NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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CHARACTERISTICS AND PROFILE DRAG OF THE

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NACA 35-215 LAMINAR-FLOW AIRFOIL AT

HIGH REYNOLDS NUMBERS

By J. W. Wetmore, J. A. Zalovcik, and Robert C. Platt

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Corps.

A FLIGHT INVESTIGATION OF THE BOUNDARY-LAYER

CHARACTERISTICS AND PROFILE DRAG OF THE

NACA 35-215 LAMINAR-FLOW AIRFOIL AT

HIGH REYNOLDS NUMBERS

By J. W. Wetmore, J. A. Zalovcik, and Robert C. Platt

SUMMARY

Tests have been conducted in flight to determine the boundary-layer characteristics and the profile drag of the NACA 35-215 airfoil section at high Reynolds numbers. These tests were made on a test panel of 17-foot chord mounted on the left wing of a Douglas B-18 airplane just outside of the propeller slipstream. Tests were made to determine the transition points and the boundary-layer velocity profiles for various surface and power conditions over a range of airplane lift coefficients from 0.20 to 0.46 for which the range of corresponding Reynolds numbers was 30,000,000 to 20,000,000. The profile-drag coefficient of the panel was determined for the best surface condition both with power on and with the engines and propellers stopped over a range of airplane lift coefficients from 0.21 to 0.32 with a Reynolds number range of 32,000,000 to 16,000,000. In addition, the profile drag of the upper surface alone was determined for the same power and surface condition and over approximately the same range of airplane lift coefficients and Reynolds numbers.

With the best surface condition and the left engine stopped, the laminar boundary layer was maintained to 42.4 percent of the chord on the upper surface at a lift coefficient of 0.220 and a Reynolds number of 26.700,000. The results of the transition tests indicated a reduction of about 3 percent of the chord in the laminar-flow run over the upper surface due to operation of the engines and propellers. As a result of reducing the indicated amplitude of the transverse waves on the upper surface from 0.005 to 0.001 inch, the transition point moved back from about 32.5 to about 42.5 percent of the chord. The velocity surveys in the laminar boundary layer indicated that values of boundary-layer Reynolds number R_{δ} (based on the distance above the surface at which the dynamic pressure in the boundary layer is one-half that just outside the boundary layer) exceeding 8000 are attainable in flight on suitably designed and carefully finished airfoils.

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The profile-drag coefficient of the test panel with engines stopped was found to remain substantially constant at a value of about 0.0048 for flight conditions ranging from an airplane lift coefficient of 0.21 and a corresponding Reynolds number of about 30,000,000 to a lift coefficient of 0.32 and a Reynolds number of 24,000,000. Over the same range of conditions the profile-drag coefficient of the upper surface alone varied from about 0.0022 at the lowest lift coefficient tested to 0.0028 at the highest lift coefficient. With both engines operating at full throttle the drag coefficient due to both surfaces and that due to the upper surface alone were both increased on the order of 8 to 10 percent.

The results of the tests indicate the desirability for continued flight research on airfoils at large scale to supplement the development work of the tunnels.

INTRODUCTION

During the earlier stages of the Committee's work on the development of laminar-flow airfoils (reference 1), it was found that by suitably designing the profile of an airfoil a favorable or accelerating prossure gradient could be maintained over as much as 80 percent of the chord back of the leading edge. Tests of some of these airfoils in the wind tunnels and in flight showed that within the lower flight range of Reynolds numbers the laminar boundary layer extended as far back as 80 percent of the chord from the leading edge, with the result that the profile drag was extremely low.

In the higher Reynolds number ranges, say, above 20,000,000, it was expected that other methods might be required to obtain the desired extensive laminar boundary layers and resulting extremely low drags. The present investigation was undertaken with the object of investigating methods of prolonging the laminar flow at high Reynolds numbers and to give data for comparison with wind-tunnel data. Consequently, a suitable wing was chosen with these objects in view rather than with this object of choosing an optimum section for any particular practical application. This report represents results of the tests of the plain airfoil. These tests covered a range of Reynolds numbers between 20,000,000 and 30,000,000 and included variations in power condition and surface condition. An investigation of the effect of section slots for boundary-layer control will be covered in a subsequent report.

The tests were made with a B-18 airplane which was made available for this project by the Army Air Corps.

APPARATUS

The Douglas B-18 airplane is a bimotored, fully cantilever, midwing monoplane with a wing area of 958.6 square feet and a design gross weight of 23,200 pounds. It is powered with Wright Cyclone R-1820-45 engines (810 horsepower at 2100 rpm and 8700 feet) fitted with 3-blade propellers having a diameter of 11 feet 6 inches. Hamilton Standard, hydraulically controlled, constant-speed propellers are normally used on this airplane, but for most of the present tests, they were replaced by Curtiss electrically controlled full-feathering propellers in order that the ongines could be stopped during flight. The weight of the airplane as flown was approximately 22,000 pounds.

A test panel having the NACA 35-215 airfoil section (table I) was mounted on the left wing of the airplane. The chord of the panel was 17 feet and the span was 10 feet at the leading edge, tapering to 5 feet at the trailing edge. It was constructed of laminated white pine in the form of a hollow shell with walls about 2 inches thick; the outside profile was accurately shaped to templet size. The surfaces were sprayed with several coats of lacquer base filler and rubbed down with various grades of water cloth, the final finish being obtained with a No. 400 water cloth. The panel was supported on the wing by rubber pads running along the top and bottom of the wing spars and was secured in place by means of steel straps. The position of the panel was such that the inboard end of the leading edge was about 1 foot outboard of the propeller disk, the leading and trailing edges were normal to the plane of symmetry of the airplane, and the plane of chord lines coincided approximately with the plane of chord lines of the wing. The panel was faired into the wing by means of fabric stretched taut over a wooden framework. The weight of the panel and fairing was 1394 pounds: satisfactory lateral balance for all conditions of flight was obtained by removing all fuel from the left-wing tanks and adding 350 pounds of ballast in the right wing tip. Figure 1 is a photograph of the test panel mounted on the wing; its dimensions and location are shown in figure 2.

The upper surface of the panel was refinished several times during the course of the tests so that various surface conditions are represented in the results. An index of the surface waviness, i. e., the magnitude of the transverse waves, was obtained by measuring the curvature variation along the surface by means of the device shown in figure 3. Finishing the lower surface was found to be very difficult so that no attempt was made to refinish it and no waviness measurements were made on it. The condition of the lower surface throughout the investigation is believed to have been about the same as the initial condition of the upper surface.

Free-stream static and total pressures were measured by means of static- and total-pressure tubes which were calibrated with a static head suspended below the airplane.

The characteristics of the boundary layer were determined by means either of 5-tube or 2-tube racks. The 5-tube racks were each composed of a static-pressure tube and four totalpressure tubes arranged to measure the static pressure just outside the boundary layer and the total pressure close to the surface and at various distances above the surface within the boundary layer; they were used to determine the velocity profile of the boundary layer. In cases where it was desired to determine only the point at which transition cocurred the 2-tube racks, each consisting of a static tube located just outside the boundary layer and a total-pressure tube located close to the surface, were used.

Wake-pressure surveys for the determination of profile drag were accomplished by means of a bank of 25 total-pressure and 6 static-pressure tubes located 12 percent of the chord back of the trailing edge on the panel center line and extending through the entire wake. The total-pressure tubes were spaced 0.60 inch apart. A bank of tubes consisting of 21 total-pressure tubes, spaced 0.25 inch apart, and 3 static-pressure tubes, mounted at the center of the trailing edge and extending cnly through the upper surface wake was used for the determination of the profile drag of the upper surface alone.

All pressures were measured by means of a multiple-tube alcohol manometer and were recorded photographically.

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TESTS

Boundary-layer measurements were made on the upper surface of the test panel over a range of airplane lift coefficients from about 0.20 to 0.46; the range of corresponding Reynolds numbers was from about 30,000,000 to 20,000,000. Several conditions of the panel surface, as indicated in figure 4, and various power conditions were investigated. The power conditions covered were as follows: both engines full throttle; both engines idling; left engine stopped, right engine full throttle; right engine stopped, left engine full throttle; both engines stopped. Only a few tests were made on the lower surface of the panel because of its inferior condition.

The profile drag due to both surfaces and that due to the upper surface alone was determined with the panel surfaces in the final condition and for two power conditions: both engines at full throttle and both engines stopped. The profile-drag measurements covered a range of airplane lift coefficients from 0.21 to 0.32 with a range of corresponding Reynolds numbers from 32,000,000 to 24,000,000.

Inasmuch as it was necessary to dive the airplane in order to attain the low lift coefficients desired, the relative lag of the various pressure tubes and lines was determined by special tests and the results were corrected accordingly.

