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A New Standard for the Prediction of Full-Scale Spin and Recovery Characteristics from Model Tests

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Summary.—The important features of a model, which affect the scale effect in the spin and recovery are discussed in the light of several model to full-scale comparisons and the general background of spinning experience. These features have been shown to be the λ of the spin, the thickness/chord ratio of the wing and the inertia ratio B/A of the model. Using these parameters, a new standard for the prediction of the full-scale spin and recovery from the model test has been presented.

1. *Introduction.*—In 1934 S. B. Gates[1] proposed the vane technique for model spinning tests and this technique, with small modifications, has proved invaluable up to the present day. In proposing this technique, he suggested that the scale effect on the model yawing-moment coefficient was the most important of all the scale effects and compensation could be made for it by applying a pro-spin yawing moment to the model by a vane on an outrigger attached to the inboard wing tip. The early experience suggested that, if the model recovered from the spin by normal control movements when $0 \cdot 010$ C_n' (10 units) of pro-spin yawing moment was applied to the model, then the full-scale aircraft should recover from the spin. The original standard for recovery is shown diagrammatically in Fig. 1.

In the light of further full-scale spinning experience, this standard was modified to 15 units in 1937[2] and applied to tests with the model pitching moment of inertia increased by 10 per cent above its calculated value to cover possible errors in calculation.

As more full-scale data accumulated, it became necessary to analyse it in more detail and this was attempted by Pringle[3] in 1943. It had become important to ascertain the apparent variability of the 'scale effect' and to decide how much of this was due to genuine aerodynamic differences and how much to failure to simulate the full-scale loadings and other experimental conditions relating to the achievement of dynamic simularity. In particular, it was essential to decide whether the scatter due to unknown causes was large compared with the true aerodynamic scale effects between the model and full-scale spin and recovery for, if so, the model test would lose all its practical value. Pringle attempted a statistical analysis, using the normal error law with various values of the yawing-moment scale effect, Z. The values of Z for different aircraft are given in the upper diagram of Fig. 2, whilst an error-distribution curve of the frequency which any given value of Z occurs among these aircraft is shown in the lower graph of Fig. 2. If an error-distribution curve of this type is accepted, then a prediction from the model tests may be in error for the average case by $\pm$ 7 units or in the extreme case by $\pm$ 20 units. Predictions based on a criterion having possible errors of this order place the whole technique in jeopardy.

* R.A.E. Report Aero. 2538, received 3rd February, 1956.

It therefore became urgent that the model scale-effect allowances should be revised. During the past four years spinning tests have been completed on six fully instrumented aircraft and of these, five model comparisons with the full-scale spins have been made in the tunnel. From these comparisons and other general tunnel full-scale experience, it has been possible to suggest some new model standards. These standards have been derived from straight-wing aircraft with relatively low inertia ratios B/A and care will be needed in the interpretation of these standards for swept-wing aircraft and aircraft having high inertia ratios.

2. *Scale Effect on Wings.*—In the spin there is a continuous variation of incidence across the span of the aircraft, the falling wing tip being at the maximum and the rising wing at the minimum incidence. The actual value of the incidence at the wing tips depends upon the mean incidence of the wing and the non-dimensional rate of rotation (λ) of the spin.

There are no recent rolling balance tests to indicate how the yawing-moment and rolling-moment coefficients on a given wing change with α, λ and Reynolds number and therefore any conclusions drawn must rely upon static tunnel tests, which unfortunately seldom go above the stall.

Figs. 3, 4, 5 and 6 from Ref. 4 show the variation of C_L and C_D with Reynolds number for four symmetrical wing sections at incidences up to 28 deg. These tests indicate that when the wing is fully stalled ($\alpha > 30$ deg), the differences in C_L and C_D caused by changes in Reynolds number in the range $3 \cdot 3 \times 10^5$ to $3 \cdot 1 \times 10^6$ are very small, whereas for incidences between 8 and 24 deg the change in C_L with Reynolds number is very marked.

Using these results, some calculations have been made to find the differences in the wing yawing (C_n') and rolling (C_l') moment coefficients (body axes) between the Reynolds number of $3 \cdot 3 \times 10^5$ and $3 \cdot 1 \times 10^6$.

The assumptions made were :

(*a*) Zero sideslip at the c.g.

(*b*) Above an incidence of 30 deg, change in Reynolds number had a negligible effect.

The calculations were based on elementary strip theory, assuming that the forces on any element of the wing are a function of the local α, C_L and C_D at that point. The results are shown in Fig. 7. They demonstrate that the differences between C_n' and C_l' on a given wing at two Reynolds numbers are a function of the wing section, mean incidence and λ and also serve to emphasise the difficulty of an accurate assessment of the scale effect under all spin conditions.

3. *Model Full-Scale Comparisons.*—Instrumented spinning tests have been made on six aircraft, the *Meteor* 8[5], the *Provost*[6], the *Balliol*[7], the *Wyvern*[8], the *Vampire*[9], and the *Swift*[10] and model tests have so far been made for comparison on five of them. These test results have been or are about to be published but a brief mention of the more important results will be made here.

The Wyvern.—Early model tests on this aircraft showed it to have an extremely poor recovery standard (threshold of recovery = 4 units of applied pro-spin yawing moment), and a prediction of failure for the full-scale recovery was made. The aircraft, in fact, had a low-incidence spin and the recovery was quite normal.

The Percival Provost.—This aircraft was predicted to have a normal spin and recovery, although early model tests did show a tendency to spiral rather than spin at low values of applied pro-spin yawing moment (7 units), but this was thought not to be important as it occurred far below the normal scale-effect allowances. Full-scale spinning trials showed that the aircraft was extremely difficult to spin and generally spiralled. Modifications had to be made to the outboard section of the wing to increase the spinning tendency. This indicated that the scale-effect allowances should be less than 7 units.

The Balliol.—Early model tests predicted that the spin and recovery of this aircraft would be border-line with a marked tendency for the development of a flat spin. Full-scale tests showed that the aircraft had a satisfactory, though oscillatory, spin and recovery and later model comparisons indicated that the ' scale effect ' was of the order of only 5 units.

The Meteor Mk. 8.—Very comprehensive full-scale spinning tests have been made on this aircraft covering five different inertia ratios B/A. The full-scale spinning tests indicated that as B/A was increased, the spin became steeper and/or more oscillatory and recovery was easier and quicker. Model-test comparisons did not reproduce this trend, the model having approximately the same recovery threshold irrespective of inertia loading.

