BIPLANE AND TRIPLANE WING LIFT AND EFFICIENCY

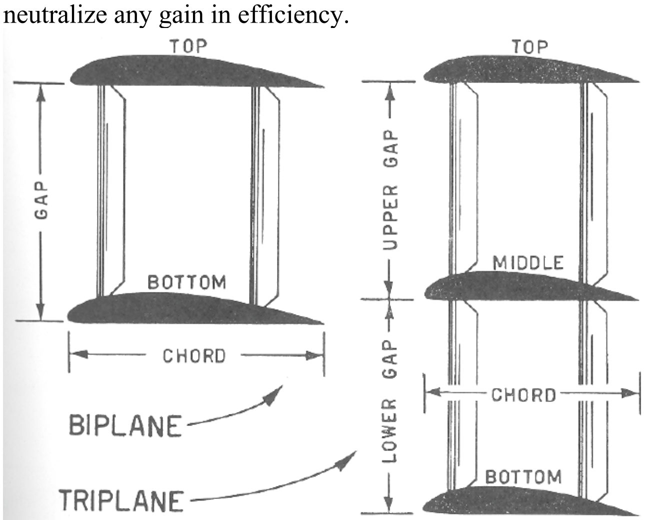
By George White

Foreword: I recently had the good fortune to have local member Carl Johns loan me a rare book entitled "Model Airplane Design and Theory of Flight," written in 1941 by none other than the famous Charles Hampson Grant (yes it's the guy whose life is celebrated each year with a worldwide launch of his Cloud Tramp). I found the information in it so fascinating and enlightening, I went on Amazon and found one. Interestingly enough, it was once owned by a Ltjg Hugh Robertson, Jr., while stationed at the Naval Hospital here in Pensacola in 1942. The book has come full circle. I'll be writing articles in future issues of this rag based upon information contained in the book — information which may not be well known among many of us balsa bashers. Let the reader understand that I'm going to be extracting Grant's exact words and illustrations, condensing them, and for ease of reading the constant use of quotation marks is omitted.

When considering the use of a biplane or triplane model, the question to be asked should be "what is the lift compared to an equivalent wing area of a monoplane?" and "What is the efficiency (lift/drag) of such a setup?" Grant discusses two factors influencing the answers to those questions, i.e. interplane gap and stagger.

Gap. Grant defines the gap as the vertical distance between two lines drawn parallel to the thrust line through the leading edges of the upper and lower wings as shown below. The gap between two airfoils affects both the efficiency and lift; and while it may be convenient to place them close, the closer they are the less total lift is produced and efficiency is lessened. If the wings are set so the gap equals three times the chord there is practically no loss of lift or efficiency.

However, it is usually inconvenient to combine wings with a gap greater than 1 1/2 times the chord. Customarily the gap equals the wing chord; for by making the gap wider, struts are lengthened and enough added resistance is produced to neutralize any gain in efficiency.

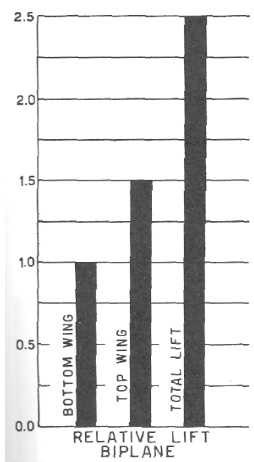


In spite of the previous statement, Grant suggests a gap equal 1-1/2 times the chord for models. He cautions to never use a gap less than one times the chord, nor more than three times, for there is no advantage in doing so.

BiPlanes. When you consider the lift and efficiency of a monoplane wing as "one", the table below shows the percent of lift and the relative efficiency of a biplane in comparison to that monoplane model at various angles of attack, from 4º to 10º. This assumes the chord remains constant.

Biplane Lift and Efficiency Table

Gap/chord	Comparative Lift in %				Comparative Lift/Drag in %			
	4º	6º	8º	10º	4º	6º	8º	10º
.075	74	75	76	77	75	78	81.5	85.5
1.0	81	82	83	83.5	79.2	81.5	84	87
1.25	86	86.5	87	87.3	82.5	84.5	86.2	88.5
1.5	88	88.5	89	89.2	85.5	87	88.5	90



Triplanes. The lift and efficiency of a triplane is even less than that of a biplane. Grant advises using a gap of not less than 3/4 nor no more than 1-1/2 times the chord. Of course the larger the gap, the greater the relative lift and efficiency. The following tables show the relative lift and efficiency of monoplane, biplane and triplane models at various angles of attack with a gap of 1-1/4 times the chord, again assuming the same chord.

