V-Tails for Models - William F. McCombs - Model Aviation - July 1996

So-called V-tails have been used on gull-scale airplanes such as the Beechcraft Bonanza and the Davis DA-2A, and modelers have used them occasionally on FF duration models and RC models. To the author's knowledge, however, there have been no design procedures published for the modeler's purpose. The purpose of this article is to provide the reader with a procedure for sizing V-tails for FF and RC.

A V-tail is shown in Fig. 1. It consists of two panels having a dihedral angle, A, and a total panel area, S. S is the area if both halves of the V-tail were laid flat. A narrow center section can he provided for easy mounting on the fuselage.

The problem is to determine the proper values for

a) The total V-tail area, S
b) The dihedral angle, A

Required Data:

One must first determine what would be the proper vertical tail area, S_V and horizontal tail area, S_H, if conventional tail surfaces, Fig. 2, were to be used. The V-tail should have the same "effective" vertical and horizontal tail areas as these do. This also, of course, applies to converting a conventional tail to a V-tail configuration.

The proper area for a horizontal tail is widely discussed in the model literature. It is that which gives a reasonable "tail volume coefficient" (which depends upon the type of model). For those interested, that is discussed in Ref (1) for Scale and non-Scale models.

The proper area for a vertical tail for FF models is that which is just large enough to prevent any hint of a Dutch roll, Fig. 3, or a "wandering" flight, but also small enough to avoid any spiral instability trouble, Fig. 4. With RC models a relatively larger vertical tail, about 50% larger, is needed for better flight control and maneuvering.

Obtaining a proper vertical tall size by formula and tests is discussed in Ref. (1) and also in Refs. (2) and (3).

Sizing the V-Tail: Knowing the proper conventional tail areas, S_V and S_H, one can proceed to design the V-tail as follows (the derivation of the formulas is discussed at the end of the article). The total area of the V-tail, S, should be

$$S = S_V + S_H \quad (1)$$

The dihedral (or cathedral) angle, A, of the V-tail should be

$$A = \arctan\sqrt{S_V/S_H} \quad (2)$$

The chord, or average chord, of the V-tail should be the same as that of a conventional horizontal tail if it were being used. These values of S and A will result in a V-tail having the same "effective" vertical and horizontal areas as the conventional tail would, and hence essentially the same stability characteristics. The effective vertical tail area of the V-tail is

$$S_{Veff} = S\sin^2 A \quad (3)$$

The effective horizontal tail area of a V-tail is

$$S_{Heff} = S\cos^2 A \quad (4)$$

Example Calculation: Suppose that a FF duration model has a conventional tail with S_H = 60 sq. in and S_V = 11 sq. in. Then for an equivalent V-tail

$$S = 11 + 60 = 71 \text{ sq. in.}$$

$$A = \arctan\sqrt{11/60} = \mathbf{23.2^0}$$

For this tail the "effective" vertical and horizontal tail areas are

$$\begin{aligned} S_{Veff} &= S\sin^2 A = 71 \sin^2 \mathbf{23.2^0} \\ &= 71(.155) \\ &= 11 \text{ sq. in.} \end{aligned}$$

$$\begin{aligned} S_{Heff} &= S\cos^2 A = 71\cos^2 \mathbf{23.2^0} \\ &= 71(.845) \\ &= 60 \text{ sq. in.} \end{aligned}$$

which are the required values (S_H and S_V). Note that the effective areas are not the projected areas, which would use the sine and cosine directly. If, as is sometimes erroneously done, the projected areas were used to size the V- tail, it would he too small (e.g., S = 61 and A = 10.4^0 for the above case). This also applies to a wing with dihedral; its effective area being not its projected area but rather its area times the cosine squared of the dihedral angle.

Flight Trimming: For FF models the V-tail is made as a separate unit and attached to the fuselage. The gliding speed (pitching trim) is adjusted as with a conventional stab, by shimming the leading or trailing edge as needed. The same is true for a FF duration model's gliding turn; the tail being tilted so that one tip is higher than the other.

For FF Scale models, tilted tails are not applicable, so the V-tail is canted, as seen in a plan view, so that one tip is slightly more forward than the other, as needed (or tabs can also he used: left tab down and right tab up for a right turn and vice-versa for a left turn). Powered flight trimming is done in the same manner as with conventional tails, using downthrust and sidethrust. See Ref. (1) for more about trimming.

For RC models hinged "elevons" are needed as for full-scale airplanes. Provision must he made to control these in such a manner that both pitching and turning trim can he "mixed" as needed for maneuvering. Since the elevons must provide both pitching and turning trim simultaneously, it is helpful to provide a wider elevon chord than with a conventional horizontal tail's elevator (about one-third wider). For any given trim (lift coefficient) the actuator load (and battery drain) will be greater for elevons than for a rudder or elevator by factors of 1/sinA and 1/cosA respectively.

