EFFECT OF STAGGER AND DECALAGE ON BIPLANE COMBINATIONS OF THICK AIRFOILS AT HIGH ANGLES OF INCIDENCE

by

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I. Introduction

There have been previously made a considerable number of tests on effect of stagger and decalage on biplane combinations in different countries and especially in England. As far as it is known, however, there have been no tests made upon biplane combinations of thick airfoils.

Modern practice of airplane design, especially in commercial aviation, where the question of maximum pay-load carried is the one of necessity, turns its attention once and again to airfoils of high lift, which would permit a higher wing loading and hence reduced wing area without sacrificing the landing speed.

The class of the wing sections possessing a much higher maximum lift coefficient is that of thick airfoils.

The most important and immediate problem in commercial aviation, which (problem) goes together if not ahead of the question of getting more revenue, is that of safety of operation, which in its turn insistently reminds us that there is still a great deal to do in order to make flying absolutely safe.

It is well known that there is some danger of stalled flight, as it brings the machine to the very border, where the autorotation can start and further develop into the spin, - a manoeuver undoubtedly extremely hazardous for an airplane.

In a steady flight compensation for decrease of speed is given by increase of angle of attack to secure lift capable of sustaining the airplane. It is no longer true after the angle of attack corresponding to maximum lift is passed, as with speed

decreased the increase of angle of attack causes still further drop in lift. Airplane begins to descend rapidly, which in conjunction with loss of control and possible small disturbance may result in a spin. As there are on record quite a number of the accidents which occured due to non-recovery from a spin, the analysis of that question becomes of vital importance.

II. Object of investigation and limits of work

The main purpose of the research was to discover whether there is any possibility to reduce, if not to prevent entirely, the liability to spin by the use of a proper biplane combination of thick airfoils, for which, as was suggested by Professor E. P. Warner, solution might easier be found.

The investigation aimed to give an estimation of the characteristics of wing combinations of thick airfoils at various stagger, decalage and also gap to chord ratio, and bring out qualities beyond the critical angle and aerodynamic efficiency within the ordinary flying range.

The tests were confined to the limits of angle of attack between +10° and +32°, within which region only autorotation can take place and all the properties of a combination in this respect can be fully displayed.

III. Airfoils used and methods of attack

Experiments were conducted in the Massachusetts Institute of Technology 4 foot Wind Tunnel on NPL balance at constant speed

40 mph. with standard 18" x 3" Göttingen 387 steel airfoils of constant chord and thickness ratio.

An attempt was made to cover as broad range of different combinations of stagger, decalage and gap to chord ratio as it was deemed rational and justifiable. It was intended also to make a number of runs with increased speed, which, unfortunately, could not be done due to the possibility of overstraining the balance.

The method of approaching to the solution of the problem is at once suggested by the consideration of the fact that the probability of stalling is more possible with a machine with well pronounced burble point or sharp peak of Zc curve than when this curve at the critical angle is more flat.

For this reason the results were considered and inferences made on the base of the shape of Zc curves (coefficient of the normal force versus angle of attack), which were plotted for each combination tested.

The criterion of greater or less tendency to autorotation of a biplane combination was the shape of Zc curve in the region of its maximum. Namely, the combination with furthermost maximum point for the curve, which in the same time is itself well flattened on a considerable range of angle of attack before Zc maximum, can be judged as the best for non-spinning qualities. The magnitude of Z force itself has no immediate influence upon the non-spinning qualities of a combination, but it clearly shows in what direction its aerodynamic characteristics are affected. Drop of Zc at lower

angles means a loss of lift, possible decrease of $\frac{L}{D}$ thereby affecting the performance of the airplane.

The best all-around combination is therefore that which has Zc curve with higher ordinates, with pronounced flattening at a considerable range of angle of attack and furthermost point of maximum.

IV. Adjustable jig for assembling the model and apparatus for supporting it in Wind Tunnel

At the very outset of the conducting research the writers were confronted with the question how to secure the accuracy of settings of the wings for different stagger, decalage and gap to chord ratio. Arrangements used by earlier investigators of the similar problem for thin airfoils were either cumbersome and inconvenient through the necessity of being placed in the Wind Tunnel together with model (R & M 872) or were not able to secure beforehand the desired values of variables for a given combination at a time, as in earlier German, British, and American tests (see Reference List).

And yet upon the precision of the work, especially in decalage changes, where the difference of such a small value of an angle as 1-1/2° between two successive settings of wings was required, depended the whole result of investigation. The necessity of having some kind of device enabling the rapid assembly of the wing combination at any desired set of variables was especially urgent because a broad range (nearly 90) of different combinations

was planned to be investigated.

Such a device was worked out on the principle of an adjustable jig, and is adaptable to rapid dismantling and assembling of the airfoils for any desired set of the assumed variables.

The definitions of stagger, decalage and gap as they are given in N.A.C.A.T.R. No. 157 were put in the foundation for constructing the jig, which with model assembled for stagger +25%, decalage +4° and $\frac{G}{C} = 1.25$ is shown in Fig. 9.

As the stagger, decalage and gap are the three variables, properties of which are to be analyzed, it is worthwhile to give their definitions here for ready reference of the reader.

Stagger is the amount of advance of the leading edge of an upper wing of a biplane over that of a lower, expressed as a percentage of gap or in degrees of the angle whose tangent is the percentage just referred to. It is considered positive when the upper wing is forward, and is measured from the leading edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the leading edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry.

A little retreatment from this definition was made in expressing the stagger as percentage of the chord instead of that of the gap, as is often the case in practice and which is the most convenient here, because the chord was kept constant throughout the whole investigation, while the gap was one of the

three fundamental variables.

Decalage is the acute angle between the wing chords of a biplane. It is positive if the angle divergent forward, and negative in the opposite case.

Gap is the distance between the planes of the chords of the upper and lower wings of a biplane, measured along a line perpendicular to the chord of the upper wing at any designated point of its leading edge.

The jig can be applied to any kind of wing sections, either of the same or different chords, and for any set of stagger, decalage and $\frac{G}{C}$ ratio.

It consists of two main parts (Fig. 1 and Fig. 2), made in pairs either of wood, or preferably, of metal, and of a number of blocks (Fig. 3, 4, 5, 6 and 11) of different height for various $\frac{G}{C}$ ratios and of different angle of inclination of the upper surface for various decalages. All these blocks are also in pairs as is seen from Fig. 8.

The application of the device to the assembling of any kind of biplane combination is clearly understood from the consideration of Fig. 7. Lines a, b, c, d, etc. determine the position of leading edge of the lower wing for a required stagger; a block inserted between upper and lower main parts gives a desired $\frac{\text{gap}}{\text{chord}}$ ratio; and a bevel block (or with parallel edges for zero decalage) placed under the lower wing furnishes a necessary decalage. Upper wing is always in the same position.

After the wings are properly placed they are rigidly tied up by the wedges of soft wood, while a connecting strut (see Fig. 10) on the top and an adjustable cross-bar on the bottom are set up and tightly fastened to the wings. The model then takes a form of a rigidly connected system, can be taken out of the jig and placed in the Wind Tunnel.

The cross-bar (Fig. 12) was designed by the members of the Wind Tunnel Staff of M. I. T. and was used before in similar experiments. Its movable blocks on parallel guides are set apart at such a distance as to bring the ends of wing spindles right into the holes of those blocks (Fig. 10).

V. Corrections due to supporting apparatus

These corrections included the effect due to the resistance offered by the apparatus to the relative flow of the air and interference effect due to spindles altering the airflow about the tip of the model. To obtain the effect of apparatus upon the drag and lift it was tested alone in the ordinary way with the wind on over the whole range of incidences. To compensate for interference effect both spindles were projected by 7/8" longer than when with wings, as the practice of that Wind Tunnel established. Two runs were made: with spindles in the most outward position, corresponding to maximum gap, and in most inward position, that for the minimum gap. Average value of drag was taken giving inappreciable error (1.6% maximum). Zero readings (with no wind) for the model appeared different for each angle of

attack, the difference though being small. Here also average zero reading was taken with negligible error (1.15% the highest). Such small errors are well permissible in the case under consideration where relative merits of combinations are compared, the exact absolute magnitudes of the coefficients not being of importance.

VI. Presentation and discussion of results

The results are presented in the form of tables 1 - 11, charts 1-12 and a subjoined diagram, showing the relative merits of the various wing combinations as regard to non-spinning qualities and aerodynamic features as well.

All coefficients are expressed in pounds per square foot per mile per hour and were calculated by the usual formulae:

$$Lc = \frac{L}{2S\,V^2}$$

$$Dc = \frac{D}{2S\,V^2}$$

$$Zc = Lc\,\mathrm{Cos}\alpha + Dc\,\mathrm{Sin}\alpha$$

The beginning and end of autorotation was determined by the equation:

$$\frac{dLc}{d\alpha} + Dc = 0$$

The character of the airflow, as set up by a given combination, is indicated also. The property of the combination to create a smooth steady flow of the air around itself may

possibly prevent the turning of the airplane into a spin in a stalled flight, when a small disturbance is sufficient to start spinning. Unfortunately, this quality is possessed in a greater degree by the combinations, which are perhaps the worst both from non-spinning and aerodynamical points of view. They are those with negative stagger and negative decalage. The steadiness of the airflow, however, around these combinations was remarkable; permitting the reading of drag to the third decimal figure with ease, and almost no turbulent effect was present.

The most unfavorable combination in this respect is that with stagger 0%, which, except for higher $\frac{G}{C}$ ratio and positive decalage, furnished the most turbulent flow of the air, preventing any measurements beyond the critical angle. As a rule zero stagger, combined with low gap-chord ratio and negative decalage (also high gap-chord ratio and large negative decalage) gives a combination very poor aerodynamically with no good non-spinning qualities either. Change to positive decalage together with the introduction of high gap-chord ratio improves very considerably aerodynamic characteristics of the combination (combinations nos. 19, 20, 29, 46, 50 and 51), though not decreasing much its tendency to spin.

Combination No. 50 with zero stagger, + 2-1/2° decalage and $\frac{G}{C}$ = 1.25 is the best aerodynamically of all tested and has a limited (though not a short one) range of autorotation, but unfortunately autorotation starts at an early angle of attack (20°).

Introduction of positive stagger (charts nos. 11 and 12) together with low gap-chord ratio and negative decalage give the best combinations as far as non-spinning qualities are concerned, whereas aerodynamically they are not as good. (Combinations nos. 1, 2, 3, 4, etc.) On the other hand positive stagger combined with high gap-chord ratio and positive decalage give combinations much better aerodynamically but poor with respect to early angle of autorotation, though the range of autorotation is the shortest. (Combinations nos. 67, 68, 56, etc.)

Effect of gap-chord ratio is not appreciable as far as autorotation is concerned, except for zero stagger and high positive decalage (chart No. 10, combinations nos. 12, 19 and 51), but is of importance aerodynamically. As it might be anticipated, the higher gap-chord ratio gives the greater values for Zc due to the fact that shielding effect of the lower wing on the upper one is decreased. This is, however, not true in all instances (chart no. 9) due to influence of varying stagger and decalage, the last one being probably responsible for rather erratic and not quite consistent curves of effect of gap to chord ratio.

As to the effect of decalage, the consistency here is almost complete, perhaps without any exceptions. Namely, negative decalage is very favorable for non-spinning qualities of the combination, shifting the maximum point of Zc curve to the right, whereas it considerably decreases the aerodynamic efficiency of combination within flying range of angle of attack. On the other

hand, positive decalage greatly improves aerodynamical characteristics of the combination, but increases its tendency to spin in a very marked degree.

That rule does not step out clearly with high negative stagger due to a great shielding effect, but is very well pronounced for high positive stagger (charts nos. 2, 3, 4, 7, 8).

VII Final conclusions

Conclusions are not of a very satisfactory sort, as, unfortunately, for a combination to possess a quality of the least tendency to spin at high angles, means to be very poor aerodynamically for angles within the ordinary flying range. To improve the non-spinning qualities of a biplane combination means to make a material sacrifice in lift.

The best non-spinning combination, which begins to autorotate as late as 26°, is that of +25% stagger, .75 gap to chord ratio and -2-1/2° decalage.

The least range of autorotation has the combination of +50% stagger, 1.00 gap to chord ratio and +4° decalage.

The best combination aerodynamically is 0% stagger, 1.25 gap to chord ratio and +2-1/2° decalage.

As a compromise the best all-around combination is +50% stagger, 1.00 gap to chord ratio and -2-1/2° decalage (no.3), which combines the average values of lift (between those of very high and very low) and sufficiently late start of autorotation (24°).

As an alternative, a combination of less steady airflow with the rest of the things being the same as before mentioned is that of +25% stagger, 1.00 gap-chord ratio and -1-1/2° decalage (no. 7).

As to the airfoil alone, representing the properties of a monoplane, it is seen from chart and table no. 1 and subjoined diagram ("Combination" no. 40) that airfoil alone occupies almost exactly the middle position between the two extremes of biplane with respect to tendency to autorotation and in the same time possesses very high aerodynamic characteristics for angles of flying range. The autorotation range of the airfoil alone is very limited also. These are very considerable advantages which speak in favor of monoplane and may give explanation of the extensive use and success obtained by monoplanes with thick airfoils.

The experiments made can not be absolutely conclusive, as other wing sections might be more favorable than that employed, also there may be an advantage in using two wings of different sections and different chords. Some influence might be expressed from transverse overhand of the upper wing, change of aspect ratio, etc.

It should be noted also that in computing coefficients no account was taken of the change of lift and drag at the wing tips; therefore, the conclusions can only be regarded as showing the type of result to be expected and not the actual numerical values.

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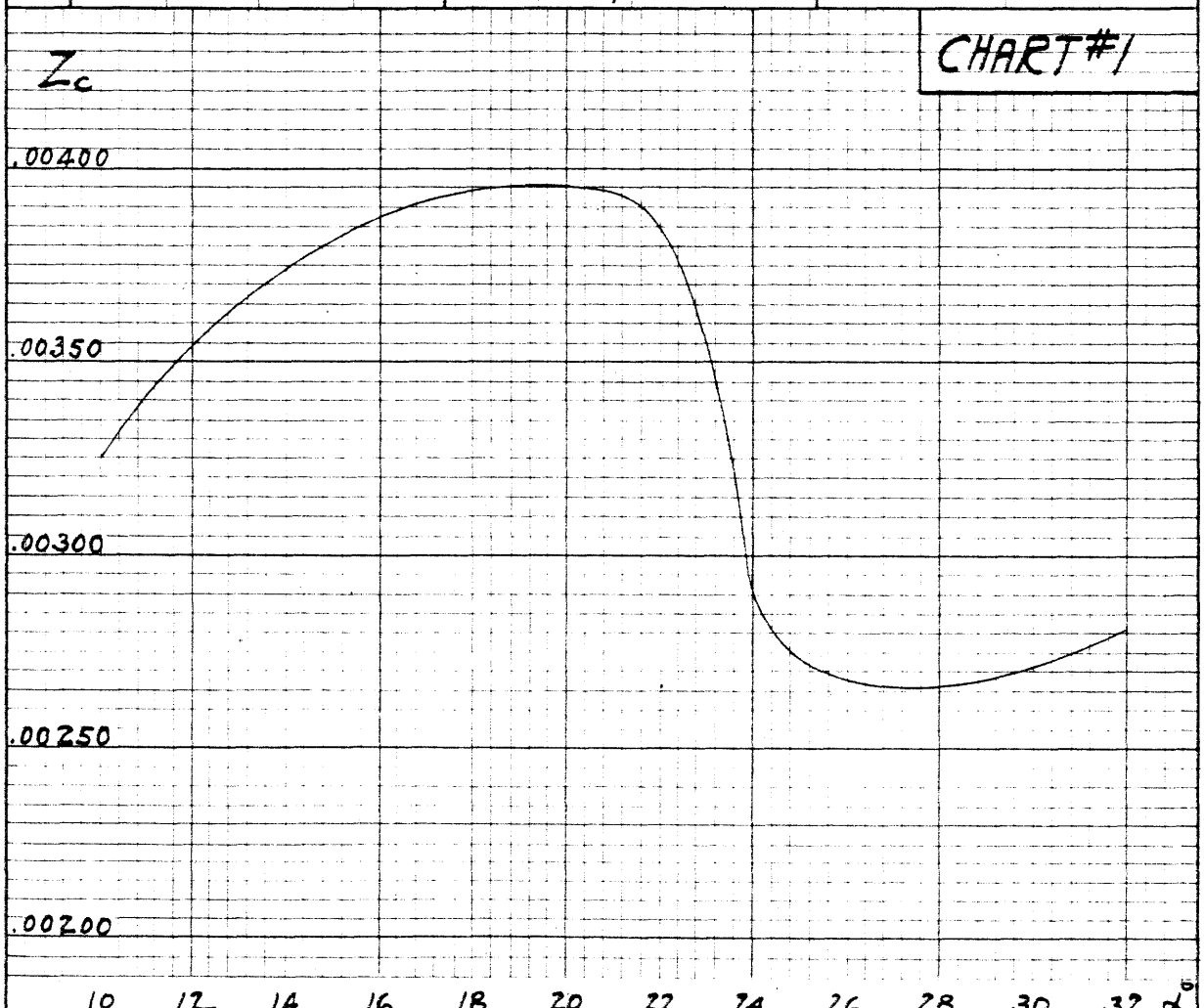
TABLE #1

GÖTTINGEN 387 ALONE

α°	SPEED 30 M.P.H.				SPEED 40 M.P.H.				SPEED 50 M.P.H.			
	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE
10					.00325	.00028	.00326					
12					.00353	.00033	.00353					
14					.00374	.00038	.00375					
16					.00389	.00045	.00386					
18					.00396	.00051	.00393					
20					.00399	.00061	.00396	20° BEGINS				
22					.00385	.00074	.00385					
24					.00271	.00110	.00292					
26					.00235	.00127	.00267	26° STOPS				
28					.00234	.00133	.00269					
30					.00230	.00144	.00271					
32					.00234	.00157	.00282					

CHART #1



NOTE: EVERYWHERE IN THIS THESIS COEFFICIENTS ARE POUNDS PER SQUARE FOOT PER MILE PER HOUR

TABLE #2

STAGGER = +100%

GAP / CHORD = 1.00

α°	DECALAGE = +2½° Lc	Dc	Zc	AUTOR RANGE
10	.00332	.00040	.00336	
12	.00364	.00048	.00365	
14	.00390	.00057	.00393	
16	.00413	.00066	.00415	16° BEGINS
18	.00427	.00081	.00431	
20	.00380	.00111	.00396	
22	.00359	.00121	.00379	22° STOPS
24	.00359	.00133	.00382	
26	.00355	.00142	.00382	
28	.00355	.00153	.00386	
30	.00356	.00165	.00391	
32	.00353	.00175	.00394	

