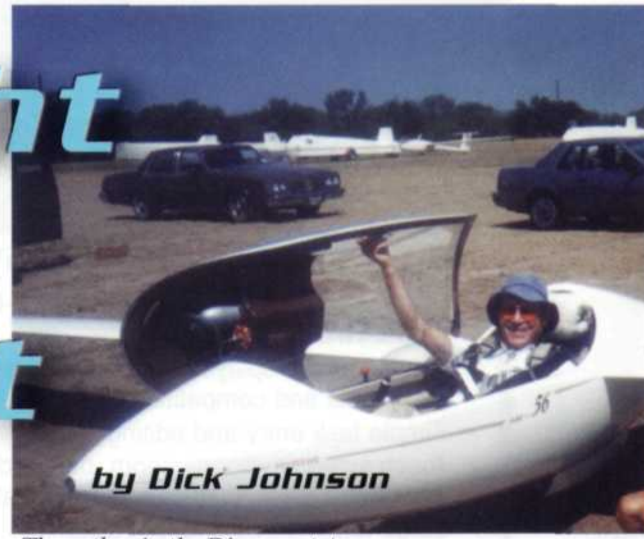
Flight Test Evaluation

by Dick Johnson



The author in the Diana prototype.

Proud owner Jack Wyman standing beside the test SZD-56-1 Diana after a test flight.

The test SZD-56-1 resting on Caddo Mills Runwny 31 while awaiting a tow.

Summary

The SZD-56-1 DIANA is the newest 15-meter single seated racing sailplane to enter production at the well-known Bielsko sailplane factory in Poland. It is claimed to be the most technologically advanced sailplane in the world, and it may well be. Its DIANA name is from the mythological Roman Goddess of the hunt, which is appropriate for a racing sailplane. It is indeed unique in that it is constructed almost entirely with a high strength carbon fiber and aramide epoxy composite, and it has only 87.84 sq ft (8.16 sq m) of wing area. Its empty equipped weight is only about 400 pounds, which is unusually light for a modern 15-meter racing sailplane. It has a very small chord and thin wing, and yet it is JAR-22 certified to an unusually high 146 kts (270 kph) indicated airspeed (about 148 kts CAS by my measurements). Its tail surfaces are also thin and of small chord, and the small streamlined pod type fuselage narrows to a surprisingly small diameter behind the wing.

Introduction

Figure 1 shows a 3-view drawing of the DIANA sailplane, and Table 1 summarizes the Flight Manual's technical data. Note its slim clean lines and its relatively long and thin tail boom; all made possible through the use of modern stiff and high strength synthetic fibers. The retractable main landing wheel is a Tost 4.00 inch wide by 4 inch hub diameter unit equipped with a Tost drum brake. The wheel extends a full wheel diameter below the fuselage, thereby providing excellent ground clearance. The wheel is nicely shock mounted on rocking arm links that are supported by dual elastomeric shock absorbers. The wheel brake is actuated by a squeeze handle that is well located on the forward side of the airbrake actuation handle. The sailplane's light landing weight negates the need for a heavier and more powerful wheel brake. The tail wheel is a small 4 inch diameter solid rubber unit that performs well in preventing the sailplane from weather cocking during crosswind takeoffs and landings; provided the pilot keeps the control stick full aft during those ground rolls.

