Basic Dolphin Tactics

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ABSTRACT

This paper presents the qualitative considerations relating to changes of the performance characteristics of a sailplane as influenced by the method of flight speed control which the pilot applies. Pilotage utilizing the proper dynamic flight techniques can transform atmospheric energy and realize performance gains in the region of 20% or more. These considerations relate to sailplanes of modern design with an L/D of 35:1 or better.

Factors involved: $E_c = E_p + E_k + E_{st}$

E_c = Total Energy
E_p = Potential Energy
E_k = Kinetic Energy
E_{st} = Energy Loss

The mutual relations between the specific components of total energy play a large role in the range of changing and forming the effective performance curve.

The second part of this paper presents the results of a simplified analysis of flight performance based on recorded parameters of dynamic mode flight tests.

PART I

Obtaining the best possible results from a cross-country flight, under any given terrain and meteorological conditions, requires taking the utmost advantage of these conditions as well as of the performance capabilities of the given sailplane as related to these conditions. The basic function of the pilot, during such a flight, is to skillfully apply the most modern technology available related to such cross country soaring tactics.

Cross-country soaring began after discovery of thermal type lift during the late 1920's in Germany. In 1935 the world distance record was set there - 504km. Exceptional flights were being made during this period using sailplanes with a glide ratio of 25:1 and achieving 35km/hour. Pilots flew cross-country using only "seat of the pants" techniques and long flights were rather incidental resulting from exceptional weather conditions. In 1937, in Russia, Victor Rostorguyev upped the distance record to 652km and stated that he flew mostly in indicated lift of 1,200 feet per minute, but sometimes it got bad and dropped to 800 feet per minute! The 794km distance record set in 1939, in Russia by Mme. Olga Klepikova, using "seat of the pants" techniques, was made in even stronger lift conditions!

In 1937, the academic soaring group at the Lwow Polytechnical Institute in Poland, began the investigation of optimization of cross-country soaring techniques. It was Mr. Witold Kasprzyk who originated and, in 1937, published his classical formula relating sailplane performance to the thermal energy available during a cross-country flight which would optimize cross-country speed and, at this point, scientific soaring really took off. Immediately, the distances and cross country speeds of flights in Poland increased substantially. This included the 578km goal flight of Tadeusz Gora, which earned him Lilienthal Medal Number 1. As originally used, the data, calculated from Kasprzyk's formula for the given sailplane, was carried on a convenient cardboard chart mounted on the instrument panel. Nowadays it is used in slide rule form, as a ring around the variometer dial or in a miniature computer built into the variometer.

In 1956, in Montreal, Canada, Mr. Kasprzyk published his work "Cross Country Flying In High Performance Sailplanes" wherein he further expanded his formula to relate to the high performance of more modern sailplanes which would attain glide ratio's of 34:1. Herein, he pointed the way to increasing cross-country speeds by flying straight and seldom circling in thermals under proper meteorological conditions.

In 1970, Mr. Wojciech Mozdyniewicz, at the Warsaw Polytechnical Institute in Poland, further improved the Kasprzyk method by his addition of dynamic techniques to it which he named "Dolphin Tactics." Again, cross-country speeds and distances increased.

High performance sailplanes of modern design, with about a 35:1 glide ratio, flying in moderate thermal dispersal conditions, in lift of about 2 meters per second, can utilize the dynamic flight mode of "Dolphin Tactics" to optimize cross-country speed performance. Dolphin flight tactics require that the pilot constantly change airspeed while circling, essing, banking or otherwise changing the course direction, properly related to the air mass in which the sailplane is flying at the given moment. The rate of change of the airspeed during each manuever must also be optimized. Flight altitude and deviations off course must also be considered. Optimization of these factors requires the correct evaluation of the atmospheric conditions on course, the performance capabilities of the given sailplane and the correct matching of the flight dynamics with the actual state of the vertical motion of the air mass on course.

