

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



WPR22FA100

STRUCTURES

Group Chair's Factual Report

March 6, 2024

A. ACCIDENT

Location: White Hills, Arizona
Date: February 19, 2022
Time: 1328 Mountain Standard Time (MST)
2028 Coordinated Universal Time (UTC)
Airplane: Van's RV-7A, N787NV, SN 72097

B. STRUCTURES GROUP

Group Chair	Clinton R. Crookshanks National Transportation Safety Board Aurora, Colorado
IIC	Andrew Swick National Transportation Safety Board Phoenix, Arizona
Group Member	Elliott Simpson National Transportation Safety Board Los Angeles, California
Group Member	John C. Waugh Federal Aviation Administration Las Vegas, Nevada
Group Member	Rian Johnson Van's Aircraft, Inc. Aurora, Oregon

C. DETAILS OF THE INVESTIGATION

The investigator-in-charge responded to the accident and examined the airplane February 19-20, 2022. All major components of the airplane were located at the main wreckage location or in the debris field that extended about 1,500 feet south-southeast of the main wreckage. The wreckage was recovered to the Air Transport facility in Phoenix, Arizona, where the Structures Group examined it on April 12, 2022.

D. FACTUAL INFORMATION

1.0 Airplane

The Van's Aircraft RV-7A is an experimental, amateur built, mostly all metal airplane equipped with low wings, a conventional tail, and tricycle landing gear. The RV-7 airplane is mostly identical except has a conventional landing gear arrangement. The airplane seats two occupants, side-by-side, and is typically powered by a four-cylinder engine equipped with a constant speed two-blade propeller. The airplane is 20 feet, 4.5 inches long, has a wingspan of 25 feet, and is 7 feet, 5 inches tall at the tail (Figure 1). The recommended center-of-gravity (CG) range is 78.7 to 86.82 inches aft of the datum (15-29% MAC¹) where the datum is located 70 inches forward of the wing leading edge.

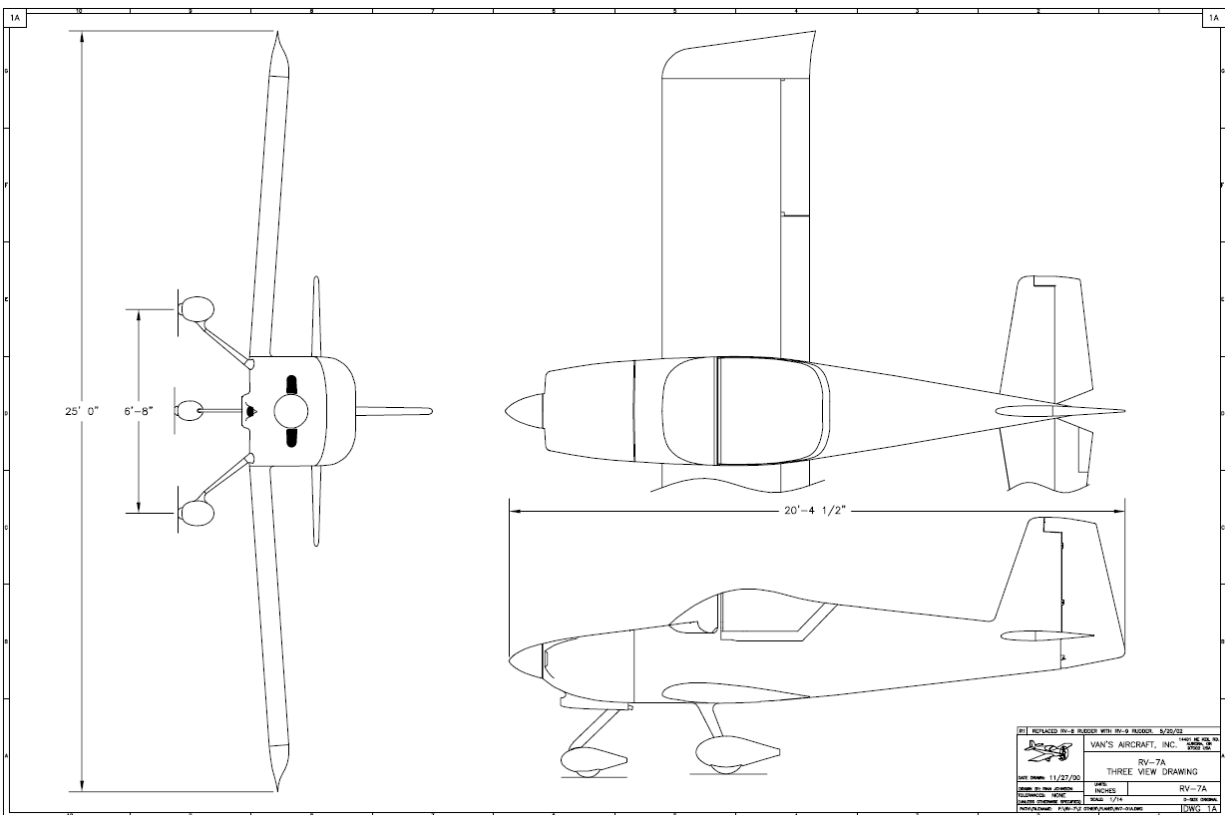


Figure 1. Van's Aircraft RV-7A 3-view drawing (provided by Van's).

The pilot of the accident airplane was the owner/builder and the airplane was completed in 2019. The accident airplane was powered by a Lycoming YIO-360-M1B

¹ Mean Aerodynamic Chord - Wing chord length is defined as the straight-line distance between the leading edge and trailing edge of an airfoil. The average chord length along the wingspan is the mean aerodynamic chord. For a straight, rectangular wing airplane such as the RV-7A the wing chord and MAC are the same. CG is referenced to the percent distance along the MAC or aft of the leading edge.

fuel injected engine driving a Hartzell two-blade, constant speed propeller. The owner had published a pilot operating handbook (POH) specific for the accident airplane that was recovered in the wreckage and contained performance information, limitations, checklists, and weight and balance information. The POH listed the tail height as 7 feet, 10 inches, the maximum weight in normal category was 1,800 pounds, and the empty weight was 1,134 pounds in the performance specifications section. The airspeed limitations section of the POH contained the following table.

Table 1. POH Airspeed Limitations N787NV

	SPEED	IAS	REMARKS
V_{NE}	Never Exceed Speed	200 kts	Do not exceed this speed in any operations.
V_{NO}	Maximum Structural Cruising Speed	156 kts	Exceed this speed only in smooth air.
V_A	Maneuvering Speed	123 kts	Do not make full control movements above this speed. Full elevator deflection will result in a 6g load at this speed.
V_{FE}	Maximum Flap Extended Speed	95 - 20deg 87 - Full	Do not exceed this speed with flaps down
V_y	Best Rate of Climb	96 kts	
V_x	Best Angle of Climb	78 kts	
V_s	Stall Speed Clean	54 kts	
V_{SO}	Stall Speed Landing Configuration	52 kts	

Per the Van's RV-7/7A Construction Manual, Section 15, the maximum structural cruising speed should be 167 kts. The speed stated in the table is consistent with the recommended maximum structural cruising speed for the RV-9/9A airplane.

A section of the POH titled Aerobatic Information had a weight limitation of 1,600 pounds and the following recommended entry speeds for the listed maneuvers: Loops, Horizontal Eights 122-165 kts, Immelmann Turns 130-165 kts, Aileron Rolls, Barrel Rolls 104-165 kts, Snap Rolls 69-95 kts, Vertical Rolls 156-165 kts, Split-S 87-96 kts. These were consistent with the information published by Van's.

The weight and balance section of the POH had three maximum weights; aerobatic category 1,600 pounds, utility category 1,700 pounds, and normal category 1,900 pounds². The CG limitations were stated to be 78.7 inches to 86.82 inches aft of

² Van's recommends a maximum aerobatic weight of 1,600 pounds and a maximum gross weight of 1,800 pounds in Section 14 of the RV-7/7A Construction Manual. There is no published recommended weight for normal category.

the datum with the datum located 70 inches forward of the wing leading edge (15%-29% MAC). The empty weight in this section was listed as 1,160 pounds and appeared to be from an actual weighing of the airplane with an empty CG location at 80.48 inches aft of the datum. Various example calculations of the weight and balance were contained in the section with different combinations of loading scenarios.

