WINDEX 1200
Design Process and Progress Report

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WINDEX 1200 DESIGN PHILOSOPHY

The powered sailplane gives its pilot maximum freedom of the skies with a minimum of the trouble and waiting usually associated with gliding activities.

WINDEX 1200 is primarily a high-performance sailplane, but its concept of a low-drag fin-mounted engine installation and a variable pitch propeller turns it into an efficient touring aircraft with a cruising speed of 210 km/h (130 mph) at 50% power.

In addition the airframe is stressed for aerobatic maneuvers and designed to JAR 22 A. This may be exploited accordingly or could be regarded as an extra safely margin in normal flying.

Powered sailplanes as such are nothing new. Different types have been available for a number of years. Most so far fall into one of three categories: 2-seat trainers with acceptable power-on performance but at best mediocre gliding capability; 15–25 meter span sailplanes based on racing designs and with retractable engines with excellent gliding capability but heavy and with relatively poor power performance and the need for ground assistance; and finally, homebuilt powered gliders with poor performance in either mode.

WINDEX 1200 is an attempt at a different concept; a powered high-performance sailplane that can be easily handled on the ground by one person.

Even with engine nacelle, propeller and 20% smaller span it has as its target a soaring performance equal to or better than a 15-meter Standard *Cirrus* glider. Its target rate of climb is approximately 4.5 meters/sec. (875 fpm) under power.

To achieve this target performance has required a unique concept, advanced aerodynamics, modern aerospace materials with sophisticated manufacturing methods, derived innovative mechanical designs and a special engine and propeller package. The performance and handling qualities of the pre-prototype WINDEX 1100 have verified the feasibility of a small high-performance powered sailplane. The design team has been engaged in the development work for more than four years.

To make it affordable the WINDEX 1200 will be offered as a kit, where major airframe components are supplied as moldings but much of the time-consuming fitting work is left to the builder.

WINDEX 1200 CONFIGURATION

The WINDEX 1200 powered glider has a conventional tail configuration. This choice is based on considerations of performance as well as handling qualities. The alternatives, canards and tailless aircraft, lack in one or the other of those respects.

A canard configuration requires an extremely large span of the canard surface or has to be statically unstable in pitch to offer a reasonably low trim drag. The canard position far forward makes it very difficult to attain laminar flow on the fore fuselage.

Moreover, a long tail arm on the fuselage is still required to carry the fin in order to achieve acceptable lateral handling qualities, both on canards and "tailless" configurations.

On these grounds it seems to be the best choice to use the tail arm to carry both a vertical and horizontal tail.

For a single-engined aircraft the normal position of the engine and propeller is in the front end of the fuselage. This position has many merits but one serious handicap for a powered glider lies in the difficulty of getting really low fuselage drag. The same objection could to some extent be raised against various pusher configurations with pod and single or twin booms. The high landing gear necessary with a front-mounted propeller is undesirable for a low-drag sailplane.

From a pure drag point of view a pusher with the propeller in the tail is to be preferred. This alternative, however, has a number of inherent drawbacks, such as disturbed inflow to the propeller, long mechanical transmission, no slipstream effect on the rudder, ground clearance problems, etc.

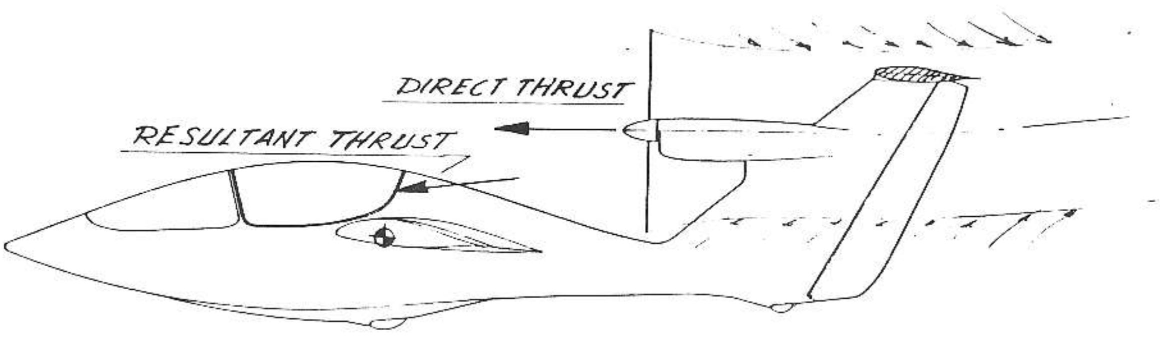
On the WINDEX 1200 the horizontal tail is mounted above the propeller thrust line and the interference from this surface that blocks the inflow to the slipstream asymmetrically will turn the resulting thrust vector downwards, thus reducing the nose-down pitching moment.

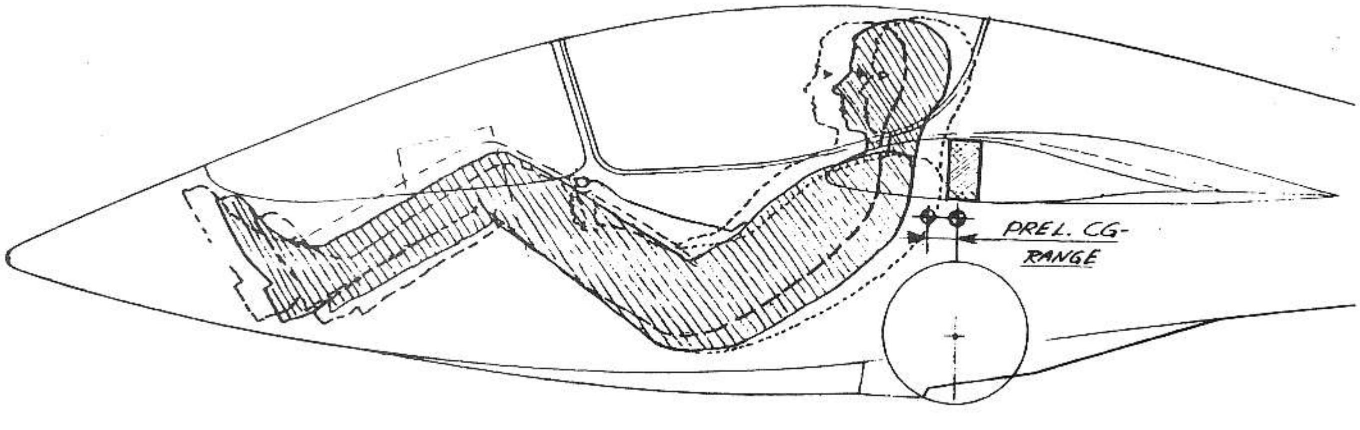
The position of engine and propeller chosen for WINDEX 1200 is at the leading edge of the vertical tail. This location has a number of merits but of course also poses some problems.