Factors which affect cross-country speed, other than the movement of the air mass in which the sailplane is flying, are: air density, the wing loading at which the sailplane is flying, and the lift coefficient. Lift coefficient and wing loading have the greater influence; however, flight altitude must also be considered. The interrelation of these factors is shown in Fig. 1.

$$V = \sqrt{\frac{2Q}{\rho S}}\ \frac{1}{\sqrt{C_Z}} \quad (m/S)$$

V - AIRSPEED (m/S)

ρ - AIR DENSITY (kGS^2/m^4)

Q - SAILPLANE WEIGHT (kG)

S - WING AREA (m^2)

C_Z - LIFT COEFFICIENT (-)

FIG. 1

As to the dynamic aspects of the flight, change of speed of the sailplane plays the basic role, thus acceleration or deceleration, positive g or negative g, causes an artificial change of sailplane weight - either decreasing or increasing it. During these moments of either acceleration or deceleration, the wing loading changes momentarily modifies the performance of the given sailplane as related to its performance at a given airspeed and a given wing loading during steady state flight. Dwg. 1 and Fig. 2 show the relationship of these g forces.

$$Q_P = \frac{QV^2}{gR} \quad (kG)$$

Q_P - APPARENT CHANGE OF WEIGHT (kG)

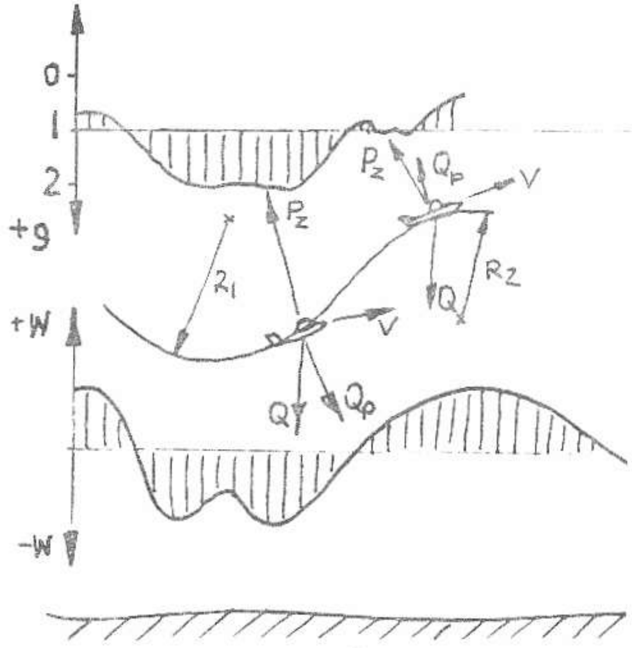
Q - IN FLIGHT WEIGHT (kG)

V - AIRSPEED (m/S)

G - ACCELARATION (m/S^2)

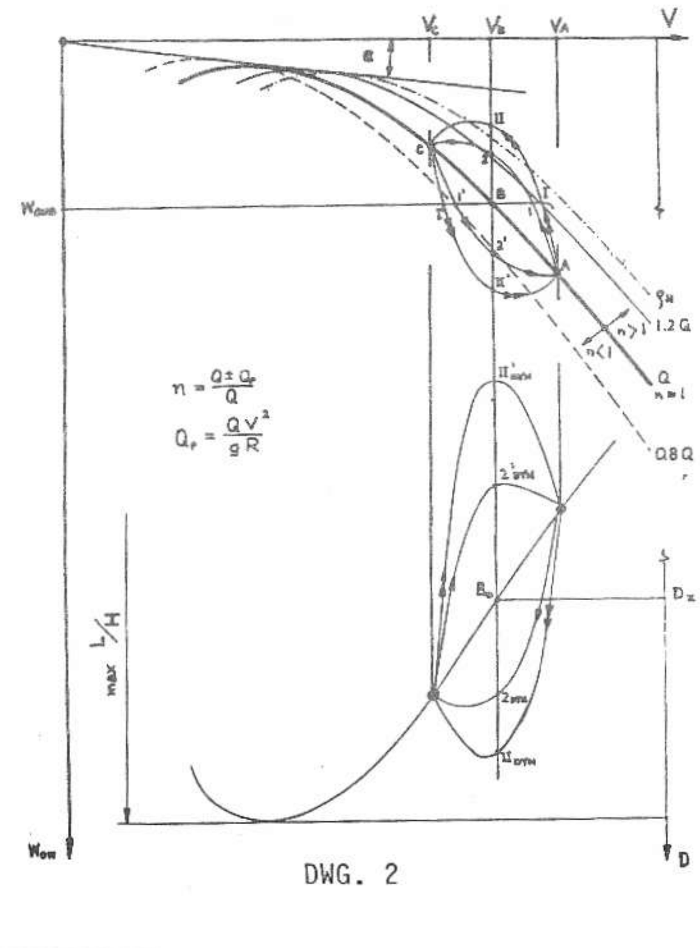
R - FLIGHT PATH RADIUS (m)