1.1 RV-7/7A Horizontal Stabilizer and Elevators

The mostly aluminum full span horizontal stabilizer is of conventional construction with a front spar, rear spar, and three ribs covered by a one-piece skin that wraps around the leading edge. The center portion of the built-up c-channel front spar is parallel with the lateral axis and the left and right sides are swept back from the inboard ribs to the outboard ends. The built-up c-channel rear spar is parallel with the lateral axis along its entire length. The outboard tip rib on both sides is one-piece with a composite tip cap installed on the outboard side forward of the front spar. The center ribs on both sides consist of a nose rib attached to the forward side of the front spar and a main rib that spans the distance between the front and rear spars, all parallel to the longitudinal axis. The inboard ribs on both sides consist of a nose rib attached to the forward side of the front spar and a main rib that spans the distance between the front and rear spars, all angled to match the shape of the aft fuselage. An elevator center hinge bearing is installed on the aft side of the rear spar at the centerline. Inboard and outboard hinge brackets are installed on the aft side of the rear spar on both the left and right sides. The horizontal stabilizer front and rear spars are attached to bulkheads in the aft fuselage.

The mostly aluminum left and right elevators are of conventional construction with a main spar and two end ribs covered by a one-piece stiffened skin with a formed trailing edge. Stiffeners are installed on both the upper and lower skins. The inboard root rib on each elevator is angled to allow for rudder movement and the trailing edge is swept forward along its length. The outboard root rib on each elevator extends forward of the main spar for installation of the elevator counterweights with a composite tip cap installed on the outboard side. An elevator control horn is installed on the inboard end of each elevator main spar. Inboard and outboard elevator hinge rod end bearings are installed on the forward side of the main spar on both sides. The left elevator has a trim spar installed between the inboard root rib and the center elevator rib that attaches to the elevator trim tab. A manual or electric trim mechanism is installed between the left elevator skins at the inboard, forward corner for actuation of the trim tab.

1.2 RV-7/7A Vertical Stabilizer and Rudder

The mostly aluminum vertical stabilizer is of conventional construction with a front spar, rear spar, and three ribs covered by a one-piece skin that wraps around the leading edge. The upper tip rib spans from the leading edge to the rear spar with

a composite tip cap installed on the upper side forward of the front spar. The center rib is attached between the front and rear spars with no nose rib forward of the front spar. The lower root rib consists of a nose rib installed on the forward side of the front spar and a center rib installed between the front and rear spars. The vertical stabilizer rear spar extends down below the lower root rib to attach to the fuselage bulkhead and the lower end of the rudder. The vertical stabilizer front and rear spars are attached to bulkheads in the aft fuselage. Three hinge brackets are attached to the aft side of the rear spar for the rudder.

The mostly aluminum rudder is of conventional construction with a main spar and two end ribs covered by left and right stiffened skins. Eight stiffeners are installed on the left and right rudder skins. The rudder skins are riveted together with an aluminum strip to form the trailing edge. Instructions for building the rudder included the use of sealant (or double-sided tape) between the skins and trailing edge strip to aid in construction. The upper tip rib extends forward of the main spar for installation of the rudder counterweight with a composite tip cap installed on the upper side. The rudder bottom rib extends from the main spar to the trailing edge with a composite tip cap installed on the lower side. Three rudder hinge rod end bearings are installed on the forward side of the front spar and the control horn is installed at the lower end.

2.0 Wreckage Examination

The wreckage examination focused on the empennage of the accident airplane and the items that separated prior to ground impact. The left wingtip, left horizontal stabilizer and attached elevator, left elevator counterweight, vertical stabilizer and an attached portion of rudder, rudder counterweight, a piece of rudder skin, the canopy frame, and plexiglass fragments separated during the event and were recovered away from the ground impact point and main wreckage. The lower 2 ft of the rudder remained attached to the empennage by the control cables and was recovered with the aft fuselage at the main wreckage site.

The left wingtip separated prior to ground impact and was recovered in four pieces. All the wingtip attachment screws remained installed in the nutplates and portions of wing skin were captured beneath some of the screw heads. The left wingtip light and lens were intact in the leading edge of one of the fragments. The right wingtip separated during ground impact but only two identifiable pieces from the upper and lower aft sections were recovered. Some of the attachment screws remained installed in the nutplates and portions of wing skin were captured beneath some of the screw heads.

The right horizontal stabilizer and elevator remained partially attached to the empennage and were deformed and curled downward about 45° along the length (Figure 2). The horizontal stabilizer front spar was fractured at the right outboard end of the center reinforcement angles. The right horizontal stabilizer remained attached to the empennage by the rear spar. The right elevator remained attached by both of its hinges

and the center bellcrank. There was impact damage to the outboard leading edge of the right horizontal stabilizer, and the right elevator counterweight was separated and recovered at main wreckage site.



Figure 2. Right horizontal stabilizer and elevator (NTSB photo).

The left horizontal stabilizer and attached elevator separated prior to ground impact (Figure 3). The inboard 20 inches of the left horizontal stabilizer was deformed upwards. The left elevator remained attached at both hinges. The elevator trim tab remained attached. The trim tab control arm remained attached to the tab, but the arm was bent and had broken away from the linear actuator at the forward rod end. A small portion of the left elevator lower skin, about 6 inches by 8 inches, where the trim motor attached was separated. The trim motor assembly was separated from its mounting point with portions of the plastic mounting tabs still attached. The left elevator inboard root rib was separated with a 5-inch section of the elevator torque tube attached. The left elevator tip and counterweight assembly separated as a complete unit.



Figure 3. Left horizontal stabilizer and elevator (NTSB photo).

The horizontal stabilizer front spar center section, about 17 inches long, remained attached to the shelf and fuselage bulkhead by four bolts through the lower reinforcement angle and was rotated aft about the lower spar cap (Figure 4). There was slight forward deformation to the left side of the upper and lower front spar reinforcement angles and pronounced aft and downward deformation to the right side of the upper and lower front spar reinforcement angles. The left horizontal stabilizer inboard main rib remained partially attached to the front spar with a piece of upper skin attached. The horizontal stabilizer c-channel front spar was fractured on both the left and right sides at the ends of the reinforcement angles. The vertical stabilizer forward attach point remained attached to the horizontal stabilizer front spar center section. The vertical stabilizer c-channel forward spar was fractured at the upper end of the attach fitting and the spar web was bent aft about 90°. Van's Aircraft Service Bulletin SB 14-01-31 (horizontal stabilizer forward spar doubler) had been complied with.



Figure 4. Horizontal and vertical stabilizer attach points, looking down (NTSB photo).

The four horizontal stabilizer rear spar attach bolts were all intact and installed through the vertical fuselage flanges. Both vertical fuselage flanges were deformed aft. The upper and lower rear spar reinforcement bars were still connected to the right vertical fuselage flange and were fractured about 2.5 inches left of centerline through the left attach point holes. The upper reinforcement bar had no obvious deformation on either side of the fracture point. The lower reinforcement bar was buckled and deformed on both sides of the fracture consistent with left horizontal stabilizer separation in a downward and leading edge down direction. The left elevator torque tube was fractured from the elevator horn and the right elevator torque tube remained attached. The rod end remained connected to the lower end of the elevator horn and was free to move. The rod end was fractured in the threaded area. The vertical stabilizer rear spar attach points were intact with the left and right attach bolts installed. The vertical stabilizer rear spar and doubler were fractured above the attach points and the remaining portions were bent aft above the attach points. The lower rudder hinge rod end remained attached to the brackets and was free to move. The rod end was fractured in the threaded area and exhibited downward deformation. The right rudder stop was deformed upwards, and the left rudder stop was intact. There was no evidence of repeated impact on the rudder stops.

