L.O. File

L.O. 9542A FILE BM49-7-12 PREPARED BY RJT CHECKED BY RJT OM	NATIONAL AERONAUTICAL ESTABLISHMENT OTTAWA, CANADA LABORATORY MEMORANDUM SECTION Aerodynamics	NO. AE-46 PAGE 1 OF 17 COPY NO. 4 DATE 31 August '53

DECLASSIFED on August 29, 2016 by Steven Zan.

Initial

SECURITY CLASSIFICATION ~~Secret and discreet~~

SUBJECT SOME NOTES ON THE QUESTION OF SUPERSONIC FIGHTER SIZE

PREPARED BY R. J. Templin

ISSUED TO Internal

THIS MEMORANDUM IS ISSUED TO FURNISH INFORMATION IN ADVANCE OF A REPORT. IT IS PRELIMINARY IN CHARACTER, HAS NOT RECEIVED THE CAREFUL EDITING OF A REPORT, AND IS SUBJECT TO REVIEW

S U M M A R Y

This note describes recent work carried out by the Aerodynamics Laboratory to estimate the airframe weight of a supersonic all-weather fighter designed to meet the RCAF Specification AIR-7-3, powered by two hypothetical engines of approximately thirty to thirty-six inches diameter. Discussions between the NAE, the RCAF, and the A.V. Roe Aircraft Division are also described.

As a result of this work it is difficult to escape the conclusion that the aircraft firm has fallen far short of a maximum effort to design for minimum weight, and that the RCAF have contributed to this situation by specifying armament requirements too loosely, by specifying engine requirements too rigidly, and by neglecting to take adequate account of economic considerations. On the other hand they remain far from convinced of the practicability of the small-engine proposal.

SOME NOTES ON THE QUESTION OF SUPERSONIC FIGHTER SIZE

1. INTRODUCTION

At intervals during the past two years the Aerodynamics Laboratory has made brief studies of the factors affecting supersonic fighter size and weight in order to provide background for assessing various proposals submitted by A.V. Roe Canada to meet the R.C.A.F. fighter specification (now called Spec. AIR-7-3). At the same time the question of engine size has been studied by the Gas Dynamics Section and about a year ago it was recommended (Ref. 1) that the proposed fighter be designed around two engines of about 30 inches basic diameter which it was felt would be within the capacity of the A.V. Roe Engine Division to design and develop.

This suggestion was largely ignored because it was felt by the R.C.A.F. and by A.V. Roe that the engine proposal was impractical and also because there would be no alternative available in case of failure. Nevertheless the Company recently completed a weight estimate (Reference 2) for such an aircraft and arrived at a gross weight of 41,000 lb. The performance of the aircraft fell far short of the R.C.A.F. specification because of the low thrust weight ratio; thrust had been reduced from a basic sea level static value (unreheated) of 15,000 lb. per engine to 10,000 lb. per engine, whereas gross weight had decreased by a much smaller ratio from 48,375 lb. for the C-105 to 41,000 lb. for the hypothetical "small" aircraft. No doubt it was assumed that this study would put a stop to the discussions of size, since the R.C.A.F. had already specified the larger engines and were not prepared to accept a decreased performance.

About one month ago, however, M.S. Kuhring prepared an estimate (Reference 3) of the saving in cost in developing and producing 500 aircraft of 41,000 lb. weight as compared with the same number at 48,375 lb., taking into account the difference in fuel costs over a five year period and also the difference between development costs of the proposed small engines and the cost of building larger engines under license in Canada. The estimated saving was of the order of a quarter of a billion dollars, even if no account is taken of the fact that whatever engine is chosen for this aircraft may also be used in some as yet unspecified F-86 replacement aircraft. This large saving aroused interest once more in the question of fighter size, and it appeared also that the A.V. Roe estimate of 41,000 lb. was excessive, so that still further saving might be made with little or no loss in aircraft performance.