FIG. 2

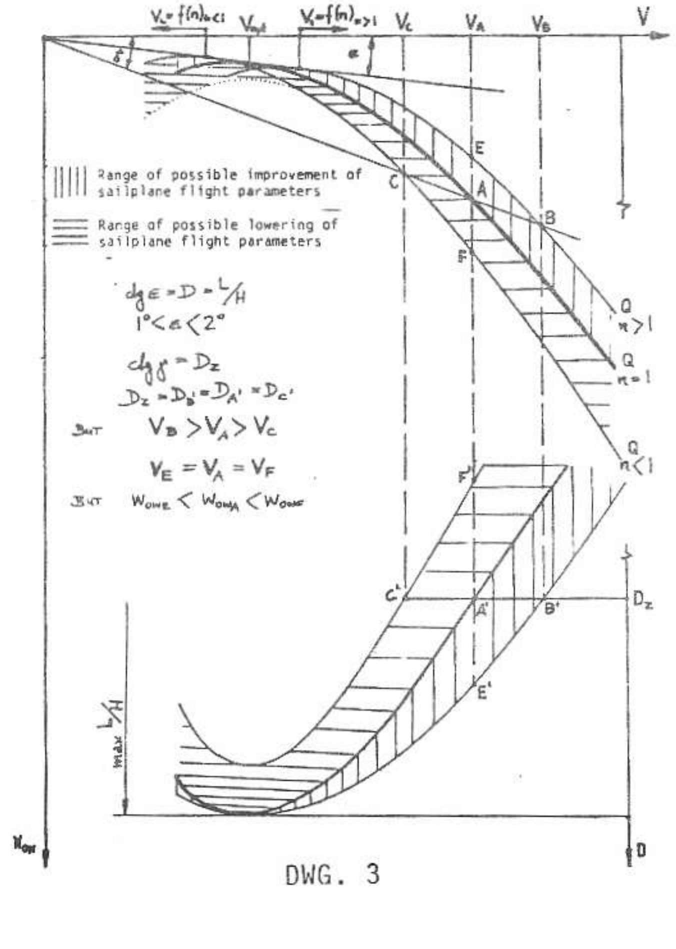


DWG. 1

Drawings 2 and 3 further illustrate these dynamic factors. Let us assume we are in gliding flight holding a constant given airspeed in completely quiet air - Va on the drawing. The sink rate of the sailplane at this given airspeed is WowA. We thus establish point A on the performance curve of the sailplane at a given wing loading. If we now rapidly decrease the speed to Vc, giving point C on the performance curve, position Vb is established. This represents some airspeed between Va and Vc. However, the rate of sink, Wow, will not now be that shown by the performance curve for this speed, point B, but will be some amount less - say point II or point 2. This occurs because decreasing the speed artifically increases the sailplanes weight and thus the wing loading. The amount of this weight increase depends on the rate of decelaration. Only under one condition will these points, when changing speed from Va to Vc or from Vc to Va, lie on the actual performance curve for the given sailplane. This occurs when the acceleration rate never exceeds 1g, meaning that the rate of change of the speed must be "infinitely slow." When speed is reduced from Va to Vc, the performance curve no longer lies on line A-B-C, but is above it along, for example, line A-I-II-C or along line A-1-2-C. This infers that g factors momentarily modify the performance aspects of a given sailplane as compared



DWG. 2



DWG. 3

to its performance during steady state flight.