The vertical stabilizer separated mostly intact prior to ground impact (Figure 5). The front and rear spars were fractured at the lower end of the stabilizer. A portion of

the rudder between the center and upper hinges remained attached. The portion included the leading edge and the left skin with four stiffeners attached. All the stiffeners exhibited buckling damage. The complimentary right rudder skin section, including three stiffeners, was separated. The entire rudder trailing edge was splayed open, and all the trailing edge rivets were pulled through the skin. The rudder trailing edge strip was separated and not recovered. There was no evidence of adhesive or sealant on the rudder skins at the trailing edge. The rudder tip and counterweight assembly separated prior to ground impact. The left rudder skin below the counterweight included the upper stiffener and the right rudder skin below the counterweight included the upper two stiffeners. There was a saw-tooth fracture of the right rudder skin below the counterweight. The lower portion of the rudder remained connected to the empennage by the rudder cables but was separated for the exam. The lower rudder from the center hinge to the lower end was mostly intact but damaged. The trailing edge was splayed open, and the bottom tip cap was installed.



Figure 5. Vertical stabilizer and rudder (NTSB photo).

There was no evidence of corrosion on the structure examined. All the fracture surfaces examined had a dull, grainy appearance consistent with overstress separation.

3.0 Flight Data

A Dynon SkyView D1000 panel-mounted display was recovered from the wreckage and sent to the NTSB Vehicle Recorders Division. See the Cockpit Displays Specialist's Factual Report in the public docket for the details of the data recovered.

Examination of the data by the group and IIC showed the airplane was in cruise flight to the southwest at a GPS altitude about 5,600 feet in the minutes preceding the accident. About 3 minutes prior to the last recorded data point, the data showed the airplane was wings level at a GPS altitude about 5,575 ft and an airspeed about 138 KIAS³ (150 KTAS⁴) when a left roll maneuver began. The airplane rolled more than 360° in about 10 seconds. During the maneuver a maximum nose down pitch about 37.5°, a maximum airspeed about 175 KIAS (188 KTAS), a maximum vertical acceleration about 2.9 g, and a maximum rate of descent about 7,875 fpm were recorded and the airplane lost almost 1,000 ft of altitude.

During the next 2.5 minutes the airplane was mostly wings level while ascending, slowing, and returning to its initial course. About 11.5 seconds before the last recorded data point, the airplane was wings level at a GPS altitude about 5,609 ft, an airspeed about 138 KIAS (150 KTAS), a magnetic heading about 142°, a slight nose up pitch about 1.8°, and a vertical ascent rate about 215 ft/min when a right roll maneuver began. During the maneuver the airplane rolled right to a maximum recorded angle about 166° and the flight path angle decreased continuously to about 62° nose down. The descent rate increased to 9,587 fpm in 7 seconds before being recorded at 9,999 fpm for the final 4.5 seconds. The last recorded data point showed the airplane at a GPS altitude about 3,199 ft, an airspeed about 248 KIAS (262 KTAS), a magnetic heading about 307°, a nose down pitch attitude about 61.7°, a right roll about 133.1°, and a vertical acceleration about 4.1 g. The data showed that the throttle was not reduced during either maneuver.

4.0 Weight and Balance

The group used the information from the pilot's published POH that was recovered in the wreckage and the recorded flight data to estimate the accident airplane's weight and balance during the accident flight. Prior to the first maneuver the Dynon recorded a fuel remaining level of 31.9 gallons. Using a fuel density of 6 lb/gal and a pilot weight of 292 lb from his most recent medical, the following weight and balance was calculated.

³ Knots indicated airspeed

⁴ Knots true airspeed

	<u>WEIGHT</u>	<u>ARM</u>	<u>MOMENT</u>
AIRCRAFT	1160	80.48	93356.8
FUEL	191.4	80	15312
PASSENGER	0	97.48	0
PILOT	292	97.48	28464.16
BAGGAGE	20	126.78	2535.6
GROSS WEIGHT	1663.4		
CG LOCATION	83.97		24.08 %

Prior to the second maneuver, the Dynon recorded a fuel remaining level of 31.6 gallons. Using the same fuel density and pilot weight, the following weight and balance was calculated.

	<u>WEIGHT</u>	<u>ARM</u>	<u>MOMENT</u>
AIRCRAFT	1160	80.48	93356.8
FUEL	189.6	80	15168
PASSENGER	0	97.48	0
PILOT	292	97.48	28464.16
BAGGAGE	20	126.78	2535.6
GROSS WEIGHT	1661.6		
CG LOCATION	83.97		24.09 %

5.0 Surveillance Video

A surveillance video was obtained from a gas station located across the road from the airplane main impact location. The original video could not be retrieved from the camera system, but a recording of the playback at slow speed was obtained. A surveillance video was also obtained from a hangar adjacent to the main impact location. The IIC produced image sequence analyses of the airplane's decent to impact superimposing several images from each video onto one frame that detailed the flight path and separation of components. Both can be found in the public docket. Examination of the gas station video and sequence analysis by the group and IIC revealed that the recording likely started after the end of the recorded data when the airplane was descending towards the ground. An attempt was made to correlate the slow-motion video with actual time. The initial frames of the video appear to show the airplane intact. About 0.4 s after the airplane appears, a dark colored piece departs the airplane and falls slowly to the ground. About 0.7 s after the airplane appears, a large white puff appears coincident with the airplane. The puff dissipates over time and several smaller light-colored pieces of debris fall to the ground. About 0.8 s after the airplane appears two dark colored pieces depart the airplane and fall slowly to the ground and the airplane descent angle noticeably steepens. Several smaller pieces of debris can be seen falling to the ground throughout the recording.

The airplane impacts the ground about 1.4 s after it first appears. In the hangar video and sequence analysis, the airplane fuselage and wings appear mostly intact immediately before impact. The ailerons and flaps appear to be attached and the left wingtip appears to be separated. The right horizontal stabilizer appears to be attached but the left horizontal stabilizer and elevator and vertical stabilizer and rudder are not evident.

6.0 Tests and Research

The group examined several other in-flight breakup events that occurred with similar Van's airplanes to include the RV-4, RV-7/7A, and RV-9/9A. Each of these events had damage characteristics similar to the accident. The events can be grouped into two separate types, maneuvering events or weather encounters with one additional event not associated with either of these. The RV-9/9A airplane is not designed or intended for aerobatics. The maximum permissible airspeed under any condition, V_{NE} , should be marked on the airspeed indicator with a red line and is defined by Van's for each model as follows:

RV-4	182 kts	210 mph
RV-7/7A	200 kts	230 mph
RV-9/9A	182 kts	210 mph

6.1 RV-4 and RV-9/9A Design Differences

There are some differences in the designs of the horizontal stabilizers, elevators, vertical stabilizers, and rudders between the RV-7/7A and the RV-4 and RV-9/9A airplanes as outlined below.

The mostly aluminum RV-4 horizontal stabilizer is very similar to the RV-7 horizontal stabilizer with a swept leading edge, 3 ribs on each side, a center elevator hinge, and 2 outboard elevator hinges on each side. The RV-9 horizontal stabilizer is of mostly aluminum conventional construction but is rectangular with straight leading and trailing edges that are parallel to the lateral axis. The inboard rib is angled to match the fuselage and there are 4 interspar ribs on each side. Nose ribs extend forward of the front spar at the outboard and middle rib locations. An elevator hinge is installed on the rear spar at the center location and there are two outboard elevator hinges on each side.

The mostly aluminum RV-4 elevators are very similar to the RV-7 elevators with a swept forward trailing edge, angled inboard ribs for rudder movement, and one-piece stiffened skins with a formed trailing edge. The outboard ribs on the RV-4 elevators extend forward to the leading edge incorporating the counterweights unlike the partial span end ribs on the RV-7. The RV-9 elevators are of mostly aluminum conventional construction with a straight trailing edge and a single skin rolled at the leading edge around the spar with stiffeners installed on the upper and lower surfaces. The trailing edge is fastened together with an aluminum strip. The

outboard ribs on the RV-9 elevators extend forward to about $\frac{3}{4}$ span with the counterweights incorporated.