RESULTS ·

Results of the investigation are presented in figures 5 to 10 and in tables II to V. In figure 5 the distributions of pressure coefficient, S, $(S=q/q_0)$, over the forward parts of the surfaces are shown. All experimental points in figure 5 are for positions along the center line of the upper and lower surfaces of the test panel and were determined by means of the boundary-layer racks. Transition results are presented in tables II and III for four surface conditions as shown in figure 4, and for various engine and propeller conditions. The ranges of lift coefficient and Reynolds number covered in each test run are included in addition to the particular lift coefficients and Reynolds numbers at which transition occurred. The method of determining the conditions for transition is indicated in figure 6. In figures 7 and 8 the velocity distributions in the laminar-boundary layer are shown for various chordwise and lateral positions on the upper and lower surfaces as plots of u/U against $\frac{y}{c}$, R, where u is the velocity within the boundary layer, U is the velocity just outside the boundary layer, y is the distance from the surface at which u is measured, c is the panel chord, and R is the Reynolds number in terms of the panel chord and the free-stream velocity; this method of plotting eliminates the effect of variations in Reynolds number. Values of R₅, the boundary-layer Reynolds number in terms of U and of the value of y at which u/U = 0.707, are listed in table IV for various conditions under which transition to turbulent flow was probably imminent. The profile-drag coefficients for both surfaces and for the upper surface alone are given in figures 9 and 10, respectively, and in table V.

DISCUSSION

The pressure distribution over the forward 53 percent of the chord on the upper surface and over 40 percent of the chord on the lower surface was determined from the static-pressure measurements obtained with the boundary-layer racks. Inasmuch as the section lift coefficients c_1 could not be evaluated without pressure-distribution data over the entire panel chord, the results of the investigation are presented in relation to the airplane lift coefficient C_L . A spanwise variation in the surface pressures indicated that the section lift coefficient varied on the order of 4 or 5 percent over the range of spanwise positions covered in the tests, being highest inboard and lowest outboard of the panel center line. The section lift coefficient at the center of the test panel is estimated to be about 0.90 of the airplane lift coefficient.

The experimental pressure distribution shown in figure 5 was obtained at an airplane lift coefficient of 0.238 so that the section lift coefficient was probably about 0.22 as compared to the value of 0.20 at which the airfoil is designed to operate. This small difference in lift coefficient would probably not materially affect the shapes of the curves. The minimum pressure on the upper surface is shown to occur at about 45 percent of the chord.

The transition conditions summarized in tables II and III are defined as the conditions at which, for a given chordwise position, a slight departure from the given lift coefficient-Reynolds number combination would cause transition from laminar to turbulent flow. The transition was generally well defined by an abrupt rise in the velocity close to the surface as illustrated in figure 6.

Comparison of the transition results for the various conditions tested is rather uncertain in some cases owing to the fact that there is no fixed relation between airplane lift coefficient and Reynolds number; i. e., for a quantitative evaluation of the effect, for example. of the power or surface condition on the extent of the laminar-boundary layer, comparison should be made at the same lift coefficient and at the same Reynolds number. There are, however, several conclusions indicated by the results. With the best surface condition tested (condition D, fig. 4) and with the left engine stopped the laminar boundary layer was maintained to 42.4 percent of the chord on the upper surface. As shown in table II, transition was observed at this station at several different combinations of CT and R owing to the unavoidable variation in the relation of R to $C_{\rm L}$ between different test runs. At an airplane lift coefficient of 0.220 which most nearly approaches the design lift coefficient of the panel $(c_1 = 0.20)$, the Reynolds number for transition at 12.4 percent of the chord was 26.7 millions. The transition point on the lower surface was not determined for exactly the foregoing conditions but, as shown in table III, at a lift coefficient of 0.247 and a Reynolds number of 26.8 millions transition occurred at 28.4 percent of the chord so that for $C_T = 0.220$, representing a more unfavorable condition for the lower surface, the extent of the laminary layer would be somewhat less than 28.4 percent of the chord. This result is an indication of the degree of inferiority of the lower surface condition as compared to that of the best upper surface condition.

The influence of surface condition on the position of transition is shown more directly by comparison between the transition results obtained with the different upper surface conditions. With condition A, for which the indicated amplitude of the transverse surface waviness was as much as 0.005 inch, and with the left engine stopped, transition occurred at 32.5 percent of the chord and 24 inches outboard of the panel center line at an airplane lift coefficient of 0.247 and a Reynolds number of 26.4 millions. For surface condition D, with an indicated waviness amplitude of 0.001 inch, and the same power condition the transition occurred at 42.4 percent of the chord at the same Reynolds number and a more unfavorable lift coefficient of 0.256. The result of the improvement in the upper surface condition was therefore an increase in the extent

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of the laminar boundary layer of at least 10 percent of the chord. The effects of the intermediate surface conditions are not definitely indicated by the results.

Operation of the engines and propellers had an adverse effect on the extent of the laminar layer. Comparison of the results obtained with both engines operating at full throttle with those obtained with both engines stopped indicates a reduction in the laminar-flow run of about 3 percent of the chord.

In figures 7 and 8 boundary-layer velocity distributions, determined for several conditions from the tests, are compared with the theoretical Blasius flap-plate distributions. In general, the experimental points conform to the theoretical profile shape within the probable limits of accuracy of the measurements. The effect of the favorable pressure gradient, which is maintained over the forward 45 percent of the 35-215 airfoil section, is evidenced in figure 7 by the values of equivalent flat-plate length, corresponding to the Blasius profiles, which are generally less than the actual distance along the surface from the stagnation point.

The values of R8 derived from the measured velocity distributions in the laminar boundary layer and listed in table IV range from about 7500 to 9000. Although individual values may not be entirely reliable, the results, in general, are sufficiently consistent to permit the conclusion that values of R_{δ} of at least 8000 are attainable before transition occurs in flight on suitably designed and carefully finished airfoils. The value 8000 represents a considerable increase over the highest values obtained in the original NACA low-turbulence tunnel on laminar-flow airfoils similar to the 35-215 section; this comparison indicates that even with extremely low turbulence in the tunnel air stream, boundary-layer and profile-drag measurements may be subject to considerable revision when applied to flight conditions. It is pointed out that while the value $R_8 = 8000$ may not be the ultimate attainable, this value has been attained and therefore may be used as a guide in estimating what may be expected in the extent of the leminar boundary layer and hence in profile drag for airfoils having pressure-distribution characteristics generally similar to those of the 35-215 airfoll.

The profile-drag coefficient of the panel was determined from the full-wake surveys in accordance with the momentum method as developed by Jones. (See reference 3.) For the power-off condition the coefficient is substantially constant over the range of lift coefficient and Reynolds number investigated and has a value of about 0.0048. With power on the value is increased to about 0.0052 or 8 percent.

In view of the inferior condition of the lower surface of the panel the profile-drag measurements on the upper surface alone are considered as more nearly representative of the capabilities of the airfoil. The drag coefficients were evaluated from the half-wake surveys by the method of Squire and Young. (See reference 4.) As shown in figure 10, for the power-off condition the coefficient increased from about 0.0022 at an airplane lift coefficient of 0.23 and a Reynolds number of 29,000,000 to 0.0028 at a lift coefficient of 0.32 and a Reynolds number of 24,000,000. It is reasonable to assume that for equally good surface conditions the drag due to the lower surface would be less than that of the upper surface so that the minimum drag coefficient of the airfoil would be somewhat less than 0.0044. The adverse effect on the drag coefficient due to engine and propeller operation is substantiated by the power-on results which show an increase in drag coefficient of about 10 percent over the power-off values.

In reference 4, in addition to the method of determining profile drag from wake surveys, there is developed a method of predicting the drag from a knowledge of the location of the transition point, the laminar boundary-layer velocity distribution immediately forward of the transition point, and the pressure distribution between the transition point and the trailing edge. To make use of this method the experimental pressure-distribution curve for the upper surface given in figure 5 was extended from 53 percent of the chord to the trailing edge where the pressure was known from the halfwake surveys. The profile-drag coefficient of the upper surface was then calculated for the cases of transition at 42.5 percent and 32.5 percent of the chord, both at a Reynolds number of 28,000,000. For the 42.5 percent location the drag coefficient was 0.0023 which is in close agreement with the value obtained by the wake-survey method. With transition at 32.5 percent of the chord the drag coefficient was calculated to be 0.0028. These results indicate a reduction of about 18 percent in the profile drag due to the improvement in surface condition between condition A and condition D.

The significance of the values of profile drag obtained from the tests of the 35-215 airfoil section may become more apparent from suitable comparisons. For example, the theoretical turbulent skin-friction drag coefficient for two sides of a flat plate at the Reynolds number at which the value of 0.0048 was obtained for the test panel is 0.0052 or about 8 percent greater. The minimum profile-drag coefficient for the conventional NACA 0015 airfoil section is estimated to be 0.0057 at the same Reynolds number or about 20 percent greater than that of the 35-215 section. Comparison on the basis of the upper surface drag indicates that the single surface turbulent skin friction of a flat plate is about 12 percent greater and the single surface drag of the 0015 section about 30 percent greater than the upper surface drag of the 35-215 airfoil section.

