"How Do Vortex Generators Work?"

Vortex generators work by introducing energy into the boundary layer. Experiments have shown that the more stagnant the boundary layer is, the more likely it is to separate from the surface. Placing a vortex generator upstream of the area of stagnation, re-energizes the flow, thus inhibiting separation.

If there is any doubt as to the nature of airflow on or around a particular geometry it may prove necessary to conduct tuft tests. Tufting by itself is not a difficult process but it is time consuming and often costly. A complete discussion of tufting is beyond the scope of this writing. Suffice it to say that it consists of attaching small lengths of contrasting string or wool to the aircraft surface to be analyzed. The tufts are placed in a uniform pattern and secured with adhesive tape. Observers in a companion aircraft will then fly carefully in close formation with the aircraft being tested and film the behavior of the tufts. Subsequent analysis of the film or video tape permits developers to modify a surface. Afterwards, the tuft tests are again conducted and the changes, if any, evaluated. This process is conducted as often as is believed necessary, until the desired result is obtained.

An alternative method of testing boundary layer flow is to mix a dye such as copy machine toner with an oil having a very high viscosity and "painting" the mixture upstream of the surface to be tested. The direction and speed of migration of the oil is an excellent indicator of the boundary layer activity.

Permanent adhesion of the VG's is not desirable for evaluating their contribution. It is easier (and preferable) to secure them temporarily to the aircraft with 2" duct-tape or clear wrapping tape. The latter is preferred as it has a much thinner edge and is less likely to trip the air flow. More on this taping process is to be found in the section on installation.

"Can I Expect A Drag Penalty?"

Placing anything into a stream of moving air will cost you some form of energy loss. Even the best wing produces some drag. The question that needs to be asked is *"What are the benefits and will they offset any drag penalty"*. Under normal circumstances, the answer is *yes.* Increased drag notwithstanding, some aircraft have actually flown faster on the same or reduced power because the generators smoothed out power robbing drag turbulence. Others, like the Piper Navajo, have realized significant increases in usable gross weight, lower stall speeds and a reduction of the minimum safe single engine speed, simply by using after-market vortex generators on the wings, nothing else! And, with approval by the FAA.

So, whatever drag might be caused by the VG is usually offset by it's benefits. None of the owners of VG equipped Rutan designed a/c we questioned have reported any loss of speed as a result of using VG's. If there has been a loss of speed, it has been a value too small to be measured with conventional instrumentation.

Using Vortex generators on Wing sections

Placement of vortex generators on airfoils is fairly straight forward. Typically, a complete row of vortex generators forms a "fence" that is parallel to the leading edge of an airfoil. The sail appears to perform best when placed in pairs (one left and the other right) with each sail at a 15^0 angle **to the streamline,** not to the leading edge of the wing! On Long-Ez's, the VG's appear to perform best when the leading edge of the "sail" is located at 50% of chord. See the enclosed drawing for orientation and placement for Long-Ez's.

What about using Vortex Generators on the fuselage?

We have only conducted tests on wing sections so we are not in a position to make any specific recommendations on alternative applications at this time. However, the potential for gains in non airfoil installations has already been amply demonstrated. One manufacturer of a biplane configured, composite amphibian, had considerable difficulty getting the aircraft to take off, especially from water. A series of tuft tests revealed severe separation of the boundary layer on the fuselage, upstream of the cabin mounted, pusher propeller. The air was so disturbed that the prop simply could not get a bite, thus causing a loss of thrust. Vortex generators cured the problem. In fact the improvement in take-off performance is purported to have been so dramatic that the designer of the amphibian was able to change to a courser pitch prop and realize gains in cruise speed as well! There have been numerous unconfirmed reports of significant increases in speed on some Vari-Ez's as a result of careful placement of VG's on engine cowlings and wheel pants. Others claim that VG's have lowered engine operating temperatures by altering the flow of cooling air.

Please remember that while airflow on a wing is reasonably predictable, fuselages, especially those with tractor engine installations, produce complicated airflow. Without testing it is difficult to responsibly predict what results will be obtained.