Pilots flying modern sailplanes in the reclining position can easily withstand g factors of positive 2 and negative 3/4. This places it well within the realm of the possibility of exploiting these dynamic soaring methods.

It should be noted that energy gains are acquired only when the speed is being decreased. Conversely, speed increase is accompanied by energy loss. When speed is being increased, the performance parameters fall below the steady state flight performance curve as shown by C-I'-II'-A or C-1'-2'-A.

The lower part of Dwg. 2 and 3 show the effect of these dynamic factors on the glide ratio performance of the given sailplane.

The sustained time phases in such non-steady-state dynamic flight are a function of the aerodynamic characteristics of the sailplane correlated with the proper control of the g factors as related to the vertical motion of the airmass. These phases last from a few to tens of seconds.

It should be observed here that the optimum results with these techniques should be obtained by flying through the downdraft portion (in the high wing loaded condition - positive g mode) before encountering the lift area, for more effective penetration. This is better than entering the lift area in the low wing loading condition (negative g mode). This will provide a more effective climb, not only due to the momentary lighter wing loading but also because of the longer elapsed time spent in the lift area due to the lower entry speed resulting from the previous deceleration maneuver. Here, it is interesting to note the results upon entering the core of a strong thermal, or other strong lift area, at minimum speed in the 0g mode and maintaining this mode momentarily, then automatically being at minimum sink speed for a maximum time phase in the high lift area. The ideal solution would be to have information instantly available to the pilot about the actual conditions of the air mass directly ahead of the sailplane at a distance of about 50-200 yards. This would ease the implementation of these dynamic techniques.

PART II - A SIMPLIFIED ANALYSIS OF SAILPLANE FLIGHT DYNAMICS

The following qualitative and quantitive analysis of a specific sailplane in the dynamic flight mode are based on inflight instrument recordings. Speed and altitude were recorded simultaneously on the revolving drum of a specially designed and built instrument called a "Speedobarograph" (Dwg. 8). Acceleration and sinking speed readings were recorded simultaneously by a motion picture camera photographing the sailplane's instrument panel during the flight tests.

Test Sailplane - Jantar I

Best Glide Ratio - 43.9-1 at 83 $[km/H]$

Wing Loading - 28.4 $[kG/m^2]$

Assume:

-1° Quasistationary atmospheric conditions,

-2° Static and dynamic similarity of all flight conditions during every test (all tests were performed during late evening hours in stable atmospheric conditions).

The analysis was subjected to 3 flight tests.

Test Tasks:

1. Establish a constant airspeed $V_L = 83\ [km/h]$
2. Increase the speed to; $V_M \cong 250\ [km/h]$

2A. During Acceleration - maintain constant but do not exceed

Test I;		a = 0.9g	(-10%)
Test II;	2B.	a = 0.5g	(-50%)
Test III;	2C.	a = 0.0g	(-100%)

3. Decelerate in climbing flight - maintain but do not exceed

Test I;	3A.	a = +1.1 g	(+10%)
Test II;	3B.	a = +1.5 g	(+50%)
Test III;	3C.	a = +2.0 g	(+100%)

4. Establish constant airspeed. $V_L = 83\ [km/h]$
5. Repeat the runs.

Each test was run in a time frame; $T = 6$ [min.] Supplement: time of one revolution of the speedobarograph drum - $T_0 = 60$ [min.]