α°	DECALAGE = -2½° Lc	Dc	Zc	AUTOR RANGE
10	.00305	.00034	.00307	
12	.00339	.00041	.00340	
14	.00374	.00048	.00375	
16	.00404	.00057	.00402	
18	.00424	.00064	.00417	
20	.00442	.00075	.00442	22° BEGINS
22	.00441	.00084	.00442	
24	.00387	.00113	.00400	
26	.00368	.00126	.00386	
28	.00357	.00138	.00381	
30	.00354	.00150	.00381	
32	.00346	.00163	.00381	

STAGGER = +75%

GAP / CHORD = 1.00

α°	DECALAGE = +2½° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = -2½° Lc	Dc	Zc	AUTOR RANGE
0	.00152	.00012	.00152		.00106	.00009	.00105	
2	.00192	.00016	.00191		.00138	.00011	.00139	
4	.00223	.00021	.00217		.00177	.00014	.00180	
6	.00257	.00026	.00259		.00214	.00018	.00215	
8	.00292	.00032	.00286		.00247	.00023	.00240	
10	.00327	.00040	.00330		.00302	.00031	.00303	
12	.00353	.00046	.00347		.00339	.00039	.00332	
14	.00382	.00056	.00384		.00368	.00045	.00368	
16	.00402	.00064	.00404	16° BEGINS	.00393	.00053	.00393	
18	.00412	.00076	.00416		.00414	.00060	.00411	
20	.00380	.00102	.00393		.00429	.00069	.00428	22° BEGINS
22	.00349	.00116	.00368		.00432	.00079	.00431	
24	.00343	.00128	.00366		.00422	.00091	.00423	
26	.00339	.00138	.00366	26° STOPS	.00367	.00119	.00391	
28	.00339	.00146	.00369		.00347	.00131	.00370	
30	.00331	.00156	.00365		.00338	.00143	.00365	30° RETAR.
32	.00331	.00165	.00370		.00331	.00153	.00362	

STAGGER = +50%

GAP / CHORD = .75

α°	DECALAGE = +2½° Lc	Dc	Zc	AUTOR RANGE
10	.00303	.00035	.00305	
12	.00330	.00041	.00332	
14	.00354	.00049	.00354	
16	.00373	.00058	.00374	
18	.00386	.00068	.00388	20° BEGINS
20	.00385	.00079	.00389	
22	.00329	.00107	.00344	24° RETAR.
24	.00312	.00119	.00334	
26	.00304	.00126	.00329	
28	.00297	.00134	.00326	28° STOPS
30	.00298	.00142	.00330	
32	.00298	.00151	.00334	

α°	DECALAGE = -2½° Lc	Dc	Zc	AUTOR RANGE
10	.00285	.00030	.00282	
12	.00316	.00036	.00317	
14	.00346	.00044	.00346	
16	.00372	.00051	.00372	
18	.00393	.00057	.00392	
20	.00412	.00066	.00410	
22	.00412	.00074	.00411	24° BEGINS
24	.00411	.00082	.00411	
26	.00361	.00114	.00376	
28	.00331	.00126	.00352	
30	.00322	.00137	.00348	
32	.00312	.00144	.00342	

TABLE #3

STAGGER = +50%

$\frac{GAP}{CHORD} = 1.00$

α°	DECALAGE = +2½° L_c	D_c	Z_c	AUTOROT RANGE	DECALAGE = −2½° L_c	D_c	Z_c	AUTOROT RANGE
0	.00148	.00013	.00148		.00134	.00009	.00135	
2	.00182	.00017	.00183		.00169	.00013	.00169	
4	.00214	.00021	.00215		.00208	.00017	.00208	
6	.00249	.00025	.00251		.00240	.00022	.00243	
8	.00281	.00031	.00282		.00274	.00027	.00268	
10	.00322	.00039	.00324		.00297	.00032	.00299	
12	.00356	.00045	.00358		.00328	.00038	.00323	
14	.00390	.00052	.00391		.00350	.00044	.00351	
16	.00391	.00060	.00393		.00381	.00052	.00381	
18	.00405	.00071	.00408	20° BEGINS	.00403	.00059	.00402	
20	.00405	.00081	.00409		.00413	.00066	.00411	
22	.00349	.00108	.00365		.00413	.00075	.00412	
24	.00329	.00119	.00349		.00412	.00089	.00413	24° BEGINS
26	.00325	.00127	.00348	26° STOPS	.00363	.00116	.00378	
28	.00322	.00136	.00347		.00330	.00130	.00353	
30	.00314	.00143	.00344		.00319	.00136	.00344	30° RETAR
32	.00313	.00155	.00348		.00305	.00154	.00341	

α°	DECALAGE = +4° L_c	D_c	Z_c	AUTOROT RANGE	DECALAGE = +1½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00323	.00040	.00325		.00303	.00033	.00305	
12	.00356	.00047	.00352		.00330	.00040	.00331	
14	.00367	.00054	.00369		.00359	.00047	.00359	
16	.00381	.00063	.00384	18° BEGINS	.00380	.00054	.00380	
18	.00390	.00075	.00394		.00392	.00062	.00392	
20	.00343	.00099	.00356		.00400	.00072	.00401	20° BEGINS
22	.00319	.00111	.00338	22° STOPS	.00388	.00085	.00393	
24	.00316	.00118	.00336		.00339	.00110	.00350	
26	.00316	.00129	.00341		.00327	.00119	.00347	27° STOPS
28	.00312	.00137	.00341		.00323	.00128	.00346	
30	.00310	.00146	.00342		.00314	.00137	.00341	
32	.00305	.00153	.00341		.00309	.00146	.00340	

α°	DECALAGE = −1½° L_c	D_c	Z_c	AUTOROT RANGE	DECALAGE = −4° L_c	D_c	Z_c	AUTOROT RANGE
10	.00292	.00031	.00294		.00270	.00028	.00272	
12	.00320	.00037	.00321		.00301	.00033	.00301	
14	.00353	.00043	.00353		.00331	.00040	.00331	
16	.00373	.00050	.00373		.00355	.00046	.00354	
18	.00393	.00057	.00390		.00385	.00053	.00383	
20	.00406	.00064	.00403		.00399	.00060	.00396	
22	.00411	.00073	.00407	22° BEGINS	.00404	.00066	.00403	
24	.00401	.00086	.00401		.00415	.00076	.00407	24° BEGINS
26	.00348	.00110	.00353		.00402	.00086	.00400	
28	.00322	.00124	.00347	28° RETAR	.00356	.00110	.00367	
30	.00315	.00133	.00340		.00320	.00128	.00340	
32	.00306	.00143	.00336		.00282	.00150	.00320	

TABLE #4

STAGGER = +50%

GAP / CHORD = 1.25

α°	DECALAGE = +2½° Lc	Dc	Zc	AUTOR RANGE
10	.00328	.00039	.00331	
12	.00352	.00045	.00353	
14	.00374	.00052	.00375	
16	.00387	.00059	.00388	
18	.00397	.00069	.00399	18° BEGINS
20	.00372	.00086	.00380	
22	.00330	.00105	.00347	
24	.00322	.00113	.00340	23° - 28° RETARDED
26	.00314	.00122	.00337	
28	.00308	.00130	.00333	
30	.00292	.00143	.00324	
32	.00259	.00171	.00311	

α°	DECALAGE = -2½° Lc	Dc	Zc	AUTOR RANGE
10	.00283	.00030	.00285	
12	.00314	.00036	.00315	
14	.00347	.00042	.00346	
16	.00372	.00049	.00372	
18	.00391	.00056	.00389	
20	.00405	.00062	.00402	
22	.00408	.00071	.00406	22° BEGINS
24	.00404	.00082	.00403	
26	.00357	.00103	.00367	
28	.00318	.00119	.00336	
30	.00276	.00142	.00311	
32	.00257	.00160	.00303	

STAGGER = +25%

GAP / CHORD = .75

α°	DECALAGE = +4° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = +2½° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = +1½° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = 0° Lc	Dc	Zc	AUTOR RANGE
10	.00306	.00036	.00308		.00305	.00037	.00308		.00290	.00033	.00293		.00284	.00032	.00286	
12	.00330	.00042	.00335		.00330	.00043	.00332		.00322	.00039	.00326		.00319	.00039	.00323	
14	.00347	.00049	.00347		.00342	.00050	.00344		.00344	.00045	.00345		.00343	.00045	.00342	
16	.00364	.00057	.00366		.00360	.00058	.00362		.00359	.00051	.00360		.00360	.00051	.00360	
18	.00372	.00066	.00374	20° BEGINS	.00372	.00075	.00377	20° BEGINS	.00377	.00059	.00377	20° BEGINS	.00379	.00057	.00378	
20	.00378	.00075	.00381		.00377	.00076	.00380		.00395	.00068	.00395		.00389	.00074	.00392	
22	.00306	.00098	.00322		.00333	.00099	.00347		.00387	.00077	.00389		.00391	.00075	.00390	22° BEGINS
24	.00297	.00107	.00316		.00297	.00108	.00316	25° RETARD.	.00350	.00091	.00360		.00385	.00086	.00388	
26	.00284	.00115	.00306	26° STOPS	.00292	.00117	.00315		.00308	.00110	.00328		.00368	.00109	.00341	
28	.00282	.00122	.00307		.00286	.00122	.00311		.00297	.00118	.00318	26½°-30° STOPPED	.00306	.00120	.00326	
30	.00280	.00129	.00308		.00278	.00130	.00306		.00290	.00126	.00314		.00288	.00125	.00313	30° RETAR.
32	.00280	.00137	.00310		.00272	.00136	.00303		.00277	.00133	.00306		.00280	.00132	.00309	

α°	DECALAGE = -1½° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = -2½° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = -4° Lc	Dc	Zc	AUTOR RANGE	DECALAGE = -6° Lc	Dc	Zc	AUTOR RANGE
10	.00287	.00031	.00289		.00250	.00026	.00254		.00264	.00027	.00264		.00239	.00024	.00240	
12	.00313	.00036	.00317		.00280	.00031	.00280		.00293	.00032	.00296		.00271	.00029	.00274	
14	.00341	.00043	.00339		.00306	.00037	.00306		.00314	.00038	.00314		.00296	.00034	.00294	
16	.00363	.00050	.00363		.00331	.00042	.00330		.00350	.00044	.00349		.00326	.00040	.00325	
18	.00385	.00056	.00384		.00359	.00050	.00357		.00372	.00051	.00370		.00353	.00046	.00351	
20	.00388	.00064	.00387	22° BEGINS	.00375	.00056	.00374		.00389	.00057	.00386		.00373	.00053	.00369	
22	.00396	.00073	.00395		.00394	.00062	.00390		.00399	.00066	.00397		.00389	.00060	.00385	
24	.00392	.00083	.00392		.00395	.00071	.00391		.00402	.00075	.00402	24° BEGINS	.00398	.00068	.00392	
26	.00337	.00108	.00351		.00395	.00081	.00391	26° BEGINS	.00392	.00084	.00389		.00400	.00078	.00395	26° BEGINS
28	.00308	.00117	.00327	29° RETAR.	.00384	.00093	.00384		DISCONT.	DISCONT.	DISCONT.		DISCONT.	DISCONT.	DISCONT.	
30	.00295	.00126	.00319		.00331	.00115	.00344		.00308	.00120	.00325		"	"	"	
32	.00286	.00133	.00310		.00302	.00126	.00323		.00274	.00143	.00309		"	"	"	

TABLE #5

STAGGER = +25%

GAP / CHORD = 1.00

α°	DECALAGE = +2½° L_c	D_c	Z_c	AUTOR. RANGE	DECALAGE = −2½° L_c	D_c	Z_c	AUTOR RANGE
0	.00156	.00004	.00157		.00108	.00011	.00109	
2	.00189	.00017	.00190		.00142	.00012	.00142	
4	.00223	.00021	.00224		.00176	.00015	.00176	
6	.00255	.00026	.00258		.00207	.00019	.00209	
8	.00315	.00032	.00286		.00243	.00024	.00237	
10	.00316	.00038	.00319		.00276	.00029	.00279	
12	.00344	.00045	.00344		.00306	.00036	.00307	
14	.00364	.00052	.00366		.00343	.00042	.00343	
16	.00379	.00060	.00382		.00361	.00049	.00361	
18	.00389	.00068	.00391		.00382	.00055	.00381	
20	.00393	.00077	.00396		.00397	.00062	.00395	
22	.00359	.00097	.00370		.00401	.00071	.00399	
24	.00318	.00111	.00338		.00402	.00081	.00401	
26	.00313	.00119	.00334		.00389	.00096	.00392	
28	.00299	.00127	.00324		.00334	.00123	.00370	
30	.00288	.00138	.00320		.00280	.00145	.00315	
32	.00245	.00159	.00293		.00255	.00157	.00301	

24°-25° RETARDED BEGINS

24° BEGINS

GAP / CHORD = 1.25

α°	DECALAGE = +4° L_c	D_c	Z_c	AUTOR RANGE	DECALAGE = 0° L_c	D_c	Z_c	AUTOR RANGE
10	.00318	.00039	.00320		.00299	.00033	.00301	
12	.00337	.00045	.00339		.00330	.00039	.00331	
14	.00352	.00051	.00354		.00355	.00046	.00354	
16	.00371	.00059	.00373		.00375	.00053	.00376	
18	.00381	.00068	.00384		.00389	.00060	.00389	
20	.00380	.00076	.00384		.00401	.00067	.00400	
22	.00341	.00101	.00356		.00403	.00076	.00404	
24	.00308	.00110	.00327		.00397	.00088	.00399	
26	.00304	.00118	.00326		.00341	.00111	.00356	
28	.00301	.00126	.00325		.00306	.00130	.00332	
30	.00292	.00134	.00322		.00271	.00145	.00308	
32	.00255	.00162	.00303		.00246	.00162	.00295	

20° BEGINS

24°-27° STOPPED

22° BEGINS

α°	DECALAGE = −1½° L_c	D_c	Z_c	AUTOR RANGE	DECALAGE = −4° L_c	D_c	Z_c	AUTOR RANGE
10	.00293	.00032	.00297		.00260	.00027	.00261	
12	.00322	.00037	.00323		.00294	.00033	.00299	
14	.00347	.00044	.00348		.00294	.00039	.00320	
16	.00372	.00051	.00372		.00347	.00044	.00346	
18	.00389	.00058	.00388		.00369	.00051	.00367	
20	.00401	.00065	.00399		.00385	.00059	.00382	
22	.00399	.00073	.00399		.00397	.00065	.00394	
24	.00398	.00084	.00400		.00398	.00075	.00394	
26	.00358	.00109	.00370		.00394	.00091	.00378	
28	.00315	.00119	.00335		DISCONT	DISCONT	DISCONT	
30	.00273	.00146	.00311		"	"	"	
32	.00248	.00160	.00295		"	"	"	

24° BEGINS

24° BEGINS

α°	DECALAGE = +2½° L_c	D_c	Z_c	AUTOR RANGE
10	.00326	.00039	.00329	
12	.00353	.00046	.00355	
14	.00372	.00052	.00375	
16	.00390	.00059	.00391	
18	.00402	.00067	.00402	
20	.00402	.00077	.00406	
22	.00370	.00099	.00381	
24	.00329	.00112	.00347	
26	.00314	.00123	.00337	
28	.00306	.00135	.00324	
30	.00268	.00157	.00311	
32	.00242	.00168	.00296	

20° BEGINS

26° RETARDED

α°	DECALAGE = −2½° L_c	D_c	Z_c	AUTOR RANGE
10	.00288	.00030	.00292	
12	.00319	.00036	.00320	
14	.00349	.00043	.00349	
16	.00372	.00049	.00371	
18	.00391	.00056	.00390	
20	.00405	.00064	.00403	
22	.00409	.00072	.00407	
24	.00411	.00083	.00409	
26	DISCONT	DISCONT	DISCONT	
28	"	"	"	
30	"	"	"	
32	"	"	"	

24° BEGINS

TABLE #6

STAGGER = 0%

GAP / CHORD = .75

α°	DECALAGE = +6°			AUTOROT. RANGE	DECALAGE = +4°			AUTOROT RANGE	DECALAGE = +2½°			AUTOROT RANGE	DECALAGE = +½°			AUTOROT. RANGE	DECALAGE = 0°	
	L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c
10	.00300	.00037	.00303		00286	.00036	.00290		.00286	.00034	.00288		00276	.00033	00278		00267	.00030
12	.00318	.00043	.00320		.00310	.00041	.00312		.00311	00039	.00313		.00303	.00039	.00305		.00295	.00035
14	.00332	.00049	.00332		.00330	.00047	00332		.00320	.00045	.00332		.00330	.00044	.00332		.00319	.00041
16	.00347	.00056	.00349		.00344	.00054	.00346		.00348	.00051	.00349		.00345	.00050	.00346		.00341	.00047
18	.00356	.00063	.00358	20° BEGINS	.00355	.00060	.00357		.00362	.00058	.00362		.00361	.00056	.00361		.00359	.00053
20	.00360	.00071	.00364		.00360	.00067	.00362	22° BEGINS	.00365	.00064	.00366	22° BEGINS	.00369	.00063	.00369	22° BEGINS	.00372	.00060
22	.00325	.00091	.00336		.00364	.00075	.00367		.00372	.00072	.00373		.00369	.00071	.00370		.00373	.00068
24	.00284	.00098	.00301		.00356	.00085	.00360		.00360	.00084	00363		.00355	.00080	.00357		DISCONT.	DISCONT.
26	.00277	.00106	00296		.00306	.00104	.00321		DISCONT.	DISCONT.	DISCONT		DISCONT.	DISCONT.	DISCONT		"	"
28	.00271	.00113	.00293		.00280	.00113	.00301		.00289	.00125	.00310		.00291	.00122	.00315			
30	.00230	.00144	.00272		.00224	.00137	.00263	30° STOPS	.00239	.00140	00278		.00244	.00142	.00283			
32	.00214	.00164	.00263		.00224	.00152	.00274		.00225	.00149	.00270		.00229	.00154	.00276			