Suggestions for Installing Vortex Generators on a Wing

1. First draw a pencil line on a table top, clean bench or a large sheet of Formica to show the orientation of the fence or string of VG's.

2. Draw a short second line perpendicular to the first, to use as a baseline.

3. Draw an identical fence and perpendicular base line on the aircraft at the place where you wish to locate the fence of generators.

4. Dimension the fence line on the table, showing the orientation and placement of each generator. Or, cut a template out of cardboard. Precision is not paramount for performance but a little extra care here will look a lot better.

5. Lightly spray an adhesive film onto the tabletop along the peciled line. This is not structural adhesive, just a temporary agent to hold the VG's to the jigging surface during preparation.

6. Position each vortex generator using the pencil marks laid down earlier. Press each one in place to insure that it is secure.

7. Take a length of 2" wrapping tape that is long enough to span the entire fence of generators. Position it spanwise, parallel to the fence line, directly over the VG's. Ask for help if necessary. Lower the tape so that it attaches to the **top** edge of the sails.

8. Take two popsicle sticks and hold them together between both hands so that there's a slot between the sticks. Or use a heavy dinner fork with multiple tines. Position the sticks (or the fork) so the gap is parallel to and directly over each sail. Press down gently on each sail so that it punches through the tape.

9. Use the same tool to rub the tape in place on the base of each VG. Try to avoid sticking the tape to the bench or table.

10. Transfer the baseline from the table to the tape with a magic marker or pencil. Make similar marks along the length of the tape to indicate the fence line. The strip is now ready for use.

10. Slowly lift the entire strip of tape from the table. Each VG will pop off the surface as you lift. Do not pull so hard that you stretch the tape and alter the spacial relationships of the generators.

11. **TEMPORARY PLACEMENT FOR FLIGHT TESTING:** Bring the entire strip over to the aircraft with your assistant. Line it up so that the fence line marks and the base line marks on the tape are properly aligned with the marks penciled to the surface of the aircraft. When everything is oriented in the manner you want, simply lay it down and rub both the VG's and the tape with a rubber squeegee.

12. **PERMANENT ADHESION OF GENERATORS.** After flight testing, when the position and number of VG's has proven itself, lift the leading edge of the tape for its entire length and peel it back carefully like a hinge. Lift it up just enough cordwise to reveal the bottom of each generator. Do not lift the tape completely off the surface. Coat the bottom of each generator with General Electric Silicon caulk (RTV-6802 is White, RTV-6803 is Black, RTV-6008 is Translucent, RTV-6809 is tinted Aluminum) After coating all VG bases, lower the tape back onto the surface. Again with a fork or squeegee, press the tape to the surface of the aircraft. Let cure for 24 hours. Remove the tape. The adhesive on clear wrapping tape is sensitive to heat. If necessary, apply a little heat from a hair dryer and the tape should lift off without difficulty.

NOTE: CCI's vortex generators are for use on Experimental aircraft only! The FAA specifically forbids alterations to Type Certificated aircraft. The use of CCI's vortex generators on certificated aircraft constitutes an unlawful modification. Tests to determine their suitability for a "factory built" aircraft should be conducted only by qualified flight test personnel under the direct supervision of the manufacturer or holder of the type certificate and in accordance with FAA certification procedures.