The SZD 15-Meter Racing Sailplane

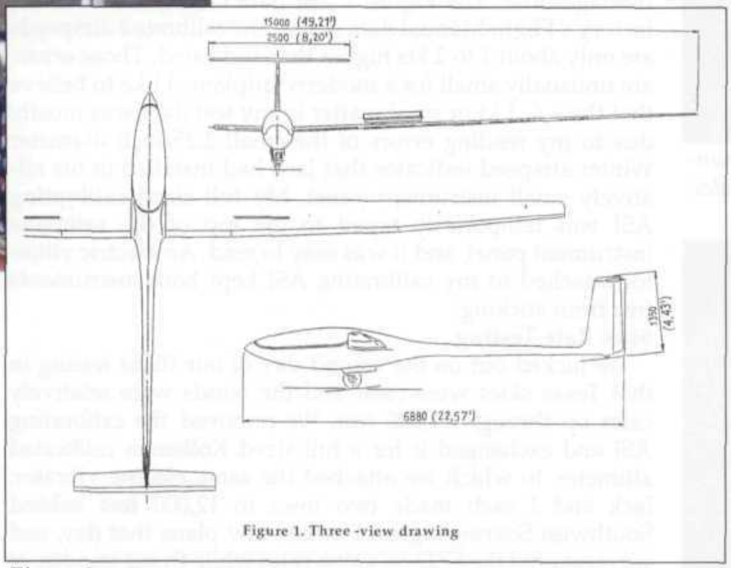


Figure 1. Three -view drawing

Figure 1

The DIANA carries two water ballast tanks in each wing; one in the forward portion of the wing, and the other in the aft portion. Each wing panel has a ballast capacity of about 80 liters (176 lb), which is almost twice their empty weight! A 6 liter tail fin tank is also provided for optimizing the sailplane's ballasted C.G. location. Each wing is provided with dual ballast dump valves located on the wing bottom surface near their root ends. The filling is performed by removing the wing tips and inserting a special O-ring equipped fiberglass funnel into the dual openings. Dual spring loaded safety valves are located on the bottom surface of the removable wing tips. Their purpose is to prevent the ballast tanks from being over pressured during flight and damaging the wings for any reason (except freezing!). That appears to be a well-planned safety feature for an overall excellent water ballast system. Regrettably, our winter flight test program at Caddo Mills did not include any flights with water ballast.

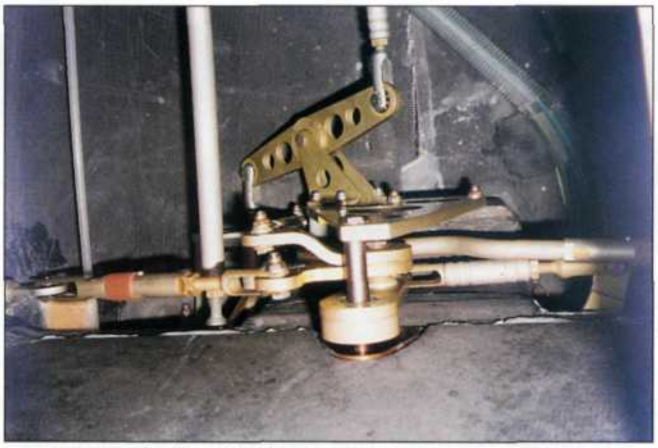
The SZD-56-1 loaded in its trailer. Note that the wing carry-thru spar, which is permanently attached to the fuselage, extends about 18 inches beyond the fuselage sides. Therefore, to keep the trailer from being overly wide, the fuselage is stowed somewhat elevated on its support dolly with the fuselage spar above the zving trailing edges.

The wings are equipped with relatively powerful top surface-only Schempp-Hirth type of airbrakes. They are easy to operate and function well. The wings are equipped with full span ailerons that serve as both flaps and ailerons. Their roll effectiveness is very high, and I found that I could perform + to - 45 degree rolls in about 3 seconds while flying at 50 kts with a full flap setting of +14 degrees. The airbrakes and water ballast controls connect automatically upon assembly; but the flapperons and elevator must be connected manually. A large access hole is provided in the fuselage top for easy and fully viewable connection of the flapperons; and those connectors are of the highly reliable Polish type with a sliding lock sleeve. The horizontal tail unit mounts on the top of the vertical fin, and the elevator control connection is fully accessible before the fin top fairing is installed.

