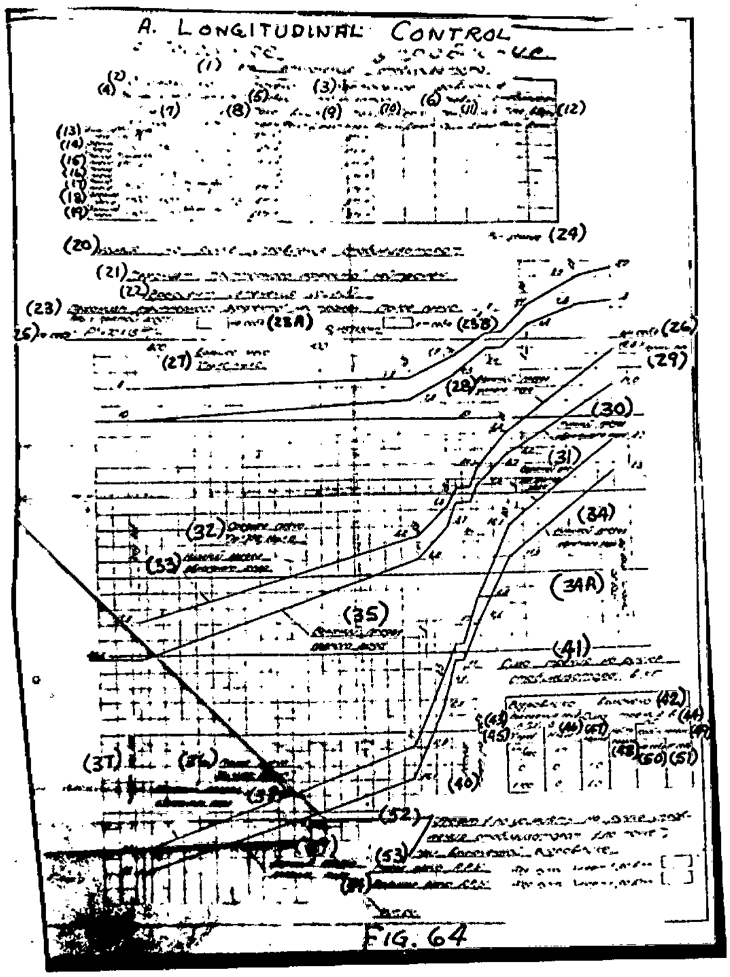


FIG. 64

50X1-HUM

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[redacted]

KEY TO FIGURE 64

(1) Stabilizer deflection angles

(2) Hydraulics engaged

(3) Normal pressure

(4) Indicated by instruments KPU-3

(5) Left stabilizer

(6) Right stabilizer

(7) V_{ind}
km/hr

(8) H_{ind}
km

(9) Maximum down
Normal Actual D actual

(10) Maximum up
Normal Actual D actual

(11) Maximum down
Actual D actual

(12) Maximum up
Actual D actual

(13) Large arm

(14) Average arm

(15) Small arm

(16) Small arm

(17) Small arm

(18) Medium arm

(19) Large arm

(20) Forces on stabilizer control lever

(21) "Trimmer effect" mechanism in neutral

[redacted]

KEY TO FIGURE 64 (cont)

(22) Gradient of change in forces

(23) "Trimmer effect" mechanism in neutral. Small arm of automatic stick control ARU (forward motion)

(23A) Pulling back

(23B) Pushing forward

(24) P kg force

(25) "Pulling back" P^{t}=70 ±15 kg/m

(26) Pushing forward

(27) Large arm
V ind = 0; H ind = 0

(28) Upper limit of forward travel

(29) 18.5 t_{lever} (mm)

(30) Lower limit of reverse travel

(31) Upper limit of forward travel

(32) Medium arm
V ind = 0; H ind = 0

(33) Lower limit of reverse travel

(34) Lower limit of reverse travel

(34A) Travel 90
Maximum travel 96

(35) Upper limit of forward motion

(36) Small arm
V ind = 1100; H ind = 0

(37) Maximum travel 220

(38) Lower limit of reverse travel

(39) Upper limit of forward travel

(40) Pilot pulls "toward himself"

KEY TO FIGURE 64 (cont)

(41) Friction force on stabilizer lever in kg

(42) Hydraulics engaged

(43) Indications of instrument KPU-3

(44) Friction force in kg

(45) V ind, km/hr

(46) H ind, km

(47) Standard

(48) Neutral position

(49) Extreme position

(50) Pull back

(51) Push forward

(52) Play (by forces) on stabilizer control lever (on point T) with hydraulics engaged

(53) Small arm of automatic stick control (ARU)
Travel of lever T_{play} = up to 6 mm

(54) Large arm of automatic stick control (ARU)
Travel of lever T_{play} = up to 10 mm

[redacted]

[redacted]

CHANGE IN ARM OF AUTOMATIC STICK CONTROL ARU-3V AS A FUNCTION OF INDICATED SPEED AND FLIGHT ALTITUDE

Изменение плеча автомата АРУ 3В в зависимости от приборной скорости и высоты полета

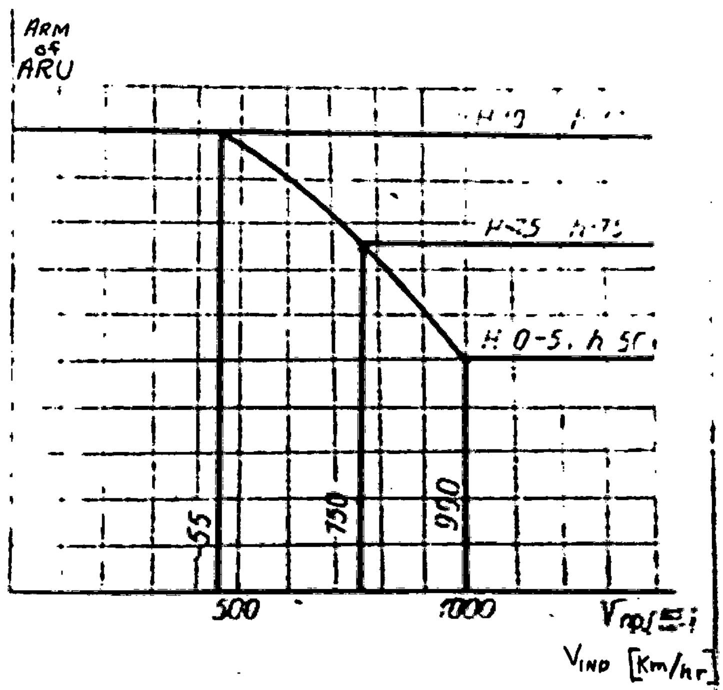


FIG. 65

Фиг65

[redacted]

зменение относительного передаточного числа продольного управления в зависимости от приборной скорости и высоты полета