The Swift.—Very recent model to full-scale comparison has been made on this aircraft after a spinning incident on one of the early aircraft. The equivalent scale effect in yawing-moment coefficient was approximately 3 units.

The above aircraft cover an inertia ratio range of 1·1 to 3·0. From the results of these recent spinning tests and the general background of spinning experience, it has been possible to suggest the new standards for the prediction of the full-scale spin and recovery characteristics. This standard is detailed in the succeeding Sections.

4. *The Derivation of the New Standard.*—In Table 1, we have a list of 30 aircraft for which there is some evidence of the full-scale spin-recovery standard as well as results from model spinning tests. In nine cases the aircraft only just recovered from the spin by normal recovery action. These are called border-line cases. Consideration of the scale effect on wings suggests that both λ and t/c will be important parameters and B/A is important, because it is proposed that, to keep the model technique simple, compensation for the scale effect in yaw only should be made. This modifies the wing tilt and therefore the inertia yawing-moment coefficient which varies with B/A.

Now let us consider each of the parameters more fully :

(*a*) In the border-line case, the model at the threshold of recovery closely resembles the full-scale recovery and therefore the $\Delta C_n'$ to achieve this threshold gives a true measure of the scale effect in yaw. The λ at the threshold of recovery of the model should be the λ of the full-scale spin. Therefore, for each border-line case, we have a unique condition, giving a clear indication of the scale-effect allowance at that particular λ in the spin. The trend of increasing scale effect with increasing λ up to 0·5 to 0·6 has been shown earlier by the strip calculations.

(*b*) Wing thickness/chord ratio t/c. The strip-theory calculations indicate that the scale effects are a function of thickness/chord ratio of the wing. In the case of the scale effect in yaw, the results (Fig. 7) indicate that the change is of the order of 5 units ($10^3\ C_n'$) for a 6 per cent change in t/c. If a unique set of curves for all aircraft is required, then the scale-effect allowance for each aircraft must be corrected for t/c and it is suggested that this should be applied according to Fig. 8.

(*c*) Inertia ratio B/A. Apart from small second-order effects, if the aerodynamic scale effects on both yaw and roll were corrected completely, the inertia ratio B/A would be unimportant, as the model would show the complete characteristics of the full-scale recovery. If the scale effect in roll is uncorrected, the model will have a spin in which the wing tilt θy will be appreciably less than the full-scale aircraft. This directly affects the inertia couples in roll and yaw and these react on the spin and recovery, making the model recovery relatively poorer as the inertia ratio B/A is increased. As, in the tunnel technique to be suggested, the scale effect in roll will not be simulated, this must be allowed for in the comparison of the model and full-scale spin. The model to full-scale comparisons, in particular on the *Meteor* 8, gave a good lead to the magnitude of this effect.

It is now a simple question of plotting the thresholds of recovery of the models (corrected for thickness/chord ratio) of aircraft which showed border-line characteristics against the function of inertia ratio $(1 - B/A)$.

In the cases quoted, the model tests were done with the vane at -130 deg to the wing chord and since the results are required to be plotted at zero applied pro-spin rolling moment, the tunnel results must be corrected to zero applied rolling moment using the work of Harper[11]. This correction is shown in Table 1.

From these points, plus a knowledge of the value of λ of these spins, it is possible to draw lines showing the expected variations of the recovery thresholds with $(1 - B/A)$ for constant λ bearing in mind the variations in scale effect due to λ shown in Fig. 7. This can be done for the whole range of λ.

Other model-test results can then be plotted for aircraft which passed or failed in their full-scale spinning trials and those passes or fails should fall on the correct side of their constant λ line showing their expected full-scale border-line recovery condition (*see* Fig. 9). Slight adjustments to positions of the constant λ lines were made at this stage.

Let us take an example to demonstrate this point. From Table 1, if we take aircraft 21, the *Magister*, we can see that in the two cases considered in which we have a fail and a pass full-scale (the aircraft was modified to improve its recovery standard in between the two tests), the important parameters are as follows :

(*a*) $\lambda = 0{\cdot}42$

(*b*) $(1 - B/A) = -0{\cdot}5$

(*c*) Corrected threshold of recovery was $17{\cdot}5$ units $10^3 C_n'$ for the pass full-scale and $9{\cdot}0$ units for the fail full-scale.

Now turning to Fig. 9 for $\lambda = 0{\cdot}42$ and $(1 - B/A) = -0{\cdot}5$, the constant λ lines show a yawing moment of $9{\cdot}7$ units for the border-line condition. This is shown as the small horizontal line. The points for the pass and fail conditions are shown as the circles either black or otherwise to represent the different full-scale results. The length of the lines between these points and the border-line condition gives a measure of how much the aircraft must be improved from the fail condition to make it at least border-line, or in the pass case, the margin the aircraft has over the border-line condition.

The number of points available, to establish Fig. 9 as a precise new spinning standard, are really very few, especially at the larger negative values of $(1 - B/A)$, but Fig. 9 presents the accepted trends of model to full-scale comparisons and the suggested boundaries fit all the available evidence reasonably well.

5. *The Prediction of the Recovery Standard of an Aircraft.*—To determine whether or not a model satisfies the standards proposed in the previous Section the model test should be analysed as follows :

(*a*) Using a dynamically similar model and the correct control movements, assess the threshold of recovery of the model in the normal way using a yaw vane only. If vanes at incidences other than -90 deg have been used, this result should then be corrected to zero applied rolling moment using either Harper's report[11] or doing additional tests to assess the effects of applied rolling moment.

(*b*) Using Fig. 8, subtract from the recovery threshold an allowance for the thickness/chord ratio and then plot the result in Fig. 9.

(*c*) If the corrected model threshold of recovery then falls above the appropriate line at constant λ (*i.e.*, the λ of the model in the steady spin at the recovery threshold), then the prediction is that the aircraft will recover from the sustained spin ; if below it, the prediction is that the aircraft will fail to recover from the sustained spin. This will apply to the particular control movements used in the model tests.

The vertical margin between the aircraft recovery point and the constant λ line is a measure of how far the aircraft is from the border-line case.