The Aerodynamics Section therefore made its own estimate of weight and submitted this to the R.C.A.F. about August 7, 1953. It is the purpose of this note to discuss events which have taken place since that meeting and to summarize the studies of weight which have been made. Technical questions relating to the design and development of a special fighter engine will not be discussed.

2. GENERAL CONSIDERATIONS

The main emphasis in the fighter work carried out by the N.A.E. has been placed on the problem of size, since it has been obvious from the beginning that the A.V. Roe final submission would have a gross weight in the neighbourhood of 50,000 lb. By present standards, this is an excessive weight for any fighter aircraft, but it has been pointed out on many occasions by the R.C.A.F. and by A.V. Roe that the important factor is not weight (or cost) per aircraft, but rather the total weight (or cost) of enough aircraft to meet the requirements of the defence situation. This is an entirely reasonable point of view, and is not in question here. It is assumed, however, that what is required is an aircraft of minimum possible weight which will meet the R.C.A.F. specification.

There are grounds for doubt that this requirement has been met in the most efficient way when the only submission is an aircraft weighing 50,000 lb. Figure 1 shows a comparison of its physical size with that of the Douglas DC-3 transport aircraft. It is fully admitted that this sort of comparison may be like comparing hand grenades and oranges. It is also admitted that Figure 1 is presented for its shock value only, but it is just this sort of shock which has prompted a closer look at the size and weight of this particular fighter, and which has caused the same sort of reaction to large fighters in the United States. In this connection it was pointed out to us recently by members of the staff of RCAF/AMTS, that there were twin engine fighter proposals in the United States in the 45,000 to 50,000 lb. class. Unless there has been a recent change in policy, however, no supersonic fighter is actually being considered which has a gross weight in excess of 30,000 lb.

In one way it is a simple matter to explain the large weight of the C-105. The R.C.A.F. specification states that the aircraft is to be a twin-engine design based primarily on the RB-106 engine, and that it must be capable of a sustained 2-g turn at M = 1.5 at 50,000 ft. at combat weight. If it is assumed that a reasonable value for the supersonic lift-drag ratio of the aircraft at combat conditions is 5, then it can be shown that the thrust of two RB-106 engines under these conditions is sufficient to sustain the required turn with an aircraft weight of 41,500 lb. The combat weight (half fuel gone) of the C-105 is 41,925 lb. In other words the R.C.A.F. specification has in fact asked for a weight about equal to that submitted by the firm. Any further refinements in either the lift-drag ratio or the aircraft weight will only lead to a performance in excess of the requirement as long as the specified engines are retained. There is, therefore, very little incentive for the Company to design a smaller aircraft, and this will be the case as long as the R.C.A.F. insist on two engines of the size they have specified.

Nevertheless it does appear that the aircraft weight could have been reduced substantially below 48,000 lb., even if the same engines are retained, and could be reduced very much further with smaller engines, with little or no reduction in performance, provided that the smaller engines are of a similar standard to the RB-106.

Various weight estimates from different sources are described below and are followed by a discussion of certain critical items.

3. WEIGHT ESTIMATES

Table I summarizes various weight estimates for supersonic fighters. In the table are six columns of weights, each one for a different aircraft.

The first column is for the Convair F-102, and has been taken from a copy of the Convair brochure dated 1 March 1952.

The second column is the Avro C-104/1 taken from the A.V. Roe brochure issued 24 July, 1952.

Next is the Avro C-105/1200 from the brochure dated May, 1953. The figure 1200 refers to square feet of wing area, which in this case is the size chosen by A.V. Roe as the best compromise for this aircraft.

Following this are two columns giving the A.V. Roe estimates for two different 30-inch engine versions. The first of these was contained in Reference 2 (July 29, 1953) and the second was tabled at a meeting at A.V. Roe on August 21, 1953.