The prime advantage is that the fore fuselage and the sensitive area (from an airflow stability point of view) at wing-to-fuselage junction can be shaped in the most favorable way without concern for engine and propeller installations. Also, the airflow into the propeller is undisturbed and the propeller slipstream makes the rudder more effective (e.g. when taxiing in a crosswind).

There is no need for long power transmission and the engine unit is easily accessible for service. The cockpit noise level should also be lower due to reduced propeller noise and to the more rearward position of engine and exhaust.

The problems are related primarily to the weight and size of the power unit. A heavy and bulky engine installation makes the configuration less attractive, both with respect to





SKETCH OF WINDEX 1200 COCKPIT WITH A 6′ PILOT
AT NORMAL FLIGHT ATTITUDE.

cg problems and engine nacelle drag. A market survey of existing engines and propellers was carried out, but no suitable alternatives were found. For these reasons a special engine and propeller unit had to be developed for the WINDEX 1200.

An affect of the comparatively high thrust axis of the propeller is the resulting pitch-down moment. However, a number of powered gliders with retractable engines and propellers have their thrust axis considerably higher without severe trim problems. Finally, a powered glider generally has low installed power and the thrust-to-weight ratio is rather low. The offset thrust axis should therefore in any case not be critical.

COCKPIT

Few gliders have really roomy cockpits because such qualities would inflict drag penalties and less competitive performance. By glider standards WINDEX 1200 should afford adequate space for even large pilots. The test pilot for the WINDEX 1100 was 6'5" with weight to match. For the WINDEX 1200 the length of the fuselage has been increased four inches and the landing gear moved slightly to the rear.

In the fuselage sketch of WINDEX 1200 is shown a "normal" size pilot, about 6 feet, with the dotted lines indicating variations from 5'6" to 6'5". The pilot's field of vision is excellent, especially in the forward-downward sector. In order to conserve laminar flow as far back as possible, the forward part of the canopy is fixed.

LANDING GEAR

The main landing gear is a single fixed unsprung 12" wheel with a drum brake. The wheel has a snug-fitting, resilient fairing. In front of the wheel is a protective landing skid. Ground handling is made easier by a fixed tailwheel.

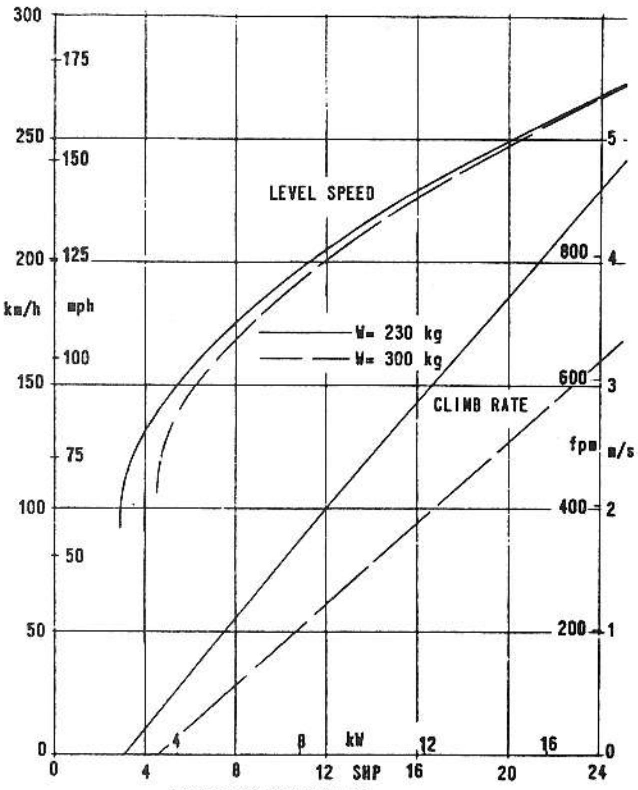
The wheel is mounted at the rear cg limit and no flights should be undertaken if the pilot is unable to make the landing skid contact the ground.

The wingtips have swept-back "winglets" that slide easily on the ground and lift the rest of the wing above the grass. The winglets will also give a certain reduction in induced drag (-4%).