α°	DECALAGE = −½°			AUTOROT. RANGE	DECALAGE = −2½°			AUTOROT. RANGE	DECALAGE = −4°			AUTOROT. RANGE	DECALAGE = −6°			AUTOROT. RANGE	DECALAGE = 0°	
	L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_s		L_c	D_c	Z_c		Z_c	
10	.00264	.00030	.00265		.00254	.00029	.00256		.00242	.00027	.00243						.00269	
12	.00289	.00036	.00291		.00286	.00035	.00288		.00272	.00033	.00273						.00297	
14	.00314	.00039	.00315		.00310	.00040	.00312		.00298	.00038	.00299						.00320	
16	.00337	.00048	.00337		.00331	.00046	.00331		.00322	.00044	.00322						.00341	
18	.00359	.00053	.00358		.00348	.00052	.00347		.00345	.00051	.00344						.00359	
20	.00368	.00060	.00364	28° BEGINS	.00365	.00059	.00364	22° BEGINS	.00359	.00056	.00357	22° BEGINS					.00371	22° BEGINS
22	.00371	.00070	.00371		.00371	.00066	.00369		.00372	.00064	.00370						.00372	
24	.00335	.00088	.00367		.00338	.00086	.00349		.00343	.00082	.00348						DISCONT.	
26	DISCONT.	DISCONT.	DISCONT.		DISCONT.	DISCONT.	DISCONT.		.00322	.00094	.00332						"	
28	"	"	"		"	"	"		DISCONT.	DISCONT.	DISCONT.						"	
30			"				"		.00249	.00133	.00283						"	
32			"				"		.00231	.00144	.00273						"	

TABLE #7

STAGGER = 0%

GAP / CHORD = 1.00

α°	DECALAGE = +6°				DECALAGE = +4°				DECALAGE = +2½°				DECALAGE = +1½°				DECALAGE = 0°	
	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c
10	.00319	.00039	.00322		.00310	.00036	.00312		.00302	.00035	.00304		.00285	.00032	.00287		.00273	.00030
12	.00338	.00044	.00343		.00339	.00043	.00340		.00324	.00040	.00326		.00316	.00038	.00317		.00307	.00035
14	.00352	.00051	.00352		.00355	.00048	.00358		.00352	.00047	.00353		.00340	.00044	.00341		.00335	.00042
16	.00364	.00058	.00366		.00378	.00072	.00383		.00368	.00054	.00369		.00363	.00051	.00363		.00357	.00048
18	.00375	.00067	.00377	20° BEGINS	.00385	.00072	.00393		.0038l	.00061	.00382		.00380	.00057	.00380		.00380	.00052
20	.00377	.00076	.00381		.00398	.00072	.00402	22° BEGINS	.00385	.00069	.00386		.00386	.00066	.00386		.00384	.00063
22	.00314	.00097	.00328		.00397	.00082	.00399		.00385	.00088	.0039l	22° BEGINS	.00386	.00073	.00387	22° BEGINS	.00385	.00071
24	.00296	.00105	.00314		.00342	.00105	.00356		DISCONT.	DISCONT.	DISCONT.		DISCONT.	DISCONT.	DISCONT.		DISCONT.	DISCONT.
26	.00286	.00111	.00307		.00304	.00111	.00322		"	"	"		"	"	"		"	"
28	.00248	.00139	.00285		.00255	.00135	.00289											
30	.00226	.00150	.00271	3½° RETAR	.00234	.00163	.00284	30° RETAR										
32	.00216	.00156	.00265		.00223	.00159	.00274											

α°	DECALAGE = −1½°				DECALAGE = −2½°				DECALAGE = −4°				DECALAGE = −6°				DECALAGE = −8°	
	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	Z_c	AUTOROT RANGE
10	.00256	.00027	.00257		.00244	.00018	.00244		.00251	.00034	.00253						.00275	
12	.00285	.00031	.00286		.00275	.00040	.00278		.00281	.00040	.00282						.00309	
14	.00314	.00038	.00314		.00303	.00037	.00303		.00310	.00045	.00311						.00336	
16	.00336	.00044	.00335		.00330	.00043	.00330		.00334	.00051	.00334						.00357	
18	.00361	.00051	.00360		.00350	.00057	.00351		.00354	.00057	.00352						.00380	
20	.00375	.00059	.00373	22° BEGINS	.00368	.00064	.00369	22° BEGINS	.00370	.00064	.00368	22° BEGINS					.00392	22° BEGINS
22	.00390	.00065	.00388		.00378	.00065	.00375		.00382	.00071	.00379						.00384	
24	.00360	.00085	.00364		.00348	.00082	.00352		.00354	.00090	.00358						DISCONT.	
26	DISCONT.	DISCONT.	DISCONT.		.00330	.00095	.00339		.00334	.00104	.00347						"	
28	"	"	"		DISCONT.	DISCONT.	DISCONT.		DISCONT.	DISCONT.	DISCONT.							
30					.00246	.00135	.00282		.00247	.00142	.00285							
32					.00230	.00143	.00272		.00230	.00154	.00278							

TABLE #8

STAGGER = 0%

GAP / CHORD = 1.25

α°	DECALAGE = +6°				DECALAGE = +4°				DECALAGE = +2½°				DECALAGE = +½°				DECALAGE = 0°	
	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c
10	.00331	.00043	.00334		.00333	.00041	.00335		.00342	.00046	.00346		.00319	.00038	.00321		.00301	.00035
12	.00355	.00049	.00361		.00355	.00047	.00357		.00365	.00052	.00369		.00344	.00044	.00346		.00326	.00040
14	.00372	.00055	.00372		.00378	.00054	.00381		.00383	.00058	.00386		.00367	.00050	.00369		.00354	.00047
16	.00375	.00062	.00378		.00397	.00061	.00399		.00401	.00065	.00405		.00386	.00057	.00388		.00377	.00053
18	.00379	.00071	.00383	20° BEGINS	.00397	.00069	.00400	20° BEGINS	.00402	.00072	.00406	20° BEGINS	.00397	.00064	.00398		.00388	.00059
20	.00334	.00090	.00346		.00397	.00079	.00396		.00403	.00084	.00409		.00395	.00072	.00397	22° BEGINS	.00396	.00068
22	.00314	.00101	.00330	23° RETOP	.00357	.00096	.00368		.00360	.00106	.00374		.00393	.00083	.00397		.00397	.00077
24	.00306	.00110	.00325		.00313	.00111	.00347		.00318	.00117	.00339		.00331	.00106	.00346		DISCONT	DISCONT
26	.00283	.00119	.00314		.00272	.00138	.00306		.00291	.00128	.00319		.00284	.00125	.00313			
28	.00243	.00146	.00284		.00247	.00161	.00295		.00257	.00150	.00294	24° PETAR	.00248	.00144	.00292			
30	.00223	.00155	.00277	30° STOPS	.00231	.00156	.00284		.00235	.00160	.00284		.00235	.00153	.00281	26° PETOP		
32	.00222	.00165	.00276		.00224	.00156	.00274	31° STOPS	.00232	.00170	.00288	STOPS	.00228	.00164	.00280			

α°	DECALAGE = -1½°				DECALAGE = -2½°				DECALAGE = -4°				DECALAGE = -6°				DECALAGE = 0°	
	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE	L_c	D_c	Z_c	AUTOROT RANGE		Z_c
10	.00301	.00032	.00303		.00273	.00029	.00278		.00267	.00027	.00268		.00229	.00023	.00230			.00303
12	.00329	.00038	.00329		.00306	.00035	.00306		.00295	.00031	.00296		.00272	.00029	.00275			.00328
14	.00354	.00044	.00355		.00333	.00040	.00333		.00326	.00037	.00326		.00300	.00034	.00298			.00356
16	.00376	.00050	.00375		.00362	.00046	.00360		.00350	.00044	.00348		.00327	.00040	.00326			.00378
18	.00395	.00057	.00394		.00375	.00053	.00373		.00372	.00050	.00369		.00356	.00046	.00353			.00389
20	.00397	.00065	.00396	22° BEGINS	.00390	.00059	.00387	22° BEGINS	.00389	.00057	.00385	22° BEGINS	.00365	.00052	.00362		.00396	22° BEGINS
22	.00397	.00077	.00398		.00390	.00067	.00388		.00390	.00065	.00387		.00381	.00061	.00378	24° BEGINS	.00396	
24	DISCONT	DISCONT	DISCONT		.00384	.00084	.00386		.00369	.00084	.00372		.00381	.00075	.00379		DISCONT	
26					DISCONT	DISCONT	DISCONT		.00349	.00098	.00357		.00355	.00089	.00359			
28					"	"	"		DISCONT	DISCONT	DISCONT		.00334	.00103	.00343			
30									"	"	"		.00274	.00131	.00304			
32													.00240	.00142	.00282			

TABLE #9

STAGGER = -25%

GAP/CHORD = 1.00

α°	DECALAGE = +6°			AUTOROT RANGE	DECALAGE = +4°			AUTOROT RANGE	DECALAGE = +2½°			AUTOROT RANGE	DECALAGE = +1½°			AUTOROT RANGE
	L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c	
10	.00314	.00037	.00316		.00312	.00048	.00315		.00295	.00033	.00298		.00290	.00032	.00292	
12	.00334	.00043	.00335		.00335	.00044	.00338		.00321	.00039	.00324		.00316	.00038	.00318	
14	.00350	.00049	.00351		.00356	.00050	.00358		.00348	.00045	.00350		.00339	.00044	.00340	
16	.00362	.00056	.00363		.00372	.00056	.00375		.00361	.00052	.00363		.00356	.00050	.00357	
18	.00364	.00063	.00365		.00378	.00064	.00380		.00377	.00058	.00377		.00369	.00056	.00368	
20	.00367	.00071	.00371		.00374	.00072	.00377		.00380	.00066	.00380		.00373	.00065	.00370	
22	.00358	.00083	.00364		.00343	.00087	.00352		.00347	.00079	.00356		.00339	.00079	.00346	
24	.00288	.00101	.00305		.00289	.00106	.00308		.00316	.00093	.00327		.00314	.00091	.00326	
26	.00234	.00120	.00264		.00239	.00121	.00268		.00250	.00114	.00276		.00247	.00113	.00272	
28	.00211	.00130	.00249		.00217	.00130	.00253		.00222	.00123	.00255		.00218	.00125	.00251	
30	.00204	.00136	.00245		.00214	.00138	.00254		.00215	.00132	.00253		.00214	.00136	.00253	
32	.00202	.00145	.00248		.00207	.00147	.00254		.00211	.00160	.00264		.00206	.00144	.00251	

α°	DECALAGE = 0°			AUTOROT RANGE	DECALAGE = -1½°			AUTOROT RANGE	DECALAGE = -2½°			AUTOROT RANGE	DECALAGE = -4°			AUTOROT RANGE
	L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c		L_c	D_c	Z_c	
10	.00288	.00032	.00290		.00285	.00030	.00286		.00274	.00028	.00274		.00242	.00025	.00243	
12	.00314	.00038	.00316		.00314	.00036	.00315		.00306	.00034	.00307		.00271	.00030	.00272	
14	.00343	.00045	.00344		.00340	.00042	.00343		.00330	.00039	.00330		.00302	.00036	.00302	
16	.00362	.00051	.00362		.00350	.00049	.00359		.00354	.00046	.00353		.00322	.00041	.00321	
18	.00377	.00058	.00377		.00372	.00056	.00377		.00368	.00054	.00367		.00343	.00047	.00341	
20	.00380	.00067	.00380		.00374	.00064	.00374		.00373	.00061	.00371		.00356	.00055	.00354	
22	.00345	.00084	.00352		.00342	.00079	.00348		.00341	.00078	.00346		.00352	.00067	.00352	
24	.00314	.00095	.00327		.00316	.00092	.00327		.00314	.00088	.00323		.00325	.00080	.00328	
26	.00274	.00111	.00296		.00267	.00112	.00290		.00296	.00098	.00310		.00310	.00090	.00318	
28	.00231	.00126	.00264		.00228	.00126	.00261		.00241	.00121	.00271		.00297	.00099	.00310	
30	.00222	.00138	.00263		.00215	.00134	.00254		.00222	.00132	.00258		.00266	.00113	.00288	
32	.00210	.00143	.00255		.00211	.00144	.00256		.00218	.00140	.00260		.00226	.00132	.00263	

TABLE #10

STAGGER = -25%

GAP/CHORD = .75

DECALAGE = +2½°

α°	L_c	D_c	Z_c	AUTOROT RANGE
10	.00290	.00034	.00293	20° BEGINS
12	.00316	.00040	.00318	
14	.00334	.00046	.00337	
16	.00350	.00052	.00351	
18	.00357	.00059	.00358	
20	.00356	.00066	.00358	
22	.00303	.00082	.00314	
24	.00276	.00091	.00290	
26	.00234	.00111	.00260	
28	.00205	.00120	.00239	28° STOPS
30	.00202	.00130	.00240	
32	.00198	.00141	.00244	

DECALAGE = -2½°

α°	L_c	D_c	Z_c	AUTOROT RANGE
10	.00238	.00024	.00239	20° BEGINS
12	.00266	.00029	.00266	
14	.00292	.00035	.00292	
16	.00318	.00040	.00316	
18	.00346	.00047	.00344	
20	.00355	.00052	.00353	
22	.00330	.00067	.00332	
24	.00308	.00076	.00312	
26	.00285	.00085	.00293	
28	.00277	.00095	.00291	
30	.00261	.00103	.00278	
32	.00211	.00125	.00248	

GAP/CHORD = 1.25

DECALAGE = +2½°

α°	L_c	D_c	Z_c	AUTOROT RANGE
10	.00322	.00037	.00324	20° BEGINS
12	.00345	.00043	.00346	
14	.00368	.00049	.00370	
16	.00381	.00056	.00380	
18	.00383	.00074	.00385	
20	.00389	.00080	.00394	
22	.00359	.00088	.00368	
24	.00305	.00112	.00325	
26	.00249	.00126	.00280	
28	.00223	.00134	.00260	24° STOPS
30	.00217	.00144	.00260	
32	.00216	.00153	.00265	

DECALAGE = -2½°

α°	L_c	D_c	Z_c	AUTOROT RANGE
10	.00264	.00028	.00266	22° BEGINS
12	.00294	.00033	.00295	
14	.00323	.00039	.00324	
16	.00347	.00045	.00346	
18	.00367	.00053	.00366	
20	.00384	.00060	.00382	
22	.00383	.00068	.00382	
24	.00347	.00087	.00352	
26	.00322	.00100	.00333	
28	.00271	.00122	.00327	
30	.00238	.00133	.00274	30° RETARDED
32	.00229	.00144	.00271	

STAGGER = -50%

GAP/CHORD = 1.00

DECALAGE = +2½°

α°	L_c	D_c	Z_c	AUTOR RANGE
10	.00318	.00039	.00321	18° BEGINS
12	.00342	.00044	.00345	
14	.00359	.00051	.00361	
16	.00369	.00058	.00371	
18	.00369	.00065	.00371	
20	.00334	.00080	.00342	
22	.00297	.00089	.00310	
24	.00281	.00094	.00296	
26	.00226	.00116	.00254	28° RETAR.
28	.00207	.00122	.00241	
30	.00198	.00130	.00237	30° STOPS
32	.00197	.00137	.00240	

DECALAGE = -2½°

α°	L_c	D_c	Z_c	AUTOROT RANGE
10	.00269	.00030	.00270	20° BEGINS
12	.00297	.00035	.00298	
14	.00322	.00041	.00323	
16	.00338	.00048	.00338	
18	.00356	.00055	.00356	
20	.00372	.00064	.00372	
22	.00318	.00077	.00325	
24	.00302	.00086	.00309	
26	.00285	.00094	.00298	
28	.00276	.00101	.00292	
30	.00264	.00107	.00282	
32	.00211	.00128	.00247	

TABLE #11

STAGGER = −75%

GAP/CHORD = .75

α°	DECALAGE = +2½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00288	.00031	.00293	18° BEGINS
12	.00311	.00037	.00312	
14	.00325	.00045	.00326	
16	.00326	.00048	.00326	
18	.00327	.00053	.00327	
20	.00282	.00063	.00287	
22	.00235	.00066	.00243	
24	.00197	.00066	.00204	
26	.00179	.00067	.00190	
28	.00156	.00069	.00170	
30	.00145	.00073	.00162	
32	.00141	.00078	.00161	

α°	DECALAGE = −2½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00231	.00023	.00232	20° BEGINS
12	.00258	.00028	.00259	
14	.00281	.00033	.00281	
16	.00299	.00040	.00299	
18	.00309	.00046	.00307	
20	.00309	.00051	.00311	
22	.00239	.00058	.00244	
24	.00209	.00061	.00216	
26	.00188	.00066	.00198	
28	.00171	.00069	.00184	
30	.00155	.00073	.00171	
32	.00141	.00076	.00160	

