CHOICE OF RUBBER MOTOR FOR LOW CEILING INDOOR

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Hewitt Phillips recently logged 19:30 with a 65 cm. FAI indoor model in a 20' ceiling. When you consider that 35' is the upper limit of the Cat. I ceiling class, how much more duration is possible in low ceiling indoor flying? In his "Endurance of Indoor Models Under Low Ceilings" (Feb. and March, 1965 MODEL AVIATION), Phillips postulated 23 minute flights in 20' ceilings and over 27 minutes in 35' ceilings.

Recent developments in indoor practice have produced excellent model designs and low structure weights for optimum duration. This leaves room for propeller development and improved application for rubber motors in order to reach these predicted high times. Four years ago the 15 minute indoor flight was rare. Fifteen minute flights are almost routine at some U.S. sites today. This recent improvement in performance has been due to a better choice of power train - primarily in choice of rubber size.

This report explains a graphical construction method of choosing rubber motors for low ceiling indoor models. There are several reasons to use a graphical analysis rather than a full mathematical approach. First, indoor models operate at airspeeds where little is known of airflow and airfoil behavior. Second, precise measurement of some flight parameters is difficult, and the behavior of the better indoor propellers (which are quite flexible) is impossible to measure in analytical fashion. Thus, a graphical approach can be used to lump many variables into a single package while you vary other parameters one at a time. Finally, the graphical approach is easy to apply with acceptable accuracy, even by those disinclined to tackle complex mathematical functions.

Any indoor model is affected by numerous non-aerodynamic variables, and this complicates serious discussions. To simplify this discussion, certain assumptions will be made and certain limitations will be set. The discussion will be limited to one airplane and propeller, adjusted for optimum flight performance. Weather conditions (temperature and humidity) in the site will be considered to be unchanging and the air will be considered to be drift-free and undistrubed. The model will be assumed to have a rate of climb entirely dependent upon torque of the motor, which can be demonstrated to be true within the limits of present measuring techniques. Other assumptions will be stated as needed.

Any analytical approach, graphical or mathematical, requires certain information about the problem to be solved. The method demonstrated here requires a flight profile (altitude vs. time) as shown in Fig. 1; a plot of prop RPM vs. time (Fig. 2); a torque curve of the motor used for Fig. 1 and a measurement of the torque at launch. The torque curve corresponding to Figs. 1 and 2 is shown in Fig. 3 and was taken after the motor had rested from the flight. It can be shown that a well broken-in motor will repeat its torque curve closely as long as the winding technique is repeated. The term "average torque" will be used later in this discussion. For the discussion average torque is that torque which is the midpoint of the linear portion of the torque curve as shown in Fig. 3.

Basically, an analytical choice of rubber size for a given site entails estimation of a flight profile. The method assumes that maximum altitude will be used without contacting the ceiling. A flight profile will be graphically developed from a torque curve and rate of climb information. The rate of climb information is in turn developed from Figs. 1, 2 and 3.

The first step is to measure rate of climb vs. time from Fig. 1. Fig. 4 illustrates how this is done. A line tangent to the flight profile expresses instantaneous rate of climb at that point, so such tangents are constructed at one minute intervals for climb and two minute intervals for descent. Each tangent is then evaluated in feet/min.:

TABLE I

1 minute -	+7.3 ft./min.	6 minutes -	0 ft./min. (level flight)
2 "	+4.5 ft./min.	8 "	-1.2 ft./min.
3 "	+3.5 ft./min.	10 "	-2.7 ft./min.
4 "	+2.0 ft./min.	12 "	-5.0 ft./min.
5 "	+0.8 ft./min.	14 "	-7.5 ft./min.

The next step is to read average RPM figures from Fig. 2 as shown in Fig. 5. The upper line of digits represents the RPM at one minute intervals, and the lower digits represent the average RPM for that interval. Fig. 6 is a copy of Fig. 3 which has been coordinated to the time scale of the flight. This is done by beginning with the torque at launch (0.2 inch-ounces for the flight of Fig. 1) and graphically subtracting the average RPM for each interval of flight. For example, the average RPM for the first minute of flight was 60; a distance equal to 60 turns is scaled off the abcissa to yield line "A". This line intersects the torque curve at .160 inch-ounces - showing that this amount of torque was left after one minute of flight. Repeat this process for each point in Table I and plot these points as shown in Fig. 7.

