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Design of a system for measuring the weight and balance of sailplanes

Annex

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1 Sailplane specifications

1.1 General data

Model	Manufacturer	Year	Type	Span (m)	Length (m)
ASK 13	Schleicher	1966	Two seater	15.4	8.18
ASK 21	Schleicher	1979	Two seater	17.0	8.35
ASW 20	Schleicher	1977	Single seater	15.0	6.80
DG-1000S	DG Flugzeugbau	2000	Two seater	20.0	8.57
G102 Astir CS	Grob	1974	Single seater	15.0	6.47
G103 Twin II	Grob	1980s	Two seater	17.5	8.18
Ka 6E	Schleicher	1955	Single seater	15.0	6.66

Table 1: Sailplanes' general data.

1.2 Weight and balance

1.2.1 Weights

Model	Empty weight (kg)	Maximum weight (kg)	Maximum weight of non-lifting parts (kg)
ASK 13	295	481	322
ASK 21	380	600	410
ASW 20	255	454	235
DG-1000S	415	750	469
G102 Astir CS	255	450	240
G103 Twin II	380	580	400
Ka 6E	190	300	190

Table 2: Empty weights, maximum weights and maximum non-lifting parts weights.

1.2.2 Weight distribution

Model	Representative[1] front weight (G1) (kg)	Representative rear weight (G2) (kg)	Max. G1 (kg)	Max. G2 (kg)	Min. G1 (kg)	Min. G2 (kg)
ASK 13	295.4	4.6	318.2	272.1	7.9	1.8
ASK 21	360.4	14.6	389.4	334.1	15.9	10.6
ASW 20	225.8	39.2	251.6	202.6	46.2	34.4
DG-1000S	387.8	52.2	430.2	345.3	59.8	48.5
G102 Astir CS	218.4	31.6	249.5	196.9	36.5	24.9
G103 Twin II	359.1	20.9	382.9	337.4	22.6	17.1
Ka 6E	174.6	25.4	196.4	163.5	29.5	22.4

Table 3: Sailplanes' weight distributions (front and rear weighing points).

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[1] By *representative* we indicate those weights used for all uncertainty calculations.

1.3   Distances and angles

Model	L1 (m)	L2 (m)	Datum transversal position Y_D (m)	Rear weighing point height (m)
ASK 13	4.80	-0.41	0.622	0.682
ASK 21	4.61	-0.59	0.400	0.489
ASW 20	4.16	0.00	0.314	0.295
DG-1000S	5.18	-0.11	0.363	0.659
G102 Astir CS	4.09	-0.11	0.322	0.507
G103 Twin II	4.34	-0.50	0.374	0.405
Ka 6E	4.49	0.00	0.619	0.227

Table 4: Relevant distances (estimated).

Model	Estimated vertical CG position[2] (m)	Levelling angle θ_0 (°)
ASK 13	0.730	3.15
ASK 21	0.693	2.98
ASW 20	0.572	2.58
DG-1000S	0.800	1.89
G102 Astir CS	0.628	2.48
G103 Twin II	0.629	2.29
Ka 6E	0.540	5.14

Table 5: CG vertical position and levelling angle (in flight position).

1.4   Other specifications

Model	Tyre pressure (bar)	Tyre contact area (m²)	Tyre diameter (mm)	Tyre width (mm)
ASK 13	2.413	0.0129	354	122
ASK 21	2.700	0.0141	354	122
ASW 20	2.500	0.0099	354	122
DG-1000S	2.500	0.0169	380	146
G102 Astir CS	2.533	0.0097	354	122
G103 Twin II	2.500	0.0150	436	155
Ka 6E	2.413	0.0080	330	124

Table 6: Main wheel tyres data.

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[2] Measured from the ground when the sailplane is in flight position and the main wheel is touching the ground.

2 Sailplane manuals information

In this section, you will find the pages of the sailplanes' manuals which provide the necessary data used in this project.

2.1 ASK 13 [1]

– 3 –

AS – K 13 Flight Manual

1. **Operating Limitations**

   Air speeds:

Max. speed	125	mph	108 kts
rough air	87	mph	75 kts
aero tow	87	mph	75 kts
auto and winch tow	62	mph	53 kts

   Weights:

Empty weight	650	lbs
Max. weight	1060	lbs
Max. weight of non lifting parts	710	lbs

   Kategory: 2 BVS

Limit load factor	
up	4,0
down	–2,0
Safety factor	2,0

Approval of translation has been done by best knowledge
and judgement – In any case the original text
in German language is authoritative.

AS - K 13 Flight Manual

Center of gravity position in flight:

Leveling means	Tangente to rib Nr. 3 horizontal.
Datum	wing leading edge rib 3
Max. forward	2,75 behind datum point
Max. rearward	9,7 " " "

Weak link in the tow cable:

Winch tow	max.	2350	lbs
	min.	1850	lbs
Aero tow	max.	1580	lbs
	min.	1060	lbs

2. ## Operating Directions:

Winch tow:

Max. tow speed is 62 mph.

Attention. In winch tow pulling the stick back means increase of speed. When lifting off ease the stick somewhat to overcome a light tentency to pitch up. Best attitude in climb is with stick normal. Winch tow on the belly hock only.

AS - K 13 Flight Manual

With pushed and pulled stick the ailerons are some what zoomed.

The controls have stops:

Rudder control: Fixed stop at the lower hinge.

Aileron control: Fixed stop at two hard wood pieces down the front seat.

Elevator control: Backward - fixed stop at the front edge of the seat, forward - fixed stop at the ground board.

Airbrakes:

Backward: Adjustable stop at the horizontal pushrod, stops against the main bulkhead frame.
Forward: Fixed stop, cross shaft lever stops at a tube piece.

6) Weights and Center of Gravity Positions:

After repairs, after installing of additional equipment, after new painting etc. there should be watched that the empty weight center of gravity is within the limits. If necessary balance weights are to be installed.

Empty weight		616	638	660	682	705	lbs
center of gravity position	max.	21,45	21,06	20,68	20,3	20,0	
	min.	19,3	18,7	18,2	17,7	17,2	

behind datum point.

Leveling means: Tangente to rib 3 horizontal.

Datum: wing leading edge rib 3.

AS - K 13 Flight Manual

Also by condensing water considerable quantities
of humidity can enter the interior of the glider.

Strong sun irradiation will affect the finish
by time, therefore the glider should not be ex-
posed to the sun more than neceasary. The treat-
ment of the finish with good waxes and polishing
material will increase the durability and improve
the surface, an important fact for performance.
The advantages of the laminarprofil can only be
achieved by a smooth surface.

Sealing of gaps with adhesive tape will also cause
some gain of performance. However at the cockpit
caution is necessary, when parachute bail out
shall be possible.

Cleaning of the plexiglas canopy only with suitable
cleaners. If not available use pure water. Soft
cloth (gloves cloth). In no case rub with hard
cloth dry on plexiglass.
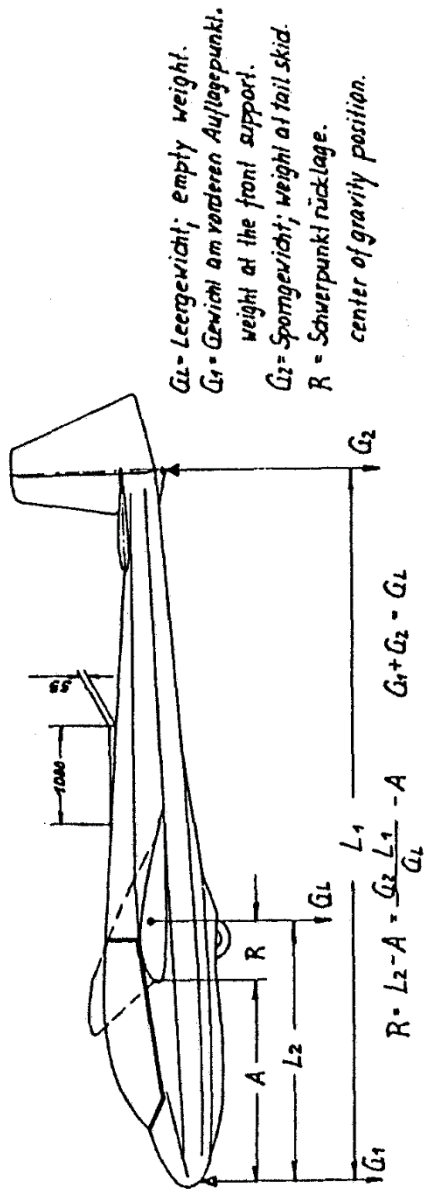
Lubrication of bearings:

So far as possible, the ball bearings are covered
and therefore need no special maintenance. Only
the bearings at the wing root, where the rigging
connections do not allow a suitable protection,
must be cleaned with gasoline when dirty and
greased again.

The control surface bearings are to be dismant-
led and greased at the annual overhauls.

Wheel: Tube pressure 35 psi.

The c.g. hock especially is exposed to dirt and
needs often cleaning and ciling.

AS-K13 Übersicht M=1:50
3-View drawing; scale 1:50

AS-K13 Wägeblatt; Balancing sheet

G_L = Leergewicht; empty weight.
G_1 = Gewicht am vorderen Auflagepunkt.
        weight at the front support.
G_2 = Spanngewicht; weight at tail skid.
R = Schwerpunkt rücklage.
      center of gravity position.

$$R \cdot L_2 = A \cdot \frac{G_2 \cdot L_1}{G_L} - A$$

$$G_1 + G_2 = G_L$$

	280	290	300	310	320	kp
G_L = Leergewicht; empty weight						
R { Vorderste Schwerpunktlage; most forward position of Cal.Gr. empty min.	490	475	462	449	437	mm
Hinterste Schwerpunktlage; most rearward position of Cal.Gr. empty max.	545	535	525	516	508	mm

2.2 ASK 21 [2]

I.5   DESCRIPTION

The ASK 21 is designed to meet the needs of modern
gliding training. It has an all fiberglass sandwich
structure.
Midwing with T-tail, tandem seat arrangement, airbrakes
on upper wing only.
The glider is stressed for aerobatics (inverted flight
included).