CHANGE IN RELATIVE GEAR RATIO OF THE LONGITUDINAL CONTROL AS A FUNCTION OF INDICATED SPEED AND FLIGHT ALTITUDE

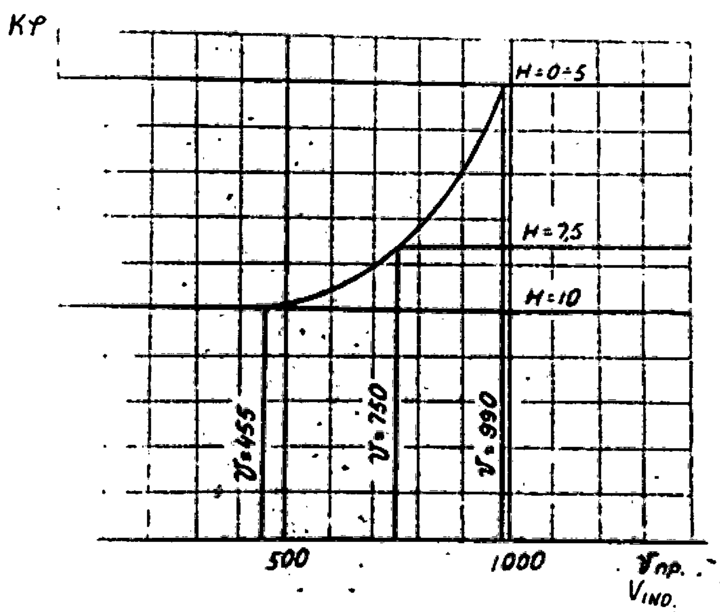
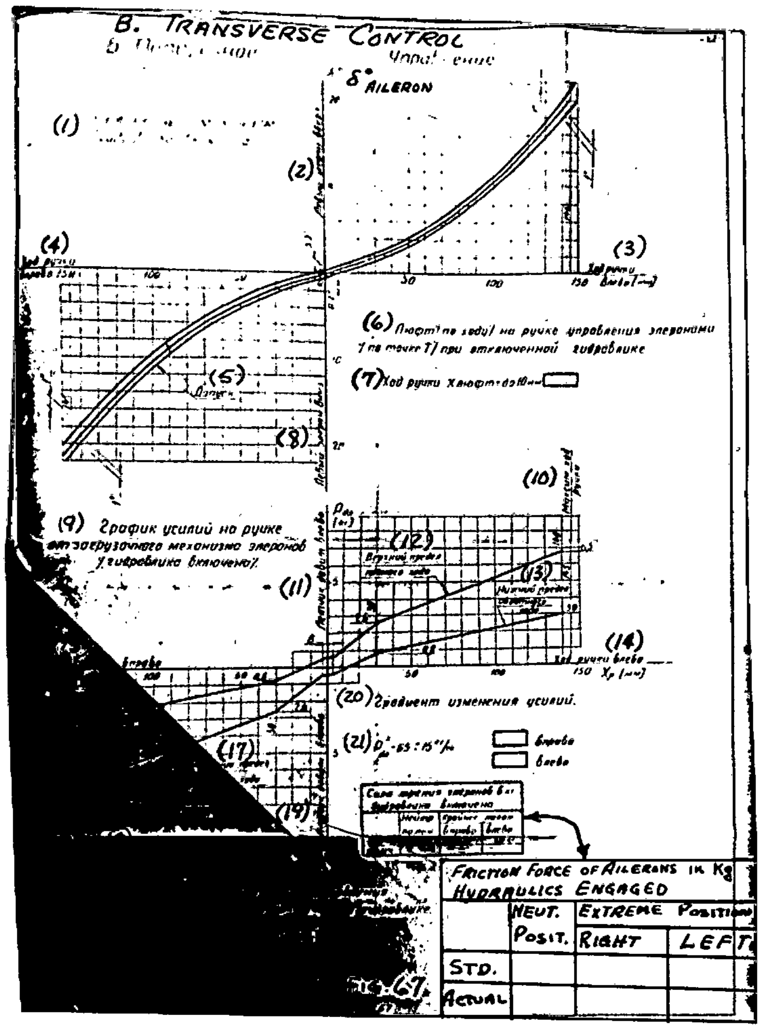


FIG. 66
Фиг. 66

[redacted]

50X1-HUM

50X1



FRICTION FORCE OF AILERONS IN KG HYDRAULICS ENGAGED	NEUT. POSIT.	EXTREME POSITION RIGHT	LEFT
STD.			
ACTUAL			

FIG. 67

[redacted]

50X1-HUM

KEY TO FIGURE 67

(1) Nonlinear mechanism (hydraulics engaged)

(2) Left aileron up

(3) Leftward travel of the lever (mm)

(4) Rightward travel of the lever

(5) Allowance

(6) Play (in travel) on the aileron control lever (on point T) with hydraulics disengaged

(7) Travel of the lever T_{play} = up to 10 mm

(8) Left aileron down

(9) Graph of forces on the lever from the load mechanism of ailerons (hydraulics engaged)

(10) Maximum travel of the lever

(11) Pilot presses leftward

(12) Upper limit of forward travel

(13) Lower limit of reverse travel

(14) Leftward travel of the lever T_1 (mm)

(15) Rightward travel of the lever

(16) Lower limit of reverse travel

(17) Upper limit of forward travel

(18) Maximum travel of the lever

(19) Pilot presses rightward

(20) Gradient of change in forces

(21) $P_I^t = 65 \pm 15$ kg/m

(22) Play (by forces) on the aileron control lever (on the point T) with hydraulics disengaged