The wing airfoil is listed as an NN 27-13 laminar section of 13% thickness-to-chord ratio, and the wing is only about

Span		15.00	[m]	49.21	[ft]
Length		6.88	[m]	22,57	[ft]
Height (fin with tail wheel)		1.35	[m]	4.43	[ft]
Wing profile		NN 27-13 (13% thickness)			
Root chord		0.67	[m]	2.20	[ft]
Mean Standard Chord		0.5706	[m]	1.872	[ft]
Wing area		8.16	[sqm]	87.84	[sqft]
Aspect ratio		27.57			
Dihedral		2	[deg]		
Tailplane span		2.50	[m]	8.20	[ft]
Empty mass (approx.)		182	[kg]	401	[lb]
All-up mass:	-without water ballast	297	[kg]	655	[lb]
	-with water ballast	410	[kg]	904	[lb]
Maximum cockpit load		115	[kg]	253	[lb]
Wing surface loading:	-maximum	50.25	[kg/sqm]	10.30	[lb/sqft]
	-minimum	29.66	[kg/sqm]	6.08	[lb/sqft]

Table 1



A view thru the large fuselage top access hole showing the manually connected flapperon links at the left and right hand sides. Note the all-carbon fuselage construction.

The top of the vertical tail fin before the horizontal tail is installed. The stabilizer attachment pin and lugs are to the right, and the elevator control arm is protruding upward in the middle.

The horizontal tailplane locked onto the top of the vertical fin before the fairing is installed. The elevator control link is manually connected to the vertical control arm.

3.42 inches thick at the root! The airfoil appeared to perform very well during our 8 test flights despite not being equipped with any turbulators.

The SZD-56 had been in development in Poland for several years, and it finally went into production during 1998. The production model is designated the SZD-56-1. Jack Wyman of Manchester, Michigan, purchased the first production unit, and he received it late last summer ('98). When he and his also-pilot wife Dody kindly offered to trailer it down to Texas for flight testing at Caddo Mills in November, I was naturally delighted.

Airspeed Calibration

First the airspeed calibration instrumentation was installed, and a 9,000 ft high tow was made to calibrate the SZD-56's airspeed system from 40 to 125 kts indicated. Those test data are shown in Figure 2. The sailplane's airspeed system pitot was located in the fuselage nose air vent inlet, and its static sources were located on the sides of the fuselage nose. The Figure 2 test data closely matches the factory's Flight Manual data in that the calibrated airspeeds are only about 1 to 2 kts higher than indicated. Those errors are unusually small for a modern sailplane. I like to believe that the +/-1 kt or so of scatter in my test data was mostly due to my reading errors of the small 2.25 inch diameter Winter airspeed indicator that Jack had installed in his relatively small instrument panel. My full sized calibrating ASI was temporarily taped to the top of the sailplane instrument panel, and it was easy to read. An electric vibrator attached to my calibrating ASI kept both instruments free from sticking.

Sink Rate Testing

We lucked out on the second day of our flight testing in that Texas skies were clear and the winds were relatively calm up through 12,000 feet. We removed the calibrating ASI and exchanged it for **a** full sized Kollsman calibrated altimeter, to which we attached the same electric vibrator. Jack and I each made two tows to 12,000 feet behind Southwest Soaring's great Pawnee tow plane that day, and we measured the SZD-56's sink rates while flying steadily at indicated airspeeds varying from 40 to 115 kts. The sink rate test data were corrected to sea level standard atmosphere conditions. Those data are shown plotted versus calibrated airspeed in Figure 3.

To present a clearer data plot, only the averaged sink rate for the 4 test flights is shown at each test airspeed. A minimum sink rate of slightly less than 100 ft/min is indicated at 41 kts, and a best L/D of about 45 is shown at 53 kts. An unusual shape to the measured polar curve occurred where the 4 flight test data consistently indicated almost identical sink rates when flying at 76 and 82 kts! The reason for that anomalous data is uncertain, but likely due to some quirk in the wing's airflow at those airspeeds. That was further investigated during the following wing drag rake and oil flow testing, but no causes were found. The L/D measured during the 4 separate test flights at 82 kts CAS (80 kt IAS) was about 31, which is excellent for an unballasted 15-meter glider. If the test sailplane were ballasted to its full certified 904 lb (410 kg) flight weight, the 82 kt cruise speed would theoretically increase to 82 x sq root (904/573) = 103 kts! Likely the L/D = 31 would also increase somewhat because of a reduction in the sailplane's skin friction coefficients with the 21% increase in airspeed.