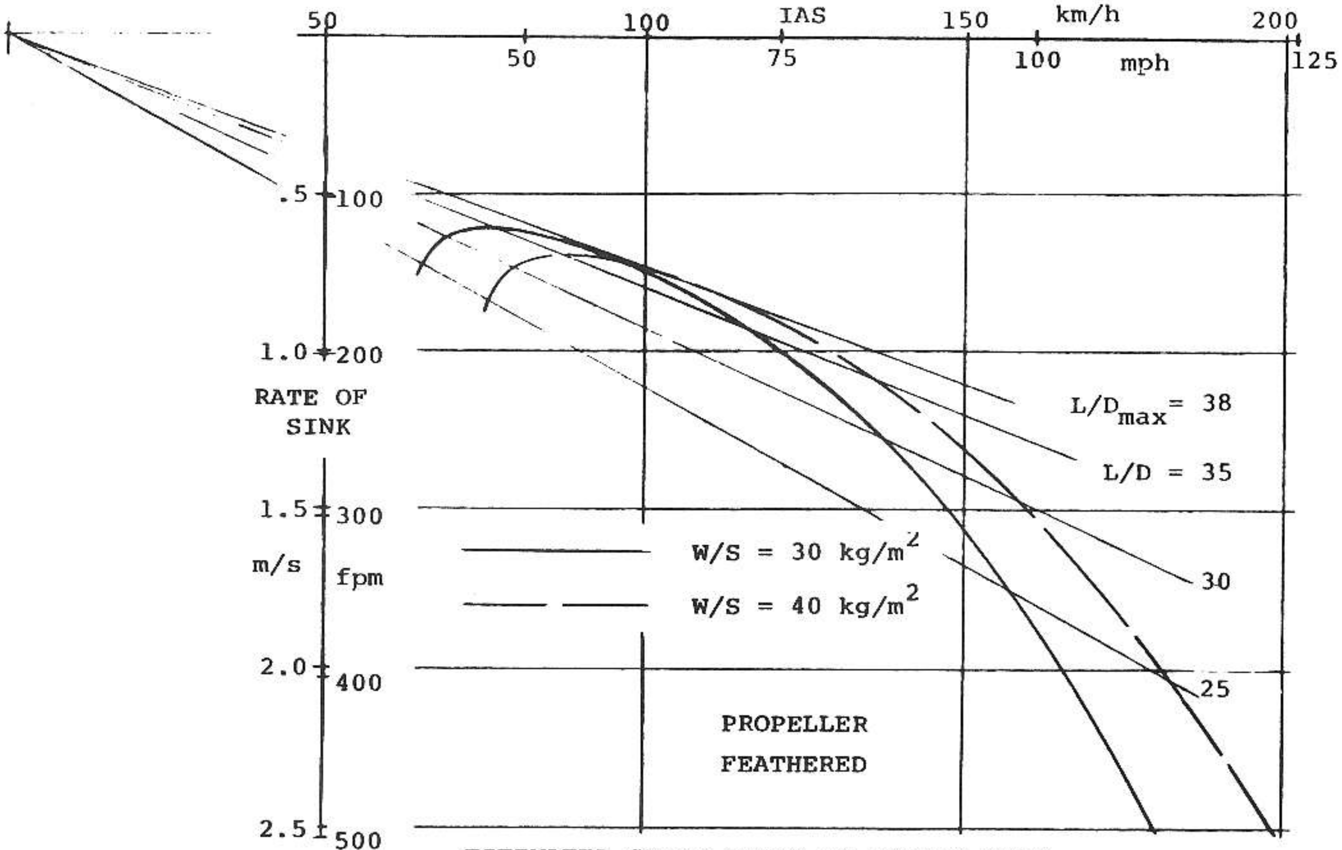
PERFORMANCE

1. Speed Polar

The estimated gliding performance of WINDEX 1200 is presented in the traditional way as a speed polar of sink rate vs. flight velocity. The diagram is based on flight test data from the pre-prototype WINDEX 1100, recalculated to account for the higher aspect ratio of WINDEX 1200 and some other modifications and refinements.



CALCULATED PERFORMANCE:
SPEED AND CLIMB RATE VS ENGINE POWER



ESTIMATED SPEED POLAR OF WINDEX 1200

The lift/drag ratio (L/D) is a classical measure of aerodynamic efficiency. When it comes to the practical exploitation of this quality it should be recognized that the possibility to cover a certain area from a given height, either to find a suitable landing area or to find a promising cumulus cloud, increases by the square of the L/D ratio. This fact underlines the importance of a high L/D especially at the higher speeds used between thermals. The WINDEX 1200 L/D ratio is 32 at 150 km/h (94 mph). Best L/D is 38 at 100 km/h (62 mph), at wing loading 40 kg/sq.m (8.1 lbs/sq.ft) at 300 kg (660 lbs) gross weight.

2. Speed and Climb Rate vs. Engine Power

The calculated level flight speed is shown as speed vs. engine shaft horsepower. The assumed propulsive efficiency is 85%. The calculations are based on the same data as the speed polar and no extra cooling drag has been taken into account.

At 25 shp the calculated level speed is approximately 270 km/h (168 mph). A more useful power setting is 50% power corresponding to 210 km/h (131 mph).

A comparatively high level speed under power is not a prime objective, but a consequence of the configuration selected, with a fixed, well-cowled propeller, in combination with an extremely low-drag airframe.

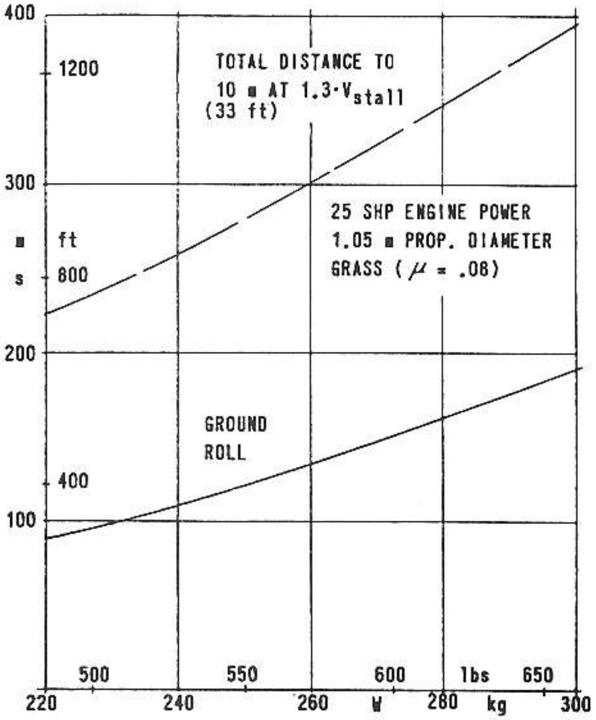
The rate of climb is reasonable with respect to the low installed engine power. From a safety point of view, the climb rate of approximately 4.4 m/s (800 fpm) should be more than adequate even at maximum takeoff weight.

3. Takeoff Distance vs. Takeoff Weight

The ground roll and the total distance to a height of 10m (33 ft) vs. takeoff weight is presented in the diagram assuming 25 shp engine power.

More normal values of takeoff weight are to the left half of the diagram. A weight of more than 250 kg will remove the aircraft from the Aerobatic into the Utility category.

The calculations assume a normal grass runway (coefficient of friction 0.08) and no wind.



TAKE OFF DISTANCE VS TAKE OFF WEIGHT

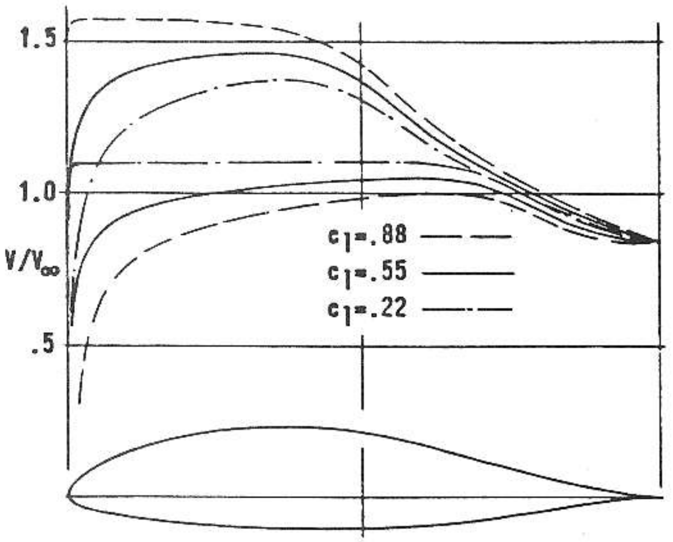
WINDEX LAMINAR WING SECTION

The WINDEX 1200 wing section is derived especially for the aircraft using up-to-date concepts of low Reynolds-number aerodynamics. The section is thoroughly wind tunnel tested and further flight tested on the WINDEX 1100.