Test I

Beginning Height:

$$H_I = 1360 \; [m]$$

in Test I the sailplane in time frame $T = 6$ [min.], repeated the runs; m_A

1. $$m_A = 3$$

2. Height used: H_A

$$H_A = 485 \; [m]$$

3. Average height loss per run: h_A

$$h_A = H_A / m_A = \frac{485}{3} = 161.7 \; [m]$$

4. Lowest Average Airspeed: V_d

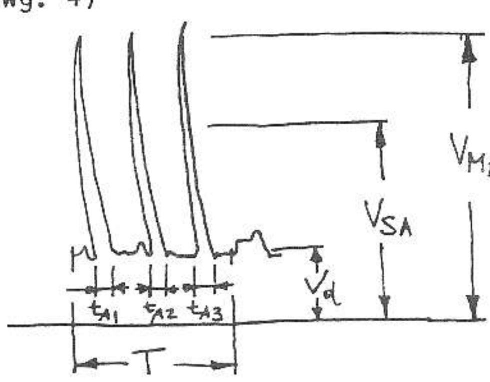
$$V_d = 83 \; [km/h]$$

5. Average maximum airspeed: V_{MA}

$$V_{MA} = \frac{V_{M1} + V_{M2} + V_{M3}}{m_A} = \frac{240.1 + 241.4 + 244.5}{3} = \frac{726}{3}$$

$$V_{MA} = 242 \; [km/h]$$

6. Average airspeed in test I: V_{SA} (Dwg. 4)



DWG. 4

$$t_{A1} = 52 \; [s]$$

$$t_{A2} = 42 \; [s]$$

$$t_{A3} = 37 \; [s]$$

$$t_{AS} = \frac{t_{A1} + t_{A2} + t_{A3}}{m_A}$$

$$t_{AS} = 44 \; [s]$$

$$V_{SA} = m_A \times t_{AS} / T \times \left[V_d + \frac{m_A}{n \times T_T} \times (V_{MA} - V_d) \right] + (T - m_A \times t_A) / T \times V_d \; [km/h]$$

$$V_{SA} = 3 \times 44/360 \times \left[83 + 0.5 \times (242 - 83) \right] + (360 - 3 \times 44) / 360 \times 83 = 111.9 \; [km/h]$$

$$V_{SA} = 111.9 \; [km/h]$$

7. Average sinking speed from the performance curve: w_{OWA}

$$V_{SA} = 111.9 \; [km/h] \qquad w_{OWA} = 0.97 \; [m/s]$$

8. Calculated height; H_{1A}

$$H_{1A} = T * w_{OWA} = 360 * .97 = 349.2 \; [m]$$

9. Difference between the actual height loss and calculated theoretical height loss: ΔH_A

$$H_A - H_{1A} = 485 - 349.2$$

$$\Delta H_A = +135.8 \; [m]$$

10. Actual sinking speed; w_{OWAR}

$$w_{OWAR} = \frac{HA}{T} = 1.35 \; [m/s]$$

11. Actual point on the performance curve; A

$$A \begin{cases} V_{SA} = 111.9 \; [km/h] \\ w_{OWAR} = 1.35 \; [m/s] \end{cases}$$

12. Conclusion: This analysis shows strong apparent negative factor influence on the sailplanes flight characteristics when a small g factor in the range of ± 10% g is maintained during acceleration and deceleration and in shaping the actual dynamic characteristics of its performance curve in the unfavorable region of change of the sailplanes flight parameters.

Test II

Beginning height: $H_{II} = 1060 \; [m]$

In Test II the sailplane in time frame $T = 6$ [min.], repeated the runs; m_B

1. $m_B = 4$

2. Height used; H_B

$$H_B = 292 \; [m]$$

3. Average height loss per run: h_B

$$h_B = 73 \; [m]$$

4. Lowest average airspeed: V_d

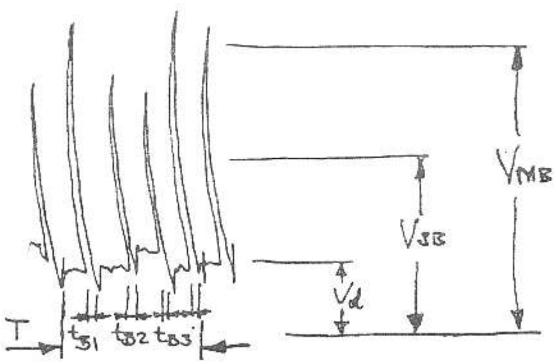
$$V_d = 83 \; [km/h]$$

5. Average maximum airspeed: V_{MB}

$$V_{MB} = \frac{V_{M1} + V_{M2} + V_{M3} + V_{M4}}{m_B} = \frac{202 - 187 + 256 + 247}{4}$$