6. *The Prediction of the Steady-Spin Characteristics.*—In the past it has been the practice to predict the characteristics of the steady spin from the characteristics of the model spin with a yawing moment applied which is equivalent to the border-line condition (15 units on the old standards). This has given quite good predictions on aircraft to which the old standards truly applied and it is proposed that a similar technique using the new border-line recovery condition should continue to be used.

The method using the new standards should be as follows :

(*a*) Using the values of $(1 - B/A)$ for the aircraft and the value of λ at the recovery threshold, the scale effect $\Delta C_n'$ can be found from Fig. 9 (*e.g.*, *Provost* (Aircraft 14), border-line value 3 units).

(*b*) Add to this value an allowance for wing t/c (Fig. 8) and then apply this total value of applied pro-spin yawing moment (corrected to zero rolling moment if necessary) to the model. From observations of the model in this condition the values of α, Ω, λ and rate of descent can be determined from the steady spin.

The prediction of the λ of the steady spin, using the λ of the model at the threshold of recovery to decide the correct scale-effect allowance, may appear to be a contradiction at first sight but, in general, the λ of the spin is a characteristic of the individual aircraft and does not vary greatly with the yawing moment applied. In an average case the λ changes $0 \cdot 004$/unit of applied pro-spin yawing moment and therefore there has to be a very large difference in yawing moment between the threshold of recovery and the correct scale-effect allowance to make any appreciable difference. There are occasional exceptions in which large steps occur in the λ of the spin for very small changes in applied pro-spin yawing moment but on any system of prediction these would have to be treated as special cases depending upon the particular characteristics of the aircraft under test.

The time to recover full-scale can also be determined from this condition by doing a model recovery and measuring the time for the model to stop spinning after control reversal.

The model tests should also be made with the A.U.W., rolling and pitching moments of inertia increased separately by 30 to 50 per cent, to cover the increases in aircraft A.U.W. and inertias, after the model tests have been done and before the flight tests of the production aircraft.

7. *Discussion.*—From an examination of Fig. 9, it can be seen that it should now be possible to predict the characteristics of an aircraft spin and recovery to within $\pm$ 3 units (10^3 C_n') of applied pro-spin yawing moment within the limits $(1 - B/A) = + 0 \cdot 5$ to $- 1$. This will considerably improve the accuracy with which the predictions can be made within this range and extrapolations outside the range will be easy with little further evidence.

As the criterion has been kept as simple as possible there are a number of limitations which should be remembered when applying it to a particular model test.

(*a*) Aircraft with wings having high taper ratios will probably show much smaller scale effects than those of the more conventional straight-wing types. Deltas are a particular example of this and further evidence on deltas will be obtained from the Javelin spinning tests.

(*b*) In the case of a model having an oscillatory spin, the results can only be used as a very rough guide to the characteristics of the spin full-scale. This is due to the fundamental difference between the model and full-scale oscillatory spin in the phasing of the oscillations in rate of roll and incidence.

With the increases in Reynolds number available in the Bedford tunnel, it must be expected that these standards will have to be modified in certain conditions. If Figs. 3 to 6 are re-examined it can be seen that the variations of the $C_L - \alpha$ curve with Reynolds number is a function of thickness/chord ratio. For the thin wing ($t/c = 0 \cdot 09$), little change occurs until the Reynolds number is greater than 1×10^6 and therefore no modification should be required. For thick wings ($t/c = 0 \cdot 18$), a progressive change takes place with Reynolds number from 4×10^4 to 1×10^6. In this case a progressive adjustment of the scale-effect allowance will be required as the tunnel Reynolds number is increased.

A trend in design which can be expected in the future is for aircraft to have increasing values of B/A. Aircraft in this country in the project stage have values of B/A up to 10 and in America up to 20. Until some full-scale experience at these high values of B/A has been obtained the prediction of their spinning characteristics will be difficult, but the following trends have already been indicated.

(i) In the model spinning tests, the constant λ lines (Fig. 9) appear to be flattening out at high B/A but so far there is no evidence that the slope changes sign. This would indicate that for models of aircraft at high values of B/A, the model spin in the tunnel, without allowance for scale effect, will give a pessimistic answer for the full-scale recovery; anti-spin yawing moment may have to be applied in these cases.

(ii) The effect of the ailerons on the spin and recovery has been shown to be extremely important. In the cases of some swept-wing aircraft flying at present, having values of B/A of 2 to $3 \cdot 5$, the effect of ailerons is so great that in-spin aileron (stick to the left in a spin to the left) will make the aircraft recover from the spin without moving the other controls and out-spin aileron (stick to the left in a spin to the right), will prevent recovery from the spin irrespective of the movements of the other controls.

The effect of ailerons must be taken into consideration when assessing an aircraft and can, of course, be represented on the model. On swept-wing aircraft, the effect of ailerons on the full-scale spin is greater than on the model spin and further model to full-scale comparisons will be required before accurate quantitative predictions of the aileron effects can be made from the model tests.

At present there is no conclusive evidence that the results shown in Fig. 9 apply to swept-wing aircraft but those already tested full-scale and model-scale appear to give agreement with the criterion. It is suggested that this method be used for swept-wing aircraft until more definite evidence is available.

Discussion of the scale effects on the body have been avoided in this analysis, as the evidence, which is available at present, indicates that this is a small effect, but that may not be so in the future. Recent results in America indicate that the body shape on models having long circular fuselages may have to be modified so that the pitching and yawing moments on the model should be made to more nearly represent the full-scale spinning condition.

8. *Conclusions.*—Experience has proved that the simple standard for the prediction of the characteristics of the full-scale spin and recovery from model tests is not satisfactory. It has been shown that a satisfactory empirical method of allowing for scale effect, retaining a simple tunnel technique can be obtained by taking into account :

(*a*) the thickness/chord ratio of the wing,

(*b*) the λ of the spin at the threshold of recovery of the model,

(*c*) the inertia ratio B/A of the aircraft.

It is estimated that by the proposed method the full-scale spin and recovery can be predicted to within an accuracy of $\pm$ 3 units ($10^3 C_n'$) for values of $(1 - B/A)$ within the range $+ 0 \cdot 5$ to $- 1 \cdot 0$, with reasonable chance of extrapolation outside this range, whereas previously errors of up to 25 units ($10^3 C_n'$) have been apparent.