GAP/CHORD = 1.00

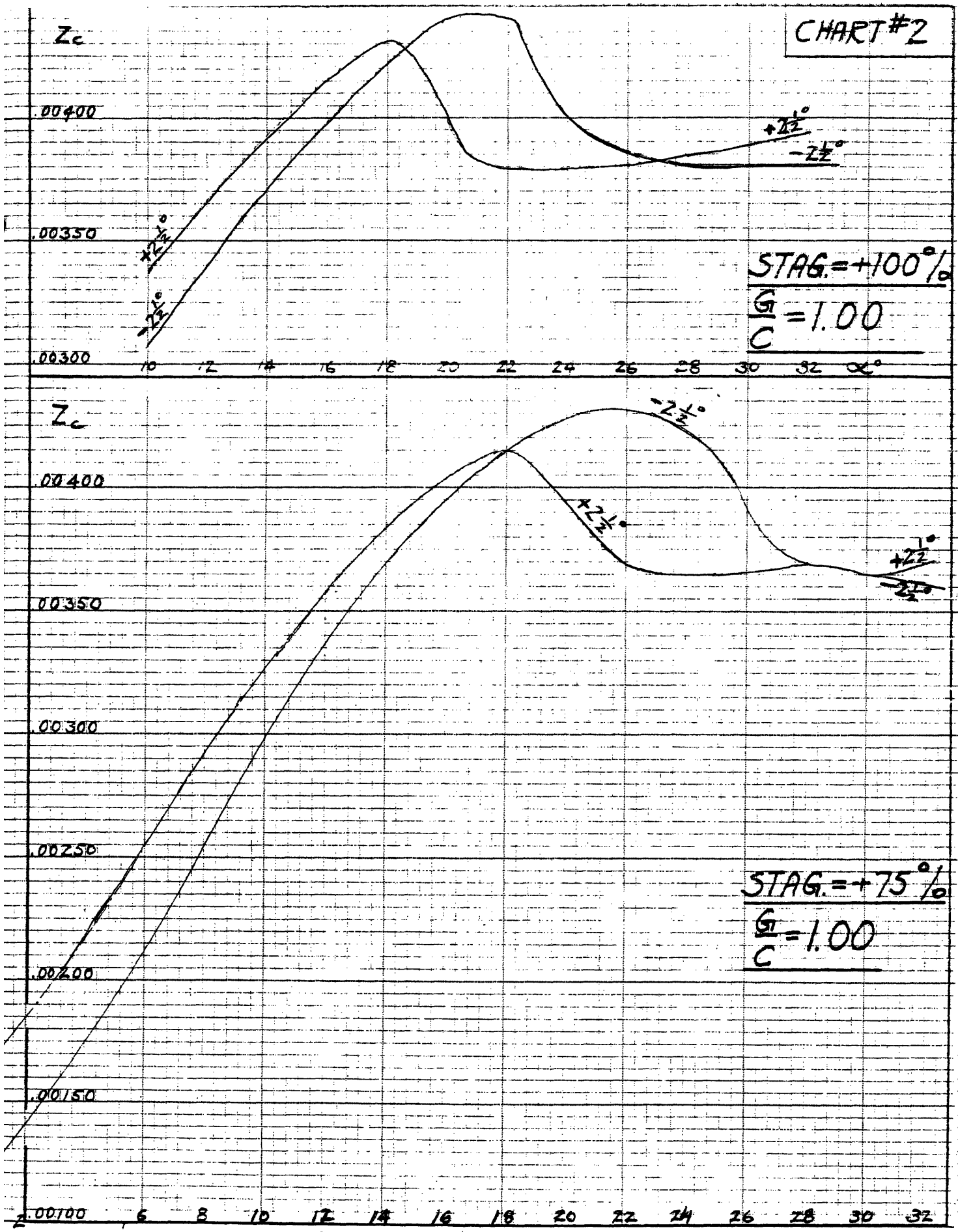
α°	DECALAGE = +4° L_c	D_c	Z_c	AUTOROT RANGE
10	.00312	.00035	.00314	18° BEGINS
12	.00336	.00041	.00335	
14	.00352	.00047	.00353	
16	.00356	.00052	.00356	
18	.00355	.00058	.00356	
20	.00351	.00066	.00353	
22	.00305	.00077	.00312	
24	.00263	.00083	.00272	
26	.00241	.00087	.00255	
28	.00224	.00090	.00240	
30	.00205	.00092	.00224	
32	.00187	.00094	.00209	

α°	DECALAGE = +2½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00317	.00040	.00320	18° BEGINS, 30° STOPS
12	.00343	.00046	.00345	
14	.00362	.00053	.00364	
16	.00369	.00059	.00372	
18	.00368	.00066	.00371	
20	.00355	.00074	.00360	
22	.00292	.00083	.00303	
24	.00260	.00089	.00273	
26	.00241	.00093	.00258	
28	.00227	.00096	.00246	
30	.00190	.00113	.00223	
32	.00187	.00115	.00220	

α°	DECALAGE = +1½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00288	.00030	.00290	18° BEGINS
12	.00313	.00035	.00313	
14	.00335	.00042	.00333	
16	.00349	.00048	.00349	
18	.00354	.00055	.00355	
20	.00345	.00061	.00346	
22	.00291	.00072	.00298	
24	.00257	.00078	.00268	
26	.00241	.00083	.00254	
28	.00226	.00090	.00241	
30	.00208	.00093	.00225	
32	.00192	.00094	.00213	

α°	DECALAGE = −2½° L_c	D_c	Z_c	AUTOROT RANGE
10	.00263	.00028	.00265	20° BEGINS
12	.00293	.00033	.00294	
14	.00316	.00047	.00319	
16	.00330	.00049	.00330	
18	.00343	.00053	.00343	
20	.00345	.00060	.00346	
22	.00305	.00072	.00311	
24	.00270	.00077	.00279	
26	.00255	.00085	.00267	
28	.00239	.00089	.00253	
30	.00230	.00096	.00248	
32	.00208	.00103	.00231	