The information shown in Fig. 7 can be considered to be sufficiently accurate for predicting performance of that model/prop combination so long as the motor weight is not varied more than plus or minus 10%. For maximum utility, the "calibration" flight should be made in a moderately high ceiling to get a good range of torque and rate of climb information. Two conditions should be observed: the flight must not touch the ceiling or obstructions, and the model must not run out of turns before landing.

Now to "predict" flight duration for a different motor, using Fig. 7 and the torque curve for that motor. It is reasonably accurate to apply the data from Fig. 5 to the new motor as has been done in Fig. 8 for a motor which has a slightly higher average torque than the motor of Fig. 3.

78 Fig. 9 shows two curves developed by "the method". An initial assumption of 10 ft./min. rate of climb was made for the first 30 seconds of flight (it is extremely difficult to determine actual rate of climb right after launch). Draw a line of this slope from the launch altitude (shown as 1') to intersect the ordinate of 30 seconds duration. From Fig. 8, (note that the same launch torque of 0.2 inch-ounces was used), the torque after one minute has dropped to .165 inch-ounces. From Fig. 7, this corresponds to 7.4 ft./min. climb. Draw a line segment with this slope from the end of the first segment to the ordinate for 1.5 minutes. Effectively, this defines an average rate of climb for the interval from 30 seconds to 1.5 minutes, as an approximation of the expected flight path. Shorter intervals could be used at the expense of complexity, but one-minute intervals give a good approximation.

This process was repeated at one-minute intervals to create curve "A" in Fig. 9. Note that the predicted peak altitude is 33.5' - which might be disastrous in a 30' site! In cases where the predicted curve intersects the ceiling only slightly, a safe flight can be made by allowing some turns to run out before launch. To estimate how long to let the prop turn, draw a line "C" at some altitude above the floor to subtract the required clearance. This line intersects the curve at "D" and indicates that 15 seconds of prop run would cut the climb to a safe level. This restricts the height of curve "A" to about 30' and reduces the total flight time to about 18 minutes - in place of the 19 minutes it would have lasted in an unlimited ceiling.

Curve "B" on Fig. 9 was developed in similar fashion from Fig. 5 and the torque curve of Fig. 10. Fig. 10 was taken from a motor with lower average torque than the motor of Fig. 3, and launch torque was raised to 0.25 inch-ounces to help compensate for a shorter expected period of climb. The shorter climb can be deduced from the fact that only 225 turns separate 0.2 inch-ounces and 0.1 inch-ounces (level flight torque) instead of 290 turns for Fig. 3 and 370 turns for Fig. 9. As can be seen, this was still insufficient launch torque since the predicted altitude was only 28'. Clearly, this motor would only give about 14 minutes without allowing the model to "rafter-bang".

This method has several applications, most of them dealing with choice of motor size. You can predict in advance the approximate motor size for a new site provided you have an accurate measure of the ceiling height. You can decide which of several models to fly in a given site, based upon the rubber sizes you have on hand. Experience in using the method enables you to notice small changes in model trim <u>before</u> you lose the contest instead of during an agonized re-appraisal <u>on the</u> way home.

This approach has several advantages which help offset the extra work of applying the method. From a practical standpoint, you need to make up the motors and run the torque curves ahead of time. This immediately helps to eliminate low quality rubber. If poor rubber is all you seem to have, it will tell you just <u>how</u> poor it is and you can fly accordingly. You also become very familiar with the capabilities and limitations of your models, and the better ones stand out clearly in a way that casual test flying can never show.

I wish to acknowledge help from many people on this paper. Jim Clem (the indoor man, not the "Witch Doctor" man) started me thinking about prediction of flight duration and closely assisted me with flight measurements and discussion of various approaches. Jim Richmond and Charlie Sotich have contributed much in random thoughts and concepts concerning application of pirelli. Hal Crane has furnished pages of flight data from his flights in the 20' Willis school site in Hampton, Virginia. Ernie Kopecky has furnished high ceiling data on his models and power. I have already acknowledged Hewitt Phillips' article - and he has furnished other information from time to time also. I could go on, because the list is endless!