LIST OF SYMBOLS

α		Mean angle of incidence (deg)
Ω		Rate of rotation about the axis of the spin
b		Wing span
V		Rate of descent in the spin ft/second
λ	$=$	$\dfrac{\Omega b}{2V}$
L'		Inertia moments about aircraft body axes—Rolling
M'		Inertia moments about aircraft body axes—Pitching
N'		Inertia moments about aircraft body axes—Yawing
A, B, C		Moments of inertia in roll, pitch and yaw
θy		Angle of wing tilt relative to horizon, positive when inner wing is down
C_n'		Yawing-moment coefficient (Body axes)
C_m'		Pitching-moment coefficient (Body axes)
C_l'		Rolling-moment coefficient (Body axes)
t/c		Thickness/chord ratio
Z		Difference in yawing-moment coefficient between the model and full-scale spin
β		Angle of sideslip at c.g.
γ		Helical path angle of c.g. $\beta = \theta y - \gamma$

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TABLE 1

Summary of Model and Full-Scale Spin and Recovery Data

Number	Aircraft	Model threshold			R. & M. 2831. Correction for applied rolling moment			Correction for t/c		Corrected C_n'	$1 - B/A$	Full-scale pass, borderline or fail	Remarks
		$10^3 C_n'$	λ at the threshold of recovery	α	For vane at -130 deg C_n' tan 40	$\frac{dC_n}{dC_l'}$	Corrected C_n'	Mean t/c	t/c correction				
1	*Athena* ..	13·2	0·33	62	11	+0·08	14	0·13	−3·3	+10·7	−0·67	P	
2	*Attacker* ..	10·5	0·13	43	8·8	+0·52	15·1	0·107	−1·4	13·7	−1·56	P	
3	*Balliol* ..	14	0·35	65	11·7	+0·13	15·5	0·16	−5·7	9·8	−0·8	P	
4	*Cornell* ..	22	0·48	62	18·4	+0·13	24·4	0·14	−4·1	20·3	−0·77	P	
5	Swept-wing ..	6·5	0·17	48	5·42	−0·13	5·8	0·10	−0·8	5·0	+0·41	F	
6	Swept-wing ..	12·5	0·175	45·5	10·4	−0·07	11·8	0·09	−0	11·8	+0·06		
7	*Firefly* 4 ..	12	0·28	68	10	0	12	0·13	−3·3	8·7	−0·34	P	Cleared to four turns
8	*Fury*	12	0·255	55	10	+0·03	12·3	0·12	−2·5	9·8	−0·5	P	
9	*Harvard* ..	14·2	0·480	65	10·3	+0·03	12·8	0·135	−3·0	11·5	−0·5	B	Fails full-scale at aft c.g.
10	*Meteor* 7 ..	25·5	0·22	60	21·3	+0·09	27·5	0·105	−1·2	26·3	−0·7	P	
11	*Meteor* 8 ..	21·0	0·174	50	0	—	21·0	0·105	−1·0	20	−0·6	P	
	Meteor 8 ..	21·0	0·152	50	—	—	21·0	0·105	−1·0	20	−1·2	P	
12	Straight-wing	16	0·2	54	13·4	+0·22	19·0	0·10	−0·8	18·2	−1·0	P	
13	*Prentice* ..	28·5	0·62	68	23·8	−0·07	26·8	0·14	−4·1	22·7	+0·06	B	Prototype fails full-scale
14	*Provost* ..	17·5	0·32	60	0	—	17·5	0·14	−4·1	13·4	−1·02	P	
15	*Sea Fury* ..	10·5	0·28	60	8·8	0	10·5	0·12	−2·5	8	−0·34	P	Cleared to four turns
16	Swept-wing ..	12·2	0·115	44	10·2	+0·22	14·4	0·10	−0·8	13·6	−1·06	P	
17	Straight-wing	15·0	0·3	48	0	—	15·0	0·10	−0·8	14·2	+0·23	B	Some aircraft had extremely long recovery times
18	Straight-wing	4	0·17	40	0	—	4·0	0·13	+3·3	0·7	−0·75	P	
19	Swept-wing ..	9·0	0·13	44	0·7	0·05	9·5	—	—	9·5	−1·6		
20	*Night Hawk* ..	19½	0·48	—	16·5	−0·05	18·5	0·146	−4·5	14·0	−0·01	B	
	Night Hawk ..	23			19·2	−0·05	22·0	0·146	−4·5	17·5	−0·01	P	
21	*Magister* ..	13·5	0·42		11·3	+0·02	13	0·145	−4·5	9	−0·5	F	
	Magister ..	22	0·42		18·5	+0·02	21·5	0·145	−4·5	17·5	−0·5	P	
22	*Spitfire* ..	15	0·31		12·5	0	15·0	0·11	−2	13	−0·29	P	
23	*Defiant* ..	16	0·3		13·5	+0·25	19·3	0·15	−5	+14·3	−1·12	P	
24	*Australian Trainer*	27	0·6		22·6	0	27	—	—	—	−0·24	P	
25	*Miles M*20 ..	6	0·26		5	−0·06	5·5	0·168	−7	− 1·5	+0·02	F	
	*Miles M*20 ..	8			6·7	−0·06	7·5	0·168	−7	+ 2·5	+0·02	B	
	*Miles M*20 ..	22			18·5	−0·06	21	0·168	−7	14	+0·02	P	
26	*Moth Minor* ..	24·5	0·615		20·5	−0·03	24	0·166	−6·5	18	−0·2	B	
27	*Hurricane* ..	14·5	0·395		12·0	0	14·5	0·158	−5	9·5	−0·3	B	
28	*Miles M*18 ..	24	0·55		20	+0·02	23·5	0·175	−7·5	16·5	−0·47	B	
	*Miles M*18 ..	31	0·55		26	+0·02	30·5	0·175	−7·5	23·5	−0·47	P	
29	*Oxford* ..	16·0	0·25					0·12		12·6	+0·4	B	There is very little information available on these aircraft
30	*Skua*	9·4	0·32					0·122		+ 2·0	−1·3	B	