Wing Chordwise Waviness Measurements

Our test sailplane was new from the factory and it was beautifully finished with a Vorgelat T35 gelcoat. The magnitude of the SZD-56's wing surface chordwise waves were measured with a standard 2 inch long wave gage at 4 spanwise locations on each wing panel, and those data are shown in Figure 4. The magnitude of those waves were remarkably low, averaging less than .0015 inches peak-to-peak, and that is outstandingly smooth. In the past I had considered a waviness of about .004 inches to be adequate for **a** sailplane's wing to achieve their full potential for low drag laminar flow, but perhaps less than .004 inches is a bet-

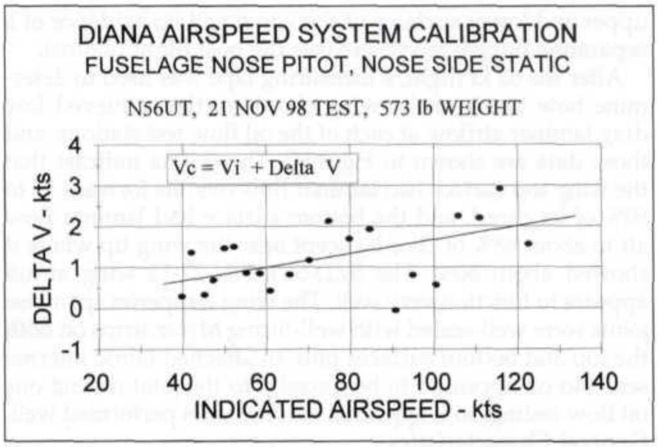


Figure 2

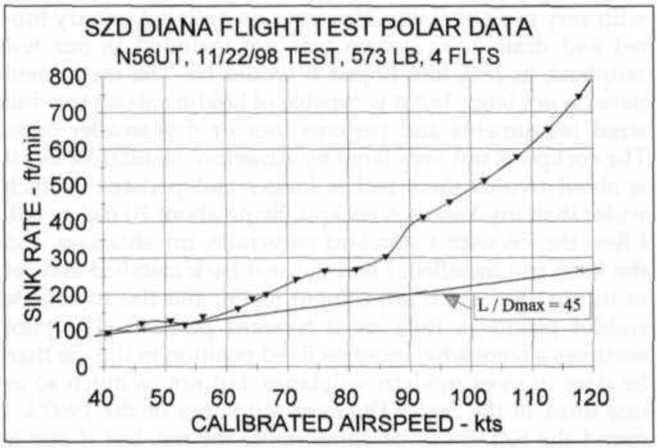


Figure 3

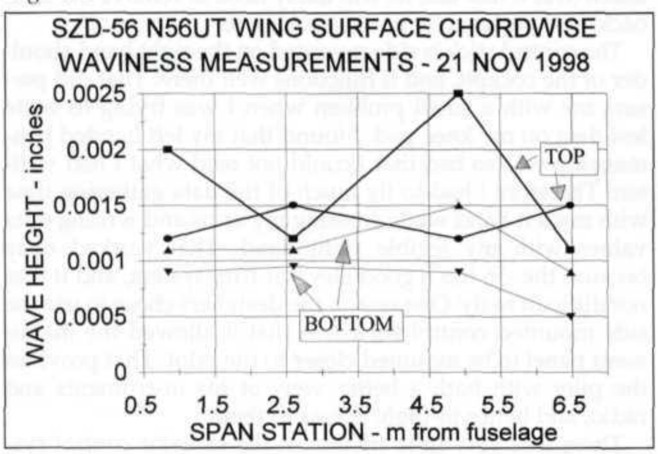


Figure 4

Figure 4

ter criteria, especially at the higher airspeeds.

Wing Drag Rake Testing

To better understand the DIANA's wing profile drag characteristics, a +/-16 mm (.63 in) high drag rake was taped to the sailplane's left wing panel trailing edge about 1-meter out from the fuselage side. The goal of this drag rake test was not to actually measure the wing profile drag at the 1-meter outboard test station, but to determine the optimum flap settings as a function of sailplane airspeed. To do that we connected the high pressure side of our Rico Drag meter to the sailplane's pitot pressure line, and the low pressure side of the Rico meter to the wing mounted drag rake.