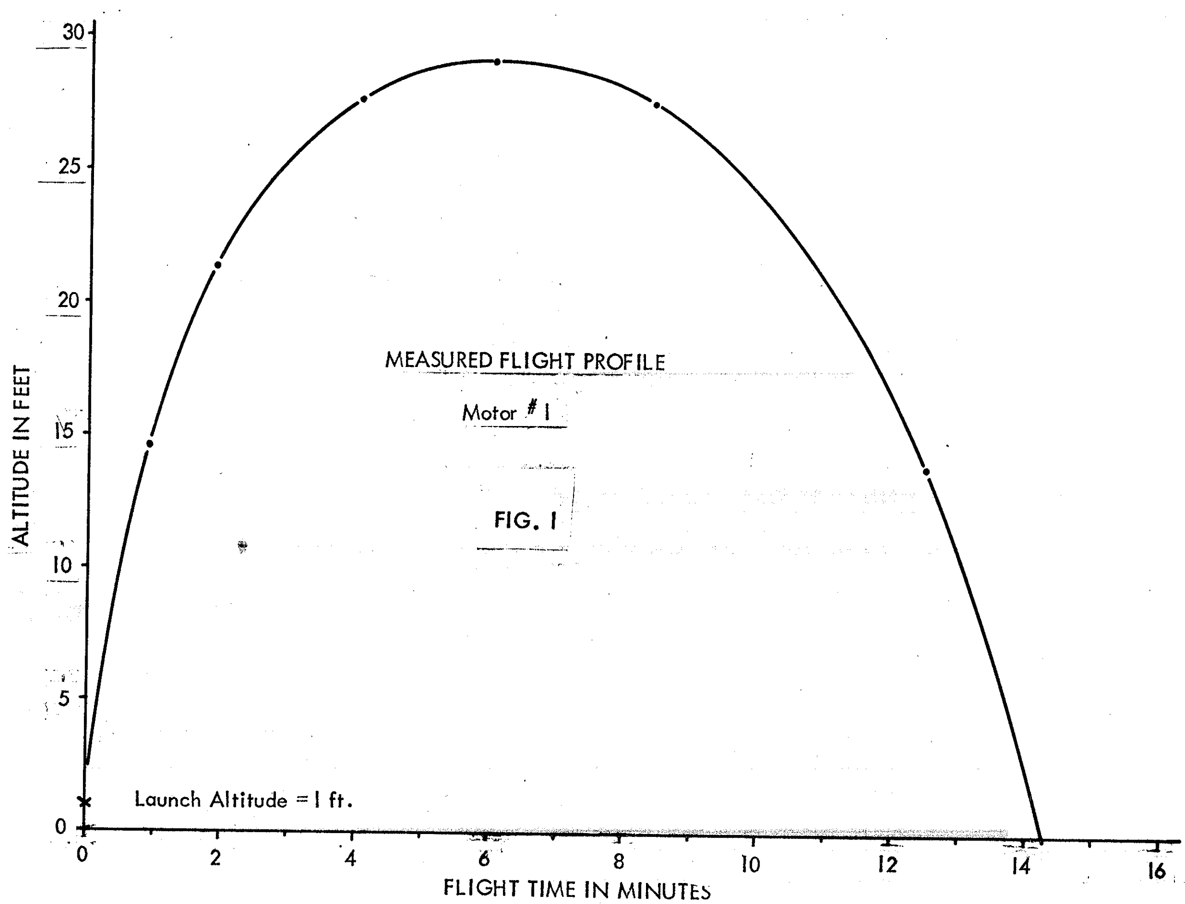


FIG. 1

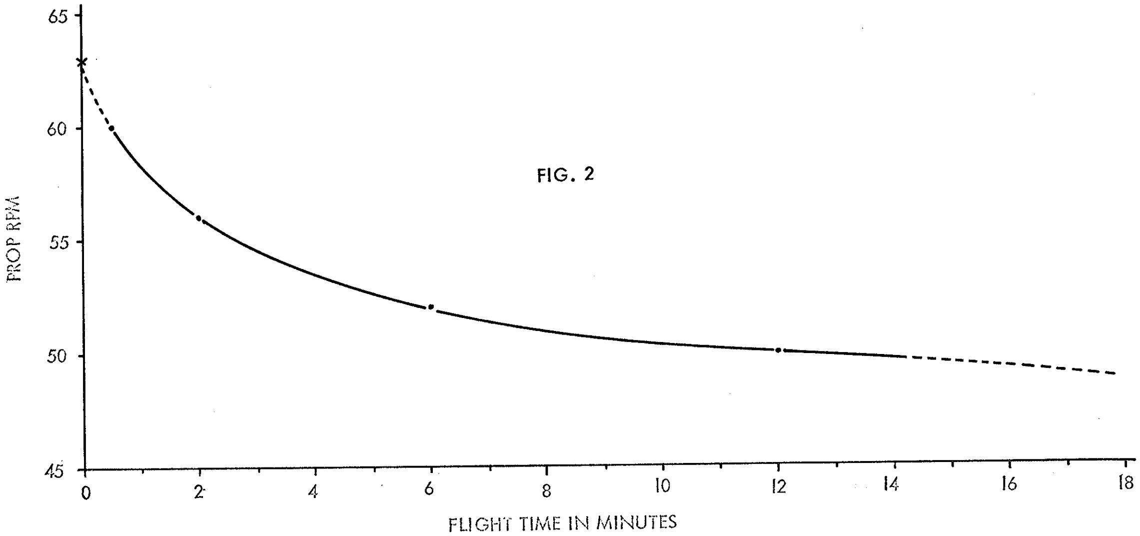


FIG. 2