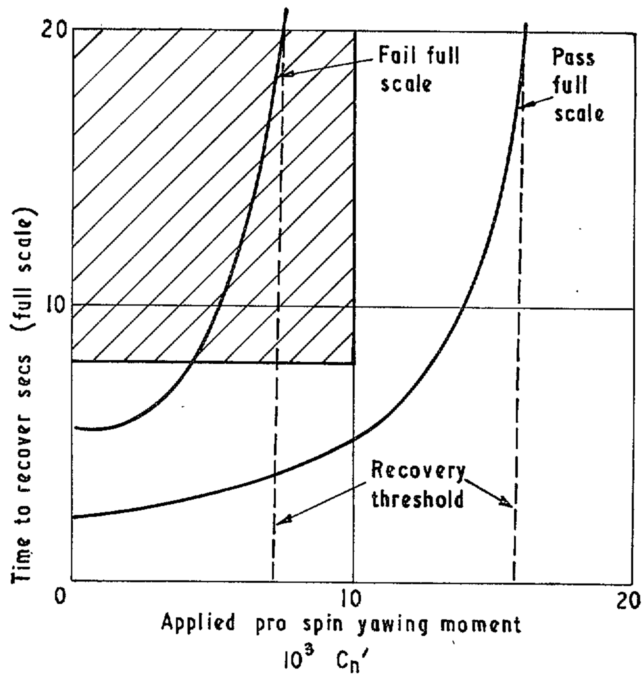


FIG. 1. Model spinning standards.

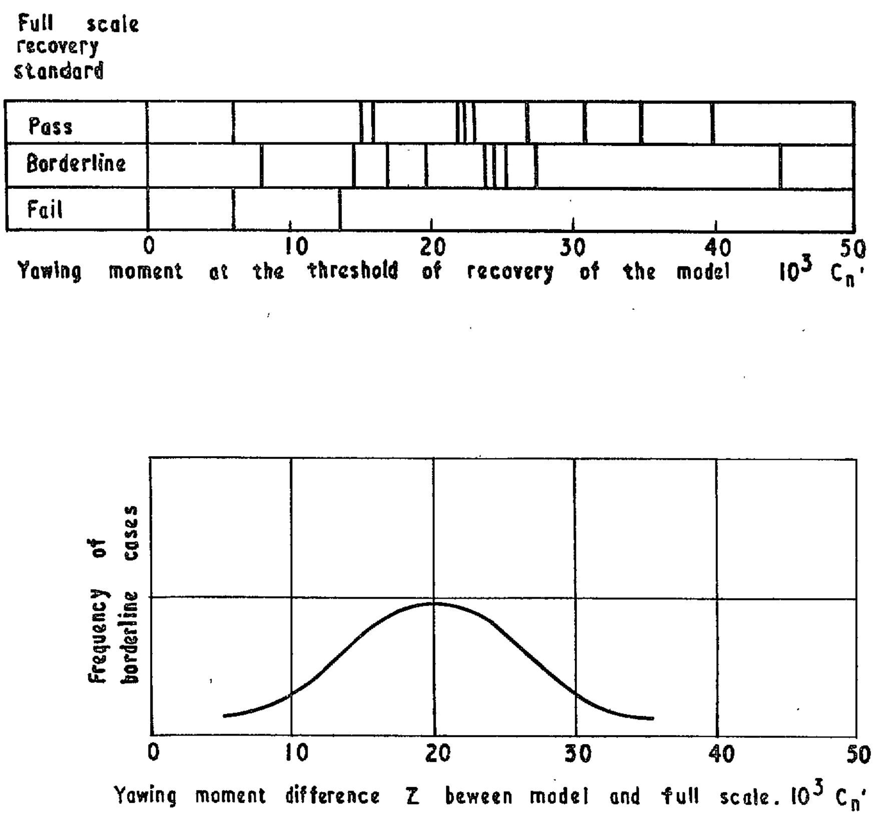


FIG. 2. The comparison of model and full-scale recoveries and the distribution of border-line cases.

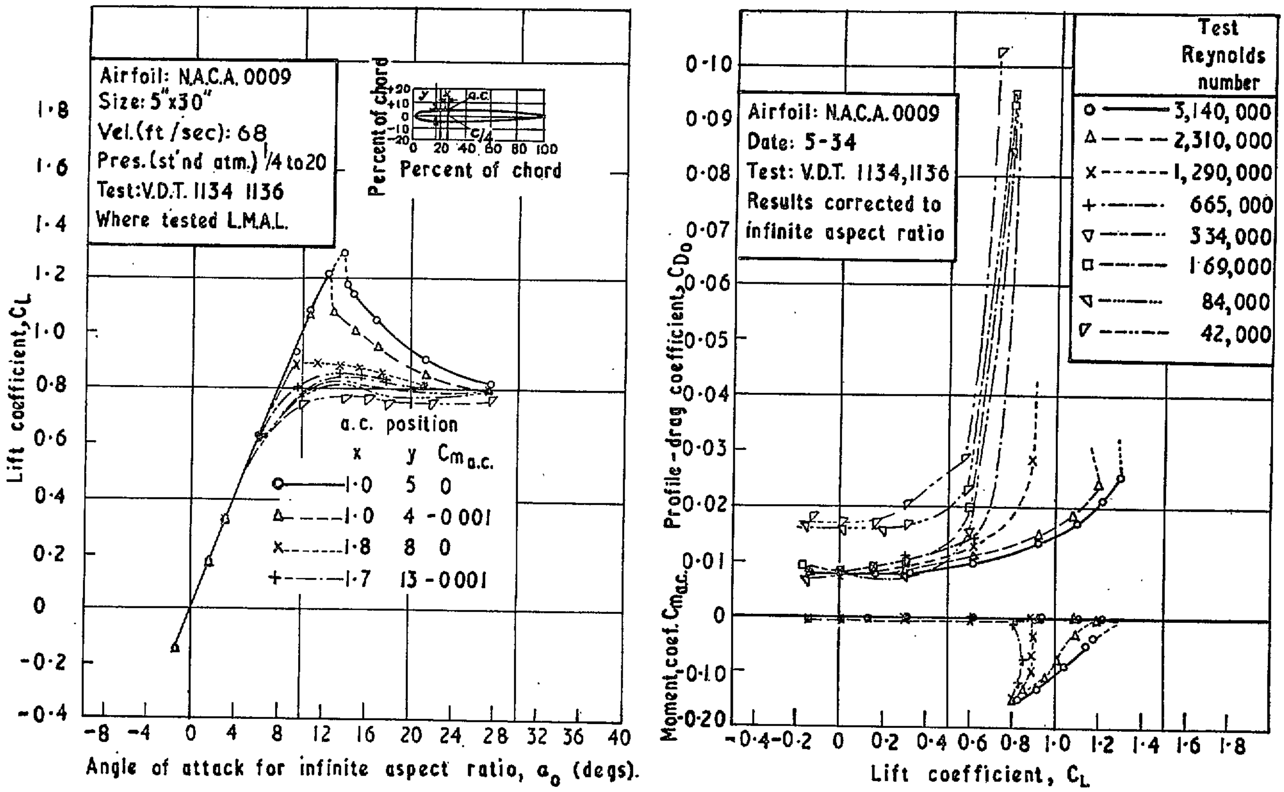


FIG. 3. Variation of C_L and C_D with Reynolds number on a wing of 0009 section.