Stability: The previous sizing procedure provides essentially the same stability characteristics as with a conventional tail. However, if any Dutch roll shows up, the effective vertical tail area is not large enough. More area can be added by increasing the dihedral angle slightly (which requires "surgery"), or more easily by cementing small sheet-balsa vertical fins to the ends of the panels (as shown in Fig. 5.) in the amount necessary (through flight tests) to eliminate the Dutch roll. (a) and (c) are preferable to (b) and (d).

If any spiral instability trouble shows up, the V-tail's effective vertical tail area is too large, so the dihedral angle must be reduced slightly, as found necessary to eliminate the trouble (also see Ref. 1). From a spiral stability consideration, cathedral as in (c) and (d) is preferable to dihedral for FF duration models.

V-tails on full-scale airplanes usually have a dihedral angle of about 40^0. This usually gives too much effective vertical tail area for FF Scale models of these subjects, causing spiral stability troubles since they have little or no wing dihedral (see Ref. 1). For better flying ability and more duration capability, their tail dihedral needs to be reduced to about 30 or less-even though this is a Scale deviation.

Sometimes a concern is expressed that the tail dihedral, particularly if large, causes an "interference" effect on the airflow over the tail, making the formulas inaccurate. Wind tunnel tests by the NACA many years ago showed that this is insignificant for dihedral angles up to at least 40^0, which is larger than any model or full-scale airplane really needs.

Actually, the formulas are accurate only when the vertical tail and the V-tail are equally effective in generating (lateral) lift. In most cases this is not true, since the aspect ratio (AR) of the V-tail is much larger than that of the vertical tail it is replacing. A larger AR means more lift-generating ability, so the effective area of the V-tail, SVeff per the formulas, will be too large - more than 100% too large in more extreme cases.

This too-large effective area is why, for FF models particularly, a V-tail sized per the formulas might cause spiral instability or related troubles. To avoid this, the value of S_V should be reduced before using it in the formulas, which will result in smaller values for S_{Veff}..

An approximate procedure for doing this is to multiply the value of S_V by the factor mV/mV_{-tail}, where m is the slope of the lift curve (lift generating ability), and then using this for S_V in the formulas.

The values of m can be obtained from Fig. 6 by entering with the values of AR, the figure showing how to calculate AR for the tails. For the V-tail it is calculated as $span^2/S$, but since its span and S are not yet determined, a fair approximation is to use the span and area (S_H) of the horizontal tail being replaced. An example illustrates the procedure.

For example, suppose that the vertical tail area is 11 sq. in. as in the previous example, that it is forward or aft of the horizontal tail, and has a height, b, of 3.8 in. Its AR is $3.8^2/11$ = 1.31. Entering Fig. 6 with this one obtains $m_V = .034$. For the horizontal tail, suppose that S_H is 60, as before, the span is 16 in. and its chord is 3.75 in. Its AR is then $16^2/60 = 4.27$ and per Fig. 6 $mV_{-tail} = .060$. The revised value of S_V is

$$S_V = 11(.034/.060) = 6.23$$

and this is used in the formulas to give

$$S = 6.23 + 60 = 66.23$$

$$A = \arctan \sqrt{6.23/60} = 17.9^0$$

and these values, smaller than before, would be used for the V-tail. If the actual vertical tail were located above or below the horizontal tail, its AR would be, per the figure, AR $1.55(3.8)^2/11 = 2.03$ and m_V would be .045. This would give

$$S_V = 11(.045)/.060 = 8.25$$
$$S==8.25 + 60 = 68.25$$

$$A = \arctan \sqrt{8.25/60} = 20.3^0$$

Since the span and S of the V-tail are now known (span = S/chord = 68.25/3.75 = 18.2 inches), the calculations using these values to get a better value of AR for the V-tail and, then, of S and A.

For RC and CL models the above refinement procedure is applicable but not normally needed, since any excessive SVeff is small and also not likely to be a problem, unlike for FF. Hence the formulas can be used directly for them.

As discussed under **Required Data** and as in the examples, to design a V-tail one must first know what reasonable conventional tail sizes are, including their AR values. For a "new" model these are not, of course, available-so they must be determined as suggested under Required Data.

For those who do not want to go through that effort, a rough approximation is as follows for FF duration models of currently typical designs:

Assume the horizontal tail to have an area of about 30% of the wing area and an AR of 4.5. Then for gas models assume the vertical tail to be 4% of the wing area with an AR of 1.3, and for rubber models 6% of the wing area and an AR of 1.6. With a relatively long fuselage, as on some types, a smaller horizontal tail of 20-25% of the wing area would be more realistic.

In the end, of course, a proper or satisfactory vertical tail size for any model is assured only by flying, per Ref. 1, 2, and 3 and for a new model may involve considerable "cut-and-try" efforts. For a V-tail such efforts are even more troublesome and tedious, but can be greatly reduced by the previous formulas and procedures.

Derivation of Formulas: The derivations of formulas (1) through (4) are not presented because of space requirements and their complexity. However, anyone wanting them can send a two-stamp SASE to the author at the address given in Ref. 1.