Technical Data

Span	17,00 m	=	55,74 ft
Length	8,35 m	=	27,4 ft
Height	1,53 m	=	5,02 ft
Aspect ratio	16,1		
Wing area	17,95 m^2	=	192,96 sqft
Max. all up weight	600 daN	=	1320 lbs
Max. wing loading	33,4 daN/m^2 =		6,84 lbs/sqft

Airfoil: Wortmann FX SO2 196 (inner wing)
            Wortmann FX 60 -126 (wing tip)

Winch Tow: Weak Link   1000 daN
Aero Tow : Weak Link   600 daN

March 9, 1983

Airspeed indicator markings (IAS)

Red line (max. permissible airspeed):
    151,2 kts = 174,0 mph = 280 km/h

Yellow arc (caution range):
    97,2 - 151 kts = 112 - 174 mph = 180 - 280 km/h

Green arc (normal range):
    43,0 - 97 kts = 50 - 112 mph = 80 - 180 km/h

Yellow triangle (approach speed):
    49,0 kts = 56,0 mph = 90 km/h

II.5   CREW   : 2 persons

Minimum crew   : 1 person (min.weight 70 daN = 154 lbs

Caution: Solo flights may only be conducted from
          the front seat !

II.6   WEIGHTS

Empty weight   approx. 792 lbs = 360 daN
Max. all up weight   1320 lbs = 600 daN
Max. weight of non lift
producing members   902 lbs = 410 daN.

March 9, 1983

IV.2   DAILY INSPECTIONS

Prior to flight operations the following checks must be accomplished:

1.a.   Open canopy! Check that the main pins are properly secured.

   b.   Check the proper connection of the ailerons and airbrakes through the access hole on the left side above the wing. Are the quick-release connectors secured with spring clips ?

   c.   Check for foreign bodies !

   d.   Check the control circuits force and that all controls are free-moving. Apply full deflections and load the control circuits with fixed controls and airbrakes.
   Check the plastic tubes inside the S-shaped rudder pedal tubes for proper and tight fit.

   e.   Check tire pressure:
              Nose wheel 2,0 bar (28 psi)
              Main wheel 2,7 bar (38 psi)
              Tail wheel (If installed) 2,5 bar (35,6 psi).

   f.   The condition and function of the tow release mechanism is to be checked. Actuate the tow release: does it snap back freely ? Engage and disengage the ring pair. Check the automatic release of the C.G. towing hook with the ring pair which must release auto matically backwards.

   g.   Check the wheel brake. Pull the airbrake lever; at the end of its travel an elastic resistance must be felt.

2.a.   Check upper and lower wing surface for damages !

   b.   Aileron: its condition, free-movingness and play is to be check ed ! Check also the pushrod connection.

   c.   Airbrake: its condition, fit and locking is to be checked.

3.   Check the fuselage for damages, in particular also the bottom side.

4.   Check that the tailplane is properly assembled and secured. Check also the pushrod connection ! Secured with spring clips ?

TN-No.20 dated October 16, 1987

- 3. NOV. 1987

VI.   CENTER OF GRAVITY (CG)

VI.1   WEIGHING PROCEDURE OF CG AT EMTY WEIGHT
        Prior to determining the CG in flight the CG at empty
        weight has to be established by weighing the glider.
        For this procedure the glider must be put on two pair
        of scales (one at the nose wheel and one at the tail
        skid).
        NOTE: the glider must be set on the two pairs of
        scales very carefully in order to prevent that the
        scales get misaligned; (this could lead to erroneous
        results).
        The Datum Line (DL) is situated at the wing leading
        edge of the straight center part of the wing.
        Levelling means: wedge on rear top edge of fuselage
        1000 : 52 horizontal.

        Empty weight CG :
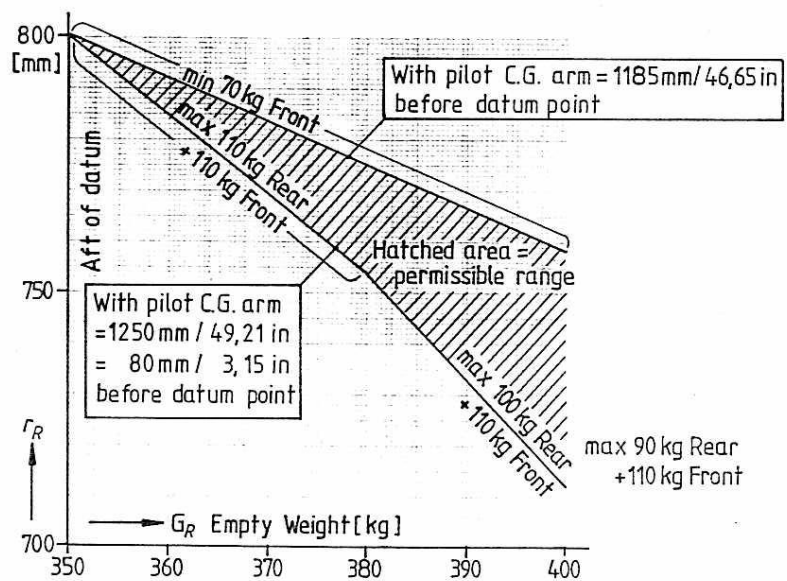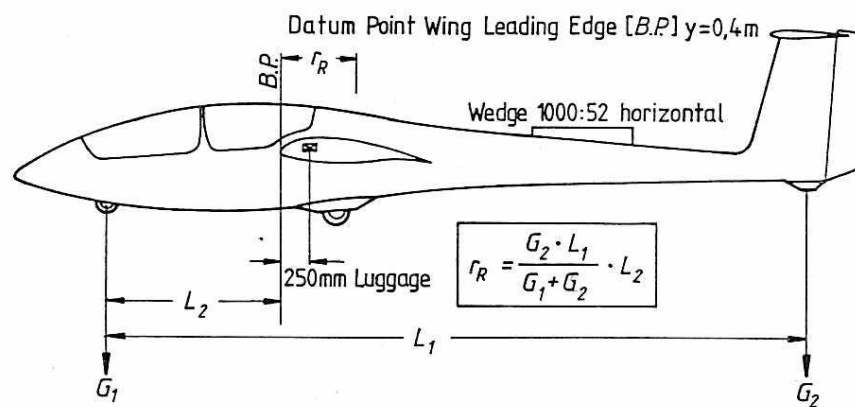   Weight at the nose wheel: lbs
        Weight at the tailskid: lbs
        Support point nose wheel: in
        Support point tailskid: in

        NOTE: determination of empty weight and empty weight CG
        must be done without any additional balance weights
        (e.g. trim cushion).
        Be careful not to exceed the maximum weight of non lift
        producing parts when using maximum payload. The total
        weight of non lift producing parts contains the indivi-
        dual weights of fuselage, elevator and maximum payload
        and must not exceed 410 daN = 920 lbs (the payload must
        be reduced accordingly).

March 9. 1983

Weight and Balance Sheet

Datum Point Wing Leading Edge [B.P.] y=0,4m

Wedge 1000:52 horizontal

$$r_R = \frac{G_2 \cdot L_1}{G_1 + G_2} \cdot L_2$$

250mm Luggage

With pilot C.G. arm = 1185mm/46,65 in
before datum point

min 70 kg Front
max 110 kg Rear
+110 kg Front

Hatched area =
permissible range

With pilot C.G. arm
=1250 mm / 49,21 in
= 80 mm / 3,15 in
before datum point

max 100 kg Rear
+110 kg Front

max 90 kg Rear
+110 kg Front

r_R

G_R Empty Weight [kg]

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The CG should be recalculated after repair, repainting
or installation of additional equipment, but not later
than 4 years after the last weighing.
The empty weight, empty weight CG position and maximum
load should be recorded after each weighing on page
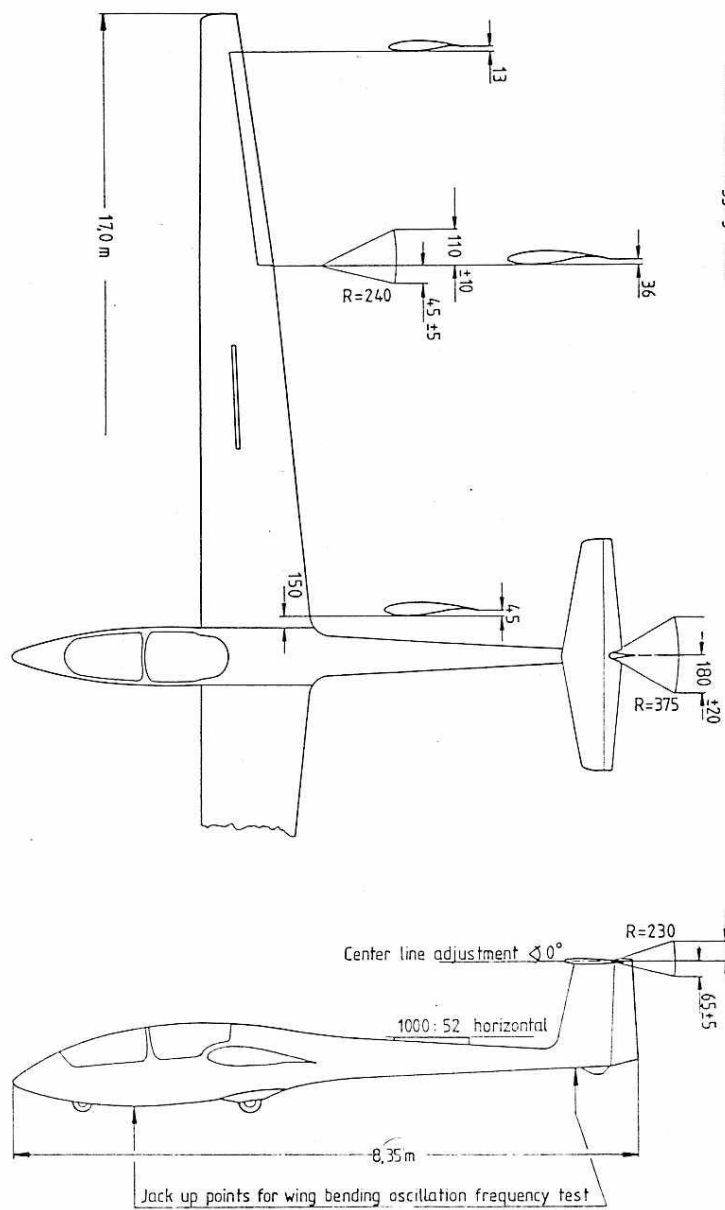of the Flight Manual by a competent person.

VI.2   EMPTY WEIGHT CG POSITION

With the empty weight CG according to the below-mentioned
limits and the pilot weights according to the load table.
the in flight CG will be within the approved range.