CONCLUDING REMARKS

A laminar boundary layer was maintained over the upper surface of the NACA 35-215 test panel to x/c = 0.424 where transition to turbulent flow occurred at a lift coefficient of 0.220 and a Reynolds number of 26,700,000. Improving the condition of the upper surface so that the indicated amplitude of the transvorse waves, as measured with the surface curvature gage, was reduced from 0.005 inch to 0.001 inch resulted in increasing the extent of the laminar boundary layer from 32.5 percent to 42.5 percent of the chord, thereby probably reducing the profilo-drag coefficient of the upper surface about 18 percont. The results of the transition tests indicated a forward movement of the transition point of about 3 percent of the chord due to operation of the engines and propellers.

The velocity surveys in the laminar boundary layer indicated that values of boundary-layer Reynolds number R_{5} (based on the distance from the surface at which the dynamic pressure in the boundary layer is one-half that just outside the boundary layer) exceeding 8000 are attainable in flight on suitably designed and carefully finished airfoils.

The profile-drag coefficient with power off was very nearly constant with a value of 0.0048 for flight conditions ranging from an airplane lift coefficient of 0.21 and a corresponding Reynolds number of about 30,000,000 to a lift coefficient of 0.32 and a Reynolds number of 24,000,000. For the same range of conditions the profile-drag coefficient of the upper surface alone varied from 0.0022 to 0.0028. The effect of full-throttle operation of the engines and propellers increased the profiledrag coefficients as measured for both surfaces and for the upper surface alone on the order of 8 to 10 percent. Comparison of the results of the present flight tests on the 35-215 airfoil section with data obtained on generally similar airfoils in the original NACA low-turbulence wind tunnel showed that in flight the laminar boundary layer was maintained to values of R_8 considerably greater than the highest values that were attained in the tunnel. This result indicated that even in tunnel air streams of extremely low turbulence the effect of the residual turbulence might be appreciable, and thereby demonstrated the necessity of continued flight research on airfoils of large scale to supplement the development work of the tunnels.

Langley Memorial Aeronautical Laboratory, National Advisory Committee for Aeronautics, Langley Field, Va., May 5, 1941.

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TABLE I ORDINATES OF NACA 35-215 AIRFOIL