$$V_{MB} = 223 \; [km/h]$$

6. Average airspeed in Test II; V_{SB} (Dwg. 5)



DWG. 5

$t_{B1} = 19 \; [s]$ $\quad t_{B3} = 29 \; [s]$

$t_{B2} = 18 \; [s]$ $\quad t_{B4} = 22 \; [s]$

$$t_{BS} = 22 \; [s]$$

$$V_{SB} = 105.7 \; [km/h]$$

7. Average sinking speed from the performance curve: w_{OWB}

$$V_{SB} = 105.7 \; [km/h] \qquad w_{OWB} = .87 \; [m/s]$$

8. Calculated height: H_{1B}

$$H_{1B} = 313.2 \; [m]$$

9. Difference between actual height loss and calculated theoretical height loss: ΔH_B

$$\Delta H_B = -21.8 \; [m]$$

10. Actual sinking speed: w_{OWBR}

$$w_{OWBR} = \frac{H_B}{T}$$

$$w_{OWBR} = 0.81 \; [m/s]$$

11. Actual point on the performance curve; B

$$B \begin{cases} V_{SB} = 105.7 \; [km/h] \\ W_{OWBR} = 0.81 \; [m/s] \end{cases}$$

12. Conclusion: This analysis shows the significant influence of the positive g factor on the sailplanes flight characteristics when a g factor in the range of ± 50%g is maintained while accelerating and decelerating, and in shaping the actual dynamic characteristics of its performance curve - in the favorable region of change of the sailplanes flight parameters.

Test III

Beginning height: $H_{III} = 1050 \; [m]$

In Test III the sailplane in the frame T = 6 [min.], repeated the runs: m_C

1. $m_C = 5$

2. Height used: H_C

$$H_C = 317 \; [m]$$

3. Average height loss per run: h_C

$$h_C = 63 \; [m]$$

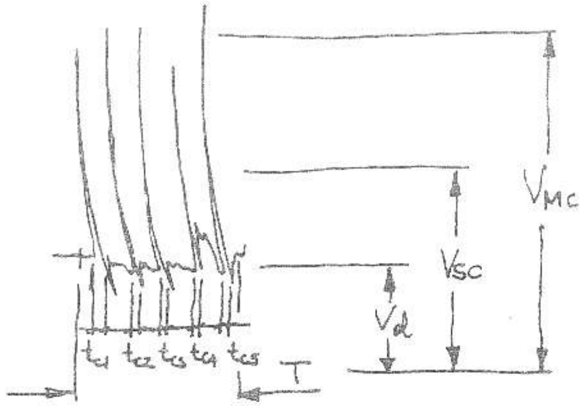
4. Lowest average airspeed: V_d

$$V_d = 83 \; [km/h]$$

5. Average maximum airspeed: V_{MC}

$$V_{MC} = 234.4 \; \left[\frac{km}{h}\right]$$

6. Average airspeed in Test III: V_{SC} (Dwg. 6)



DWG. 6

$t_{C1} = 18$ [s]
$t_{C2} = 19$ [s]
$t_{C4} = 17$ [s]
$t_{C5} = 27$ [s]

$t_{CS} = 20.2$ [s]
$V_{SC} = 118.2$ [km/h]

7. Average sinking speed from the performance curve: W_{OWC}

$V_{SC} = 118.2$ [km/h] $w_{OWC} = 1.12$ [km/s]

8. Calculated height: H_{1C}

$H_{1C} = 403.2$ [m]

9. Difference between actual height loss and calculated theoretical height loss: ΔH_C

$\Delta H_C = -86$ [m]