The mostly aluminum RV-4 vertical stabilizer is very similar to the RV-7 vertical stabilizer except it is about 5 inches shorter and the upper composite tip cap extends from the rear spar to the leading edge. The RV-9 vertical stabilizer is the same as the RV-7.

The mostly aluminum RV-4 rudder is of conventional constructions with a main spar and two end ribs covered by a one-piece stiffened skin with a formed trailing edge. There are 7 stiffeners installed on each side of the rudder skin. There is no counterweight on the RV-4 rudder. The RV-9 rudder is the same as the RV-7 rudder.

6.2 Maneuvering Events

The following events all involved some type of maneuvering prior to the inflight breakup. In most cases the data shows some type of aerobatic maneuver that precedes the loss of control, a likely increase in airspeed, and subsequent inflight breakup.

6.2.1 RV-4, VH-ZGH

On February 23, 2007, an experimental amateur built Vans RV-4 airplane, VH-ZGH, experienced an inflight breakup while descending in a spiral dive after performing aerobatics near Clyde North, Victoria, Australia. The Australian Transport Safety Bureau (ATSB), investigated the accident (200701033) and published the [final report](#). The investigation concluded that the airplane was overweight and outside the CG limits for the flight and the pilot likely lost control during an aerobatic maneuver resulting in an unrecoverable spin. The airplane structure failed as a result of exceeding design limits. The left and right sides of the horizontal stabilizer, vertical stabilizer, rudder, and elevator counterweights separated from the airplane during the accident sequence and were recovered up to 380 feet from the main wreckage (Figure 6). The main wreckage was partially consumed by a post-crash fire. The vertical stabilizer was mostly intact with the upper half of the rudder attached and the lower half of the rudder separated. The rudder had a formed trailing edge versus a fastened one. The left and right horizontal stabilizers separated mostly intact leaving the center section of the front spar and most of the rear spar attached to the fuselage. Most of the left and right elevators remained attached to the stabilizer rear spar that remained attached to the fuselage. The rear spar and elevators were deformed down and aft significantly. The left and right elevator counterweights were separated and recovered adjacent to the burned main wreckage.



Figure 6. RV-4, VH-ZGH, empennage components layout (ATSB photo).

The cockpit area and instrument panel were mostly consumed by fire. There was no other data available to determine the airplane's speed during the descent, but witnesses reported a rapid increase in speed during the dive.

6.2.2 RV-7A, C-GNDY

On January 23, 2010, an experimental amateur built Vans RV-7A airplane, C-GNDY, experienced an inflight breakup while flying in formation with another airplane and filming aerobatic maneuvers near Wolfe Lake, Ontario, Canada. The Transportation Safety Board of Canada (TSB) investigated the accident (A10O0018) and published the [final report](#). The investigation concluded that the airplane speed reached 234 KIAS during the maneuvering sequence and encountered either flutter or overstress of some rudder components causing the vertical stabilizer and parts of the rudder to separate from the airplane. The vertical stabilizer and upper half of the rudder separated during the accident and were recovered about 0.6 nm from the main wreckage. The vertical stabilizer was mostly intact with the left half of the upper rudder installed (Figure 7). Two pieces of the upper right rudder skin and the trailing edge strip were recovered in the debris field. The lower half of the rudder remained attached to the airplane and the trailing edge was splayed open. There was no

evidence of sealant on the rudder trailing edge skins. The rudder counterweight was not recovered.



Figure 7. RV-7, G-GNDY, separated vertical stabilizer and rudder (TSB photo).

The airplane was equipped with an Electronic Flight Instrument System (EFIS) that recorded flight data at 5 second intervals (5 Hz). During the maneuvers the EFIS recorded a maximum vertical acceleration of 3.5 g, a roll of 115°, a pitch up of 19°, a pitch down of 45°, a maximum rate of descent about 12,000 feet per minute, and an airspeed of 234 KIAS. The video camera installed recorded the flight and showed that “during a pull-out from a rapid descent, there was a sudden onset of an airframe vibration (shuddering around the longitudinal axis), which was followed by a yawing motion, a roll and ground impact.” The investigation concluded that the airplane gross weight was likely between 1,636 pounds and 1,775 pounds.

6.2.3 RV-7A, N174BK

On September 20, 2013, an experimental amateur built Vans RV-7A airplane, N174BK, was destroyed during an inflight breakup and impact with terrain after a rapid loss of altitude and increase in airspeed near the Township of Hamilton, New Jersey. The NTSB investigated the accident (ERA13FA424) and determined that the

probable cause was the pilot's improper aerobatic maneuver that resulted in a loss of control, exceedance of the airplane's design limitations, and a subsequent inflight breakup of the airplane. The final report and public docket can be found [here](#) by entering the accident number. During the accident the left horizontal stabilizer, left elevator, vertical stabilizer, rudder, left wingtip, and canopy separated and were recovered up to 0.6 mile from the main wreckage. The vertical stabilizer separated mostly intact, and the rudder separated from the vertical stabilizer in three pieces (Figure 8). The rudder trailing edge remained fastened together. The left horizontal stabilizer separated mostly intact leaving the inboard half of the rear spar attached to the fuselage. The left elevator with the trim tab attached separated from the stabilizer and the outboard portion of the elevator with the balance weight separated. The structures study determined that the left horizontal stabilizer damage was consistent with down loading and the vertical stabilizer damage was consistent with loading to the left.



Figure 8. RV-7A, N174BK, separated empennage components (NTSB photo).

There was no recorded data onboard the accident airplane, so a performance study was conducted based on the available radar data. The study determined that the airplane was likely in cruise flight about 130 KIAS about 6,500 feet altitude when it entered a nearly inverted attitude, lost about 3,500 feet of altitude, accelerated to

about 220 KIAS, and reversed direction in 10 seconds. The study stated the “the large loss of altitude in a short time would produce increases in airspeed to 220 KIAS or greater.” A generalized rule of thumb is that true airspeed is about 2% higher than indicated airspeed for each 1,000 feet of altitude which would make the airspeed in this accident about 249 KTAS.

6.2.4 RV-7, N307AB

On December 10, 2015, an experimental amateur built Vans RV-7 airplane, N307AB, experienced an inflight breakup and impacted terrain near Hurricane, Utah. The NTSB investigated the accident (WPR16FA036) and determined that the probable cause was the pilot’s aerobatic maneuver leading to airspeeds above the never exceed speed of the airplane which resulted in rudder flutter and an in-flight breakup. The final report and public docket can be found [here](#) by entering the accident number. During the accident, the left and right horizontal stabilizers, left and right elevator counterweights, vertical stabilizer, half of the rudder, rudder counterweight, left wingtip, left outboard wing, and canopy separated and were recovered up to 1,400 feet from the main wreckage. The vertical stabilizer separated mostly intact with the upper half of rudder attached (Figure 9). The rudder counterweight was separated from the top of the rudder and the trailing edge of the rudder was splayed open. The lower half of the rudder remained attached to the fuselage with the trailing edge splayed open. There was evidence of sealant between the rudder skins and trailing edge strip. The left and right horizontal stabilizers separated mostly intact leaving the center section of the front spar and most of the rear spar attached to the fuselage. Deformation on the horizontal stabilizers was consistent with separation in a downward direction. Most of the left and right elevators remained attached to the stabilizer rear spar that remained attached to the fuselage. The elevators and rear spar were deformed down and aft significantly. The outboard half of the left wing separated from the airplane with signatures consistent with downward separation. The outboard half of the right wing remained attached but had downward deformation.



Figure 9. RV-7, N307AB, separated vertical stabilizer and partial rudder (NTSB photo).