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UPPER	SURFACE	LOWER	SURFACE		
$\frac{X}{C} \times 100$	¥ ×100	$\frac{X}{C} \times 100$	<u>y</u> x100		
0	0	0	· 0		
1.085	1.857	1.415	-1.563		
2.307	2.619	2.693	-2.101		
4.786	3.674	5.214	-2.792		
7.278	4.510	7.722	-3.322		
9.777	5.211	10.223	-3.759		
14.788	6.344	15.212	-4.448		
19.809	1.221	20.191	- 4.973		
24.838	7.899	25.162	-5:375		
29.873	8.416	30.127	-5.680		
34.913	8.774	35.087	-5.988		
39.958	8.961	4 0.042	-5.989		
50.077	8.702	49.923	-5.762		
60.150	7.265	59.850	- 4.703		
70.137	5.277	69.863	-3.295		
80.086	3.123	79.914	-1.817		
85.056	2.098	84.94.1	-1.140		
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44./ 32.5 27.7 32.5	3 4 11 7 7 8 9 10 11 7	A A A A A A B C A	.265 .245 .245 .221 .234 .234 .210 .264 .226 .221 .234	27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	.459 .446 R1. .292 eft .375 .325 .261 .370 .277 .301 .375	20.3 1/9.9 ght 25.6 22.5 22.5 22.5 26.4 24.8 26.5 26.5 26.5	Eng 	 	7: 5+op	256 219ht	27.1 En 	256	27./ e Fa 280 T		Г Бго 1 1 1 1	// 7 // 7	T +ro 	.247	 268 r		
44./ 32.5 27.7	3 4 11 7 7 8 9 10 11 7 8	A A A A A A A B B C	.265 .245 .245 .234 .234 .234 .246 .224 .226 .221 .234 .225	27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	,459 .446 R1. .292 eft .375 .325 .261 .310 .277 .301 .375 .301 .375 .261	20.3 1/9.9 ght 25.6 22.5 22.5 22.5 22.5 26.4 24.8 26.5	Eng .247	 	T: Stop 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 7	256 2194+ .269	27.4 E n 24.8 T 	256	27./ - - 2.80 - 2.80 - 2.6.8 - -		r bro 1 1 1 1 1	// 7 // 7	T 4 ro 	.247	 24.8 		
44./ 32.5 27.7 32.5	3 4 11 7 7 8 9 10 11 7	A A A A A B B C C A A A	.265 .245 .245 .234 .234 .234 .210 .264 .226 .221 .236 .236 .226 .226	27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	.459 .446 R1. .292 eft .375 .325 .310 .277 .304 .375 .304 .375 .310 .310 .277	120.3 1/9.9 ght 125:6 Eng/1 22.5 122.5 122.5 124.8 124.8 124.8 126.5	Eng	 	T: Stop 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 7 T T	256 2194+ .269	27.4 En 	256	27./ e Fa 280 T 26.8 		r hro 1 1 1 1 1 1	// 7 // 7	T 4 ro - - - - - - - - - - - - - - - - - - -	.247	 268 r		
44./ 32.5 27.7 32.5	3 4 11 7 7 8 9 10 11 7 8 9 10	A A A A B C A B C A B B C	.265 .245 .245 .234 .234 .234 .210 .264 .226 .221 .237 .216 .226 .226 .226 .226	27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	.459 .466 R1. .292 eft .375 .325 .261 .370 .277 .325 .36 .370 .370 .370 .370 .370 .370 .370 .370	120.3 1/9.9 ght 125.6 22.5 122.5 122.5 124.8 124.8 124.8 124.8 124.8 124.8 124.8 124.8 124.8 124.8 124.8	Eng	 	T: Stop 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 7	256 2194+ .269	27.4 E n 24.8 T 	256	27./ - - 2.80 - 2.80 - 2.6.8 - -		Г Бро 1 1 1 1 1 1	// 7 // 7	7 - 4 ro 	.247			
44./ 32.5 32.5 37.4	3 4 11 7 7 8 9 10 11 7 8 9 10 11 7 8 9 10 11 7 8 9 10 11 7 8 9 10 11 7 8 9 10 11 7 7 8 9 10 11 7 7 8 9 10 11 7 7 8 9 10 11 7 7 8 9 10 11 11 7 7 8 9 10 11 11 7 7 8 9 10 11 11 7 7 8 9 10 11 11 11 7 7 8 9 10 11 11 11 11 11 11 11 11 11 11 11 11	A A A A A A B C C A A A B B B B	.265 .245 .245 .245 .234 .234 .234 .226 .227 .237 .264 .220 .226 .220 .229 .256	27,0 27,3 27,3 27,8 27,8 27,8 27,8 27,8 27,8 27,8 27,6 28,0 28,0 28,0 28,0 28,0 28,0 28,0 28,0	.459 .466 .7466 .292 .292 .375 .375 .375 .375 .375 .375 .375 .375	20.3 1/9,9 gh+ 25:6 25:6 22.5 22.5 22.5 24.8 24.8 26.9 26.9 26.9 26.9 26.9 26.9 26.9 26.9 26.9	Eng	1 1 1 1 1 1 1 1 1 1 1 1 1 1	T: Stop - <td>256</td> <td> 27.4 En </td> <td>256 9/70 2/0 .269 .269 .243 .255</td> <td>127./ F4 1280 1</td> <td></td> <td>r hro </td> <td></td> <td>7 </td> <td>.247</td> <td></td> <td></td> <td></td>	256	27.4 En 	256 9/70 2/0 .269 .269 .243 .255	127./ F4 1280 1		r hro 		7 	.247			
44./ 32.5 32.5 37.4 40.0	3 4 11 7 7 8 9 10 11 7 8 9 10 19	A A A A B C A A A B B B B D	.265 245 .245 .234 .234 .234 .226 .226 .226 .226 .226 .226 .226 .22	27,0 27,3 27,8 27,8 27,8 27,8 27,8 27,8 28,0 26,6 29,1 29,1 29,1 29,1 29,1 29,1 29,1 29,2 20,2	.459 .466 R1. .292 eft .375 .325 .261 .375 .261 .375 .267 .375 .267 .375 .267 .375 .267 .323 .229 .323 .229 .323	20.3 1/9,9 gh+ 25.6 Emg/17 22.5 22.5 22.5 22.5 26.4 24.8 26.5 26.5 26.5 26 26 26 26 26 26 26 26 26 26 26 26 26	Eng	1 1 1 1 1 1 1 1 1 1 1 1 1 1	T: Stop - <td>256</td> <td> 27.1 Em </td> <td>256 9/70 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/</td> <td> 27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 </td> <td>11 7</td> <td>T T I</td> <td></td> <td>7 </td> <td>.247</td> <td></td> <td></td> <td></td>	256	27.1 Em 	256 9/70 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/	27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 	11 7	T T I		7 	.247			
44./ 32.5 32.5 37.4	3 4 11 7 7 8 9 10 11 7 8 9 10 19	A A A A A A B C C A A A B B B B	.265 .245 .245 .245 .245 .245 .234 .234 .226 .227 .234 .226 .229 .229 .229 .226 .229 .226 .229 .229	27,0 27,3 27,3 27,8 27,8 27,8 27,8 27,6 28,0 28,0 28,0 28,0 28,0 28,0 28,0 28,0	,459 466 R1, ,292 eft 375 325 ,261 375 ,261 375 ,261 ,375 ,261 ,375 ,261 ,375 ,261 ,277 ,323 ,261 ,277 ,323 ,261 ,227 ,227 ,227 ,227 ,227 ,227 ,227 ,22	20.3 1/22 ght 25.6 25.6 25.6 25.6 25.6 25.5 26.4 24.8 26.5 26.4 26.5 26.4 26.5 26.4 26.5 26.4 26.5 26.7 26.7 26.7 26.7	Eng	1 1 1 1 1 1 1 1 1 1 1 1 1 1	T: Stop - <td>256</td> <td> 27.4 En </td> <td>256 9/77 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0</td> <td> 27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 </td> <td>.220</td> <td>r hro </td> <td></td> <td>T -</td> <td>.247</td> <td></td> <td></td> <td></td>	256	27.4 En 	256 9/77 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0	27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 	.220	r hro 		T -	.247			
44./ 32.5 32.5 37.4 40.0	3 4 11 7 7 8 9 10 11 7 8 9 10 19	A A A A B C A A A B B B B D	265 245 245 234 234 227 26 227 226 227 226 229 226 229 2256 229 229 229 229 229 229 229	27.0 27.3 27.8 27.8 27.8 27.8 27.8 27.8 27.6 28.0 28.0 28.0 28.0 28.0 28.0 28.0 28.7 28.7 28.7 28.7 28.7 28.7 28.7 28.7	,459 ,466 R1, ,292 eff ,375 ,261 ,375 ,261 ,375 ,261 ,375 ,277 ,373 ,276 ,373 ,277 ,323 ,272 ,272 ,323 ,272 ,272	20.3 1/9,9 gh+ 25.6 Emg/17 22.5 22.5 22.5 22.5 26.4 24.8 26.5 26.5 26.5 26 26 26 26 26 26 26 26 26 26 26 26 26	Eng 	1 1 1 1 1 1 1 1 1 1 1 1 1 1	T: Stop - <td>256</td> <td> 27.1 Em </td> <td>256 9/77 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0</td> <td> 27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 </td> <td>.220</td> <td>T I <t< td=""><td></td><td>T -</td><td>.247</td><td> 24.8 </td><td></td><td></td></t<></td>	256	27.1 Em 	256 9/77 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0	27./ <i>Fa</i> 280 <i>T</i> 26.8 26.8 26.8 	.220	T I <t< td=""><td></td><td>T -</td><td>.247</td><td> 24.8 </td><td></td><td></td></t<>		T -	.247	 24.8 		
44./ 32.5 32.5 37.4 40.0	3 4 11 7 7 8 9 10 11 7 8 9 10 19	A A A A B C A A A B B B B D	265 245 245 234 234 227 26 227 226 227 226 229 226 229 2256 229 229 229 229 229 229 229	27.0 27.3 27.8 27.8 27.8 27.8 27.8 27.8 27.6 28.0 28.0 28.0 28.0 28.0 28.0 28.0 28.7 28.7 28.7 28.7 28.7 28.7 28.7 28.7	,459 ,466 R1, ,292 eff ,375 ,261 ,375 ,261 ,375 ,261 ,375 ,277 ,373 ,276 ,373 ,277 ,323 ,272 ,272 ,323 ,272 ,272	20.3 1/29 ght 25.6 Eng/1 22.5 26.4 24.8 25.4 25.4 25.4 25.4	Eng ne 51	I I	T: Stop - <td>254 27947 269 269 269 255</td> <td> 27.1 En </td> <td>256 9/20 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0</td> <td> 27./ e Fa 12.86 T T 12.6.8 12.6.8 12.4.4 12.4.4 12.4.4 12.4.4 12.6.5 1.2.65 1</td> <td>.220</td> <td>Г // Г / / / / / / / / / / / / /</td> <td></td> <td>T -</td> <td>.247</td> <td></td> <td></td> <td></td>	254 27947 269 269 269 255	27.1 En 	256 9/20 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0	27./ e Fa 12.86 T T 12.6.8 12.6.8 12.4.4 12.4.4 12.4.4 12.4.4 12.6.5 1.2.65 1	.220	Г // Г / / / / / / / / / / / / /		T -	.247			
44./ 32.5 37.4 40.0 42.4	3 4 11 7 7 8 9 10 19 19	A A A A A A A B B C A A A B B B B D D	265 224 234 234 220 224 226 226 224 226 224 226 224 226 227 229 229 229 229 229 229 229 229 229	270 273 274 278 278 278 278 278 278 278 287 287 287	.459 .446 R1, .292 eft .375 .345 .267 .375 .267 .375 .267 .375 .267 .375 .267 .375 .267 .277 .375 .267 .277 .262 .287 .246 .287 .246 .287 .246 .287	20.3 1/9,7 ght 25.6 Engli 22.5 22.5 22.5 24.4 24.8 26.5 26.7 25.4 26.5 26.7 25.4 26.5 26.7 25.6 26.7 25.6 26.7 25.6 26.7 25.6 26.7 25.6 26.7 25.6 26.7 27.5 27.5	Eng 	I I	7: 5 + o p 	254 27947 269 269 269 255	27.1 En 	256 9/70 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/	27./ e Fa 12.86 T T 12.6.8 12.6.8 12.4.4 12.4.4 12.4.4 12.4.4 12.6.5 1.2.65 1		Г // Г / / / / / / / / / / / / /		T -	247			
44./ 32.5 32.5 37.4 40.0	3 4 11 7 7 8 9 10 11 7 8 9 10 11 19 19 19 7 7	A A A B C A B C A B C A B C A B C A B B B C A A A A	265 245 2245 234 234 234 234 224 224 224 226 227 226 229 229 229 229 229 229 229 225 229 225 225	27.0 27.3 27.8 27.8 27.8 27.8 27.8 28.0 28.0 28.0 28.0 28.0 28.0 28.0 28	.459 .446 R1, .292 eft .375 .325 .325 .325 .325 .375 .375 .375 .375 .375 .375 .375 .37	20.3 1/9.7 ght 22.5 22.5 22.5 22.5 22.5 22.5 22.5 22.5 22.5 24.8 26.5 24.8 26.5 24.8 26.5 24.9 24.9 24.9 25.4 25.6 25.4 25.6	Eng 	1 1 1 1 1 1 1 1 1 1 1 1 1 1	7: 5 + op 1 2 ed j A 1 1 1 1 1 1 1 1 1 1 1 1 1	254 27947 269 269 269 255	27.1 En 	256 9/70 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/	27.7 $= F_4$ 12,600 		T T I		T -	247	 24.8 		
44./ 32.5 37.4 40.0 42.4	3 4 11 7 7 8 9 10 19 19 19 7 8	A A A A A A B B B D D A A	265 245 234 234 234 234 234 234 224 224 224 224	270 273 274 278 278 278 278 278 277 287 287 287 287	.459 .459 .446 R1, .292 eft .375 .261 .375 .261 .375 .277 .323 .248 .287 .324 .287 .248 .287 .248 .287 .248 .287 .248 .287 .262 .287 .262 .287 .262 .267 .262 .267 .262 .267 .262 .267 .262 .267 .262 .267 .262 .267 .262 .274 .265 .267 .267 .275 .375 .267 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .375 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .376 .277 .277 .376 .277 .277 .277 .277 .277 .277 .277 .2	20.3 1/2, 2 ght 25.6 Eng/11 22.5 22.5 22.5 22.5 22.5 22.5 24.8 24.8 24.8 24.8 24.8 24.7 25.4 24.8 24.7 25.4 25.4 25.6 24.5 25.6 24.5 25.6 24.5 25.6 24.5 25.6 24.5 25.6 25.6 25.6 25.6 25.6 25.6 25.6 25.6 25.6	Eng 247	I I	7: 5 + o p 	254 7/9ht 269 269 269 269 269 250 250	27.1 En 	256 9/70 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/	27./ <i>F</i> 4 <i>T</i> 2. <u>R</u> 0 <i>T</i> 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.		I I		T -	247	 24.8 		
44./ 32.5 27.7 32.5 37.4 40.0 42.4	3 + 11 7 7 8 7 8 7 10 11 19 19 19 19 19	A A A A A A A B B B C C A A B B B D D D D	265 224 234 234 220 220 224 220 224 220 224 220 229 229 229 225 229 225 238 238 238 224 224 224 224 225	2 7 0 2 7 0 2 7 8 2	.459 .446 R1. .292 eft .375 .241 .375 .241 .375 .261 .375 .261 .375 .267 .375 .267 .323 .248 .287 .287 .287 .282 .287 .282 .287 .282 .287 .282 .284 .287 .282 .284 .287 .282 .284 .287 .284 .287 .284 .287 .284 .287 .284 .287 .284 .287 .287 .287 .297 .297 .297 .297 .297 .297 .297 .29	20.3 1/9,7 ght 25.6 Emgin 22.5 22.5 22.5 22.5 24.4 24.8 26.9 26.9	Eng .247	1 1 1 1 1 1 1 1 1 1 1 1 1 1	7: 5 + op 1 2 ed j A 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9ht 269 269 269 269 269 250 250	27.1 En 	256 9/70 210 220 220 220 220 220 220 220 220 22	27./ <i>F</i> 4 <i>T</i> 2. <u>R</u> 0 <i>T</i> 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.		T I		T -	247	 24.8 		