The 17% thick section is laid out to sustain a much longer laminar run on the lower side than on the upper side. Wing-section geometry and resulting pressure gradients are so designed as not to make the airfoil maximum lift characteristics unduly sensitive to rain or bugs, or necessitate the use of turbulators for cutting down the length of the laminar bubble.

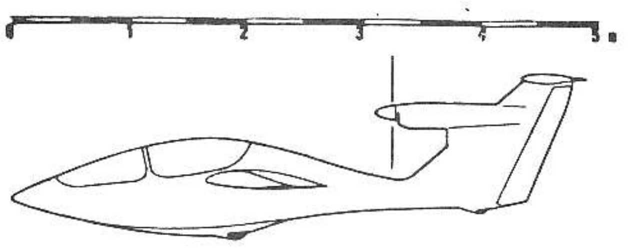
The WINDEX airfoil section has comparatively low drag and wide low drag range that is further expanded by use of a 22.5% chord trailing edge flap.

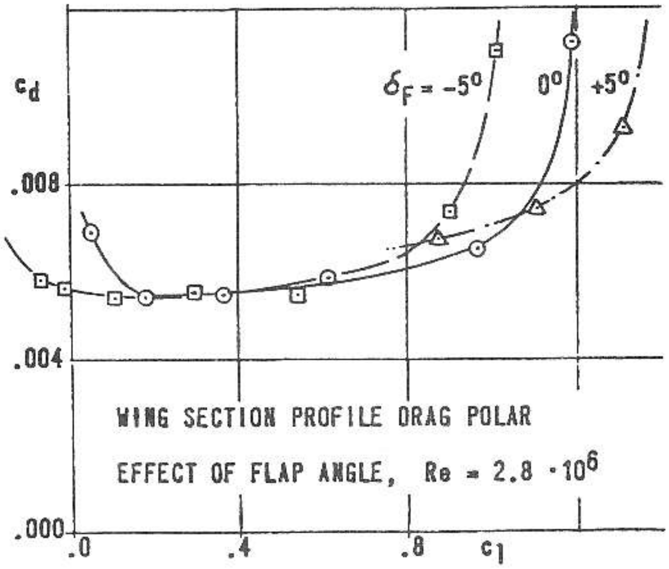
The basic airfoil has very docile stall characteristics in both smooth and rough conditions.



SPECIAL LAMINAR AIRFOIL SECTION.
PRESCRIBED VELOCITY DISTRIBUTIONS WITH RESPECT TO THE ANTICIPATED FLIGHT ENVELOPE.

WIND TUNNEL TEST CONDUCTED AT FFA, STOCKHOLM HAS INCLUDED EFFECTS OF FLAP ANGLES, SURFACE ROUGHNESS ETC AT FULL SCALE REYNOLDS NUMBERS.

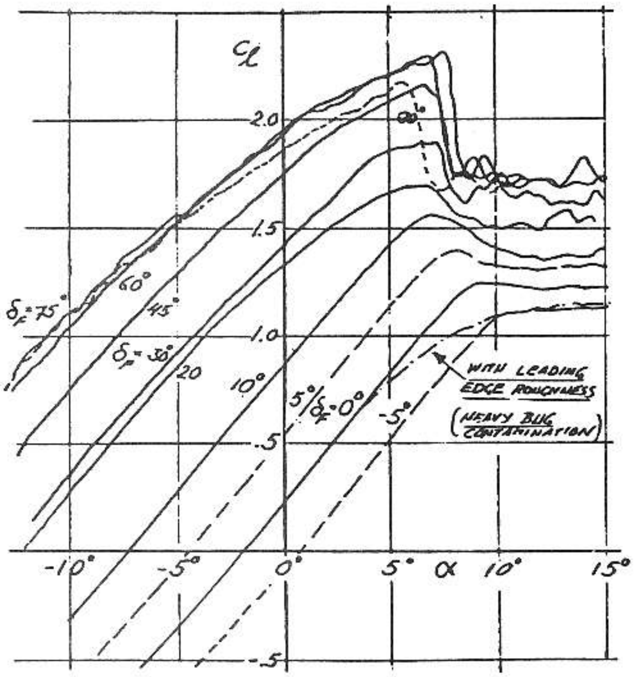




WING SECTION PROFILE DRAG POLAR

EFFECT OF FLAP ANGLE, Re = $2.8 \cdot 10^6$

MEASUREMENTS IN L2/KTH 1984



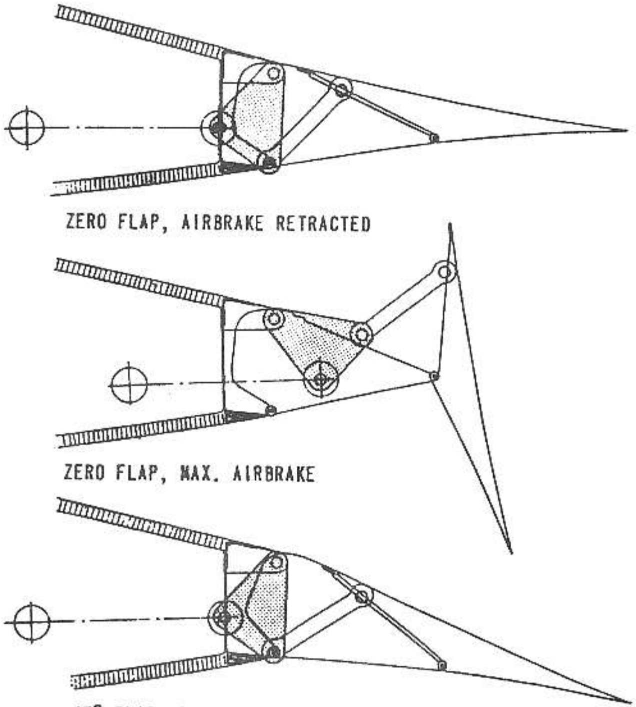
2-DIM. EXPERIMENTAL LIFT CHARACTERISTICS OF THE WINDEX 1100 AIRFOIL SECTION AT VARIOUS FLAP ANGLES. RE= $2 \cdot 10^6$

AIRBRAKES

Airbrakes are very valuable safety devices on aerodynamically clean aircraft when used as divebrakes to limit terminal velocity. On gliders they are normally used for glide path control and this function usually determines the required drag area of the device.

The aerodynamic advantage of the selected type is that deflection of the airbrake creates increase in profile drag with very little change in lift at constant angle of attack. (Modern upper-side-only type airbrakes give considerable decrease in lift.) The structural advantage of the flap-type airbrake is that the wing torsion box can be kept intact.

One problem particular to the flap-type airbrake is combining this principle with a camber-changing trailing edge flap. With the control linkage shown the deflection of the airbrake can be superimposed on any flap setting.