There was no recorded data onboard the accident airplane and only limited radar data associated with the accident flight was recovered. The airplane's altitude and speed prior to and during the accident sequence could not be determined. Recovered photographs from an onboard GoPro camera indicated the airplane performed a roll to an inverted attitude and a subsequent pitch up maneuver to an opposite heading consistent with a split-s maneuver prior to the separation of the vertical stabilizer. The estimated weight and balance information showed that the airplane weight likely exceeded the maximum aerobatic weight of 1,600 pounds at the time of the accident.

6.2.5 RV-7, ZK-DVS

On January 1, 2018, an experimental amateur built Vans RV-7 airplane, ZK-DVS, experienced an inflight breakup after entering a highspeed descent from an unusual attitude near Te Kopuru, Northland, New Zealand. The Civil Aviation Authority of New Zealand investigated the accident (17-8080) and published the [final report](#). The investigation concluded that the pilot entered a high speed descent from an unusual attitude and was unable to recover the airplane which led to a rudder flutter event when the airplane exceeded the design limitation airspeed. During the accident sequence the vertical stabilizer, portions of the rudder, left wingtip, right wing, and left elevator counterweight separated from the airplane and were recovered up to 2,000 feet from the main wreckage. The vertical stabilizer was mostly

intact with the upper half of the rudder attached (Figure 10). Some lower rudder structure and the rudder counterweight were separated and found in the debris field while a portion of the lower rudder remained attached to the fuselage. The rudder trailing edge was splayed open and there was no evidence of sealant on the trailing edge skins or strip. The left and right sides of the horizontal stabilizer with attached elevators remained attached to the fuselage but were deformed down and aft. The right wing was reported to have failed downward in negative overload.



Figure 10. RV-7, ZK-DVS, separated vertical stabilizer and rudder (NZ CAA photo).

The accident airplane was equipped with an EFIS that recorded flight information at 5 Hz. The recorded data showed a maximum airspeed of 244 KIAS at an altitude of 2,310 ft during the descent. The data also showed that the throttle was not reduced during the maneuver. The investigation calculated that the airplane weighed about 1,800 pounds at the time of the accident. A generalized rule of thumb is that true airspeed is about 2% higher than indicated airspeed for each 1,000 feet of altitude which would make the airspeed in this accident about 254 KTAS.

6.3 Weather Encounter Events

The following events all involved some type of weather encounter prior to the inflight breakup. In most cases the data shows flight into instrument meteorological conditions that precedes the loss of control, likely increase in airspeed, and in-flight breakup.

6.3.1 RV-9, N807LK

On July 22, 2016, an experimental amateur built Vans RV-9A airplane, N807LK, experienced an inflight breakup and impacted terrain near Springfield, Ohio. The NTSB investigated the accident (CEN16LA281) and determined that the probable cause was the pilot's decision to fly into known thunderstorms, which resulted in an inflight breakup. The final report and public docket can be found [here](#) by entering the accident number. During the accident the vertical stabilizer, rudder, and left elevator counterweight separated and were recovered up to 0.63 nm from the main wreckage. The vertical stabilizer separated mostly intact, and the rudder fractured near the center hinge point and separated (Figure 11). The upper and center rudder hinges were pulled from the stabilizer rear spar. The rudder counterweight was separated from the top of the rudder and the trailing edge of the rudder remained fastened together. The left and right horizontal stabilizers and elevators remained attached to the fuselage with little deformation or damage.



Figure 11. RV-9, N807LK, separated vertical stabilizer and rudder (NTSB photo).

There was no recorded flight data recovered from the airplane. Recorded radar data showed the airplane descending at 6,450 fpm when radar contact was lost.

6.3.2 RV-9A, N4889R

On September 13, 2020, an experimental amateur built Vans RV-9A airplane, N4889R, experienced an inflight breakup and impacted the water near Steinhatchee, Florida. The NTSB investigated the accident (ERA20LA315) and determined that the probable cause was the failure of the air traffic controller to provide hazardous weather information to the pilot, resulting in the flight's encounter with strong updraft conditions, an inflight loss of airplane control, and an in-flight breakup. Contributing was the pilot's decision to initiate a flight into an area under the influence of a tropical storm, with forecast rain showers and thunderstorms, which increased the potential for an encounter with significant convective weather. The final report and public docket can be found [here](#) by entering the accident number. During the accident the vertical stabilizer, rudder, left and right sides of the horizontal stabilizer, right elevator, left and right elevator counterweights and both wings were separated and recovered up to 1,300 feet from the main wreckage. The vertical stabilizer separated mostly intact with the upper half of the rudder attached (Figure 12). The upper 16 inches of the rudder above the upper hinge including the counterweight was folded over to the left upon itself. The rudder was fractured below the center hinge and the lower portion was not recovered. The rudder trailing edge was partially splayed open, and it could not be determined if there was sealant applied. The separated left side of the horizontal stabilizer was mostly intact with most of the left elevator attached. The left elevator counterweight and more than half of the left elevator upper skin were separated and not recovered. The separated right side of the horizontal stabilizer was partially intact. The right elevator separated from the right horizontal stabilizer but remained attached to the stabilizer rear spar that was pulled from the stabilizer. The right elevator counterweight was separated and not recovered.



Figure 12. RV-9A, N4889R, separated vertical stabilizer and rudder (NTSB photo).

There was no recorded flight data recovered from the airplane. Recorded ADS-B data showed the airplane at a reported altitude of 6,100 feet msl in a left, descending spiral when contact was lost.

6.3.3 RV-7A, VH-WXI

On April 23, 2021, an experimental amateur built Vans RV-7A airplane, VH-WXI, experienced an inflight breakup after the pilot became spatially disoriented after encountering adverse weather near Charters Towers, Queensland, Australia. The ATSB, investigated the accident (AO-2021-017) and published the [final report](#). The investigation concluded that the pilot became spatially disoriented and lost control of the airplane. "The aircraft's speed exceeded V_{NE} (never exceed speed or maximum airframe speed), leading to rudder flutter, airframe structural failures, and subsequent in-flight breakup." The left and right sides of the horizontal stabilizer, vertical stabilizer, rudder, and elevator counterweights separated from the airplane during the accident sequence and were recovered up to 4,900 feet from the main

wreckage. The vertical stabilizer was mostly intact with the upper half of the rudder attached (Figure 13). The lower half of the rudder was separated just below the center hinge point and recovered in the debris field. The rudder counterweight was separated and not recovered. The trailing edge of the rudder was splayed open and there was no evidence of sealant applied to the trailing edge skins. The rudder trailing edge strip was separated and not recovered. The left side of the horizontal stabilizer separated mostly intact with upward buckling. The right side of the horizontal stabilizer separated leaving the right side of the rear spar attached to the fuselage. Most of the left and right elevators remained attached to the fuselage and were deformed aft and down significantly. The left and right elevator counterweights were separated.



Figure 13. RV-7A, VH-WXI, separated vertical stabilizer and rudder (ATSB photo).

The airplane was equipped with a Dynon Skyview HDX that recorded flight data up until about 1 minute before the end of the flight. The ATSB combined the

Dynon data with recorded ADS-B data to estimate that the airplane's airspeed increased to V_{NE} about 6 seconds before the in-flight breakup. The last recorded data point had the airplane at a recorded altitude of about 6,000 ft, a left roll of 165°, pitched down at 41°, and was descending at more than 10,000 ft/min. The airspeed was 224 KIAS (249 KTAS), and the airplane was accelerating at 15 kt/s².