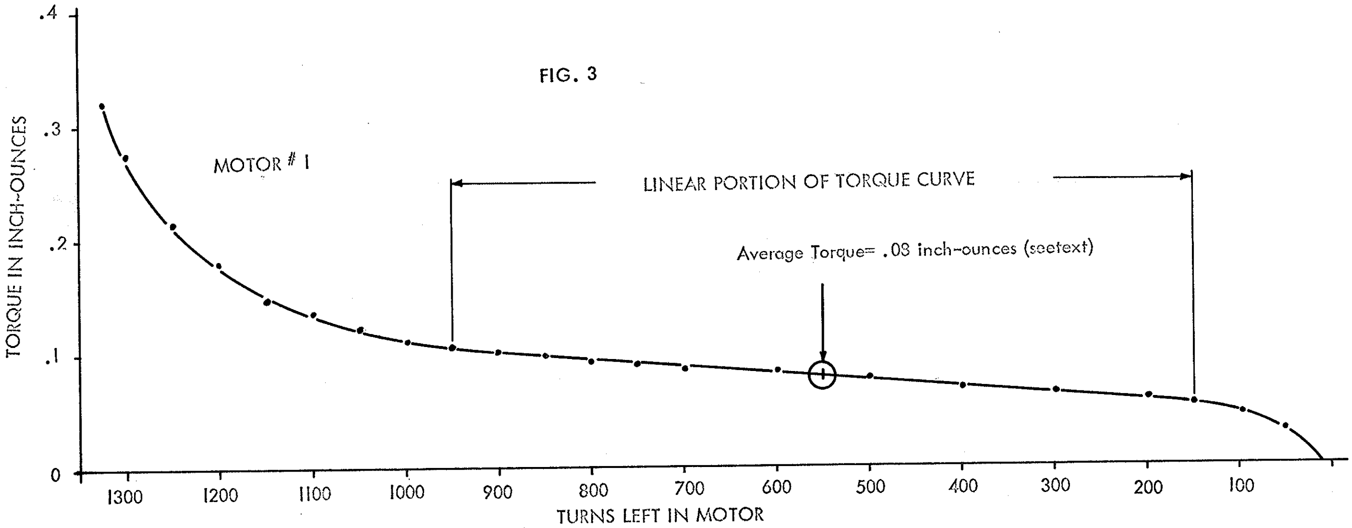


FIG. 3

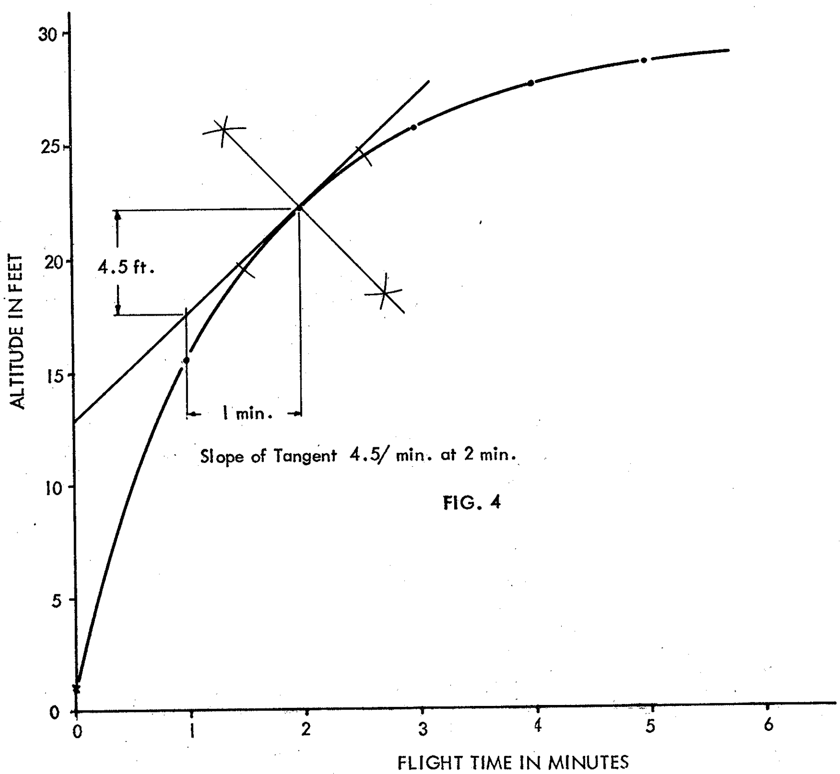