(23) Travel of the lever T_{play} = up to 6 mm

(24) Transverse control

50X1-HUM

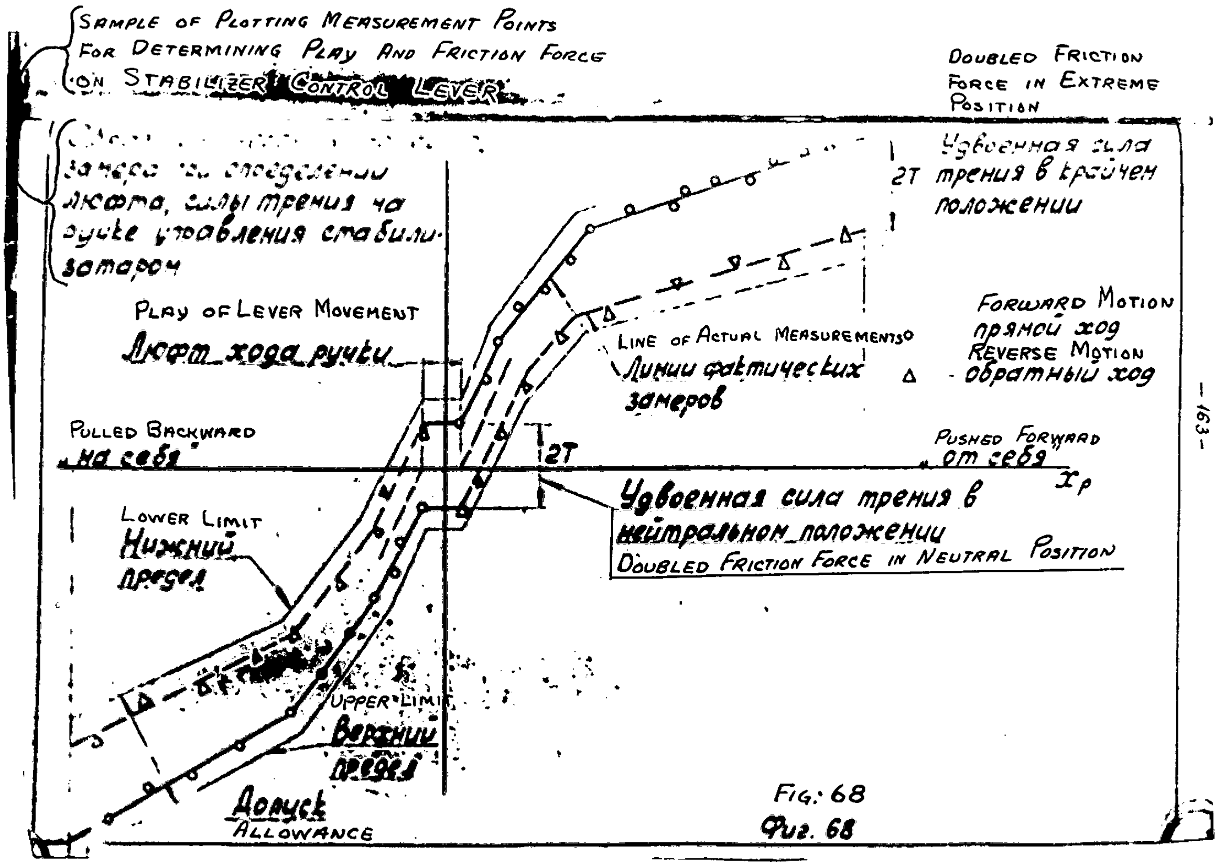


Fig: 68
Фиг. 68

50X1-HUM
50X1

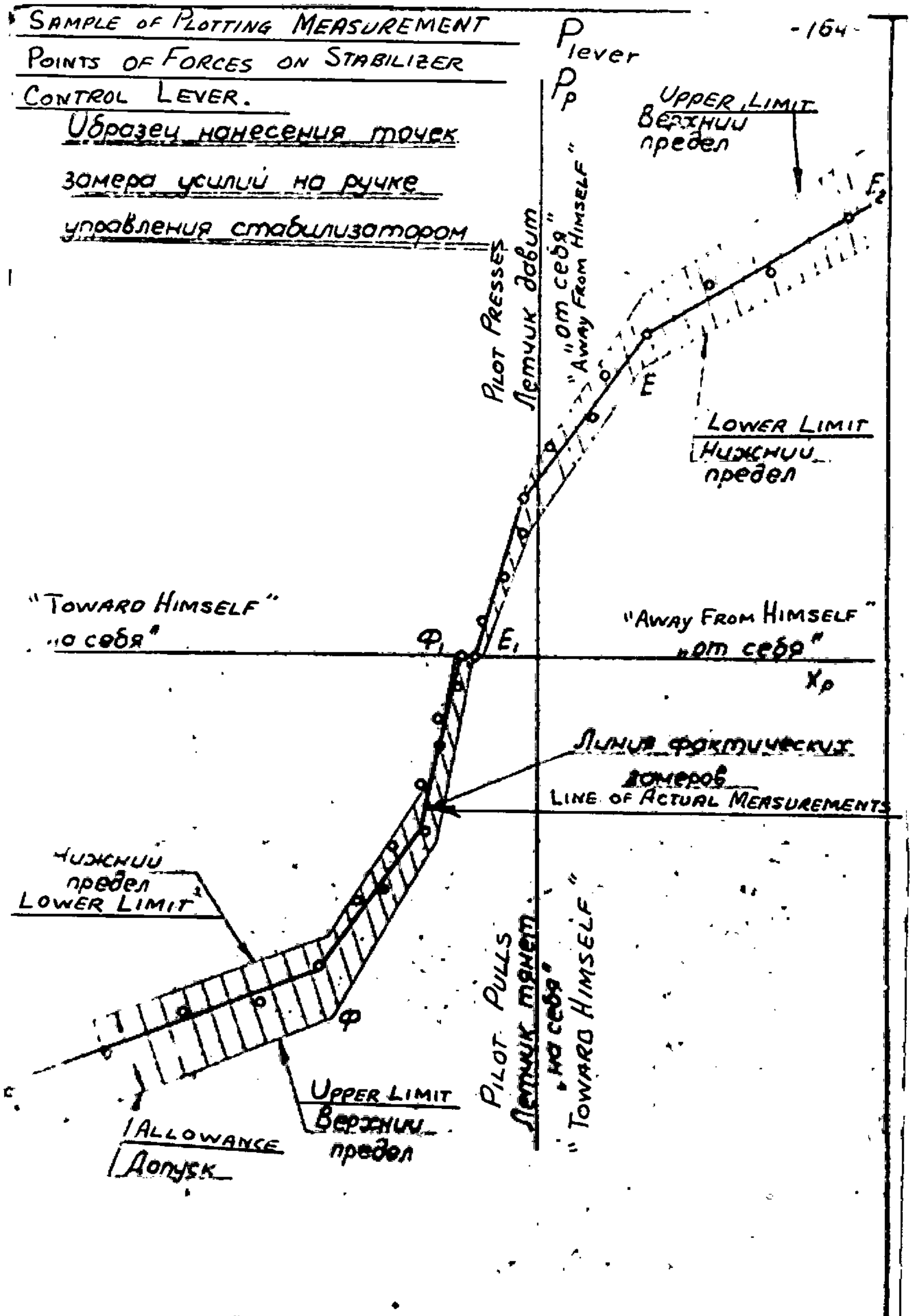


Fig. 69
Фиг. 69

50X1-HUM

S-E-C-R-E-T

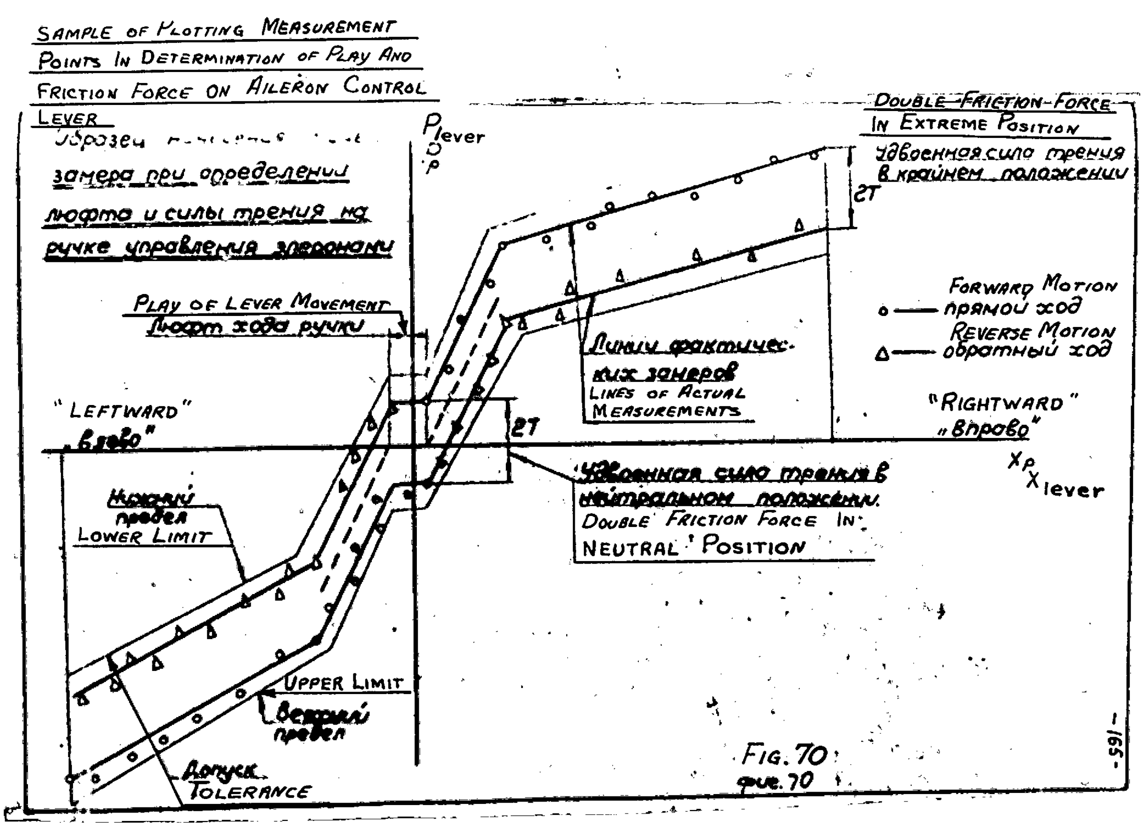


FIG. 70
фиг. 70

S-E-C-R-E-T

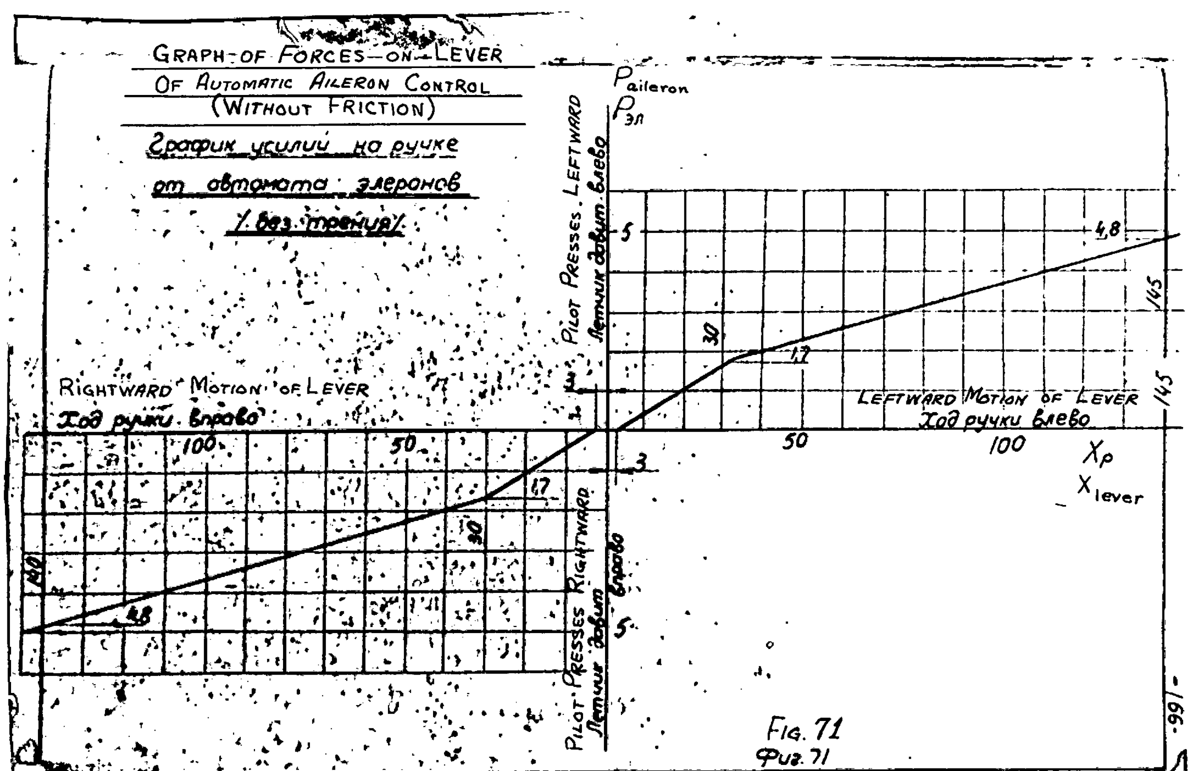

GRAPH OF FORCES ON LEVER
OF AUTOMATIC AILERON CONTROL
