EXPERIMENTAL VERIFICATION OF INDOOR MODEL FLIGHT ANALYSIS BY COMPUTER

walter erbach

INTRODUCTION

In an attempt to assist the indoor builder to improve the performance of his indoor model several theoretical solutions for the relationship between stabilizer size and wing area have been made. These solutions have been based on the static stability equation for man-carrying aircraft. This equation has been linearized by aerodynamicists using assumptionswhich are not valid for indoor models. For example, the wing is assumed to provide all of the lift. For full size aircraft this assumption is reasonable; centers of gravity must be kept well forward, in the vicinity of 25% of the wing chord, to avoid embarrassing instability. The stabilizer, as its nameimplies, is used strictly for stability. Furthermore, the center of gravity and the wing are considered to be on the line of thrust. Under these conditions the resulting stability equation plots as a simple straight line. Despite the inherent inaccuracies of this static equation for indoor model work, it has been used for such purposes. Introducing the necessary corrections for our usage results in an unmanageable situation.

There is a way out of this difficulty if we are willing to accept a brute force approach: The empirical solution by computer. The author developed such a solution a few years ago. A skeletonized indoor model flight moment equation was developed for it including as variables all items whose effects were of interest. The initial study concentrated upon those items which were considered to have the most influence: the center of gravity location (as a percentage of wing chord), longitudinal decalage (incidence), stabilizer size (as a percentage of wing area). A suitable computer program by which the model was, in effect, flown upon the computer was written. By making changes in any variable the effect upon the power required could be ascertained for that change. While hardly a sophisticated approach to the problem it was at least an approach and it gave understandable answers. A detailed discussion of the procedure was presented in a paper by the author in the 1970 Symposium. A number of graphs depicted the effect of changes in the important variables upon the power required for level flight. Portions of these "theory" graphs are repeated for comparison in this paper as the solid line curves of Figures 4, 5, 6, and 7.

Doubts immediately arose. A fixed center of pressure location had been assumed for the empirical study. This assumption had been based on a review of airfoil characteristics at high Reynolds numbers. The center of pressure does move fore and aft with changes in angle of attack but in the range normal to indoor models this fore and aft motion appeared slight enough that a fixed location at 25% of the wing chord had been used. Was such a choice acceptable for indoor models which operate at very low Reynolds numbers? Downwash was ignored or, more specifically, assumed to be constant. Since downwash places the stabilizer in a mass of air moving downwards at very low velocity, the overall effect is merely that of a slight increased angle of incidence. Is this increased angle a constant? As time became available, therefore, an experimental program to corroborate or disprove the computer results was undertaken. Because of the difficulty in obtaining level flight power values for an indoor model it was decided to use glide tests instead. Sinking speed is then a direct measure of the power required.

At first glance one would tend to question the comparison of glide tests with level flight results yet there would seem to be no valid reason precluding such comparison. Thrust in the glide is provided by the weight acting through the center of gravity while thrust in powered flight is provided by the propeller force, also acting through the center of gravity. The hope, therefore, existed that a series of glide tests, using a model similar to the computer model would either verify the type of computer results or demonstrate that the empirical study was faulty (and possibly why). The results of one very limited set of glide tests were presented in the 1970 paper. One of the author's competition models, already available, was used for these preliminary tests since its dimensions corresponded to those used in the computer work. This preliminary work, done merely to evaluate the feasibility of the test project, was so successful that the entire project was carried through to completion with this model.

TEST PROCEDURE

The actual test procedure was quite simple. The model was ballasted with a loop of clay equal in weight to propeller and motor. This loop was slung about the motor stick shifted fore and aft to change the center of gravity location. Appropriate markings were placed along the body to indicate ballast positions for the centers of gravity employed in the tests. The model with a fixed set of parameters was then glided repeatedly, hand launched, from a given altitude. The duration of each glide was recorded along with other data for the flight. At least three glides were made for each set of parameters. Normally the durations were close enough so that three glides sufficed. If not (as in the case of stalling flight), a sufficient number of glides was made to ensure consistency or meaningful results. Then one of the three major parameters under investigation was changed and the process repeated.