FIG. 4

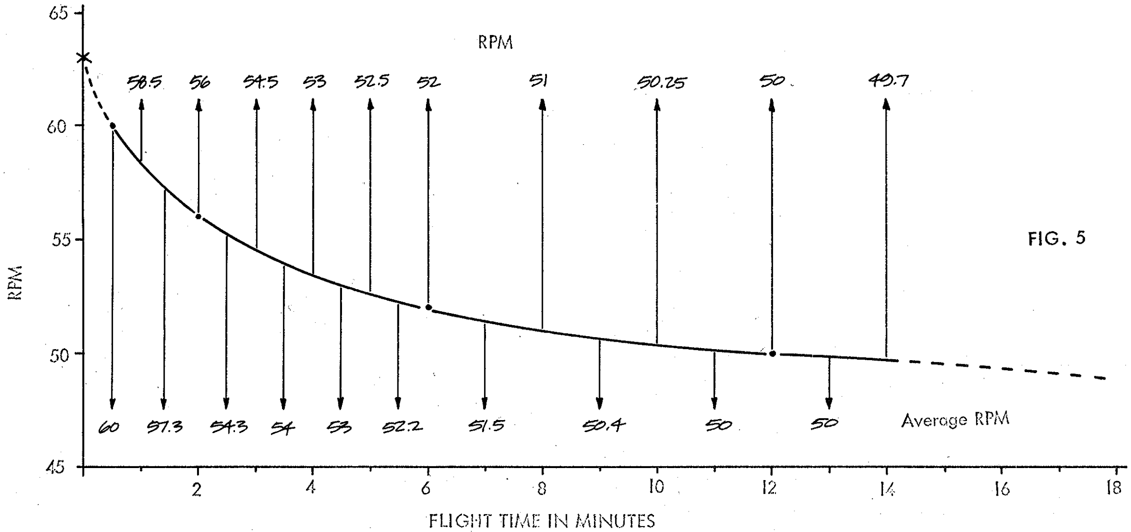


FIG. 5

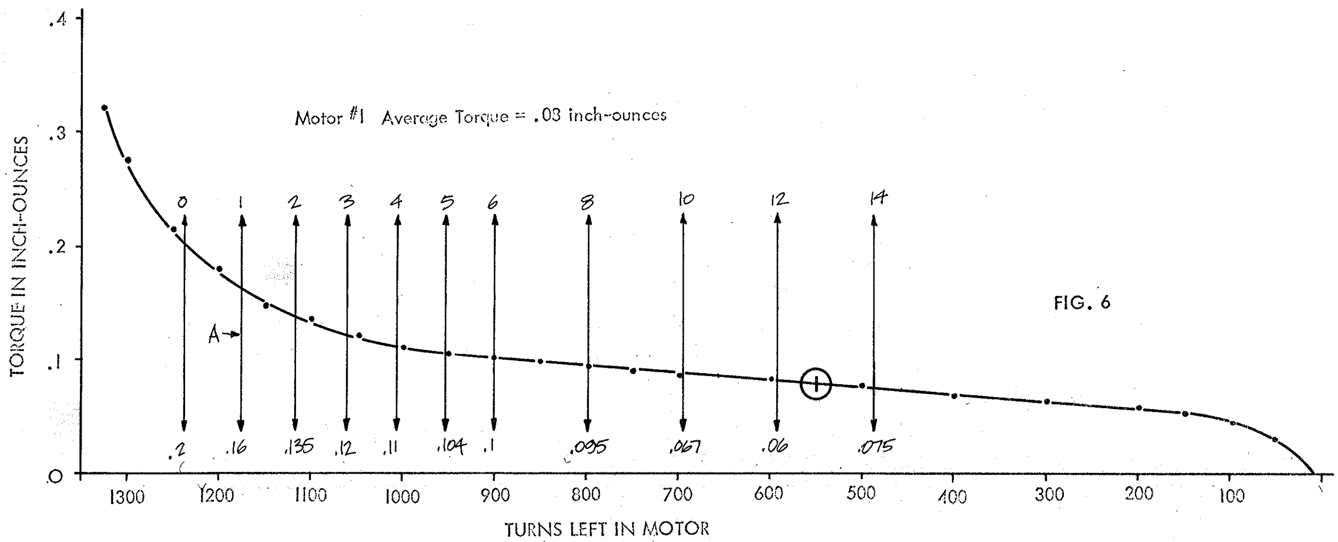