The final list of weights is that which was estimated by the Aerodynamics Laboratory, N.A.E. This list includes footnote numbers for reference to the footnotes at the bottom of the table, which explains the manner in which items in the list were estimated. The N.A.E. list has been slightly revised from the original one presented to the Air Force about August 7, but is the same as that discussed at A.V. Roe on August 22. The revisions were minor, and were made after discussion with the R.C.A.F. The largest was an increase of about 100 pounds in the weight of air conditioning and low pressure pneumatics. This is not to imply that the R.C.A.F. are in agreement with these weights; on the contrary it is probably fair to say that they disagree with the list to the extent that A.V. Roe disagree with it. Indeed, this is one of the difficulties in presenting an independent list: A.V. Roe are the aircraft designers and the R.C.A.F. is inclined to accept their opinions even when they change. One of the objections to the N.A.E. weight estimation methods is that they are mainly empirical and statistical. As will be shown below, however, A.V. Roe tend to use the same methods and in some cases, no method at all.

4. DISCUSSION OF SOME WEIGHT ITEMS

The purpose of this discussion is to show that of all the items of weight, the question of reducing the aircraft gross weight depends most of all on whether the fuselage weight can be decreased to that shown in the N.A.E. list. It also depends, of course, on whether the assumed engine and afterburner weight is correct. It was estimated on plausible assumptions, but its correctness will not be discussed here. This is a point on which the gas turbine authorities must carry the argument.

4.1 Engine and Afterburner

In the N.A.E. list (see Table I) the engine and afterburner weight was taken to be simply two-thirds of the corresponding item for the C-105/1200. This assumes, of course, that if the thrust is reduced to two-thirds of that of the RB-106, then the proposed engine is of the same standard as the RB-106 with respect to thrust-weight ratio. From one point of view this is regarded as conservative since some improvement in thrust-weight ratio may be expected when engine size is reduced. However, the RB-106 is as yet a non-existent engine and is of a very high standard compared to others in its thrust class. The value of 7,000 lb. assumed by A.V. Roe for engines plus afterburners in their original small-engine study was based on the roughest possible assumptions as described in reference 2. In their second list this has been reduced to 6,000 lb. (which is 335 lb. lower than the N.A.E. estimate) after having received some information from the Engine Division. It is not quite clear what this information was, but in any case Mr. Chamberlin of the Aircraft Division says he does not believe their afterburner weights.

4.2 Fixed Items (Power Plant)

Little discussion of these items is required here. Their total as estimated by the N.A.E. is 547 lb. The corresponding figure in A.V. Roe's first list for the 30-inch engines was 780 lb. and was later revised by them to 620 lb., mainly by reducing the weight of fuel tanks and system.

4.3 Probe

This is the measuring probe extending ahead of the aircraft nose. It measures all quantities, pressures, temperature, angles, required by the aircraft navigation equipment. A.V. Roe have estimated it to weight 50 lb. The N.A.E. estimate is 20 lb., and was estimated from data provided to us by the Flight Research Section. They have three probes for flight test work, all designed for transonic flight. One weighs 8 lb., but is considered too flexible. Another weighs 12 lb. without supports (intended for the nose of a CF-100). The third weighs

23 lb. but was constructed from the only suitable pipe stock available at the time: steel pipe about 2 inches outside diameter with ¼ inch wall thickness. It is considered to be much more rigid than necessary. A.V. Roe drawings indicate that the probe is about 7 feet long outside the aircraft. A 2½ inch rod of solid aluminum this long weighs 23 lb. Admittedly some sort of support is required inside the nose of the aircraft to transmit the loads beyond the plastic nose cone, but it is considered that this need weigh a few pounds at most. We were informed by the R.C.A.F. that the 50 pounds assumed by A.V. Roe for this item had actually been obtained from Hughes, who are to manufacture it. This appears to be not the case. Mr. Chamberlin states that actually its weight is unknown but it is likely to be heavy because of the difficulty of transmitting information measured by the probe past the radar system without interference. In his opinion this may have to be done by telemetry. This seems very unlikely. In any case the A.V. Roe balance diagram shows that they have assumed the centre of gravity of the 50 pound item to lie about half-way along its length outside the aircraft, and it has just been shown that this is incompatible with the physsically possible weight of about 20 lb.