Empty Weight		CG forward		CG aft	
daN	lbs	mm	in	mm	in
350	770	800	31,50	800	31,50
360	792	784	30,87	792	31,18
370	814	769	30,28	783	30,83
380	836	754	29,69	774	30,47
390	858	732	28,82	766	30,16
400	880	712	28,03	758	29,84

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Three view - Rigging data

March 9, 1983

17,0 m

R=240

110
+10
4,5 ±5

13

36

150

4,5

180
±20

R=375

R=230

Center line adjustment ∢ 0°

90
±5

65±5

1000 : 52 horizontal

8,35 m

Jack up points for wing bending oscillation frequency test

2.3 ASW 20 [3]

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┌─────────────────────────────────────────────────────────────┐
│              A S W  2 0 - Flight Manual                      │
├─────────────────────────────────────────────────────────────┤
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at increasing altitude, the critical flutter speed ,
however, is more or less determined by true airspeed
for light aircraft, the following speed limits are
valid for high altitude flights

Altitude		Max. Speed (indicated)	
meter m.s.l.	feet m.s.l	km/h	Knots
0-3,000	0-10.000	265	143
5,000	16,400	240	130
7,000	23,00	215	115
9,000	29,500	195	105
11,000	36,000	170	92
13,000	42,600	145	78

If the above limited values are not exceeded, the true
airspeed will be constantly 315 km/h above 3000 m /
10000 feet m.s.l. and thus is high enough to face the
strongest wind in wave flight.

** Please note : Rough air, according to airworthiness
requirements, is turbulence found in wave rotors,
thunderstorm clouds, dust devils and when skimming
mountain crests. An experienced pilot will know that
he must be aware of even stronger turbulence in
thunderstorms or in alpine regions.

Weights (masses)

Empty weight with min. equipment   ~ 255kg / 565lbs.

Max. all-up weight   454kg / 1000lbs.

Max. weight of non lift producing 235kg/ 518lbs.

Components.

Permissible water ballast   max. 120kg / 265lbs

(depending on cockpit load)   or 32 USGals.

See table on page 20.

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Weak link in towing line

600 kg (1320 lbs) for auto / winch and aerotow

In Flight Centre of Gravity

Datum point is the leading edge of the wing root rib (without the fillet of the wing - fuselage fairing).

The horizontal reference line is the centre line of the fuselage tail cone or a 1000 : 45 wedge template levelled out on the top side of the fuselage aft portion (see the page "Rigging Data" in the appendix).

In flight centre of gravity range is from 240 mm (9.45 inch) to 360 mm (14,17 inch) behind datum.

Cloud flying

The sailplane is suited for cloud flying.

Flights under icing conditions are not recommended, specially if the glider has been wet before climbing through the icing level. Experiences have shown that in the area of the rather narrow control gaps, any rain or condensation drops dry off relatively slowly and turn to ice when climbing above the freezing level. Therefore, one has to face a stiffening of the controls, leading to blocked controls in extreme cases.

Isolated climbs above the freezing level with a dry sailplane did not lead to any stiffening of the controls, even though the leading edges of wings and control surfaces showed severe icing.

Flights with water ballast above freezing level should be avoided because of the risk of icing-up of the tank ventilation.

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After landings on wet, muddy ground or in dusty fields the landing gear must be cleaned. For this purpose one removes the seat pan in order to get good access with a vacuum cleaner and to facilitate a thorough cleaning job.

The tyre pressure should be between 2,5 to 2,7 Bar (35 to 38 psi) for 790 lbs. all up weight. At maximum all up weight (when water ballast in used) 3,2 to 3,4 Bar (45.5 to 48 psi).

If the tyre pressure is too low, the tyre deforms to such a degree during landings that the landing gear doors will be destroyed.

The skidplate has to be removed in time or should be protected against excessive wear by welding several stellite beads on to it.

The rubber tailskid has been designed such that it will shear off under strong sideloads. It can be glued on again or repaired with contact cement. It is important to cover the gap from rubber skid to fuselage in order to prevent any peeling and catching of long grass.

The towing hooks are especially exposed to soil and dirt and require frequent cleaning and oiling. For this purpose remove the fibreglass seat pan.

Lubrication of the Bearings

Most ball bearings are, so far as possible, covered and, therefore, will normally require no special care for a longer period of time.

The control hinge bearings must be dismantled and re-lubricated at the annual inspection.

15000

220

6800

1000

45
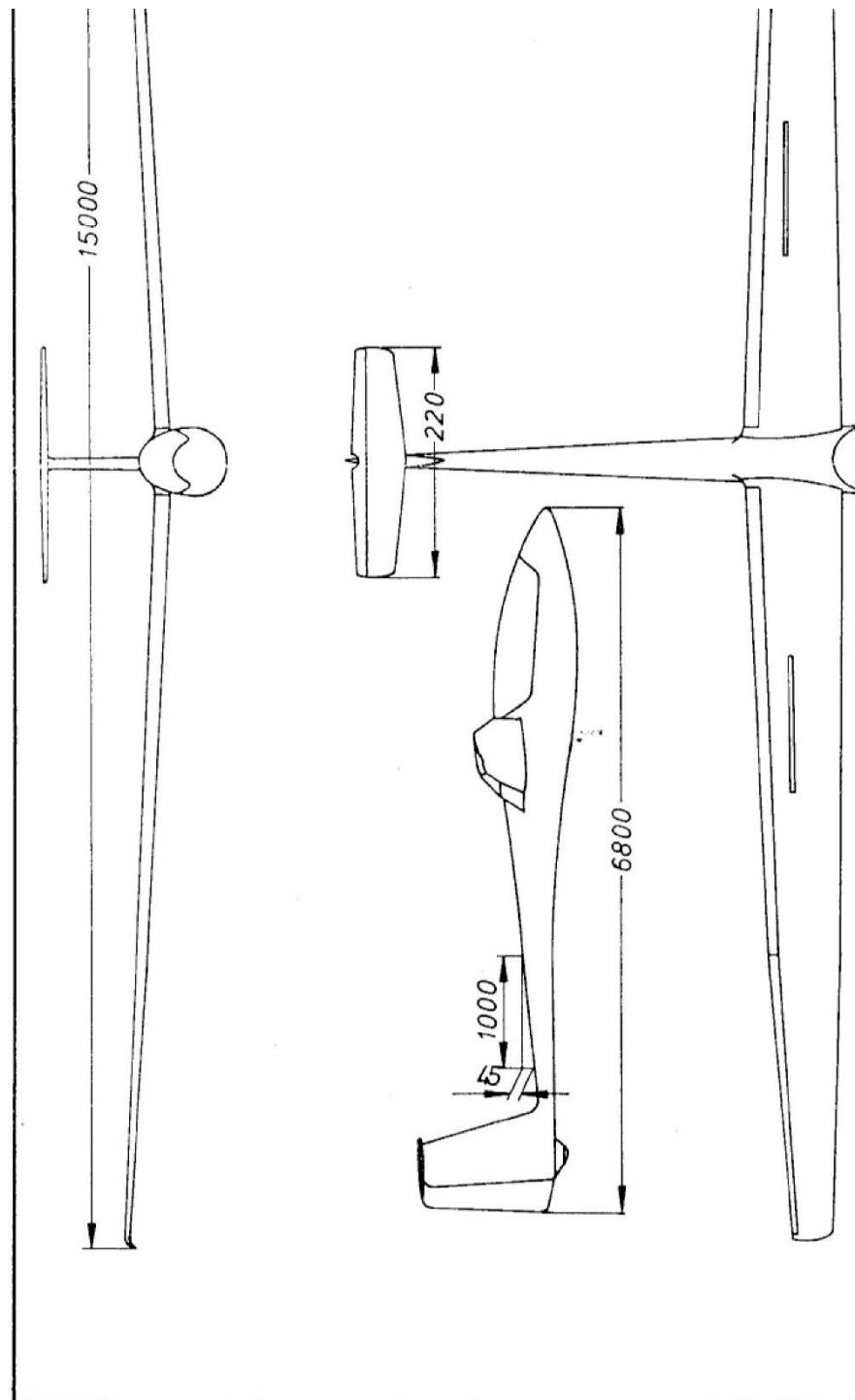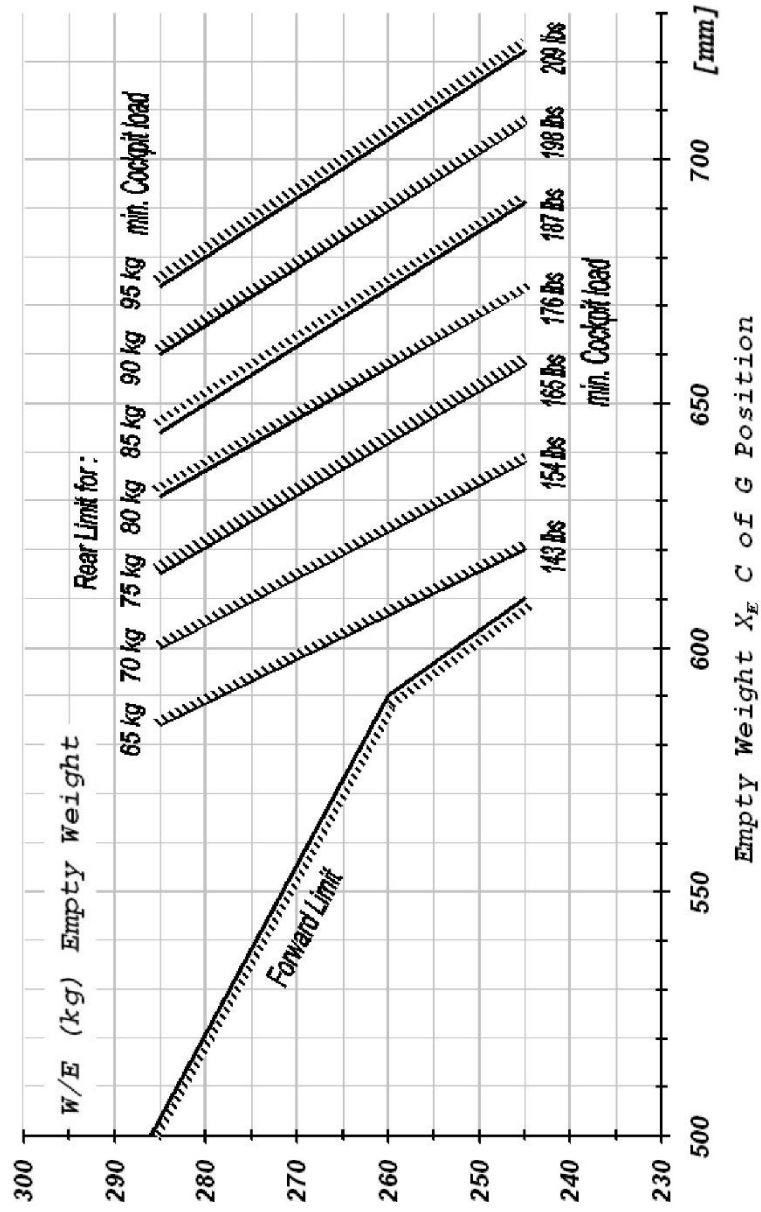
Empty Weight C. of G. Positions and Limits

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2.4   DG-1000S [4]

Flight manual DG-1000S

Technical data

Span	m	18	20
Wing area	m^2	16,72	17,53
Aspect ratio	/	19,38	22,82
Length	m	8,57	
Fuselage height	m	1,0	
Fuselage width	m	0,73	
Span of the horizontal tailplane	m	3,2	
Waterballast Wings	max. kg (l)	160	160
Waterballast fin	max. kg	6,2	
Trim ballast fin	max. kg	12	
Empty mass with basic instruments*	approx. kg	411	415
Wing loading (with one Pilot 80kg)	approx. kg/m²	29,4	28,2
max. take off mass (max. TOW)	kg	750	750
max. wing loading	kg/m²	44,9	42,8
Aerobatics		unlimited Category „A"	simple
max. TOW for aerobatics	kg	630	630
max. speed	km/h	270	270

*Options will increase the empty mass accordingly!