44./ 32.5 27.7 32.5 37.4 40.0 42.4	3 + 11 7 7 8 9 10 11 7 8 9 10 19 19 19 19 19 19 19 19 19	A A A A B B C A A B B C A A A A C	265 245 234 234 234 234 234 224 224 224 224 224	270 27.3 27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	.459 .446 R1, .292 eft .375 .347 .355 .261 .370 .277 .307 .373 .261 .370 .373 .261 .375 .261 .375 .261 .375 .262 .277 .262 .287 .246 .2340 .256 .2580 .2580	20.3 1/2, 2 ght 25.6 Eng/11 22.5 22.5 22.5 22.5 22.5 22.5 24.8 24.8 24.8 24.8 24.8 24.7 25.4 24.8 24.7 25.4 25.4 25.6 24.5 25.6 24.5 25.6 24.5 25.6 24.5 25.6 24.5 25.6 25.6 25.6 25.6 25.6 25.6 25.6 25.6 25.6	Eng 	1 1	7: 5+op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9ht 269 269 269 269 269 250 250	27.1 Em 	256 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0	27./ <i>F</i> 4 2 <u>R</u> 0 		I I			247	 24.8 		
44./ 32.5 27.7 32.5 37.4 40.0 42.4	3 4 11 7 7 8 9 10 19 19 19 19 19 19 19 19 19 19	A A A A A B B C A B B D D A A A A A A A A A A A A A	265 245 234 234 234 234 234 224 224 224 226 227 226 229 226 229 225 229 225 225 225 225 225 225 225	270 273 273 278 278 278 278 278 278 284 284 284 284 284 284 284 284 284 28	.459 .459 .446 R1, .292 eft .375 .261 .375 .261 .375 .261 .375 .277 .323 .248 .287 .323 .248 .287 .227 .262 .287 .262 .287 .262 .287 .262 .287 .262 .274 .262 .274 .262 .274 .262 .274 .262 .274 .262 .274 .262 .274 .262 .274 .262 .262 .274 .262 .264 .262 .264 .264 .274 .262 .264 .264 .264 .264 .264 .264 .26	20.3 1/2, 2 ght 25.6 Eng/11 22.5 22.5 22.5 22.5 22.5 22.5 22.5 24.8 26.5 24.8 26.5 26.5 26.5 25.4 25.6 26.5 25.6 27.5 25.6 26.5 25.6 27.5	Eng 247 247 	1 1	7: 5 + o p 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9ht 269 269 269 258 258 258 258	27.4 En 	256 9170 210 220 220 220 220 220 220 220 220 20 20	27./ F4 280 T 26.8 26.8 		7 7 1			247	 24.8 		
44./ 32.5 27.7 32.5 40.0 42.4 27.7 32.3	3 4 11 7 7 8 9 10 17 8 9 10 19 19 19 19 7 7 8 11 14 7 8 11 14 7 8 11 19 19 19 19 19 19 19 19 19	A A A A B B C C A A B B C C A A C D D C D C C C C C C C C C C C	224 224 224 224 224 224 224 226 227 224 224 224 225 225 238 238 238 238 238 225 225 225 225 225 225 225 22	270 27.8 27.8 27.8 27.8 27.8 27.8 27.8 27.8	.459 .459 .446 .71. .292 .292 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .287 .287 .274 .256 .280 .346 .276 .256 .280 .345 .256 .280 .276 .280 .286 .286 .286 .286 .286 .286 .286 .286	20.3 1/9,7 ght 25.6 Eng/1 22.5 22.5 22.5 22.5 22.5 24.4 24.8 24.7 25.4 24.7 25.4 26.7 25.4 26.7 25.4 26.7 25.4 26.7 25.4 26.7 25.6 26.7 25.7 25.7	Eng .247	1 1	7: 5+op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 719ht 269 269 269 269 269 269 269 259 259 259 259 259 259 259 259 259 25	27.1 En. 1 1 1 1 1 1 1 1 1 1 1 1 1	256 9/70 2/0 220 220 220 220 220 220 220 220 22	27./ F4 280 T 26.8 26.8 		7 7 1			247	 24.8 		
44. / 32.5 27.7 32.5 37.4 40.0 42.4 27.7 32.3 37.4	3 4 11 7 7 8 9 10 19 19 19 19 19 19 19 19	A A A A A B C A A A A A A A A A A A A A A A A A A D D	265 245 234 234 234 234 234 224 224 224 224 224	270 273 278 278 278 278 278 280 280 280 280 280 280 280 280 280 28	.459 .446 R1, .292 eft .375 .375 .375 .375 .375 .375 .375 .375	20.3 1/9.7 ght 22.5 Eng/1 22.5 22.5 22.5 22.5 22.5 22.4 22.5 22.7 22.5 22.7 23.6 22.7 23.6 22.7 23.6 22.7 23.6 22.7 23.7 	Eng 1247	1 1	7: 5 + o p 1 1 1 1 1 1 1 1 1 1 1 1 1	254 719ht 269 269 269 269 269 269 269 259 259 259 259 259 259 259 259 259 25	27.4 En 	256 9/70 2/0 .269 .269 .243 .243 .243 .243 .243 .243 .245 .256 .256 .256 .256 .256 .256 .256 .25	27./ Fa Fa 12.6.0 T 12.6.0 1 12.6.2 1 1 2.6.3 1 1 1 2.6.3 1 1 1 2.6.0 1 1 2.6.0 1 1 2.6.0 T T T T T T T T T T T T T		Image: Constraint of the second se			247			
44. / 32.5 27.7 32.5 37.4 40.0 42.4 27.7 32.5 37.4 40.0	3 4 11 7 7 8 9 10 19 19 19 19 19 19 19 19 19	A A A A A B C A A A B B C A A A A A A A A A A A A A A A A D D D D	265 245 245 234 234 234 234 224 224 224 226 227 226 229 226 229 226 229 226 229 225 238 225 238 225 238 225 238 225 238 225 225 225 225 225 225 225 225 225 22	270 273 274 278 278 278 278 278 278 278 278 284 284 284 284 284 284 284 284 284 28	.459 .459 .446 R1, .292 eft .375 .242 .375 .242 .277 .323 .248 .248 .248 .248 .248 .248 .248 .248	20.3 1/2,7 ght 25.6 Eng/17 22.5 22.5 22.5 22.5 22.5 24.8 26.5 24.8 26.5 26.7 25.4 25.5 26.7 25.4 25.5 26.7 25.5 26.7 25.5 26.7 25.5 26.7 25.5 26.7 25.5 26.7 25.5 25.5 25.5	Bo	1 1	7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 719ht 269 269 269 269 269 269 269 259 259 259 259 259 259 259 259 259 25	27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1	256 2/20 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/0 2/	27.1 $ 27.1 $ $ $		7 7 1 1			247			
44. / 32.5 37.4 40.0 42.4 37.4 37.4	3 4 11 7 7 8 9 10 19 19 19 19 19 19 19 19 19	A A A A A A B B C A A B B B D D A A A A B B D D A A D D D D D D D D	265 245 245 234 234 234 234 224 224 224 226 227 226 229 226 229 226 229 226 229 225 238 225 238 225 238 225 238 225 238 225 225 225 225 225 225 225 225 225 22	270 273 274 278 278 278 278 278 278 278 278 284 284 284 284 284 284 284 284 284 28	.459 .459 .446 R1, .292 eft .375 .242 .375 .242 .277 .323 .248 .248 .248 .248 .248 .248 .248 .248	20.3 1/9.7 ght 22.5 22.5 22.5 24.8 24.8 24.8 24.8 24.8 24.9 24.9 24.9 24.9 24.9 24.9 24.9 24.9 24.9 25.4 24.9 25.4 24.9 25.4 26.5 26.7 27.6 27.5	Eng .247	1 1	7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9h + 269 269 235 256 256 256 256 256 256 256 256 256 25	27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1	256 21/2 (2) 22/0 22/0 22/0 22/0 22/0 22/0 22/0 22	27.1 27.1		Image: Constraint of the constr			247			
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44. / 32.5 27.7 32.5 37.4 40.0 42.4 27.7 32.5 37.4 40.0 42.4	3 4 11 7 7 8 9 10 17 8 9 10 19 19 19 19 19 19 19 19 19 19	A A A B C A B C A B C A A A A A D D D D D D D D D D D D D	224 224 234 234 220 220 224 224 226 220 224 224 225 229 225 238 238 238 225 238 225 229 229	270 27.3 27.4 27.8 27.8 27.8 27.8 27.8 28.0 26.6 29.7 26.6 29.7 26.6 29.7 26.7 26.7 26.7 26.7 26.7 26.7 26.7 26	.459 .459 .446 R1. .292 eft .375 .247 .30 .247 .30 .277 .309 .277 .309 .277 .309 .277 .303 .242 .287 .310 .375 .242 .287 .225 .287 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .289 .256 .256 .256 .256 .256 .256 .256 .256	20.3 1/9,7 ght 22.5 Emg/1 22.5 22.5 22.5 24.4 24.8 26.5 26.7 25.4 24.8 26.7 25.4 24.8 26.7 25.4 25.5 26.7 25.5 26.7 26.7 26.7 26.7 26.7 26.3 26.7 27.5 27.5 27.5 26.7 27.5 26.7 27.5 26.7 27.5 27.5 26.7 27.5	Eng 	1 1	7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9h + 269 269 235 256 256 256 256 256 256 256 256 256 25	27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1	256 21/2 (2) 22/0 22/0 22/0 22/0 22/0 22/0 22/0 22	27.1 $ 27.1 $ $ $		7 7 1 1			.247			
44. / 32. 5 27. 7 32. 5 37. 4 40. 0 42. 4 27. 7 32. 5 37. 4 40. 0 42. 4 27. 7 32. 5 27. 7 32. 5 27. 7 32. 5 27. 7 32. 5 27. 7 32. 5 37. 4 40. 0 42. 4 27. 7 32. 5 27. 7 32. 5 37. 4 27. 7 37. 4 27. 7 7 27. 7 7 7 7 7 7 7 7 7 7 7 7 7 7	3 4 11 7 7 8 9 10 19 19 19 19 19 19 19 19 19 19	A A A B C A B B D D D A A A A A A D D D D D D D D D D D D D D A B B B B B B B B <t< td=""><td>224 234 234 234 234 234 245 227 244 226 227 244 226 227 237 237 237 239 239 239 239 239 239 239 239</td><td>27.0 27.3 27.4 27.8 27.8 27.8 27.8 27.8 27.8 28.0 126.6 29.7 28.0 126.6 29.7 28.0 126.6 29.7 28.0 126.2 28.0 126.2 29.7 26.3 128.3 1</td><td>.459 .459 .446 R1. .292 eft .375 .241 .375 .241 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .277 .262 .287 .274 .287 .274 .256 .287 .274 .256 .280 .321 .280 .321 .286 .276 .276 .276 .276 .276 .277 .262 .277 .262 .287 .276 .277 .264 .287 .276 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .277 .264 .277 .264 .287 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .287 .277 .264 .287 .277 .264 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .274</td><td> 20.3 1/9,7 ght 22.5 22.5 22.5 22.5 22.4 24.8 24.9 24.8 24.7 24.8 24.7 25.5 25.4 25.5 25.4 25.5 26.7 25.4 26.7 25.5 26.7 27.5 26.7 27.5 26.7 27.5 </td><td>Eng </td><td>1 1</td><td>7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1</td><td>254 7/9h + 269 269 235 256 256 256 256 256 256 256 256 256 25</td><td>27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1</td><td>256 9177 210 220 220 2274 229 239 239 239 239 239 239 239 239 239</td><td>$27,1/2 = F_{4}$</td><td></td><td>7 7 1 1</td><td></td><td></td><td>.247</td><td></td><td></td><td></td></t<>	224 234 234 234 234 234 245 227 244 226 227 244 226 227 237 237 237 239 239 239 239 239 239 239 239	27.0 27.3 27.4 27.8 27.8 27.8 27.8 27.8 27.8 28.0 126.6 29.7 28.0 126.6 29.7 28.0 126.6 29.7 28.0 126.2 28.0 126.2 29.7 26.3 128.3 1	.459 .459 .446 R1. .292 eft .375 .241 .375 .241 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .375 .261 .277 .262 .287 .274 .287 .274 .256 .287 .274 .256 .280 .321 .280 .321 .286 .276 .276 .276 .276 .276 .277 .262 .277 .262 .287 .276 .277 .264 .287 .276 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .277 .264 .287 .277 .264 .287 .277 .264 .287 .277 .264 .277 .264 .277 .264 .287 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .277 .264 .287 .277 .264 .287 .277 .264 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .277 .274 .274	20.3 1/9,7 ght 22.5 22.5 22.5 22.5 22.4 24.8 24.9 24.8 24.7 24.8 24.7 25.5 25.4 25.5 25.4 25.5 26.7 25.4 26.7 25.5 26.7 27.5 26.7 27.5 26.7 27.5	Eng 	1 1	7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9h + 269 269 235 256 256 256 256 256 256 256 256 256 25	27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1	256 9177 210 220 220 2274 229 239 239 239 239 239 239 239 239 239	$ 27,1/2 = F_{4}$		7 7 1 1			.247			
44. / 32.5 27.7 32.5 37.4 40.0 42.4 27.7 32.3 37.4 22.7 32.3 37.4 22.7 32.3 37.4 22.7 32.3 37.4	3 4 11 7 7 8 9 10 17 8 9 10 19 19 19 19 19 19 19 19 19 19	A A A A B C A B C D D A A A A A D D D D D D D D D D D A A A A A A A A A A A A A A A A	265 245 234 234 234 234 234 234 236 224 224 224 224 224 224 224 224 220 229 229 229 229 229 229 229 229 229	27.0 27.3 27.4 27.8 27.8 27.8 27.8 27.8 28.0 26.6 29.7 28.0 26.6 29.7 28.7	.459 .459 .446 .71 .446 .71 .292 .292 .375 .375 .375 .375 .375 .375 .375 .375	20.3 1/9,7 ght 22.5 Emg/1 22.5 22.5 22.5 24.4 24.8 26.5 26.7 25.4 24.8 26.7 25.4 24.8 26.7 25.4 25.5 26.7 25.5 26.7 26.7 26.7 26.7 26.7 26.3 26.7 27.5 27.5 27.5 26.7 27.5 26.7 27.5 26.7 27.5 27.5 26.7 27.5	Eng 1247 247 Bo Bo	1 1	7: 5 + op 1 1 1 1 1 1 1 1 1 1 1 1 1	254 7/9h + 269 269 235 256 256 256 256 256 256 256 256 256 25	27.4 En 1 1 1 1 1 1 1 1 1 1 1 1 1	256 9177 210 220 220 2274 229 239 239 239 239 239 239 239 239 239	27./ Fa Fa 2.80 7 12.80 7 12.80 12.8		7 7 7 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			.247			