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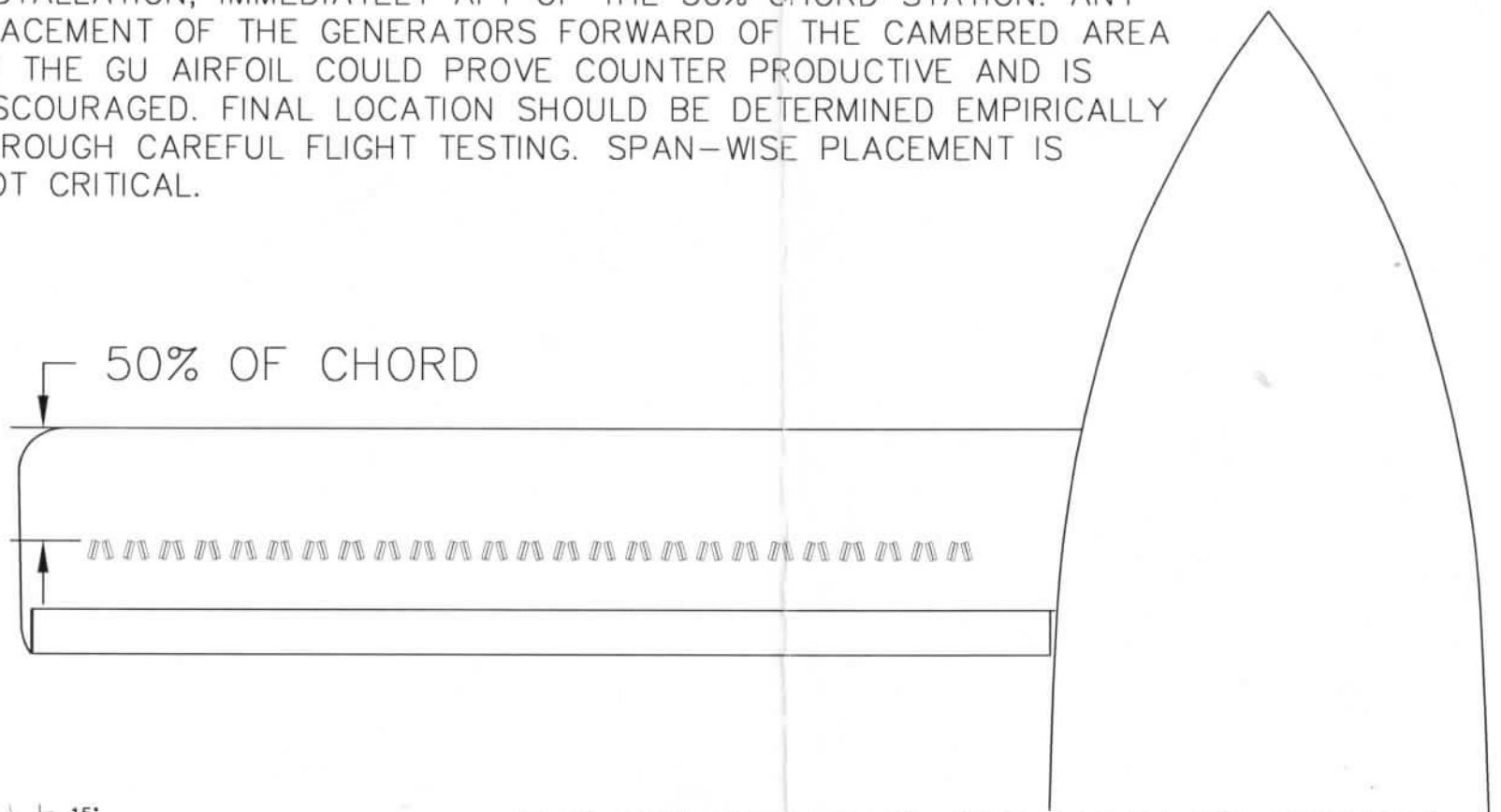
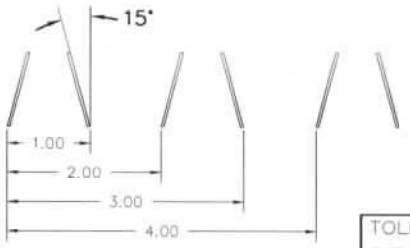
RUTAN VARI-EZ OR LONG GU CANARD SHOWING TYPICAL VORTEX GENERATOR INSTALLATION, IMMEDIATELY AFT OF THE 50% CHORD STATION. ANY PLACEMENT OF THE GENERATORS FORWARD OF THE CAMBERED AREA OF THE GU AIRFOIL COULD PROVE COUNTER PRODUCTIVE AND IS DISCOURAGED. FINAL LOCATION SHOULD BE DETERMINED EMPIRICALLY THROUGH CAREFUL FLIGHT TESTING. SPAN-WISE PLACEMENT IS NOT CRITICAL.