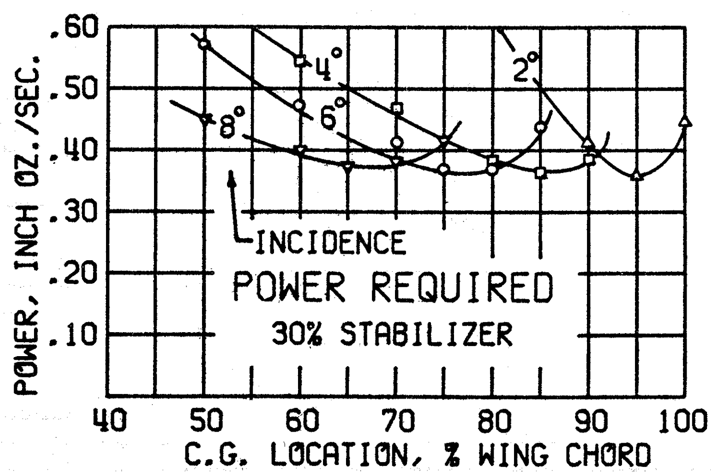
One feature of the test site (a small auditorium) suggested an 85" launch elevation; this was the height of a molding circling the room. Thus, while standing on steps at one entrance it was easy to lineup the nose of the model for constant launch height. The entrance door was kept closed to avoid disturbing drafts from this source. The hand launch procedure was spectacularly successful. Just how successful the method was can be judged by the following.

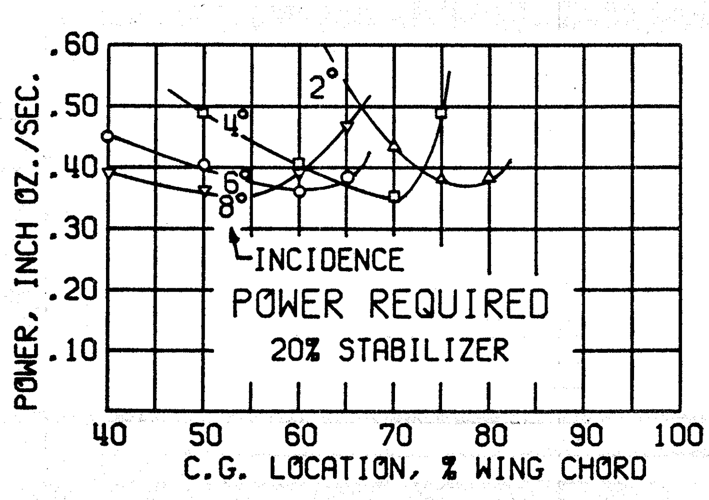
On three occasions the three glides in a set were within 0.1 second of each other. On sixteen occasions the three glides were within 0.4 second. The 0.4 second flight differential amounts to the change due an undetectable vertical draft of only forty feet per hour. Obviously, at aft centers of gravity the flight pattern changes from stable to unstable and erratic flight paths and times result. Under such conditions gliding was continued until a sufficient number of flights for an acceptable average had been made. Each one of the plotted points on the graphs of the test work, therefore, represents the average of at least three glides for that set of parameters.