Figure 5 is a sketch of a typical drag rake that I use. The vertically oriented drag rake consists of a blade with 8 equally spaced small (0.5mm ID) pitot orifices pointing directly into the airstream. Four are positioned above the wing upper surface, and four below the wing lower surface. The eight pitot orifices lead into a 1.5 mm diameter vertical chamber located at the aft end of the rake. There the eight rake pitot pressures are pneumatically averaged. The averaged air pressure is then fed to the low pressure side of the Rico meter. The theory is that the rake output pressure senses the reduction in the wing boundary layer airspeed, which can be equated to a wing profile drag force. Because of the air's viscosity, it is slowed down after passing over and under a wing, hence its averaged pitot pressure is less than that of the sailplane's nose mounted pitot.

The sailplane came from the factory with no airflow turbulators installed anywhere, and it performed well that way; therefore it was only necessary to perform one drag rake test flight.

With the above discussed wing drag rake test equipment installed, a 9,000 ft high tow was made to measure the wing relative drag pressure values over an airspeed range of 41 thru 124 kts, while searching for the lowest drag flap settings. Those test data are shown in Figure 6. Just as one would expect, the +14 degree flap setting was best at airspeeds below 47 kts, and the full negative -4 degree flap setting was best at airspeeds above 105 kts. The +4 degree flap setting appears best over the 48 thru 75 kt airspeed range,

The fuselage on its support stand ready to accept its wing panels.

An innovative fiberglass funnel is plugged into the wing tips to load water ballast into the separate forward and aft wing tanks. Note the rubber stopper, shown near the wing trailing edge, that is used to plug one of the funnel's outlets when only one tank needs to be filled. The temporarily removed wing tip shown on the ground to the right.