EACH GENERATOR IS 1" OFFSET FROM IT'S NEIGHBOR AS MEASURED AT THE OUTBOARD, TRAILING EDGE. PRECISION HERE IS NOT CRITICAL TO PERFORMANCE, ONLY TO APPEARANCE.

TOLERANCES, UNLESS OTHERWISE SPECIFIED DECIMAL: ?.030 FRACTIONAL: ? 1/32	DATE: MARCH 3, 1993	COMPUTER CERTAINTY, INC. 186-B River Rd, Annandale, NJ 08801-3519, Phone: (908) 713-0187
MATERIAL INJECTION MOLDED POLYCARBONATE	REVISION: FEB 19, 1994	
HEAT TREATMENT (NONE)		TITLE VORTEX GENERATOR CANARD & AILERON VG-1
SURFACE TREATMENT NONE		
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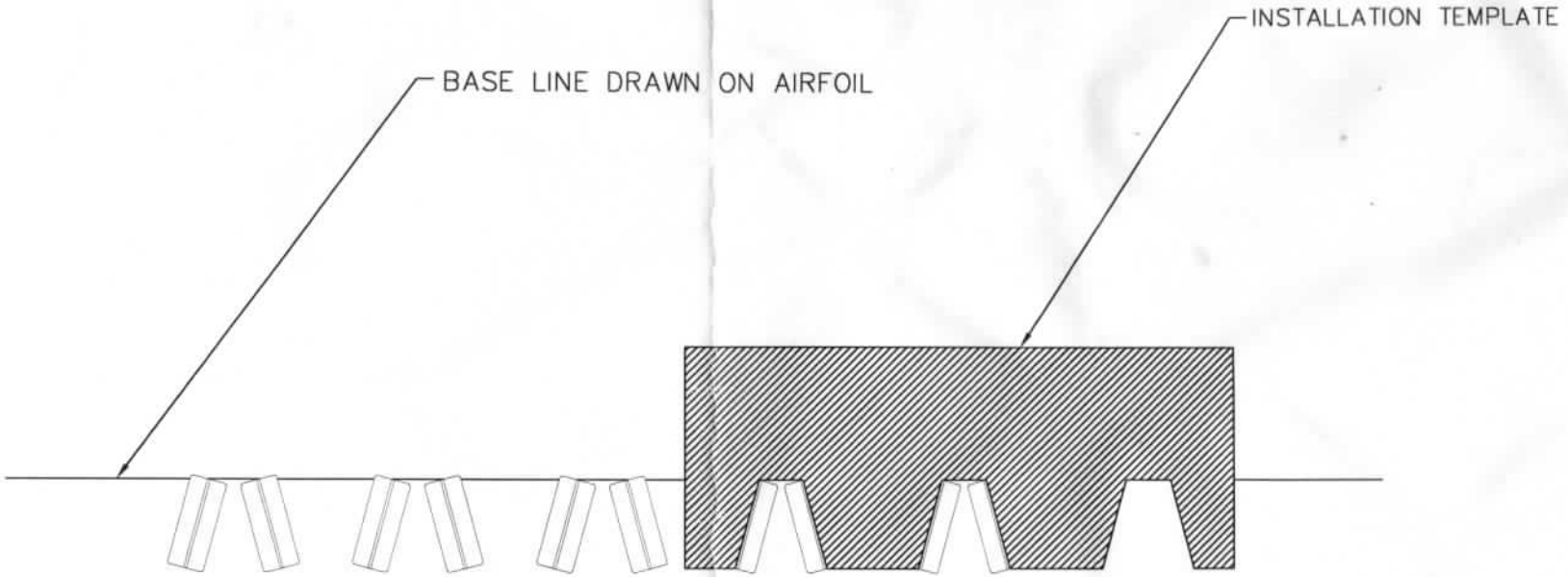