(WITHOUT FRICTION)
График усилий на ручке
от автомата элеронов
/без трения/
$P_{aileron}$
$P_{эл}$
PILOT PRESSES LEFTWARD
Летчик давит влево
PILOT PRESSES RIGHTWARD
Летчик давит вправо
RIGHTWARD MOTION OF LEVER
Ход ручки вправо
LEFTWARD MOTION OF LEVER
Ход ручки влево
X_p
X_{lever}
5
3
4,8
145
30
17
50
100

Fig. 71
Фиг. 71

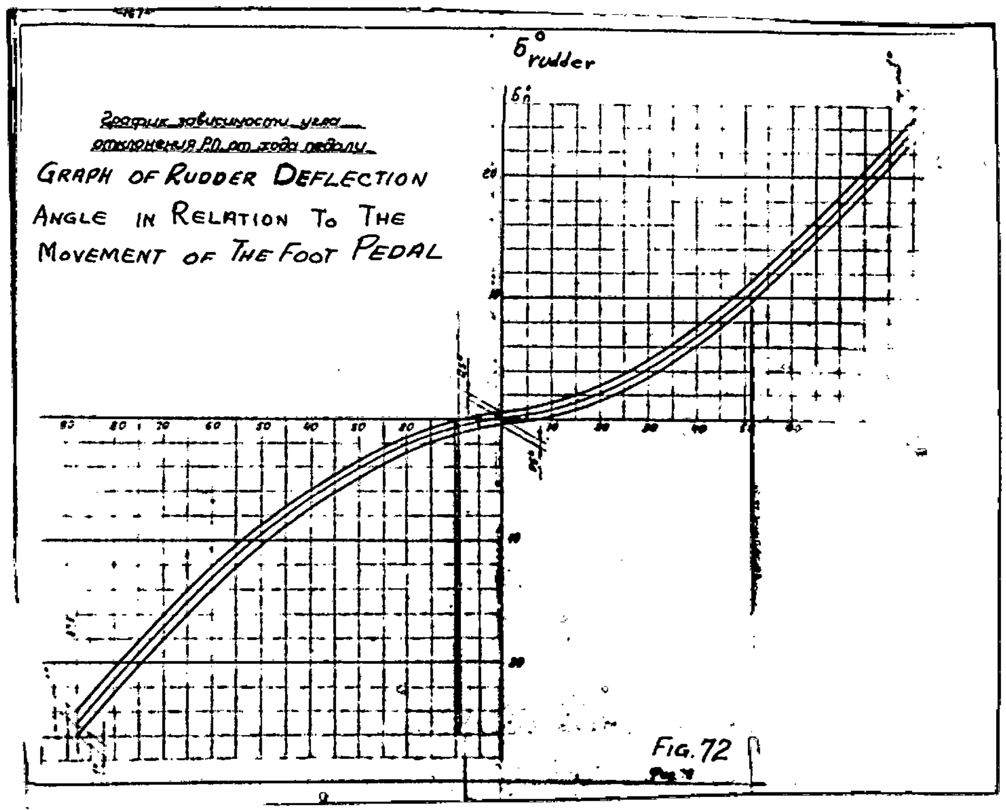
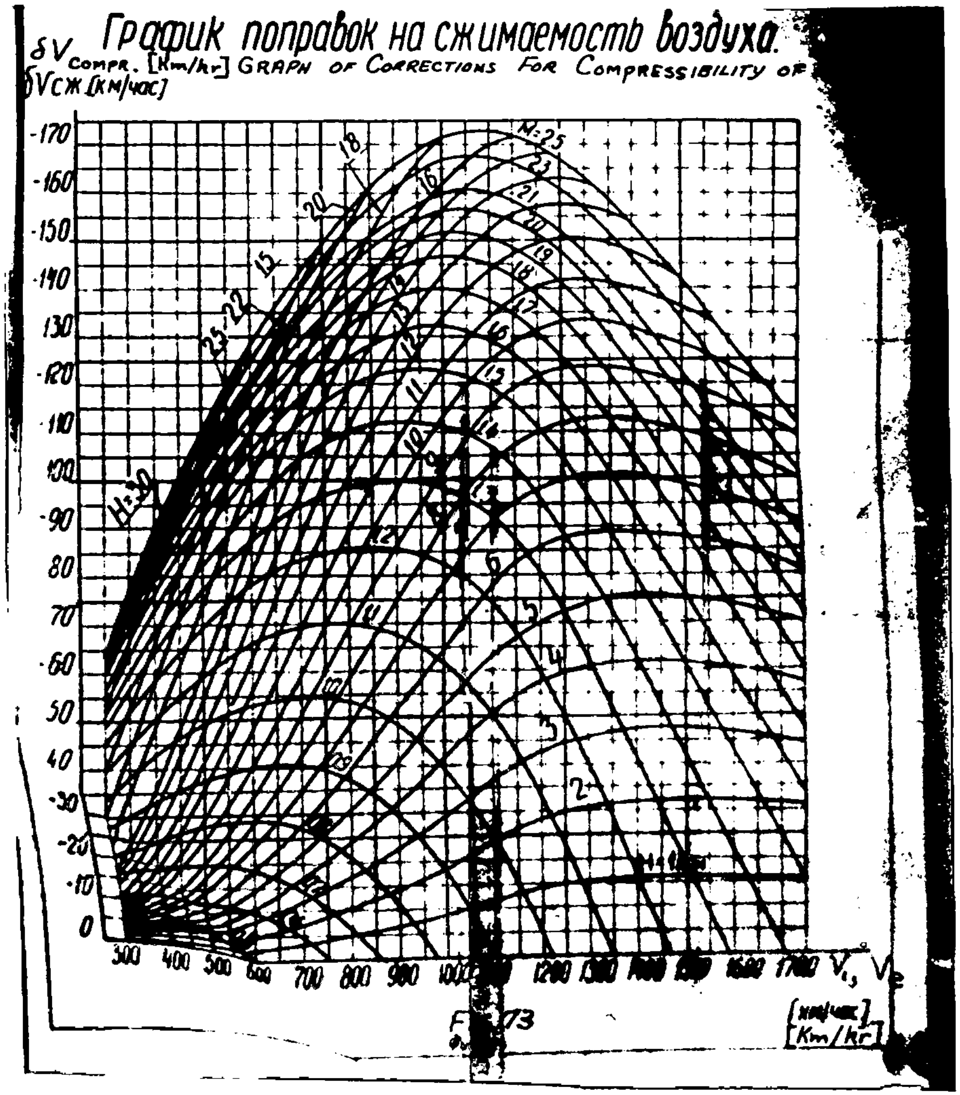