CHART #2



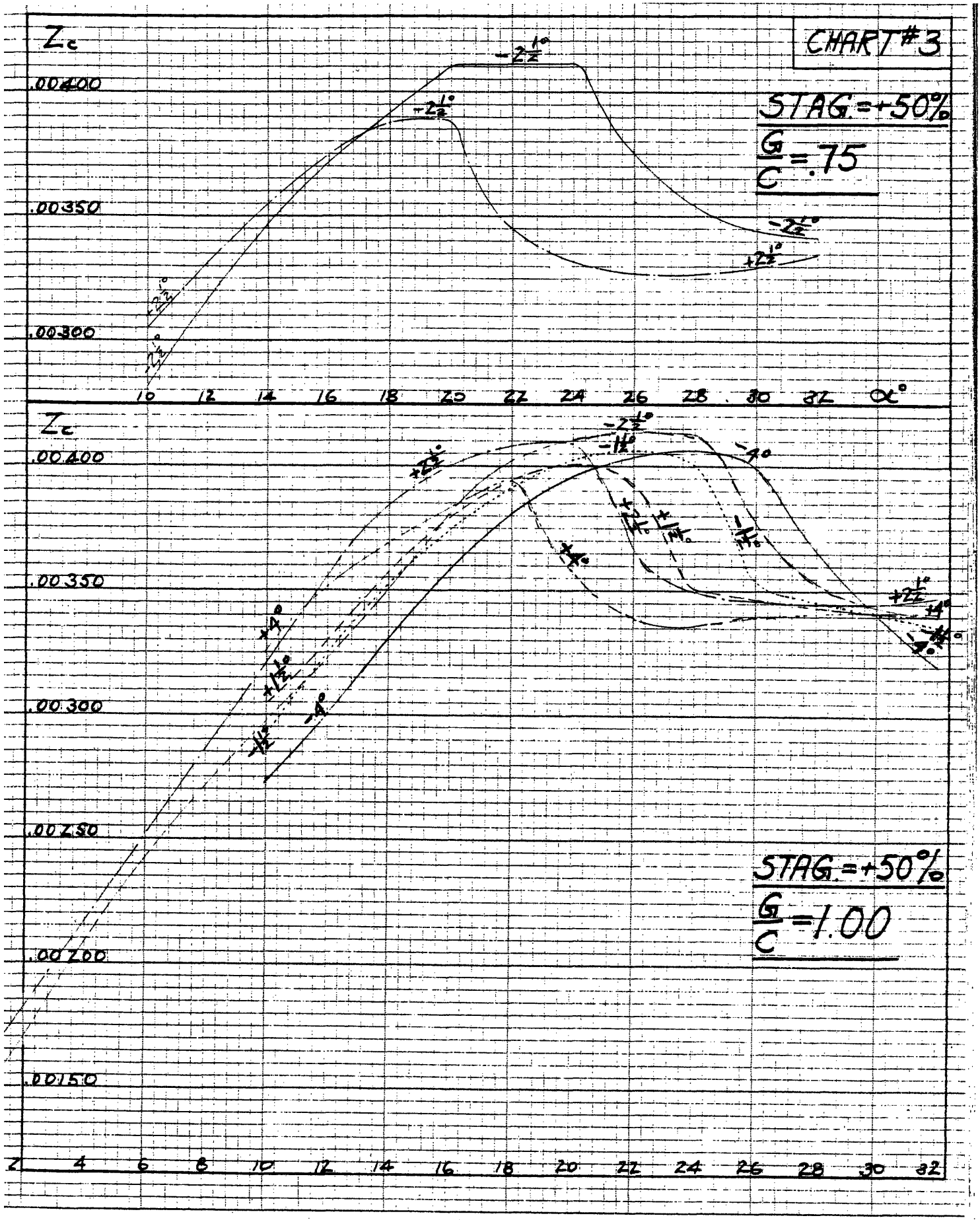
STAG. = +100°/o

$\frac{G}{C} = 1.00$

STAG. = +75°/o

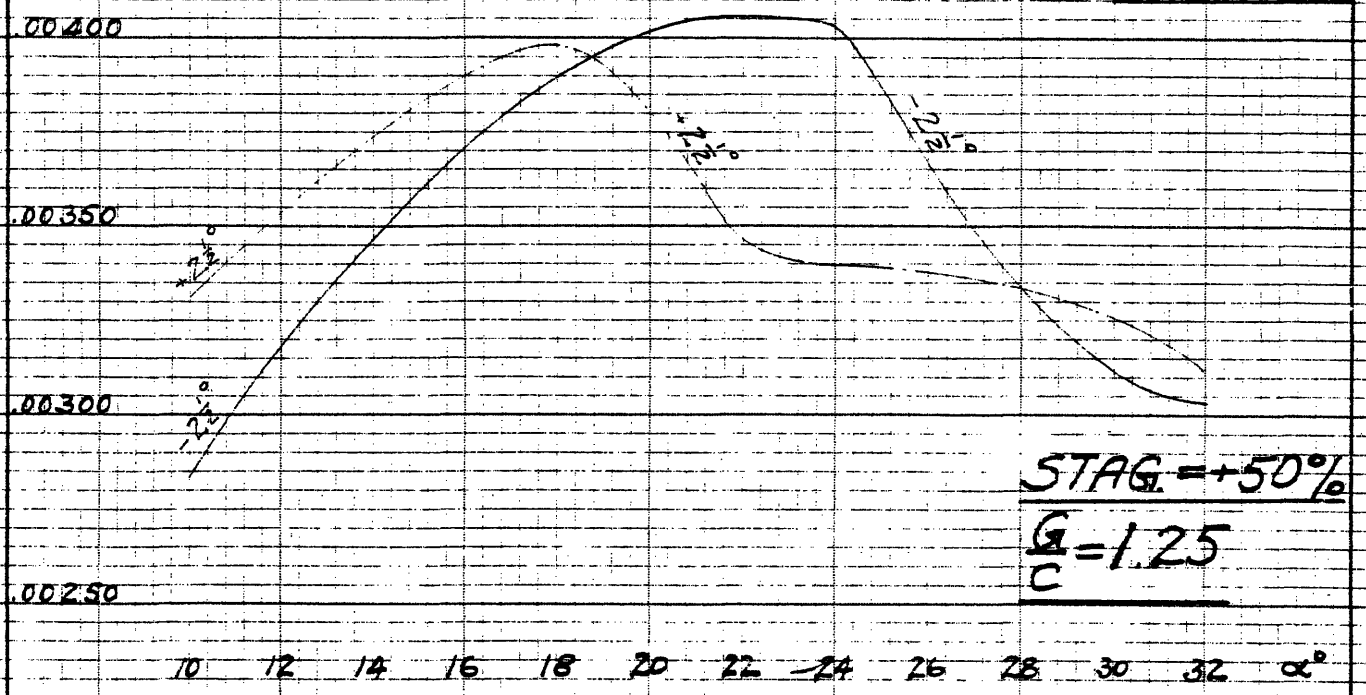
$\frac{G}{C} = 1.00$

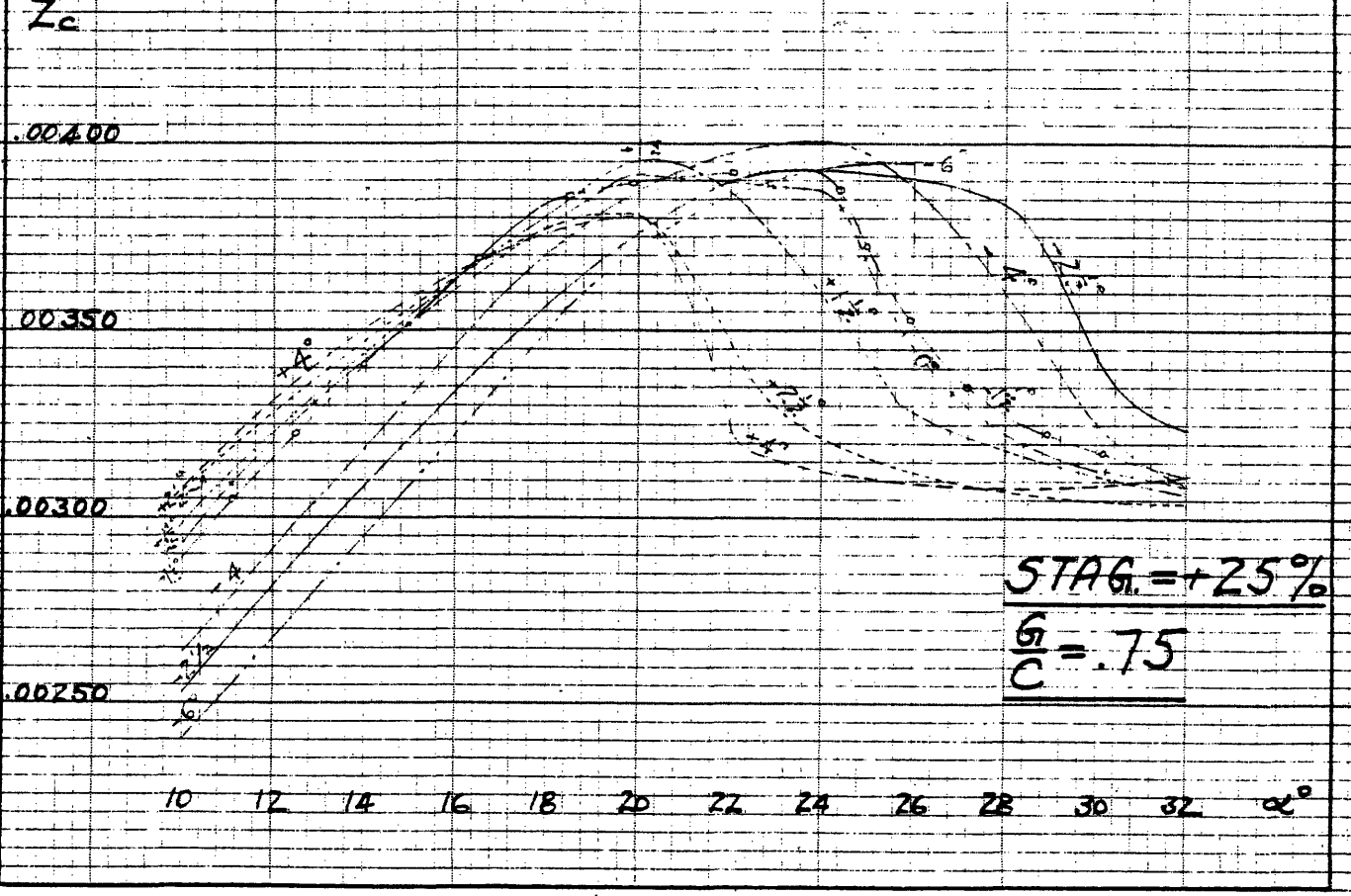
EFFECT OF DECALAGE



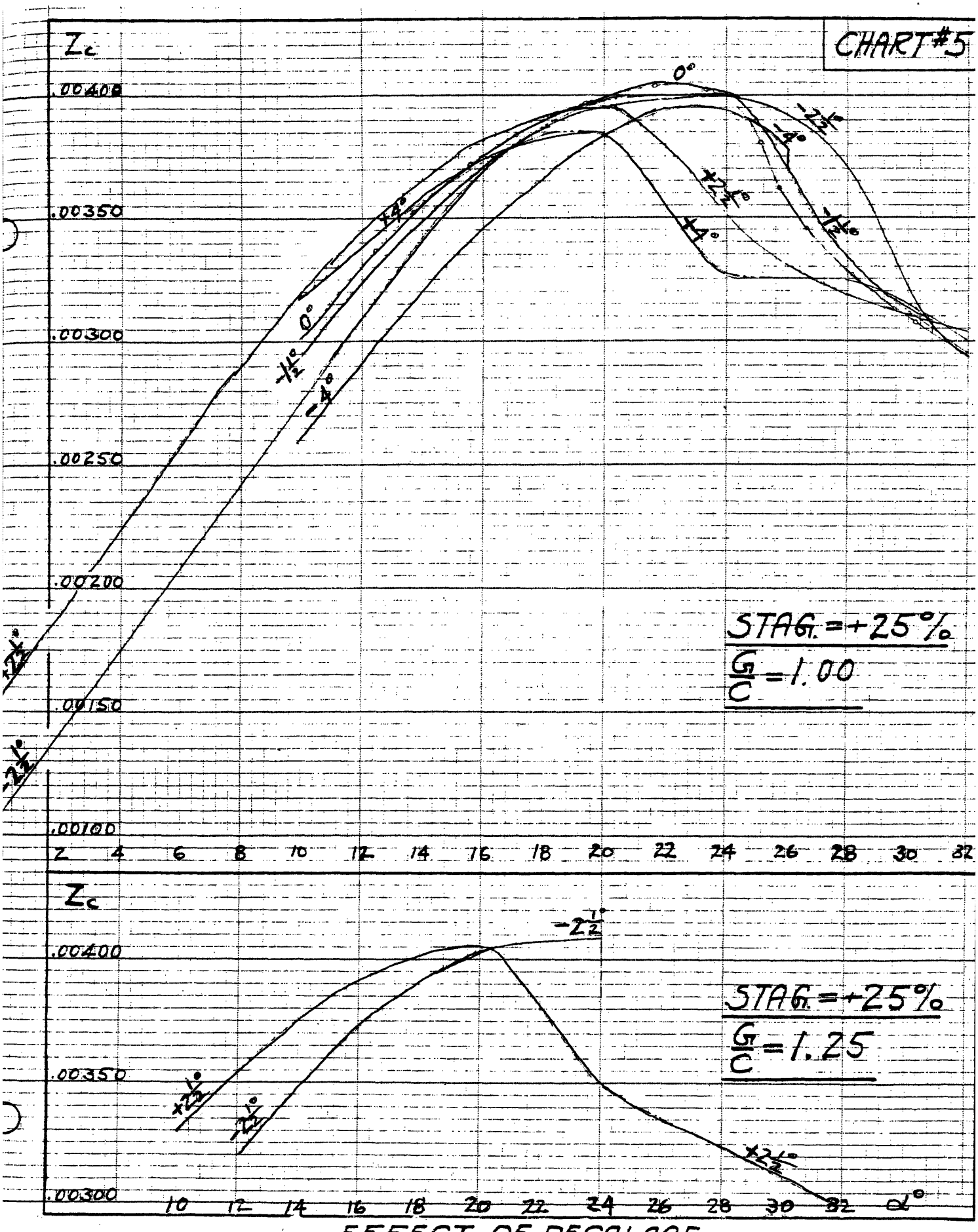
EFFECT OF DECALAGE

CHART #4



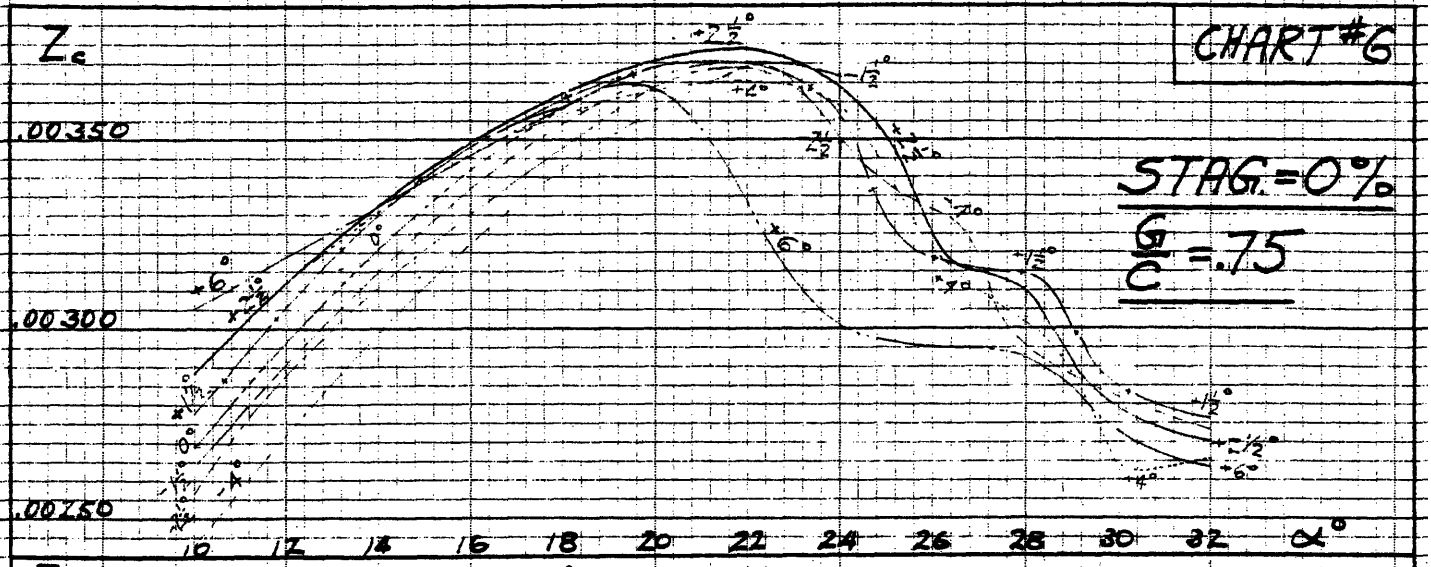


EFFECT OF DECALAGE

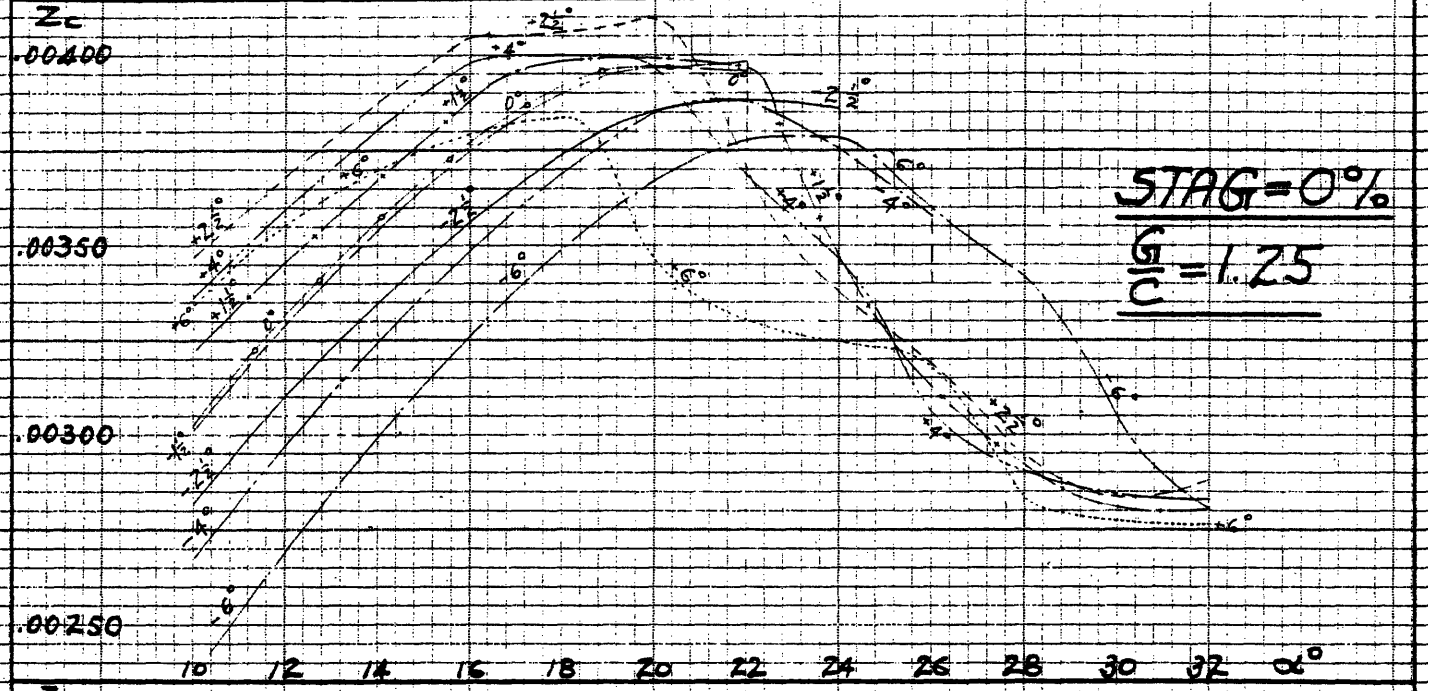


EFFECT OF DECALAGE

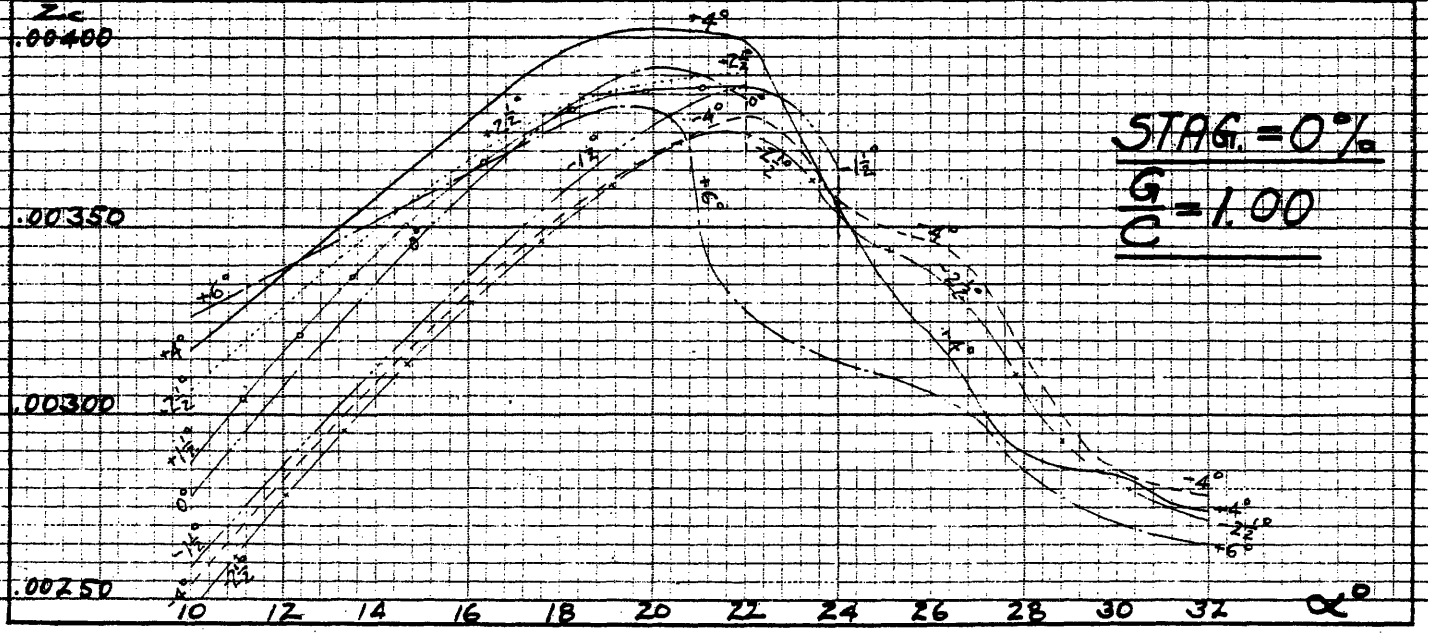
CHART #6



STAG. = 0°
G/C = .75



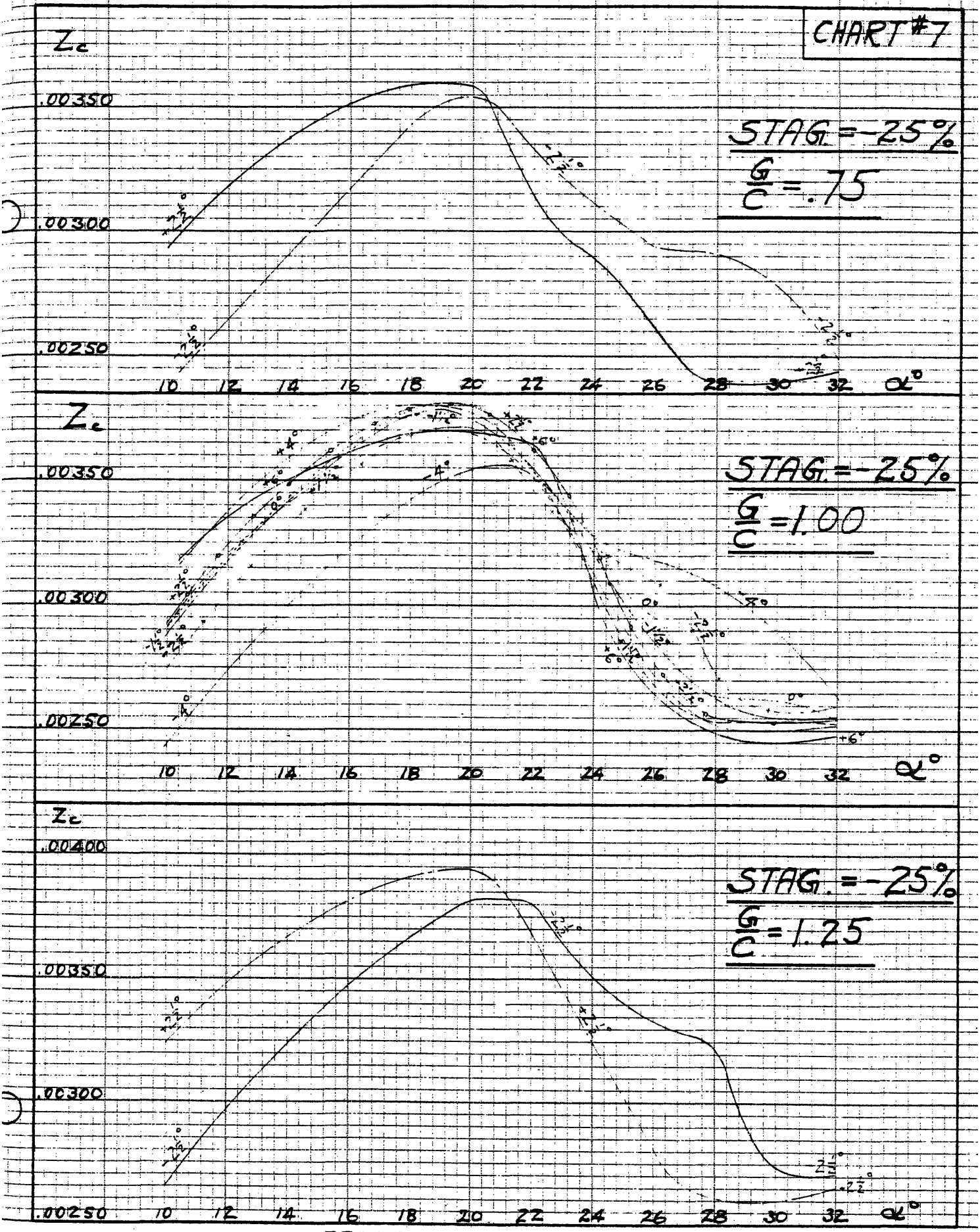
STAG = 0°
G/C = 1.25



STAG. = 0°
G/C = 1.00

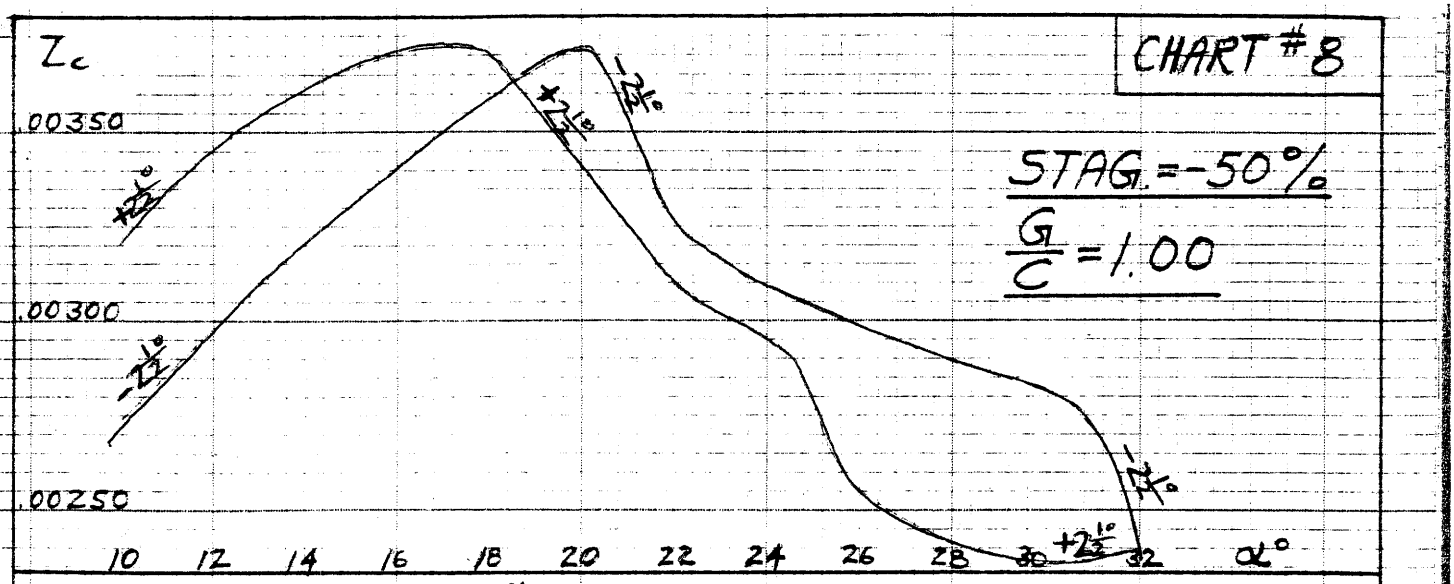
EFFECT OF DECALAGE

CHART #7



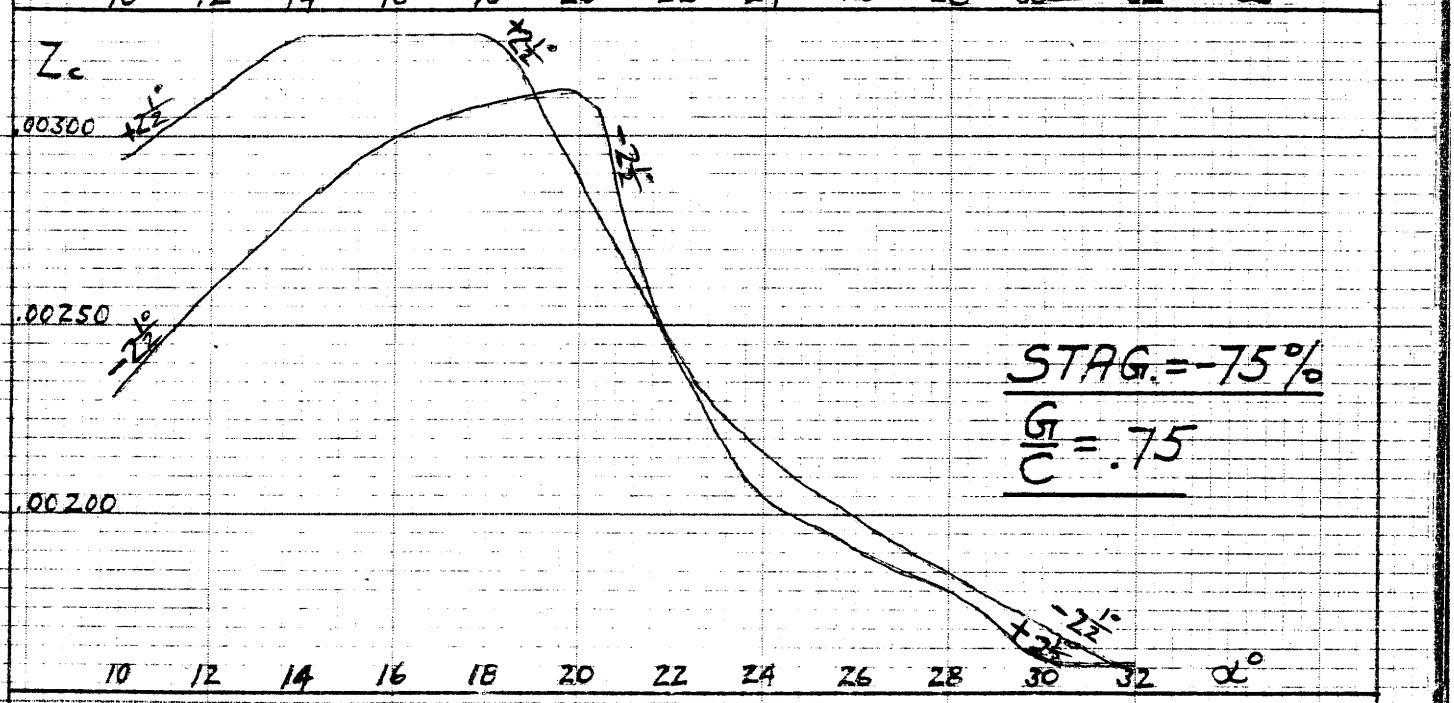
EFFECT OF DECALAGE

CHART #8



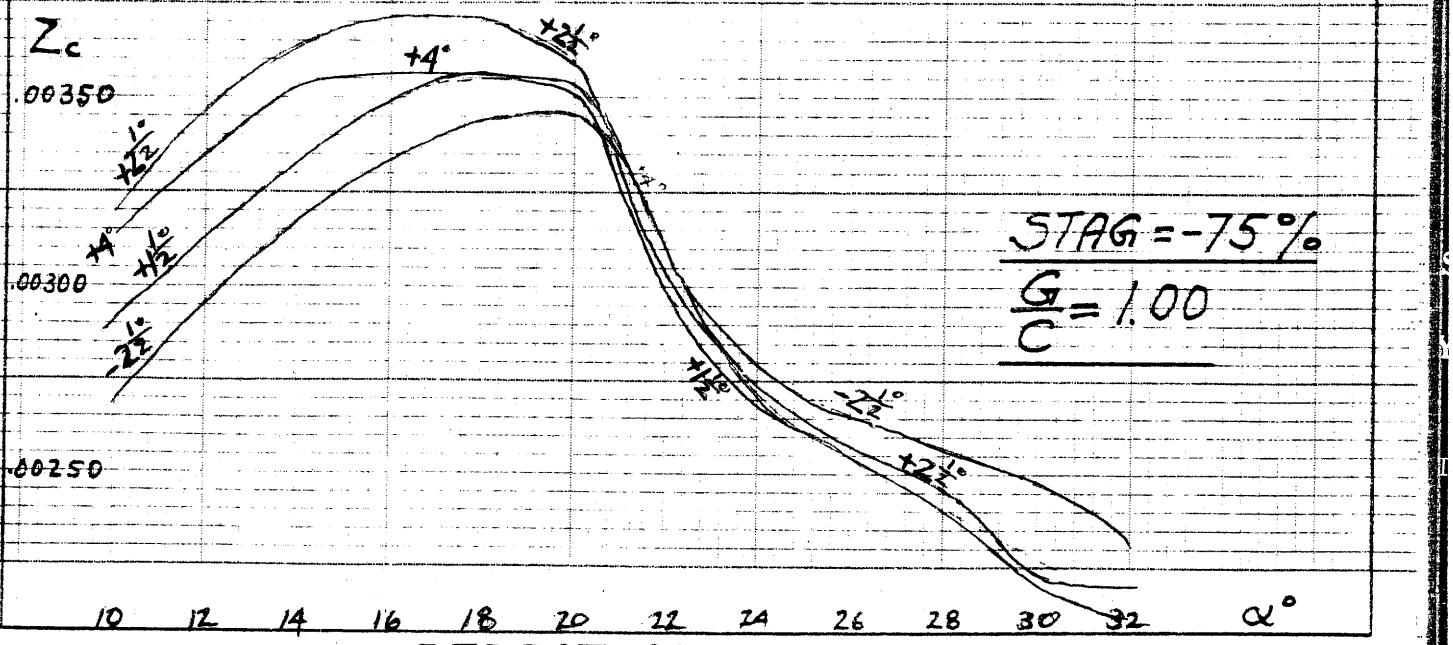
STAG. = -50%

$\frac{G}{C} = 1.00$



STAG. = -75%

$\frac{G}{C} = .75$

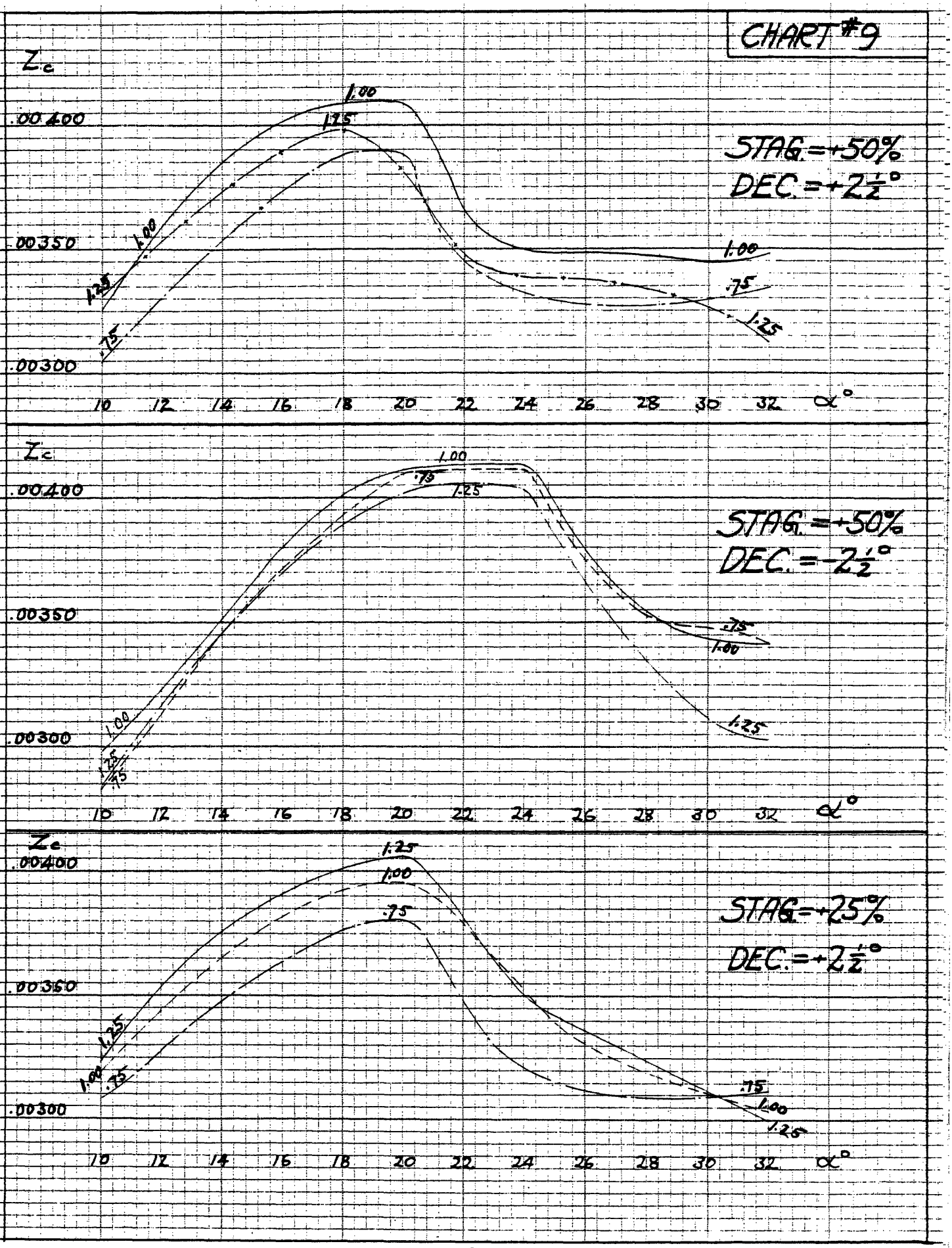


STAG = -75%

$\frac{G}{C} = 1.00$

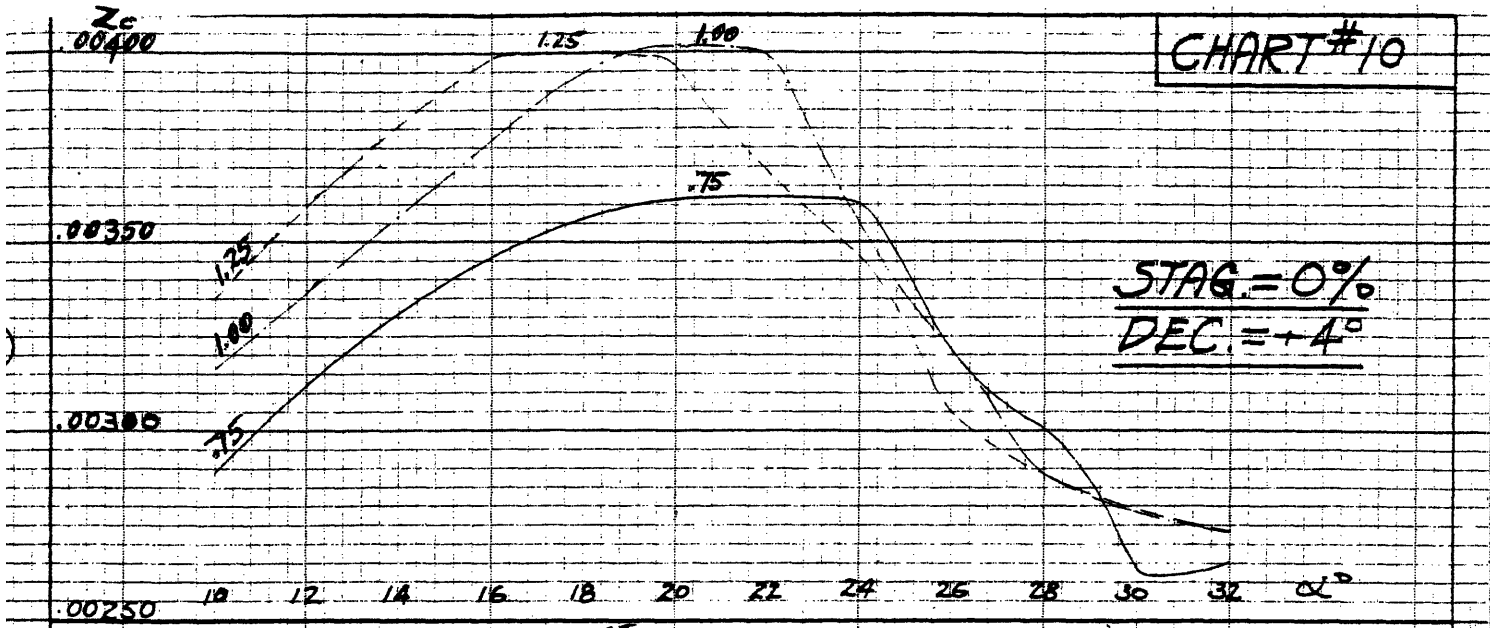
EFFECT OF DECALAGE

CHART #9

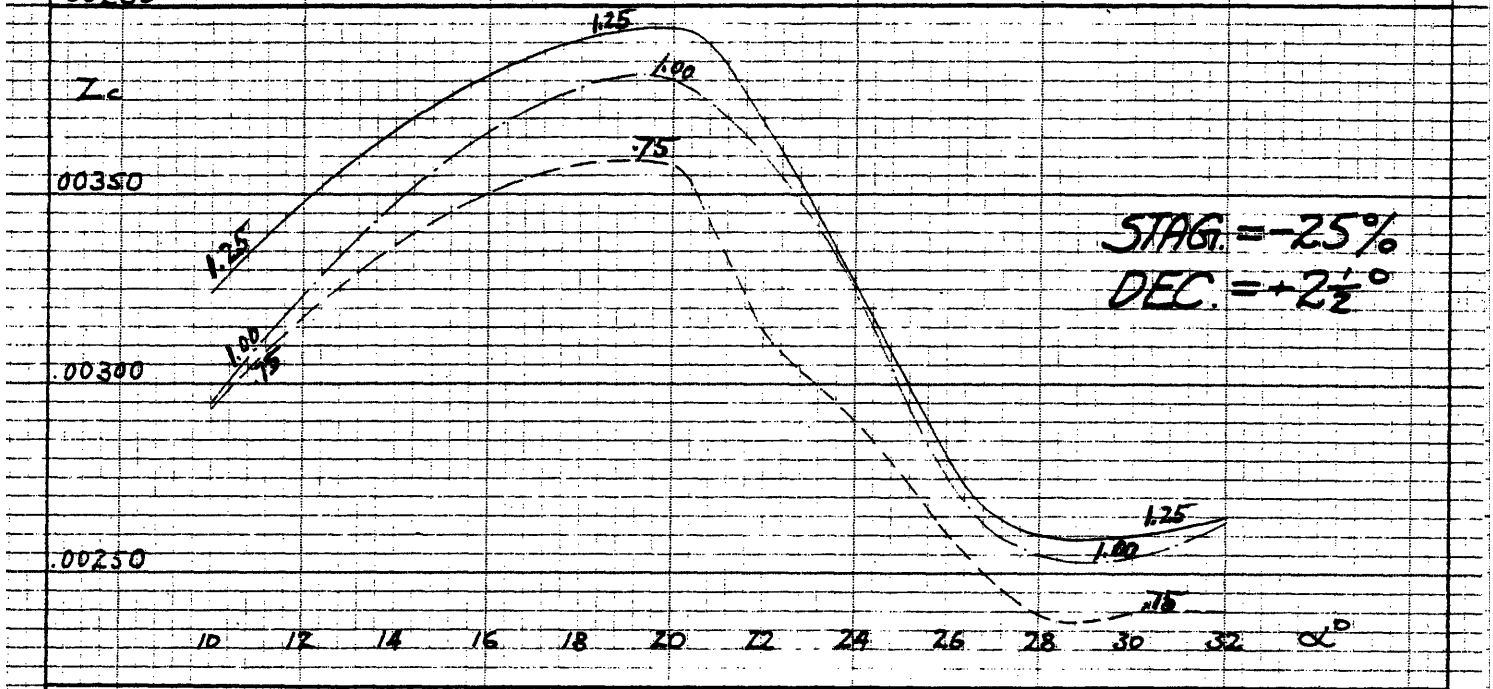


EFFECT OF GAP TO CHORD RATIO

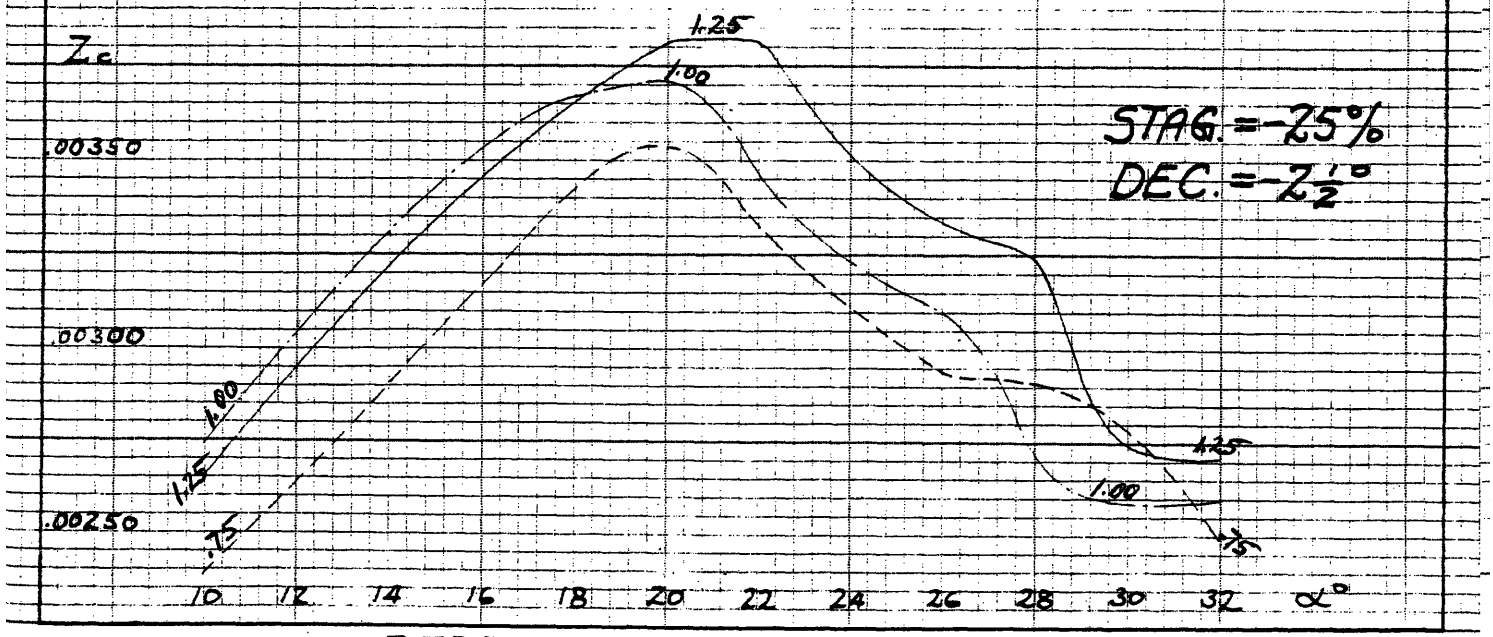
CHART #10



STAG. = 0%
DEC. = +4°



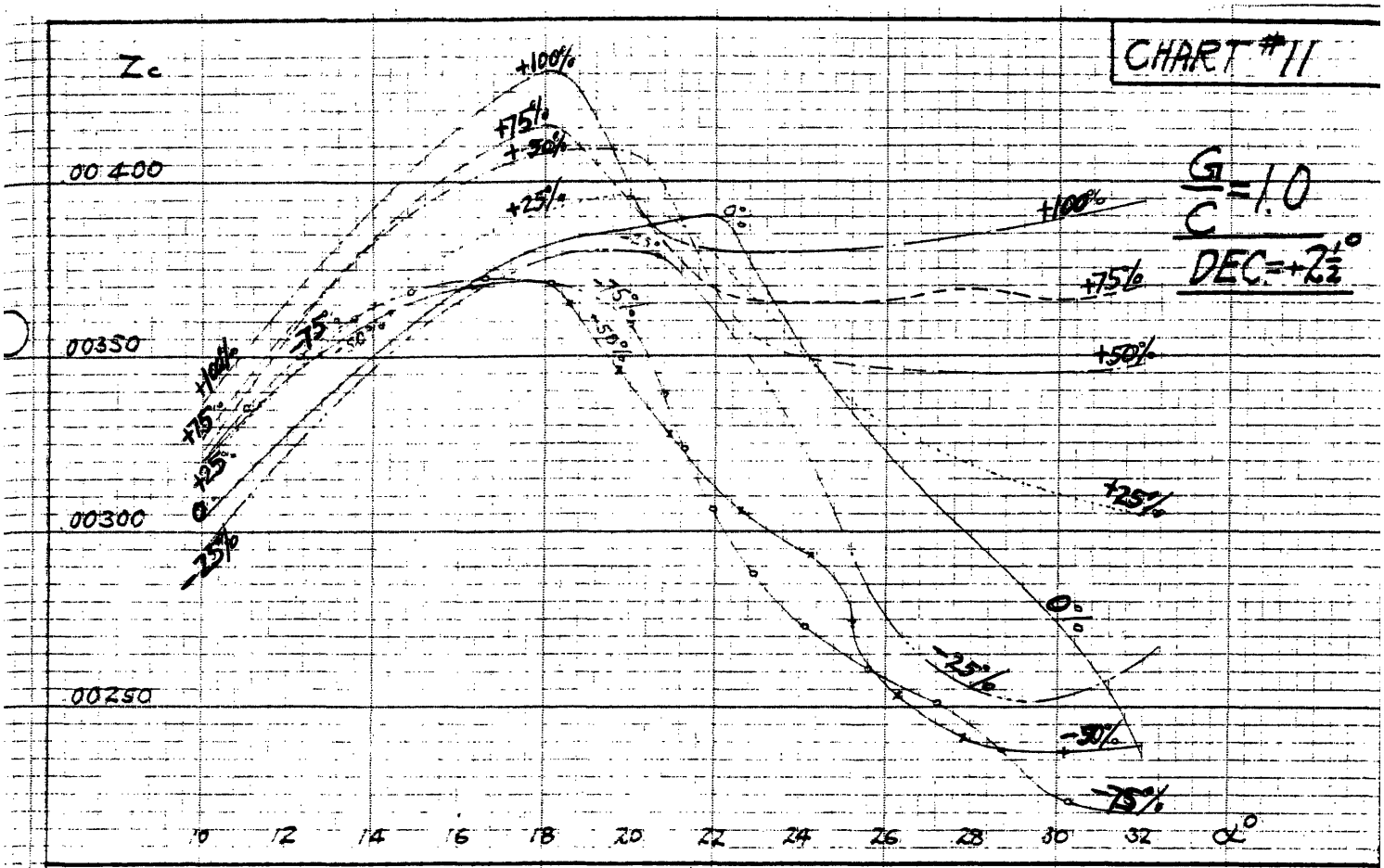
STAG. = -25%
DEC. = +2½°

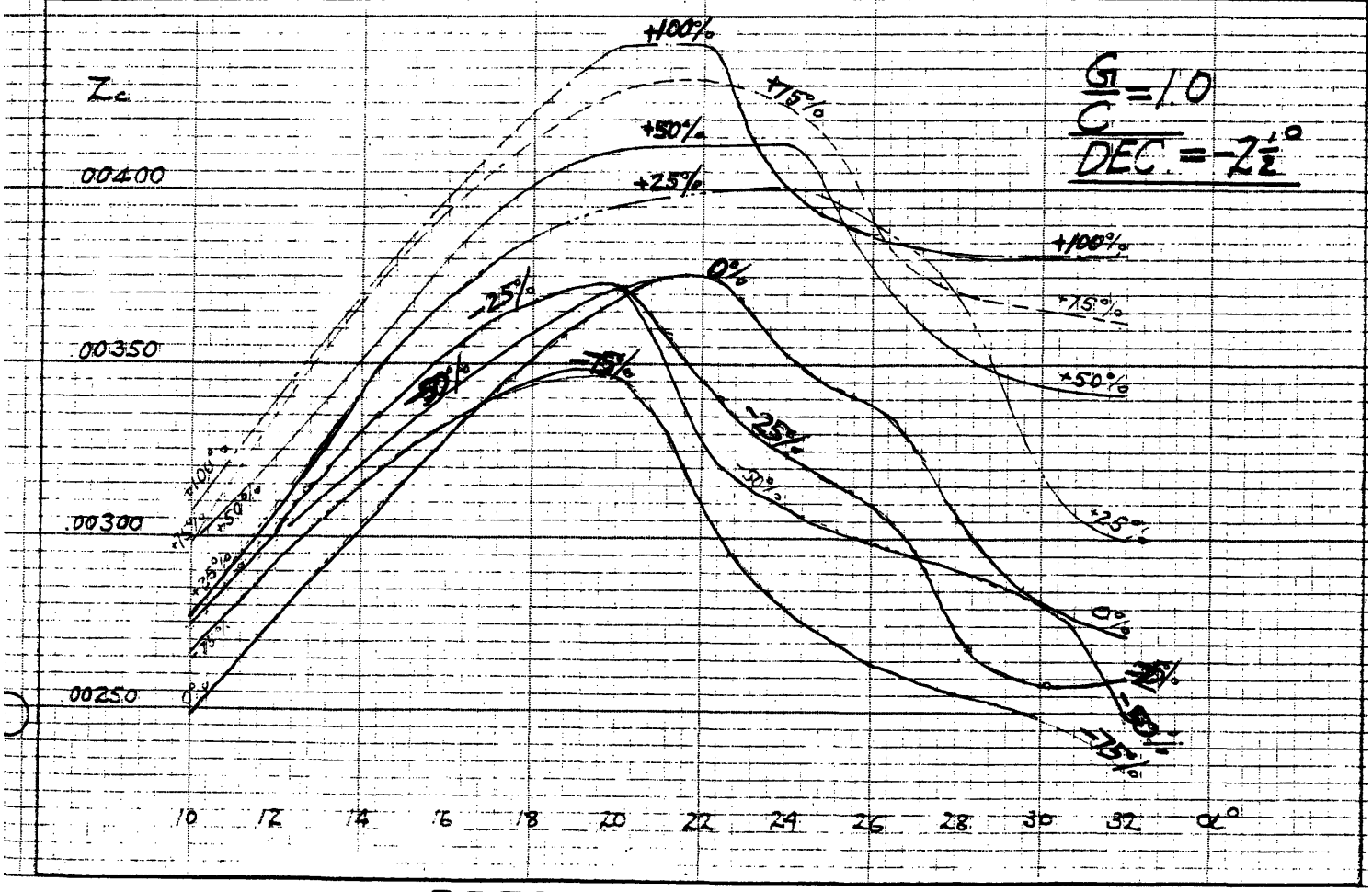


STAG. = -25%
DEC. = -2½°

EFFECT OF GAP TO CHORD RATIO

CHART #11



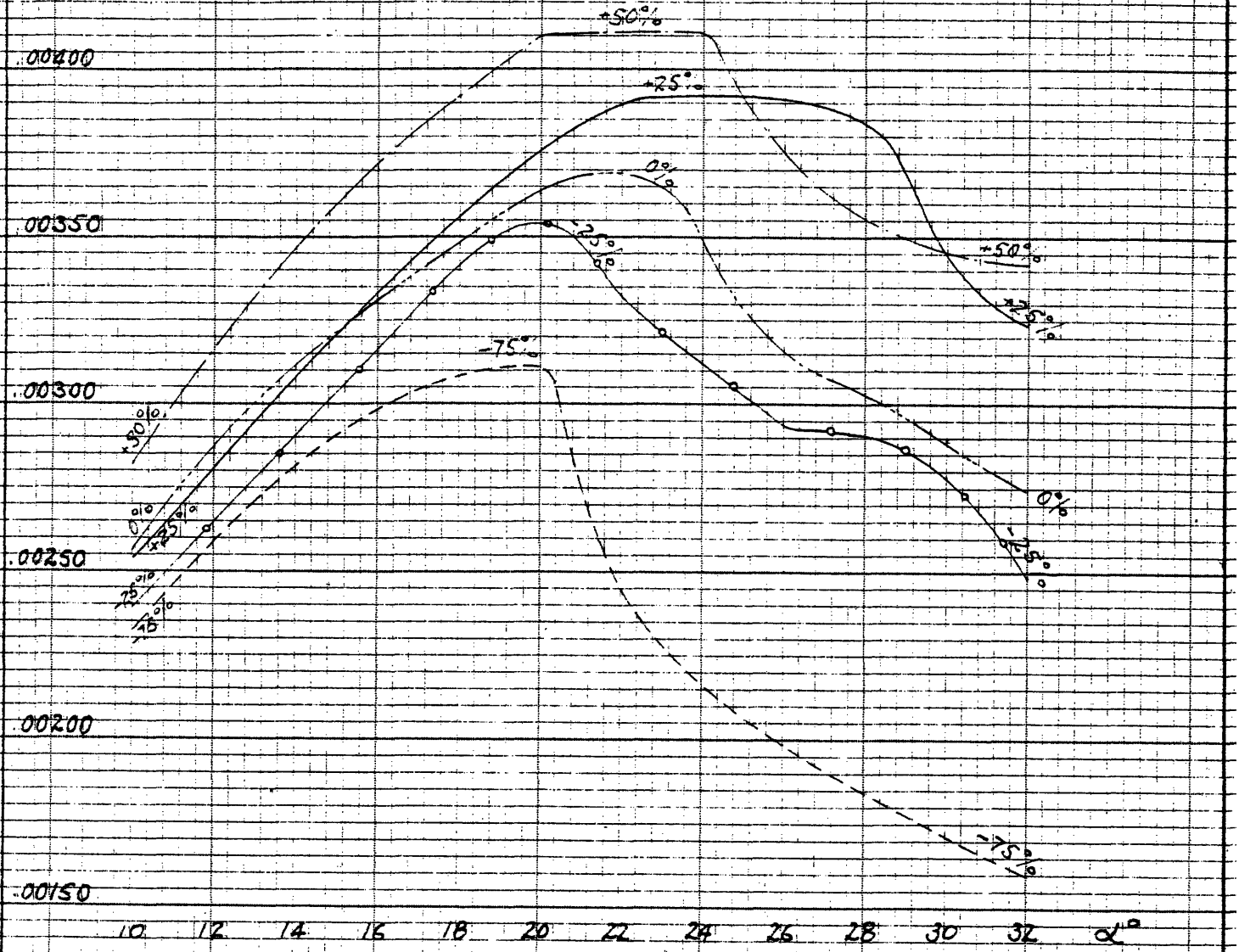


EFFECT OF STAGGER

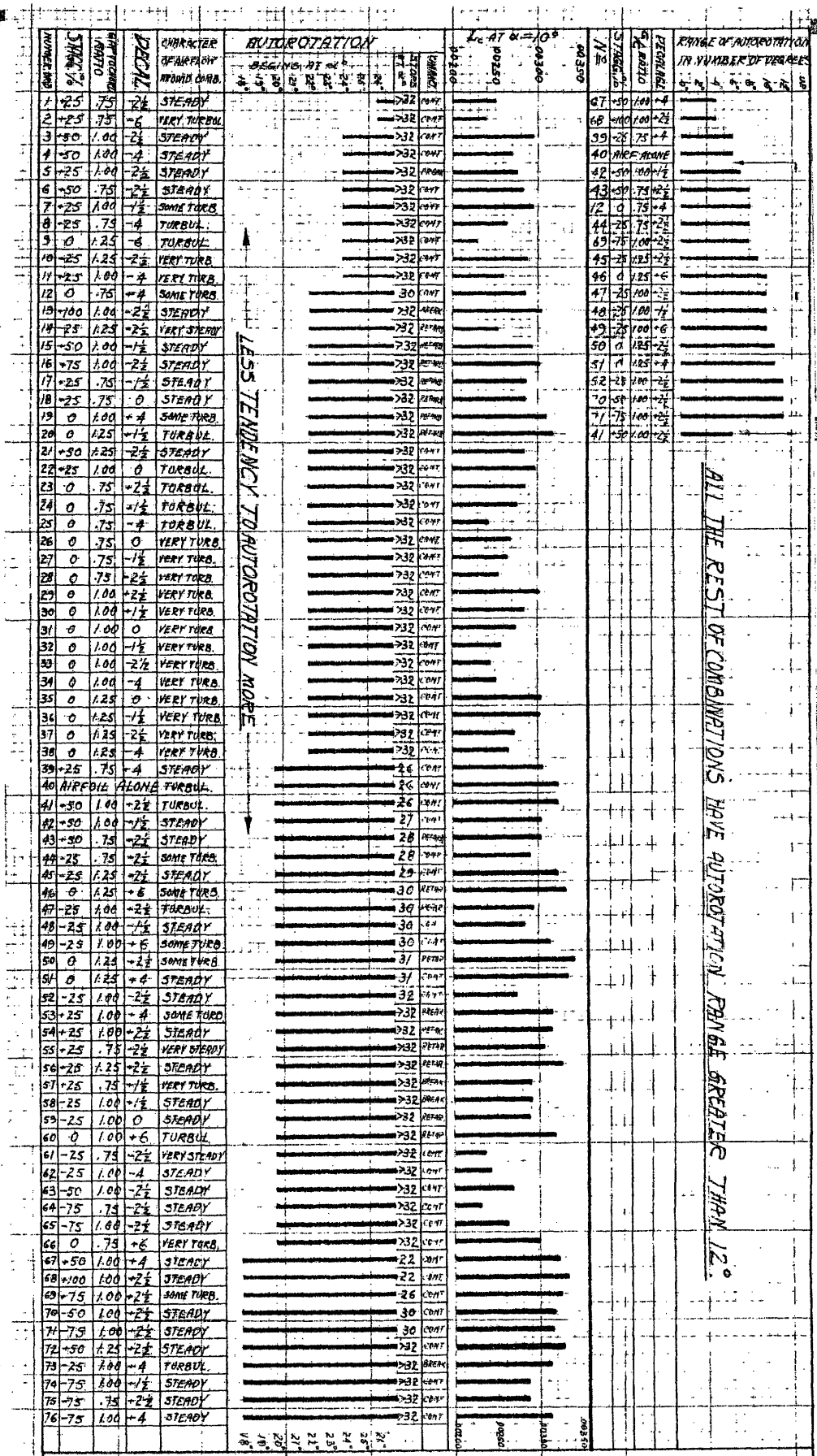
CHART #12

$\frac{G}{G} = .75$

DEC. $= -2\frac{1}{2}^{\circ}$



EFFECT OF STAGGER



NUMBER	STICK %	RUDDER RATIO	DEPTH	CHARACTER OF AIRFLOW AROUND COMB.	AUTOROTATION BEGINS AT α	STOPS AT α	DYNAMIC