TOLERANCES, UNLESS OTHERWISE SPECIFIED DECIMAL: ?.030 FRACTIONAL: ? 1/32	DATE: AUG 10, 1993	COMPUTER CERTAINTY, INC. 186-B RIVER ROAD, ANNANDALE, NJ 08801-3519, PHONE 908-713-0187
MATERIAL PVC?	REVISION: AUG 17, 1993	
HEAT TREATMENT (NONE)		TITLE VORTEX STRIP VARIES AB-930801
SURFACE TREATMENT NONE		
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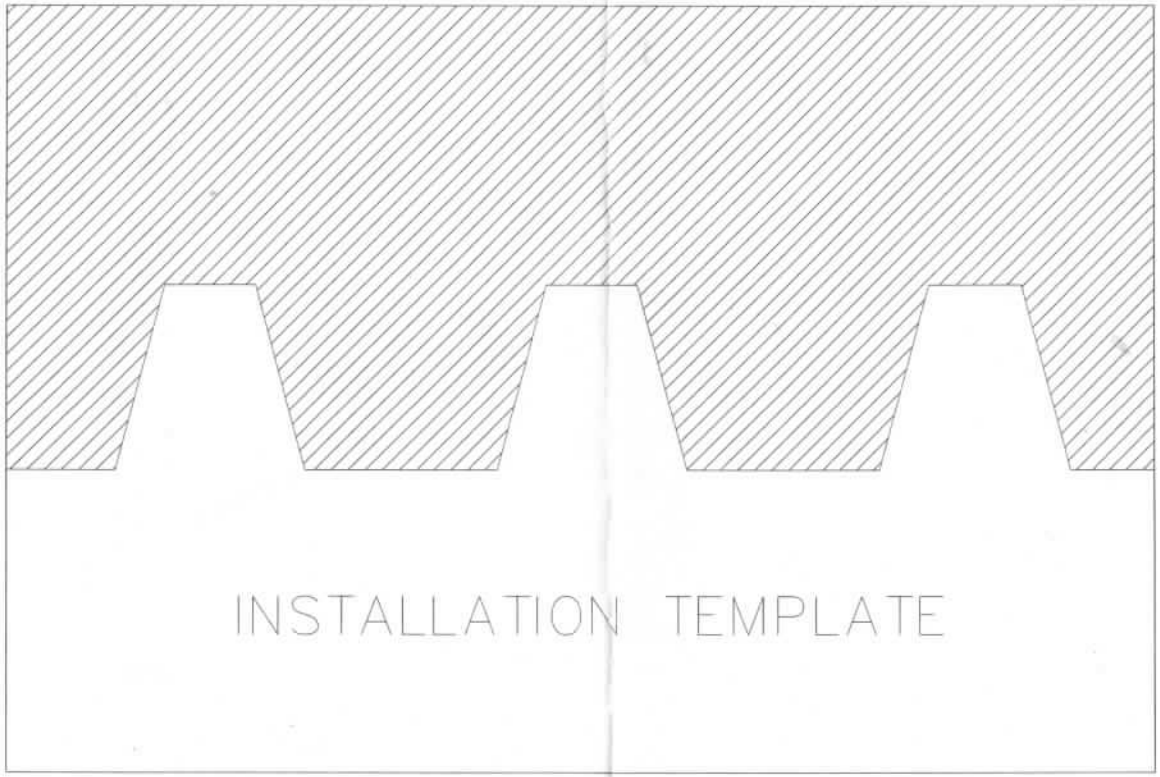

ALTERNATIVE INSTALLATION METHOD: CUT OUT THE ABOVE RECTANGULAR GEOMETRY AND GLUE IT TO A 4' X 6" PIECE OF ALUMINUM FLASHING, FORMICA OR SIMILAR THIN, STIFF STOCK. WHEN DRY, CUT AWAY EITHER THE SHADED OR UNSHADED SECTION. PLACE THE TEMPLATE AGAINST ANY TWO EXISTING PAIRS OF VORTEX GENERATORS AND USE THE REMAINING 3RD NOTCH TO POSITION THE NEXT PAIR.

NOTE: DO NOT USE THE EDGE OF THE CARD TO ALIGN THE CARD WITH THE LEADING EDGE OF A WING. VG'S SHOULD BE AT A 15 DEGREE ANGLE TO THE STREAMLINE. IF THE WING IS SWEPT BACK (OR FORWARD) TO ANY DEGREE, THE VG'S WILL NOT BE AT THE OPTIMUM PERFORMANCE ANGLE.