GRAPH OF RUDDER DEFLECTION ANGLE IN RELATION TO THE MOVEMENT OF THE FOOT PEDAL
δ° rudder

FIG. 72

[redacted]

50X1-HUM

50X1

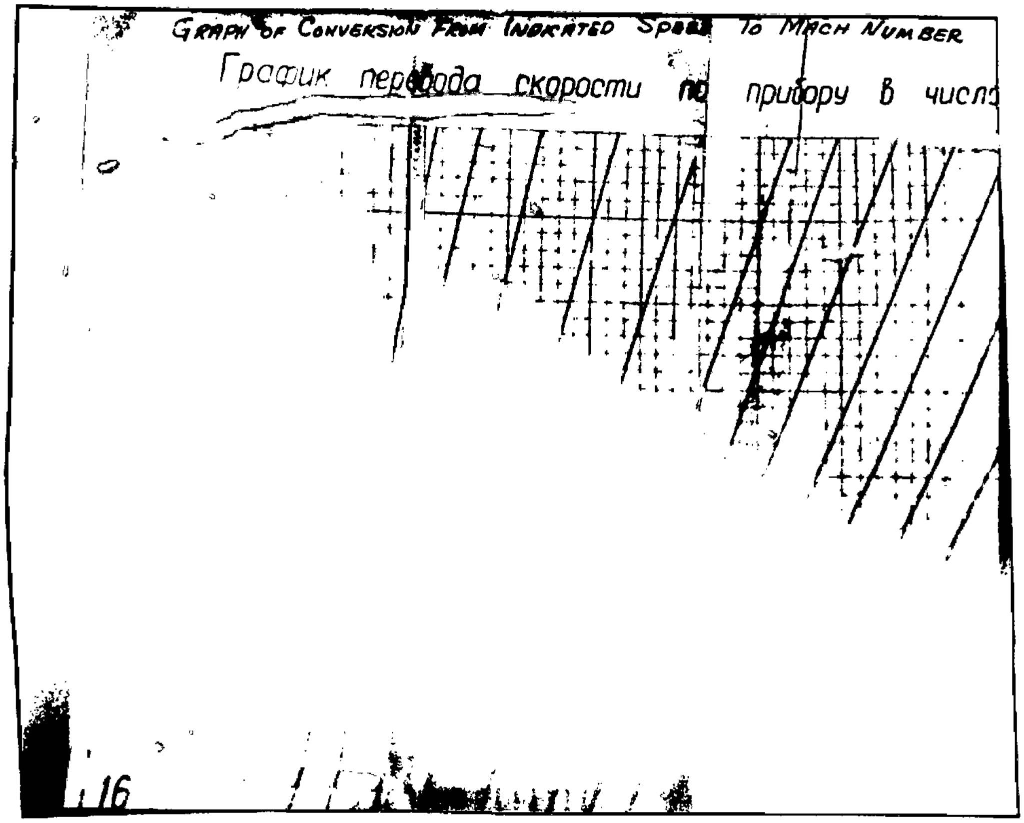


[redacted]