6.3.4 RV-9A, N192MH

On July 25, 2020, an experimental amateur built Vans RV-9A airplane, N192MH, experienced an in-flight breakup and impacted terrain near Tryon, Nebraska. The NTSB investigated the accident (WPR22FA266) and determined the probable cause was the non-instrument rated pilot's decision to continue flight towards deteriorating weather conditions and subsequent failure to remain in visual instrument meteorological conditions, which resulted in a loss of control, exceedance of the airspeed design limitations, and in-flight breakup of the airplane due to rudder flutter. The final report and public docket can be found [here](#) by entering the accident number. Radar and ATC information showed the pilot reported they were at 12,300 ft and "still in the soup". Radar information then showed the airplane was descending and the airspeed exceeded V_{NE} by about 70-80 kts depending on the actual wind conditions before the data ended. During the accident the vertical stabilizer, rudder, left and right sides of the horizontal stabilizer, right elevator, left and right elevator counterweights, the left outboard wing, and both wingtips separated and were recovered up to 1 mi from the main wreckage. The vertical stabilizer separated mostly intact with the rear spar pulled out and separated (Figure 14). The vertical stabilizer rear spar was twisted along its length, had diagonal buckling damage, and remained attached to the lower rudder section through the center hinge. The upper half of the rudder was separated with the upper hinge pulled from the stabilizer rear spar. The rudder counterweight was separated. A piece of the left center rudder skin was recovered, and a piece of the right center rudder skin was not recovered. The rudder trailing edge was splayed open and there was evidence of sealant applied. The left side of the horizontal stabilizer was mostly intact with most of the left elevator attached and they remained attached to the aft fuselage that had separated from the airplane. The right side of the horizontal stabilizer was separated and partially intact and had a portion of the right elevator between the center and outboard hinges attached. The inboard portion of the right elevator was recovered in the debris field. The outboard left wing, left aileron, and a portion of the left flap separated and had signatures consistent with downward separation. The right wing remained attached to the fuselage but had downward deformation. Both wingtips were separated and fractured into multiple pieces.



Figure 14. RV-9A, N192MH separated vertical stabilizer and rudder (NTSB photo).

The airplane was equipped with a Dynon D10 EFIS that was removed from the wreckage. The NTSB Recorders Lab confirmed that there was no data recorded on the unit. The NTSB vehicle performance division estimated the airspeeds based on the recorded ADS-B data and atmospheric conditions at the time of the accident. The maximum airspeed was about 230-235 KCAS⁵ (249-262 KTAS) depending on the actual wind conditions just before the last recorded data point.

6.3.5 RV-7, N977RV

On June 2, 2023, an experimental amateur built Vans RV-7 airplane, N977RV, experienced an inflight breakup and impacted terrain near Gibbon, Nebraska. The NTSB is investigating the accident (CEN23FA220). The preliminary report can be found [here](#) by entering the accident number. Preliminary ATC information revealed the pilot had requested a lower altitude due to encountering ice. After beginning the descent, the pilot was advised by ATC of “extreme precipitation” in the area and about 1 minute later ATC approved a lower altitude. No further communication was received from the pilot. During the accident the vertical stabilizer, rudder, and pieces of the horizontal stabilizer fairings separated before ground impact and were recovered up to 130 feet from the main wreckage. The vertical stabilizer separated mostly intact (Figure 15). The center rudder hinge was intact on the vertical stabilizer

⁵ Knots calibrated airspeed

with a section of the rudder spar attached. The upper half of the rudder was separated with the upper hinge pulled from the stabilizer spar. The rudder counterweight remained attached. A piece of the right center rudder skin was separated and recovered. The lower half of the rudder was separated and recovered. The rudder trailing edge was splayed open and there was evidence of sealant applied. The rudder trailing edge strip was separated and not recovered. The horizontal stabilizer and both elevators remained attached to the fuselage and had ground impact damage.



Figure 15. RV-7, N977RV, separated vertical stabilizer and rudder (NTSB photo).

The avionics were recovered from the wreckage and sent to the NTSB Recorders Lab for download. Data was recovered from the iFly EFB app on the iPad that was carried in the airplane to include GPS altitude and groundspeed information at the end of the flight. The NTSB vehicle performance division estimated the airspeeds based on the recorded ADS-B data and atmospheric conditions at the time

of the accident. The maximum airspeed was about 170 KCAS (204 KTAS) before most of the ADS-B data became unreliable. The ADS-B pressure altitude data was deemed reliable beyond this point and was used to calculate the airspeed based on the rate-of-descent. The computed maximum airspeed at the last reliable pressure altitude of 7,900 ft MSL was about 287 KTAS.

6.4 Other Event

One other event was examined that was not associated with maneuvering or a weather encounter.

6.4.1 RV-7, N731RV

On July 27, 2017, an experimental amateur built Vans RV-7 airplane, N731RV, experienced an inflight breakup and impacted terrain near Arlington, Arizona. The NTSB investigated the accident (WPR17FA134) and determined that the probable cause was the inflight overstress separation of the vertical stabilizer and rudder during flight which resulted in the pilot's inability to maintain airplane control. Contributing to the accident was an inflight collision with a bird. The final report and public docket can be found [here](#) by entering the accident number. During the accident the vertical stabilizer, rudder, and most of the canopy plexiglass were separated and recovered about 1 mi from the main wreckage. The vertical stabilizer separated mostly intact with a section of the rear spar pulled out and separated (Figure 16). The lower end of the separated section of vertical stabilizer rear spar had twisting deformation. The upper portion of the rudder with the counterweight was separated and included a section of the rudder spar with the upper hinge point. The hinge rod end bearing was intact, and the hinge brackets were pulled from the vertical stabilizer. The center portion of the rudder was separated and fractured into two pieces. A section of the right center rudder skin was not recovered. The lower half of the rudder below the center hinge was separated mostly intact. The center hinge rod end bearing remained attached to the rudder and the hinge brackets remained attached to the vertical stabilizer spar. The hinge bolt was fractured and not recovered. The rudder trailing edge was splayed open and there was evidence of sealant applied. The horizontal stabilizer and elevators remained attached to the fuselage and exhibited ground impact damage. The right wing remained attached to the fuselage, and the outboard portion had downward deformation.



Figure 16. RV-7, N731RV, separated vertical stabilizer and rudder (NTSB photo).

There was no recorded flight data recovered from the airplane and the radar information showed the airplane was in level flight to the northeast at 7,600 ft msl before the event.

6.5 Van's Aircraft Published Information

When purchasing a kit aircraft, Van's supplies the builder with the plans and a construction manual. The RV Aircraft Construction Manual includes Section 15 Final Inspection and Flight Test. The following table showing the airspeed indicator markings is included in Section 15 (Figure 17). Clarifying information was added at Revision 9 to Section 15 on December 5, 2023, specifying that the red line marking for V_{NE} is for both indicated and true airspeeds. Note that all speeds are given in statute miles per hour. To convert to kts the values shown should be divided by 1.151. The following statement was also clarified in Section 15 - Flutter Testing at Revision 9. "Flutter testing of factory prototypes has resulted in establishing a true and indicated NEVER EXCEED SPEED (V_{ne}) of 210 statute mph for the RV-3,4 and RV-6/6A, 230 statute mph for the RV-7/7A/8/8A, and 210 statute mph for the RV-9A. This speed was determined through flutter testing at a speed of 20mph above V_{ne} . (FAA certification criteria require flutter testing up to V_{ne} plus 10% or about 20mph)". Prior revisions of Section 15 specified that the red line marking for V_{NE} was for indicated airspeed.

SPEEDS IN STATUTE MILES PER HOUR	RV-4	RV-6/6A	RV-7/7A/8/8A	RV-9/9A	RV-10
Bottom of White Arc: (Approx. Indicated stall speed with full flaps)	54	55	58	49	60
Top end of White Arc: (Max. speed with full flaps)	100	100	100	90	100
Bottom of Green Arc: (Approx. indicated stall speed without flaps)	58	59	64	56	70
Top end of Green Arc: (Max. structural cruise speed)	180	180	193	180	180
Blue Line: (Maneuvering speed-Max. permissible speed at which full control can be applied. Speed at which full elevator control would impose loads exceeding limits)	134	134	142	118	144
Yellow arc: (caution range, to be flown only in calm or light turbulence conditions)	180-210	180-210	193-230	180-210	180-230
Red Line: VNE (IAS and TAS: Maximum permissible speed under any condition)	210	210	230	210	230

Note: The RV-9/9A is NOT designed or intended for aerobatics.