This is perhaps too small an item to cause concern, but it does so only because it may be an indication of lack of close control in other items.

4.4 <u>Surface Controls</u>

The N.A.E. estimate is 466 lb. The original A.V. Roe estimate was 675 lb. for the "small" aircraft and was later reduced to 485 lb.

4.5 <u>Hydraulic System</u>

The final A.V. Roe estimate is 615 lb. (originally 660 lb.). The N.A.E. estimate is 604 lb.

4.6 <u>Electrical System</u>

The A.V. Roe estimate for this item in all cases is 700 lb. The N.A.E. estimate is 594 lb. which was obtained by plotting all A.V. Roe previous estimates against aircraft weight and fitting the best straight line to them. The straight line does not go through the origin, indicating, as would be expected, that part of the weight is a constant. A.V. Roe now appear to claim that the total electrical system weight is a constant. We are hardly in a position to argue, except to point out that the equivalent item for the Convair F-102 is 500 lb.

4.7 Air Conditioning and Low-Pressure Pneumatics

For the N.A.E. list this was simply reduced to two-thirds of the corresponding item for the C-105/1200. There is, of course, no justifiable reason for this since it seems obvious that the air conditioning, at any rate, should depend only on the pilot's requirements (and possibly also that of the armament). Perhaps, however, this is not the case. The item weight of 625 lb. listed by A.V. Roe for the C-105 (and also for the 30-inch version) is left unchanged in the two-seat version of the C-105. When Mr. Chamberlin was questioned on this point he stated that the two seat version was intended as a trainer only and the air conditioning requirements would be less in this case. However, the brochure (Reference 4) from which these figures were taken definitely states that the two-seat aircraft was intended not only as a trainer but as an alternative fighter in case of changes in the equipment.

Therefore this item was assumed to depend on aircraft size and was reduced to 423 lb. for the small aircraft. It should be noted that the corresponding figure for the C-104/1 was 215 lb. and for the C-104/2 was 355 lb. (The latter figure is not given in Table I).

4.8 Anti-Icing and Deicing

The N.A.E. estimate is 200 lb. The original Avro estimate for the small aircraft was 300 lb. and the final estimate 250 lb.

4.9 Brake Parachute and External Finish

These items are obviously approximately proportional to gross weight and were so reduced from the corresponding figures for the C-105.

In A.V. Roe's final estimate for the small aircraft they have been reduced to our values but were the same as the C-105 in the original estimate.

4.10 Residual Fuel

This was assumed to be proportional to all-up weight and also to fuel weight and thus was taken to be 150 lb. A.V. Roe have not reduced their figure of 225 lb. for the large aircraft.

4.11 Fin

This item was taken to be 600 lb. which is two-thirds of the corresponding C-105 item since if it is assumed that fin area is reduced by two-thirds, the unit weight should be, at most, the same. Actually this is conservative due to the effects of the square-cube law in the weight of material taking bending loads. A.V. Roe, however, will not go below 675 lb. since they state that the fin can not be reduced by two-thirds. Their reason seems to be that the fin is determined by one-engine-out considerations and that the moment arm of the engine thrust can not be reduced by the square root of two-thirds due to "air spaces" around the engine even if it is assumed that engine diameter itself is reduced by the square root of two-thirds. When pressed on this point it was stated that small clearances are required around the engine to avoid interference with the structure and these are independent of engine size and are at least one-quarter inch in size. We consider, therefore, that our point is valid, since a quarter inch of clearance space can hardly affect fin size.