1.5 three view drawing
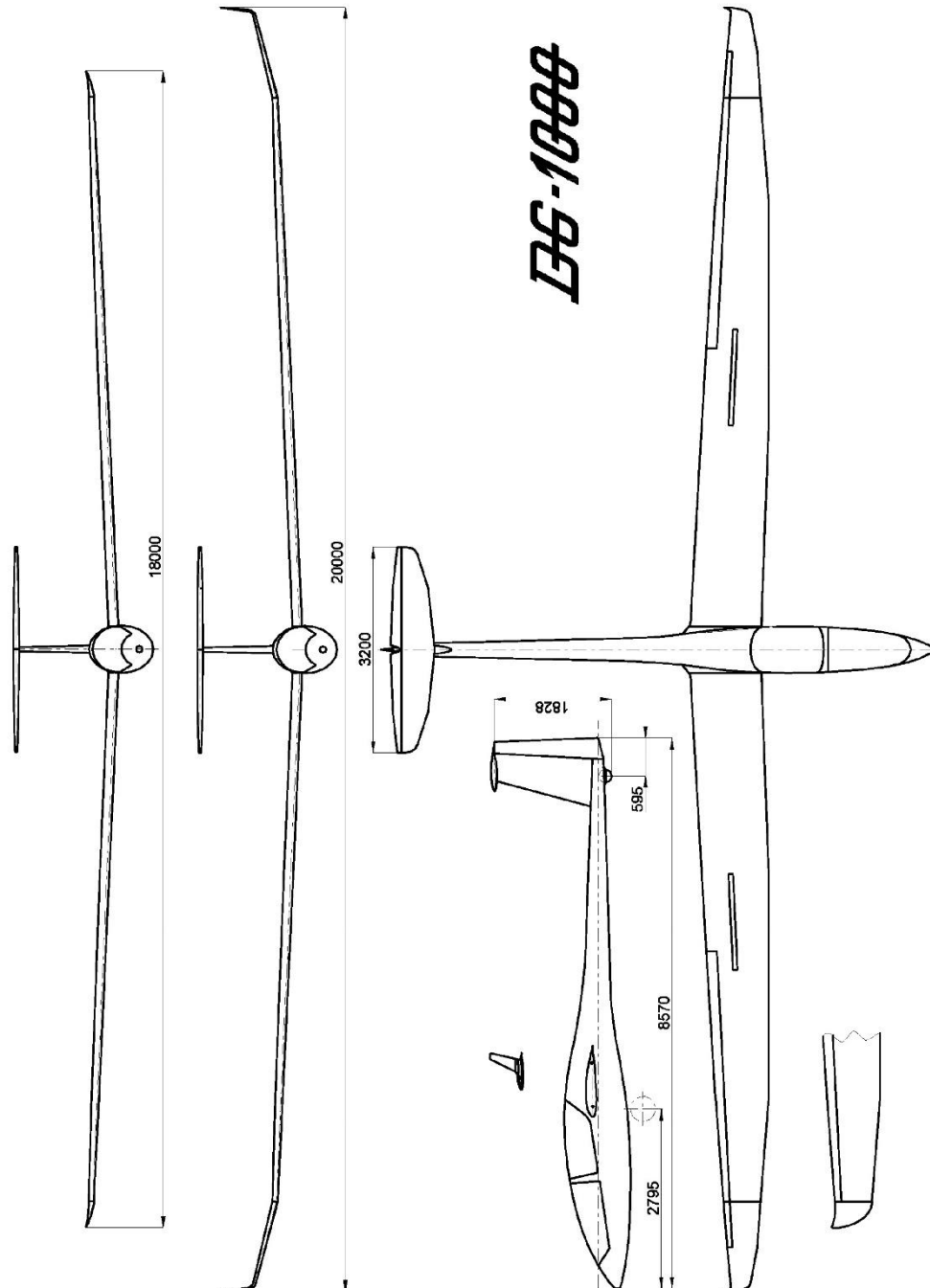
2.4 Mass (weight)

Category A „Aerobatic"

Maximum take off weight:	630 kg	1389 lbs.
Maximum landing weight:	630 kg	1389 lbs.

Category „Utility":

with waterballast:

Maximum take off weight:	750 kg	1653 lbs.
Maximum landing weight:	750 kg	1653 lbs.

without waterballast: Maximum take-off and landing mass = $W_{NLP} + W_{wings}$

W_{NLP} = Maximum mass of the non lifting parts (see below)

W_{wings} = actual mass of the wings

Maximum weight of the non lifting parts = 469 kg   1034 lbs.

Caution: It is recommended to dump the waterballast before landing on airfields. Dump the ballast before an outlanding in any case.

Maximum mass in baggage compartment: 15 kg 33 lbs.

Caution: Heavy pieces of baggage must be secured to the baggage compartment floor (screwing to the floor or with belts). The max. mass secured on one half of the floor (left and right of fuselage centre line) should not exceed 7,5kg (16.5 lbs.).

Ballast

1. Maximum waterballast

in the wings:	160 kg	353 lbs.
in the fin	6,2 kg	13.7 lbs.

2. Maximum mass in the trim-ballast box in the fin: 12 kg   26.5 lbs.

The max. take off mass is not to be exceeded with 1. and 2. together.

Warning: Follow the loading procedures see section 6.

2.13 Tyre Pressure

Main wheel	2,5 bar	(36 psi)
Nose wheel (if installed)	2,5 bar	(36 psi)
Tail wheel	4,0 bar	(58 psi)

2.14 Waterballast (Option)

Max. capacity 80 l (21.1 U.S. gal) per wing.

Filling the water ballast is only allowed with a filling system which enables determination of the exact amount of ballast filled, e.g. water gauge or calibrated canisters. Only symmetrical loading is allowed.

After filling, balance the wings by dumping enough water from the heavy wing, see 4.2.2.

Flight with leaking watertanks is prohibited, as this may result in asymmetrical loading condition.

Warning: Follow the loading chart, see section 6.8.
The max. take off weight must not be exceeded.

2.15 Fin tank (Option)

Warning: As it is dangerous to fly with empty wing tanks while ballast is resting in the fin, **it is prohibited to fill water into the fin tank if there is any risk of icing**. The flight conditions must comply with the following table:

min. ground temperature	°C	13,5	17	24	31	38
	°F	56	63	75	88	100
max. flight altitude	m	1500	2000	3000	4000	5000
	ft	5000	6500	10000	13000	16500

In addition the outside air temperature OAT gauge is to be watched.
The OAT should not be lower than 2°C (36°F)!

2.16 Trim ballast box in the fin

A box for ballast (trim-weights) is installed in the fin. It can be used to compensate the mass of the rear pilot and as a trim-possibility for heavy pilots.

Warning: Follow the loading chart see 6.8.7.

Tape the cover of the fin ballast box with tape min. 19mm (3/4 in.) wide prior to each flight.

Flight manual DG-1000S

6.1 Introduction
This section contains the payload range within which the sailplane may be safely operated.
A procedure for calculating the in-flight C.G. is also provided.

A comprehensive list of all equipment available for this sailplane is contained in the maintenance manual.

6.2 Weighing procedures
See maintenance manual DG-1000S.
Datum: Wing leading edge at the rootrib.
Reference line: aft fuselage centre line horizontal.
The weighing is to be executed with all tanks emptied, without ballast in the trim ballast boxes in the fin and in the cockpit (optional), but with fin battery Z110.

6.3 Weighing record
The result of each C.G. weighing is to be entered on page 6.7. If the min. cockpit load has changed this data is to be entered in the cockpit placard as well.
When altering the equipment, the new data can be gathered by a C.G. calculation (see section 6.9).
The actual equipment list is enclosed in the maintenance manual.

6.4 Basic empty mass and C.G.
Actual data see page 6.7. With the empty weight C.G. and the cockpit loads in the limits of the diagram on page 6.8, the in-flight C.G. limits will not be exceeded.

6.5 Mass of all non-lifting parts (WNLP)

The max. mass of all non-lifting parts is 469 kg (1034 lbs.).

WNLP is to be determined as follows:
WNLP = WNLP empty + cockpit load (pilots, parachute, baggage, trim ballast, waterballast in the fin, removable items of equipment etc.).
WNLP empty = Total empty weight incl. permanently installed equipment minus weight of the wings.

6.6 Max. mass (weight)

Category A „Aerobatic"

Maximum take off weight:	630 kg	1389 lbs.
Maximum landing weight:	630 kg	1389 lbs.