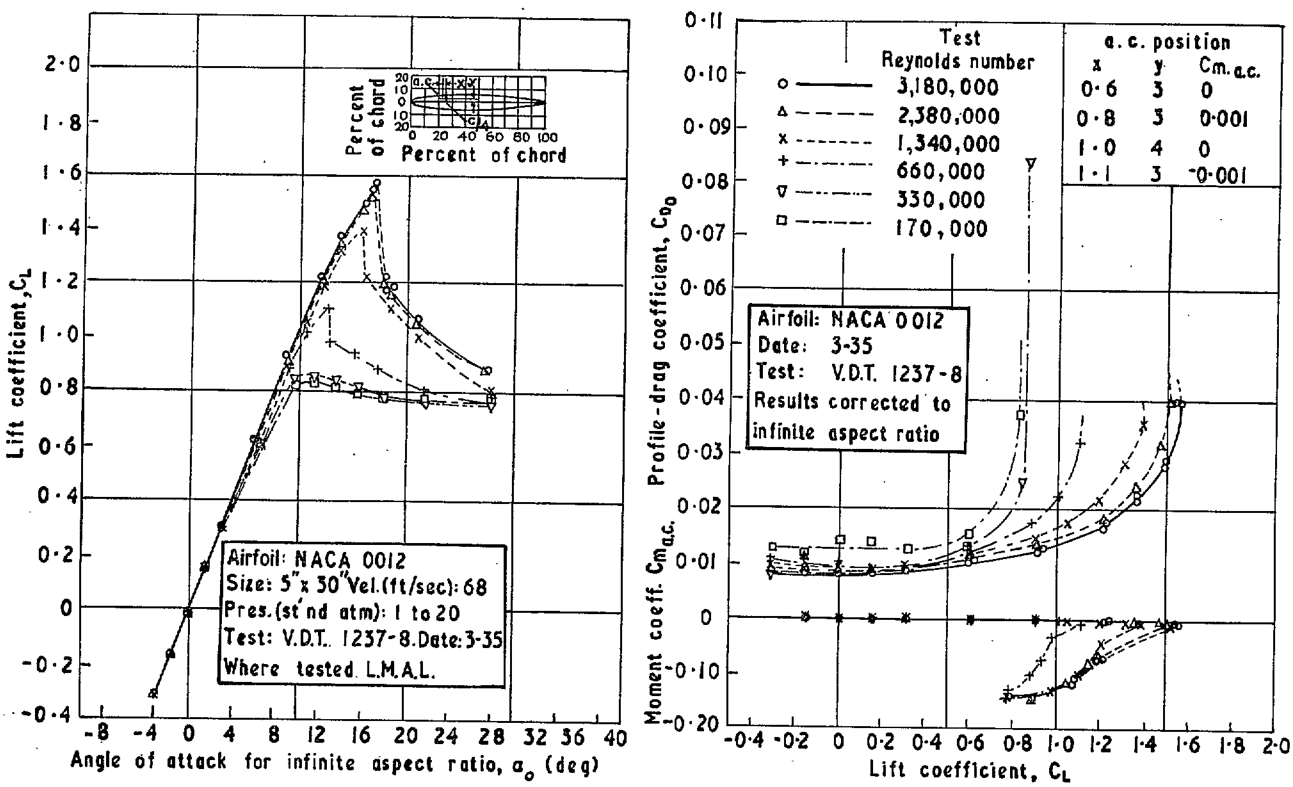


FIG. 4. The variation of C_L and C_D with Reynolds number on a wing of 0012 section.