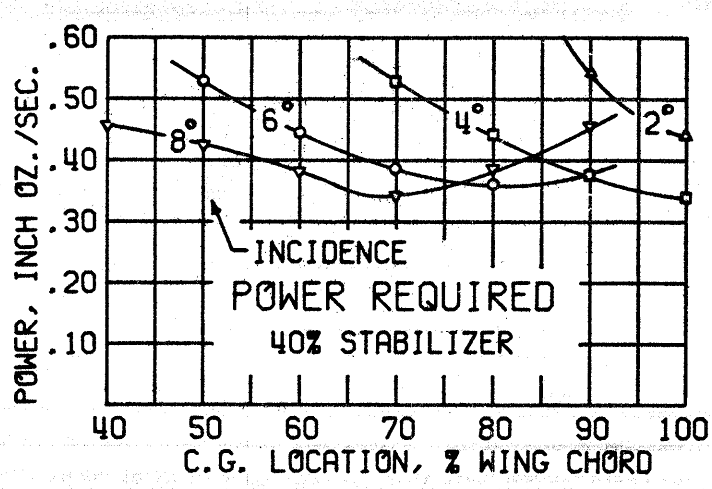
RESULTS

The glide durations were converted to power required. The power required was then graphed in a manner similar to the computer graphs to enable direct comparison. These graphs are shown in Figures 1, 2, and 3. All of the curves have approximately the same shape. They are concave upwards with a single minimum value of power required, and form a family of sorts. Increasing the incidence flattens the curve and moves the minimum power location forwards. Low incidence settings and small stabilizer sizes produce a more sharply hooked curve. This may be one reason for the popularity of large stabilizers. They are more tolerant of mis-settings. We need not "home in" as accurately on the minimum power conditions for satsifactory flight. This is not to imply that such a design is better. Comparatively speaking, paper models, which employ small stabilizers to avoid tail heaviness, fly extremely well. During the test work it became obvious that when the center of gravity was moved far enough aft for the power required to begin increasing, instability existed, hence these portions of the curves must be considered as being of only academic interest. It is worth noting, however, that the power required keeps diminishing up to the point at which instability makes its appearance. An indoor model ought always to be flying just on the verge.

For any specific values of two of the variables there is but one value of the third for which the power required is a minimum. If we decide upon a stabilizer size and use a fixed wing incidence there will be only one center of gravity location with respect to the wing chord for minimum power. This we must obtain by sliding the wing back and forth — the method used on pre-war models which had a wing clip mounting system. The usual case today is, of course, that of a given stabilizer size and a center of gravity fixed with respect to the wing chord so that the adjusting which is done is merely the altering of the wing incidence until the minimum power setting is achieved.







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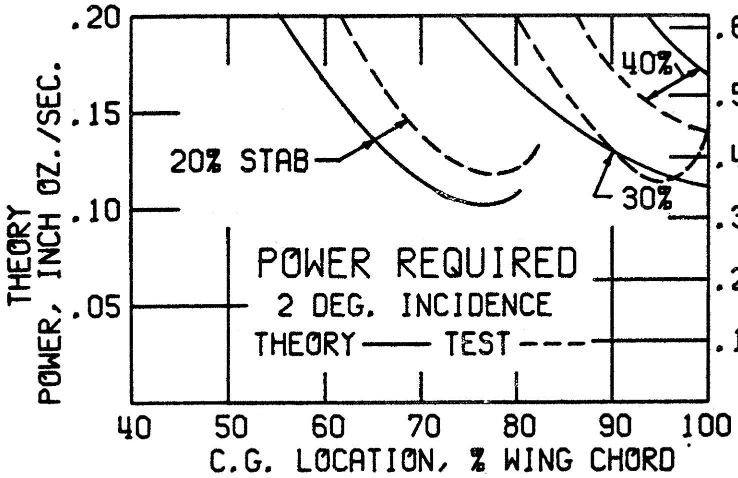
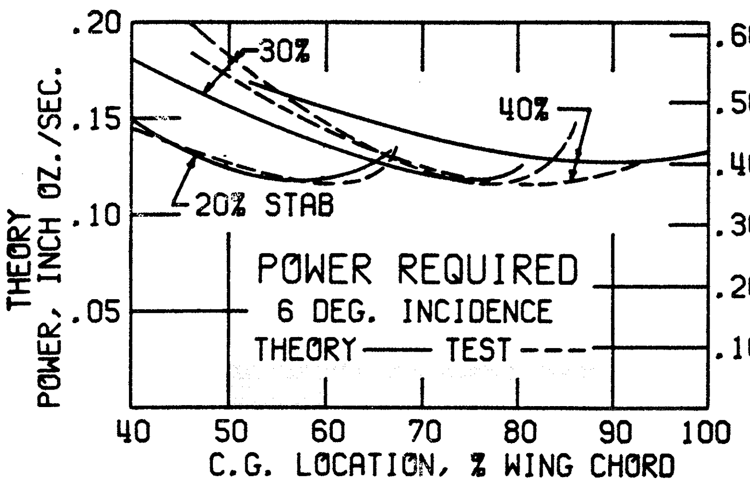