Figure 17. Van's Aircraft airspeed indicator markings (provided by Van's)

Additionally, the following excerpt from Section 15 contains published guidance for conducting aerobatics in RV airplanes (Figure 18). In addition, it is noted that the snap roll entry speed is relatively low and recommended to be 80-110 mph. The manual states that the airplane "resists easy snap roll entry" and "most RV pilots avoid snap rolls". The RV-7/7A has an aft CG limit for aerobatics at 84.5 inches aft of the datum published in Section 14 Weight and Balance.

AEROBATICS

Note: The RV-9/9A is NOT designed or intended for aerobatics.

Note: Aerobic maneuvers as defined by the FAR's include bank angles greater than 60 degrees relative to the horizon and nose-up/nose-down pitch angles of 30 degrees relative to the horizon. These maneuvers must be performed above a minimum altitude of 1500 feet AGL and all participants in the aircraft must wear a parachute.

RV airframes are stressed for aerobatics up to a gross weight of 1050 lb. for the RV-3, 1375 lb. for the RV-4/6/6A, and 1600 lb. for the RV-7/7A and the RV-8/8A with the "Dash One" wing (included in all RV-8/8A kits shipped since January, 2001.) Earlier RV-8/8As with the original wing have an aerobatic gross weight of 1550 lbs.

This means that they have design strengths of 6 positive and 3 negative Gs (plus a 50% safety factor) at up to this weight. The key word is WEIGHT. RV structures have a certain amount of strength and are capable of carrying a given load at given G load. If the weight increases, so does the stress. As the empty weight increases, the useful load decreases—less fuel and pilot/passenger load can be carried within the aerobatic weight limit. For this reason, a heavy 2-seat RV may become a single place aerobatic airplane because it cannot carry two people and remain under the aerobatic gross weight limit. We expect that the empty weights of many RV-4s and RV-6As will be over 1050 lbs. because of optional equipment installed. These will definitely be single place aerobatic airplanes. Some RVs have been built with such high empty weights that when flown by a pilot weighing much over 200 lb., are no longer structurally qualified to perform aerobatics at all. Check the specific aerobatic gross weight given in Section 14. Always remember, RVs are *not* indestructible. Like all other airplanes, they have been designed with finite limits which must be observed. As a homebuilt, any individual airplane may have different limits which in all probability will be lower than design limits.

For or those wishing to do aerobatics in their RVs, aerobatic testing should be done during the later portion of the flight test period. We suggest that aerobatics be approached cautiously, and only after becoming thoroughly familiar with control responses, handling qualities, and performance capabilities. The pilot should also have received formal aerobatic training in other aircraft. Most RVs are capable of easily performing basic aerobatic maneuvers. This capability is due to their relatively high power loading and to their aerodynamic cleanliness which produces the speed (energy) needed. But, because of this, excessive speed build-up can occur very quickly, and should be a primary concern when attempting and practicing aerobatics. As an example, one does not enter a split-S maneuver from anything near cruising speed (like you see fighters doing in the old movies) because there is no way to complete the maneuver without exceeding speed and/or G-Load limits. The safe entry speed for a Split-S is around 100-110 IAS. The point is that RV aerobatics are not the same as Pitts or Citabria aerobatics. Speed builds very fast when pointed downhill.

Elevator stick forces are relatively light, so it is not a good idea to turn the controls over to a passenger for the purpose of aerobatics. Nor is it a good idea to apply control forces similar to those you may have become accustomed to in some other aerobatic airplane, say, a Citabria or a Stearman. Over stressing could easily occur. This is why you should be thoroughly familiar with the flying and handling qualities of your RV before attempting aerobatics. Because of its light controls, the RV is a pilot-limited airplane. In other words, it is the pilot's responsibility to avoid over stressing the airplane.

Figure 18. Van's Aircraft published aerobatic information (provided by Van's).

Van's aircraft has published an aerobatic epistle [here](#) to provide information to RV pilots about performing aerobatics in their airplanes.

6.6 Van's Flutter Analysis

Van's contracted with an outside company to have a flutter analysis performed for the RV-8 airplane that was completed in October 1998. The company performed a ground vibration test (GVT) on an RV-8 airplane at the Van's factory in the zero fuel and full fuel configurations to establish the natural modes of vibration for the airplane. This information was used to perform a flutter analysis at a simulated altitude of 10,000 ft up to V_d of 256 mph or 220 kts. The results of the analysis showed the RV-8 airplane to be free from flutter above the design envelope with the control surface balance weights provided by Van's.

Since the RV-7 airplane is a derivative of the RV-8 with a wider cabin, the results of the RV-8 flutter analysis were used for the RV-7. The RV-7 flutter analysis was completed by the same company in April 2001. A GVT was performed on the RV-7 airplane with zero fuel to evaluate the changes in vibration modes. The GVT showed that the wing vibration modes differed enough to require a flutter analysis while the tail modes were essentially the same. The analysis concluded that the RV-7 wing was free of flutter to speeds well above the dive speed of the airplane. The tail flutter analysis results from the RV-8 were applicable to the RV-7.

A flutter analysis of the RV-9 airplane was conducted by the same company and completed in May 2001. A GVT was performed at the Van's factory in the zero fuel and full fuel configurations. Using these results, a flutter analysis was performed at a simulated altitude of 10,000 ft and an airspeed of 244 kts. The airspeed was chosen to be $1.2 V_d$ where V_d is at least 1.11 times V_{NE} in accordance with FAR 23.629. The analysis concluded the RV-9 airplane was free of flutter up to 244 KEAS⁶.

According to Van's, the rudder used on the RV-7 and RV-9 airplanes was sized to meet the spin recovery requirements in the Part 23 regulations. The GVTs conducted for the RV-7 and RV-9 airplanes show the first flutter mode that manifests itself with increasing airspeed is a fuselage side bending vibration mode that couples with a rudder flutter mode. The rudder damping for this mode is dependent on the density of the air flowing over the rudder and thus is dependent on the true airspeed of the airplane. The tests took into account changes in the rudder counterbalance mass. The tests showed the existing rudder counterbalance mass was sufficient to account for variations in paint and the addition of a taillight to the rudder. The GVTs and flutter analyses performed showed that the airplanes are free of flutter beyond the design never exceed speed. Van's also showed the airplanes to be free of flutter up to the design demonstrated dive speed for each of the models through flight

⁶ Knots equivalent airspeed

testing. Van's noted that the rudders analyzed and tested were built according to the design and did not incorporate any additions such as servo controlled trim tabs.

Also, according to Van's, the GVTs showed that at even higher airspeeds flutter modes involving wing symmetric bending, aileron rotation, and horizontal stabilizer bending and torsion manifest themselves. The tests took into account changes in the fuel load on the airplane. The analysis indicated that these modes may interact with each other to exacerbate the response. Based on flight testing, GVT results, and flutter analyses, Van's concluded that the airplanes meet the requirements in Part 23 regulations and are free from flutter as designed and built when operated within the prescribed flight envelope.

Van's has performed flutter flight testing of the factory prototypes of each model to establish the true and indicated never exceed speeds published. The testing was performed at speeds up to 20 mph (17 kts) above the established V_{NE} . The FAA certification requirements indicate the flutter testing should be performed up to V_{NE} plus 10%. The control stick rap testing performed at various speeds showed there was no divergent oscillations indicative of flutter and the controls returned to equilibrium.

6.7 Flight Instruments

While some RV airplanes are equipped with standard analog flight instruments, many others are equipped with digital electronic flight information systems (EFIS) that provide the pilot with all the necessary flight information. The New Zealand CAA recommended that the Experimental Aircraft Association (EAA) facilitate discussions with EFIS manufacturers to add appropriate audible warnings to EFIS in their report for the ZK-DVS accident summarized above.

6.7.1 Advanced Flight Systems (AFS)

AFS provides individual EFIS displays or entire panels for the experimental market. When utilized as a primary flight display (PFD), the units will provide speed information to the pilot. The V_{NE} for the airplane must be entered in the unit during set up. As the speed increases above V_{NE} , the speed tape changes to a red and white striped barber pole and an Alarm message box pops up at the bottom of the display for "AIRFRAME OVERSPEED" that continues alternating between red and white text. The AFS EFIS provides an audible "Overspeed" warning that repeats every 2 seconds. The warning cannot be turned off. The unit can be configured to use true airspeed (TAS), indicated airspeed (IAS), IAS & TAS, or MACH for the overspeed warning. The warning volume is configurable by the pilot using the master volume configuration. The audible alert was reportedly added as a result of the NZ recommendation.