1	+25	.75	-2½	STEADY		>32	CONT
2	+25	.75	-6	VERY TURBUL		>32	CONT
3	+50	1.00	-2½	STEADY		>32	CONT
4	+50	1.00	-4	STEADY		>32	CONT
5	+25	1.00	-2½	STEADY		>32	ABRUPT
6	+50	.75	-2½	STEADY		>32	CONT
7	+25	1.00	-1½	SOME TURB.		>32	CONT
8	-25	.75	-4	TURBUL.		>32	CONT
9	0	1.25	-6	TURBUL.		>32	CONT
10	-25	1.25	-2½	VERY TURB.		>32	CONT
11	+25	1.00	-4	VERY TURB.		>32	CONT
12	0	.75	-4	SOME TURB.		30	CONT
13	+100	1.00	-2½	STEADY		>32	ABRUPT
14	-75	1.25	-2½	VERY STEADY		>32	PETARD
15	-50	1.00	-1½	STEADY		>32	PETARD
16	+75	1.00	-2½	STEADY		>32	PETARD
17	+25	.75	-1½	STEADY		>32	PETARD
18	-25	.75	0	STEADY		>32	PETARD
19	0	1.00	+4	SOME TURB.		>32	PETARD
20	0	1.25	+1½	TURBUL.		>32	PETARD
21	+50	1.25	-2½	STEADY		>32	CONT
22	+25	1.00	0	TURBUL.		>32	CONT
23	0	.75	+2½	TURBUL.		>32	CONT
24	0	.75	+1½	TURBUL.		>32	CONT
25	0	.75	-4	TURBUL.		>32	CONT
26	0	.75	0	VERY TURB.		>32	CONT
27	0	.75	-1½	VERY TURB.		>32	CONT
28	0	.75	-2½	VERY TURB.		>32	CONT
29	0	1.00	+2½	VERY TURB.		>32	CONT
30	0	1.00	+1½	VERY TURB.		>32	CONT
31	0	1.00	0	VERY TURB.		>32	CONT
32	0	1.00	-1½	VERY TURB.		>32	CONT
33	0	1.00	-2½	VERY TURB.		>32	CONT
34	0	1.00	-4	VERY TURB.		>32	CONT
35	0	1.25	0	VERY TURB.		>32	CONT
36	0	1.25	-1½	VERY TURB.		>32	CONT
37	0	1.25	-2½	VERY TURB.		>32	CONT
38	0	1.25	-4	VERY TURB.		>32	CONT
39	+25	.75	-4	STEADY		26	CONT
40	AIRFOIL ALONE			TURBUL.		26	CONT
41	+50	1.00	+2½	TURBUL.		26	CONT
42	+50	1.00	-1½	STEADY		27	CONT
43	+50	.75	-2½	STEADY		28	PETARD
44	-25	.75	-2½	SOME TURB.		28	PETARD
45	-25	1.25	-2½	STEADY		29	CONT
46	0	1.25	+6	SOME TURB.		30	PETARD