In Figures 4, 5, 6, and 7 the computer derived curves for the skeletonized model and the experimental curves for the actual test model are plotted side-by-side for comparison. The original curves were plotted on standard graph paper and it was discovered that by using inch scale for the theory curves and a centimeter scale for the test work the pairs of curves could be placed into reasonable juxtaposition. From inspection of these

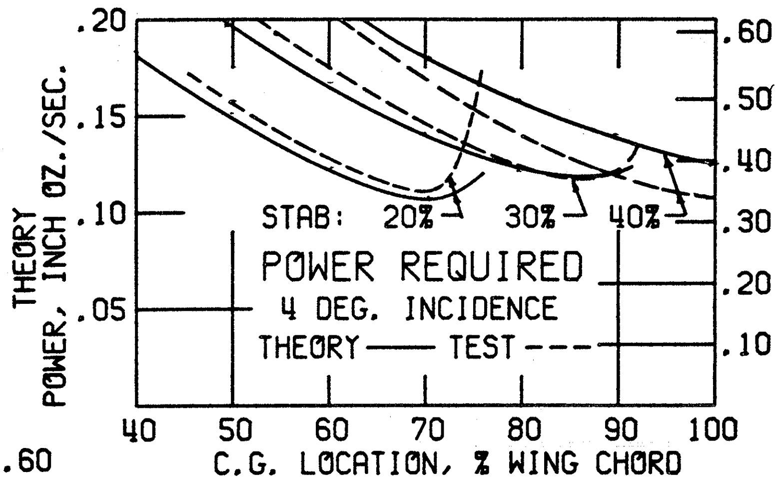
FIG 6



graphs one can conclude that the experimental work verifies the computer analysis. It is extremely questionable whether much closer agreement between experiment and the empirical computer program can be obtained. Such elements as the uncontrollable airfoils of the indoor model, lack of rigidity (flimsy tail booms and bending motor sticks) introduce unpredictable variations into the experimental work. In only one case do the computer derived curves and the test curves have a substantially different appearance, that for the 30% stabilizer and two degrees incidence. Even this can be excused: from inspection of the several curves of Figure 2 it appears as though the test run for this case could have been inadvertently made at an incidence setting of somewhat less than two degrees since the curve is offset somewhat farther to the right than one would expect relative to the remaining curves.

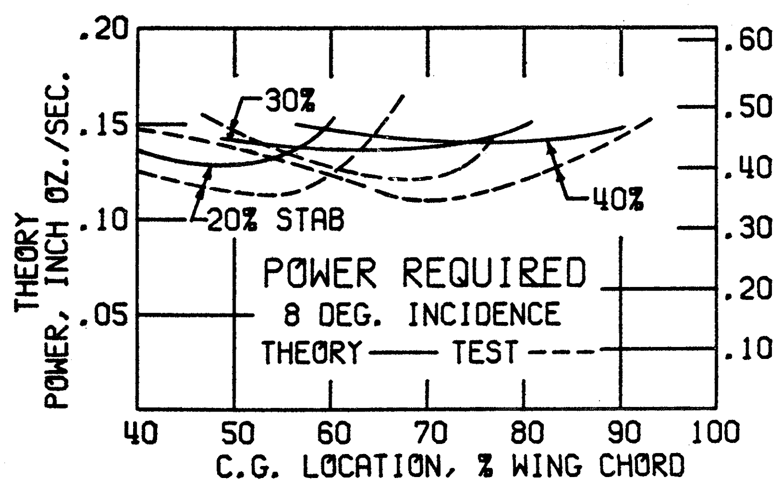
The eight degree incidence curve of Figure 3 shows a reversal of curvature at forward centers of gravity. There is a possible explanation since all the curves will show such reversal for extreme forward centers of gravity. If any model configuration is maintained at constant weight

FIG 5



while the center of gravity is moved forward far enough the model will eventually dive vertically with the wing providing no lift. The power required will not increase indefinitely but instead reach a maximum which depends solely upon terminal velocity and drag.