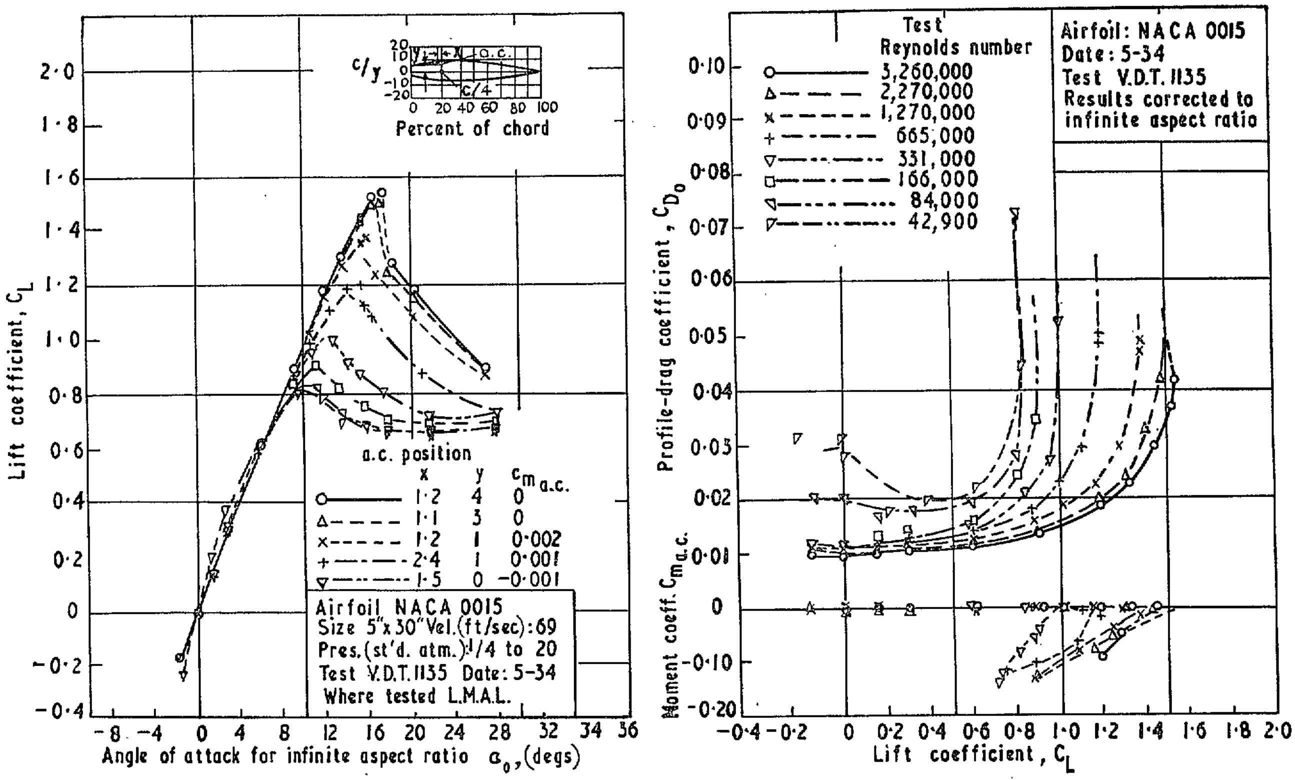


FIG. 5. The variation of C_L and C_D with Reynolds number on a wing of 0015 section.

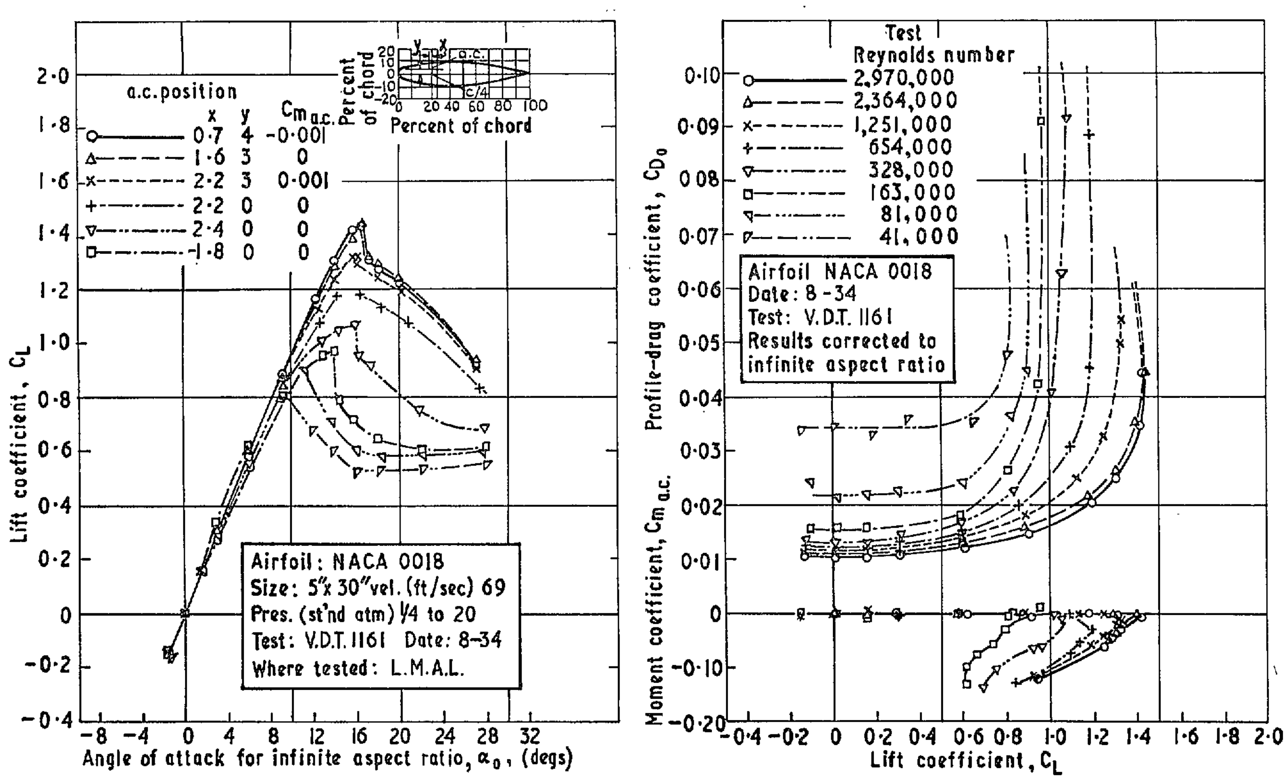
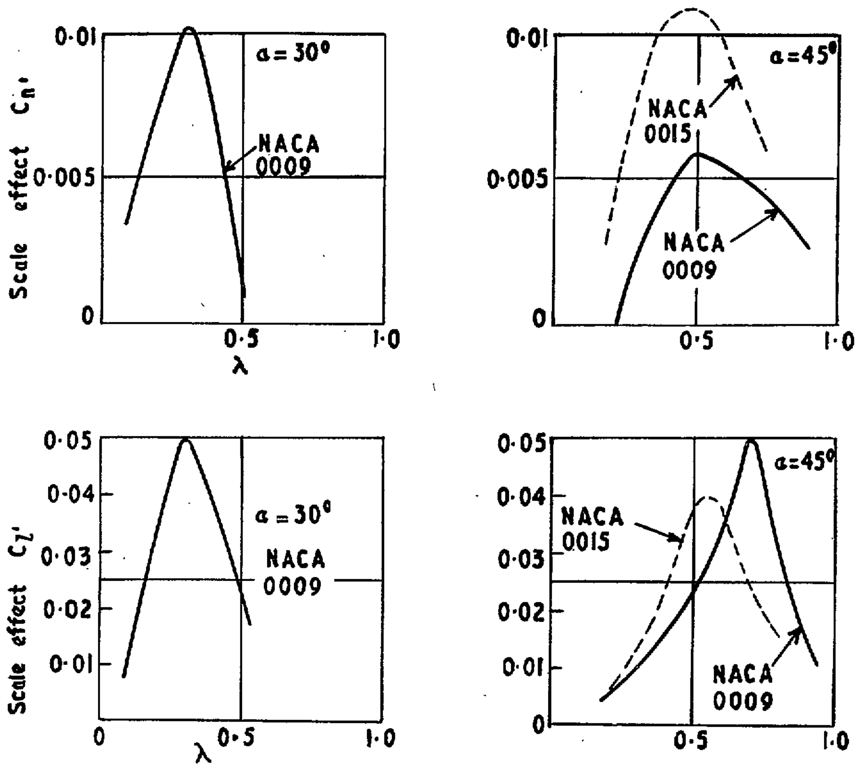


FIG. 6. The variation of C_L and C_D with Reynolds number on a wing of 0018 section.