Category „Utility"
with waterballast:

Maximum take off weight:	750 kg	1653 lbs.
Maximum landing weight:	750 kg	1653 lbs.

without waterballast: Maximum take-off and landing mass = $W_{NLP} + W_{wings}$

W_{NLP} = Maximum mass of all non lifting parts (see above)
W_{wings} = actual mass of the wings

6.7 Useful loads

Max. load **without** waterballast
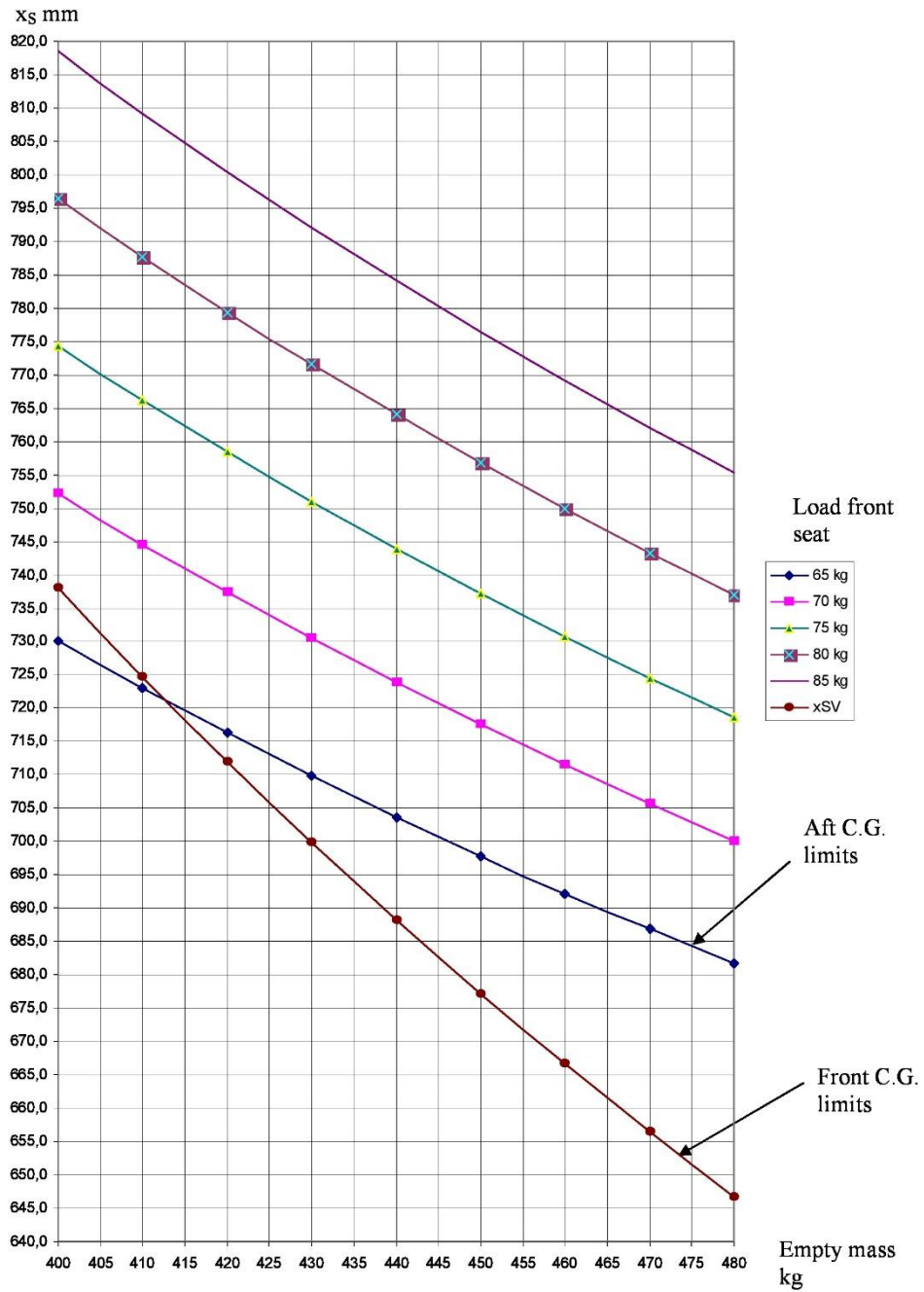= max. weight without waterballast   - empty weight

Max. load **with** waterballast
= max. weight with waterballast   - empty weight

The data is recorded on page 6.7.

6.8.9 Empty weight C.G. limits (for 6.4)

Load front seat

- 65 kg
- 70 kg
- 75 kg
- 80 kg
- 85 kg
- xSV

Aft C.G. limits

Front C.G. limits

FLIGHT MANUAL — ASTIR CS   4

Flying Limitations

Airspeed Limits (I.A.S.)

	km/h	mph	kts
Never exceed (V_{NE})	250	155	135
In rough air (V_B)	250	155	135
Manoeuvering (V_A)	170	105	92
On aerotow (V_T)	170	105	92
On winch tow (V_W)	120	74	64
Airbrakes	250	155	135
Gear extended	250	155	135

A.S.I. Colour Code

33 — 92 kts — Green Border — 60—170 km/h
92 — 135 kts — Yellow Border — 170—250 km/h
At 135 kts — Red Strip — bei 250 km/h

Weights

	lbs	kp
Empty Weight	circa 560	255
Maximum permitted weight		
without water-ballast	836	380
with water-ballast	990	450
Maximum permitted weight		
of non-supporting ports	528	240

Weak Link on Winch cable

	lbs	kp
Maximum Load	1100	500

Cloud Flying and simple Aerobatics

Permitted if water-ballast is not being carried
See pages 12 — 14

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Classification Group

Standard Class (German N)

Centre of Gravity positions

Levelling means	with a 1000:40 Incidence Board set up horizontal on the top of the rear fuselage.
Datum Line (D. L.)	Front edge of wing at root
Maximum forward position of C. of G.	250 mm behind D. L. (9.84 in)
Maximum rearward position	425 mm behind D. L. (16.73 in)

Loading Limitations ASTIR CS

Empty weight of glider and maximum cockpit load, see page 7.

Minimum cockpit load: 154 lbs (70 kp)

The permissible all up weight must NEVER be exceeded.

Maximum all up weight

without water-ballast	836 lbs	(380 kp)
with water-ballast	990 lbs	(450 kp)

The weight of water-ballast is dependent on the cockpit weight (Pilot with parachute and luggage). See page 7.

Weight deficiencies should be corrected by securing or removing some ballast in the seat.

The C. of G. of the pilot with a parachute on lies 475 mm in front of the Datum Line.

22. 5. 76

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Placards to be displayed in cockpit:

Maximum weight		kp	lbs
without water ballast:		380	836
with water ballast:		450	990

Airspeed limits	km/h	m.p.h.	knots
Never exceed	250	155	135
In rough air	250	155	135
Manoeuvering	170	105	92
On aerotow	170	105	92
On winch tow	120	74	64
Airbrakes	250	155	135
Gear extended	250	155	135

Payload (pilot and parachute)
The maximum weight must not be exceeded.

Minimum payload: 70 kp, 154 lbs.
Less weight must be compensated with
ballast in the seat.

Placards to be displayed near undercarriage:

Weak links for towing
500 kp, 1100 lbs. max.
Tire: 2,5 Atm., 36 psi

4 Four piece safety harness
5 Weighted seat cushion at least 2³/₄", thick, or parachute
6 Loading limitations Chart
7 Flying limitations Placard
8 Flight Manual
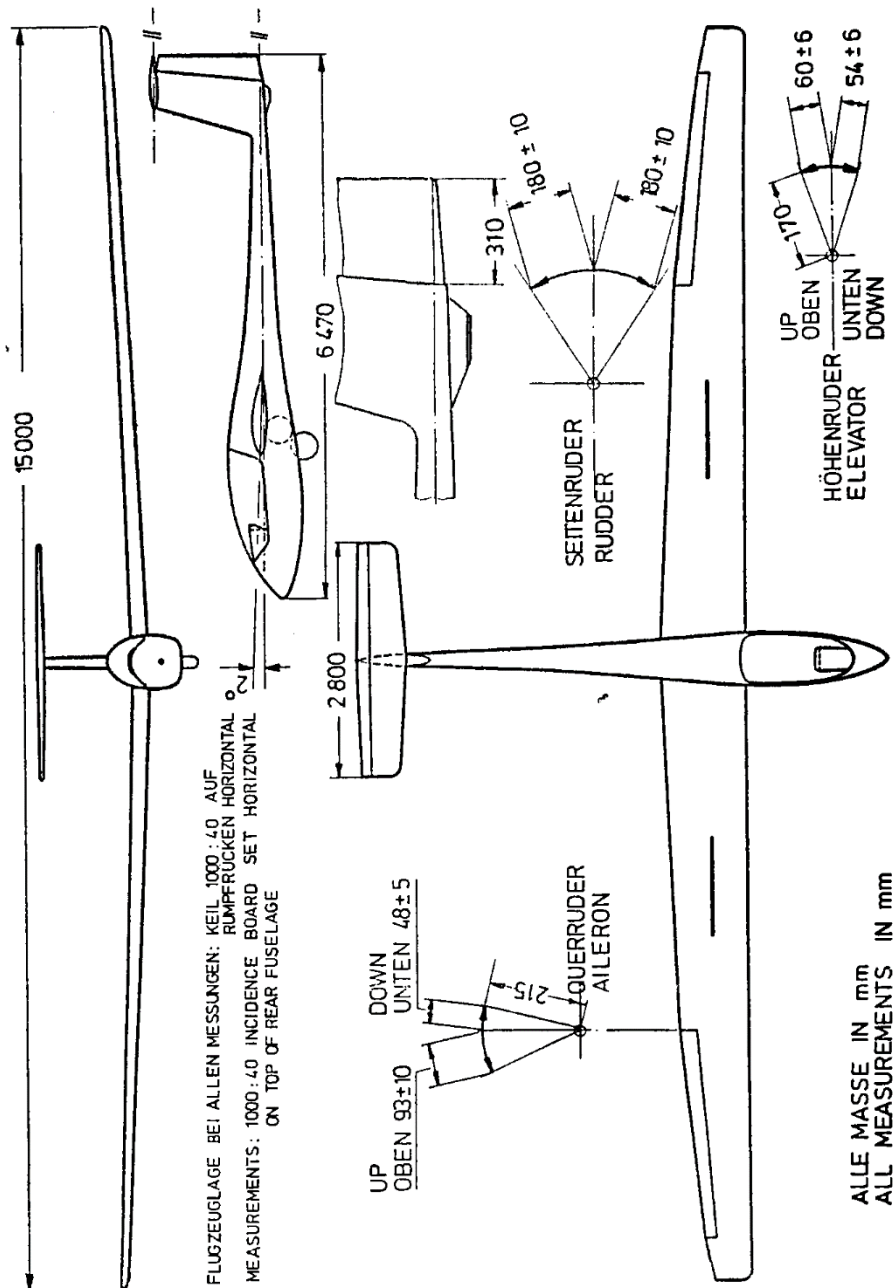
Weight and Center of Gravity positions