References

1. Making Scale Model Airplanes Fly, by W.F. McCombs, 1994 Revision (non-Scale also), Aircraft Data, Box 763576V, Dallas TX 75224; $14.95.
2. "A Practical Approach to Spiral Stability," 1994 National Free Flight Society *Symposium*, pp. 54-61. Corrected copy available as for Ref. (3) at above address.
3. "Vertical Tail Size for Models," *Model Aviation*, March-April 1992. Corrected reprints with comments available from above address for $2.95 and a two-stamp SASE.
4. *Airplane Performance, Stability and Control*, Perkins and Hage, John Wiley & Sons, 1949.

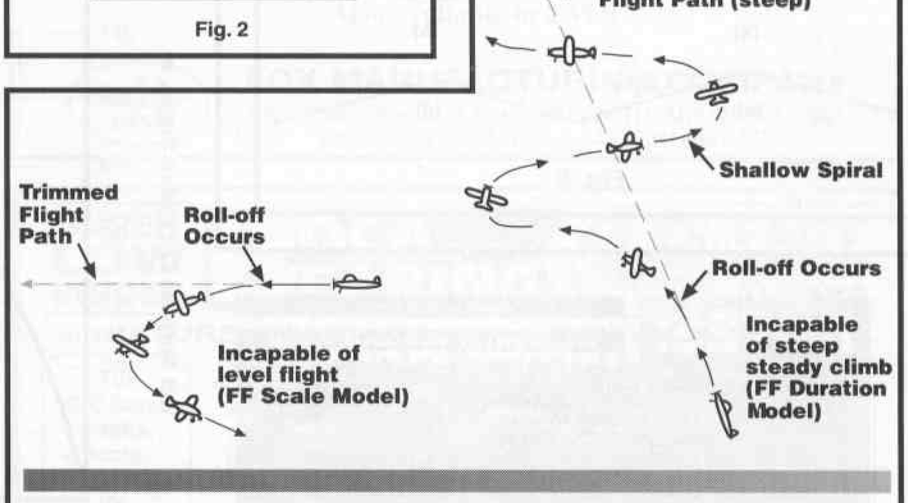
V-TAIL CONFIGURATION

Fig. 1

CONVENTIONAL TAIL SURFACES

Fig. 2

SPIRAL INSTABILITY



a) Severe Spiral Instability

b) Mild Spiral Instability

Fig. 4

DUTCH ROLL

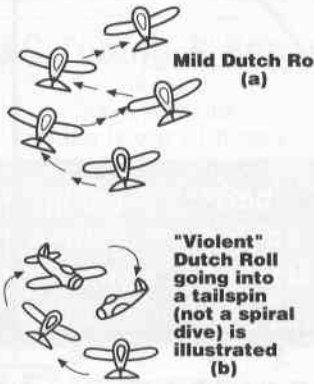


Fig. 3

ADDING FIN AREA

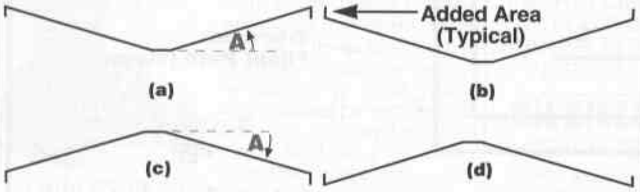


Fig. 5

TAIL SURFACE LIFT CURVE SLOPE VS. ASPECT RATIO

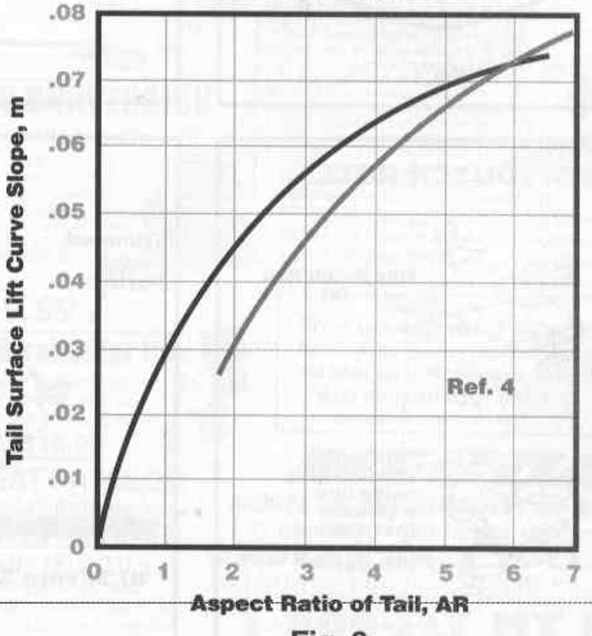


Fig. 6

NOTES:

■ Vertical Tail

▨ Horizontal Tail and V-tail

For vertical tail AR = Kb^2/S_V
where K = 1.55 if tail is above or below horizontal tail
K = 1.00 if tail is forward or aft of horizontal tail
b = height of vertical tail

For horizontal tail AR = b^2/S_H
where b = span of horizontal tail

For V-tail AR = b^2/s
where b is measured along both panels
(not horizontally between tips)
Also, AR = b/Av. chord