4.12 Wing

The wing weight is always the most complex item to estimate. For the N.A.E. list this was done with the aid of an empirical formula derived from an R.A.E. method of wing weight estimation. One of the constants in the formula was left unspecified until the best fit had been obtained with all of A.V. Roe's previous wing weights. There are twelve wings listed in A.V. Roe brochures and the final agreement between the N.A.E. formula and A.V. Roe data is reasonably good: within about one-half pound per square foot of wing area. In other words, for a wing of 800 sq. ft. area there may be a difference of opinion between ourselves and Avro amounting to about 400 lb. It is worth pointing out that the agreement between this formula and the Convair wing weight is excellent. It was thought initially that the A.V. Roe wing weights had been obtained from some sort of structural preliminary design. This is not the case. They use Ivan Drigg's formula (Reference 5). We have reason to believe that our own is better. A separate laboratory memorandum is being prepared by O.E. Michaelsen on the comparison of the two formulae with each other and with available data.

To summarize, there is little difference of opinion between ourselves and A.V. Roe on wing weight. The N.A.E. weight for the small fighter is 4870 lb., and the final A.V. Roe weight is 5750 lb. The difference is attributable to the difference in aircraft all-up weight (32,700 lb. and 37,600 lb. respectively).

In estimating wing weight for the small aircraft, the wing thickness was increased from 3 percent (wing thickness on the C-105) to 4 percent. The reasons for this are that it was felt that the resulting deterioration in performance would be small, and that more wing volume might be required for stowage of fuel. The absolute wing thickness is thus greater than that of the C-105 so that there should be no difficulty in undercarriage stowage, at least due to lack of wing thickness. The decrease in load factor due to increasing thickness by this amount is estimated to be about 0.15. Since the load factor for the C-105/1200 at M = 1.5 and 50,000 ft. is estimated by A.V. Roe to be 2.14, the small aircraft should still meet the R.C.A.F. specification provided that the aircraft thrust-weight ratio remains unchanged and that the standard of aerodynamic cleanness is the same. The first condition requires that the combat weight be reduced from the C-105 value in the same proportion as the engine thrust has been reduced. This condition is met very closely in the N.A.E. list. That the aerodynamic standard of the airframe can be retained is not so clear. A.V. Roe have pointed out that the ratio of fuselage frontal area to wing area is likely to be greater for the small aircraft in order to provide adequate intake area. This is probably true, and thus the performance of the small aircraft may well fall below the requirement, although it is believed that the amount will be small.

4.13 Undercarriage

In this item there is little difference of opinion between the N.A.E. and A.V. Roe. The undercarriage weight is roughly a constant fraction of gross weight for all aircraft listed.

4.14 Fuel

The fuel weight was taken to be the same fraction of gross weight as for the C-105, in order to provide equal radius of action. That this will be so depends on the specific fuel consumption, wing loading and aerodynamic standards remaining unchanged. The fuel weight, therefore, can not be considered to be a conservative estimate in the N.A.E. list.

4.15 Fuselage

As was mentioned previously, the fuselage weight is believed to be the major item on which the argument for a smaller fighter depends. Items of weight discussed above have given rise to differences of opinion, but these revolve around hundreds of pounds rather than thousands. The original A.V. Roe estimate for fuselage weight in their 30-inch engine aircraft was 5,351 lb. and in their revised list this was reduced to 5,262 lb. Their corresponding item for the C-105/1200 is 6,148 lb. The N.A.E. estimate is 3,780 ln., about 1,500 lb., lower than the lowest Avro estimate and about 2400 lb. less than that for the C-105/1200.