ZERO FLAP, AIRBRAKE RETRACTED

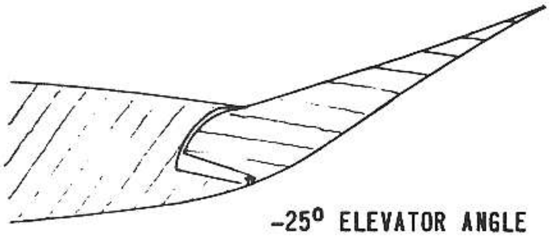
ZERO FLAP, MAX. AIRBRAKE

15° FLAP, AIRBRAKE RETRACTED

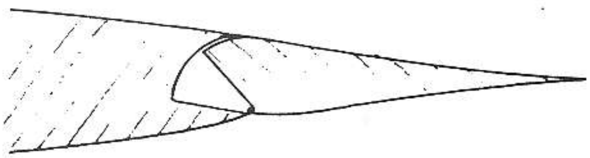
ELEVATOR

The elevator is hinged to the fixed portion of the horizontal tail with the hinge axis at the lower surface in order to improve the effectiveness at high angles of attack and corresponding high elevator angles. The local contour of the hinge line area is modified to form a gentle rounded curve at nose-up elevator positions instead of the sharp kink typical for conventional solutions.

At zero elevator deflection there will appear a shallow V-shaped depression along the hinge axis, but this does not create any noticeable increases in profile drag in wind tunnel tests. However, an increase in maximum nose-up elevator authority of up to 20% is obtained.



-25° ELEVATOR ANGLE

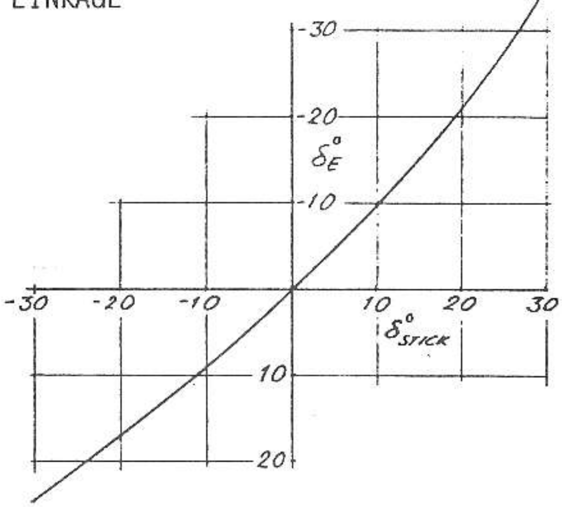


CONTROL SYSTEM

General

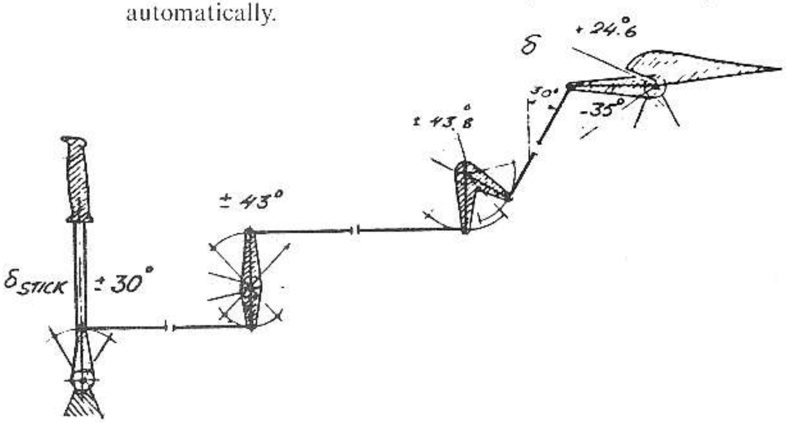
The various control surfaces are connected to the control stick and levers by means of push rods except for the rudder where wires are used for the connection to the adjustable pedals. The control stick is centrally mounted.

ELEVATOR CONTROL
LINKAGE



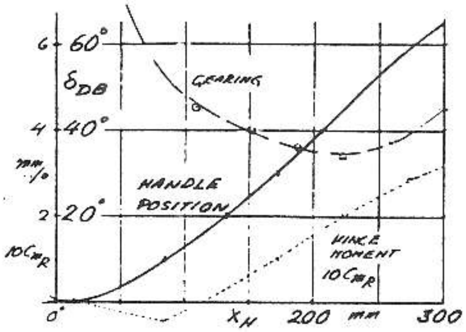
Elevator

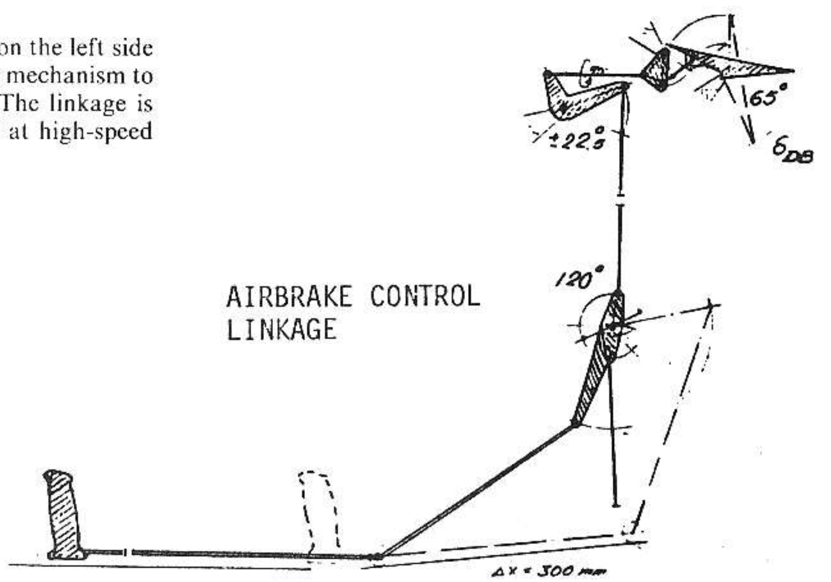
The elevator is linked to the control stick with a non-linear gear in order to make the control response less sensitive at high speeds and still permit the use of maximum elevator deflection for flare-out. When the horizontal tail is mounted on the fin the elevator will be hooked up to the control system automatically.



Airbrake

The airbrake is actuated through a handle on the left side of the cockpit. There is a locking action in the mechanism to keep the airbrake in the retracted position. The linkage is arranged to give low maximum handle loads at high-speed deployment of the airbrake.