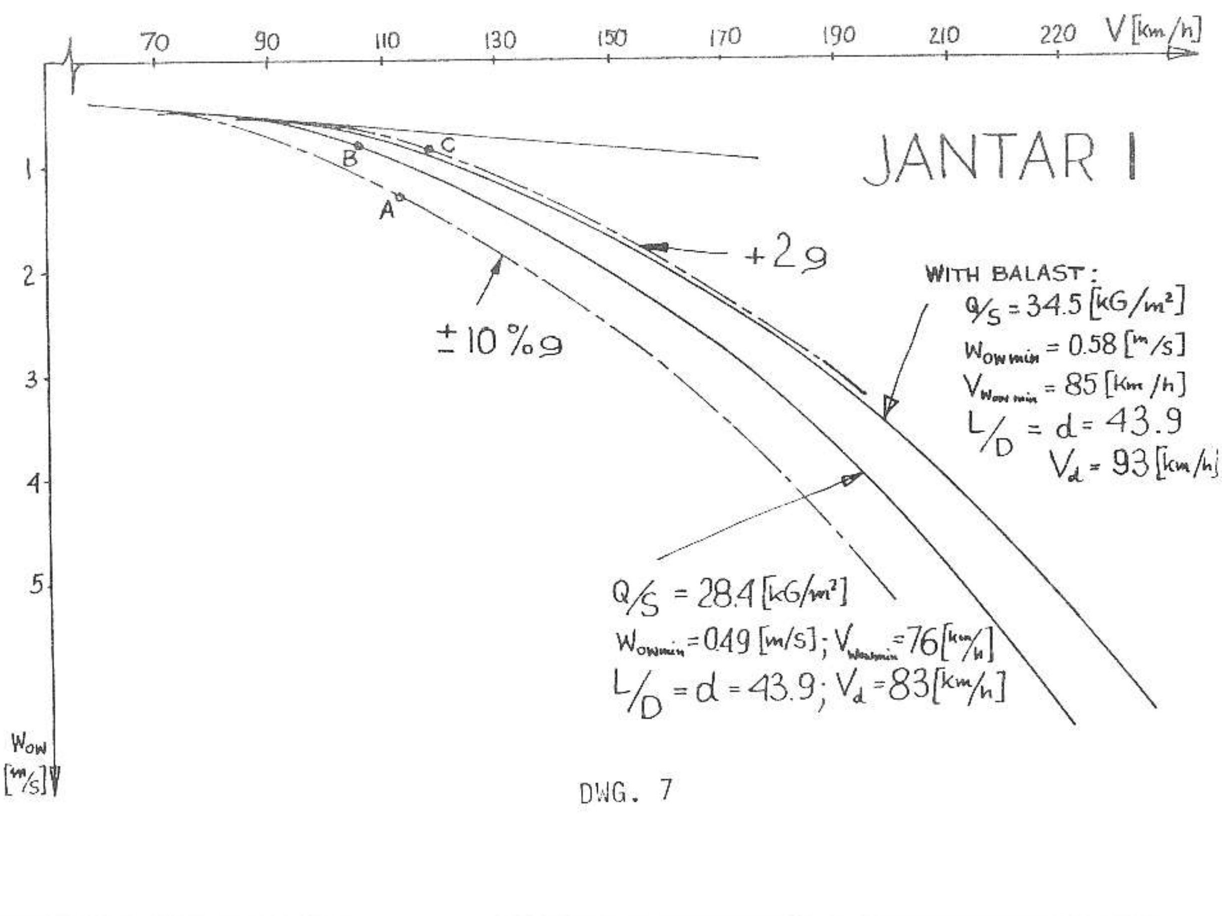
10. Actual sinking speed: W_{OWCR}

$w_{OWCR} = 0.88$ [m/s]