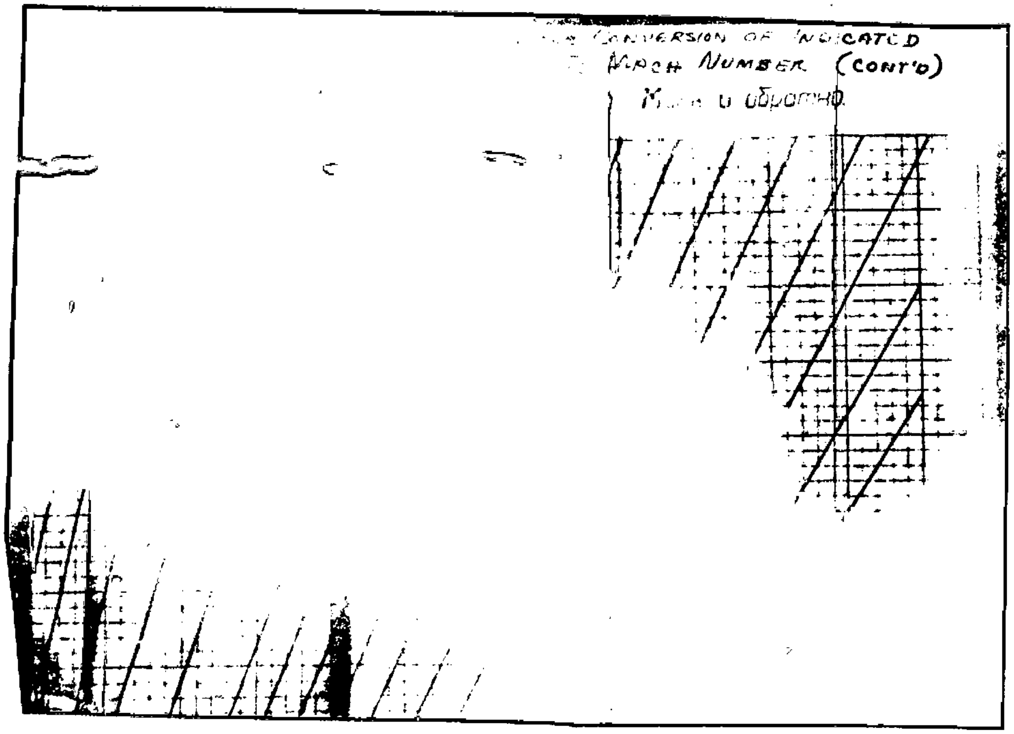
50X1-HUM

[redacted] 50X1-HUM

[redacted] 50X1

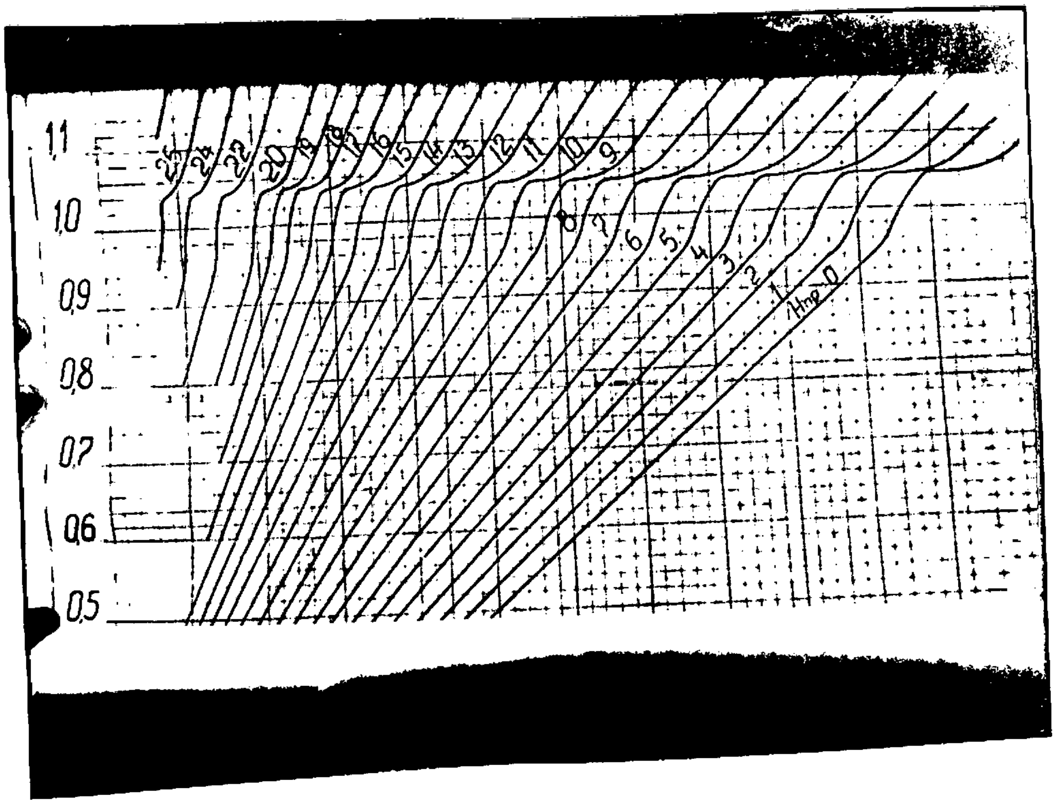


[redacted] 50X1-HUM


CONVERSION OF INDICATED
MACH NUMBER (CONT'D)


1,5
1,4
1,3
1,2
1,1

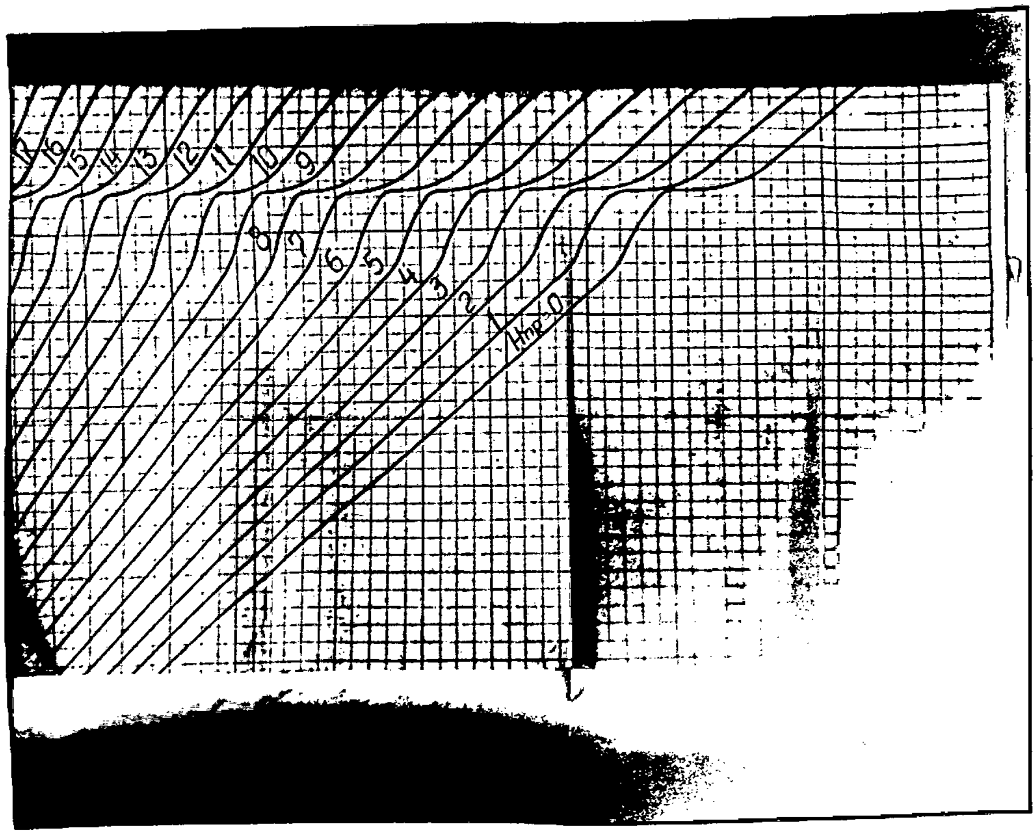
[redacted]



[redacted]