47	-25	1.00	+2½	TURBUL.		30	PETARD
48	-25	1.00	-1½	STEADY		30	CONT
49	-25	1.00	+6	SOME TURB.		30	CONT
50	0	1.25	+2½	SOME TURB.		31	PETARD
51	0	1.25	+4	STEADY		31	CONT
52	-25	1.00	-2½	STEADY		32	CONT
53	+25	1.00	+4	SOME TURB.		>32	BREAK
54	+25	1.00	+2½	STEADY		>32	PETARD
55	+25	.75	-2½	VERY STEADY		>32	PETARD
56	+25	1.25	+2½	STEADY		>32	PETARD
57	+25	.75	-1½	VERY TURB.		>32	BREAK
58	-25	1.00	+1½	STEADY		>32	BREAK
59	-25	1.00	0	STEADY		>32	PETARD
60	0	1.00	+6	TURBUL.		>32	PETARD
61	-25	.75	-2½	VERY STEADY		>32	CONT
62	-25	1.00	-4	STEADY		>32	CONT
63	-50	1.00	-2½	STEADY		>32	CONT
64	-75	.75	-2½	STEADY		>32	CONT
65	-75	1.00	-2½	STEADY		>32	CONT
66	0	.75	+6	VERY TURB.		>32	CONT
67	+50	1.00	+4	STEADY		22	CONT
68	+100	1.00	+2½	STEADY		22	CONT
69	+75	1.00	+2½	SOME TURB.		26	CONT
70	-50	1.00	+2½	STEADY		30	CONT
71	-75	1.00	+2½	STEADY		30	CONT
72	+50	1.25	+2½	STEADY		>32	CONT
73	-25	1.00	+4	TURBUL.		>32	BREAK
74	-75	1.00	+1½	STEADY		>32	CONT
75	-75	.75	+2½	STEADY		>32	CONT
76	-75	1.00	+4	STEADY		>32	CONT

NO.	STICK %	RUDDER RATIO	DEPTH	RANGE OF AUTOROTATION IN NUMBER OF DEGREES
67	+50	1.00	+4	
68	+100	1.00	+2½	
69	-25	.75	+4	
40	AIRFOIL ALONE			
42	-50	1.00	+1½	
43	-50	.75	+2½	
12	0	.75	+4	
44	-25	.75	+2½	
69	-75	1.00	-2½	
45	-25	1.25	-2½	
46	0	1.25	+6	
47	-25	1.00	-2½	
48	-25	1.00	-1½	
49	-25	1.00	+6	
50	0	1.25	-2½	
51	0	1.25	+4	
52	-25	1.00	-2½	
70	-50	1.00	+2½	
71	-75	1.00	+2½	
41	+50	1.00	-2½	

SUMMARY OF RESULTS

SUBJOINED DIAGRAM SHOWING NON-SPINNING QUALITIES BEYOND CRITICAL ANGLE, LIFT WITHIN FLYING RANGE AND CHARACTER OF THE AIRFLOW AROUND THE COMBINATION.