6.7.2 Dynon Avionics

Dynon provides individual EFIS displays or entire panels for the experimental and certified markets and has a host of legacy products that may be installed in experimental aircraft. All Dynon SkyView EFIS will provide airspeed information to the pilot when utilized as a PFD and have the ability to be configured to provide airspeed aural warnings. The V_{NE} for the airplane must be entered in the unit during setup. The airspeed tape features colored ranges, including a red range above V_{NE} . The airspeed indication is displayed in red when the speed increases above V_{NE} . An audible "Overspeed" warning is generated by the unit that will repeat at 1 Hz until the condition is cleared. The aural alert can be disabled in the maintenance menu, and the warning volume can be configured in the maintenance menu using the master volume. The unit can automatically display V_{NE} as true airspeed if desired. Non-SkyView legacy systems do not have the capability for aural warnings.

6.7.3 Garmin

Garmin provides individual EFIS displays or complete integrated panels for the experimental market. The G3X Touch or G5 configured as a primary flight display provides airspeed information to the pilot through an airspeed indicator. True airspeed is displayed at the top of the speed tape when outside air temperature is available. The speed tape changes to a red and white barber pole when V_{NE} is exceeded if the units are configured properly. The units can be configured to provide aural alerting for airspeed if the airplane is at or beyond V_{NE} . The aural alert is a synthetic voice "airspeed, airspeed" that repeats approximately every 5 seconds and the box displaying airspeed turns red with white lettering. When enabled, the volume is tied to the system Master Alert Volume setting. V_{NE} can be configured as true or indicated airspeed in the units.

6.7.4 GRT Avionics

GRT Avionics provides individual EFIS displays for the experimental market. When utilized as a PFD, the units will provide speed information to the pilot. The V_{NE} for the airplane must be entered in the unit during set up. In flight, the speed tape will be red when at or above V_{NE} . Additionally, a warning light will illuminate on the panel and a warning message " V_{NE} Exceeded" will appear on the screen. A detailed description of the alarm can be selected using a soft key where the alarm can be acknowledged and inhibited. The unit will provide an aural alert to the pilot that has been in place since the system's inception. The audio alerting function will produce a chime followed by a computer generated "Speed" warning. The audio alert currently does not repeat while the overspeed condition exists. The alerting volume for the chime and the annunciation are independently selectable. The unit can automatically display V_{NE} as true airspeed if desired.

6.8 Flutter

Flutter is an aeroelastic phenomenon that can occur when an airplane's natural mode of structural vibration couples with the aerodynamic forces to produce a rapid periodic motion, oscillation, or vibration. Flutter can be somewhat stable if the natural damping of the structure prevents an increase in the forces and motions. Flutter can become dynamically unstable if the damping is not adequate or speed is increased, resulting in increasing self-excited destructive forces being applied to the structure. Flutter can range from an annoying buzz of a flight control or aerodynamic surface to a violent destructive failure of the structure in a very short period of time. Due to the high frequency of oscillation, even when flutter is on the verge of becoming catastrophic, it can still be very hard to detect. Aircraft speed, structural stiffness, and mass distribution are three inputs that govern flutter. An increase in airspeed, a reduction in structural stiffness, or a change in mass distribution can increase the susceptibility to flutter.

True airspeed (TAS) represents the actual speed of the airplane through the air or the velocity of the air relative to the aerodynamic surface. The speed information available to the pilot with conventional analog gages is indicated airspeed (IAS) which is based on the difference between static and dynamic pressure as measured by the pitot-static system. IAS is generally what is displayed on an EFIS but they can be configured to also display TAS. TAS and IAS are the same on a standard day at sea level. Since TAS is directly related to the density of the air, any change in altitude or variation from standard temperature will result in TAS and IAS being different. As altitude or temperature increase, the density decreases, and TAS will be higher than IAS. For airplanes, such as a Van's, that operate at much higher speeds and altitudes than a typical general aviation airplane, the difference between IAS and TAS can be significant.

6.9 Federal Aviation Regulations

The following regulations are applicable to aerobatic (acrobatic) flight.

§ Sec. 23.3 – Airplane categories.

(a) The normal category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for nonacrobatic operation. Nonacrobatic operation includes:

- (1) Any maneuver incident to normal flying;
- (2) Stalls (except whip stalls); and
- (3) Lazy eights, chandelles, and steep turns, in which the angle of bank is not more than 60 degrees.

(b) The utility category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for limited acrobatic operation. Airplanes certificated in the utility category may be used in any of the operations covered under paragraph (a) of this section and in limited acrobatic operations. Limited acrobatic operation includes:

- (1) Spins (if approved for the particular type of airplane); and
- (2) Lazy eights, chandelles, and steep turns, or similar maneuvers, in which the angle of bank is more than 60 degrees but not more than 90 degrees.

(c) The acrobatic category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for use without restrictions, other than those shown to be necessary as a result of required flight tests.

(d) The commuter category is limited to propeller-driven, multiengine airplanes that have a seating configuration, excluding pilot seats, of 19 or less, and a maximum certificated takeoff weight of 19,000 pounds or less. The commuter category operation is limited to any maneuver incident to normal flying, stalls (except whip stalls), and steep turns, in which the angle of bank is not more than 60 degrees.

(e) Except for commuter category, airplanes may be type certificated in more than one category if the requirements of each requested category are met.

§ 91.303 Aerobatic flight.

No person may operate an aircraft in aerobatic flight—

- (a) Over any congested area of a city, town, or settlement;
- (b) Over an open air assembly of persons;
- (c) Within the lateral boundaries of the surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport;
- (d) Within 4 nautical miles of the center line of any Federal airway;
- (e) Below an altitude of 1,500 feet above the surface; or
- (f) When flight visibility is less than 3 statute miles.

For the purposes of this section, aerobatic flight means an intentional maneuver involving an abrupt change in an aircraft's attitude, an abnormal attitude, or abnormal acceleration, not necessary for normal flight.

§ 91.307 Parachutes and parachuting.

(a) No pilot of a civil aircraft may allow a parachute that is available for emergency use to be carried in that aircraft unless it is an approved type and has been packed by a certificated and appropriately rated parachute rigger—

- (1) Within the preceding 180 days, if its canopy, shrouds, and harness are composed exclusively of nylon, rayon, or other similar synthetic fiber or materials that are substantially resistant to damage from mold, mildew, or other fungi and other rotting agents propagated in a moist environment; or
 - (2) Within the preceding 60 days, if any part of the parachute is composed of silk, pongee, or other natural fiber or materials not specified in paragraph (a)(1) of this section.
- (b) Except in an emergency, no pilot in command may allow, and no person may conduct, a parachute operation from an aircraft within the United States except in accordance with part 105 of this chapter.
- (c) Unless each occupant of the aircraft is wearing an approved parachute, no pilot of a civil aircraft carrying any person (other than a crewmember) may execute any intentional maneuver that exceeds—
- (1) A bank of 60 degrees relative to the horizon; or
 - (2) A nose-up or nose-down attitude of 30 degrees relative to the horizon.
- (d) Paragraph (c) of this section does not apply to—
- (1) Flight tests for pilot certification or rating; or
 - (2) Spins and other flight maneuvers required by the regulations for any certificate or rating when given by—
 - (i) A certificated flight instructor; or
 - (ii) An airline transport pilot instructing in accordance with § 61.67 of this chapter.
- (e) For the purposes of this section, *approved parachute* means—
- (1) A parachute manufactured under a type certificate or a technical standard order (C-23 series); or
 - (2) A personnel-carrying military parachute identified by an NAF, AAF, or AN drawing number, an AAF order number, or any other military designation or specification number.

Submitted by:

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