50X1-HUM

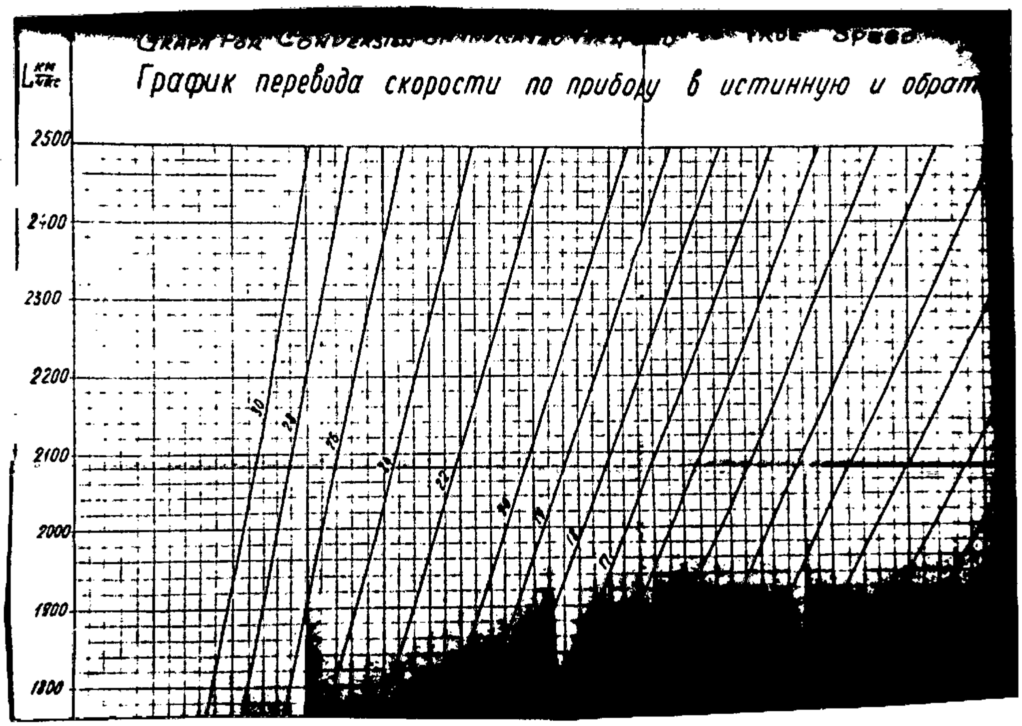
50X1



50X1-HUM

[redacted] 50X1-HUM

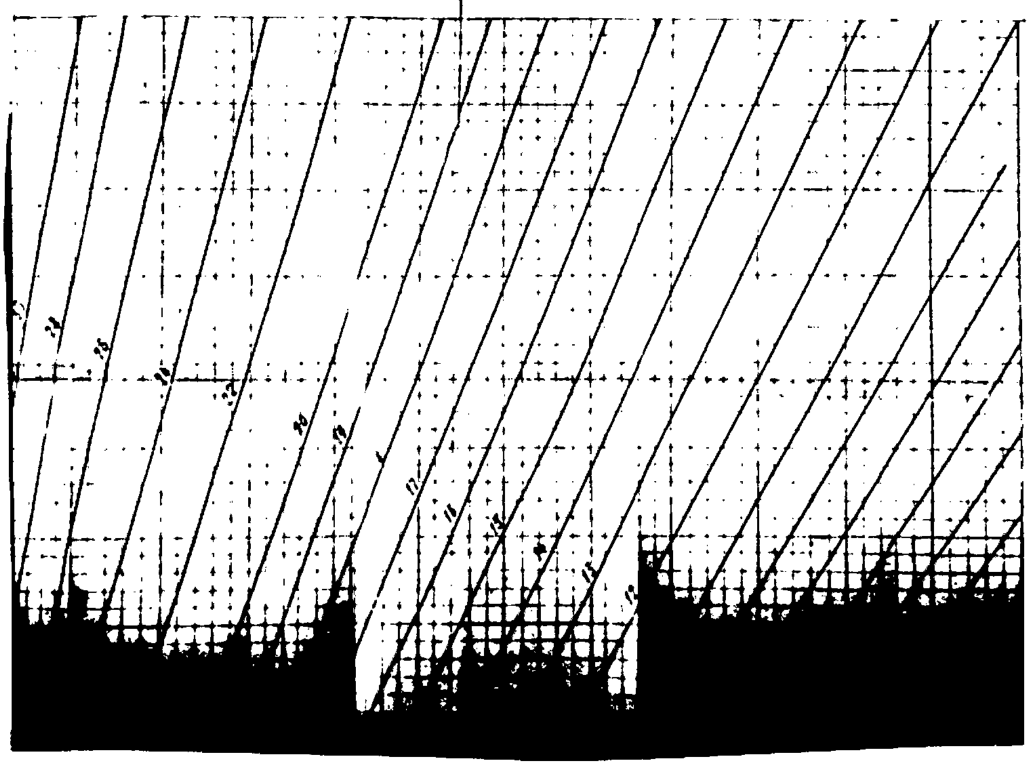
[redacted] 50X1



[redacted] 50X1-HUM

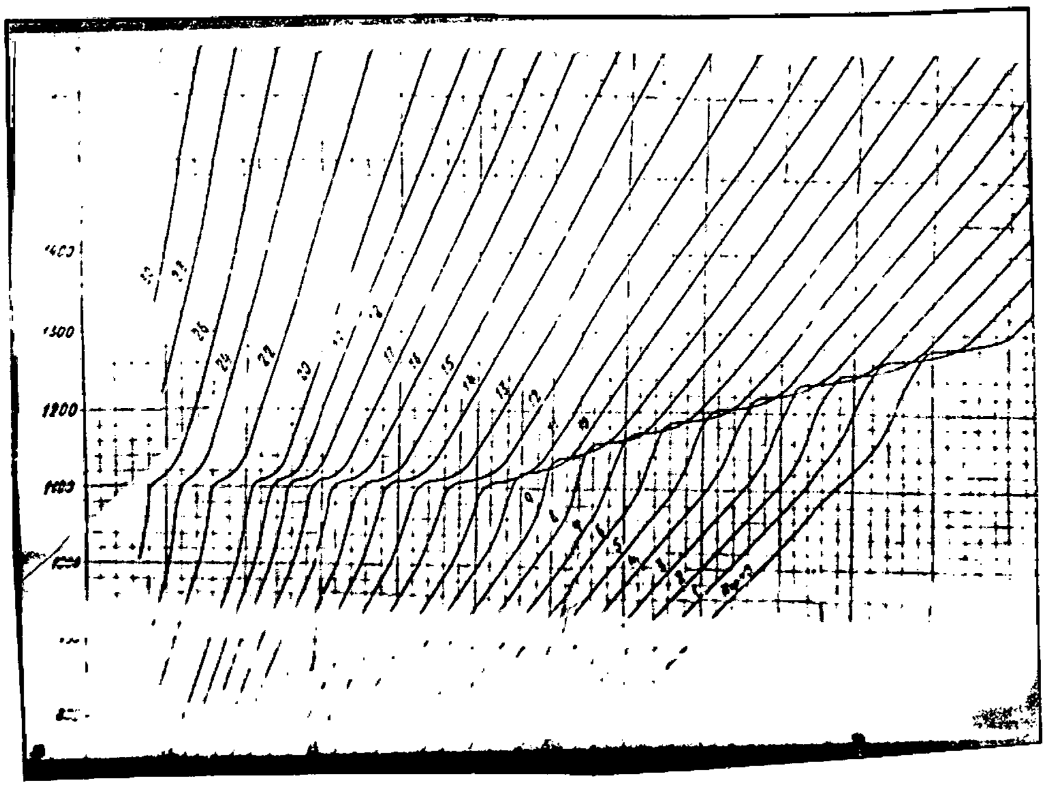
[redacted]

GRAPH FOR CONVERSION OF INDICATED SPEED TO TRUE SPEED (CONT'D)



[redacted]