When the new instruments are added and other changes in the weight of the glider made, the empty weight C. of G. position should be checked. If the limits of the empty weight C. of G. positions and the Loading Limitations Chart are adhered to, then the C. of G. of the loaded glider will lie within the permitted range.
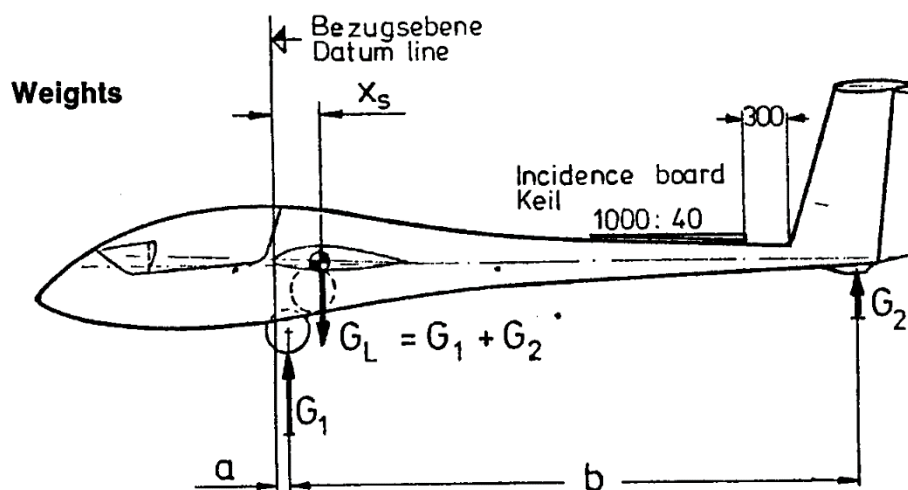
Empty Weight (lbs)	Range of C. of G. positions (mm behind the Datum Line)
506	606 — 698
517	598 — 693
528	591 — 687
539	584 — 682
550	577 — 677
561	557 — 672
572	537 — 667
583	518 — 662
594	499 — 658
605	481 — 654

Measurements

Position of the glider whilst taking all measurements:

with a 1000:40 Incidence Board set up horizontal on the top of the rear fuselage.

Elevator	upwards	2.36 ± 0.23 in	60 ± 6 mm
	downwards	2.13 ± 0.23 in	54 ± 6 mm
Rudder	left	7.09 ± 0.39 in	180 ± 10 mm
	right	7.09 ± 0.39 in	180 ± 10 mm
Aileron	upwards	3.66 ± 0.39 in	93 ± 10 mm
	downwards	1.89 ± 0.20 in	48 ± 5 mm

Angles: between the center line of the wing and the longitudinal axis of the fuselage   2°

between the cord of the tail-plane and the longitudinal axis of the fuselage   0°

FLUGZEUGLAGE BEI ALLEN MESSUNGEN: KEIL 1000:40 AUF RUMPFRÜCKEN HORIZONTAL

MEASUREMENTS: 1000:40 INCIDENCE BOARD SET HORIZONTAL ON TOP OF REAR FUSELAGE

15000

6 470

2 800

310

180 ± 10

180 ± 10

60 ± 6

54 ± 6

170

SEITENRUDER
RUDDER

HÖHENRUDER
ELEVATOR

UP
OBEN

UNTEN
DOWN

UP
OBEN 93±10

DOWN
UNTEN 48±5

215

QUERRUDER
AILERON

ALLE MASSE IN mm
ALL MEASUREMENTS IN mm

Weights

Datum Line: Front edge of the wing at the root
Levelling means: With a 1000:40 Incidence Board set up horizontal on
the top of the rear fuselage.

Weight on main-wheel G_1 =   lbs

Weight on tail-skid G_2 =   lbs

Empty Weight G_L = $G_1 + G_2$ =   lbs

Displacement of main-wheel   a =   mm

Deplacement of tail-skid   b =   mm

Empty Weight C. of G.

$$X = \frac{G_2 \times b}{G_L} + a = \underline{\qquad\qquad} + \quad = \quad \text{mm behind Datum Line}$$

Maximum Load G = 836 − G_L =   lbs

The measurements to determine the empty weight, the empty weight
C. of G., and the loading limitations should always be taken with the
glider empty of waterballast.

2.6   G103 Twin II [6]
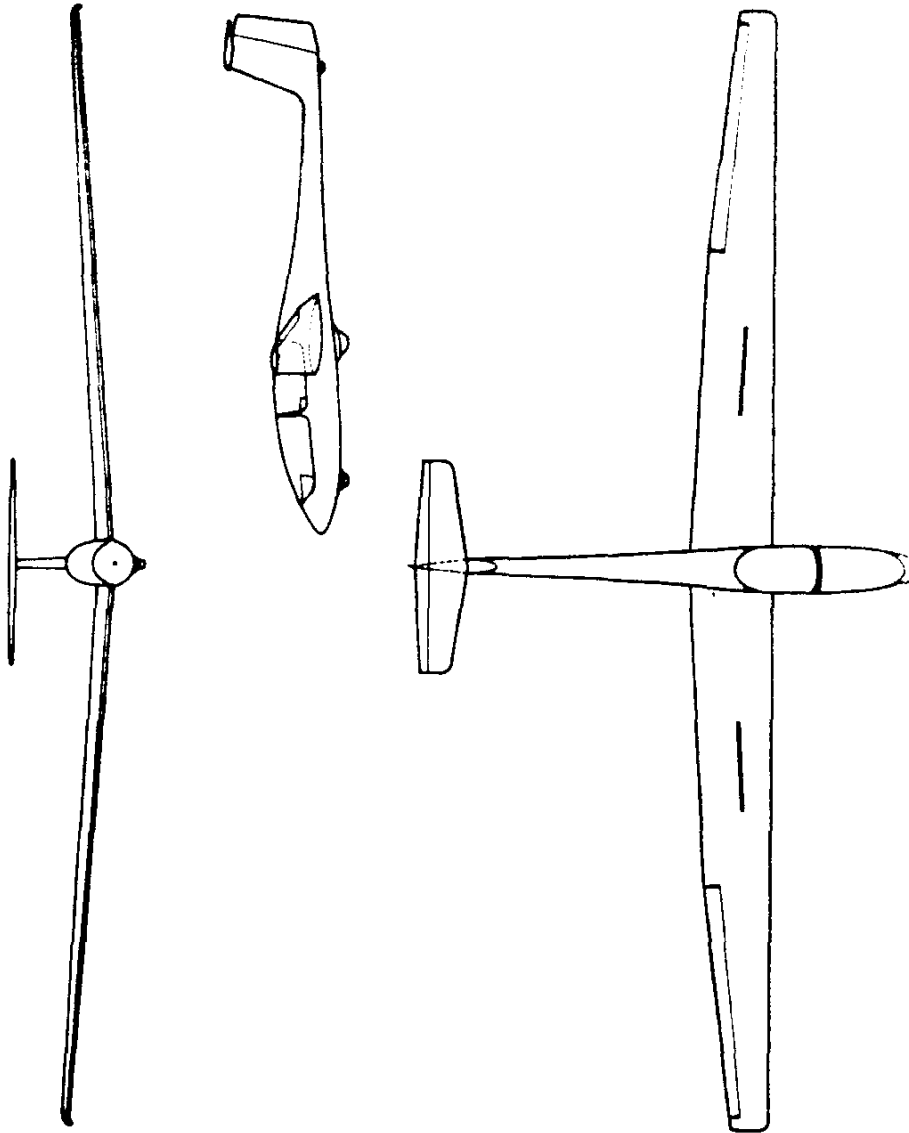
September 1981

I. 5 Description

The "TWIN II" is a high performance two seater sailplane with a T-tail, fitted with a nonretractable tandem undercarriage and upper surface airbrakes.
This sailplane is manufactured using the latest techniques in industrial Glass fibre construction.
It is designed for training, high performance and simple aerobatic flying.

Technical Data:

Span	17.5 m	(57.4 ft.)	Wing Area	17.8 m² (191.6 ft.²)
Length	8,18m	(26,8ft)		
Height	1,55m	(5,1ft)	Maximum Flying Weight	580 kg (1279 lbs)
Aspect				
Ratio	17.1		Maximum Wing Loading	32,6 kg m² (6,68 lbs ft.²)

II. Operating limitations:

II. 1 Airworthiness Group
Certification Basis: 14 CFR Sections 21.23 and 21.29 effective 1 February 1965; and Joint Airworthiness Requirements for Sailplanes and Powered Sailplanes (JAR-22),dated 1 April 1980.

II. 2 Permitted operating conditions.

The plane is licensed for:

1 VFR Day
2. Simple Aerobatics (Loops, Stall turns, Lazy eight, Chandelle and Spin).

II. 3 Minimum equipment

1. 2 Air speed indicators reading to 300 km/hr (162 kts, 187 mph)
2. 2 Altimeters.
3. Full Harness Straps in front and back cockpit.
4. Parachute or back cushion at least 7 cm (3 inch) thick for each
5. Loading limit plaque in front and back cockpit.   occupant.
6. Flight Limits plaque.
7. Flight Manual

17 th march 1982

17. März 1982

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II. 6 Weight limits

Empty weight . . . . about 380 kg(838 lbs)
     Maximum flying weight . . 580 kg(1279 lbs)
     Maximum permitted weight of non lifting parts 400 kg(882 lbs)

II. 7 Centre of gravity position

The approved range of centre of gravity positions during flight is 260 mm (10.24 inches) to 460 mm (18.11 inches) behind the datum line, equivalent to 24.7% to 43.6% of the M.A.C. of the wing.
A/c attitude: incidence board of 600:24 angle.
The datum line is the front edge of the wing at the wing root.

The approved centre of gravity range does not get exceeded by the payload distribution specified in the loading plan II. 8.

The exact position of the centre of gravity at flying weight can be calculated according to VI 5.

II. 8 Load scheme „TWIN II"

Minimum load in the front seat for all flight . .	70 kg (154 lbs)
Maximum load in the front seat	110 kg (242 lbs)
Maximum load in the back seat . . . . ·	110 kg (242 lbs)
Maximum load in the baggage compartment	10 kg (22 lbs)

The maximum flying weight of 580 kg (1279 lbs)
must not be exceeded.
Trim weights must be used at the suspensions
in front of stick bulkhead to compensate if
the front seat load is lower than 70 kg
(154 lbs). See page 14.

16th june 1982

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II. 9 **Tow hooks** and cable length

For Aerotow: Nose hook "E 75" with modification 1-73.
For Winch launch: Safety back release hook "G 72" or "G 73".

Minimum aerotow cable length   40 m (130 ft)
Minimum launch cable length   600 m (1970 ft)

II. 10 **Weak link strength**

Winch launch and aerotow   max 754 daN , max 1662 lb

II. 11 Tire Pressure

mainwheel	6.00-6	2,5-2,8	bar
nosewheel	260x85	2,5	bar
tailwheel	210x65	2,5	bar

II. 12 **Crosswinds**

The maximum crosswind component approved for take off and landing
is 20 km/h (11 kts, 12 mph).