FIG 7



Despite the fact that it is impossible to program a knowledge of stalling into the computer, the developed program clearly and correctly pinpointed the instability condition which we generally call stalling. It would appear that the so-called stalling of the indoor model is not due, initially, to loss of wing lift but to a force arrangement produced by the settings used which results in a nosing up condition. The model is not allowed to return to equilibrium flying conditions, instead the nose is pulled higher and higher until the model stalls. Any configuration having the center of gravity behind the setting for minimum power turns out to be an unstable configuration.

All the experimental graphs resemble each other rather closely. Almost all of them bottom out at approxmately the same minimum power. The following table shows the minimum power requirements as obtained by experimentation for the various stabilizer sizes and incidences.

Stab Size	Incidence			
	2°	4°	6°	8°
20%	.375	.353	.355	.357
30%	.355	.355	.365	.373
40%	.353	.338	.353	.34

Power required, inch ounces per second

In comparing the values in the table it should be noted that the lowest value, 0.338 for the 40% stabilizer does not represent a flyable value – this occurred at 100% center of gravity location and the test notes indicate that the model was already stalling. The same is true for the second lowest value, .34, also for the 40% stabilizer. There are differences, however, which the dedicated indoor builder may want to exploit. He should perform a series of tests similar to those performed by the author, using various stabilizer sizes, to obtain the minimum power for his model. The variation may not be great; on the other hand, only a two percent difference in power required can be extrapolated to a one minute flight time difference in a fifty minute flight. The test program will not be very elaborate since no calculations need be made. Glide time can be plotted directly against center of gravity location. The graphs will appear inverted compared to those shown in this paper so that the optimum model configuration and settings will correspond to the maximum flight time.

The test results do not show that large stabilizers have an appreciable advantage with respect to power requirements although this is not immediately obvious from the graphs. For consistency all graphs were terminated at one hundred percent center of gravity. This is slightly unfortunate, however, in the case of the forty percent stabilizer, Figure 3. The graph does not show that at one hundred percent center of gravity and four degrees incidence the model had begun to stall and that at the minimum incidence of two degrees, the model was stalling at 110 percent center of gravity – and at a greater power required than for the higher incidences! One can also tentatively conclude that a tandem wing configuration is undesirable with the standard force layout of an indoor model. Any advantage of the large stabilizer, as mentioned previously, may derive from the flatness of the power required curves. One item indirectly suggests that a small stabilizer might be better, at least worth a trial. A small stabilizer will weigh less than a large one; it will not require as stout a tail boom. The model used in the test program was ballasted to maintain a constant all-up weight, hence an actual bias in favor of the large stabilizers exists. By rights the smaller stabilizer models should have been tested at gross weights reduced by .001 to .002 ounce, a weight advantage of up to two percent.

How do the results of the glide tests compare with the power flight of the model? This comparison can be only roughly made. Other studies by the author indicate that on the average the propeller requires as much power as the model. Doubling the minimum power as obtained from the graphs and, assuming normal energy availability from a motor of the same weight as the ship, the model should have flown slightly over 28 minutes. The two best flights of the model under the best conditions under which it has been flown were just under 28 minutes.

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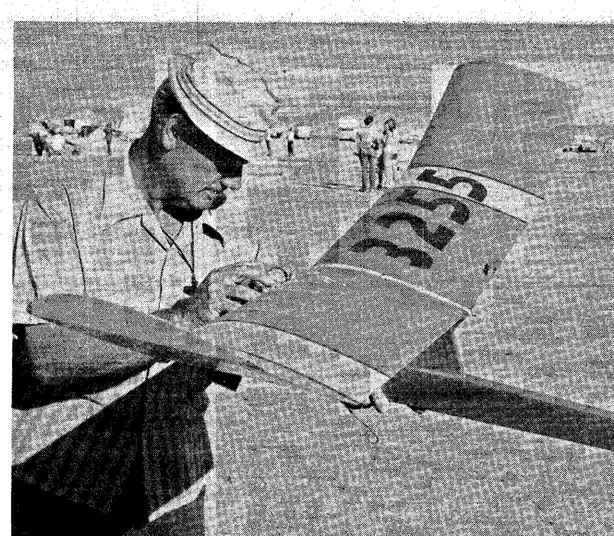
Bill Hartill, Paul Crowley



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