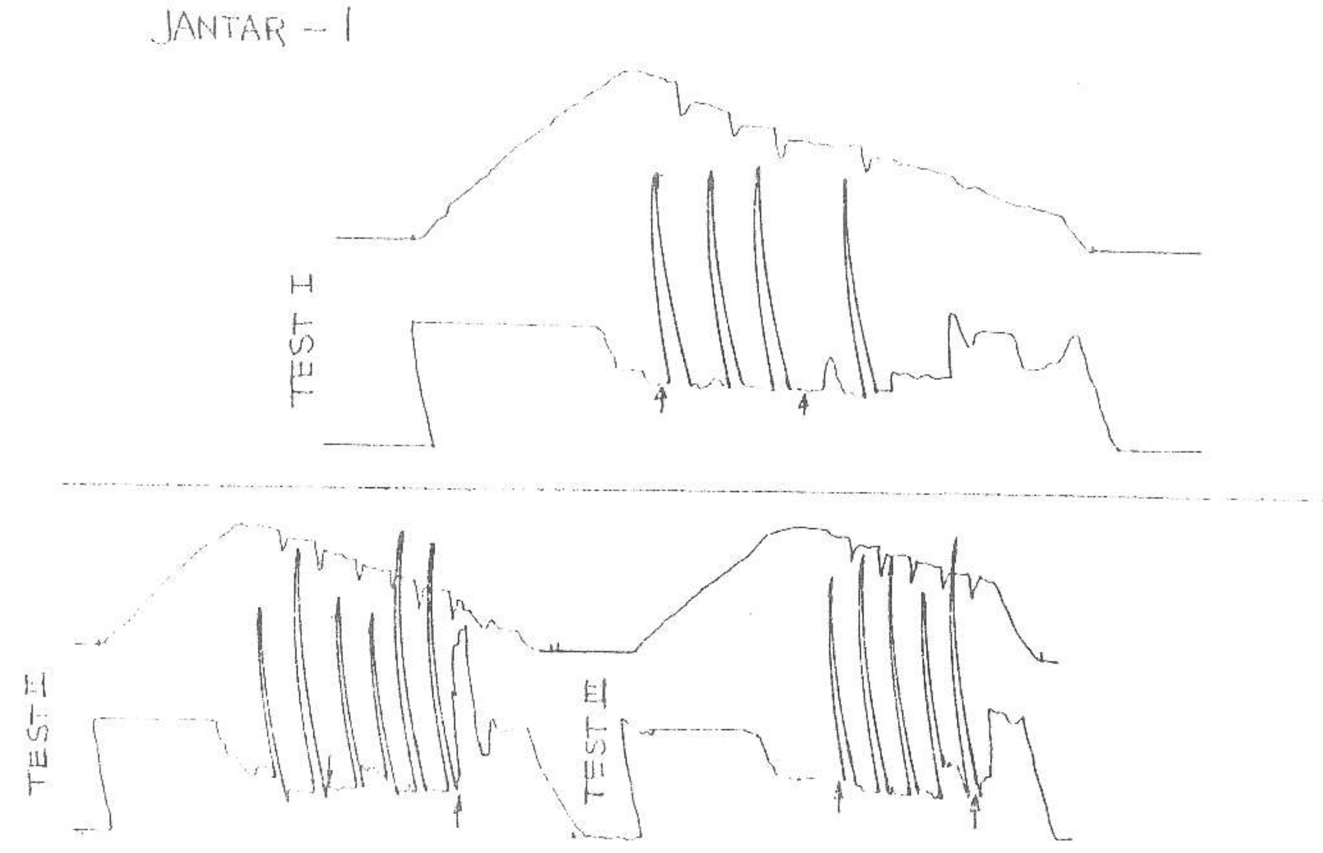
11. Actual point on the performance curve; C

C { $V_{SC} = 118.2$ [km/h], $w_{OWCR} = 0.88$ [m/s] }

12. Conclusion: This analysis shows the strong influence of the positive g factor on the sailplanes flight characteristics when a g factor in the range of ± 100%g is maintained while accelerating and decelerating and in shaping actual dynamic characteristics of its performance curve in the



DWG. 7



DWG. 8

favorable region of change of sailplanes flight parameters.

The results of the above analysis are shown in Dwg. 7.

The Dynamic State of Flight introduced beneficial changes in a sailplanes flight characteristics. Soaring pilots obviously strive to improve these characteristics. This demands a certain knowledge of the above factors.

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