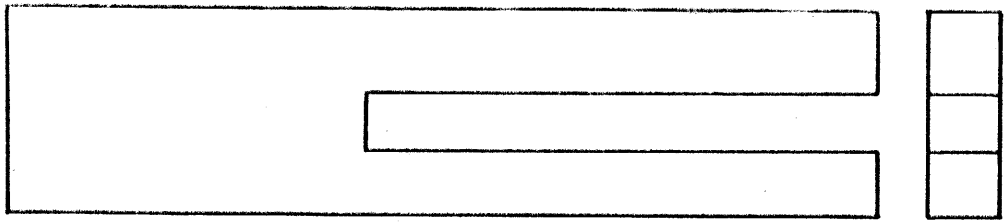


FIG. 1

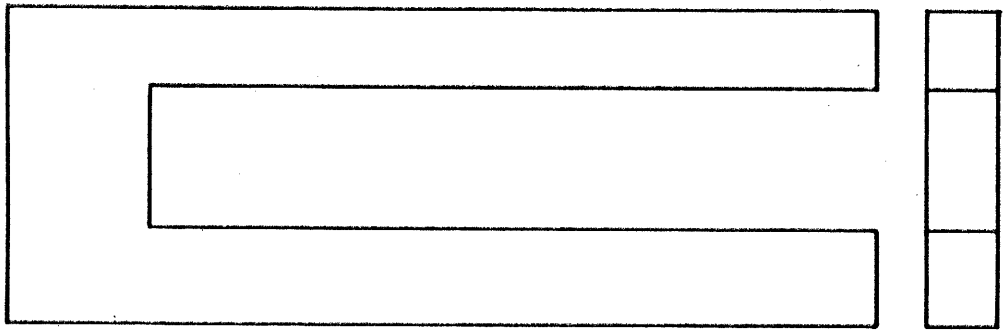


FIG. 2

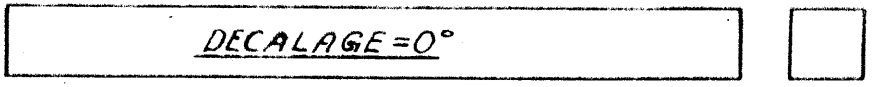


FIG. 3

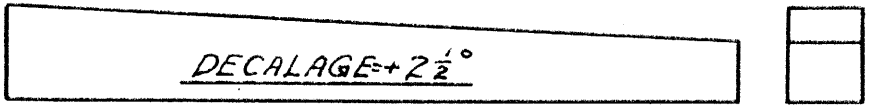


FIG. 4

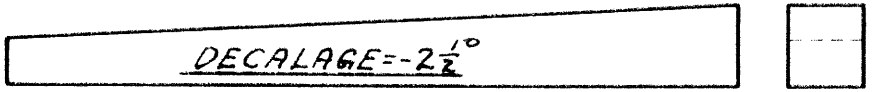


FIG. 5

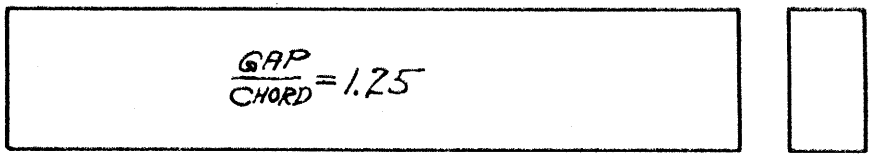


FIG. 6

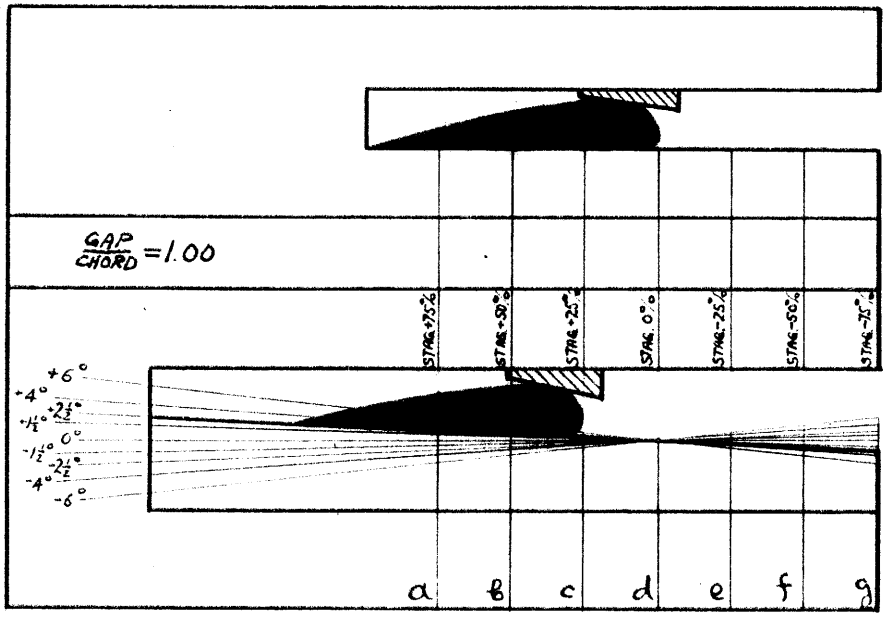


FIG. 7

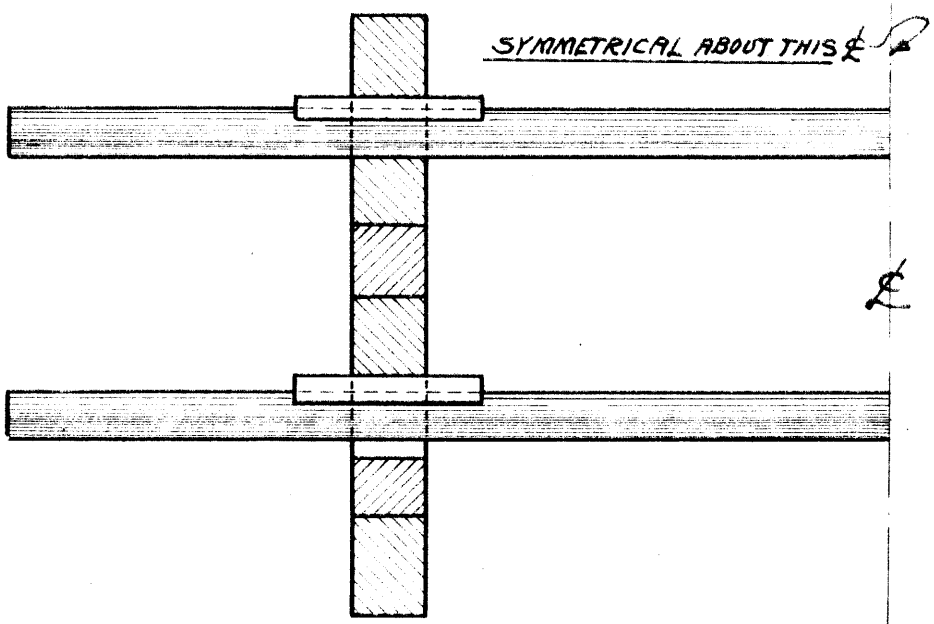


FIG. 8

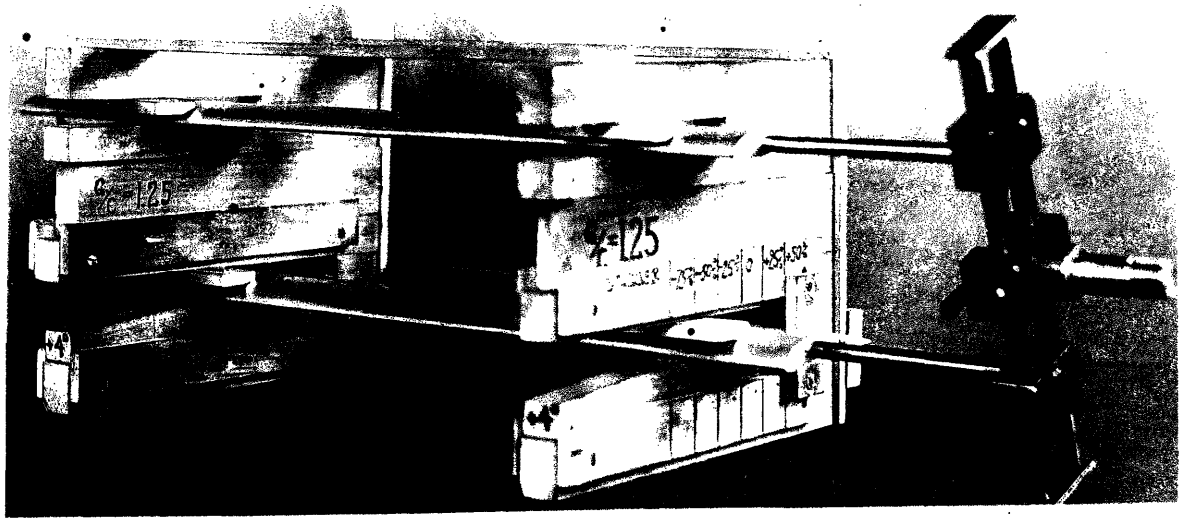


FIG. 9

WING COMBINATION AS ASSEMBLED IN THE JIG AND READY TO BE TAKEN OUT.

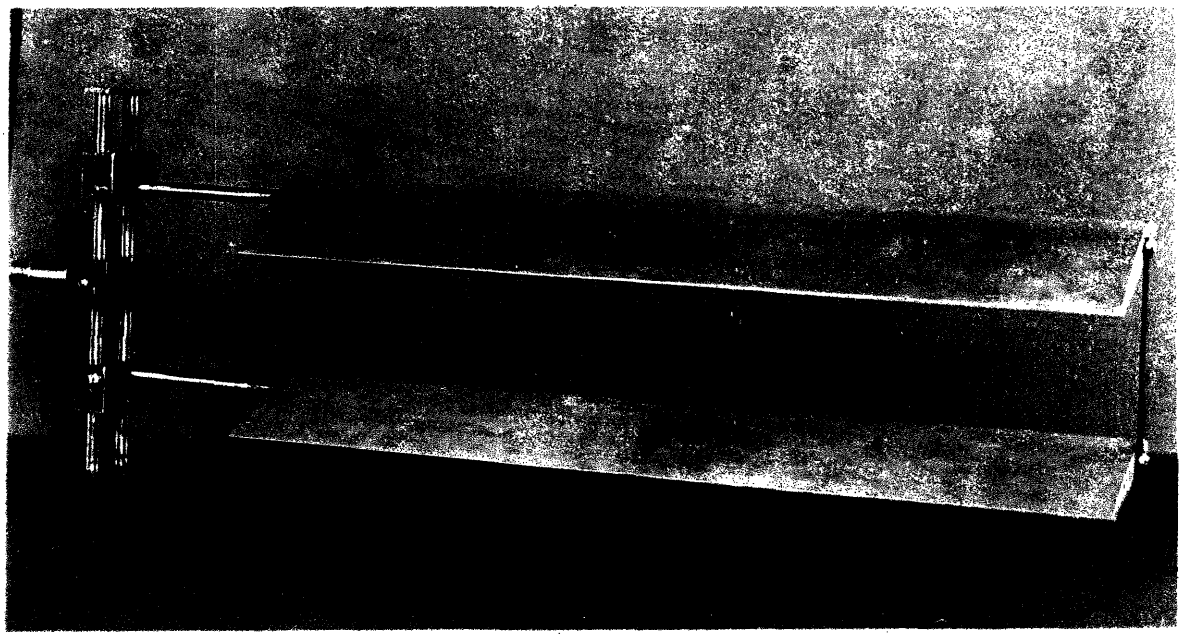


FIG. 10

WING COMBINATION READY TO BE PLACED IN WIND TUNNEL.

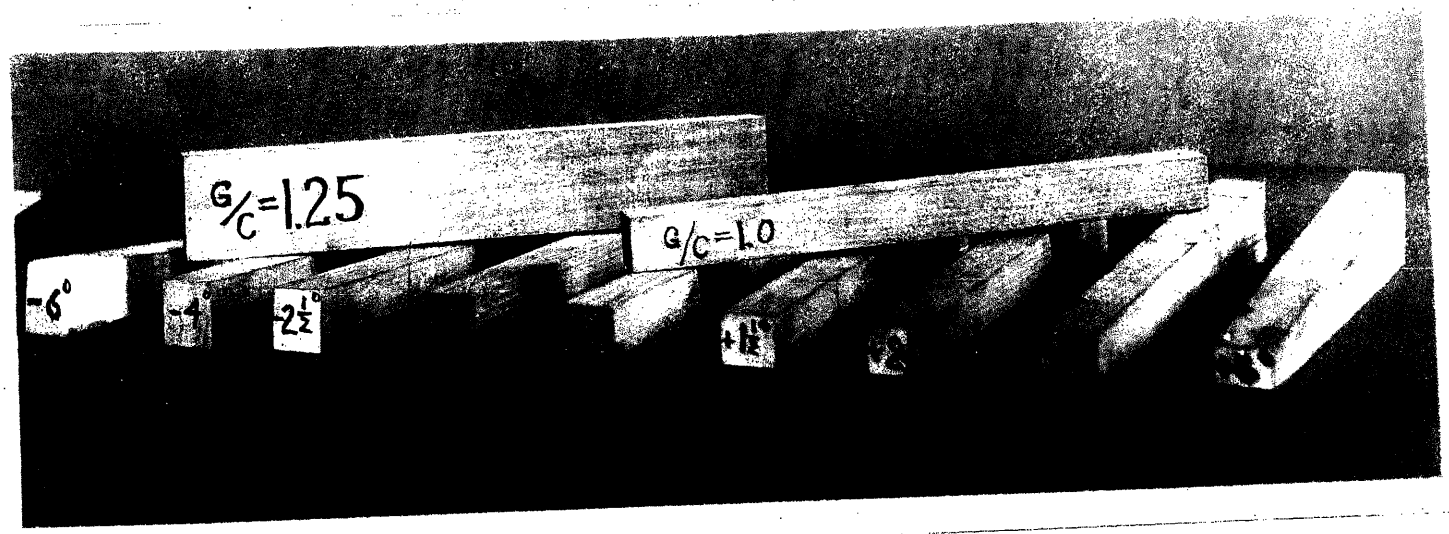


FIG. 11
DECALAGE AND GAP BLOCKS

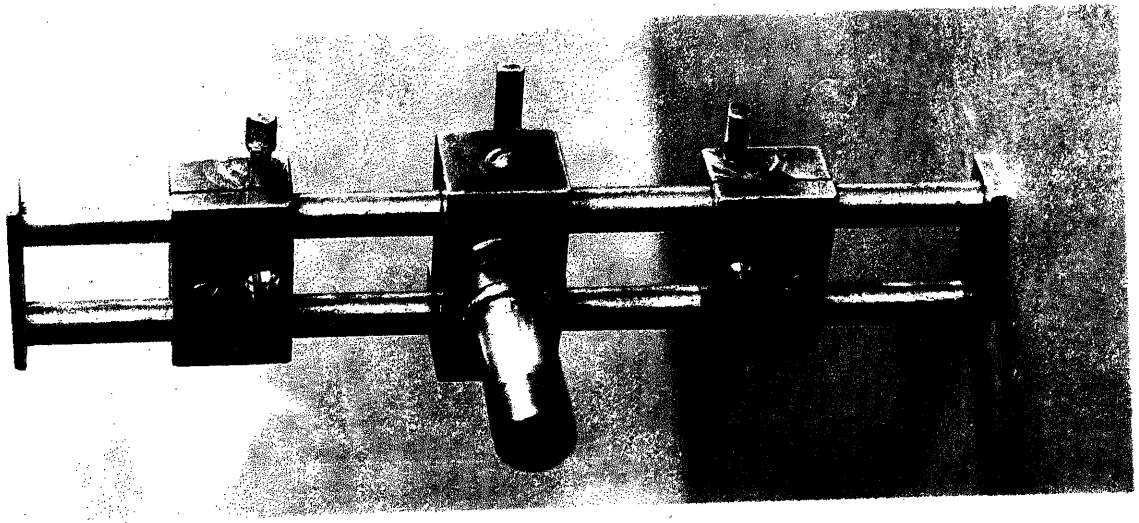


FIG. 12
ADJUSTABLE CROSS-BAR