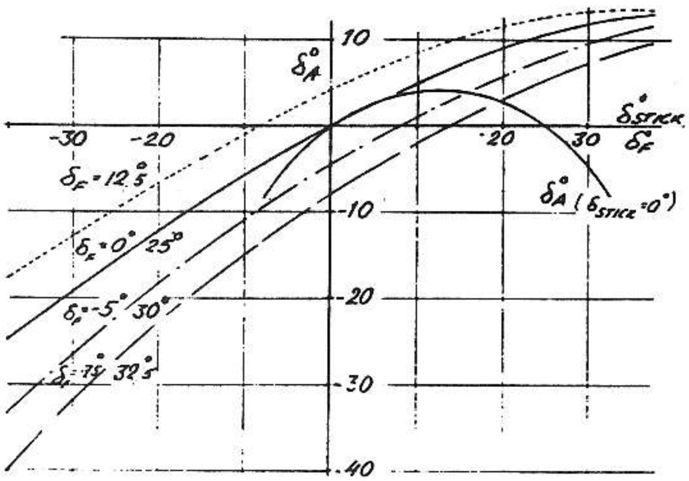


Ailerons and Flaps

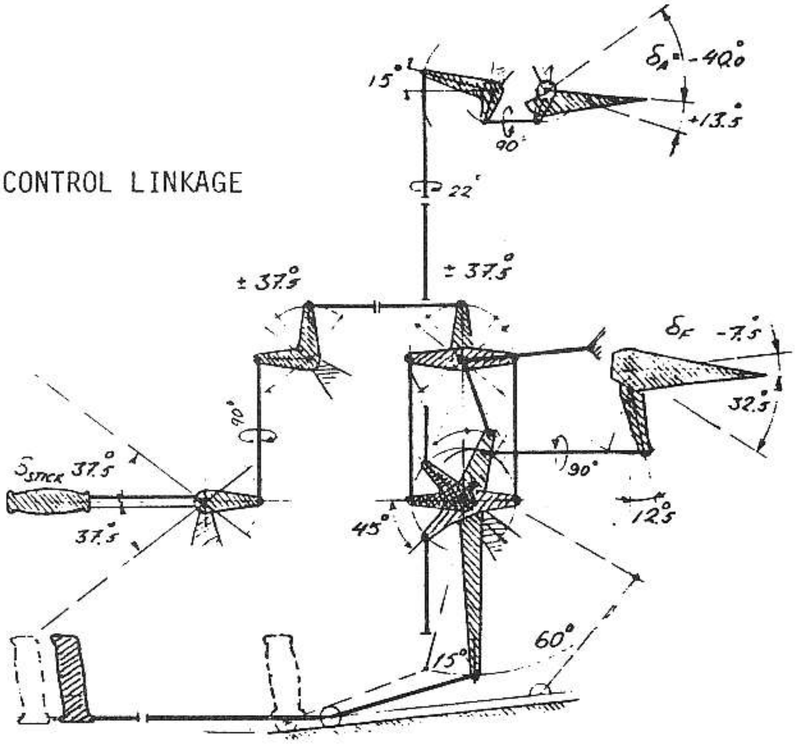
The aileron linkage has a differential mechanism that gives more upward travel than downward travel in order to reduce the profile drag contribution to the adverse yaw effect, typical for gliders especially at lower speeds.

The flap deflections are superimposed on the ailerons in such a way that at negative and small flap deflections the aileron setting will approximately follow the flap setting. This should give optimum high speed and thermal soaring effectiveness on the wing.

At higher flap settings used mainly for takeoff the ailerons have maximum downward zero setting of 5°. At still higher flap settings (25°–30°) as used for landing the ailerons return to neutral. This aileron-flap interconnection is adopted to conserve aileron effectiveness during takeoff and landing. The differential mechanism will limit the aileron downward travel at any flap and stick position to 13.5° downward deflection.



AILERON AND FLAP CONTROL LINKAGE



STRUCTURES

The basic structural material chosen for the WINDEX 1200 aircraft is glass/epoxy. The skin laminates are sandwich construction with Nomex© honeycomb core and prepregged skins. The moldings are manufactured with vacuum bag technique under heat and pressure in an autoclave. The spar caps are unidirectional glass/epoxy with wet-laminated-in fittings of AB RADAB's patented design.

In contrast to such materials as aluminum or wood, composites can be formed in exactly the desired shape without additional cost. As a consequence, the geometry of a composite aircraft can be made more complex and sophisticated with possible gains in aerodynamic and structural efficiency. On the WINDEX 1200 the opportunities to refine the geometry have been exploited during a number of development stages.

LOADS

The airframe is designed to comply with JAR 22, Aerobatics Category. For compliance the maximum flying weight is limited to 250 kg. At higher weight the aircraft will meet the Utility Category requirements (up to approximately 300 kg.)

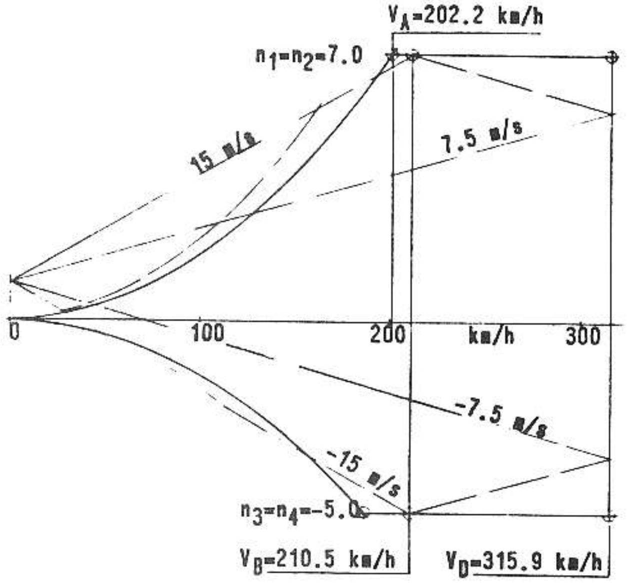
The various speed limits and maximum load factors are given in the flight envelope figure which is a combination of maneuver and gust envelope.

A computer program has been developed to study the static aerolastic behavior of the WINDEX 1200 wing with the aim of optimizing the wing structure geometry. The program uses two-dimensional strip theory to calculate the modified lift distribution due to the aerolastically-induced wing twist. The wing lift distribution is integrated yielding the torsional moment, shear load and bending moment which together with laminate strength data is used to calculate the optimum spanwise distribution of spar cap area and wing skin thickness.

The program has been used to simulate a number of extreme conditions in the WINDEX 1200 flight envelope using data derived from tests on a wing panel specimen representative of the production aircraft. These tests were carried out to determine the wing's torsional stiffness and the location of the elastic axis that provided the foundations for calculations of the wing divergence and aileron reversal velocities. The margins to V_{ne} were in both cases found to be satisfactory.