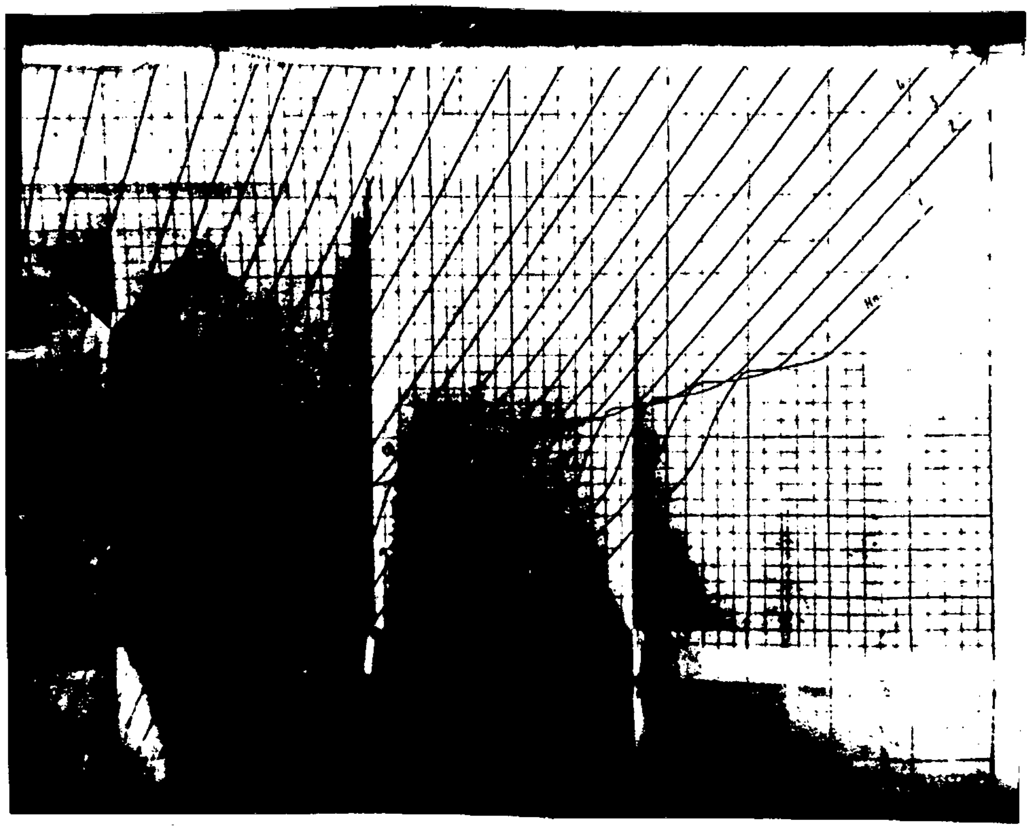
[redacted]



[redacted]

[redacted]

50X1-HUM
50X1



[redacted]

50X1-HUM

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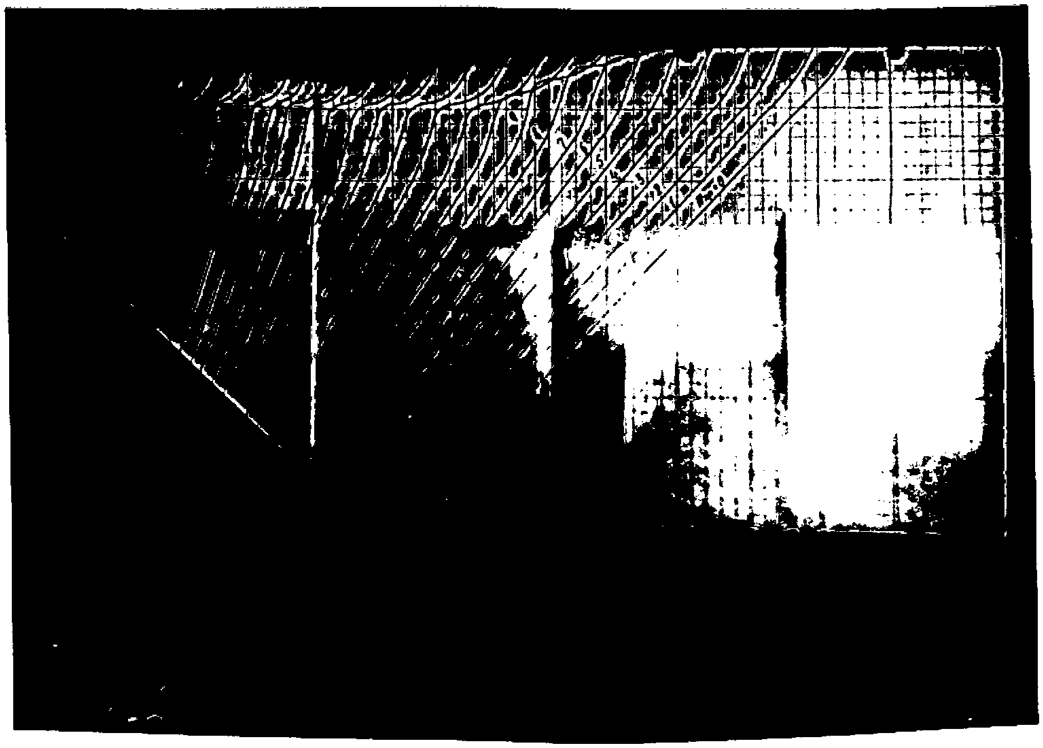
[redacted]

50X1-HUM

50X1

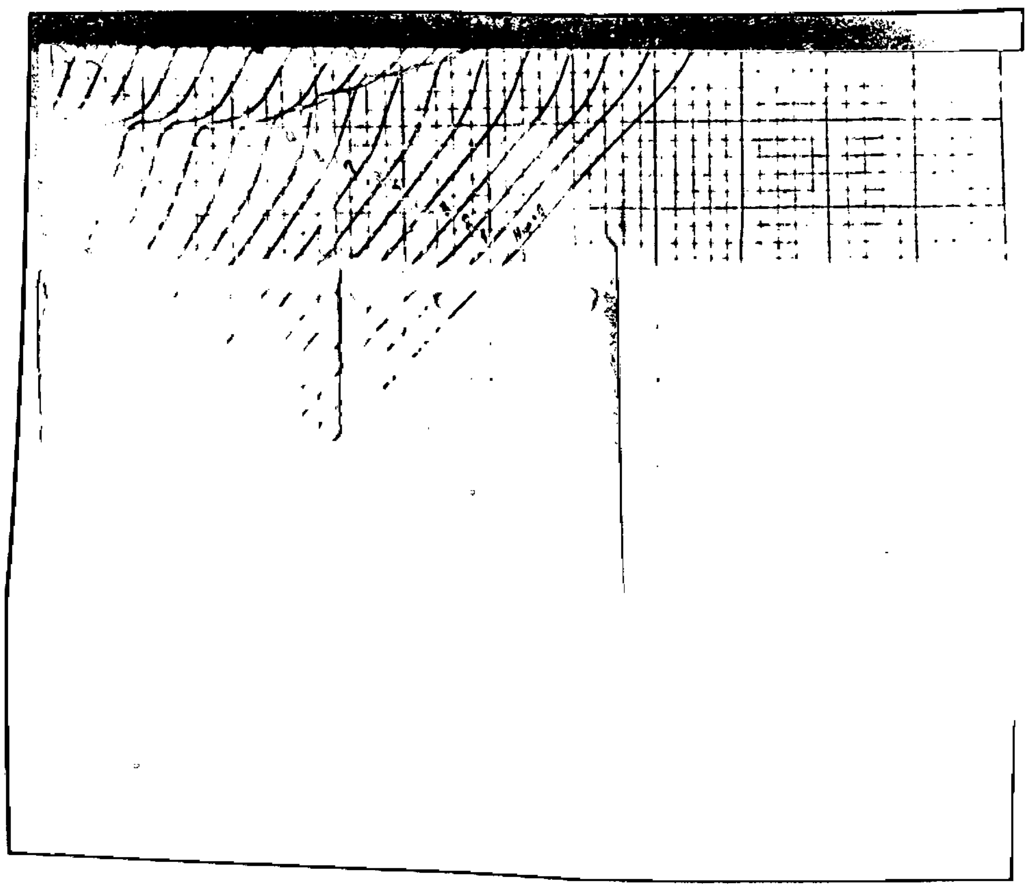


[redacted]

50X1-HUM

50X1-HUM

50X1



50X1-HUM

50X1-HUM

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