L-532

Note: Tindicates turbulent layer and L, laminar layer at a given position for the given range of flight conditions.

			•		TA	BLE	111		¢.	NATIC DMMITTE	DNAL AD	TISORY RONAUT	TOR .
<	รแพ	mary	of F	Resul	ts of	Tra	insit	noi	Tes	+s 0	on La	ower	-
			0f										
	047				• • •	÷ •				•			
<u></u>			1 8-	<u></u>		outb	oard	~mc	hes	Ce	nter	1260	ard
	La		l Po Rack		מי		4-	. /2		112		inch	4
					Cond								
Xx100	F/+	fro	e of F.	1 + t	0	С,	R/16	C,	RING	С,	RIDE	С,	7.6
<u>ر</u>	No	CL	e of F. om R/106	C_L	R/106	6.	1/00	L	10-	L	100	L.	100
					th E								
24.7	3	.Z65	127.0	.459	120.3		1			.295	125.2		1
27.5	15		29.7	.317			1	.256	27.0		1		1
28.4	7	.Z//	127.7		20,6		I		1		I	.291	24.5
30.3	4	245	27.3	.466	19.9		1				124.9		1
	7	·Z/1	27.7	,415	20.6	,353	122.3			.309	Z 3.8		1
	8	,238	26.8	.256	1 25.8		r			7	r		Ì
33.2	9	.256	27.3	.288			Γ		<u> </u>		<u> </u>		ļ
	10		29.5	1261		7	<i>r</i>		· ·		Τ		1
	14	,234			125,4		1		 	.295			1
	15		29.7	.317			<u> </u>			.322	24.2		<u>,</u>
30 (8		26.8	.256			1		 		1	· ·	$\frac{7}{T}$
38./	9		27.3	288			1		 		1		$\frac{1}{T}$
	10	.Z17		,261				<u> </u>		l		l	<u></u>
		Left	Engi	ne	Stop	ped	; R19	aht L	Engin	ne F	u// T	hrot	+/e
28.4	- 7	.234			122.5		<u> </u>		<u> </u>		!	.247	26.8
	7		127.8		22.5				<u> </u>	.265	Z 5.8	ļ	<u> </u>
	8	.210		former in the second second	26.4		Г 	·	<u> </u>		<u> </u>		<u> </u>
33.Z	9	.264			1 24.8		<i>T</i>		<u> </u>		<u>7</u>		ļ
	10	,226		,277		· · · · ·	<u></u>	 	1	+	7		1
	19		126.7		23.8	· · ·	1		1		124.2		<u> </u>
			26.5		125.4		<u> </u>	<u> </u>	<u> </u>	.275	123.7		
38.1	8		1 28.0	1261	1				1		<u> </u>		<u></u>
30.7	10	264	Z 9.1		24.8	<u> </u>	<u>.</u> 1	<u>.</u>	<u> </u>	<u> </u>	1	<u> </u>	/ T
			126.7			<u> </u>		,295	Z3.8	<u> </u>	1		<u>,</u>
39.2	- 19		126.5				1		T		1		1
		<u> </u>			Engi	hes	Stop	<u></u>		4		·	
27.5	15	.212	29.9	.321	25.5	L		.260	26.6		1		
28.4	7	1238	28.2	.340	2.2.2		1				1	.260	125.6
	7	,238	28.2	.340	22.2	,265	25.8		<u> </u>	.265	125.8		
33.Z	8	1246	126.5	,274	26.3		Γ				1		1
23.2	14	,211	29.6	.280	126.7		l	ļ		ļ	T	<u> </u>	1
• •	15	.212	Z 9. 9 .		25.5		1		!	.300	z 5.8	ļ	<u> </u>
201	8	.246	26.5	.274	1 26.3	L		<u> </u>	1				7
38.1				Both	Engi	nesi	[d/12	, <u>9</u>					
50.7													
	7	.256	25.0	.433	120.2	· ·	1		1	1		,273	129.5