The wing skin is laminated in two pieces. By joining these on the spar cap instead of at the leading edge, the critical leading edge shape is retained, and much better laminar flow characteristics are possible.

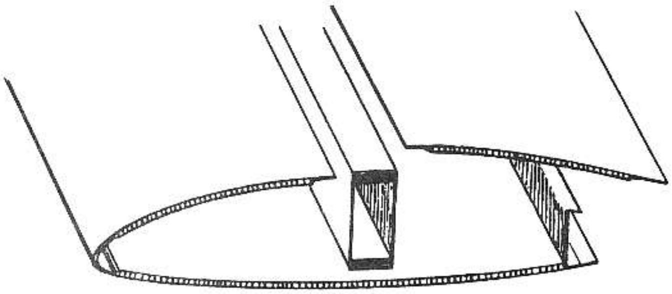
STRUCTURAL AIR LOADS



WINDEX 1200 MANEUVRE AND GUST ENVELOPE

JAR 22 AEROBATICS CATEGORY

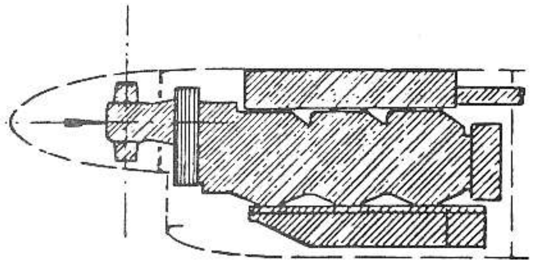
W = 250 kg



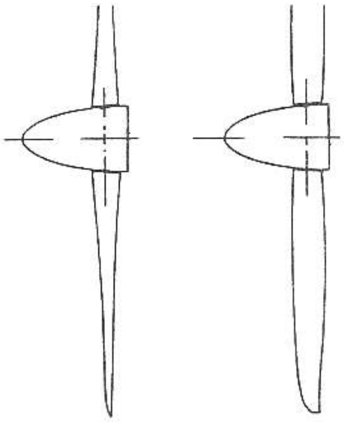
ENGINE AND PROPELLER

Engine

The WINDEX 300 engine is a specially derived 3-cylinder in-line aircooled two-stroke engine. Emphasis is put on low weight (14 kg/31 lbs installed), small frontal area (engine cowling is a circular cylinder of 220 mm/8½ in.), low vibrations and smooth running characteristics. Ignition is by flywheel magneto and prop reduction of 1:8 through polyurethane V-belts. Cylinders, pistons and connecting rods are taken from a well-proven series manufactured chainsaw engine.



The 3-cylinder in-line two-stroke engine has a number of inherent advantages. Total torque is made up from 3 evenly-spaced power pulses per revolution, which reduces transmission loads. Frontal area can be kept small. And finally, there is a positive interference (Müller effect) between the exhaust pulses from the three cylinders. To a degree this has the same effect as a tuned exhaust system but without the very large pipes typical for many high-performance two-stroke engines.



SPECIAL BLADE GEOMETRY FOR HIGH STATIC THRUST, GOOD CRUISE EFFICIENCY AND LOW DRAG WHEN FEATHERED.

$\Delta S \cdot C_D = .3$ dm^2 ($D_{prop} = 1.05$m) $\Delta L/D_{max} = .8$

WIND TUNNEL DRAG MEASUREMENTS.

Propeller

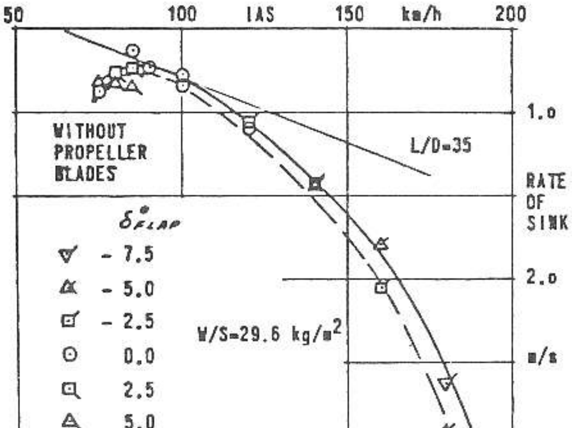
The propeller is of the two-bladed variable-pitch type with blades made of Kevlar/epoxy. Pitch is controlled by a pushrod arrangement along the centerline of the hollow propeller shaft. The propeller pitch can be varied continuously from fine pitch for takeoff and climb to higher pitch for efficient cruise and to feathered position for soaring. The pitch control handle is mounted on the right-hand side of the cockpit and the handle position directly indicated the actual blade angle.

The propeller is wind-tunnel tested to find the optimum low-drag setting in the feathered position and to measure the corresponding drag value. The resulted in presented in the figure. The drag of the feathered propeller is of the order of 4% of the total zero lift/drag of the aircraft. The same propeller in the fine pitch setting (as a fixed climb propeller) would have a drag roughly equal to that of the rest of the aircraft.

With this fact in mind it seems justifiable to assert that every truly high-performance powered glider with non-retractable engine must have a well-cowled engine installation and either a feathering or a folding propeller.

FLIGHT TEST RESULTS

All flights to date have been carried out with WINDEX 1100 as a pure glider using aerotow. General pilot opinion of the handling characteristics can be summed up as "nice and lively with quick control response, and docile stall behavior." Time to change roll angle ±45° is slightly over two seconds.



SPEED POLAR WINDEX 1100 FLIGHT TESTS SUMMER 1985

The only criticism so far has concerned the very light longitudinal (pitch) stick forces. The prototype has not had any trimming system installed, just a normal pushrod connection between stick and elevator. Increased stick force is easily provided by any one of a number of mechanical arrangements in the control system.

Flight performance has been tested on a number of flights during calm summer evenings and the results are presented in the speed polar diagram. The performance figures show a maximum L/D of 35, measured without propeller blades. The corresponds to an L/D of 35 with propeller blades in the feathered position.

A 100 km (60 mile) triangular course has been flown at 75 km/h (47 mph) in average Swedish thermal conditions. No unusual degradation of performance or handling characteristics due to rain or bug accumulation has been encountered. The airfoil section seems eminently suitable for this application.

Maximum speed has so far been limited to 230 km/h (143 mph) as the prototype is not in all respects structurally representative of the production aircraft. No flutter or undue aeroelastic effects were experienced at this speed.

Spin tests (up to 6 turns) have been carried out with the center of gravity approaching the rear limit. With the cg forward of the midpoint of the preliminary cg range the prototype would not spin.