Monoplane,Biplane,Triplane Lift Table

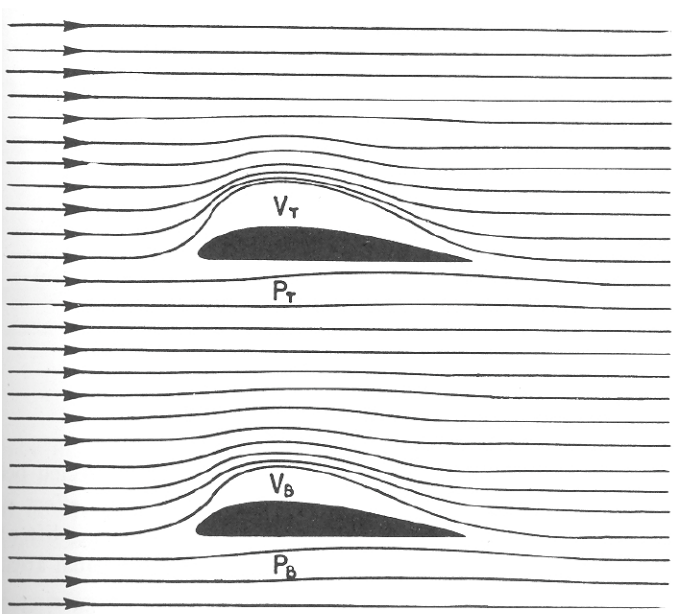
Comparative Lift in % Gap = 1-1/4 X Chord			
Incidence	Monoplane	Biplane	Triplane
0º	100	89.5	83.7
2º	100	84.5	87
4º	100	86	76.5
6º	100	86.5	77
8º	100	87	78
12º	100	88	82

Monoplane,Biplane,Triplane Efficiency Table

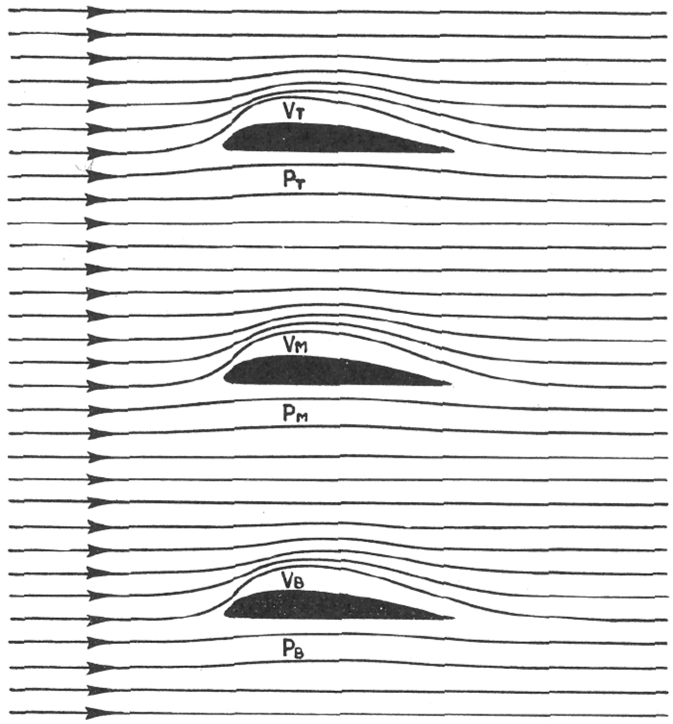
Comparative Efficiency (L/D) in % Gap = 1-1/4 X Chord			
Incidence	Monoplane	Biplane	Triplane
0º	100	74	70
2º	100	75	70.5
4º	100	82.5	76.5
6º	100	84.5	81
8º	100	85.5	83
12º	100	96	90

Grant concludes that for a biplane to equal the lift of a monoplane, the total area of both wings needs to be 25% greater than that of a monoplane. For a triplane to have the same lifting capability of a monoplane, the total area of the three wings needs to be 35% larger than the monoplane.

Why Efficiency is Lost. In the figure below notice that a vacuum is formed above the upper and lower wings, indicated by Vt and Vb, and also there is an increase in pressure directly under each each wing, Pt and Pb. When Vb and Pt are close to one another, remember that air tends to flow from high pressure to low, which in this case diminishes both Pt and Vb, and results in lift loss on both wings.



If the gap is small, this interaction results in a considerable loss of lift. In the case of the triplane airflow shown below, the middle wing is affected most because both pressure under and vacuum over that wing is reduced.



Stagger. Interference between wings is reduced by staggering. As seen below, "stagger" is the relative position of two or more wings in which the trailing edge of one is located forward of another. There are two forms of stagger — negative and positive. When the upper wing is ahead of the lower, the stagger is considered positive. Lift and efficiency increase materially with positive stagger. When wings are staggered 0.4 of the chord, both lift and efficiency increase 5%. Negative stagger of 0.4 reduces lift and in most cases efficiency in the same ratio. The degree of positive stagger shown below is that recommended for model planes.