16th june 1982

V. 2   Determination of the Center of Gravity

The determination of the center of gravity
is made with the glider supported on two
scales at heights such that an incidence
board of 600 : 24 angle is set horizontal
on the back of the fuselage. (Position on the
fuselage see sketch at page 23).
The reference plane lies at the front of the
wing at the root. The distances a and b
are measured with the help of a plumb
line. The empty weight is the sum of the
two weights G_1 and G_2.

The Center of Gravity of the pilots is
located:
1150 mm (45,3 inch) in front of the
Datum Line (1.Seat)
   40 mm (1,6 inch) behind the Datum
Line   (2.Seat)

17 th march 1982

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Procedure for determining C. of G. empty
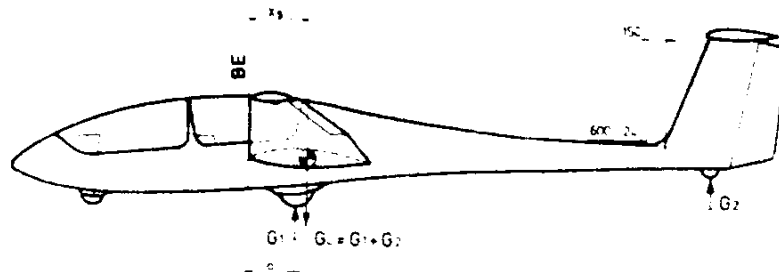
Datum Line: Front edge of the wing at the root rib.

Level Means: With a 600:24 Incidence Board set up horizontal on the top of the rear fuselage.

Weight on main-wheel G_1 =   kg / lbs
Weight on tail-skid G_2 =   kg / lbs
Empty Weight G_L = G_1 + G_2 =   kg / lbs
Distance to main-wheel   a =   mm / inches
Distance to tail-skid   b =   mm / inches

Empty Weight C. of G.

$$X = \frac{G_2 \times b}{G_L} + a = \underline{\qquad} + = \text{mm/inches behind Datum Line}$$

The measurements to determine the empty weight, the empty weight ˙C. of G. and the loading limitations must always be taken with the glider empty.

Convertion	from	to	multiply with
	kg	lbs	2,2
	mm	inches	0,0394

17 th march 1982

1 7. März 1982

If the limits of the empty weight C. of G. positions and the loading limitations chart are adhered to the C. of G. of the loaded glider will be within the permitted range.

Empty Weight		Range of C. of G. behind Datum			
		Forward		Aft	
kg	lbs	mm	inches	mm	inches
360	794	758	29. 84	773	30. 43
365	805	748	29. 45	769	30. 28
370	816	739	29. 09	765	30. 12
375	827	729	28. 70	761	29. 96
380	838	720	28. 35	757	29. 80
385	849	711	27. 99	753	29. 65
390	860	703	27. 68	749	29. 49
395	871	694	27. 32	745	29. 33
400	882	686	27. 01	742	29. 21

It should be noted that to make use of the maximum load the maximum admissable load for non-lifting parts must not be exceeded.

The weight of the non-lifting parts is the sum of the fuselage, tailplane and maximum load in the fuselage and must not exceed 400 kgs (882 lbs). Otherwise the maximum load permitted in the fuselage must be correspondingly decreased.

The Centre of Gravity should be recalculated after repair, repainting, the installation of additional equipment or when a period of 4 years hes elapsed after the last weighing.

The empty weight, empty weight C. of G. position and maximum load, should be recorded after each weighing on page 9 of the Flight Handbook.

17 th march 1982

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2.7   Ka 6E [7]

- 3 -

- Ka 6 E Flight Handbook -

1.   Operating Limitations

Airspeed limits:

	km/h	mph	kts
max. airspeed	200	125	108
max. airspeed in gusty weather	140	87	75
airplane-tow	140	87	75
Auto-winch-tow	100	62	54

Weights:

Empty weight:	appr.190 kg	419 lbs
Maximum weight:	300 kg	660 lbs
max. weight of non-supporting structure	190 kg	419 lbs

Cloudflying is permissible (see page 7   )

Catogory   2 BVS (German)

                         Airworthiness Requirements)

Max. permitted positive load factor	4,0
Max. permitted negative load factor	-2,0
Factor of safety	2,0

- Ka 6 E Flight Handbook -

C.G. Range in Flight:

Leveling means:	template 100 : 9 on top of fuselage horizontal
Datum:	wing leading edge at rib 3
C.G. range:	180 to 383 mm, 7,1 to 15,0 in. behind datum.

Weak Links in the Tow Cable:

Winch-launch	max.	635 kp	1400 lbs
	min.	525 kp	1160 lbs
Airplane-tow	max.	450 kp	990 lbs
	min.	300 kp	660 lbs

2. Operating Instructions:

Winch-launching:

Maximum permissible winch-launch airspeed is 100 km/h, 62 mph, 54 kts.

Any slight tendency for the nose to pitch up can be controlled through appropriate stick operation. For optimum climb keep the stick in normal position. Attention: In winch-launching the speed will increase when you pull back the stick.

Airplane-tow

Max. permissible airplane-towing speed: 140 km/h. 87 mph. 75 kts. Use only textile ropes for airplane-tow. For release, pull the coupling knob all the way!
Before every take-off check canopy and airbrakes for being locked.

- Ka 6 E Flight Handbook -

If necessary, balance weights are to be installed.
In each of these instances an examiner of the
governmental aviation authority is to be called
in.

Empty weight		420	440	465	485	lbs
c.g.position	min.	20,8	20,2	19,5	19,0	in.
	max.	25,1	24,6	24,1	23,7	in.

behind datum

Template 100 : 9 on fuselage horizontal
Datum: wing leading edge, rib 3.

If the empty weight c.g. position is within
these limits, then it is guaranteed that the c.g.
position in flight will be within allowable limits.
if the load in the cockpit is as specified in
paragraph 6 below.

The c.g. position in flight has conciderable in-
fluence on flight characteristics. For this
reason, observance of the certified c.g. range
is very important.

A displacement of the c.g. too far back may cause
dangerous effects: Stalling and especially spinning
behaviour (flat spinning) may worsen.

- Ka 6 E Maintenance Handbook -

Strong solar radiation will affect the finish by time. Therefore the sailplane should not be exposed to the sun more than necessary. The use of good waxes and polishing materials will increase the durability of the finish and improve the surface, and consequently the flight performance. The advantages of the laminarprofile can only be achieved by a smooth surface.

Sealing the gaps and slots by means of adhesive tapes will also be of use for improving the performance. But do not seal the cockpit if parachute bail-out shall be possible.

Clean the plexiglass canopy only by means of appropriate cleansers. If not available use pure water. Only soft cloth should be used. Never run over the plexiglass with a rough dry cloth.
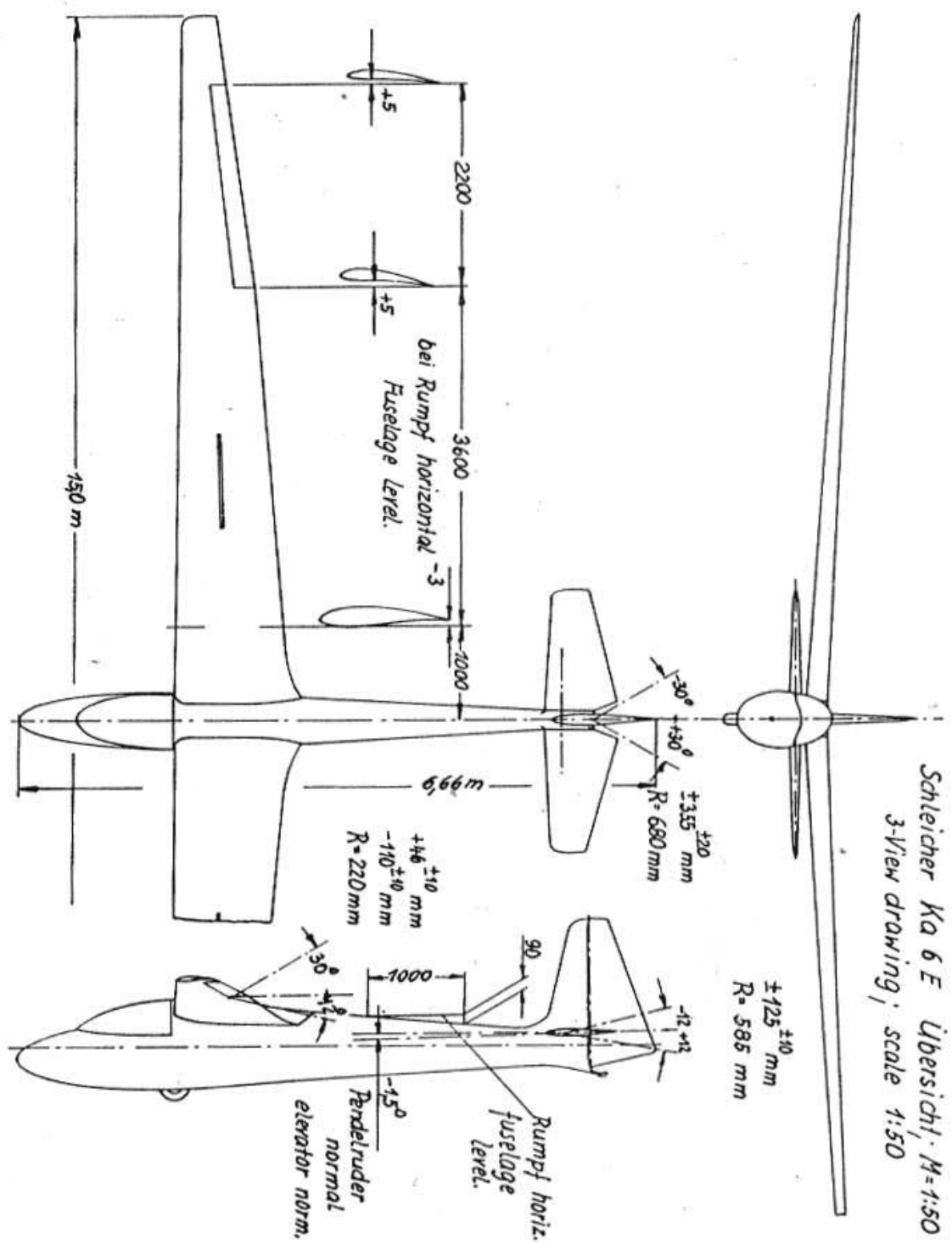
Lubrication of Bearings

So far as possible the ball bearings are sealed and therefore need no lubrication for a long period. The bearings at the wing root only, which cannot be sufficiently protected on behalf of rigging facilities, are to be cleaned with gasoline when dirty and lubricated again.
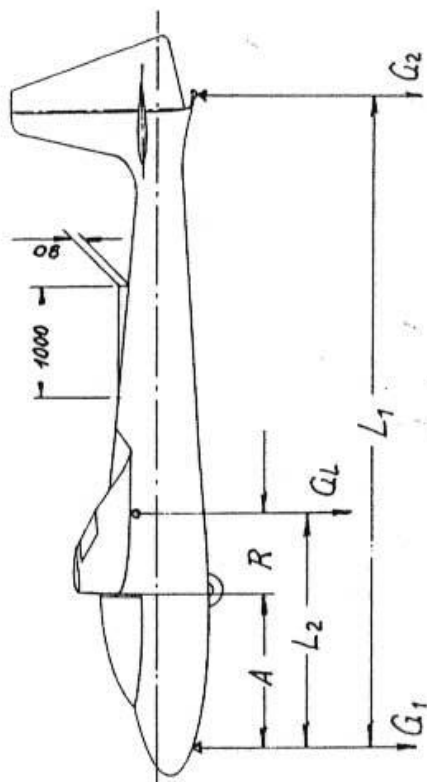
The control surface bearings are to be dismantled and greased at the annual overhauls.