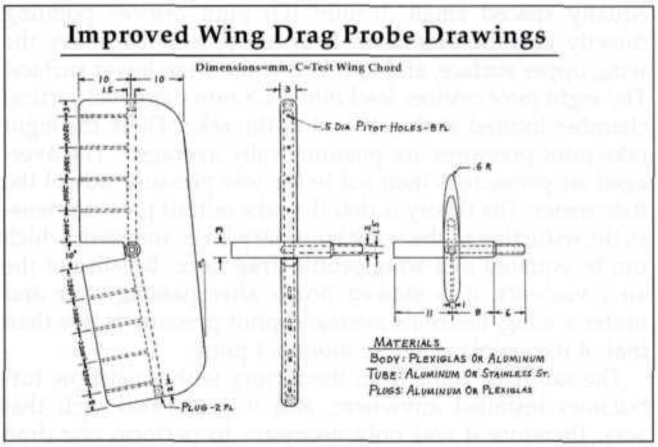


Figure 5

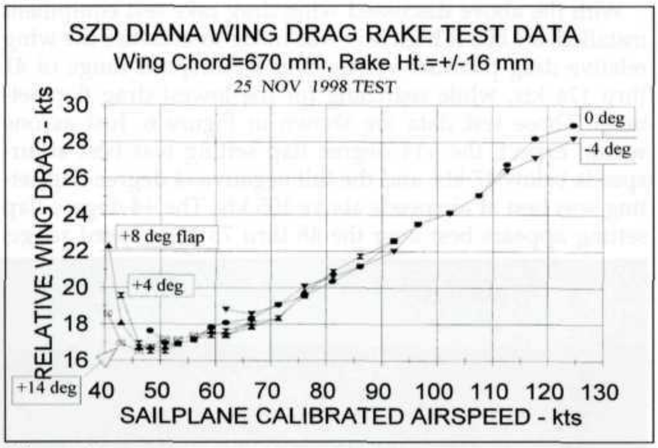


Figure 6

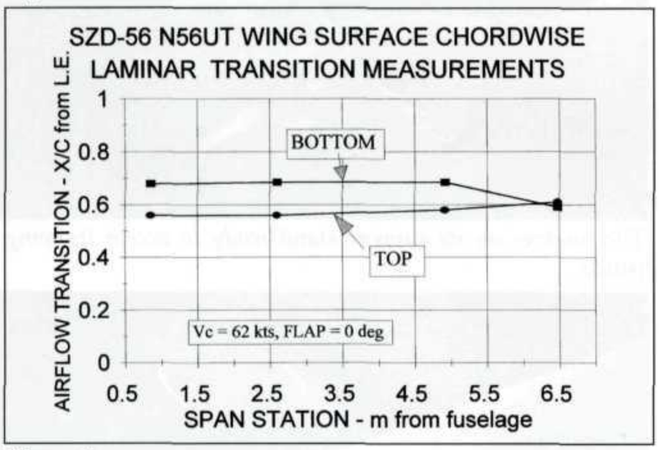


Figure 7

Figure 7

and the 0 degree flap appears best over the 75 thru 100 kt airspeed range. Note that in the 96 to 108 kt airspeed range, it did not make any difference if zero or -4 degree flap setting was used.

Oil Flow Tests

To determine how much of the SZD-56's wing surface actually achieved low drag laminar flow, and if any harmful laminar separation bubbles existed, two 20 some minute test flights were performed with darkened (used) 10W-40 motor oil applied to the left wing's top and bottom surfaces at 4 spanwise locations. The first was performed at about 51 kts with a +8 degree flap setting, and the second at about 62 kts with a 0 degree flap setting. The oil flow patterns after each flight showed extensive laminar flow on both the upper and lower surfaces of the wing, and no evidence of a separation bubble anywhere (see the post flight photos).

After the 62 kt flight, **a** measuring tape was used to determine how much of the wing chord fraction achieved low drag laminar airflow at each of the oil flow test stations, and those data are shown in Figure 7. Those data indicate that the wing top surface had laminar flow over its forward 56 to 60% of its chord, and the bottom surface had laminar flow aft to about 68% of chord, except near the wing tip where it showed about 60%. The SZD-56's NN-27-13 wing airfoil appears to function very well. The wing flapperon spanwise joints were well-sealed with well-fitting Mylar strips on both the top and bottom surfaces plus an attached fabric internal seal. No oil appeared to be forced into the joint during our oil flow testing, so it appeared that the seals performed well.

General Characteristics

A single piece forward hinged canopy provides the pilot with very good visibility. However, an optional urinary funnel and drain tube system was not included in our test sailplane, as Jack had hoped it would be. The instrument panel is not large, but it is capable of holding about two full sized instruments and perhaps four or five smaller ones. The cockpit is not very large by American standards, but it is about two or three inches longer and perhaps an inch wider than my Ventus A cockpit. Being about 70 inches tall, I flew the -56 with a standard parachute, my shoes on, and the head rest installed. I had the seat back installed and set in its next to last aft adjustment notch, and the adjustable rudder pedals in their most forward position. The pilot occupies a somewhat more reclined position in the -56 than he does in most modern sailplanes, but not as much so as one must in the Swiss Diamant sailplanes of the 1960's. I found the SZD-56 to be comfortable for me, but if one is much over 6 foot tall, he will likely need to remove the seatback, and perhaps fly in his stocking feet.

The control stick is side mounted on the right hand shoulder of the cockpit, and it functions well there. That did present me with a small problem when I was trying to write test data on my knee pad. I found that my left handed penmanship was so bad that I could not read what I had written! Therefore I had to fly much of the data gathering time with my left hand while crossing my arms and writing data values with my legible right hand. That worked okay because the -56 has a good elevator trim system, and it was not difficult to fly. One reason the designers chose to use the side mounted control stick was that it allowed the instrument panel to be mounted closer to the pilot. That provides the pilot with both a better view of his instruments and radio, and better in-flight access to them.

There was very little friction in the elevator control system, but the aileron system friction increased noticeably as the flaps were extended. I estimated that the aileron breakout friction amounted to between 1 and 2 pounds when the flaps were set to their full down +14 degree position, but decreased to about 1/2 pound when the flaps were set to their full up -4 degree position. It is likely that the sliding of the Mylar seals were causing most of that breakout friction. Jack plans to add some wax or lubricant to the flapperon surfaces upon which the full span Mylar seals slide, and that should reduce the aileron friction problem.