The airbrakes (trailing edge flaps) have proven very effective in limiting terminal velocity (to 125 km/h, 78 mph at 45° dive angle) and are also easy to handle during landing approach for control of glider slope. Very steep glide angles are possible with retained control.

Flight tests have included some aerobatic maneuvers such as loops, rolls, spins, inverted flight, etc. No particular handling problems have been encountered during these tests.

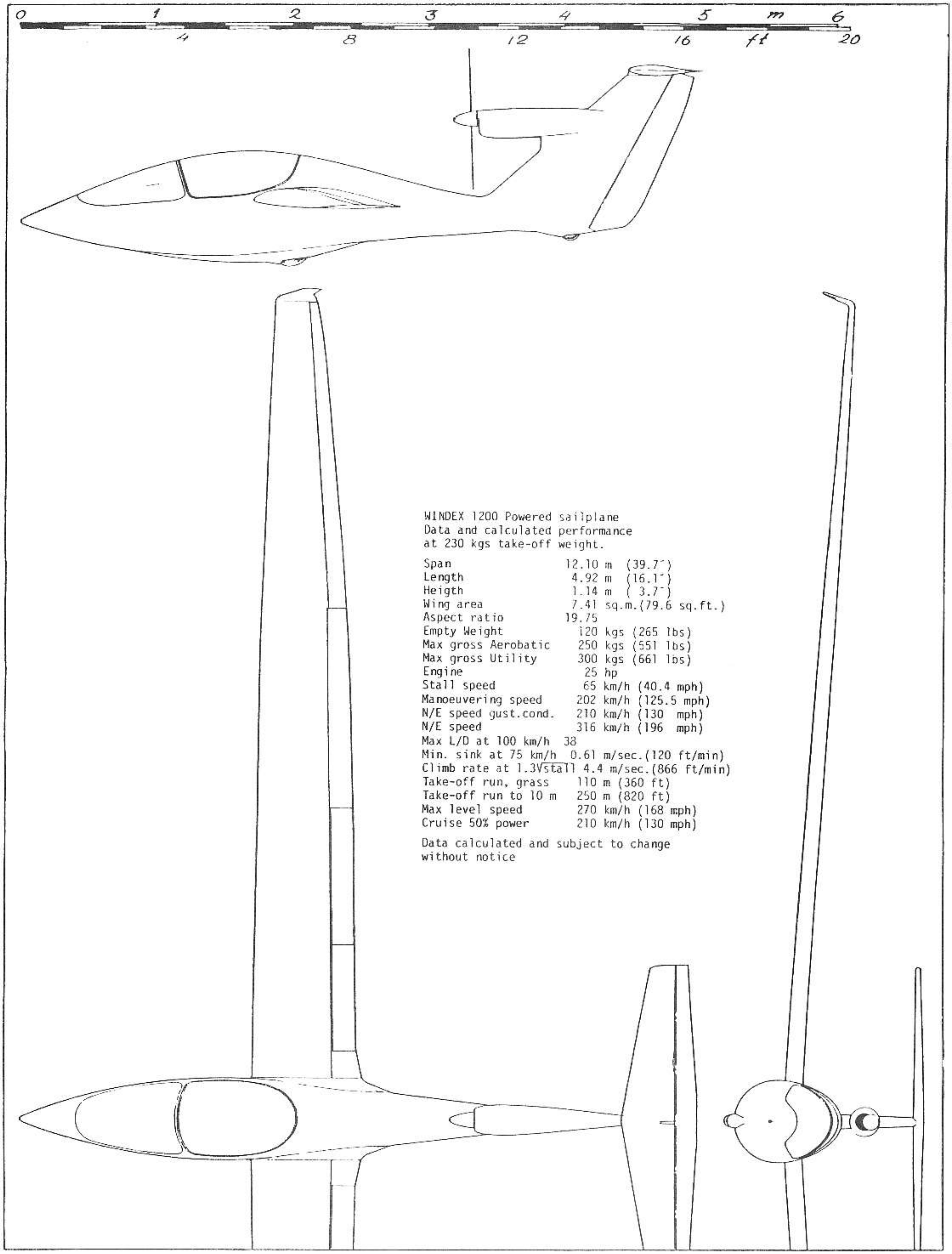
WINDEX 1200 KIT PRODUCTION PROGRESS

Work on the plugs and production molds was well underway at the beginning of 1986. Modifications incorporated include an option for increased span to 12 meters (39'4") by adding .5 meter (20") wingtips. This will increase best L/D by about 8% and reduce minimum sink by about 11%.

Kits will consist of vacuum/autoclave-molded sandwich panels of epoxy prepreg/Nomex© honeycomb (fuselage is wet-molded), canopy with frame, all hardware (AN), all joint material and glue, engine with reduction, variable pitch control propeller complete, all material for the fabrication of control mechanisms, complete building instructions, drawings and, where necessary, templates.

The wing spars are manufactured complete with central-joint fittings and are fitted in the main wing panels. The fuselage is molded as a lower and an upper half, making it possible to fit and inspect all mechanisms (they attach to the lower half) before "putting the lid on." The parts are very light (a complete half wing approximately 45 pounds), and the epoxy/Nomex© construction makes for very stiff structures, so jigs can be kept to a minimum. The wash-out (2°) is already built into the wing, and the D-section is locked with the spar already in place.

At this stage specifications have not been finalized, and of course building time will vary with the individual and his or her resources, but as there is very little surface work (joint lines only) it is felt that the average builder should not have to exceed 500 hours (with the paint job done by a professional.)



WINDEX 1200 Powered sailplane
Data and calculated performance
at 230 kgs take-off weight.

Span	12.10 m (39.7')
Length	4.92 m (16.1')
Heigth	1.14 m (3.7')
Wing area	7.41 sq.m.(79.6 sq.ft.)
Aspect ratio	19.75
Empty Weight	120 kgs (265 lbs)
Max gross Aerobatic	250 kgs (551 lbs)
Max gross Utility	300 kgs (661 lbs)
Engine	25 hp
Stall speed	65 km/h (40.4 mph)
Manoeuvering speed	202 km/h (125.5 mph)
N/E speed gust.cond.	210 km/h (130 mph)
N/E speed	316 km/h (196 mph)
Max L/D at 100 km/h	38
Min. sink at 75 km/h	0.61 m/sec.(120 ft/min)
Climb rate at 1.3$\sqrt{\text{stall}}$	4.4 m/sec.(866 ft/min)
Take-off run, grass	110 m (360 ft)
Take-off run to 10 m	250 m (820 ft)
Max level speed	270 km/h (168 mph)
Cruise 50% power	210 km/h (130 mph)

Data calculated and subject to change without notice