Tire pressure 35 psi.

The tow coupling is especially exposed to dirt and needs a frequent cleaning and oiling.

The tail skid shoe has to be soled from time to time by welding on a new steel plate. But it should be removed for this work to prevent annealing of the spring.

Schleicher Ka 6 E Übersicht; M=1:50
3-View drawing; scale 1:50

Schleicher Ka6 E Wägeblatt, Balancing sheet

G_L = Leergewicht; empty weight.

G_1 = Gewicht am vorderen Auflagepunkt; weight at the front support.

G_2 = Sporngewicht; weight at tail skid.

R = Schwerpunktrücklage; center of gravity position.

$$R = L_2 - A = \frac{G_2 \cdot L_1}{G_L} - A$$

$$G_1 + G_2 = G_L$$

Grenzen der Leergewichtsschwerpunktlagen:
Empty weight - C. of G. - position limits:

G_L = Leergewicht; empty weight		180	190	200	210	220	kg
R { Vorderste Schwerpunktlage; most forward position	min.	550	530	513	497	482	mm
Hinterste " " most rearward "	max.	652	638	625	613	603	mm

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3 Manufacturers' weight and balance procedures

From the flight manuals of the selected sailplanes, we have gathered the instructions given by the manufacturers in order to measure the weight and balance of each aircraft. A summary of the specific instructions for each model is shown next:

- **Schleicher ASK 13:**
  - **Levelling:** there are two options: either the tangent to the wing's rib number 3 has to be horizontal, or a 1000:55 wedge on top of the rear part of the fuselage must have its top side horizontal.
  - **Datum:** leading edge of the wing's rib number 3.
  - **Other considerations:** the manual indicates the front support (forward of the main wheel) as the front weighing point. Nevertheless, this would require special equipment as the front scale should be elevated as well. Therefore, we have chosen the main wheel as the front weighing point.

- **Schleicher ASK 21:**
  - **Levelling:** a 1000:52 wedge on top of the rear part of the fuselage must have its top side horizontal.
  - **Datum:** leading edge of wing's rib with transversal position y = 0.4 m.
  - **Other considerations:** the manual indicates the nose wheel as the front weighing point. However, we have chosen the main wheel (which is aft of the nose wheel) so that the front scale will not have to be elevated.

- **Schleicher ASW 20:**
  - **Levelling:** there are two options: the centre line of the fuselage tail cone has to be horizontal, or a 1000:45 wedge on top of the rear part of the fuselage must have its top side horizontal.
  - **Datum:** leading edge of the wing's root (without the fairing).
  - **Other considerations:** apart from the levelling means, the datum and the allowed CG position range, the manufacturer does not provide any instructions for the weight and balance process.

- **DG Flugzeugbau DG-1000S:**
  - **Levelling:** the top of the rear part of the fuselage must have a slope of 1000:33.
  - **Datum:** leading edge of the wing's root rib.
  - **Other considerations:** the manufacturer warns that the distances L1 and L2 should always be measured, as different weights might cause different deflections of the landing gear. For measuring L1, it is advised to measure the distance between main wheel and tail wheel centre lines.

- **Grob G102 Astir CS:**
  - **Levelling:** a 600:26 wedge (or "incidence board") on top of the rear part of the fuselage must have its top side horizontal. The distance between the leading edge of the vertical tail plane has to be of 150 mm.
  - **Datum:** leading edge of the wing's root rib.
  - **Other considerations:** the manufacturer also indicates the wheel's centre point as the location of the point weight.

- **Grob G103 Twin II:**

- o **Levelling:** a 600:24 wedge (or "incidence board") on top of the rear part of the fuselage must have its top side horizontal. The distance between the leading edge of the vertical tail plane has to be of 150 mm.
  - o **Datum:** leading edge of the wing's root rib.
- **Schleicher Ka 6E:**
  - o **Levelling:** a 100:9 wedge (or "template") on top of the rear part of the fuselage must have its top side horizontal.
  - o **Datum:** leading edge of wing's rib number 3.

4 Individual uncertainties

In this section, the uncertainties used in the propagations of uncertainties which depend on each sailplane model are shown. The definitions of each uncertainty are the following:

- ϵ_{d_L}: uncertainty of the distance between the front point weight and the laser sensor, as used in the estimation of the uncertainty of L2 with option A.
- ϵ_T: uncertainty due to the tilt of the datum bar with respect to the transversal axis, as used in the calculation of the final error of the measurement of L2.

Model	ϵ_{d_L} (mm)	ϵ_T (mm)
ASK 13	± 4.7	± 1.3
ASK 21	± 4.6	± 0.4
ASW 20	± 4.9	± 0.1
DG-1000S	± 4.5	± 0.4
G102 Astir CS	± 4.9	± 0.1
G103 Twin II	± 4.6	± 0.3
Ka 6E	± 5.1	± 2.4

Table 7: Individual uncertainties for each sailplane.

5 Mathematical proofs

5.1 Dependency of the uncertainty of X1' (or X2') on the point weight G1 (or G2)

From the propagation of uncertainties:

$$\epsilon_{X1'} = \left|\frac{\partial X1'}{\partial W1}\right| \cdot \epsilon_{W1} + \left|\frac{\partial X1'}{\partial W2}\right| \cdot \epsilon_{W2} + \left|\frac{\partial X1'}{\partial S1}\right| \cdot \epsilon_{S1} + \left|\frac{\partial X1'}{\partial S2}\right| \cdot \epsilon_{S2} =$$

$$= \left|\frac{\partial X1'}{\partial W1}\right| \cdot \epsilon_{W1} + \left|\frac{\partial X1'}{\partial W2}\right| \cdot \epsilon_{W2} + \frac{W1}{W1 + W2} \cdot \epsilon_{S1} + \frac{W2}{W1 + W2} \cdot \epsilon_{S2} =$$

Since $\epsilon_{S1} = \epsilon_{S2} = 2$ mm:

$$= \left|\frac{\partial X1'}{\partial W1}\right| \cdot \epsilon_{W1} + \left|\frac{\partial X1'}{\partial W2}\right| \cdot \epsilon_{W2} + 2 \text{ mm} =$$

$$= \left|\frac{W2 \cdot (S1 - S2)}{(W1 + W2)^2}\right| \cdot \epsilon_{W1} + \left|\frac{W1 \cdot (S2 - S1)}{(W1 + W2)^2}\right| \cdot \epsilon_{W2} + 2 \text{ mm}$$

And since $\epsilon_{W1} = \epsilon_{W2} = 0.2$ kg and $S2 > S1$:

$$\epsilon_{X1'} = \frac{W2 \cdot (S2 - S1) + W1(S2 - S1)}{(W1 + W2)^2} \cdot 0.2 \text{ kg} + 2 \text{ mm} =$$

$$= \frac{(W1 + W2)}{(W1 + W2)^2} \cdot (S2 - S1) \cdot 0.2 \text{ kg} + 2 \text{ mm} =$$

$$= \frac{S2 - S1}{W1 + W2} \cdot 0.2 \text{ kg} + 2 \text{ mm}$$

Finally, since $W1 + W2 = G1$ and, in this case, $S2 = 350$ mm and $S1 = 0$, we get:

$$\epsilon_{X1'} = \frac{350 \text{ mm}}{G1} \cdot 0.2 \text{ kg} + 2 \text{ mm}$$

And the same is true for the rear weighing point:

$$\epsilon_{X2'} = \frac{350 \text{ mm}}{G2} \cdot 0.2 \text{ kg} + 2 \text{ mm}$$

5.2 Partial derivatives of uncertainty calculations

The calculation of L2 with option A (explained in the Report) is defined as follows:

$$L2' = \frac{a^2 - b^2 + L1'^2}{2 \cdot L1'}$$

$$L2 = L2' + d_L$$

Then, the total uncertainty of L2 can be calculated as:

$$\epsilon_{L2} = \left|\frac{\partial L2}{\partial a}\right| \cdot \epsilon_a + \left|\frac{\partial L2}{\partial b}\right| \cdot \epsilon_b + \left|\frac{\partial L2}{\partial L1'}\right| \cdot \epsilon_{L1'} + \left|\frac{\partial L2}{\partial d_L}\right| \cdot \epsilon_{d_L}$$

And the partial derivatives are the following:

$$\frac{\partial L2}{\partial a} = \frac{a}{L1'}$$

$$\frac{\partial L2}{\partial b} = -\frac{b}{L1'}$$

$$\frac{\partial L2}{\partial L1'} = \frac{L1'^2 - a^2 + b^2}{2 \cdot L1'^2}$$

$$\frac{\partial L2}{\partial d_L} = 1$$

References

[1] Alexander Schleicher Segelflugzeugbau, *ASK 13 Flight—and Maintenance—Manual,* 1969.

[2] Alexander Schleicher Segelflugzeugbau, *ASK 21 Flight Manual,* 1983.

[3] Alexander Schleicher Segelflugzeugbau, *ASW 20 Flight Manual,* 1977.

[4] DG Flugzeugbau GmbH, *DG-1000S Flight Manual,* 2002.

[5] Burkhart Grob Flugzeugbau, *G102 Astir CS Flight Manual,* 1975.

[6] Burkhart Grob Flugzeugbau, *G103 Twin II Flight Manual,* 1981.

[7] Alexander Schleicher Segelflugzeugbau, *Ka 6E Flight and Maintenance Handbook,* 1965.