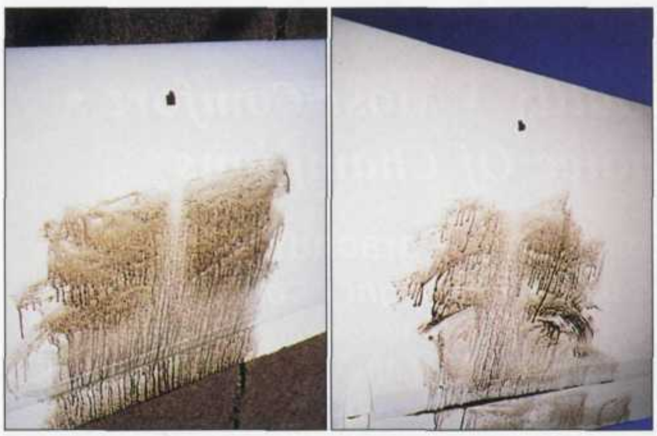
The aileron control is really outstanding. At 51 kts CAS, + to -45 degree rolls with +14 degrees of thermaling flap can be performed in about 3.0 seconds! The stall characteristics are moderately gentle. At my 573 lb flight test weight and +14 degrees of flap in level flight, I could feel buffeting at about 39 kts and stall at about 38 kts IAS. The SZD-56 is placarded against spins

The SZD-56-1 wing after a 60 kt oil flow test flight. The oil patterns indicate that low drag laminar flow was achieved on the wing top surface aft to about .56 of the chord fraction, followed by normal attached turbulent flow to the wing trailing edge. The thinned oil flow chordwise streaks shown near the center of each oil test pattern are intentionally created turbulent wedges caused by the .008 inch high black tape "bugs" attached to the wing surfaces ahead of the oil test areas.

and aerobatics; so the spin entry characteristics were not evaluated.

The thin wing panels are unique in that they are of a sparless design where the wing bending loads are resisted by thickened carbon fiber skins rather than by a conventional spar. That is efficient because it places the bending strength elements at the wing external surfaces, rather than burying them below the wing surface sandwich layer as most other sailplanes do. Partially for that reason, each wing panel weighed only about 101 lb (46 kg); yet it can carry about 176 lb (80 liters) of water ballast in each panel.

Cockpit view with control stick on upper right side, airbrake handle on upper left side aft, flap handle on upper left side forward, and landing gear handle on lower left side. Note the Rico Drag meter temporarily mounted at the top of the instrument panel, and the electric instrument vibrator temporarily mounted on the left side of the instrument panel.



Left: A closer view of one of the wing upper surface oil flow pattern after the 60 kt test flight. The gradual chordwise thickening of the oil indicates low drag laminar airflow aft to about .56 chord; and the sudden thinning of the oil aft of that point indicates normal transitioning to turbulent airflow aft to the trailing edge. Note tape "bug" near leading edge. Right: Oil flow pattern on the wing bottom surface after 60 kt flight, showing laminar airflow aft to about 68% of the wing chord. Note that for some reason considerable oil collected along the aft edge of the flapperon's Mylar seal. However, the flapperons were well-sealed and the oil did not appear to flow into the hinge cavity. Black tape airflow proof "bug" is attached near the wing leading edge.

Conclusions

The SZD-56-1 is an exciting new entry into the racing sailplane market, and it will likely be a formidable competitor when flown by experienced contest pilots in next summer's races. Its small size and light weight make it very crew friendly, and I was quite favorably impressed by its advanced design, construction and good flight characteristics. However, it is an advanced high performance racer and it is not a suitable sailplane for low time pilots. When Jack purchased N56LJT it cost about $53,000 for the sailplane, plus about $7,000 for its excellent modern fiberglass and steel alligator type trailer. The current prices, I am told, are somewhat higher.

Thanks go to Jack and Dody Wyman for bringing their great new sailplane to Texas for flight testing, and allowing me to fly it. Also, to the Dallas Gliding Association who sponsored the eight flight test tows at Caddo Mills.

About the author: *An eleven time winner in U.S. National sailplane contests and long-time contributor to* Soaring *Magazine, Mr. Johnson continues his excellent work in the area of sailplane test evaluations. He has BA and MS degrees from Mississippi State University and Stanford and currently resides in Dallas, Texas where he remains active with the Texas Soaring Association.*