Calculated for a full scale Reynolds № of $3{\cdot}1 \times 10^6$ and a model scale Reynolds № of $3{\cdot}3 \times 10^5$ wing of rectangular planform.

FIG. 7. Wing scale effect in the spin.

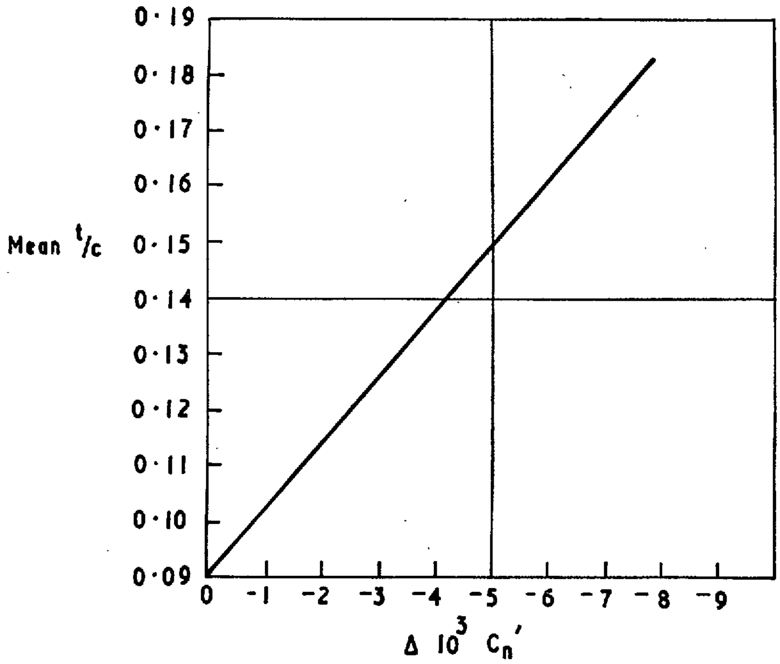


FIG. 8. Correction of recovery threshold for t/c.

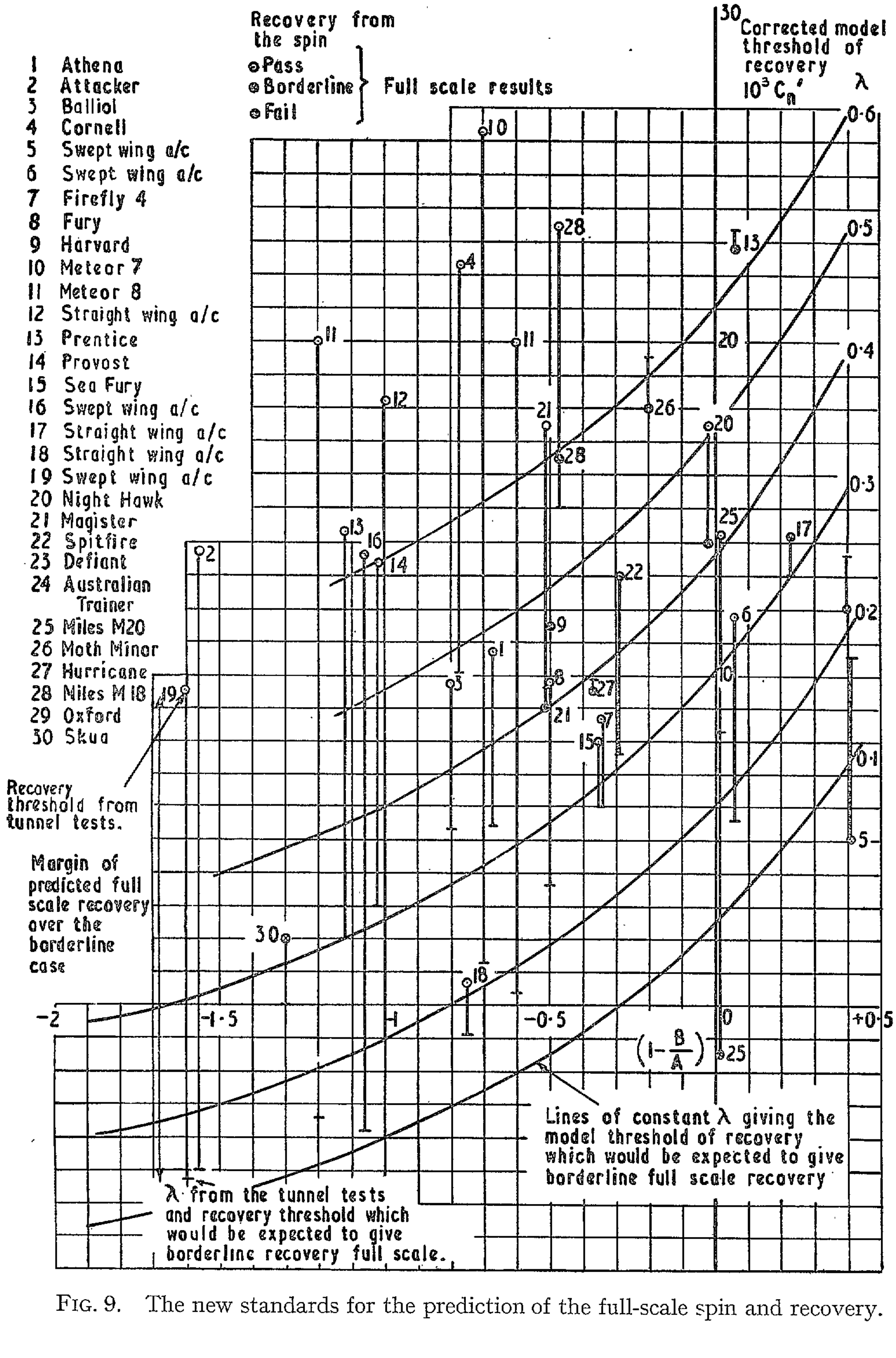


FIG. 9. The new standards for the prediction of the full-scale spin and recovery.

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