Note Tindicates turbulent layer at given position, for the given range of flight conditions.

TABLE IV COMMITTEE FOR ABBONAUTION. VALUES OF RS DETERMINED FROM BOUNDARY LAYER MEASUREMENTS ON NACA 35-215 AIRFOIL.

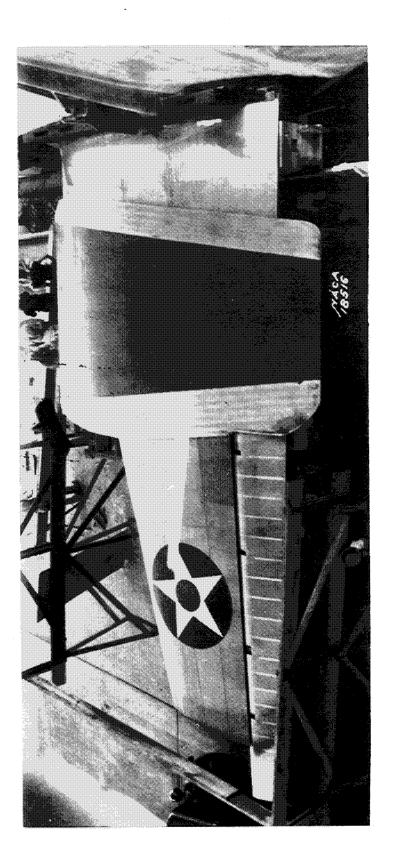
POWER CONDITION	SURFACE CONDITION	<u>X</u> x100	SPANWISE POSITION	CL	Rs
	UP	PER SURF	ACE		
	B	32.5	CENTER	.229	810 0
				.2,2,7	8000
BOTH ENGINES		32.5	CENTER	.239	8100
FULL THROTTLE	С			.261	8300
			12 INCHES	.2/1	8600
		37.4	OUTBOARD	216	8100
				. 220	8000
	B	32.5	CENTER	.250	7700
				.226	7800
LEFT ENGINE			ACUTER.	.209	8000
STOPPEDS		40.0	CENTER	.259	7700
RIGHT ENGINE	D			.280	7400
FULL THROTTLE	-		in intentio	.226	8100
/ 011 ////////		42.4	12 INCHES	.229	8200
			OUTBOARD	.259	8000
<u> </u>				.215	8600
		37.5	CENTER	.224	8400
				.270	8100
				.272	. 8100
BOTH ENGINES	C ·	<u> </u>		.213	8400
STOPPED	-	37.4		.215	9200
JI DEVELO			12 INCHES	855.	8300
			OUTBOARD	,255	8300
				.279	8000
	D	40.0	CENTER	.213	8500
	L	WER SURF	ACE	_k	- h
				.309	6700
BOTH ENGINES		33.2	CENTER	317	6500
FULL THROTTLE		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		.342	6400
	ļ	<u> </u>		.287	6900
L. F. Generation		22.2	CENTER	.293	6900
LEFT ENG. STOPPED;	<u> </u>	33.2	CENTER	.323	6700
RT. ENG. FULL THROT.				.363	6100

TABLE I SUMMARY OF RESULTS OF PROFILE DRAG TESTS ON NACA 35-215 AIRFOIL

NATIONAL ADVISORY COMMITTEE FOR A BRONAUTION

L-532

			-
POWER CONDITION	CL	R/106	Cdo
B	OTH SURFACE	5	*
	.208	31.5	.0050
	.232	29.7	.0047
	.256	27.3	.00:49
BOTH	256	28.3	.0050
ENGINES	258	28.0	.0048
STOPPED	.260	27.3	.0048
0,0,0	.260	27.6	,0047
	.283	26.0	.0048
	.300	25.3	:0049
	.322	24.3	.0048
	,214-	29:7	.0051
	.220	31.7	.0053
Вотн	.249	27.8	.0043
ENGINES	.267	30.1	.0053
FULL-THROTTLE	.282	26.1	.0052
	.311	24.3	.0053
L'P.	PER SURFACE /	ALONE	· · ·
	.226	27.8	10023
	.227	29.2	.0020
Both	236	29.0	.9022
ENGINES	.258	27.3	.0022
STOPPED	.262	26.1	.0023
JUTTLU	.270	26.0	.0025
	.293	24.5	.0026
	.322	23.6	.0028
	,213	31.4	.0025
BOTH ENGINES	226	- 27.6	.0023
FULL. THROTTLE	.258	25,9	.0025



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Figure 1.- NACA 35-215 test panel mounted on wing of a Douglas B-18 airplane.

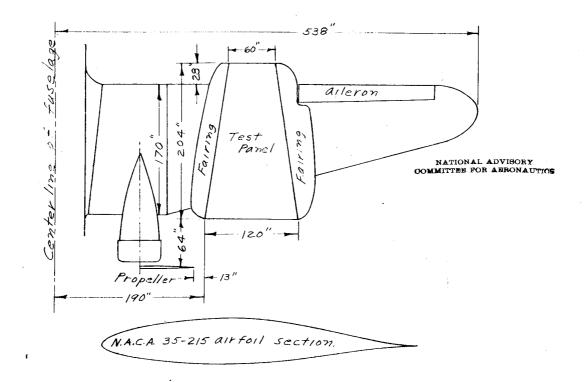


Figure 2. Sketch showing position of test panel on Wing of Douglas B-18 airplane and profile of N.A.C.A 35-215 airfoil section.