FIG. 6

FIG. 7

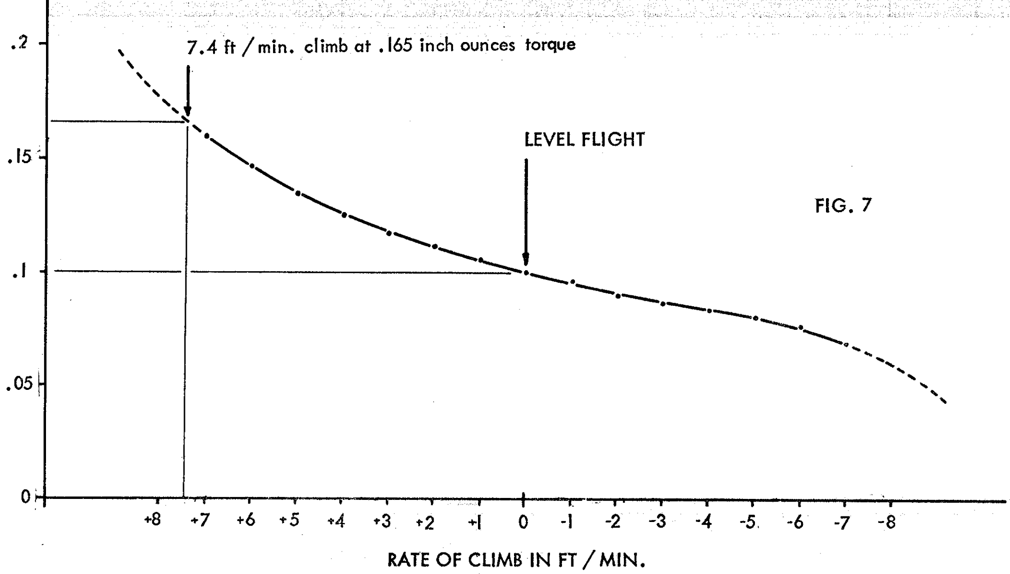
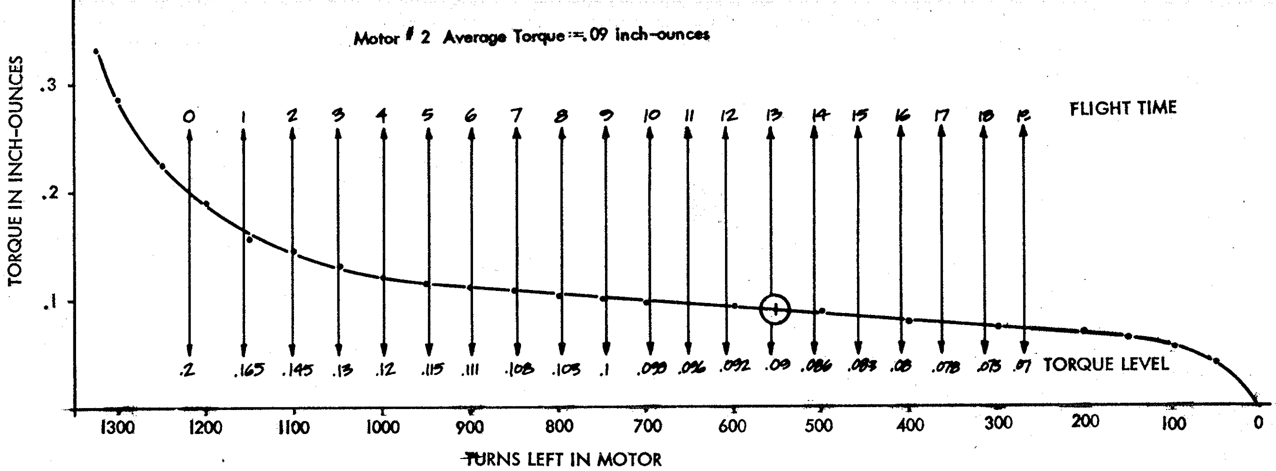


FIG. 7

FIG. 8



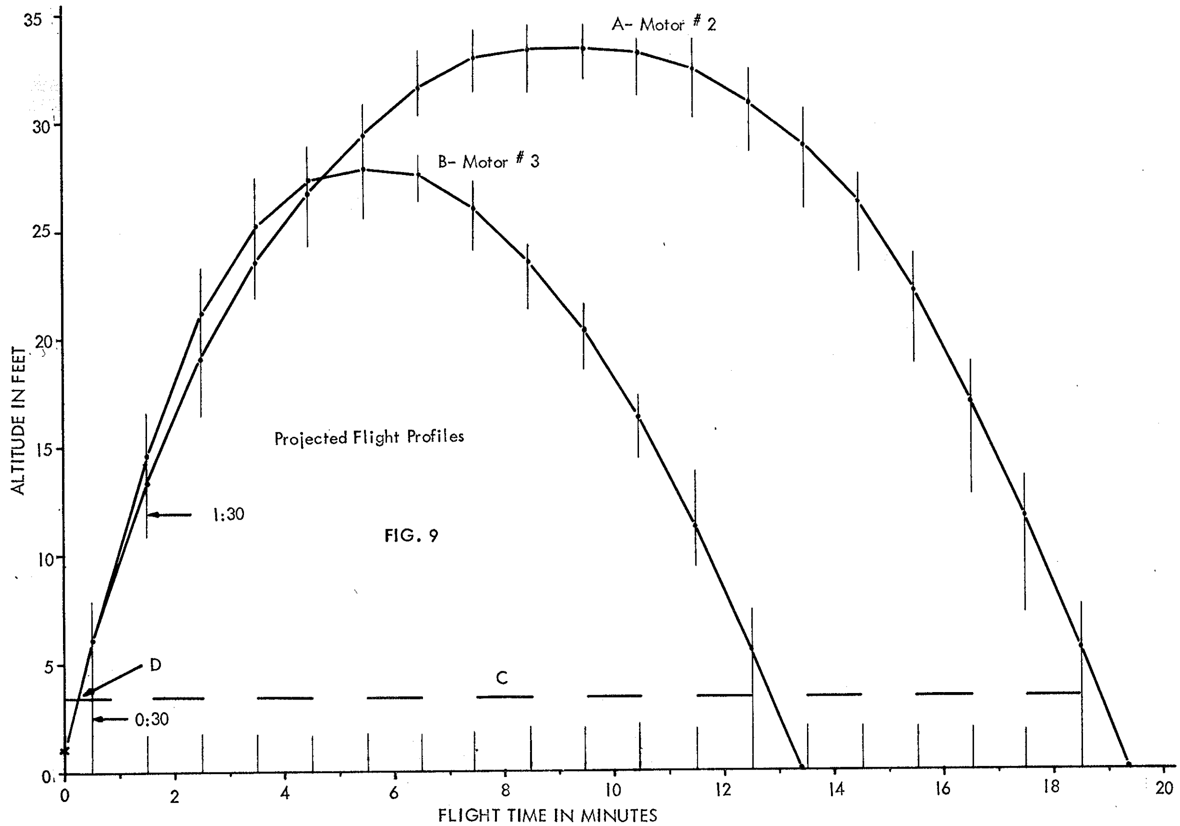


FIG. 9

FIG. 10