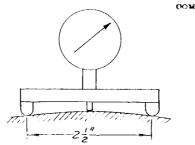
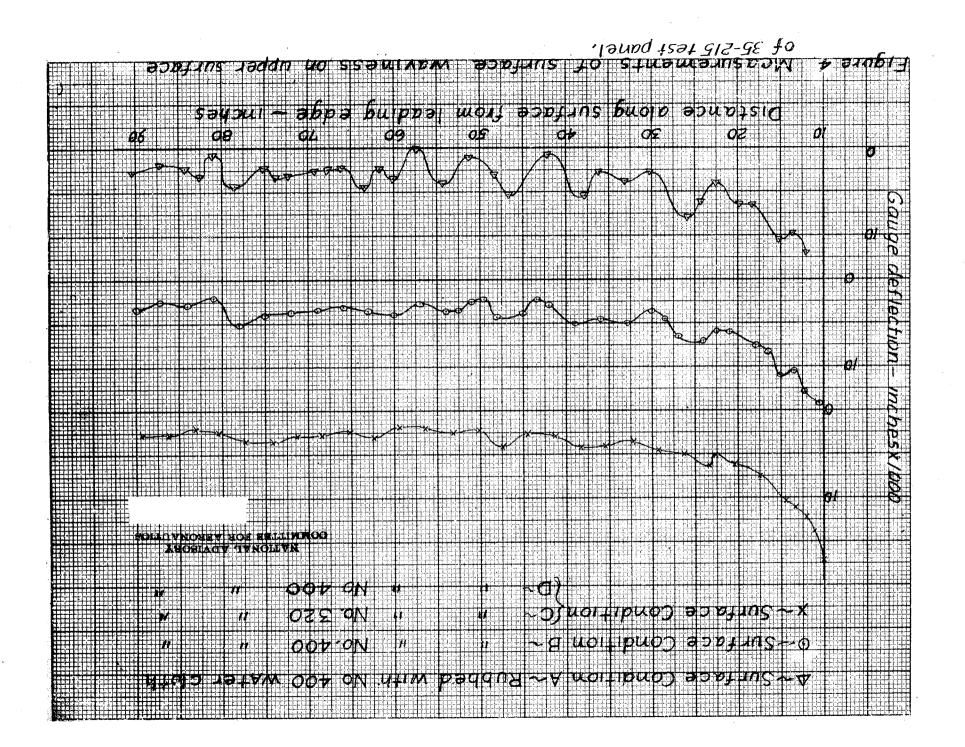
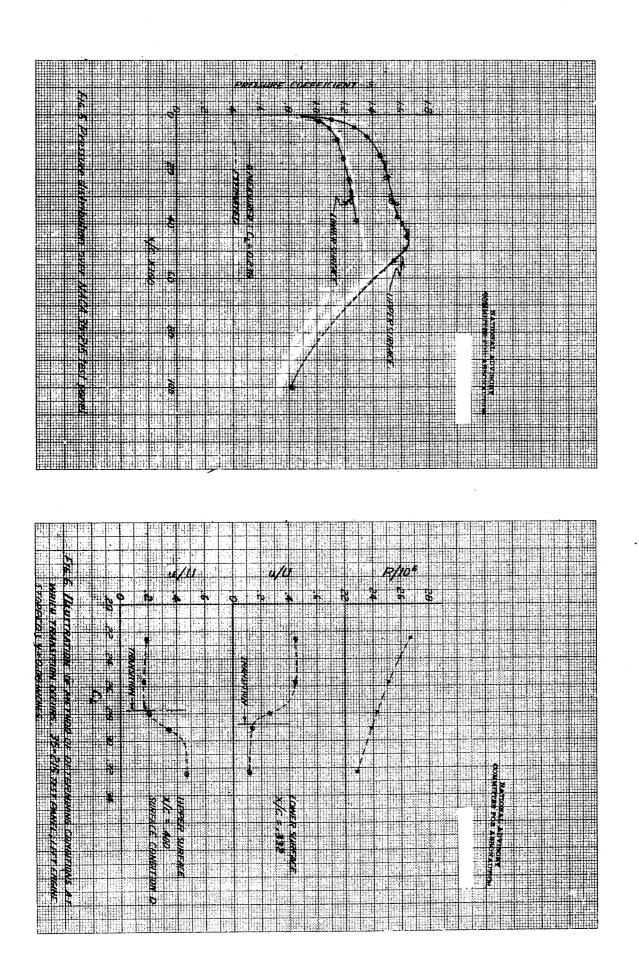


Figure 3. Sketch of curvature gauge used in making surface waviness measurements.

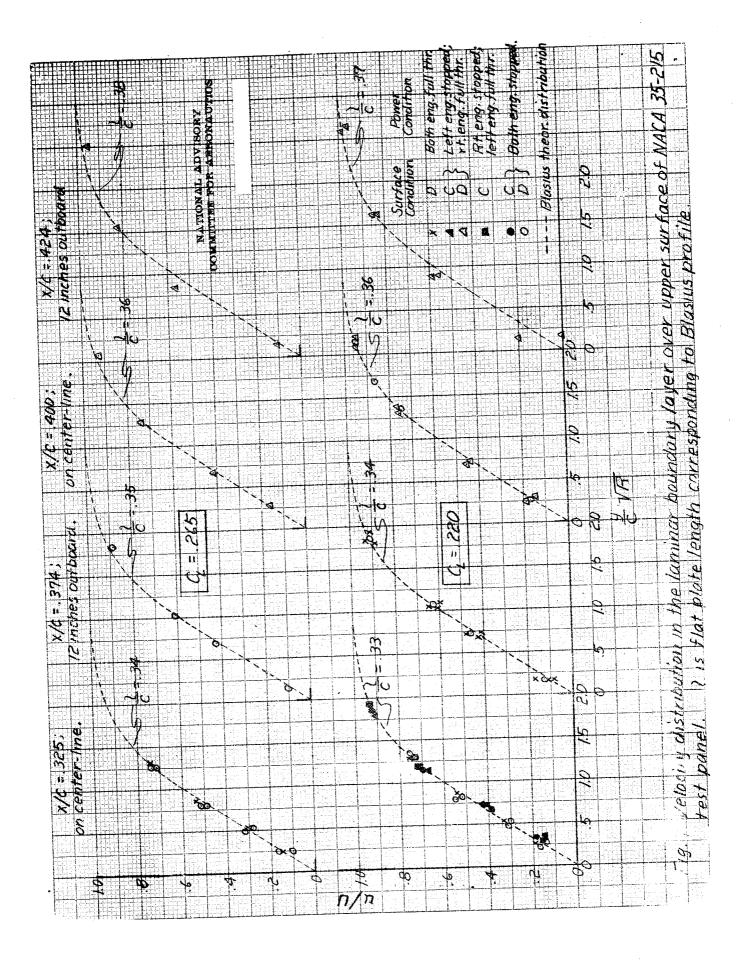
L=532



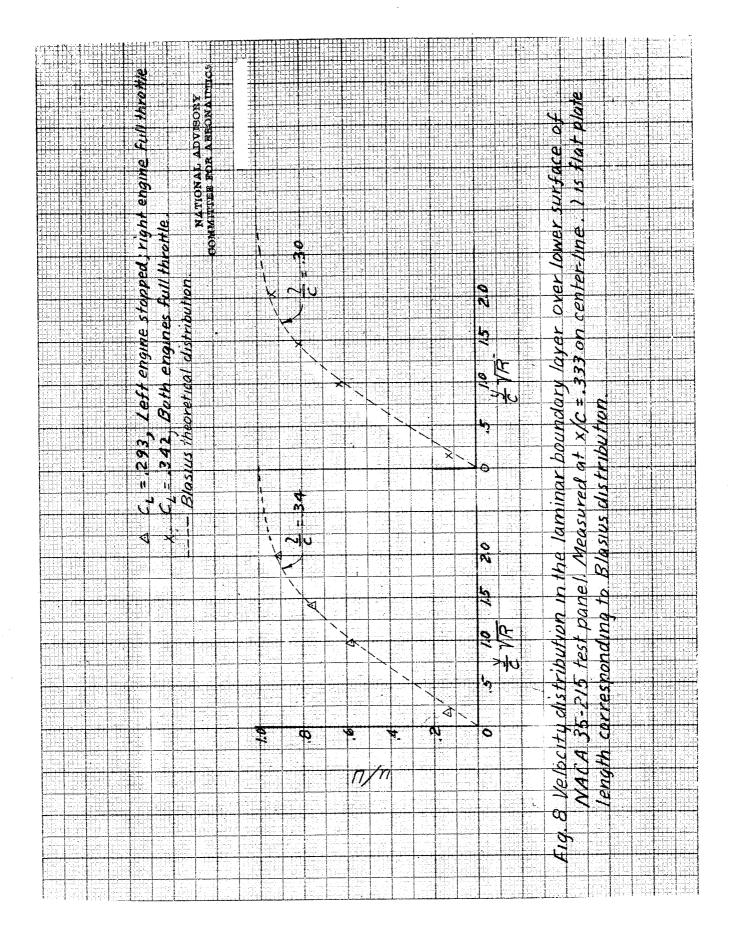
7-235



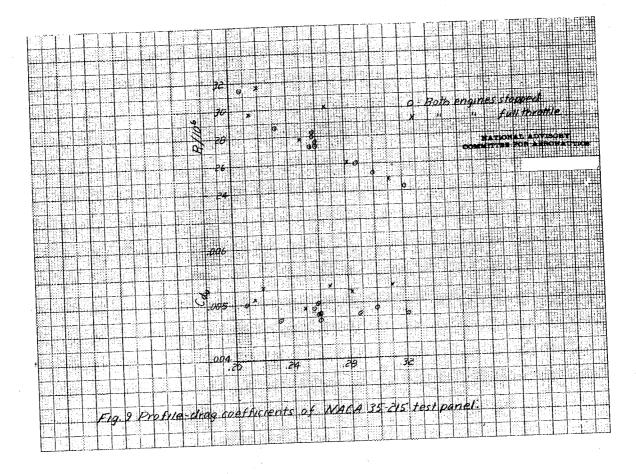
L-

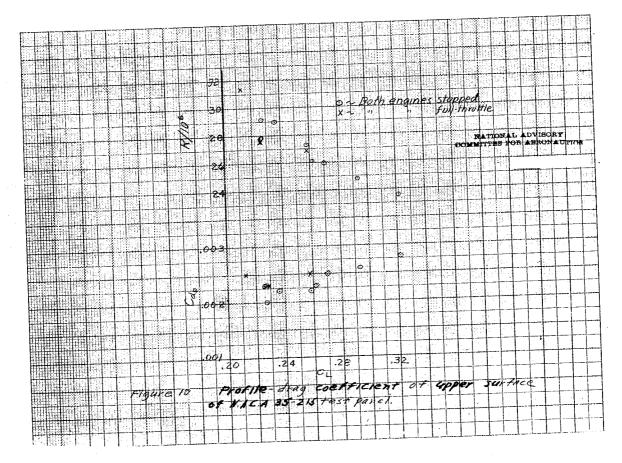


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L=532





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