In the discussions at Malton on August 21 it was generally agreed, after discussing all other items, that this was the most important one. It had been hoped, before the meeting, agreement could be reached on this point, and in order to demonstrate it graphically, Figure 2 was prepared to show the variation of aircraft weight if fuselage weight had been varied in a manner consistent with the assumptions used to estimate them in the N.A.E. list. At the same time as fuselage weight was varied in this analysis, the engine size was allowed to grow so that aircraft thrust-weight ratio remained the same, and the engine approached the Rolls-Royce RB-106 at a gross weight of about 48,000 lb. The "estimated" curve in Figure 2 is the result of this analysis, and it will be noted that it agrees roughly with the available data for several fighter proposals. This is taken to be an indication that the estimation of weight of items other than the fuselage is generally reasonable.

Thus the central question appears to be, can the fuselage size and weight be reduced substantially? At Malton, the weight group described in detail their methods of estimating fuselage weight. This was one item for which simple statistical methods evidently were not used and it was agreed by the N.A.E. representatives that for the fuselage size chosen, the weight estimate could hardly be questioned. Since this meeting, this opinion has been confirmed by us in a statistical manner. It has been stated by the R.A.E. that fuselage weights for similar classes of aircraft are roughly proportional to fuselage wetted area, which in turn is proportional to fuselage length multiplied by maximum fuselage perimeter. A comparison on this basis of various A.V. Roe estimates and of the Convair F-102 fuselage weight is shown in Figure 3. Very close correlation is obtained.

It was pointed out at the meeting, however, that the Company had not demonstrated beyond doubt that the C-105/1200 fuselage or that of the 30-inch engine study was as small as possible. Mr. Chamberlin was asked if the extent to which the armament was packed into the "30-inch" fuselage was equal to that of the C-104/1, and he replied that it was. As will be shown, this appears to be anything but true. It was also pointed out that the C-104/1 fuselage was very much smaller and weighed 3,350 lb., about 400 lb. less than the N.A.E. estimate. In reply to this Mr. Chamberlin said that the C-104/1 fuselage weight had been estimated only very roughly. Figure 3 suggests, however, that an accurate estimate probably would not have changed the figure as long as the fuselage size did not change.

In order to determine whether the fuselage size could have been made smaller, several questions have been investigated by the Aerodynamics Laboratory since the meeting at Malton. In the first place, armament bay sizes have been measured from available drawings of the various aircraft under discussion. It will be remembered that all of these aircraft are designed to carry very nearly the same armament: 6 Hughes Falcons plus 24 - 2.75 inch folding fin rockets or 50 - 2 inch folding fin rockets. It is possible to define in a somewhat arbitrary way a "required" armament stowage volume, which is a useful figure for comparison with actual stowage volumes provided. If a Hughes Falcon is assumed to require a volume equal to that of a cylinder of length equal to the Falcon length and diameter equal to the Falcon fin span, and that the folding fin rockets require a volume equal to their body volume with fins folded, then the "required" volume for the total armament load is about 134 cu. ft. Figure 4 shows the relative armament bay sizes and shapes for different fighters. It will be seen that the C-105/1 provided less volume than the Convair F-102, but that, contrary to Mr. Chamberlin's statement, the Avro 30-inch engine study provided considerably more. The volume of the armament bay on the C-105/1200 is luxurious, to say the least, being about 2.3 times the "required" figure arrived at roughly above.

It must be admitted that even the largest armament bays are a small fraction of the total fuselage volume in each case and so it would appear that reduction of armament space alone will not contribute much toward reduction in fuselage weight. It is suggested, however, that the luxurious armament bays on the large Avro aircraft merely reflect a general slackness throughout the fuselage, although it has been continually stated by the A.V. Roe Aircraft Division and by the R.C.A.F. that these fuselages are tightly packed. The question immediately arises as to how Convair managed to carry the same armament and radar in a much smaller fuselage. A study of the Convair brochure shows that, in fact, they have been careful to leave very little empty space. For example the Hughes equipment is carried in the nose of the aircraft instead of behind the cockpit, in spite of the fact that a side elevation of the front fuselage portion of this aircraft is very nearly identical in shape to that of the Avro front fuselage. This comparison is shown in Figure 5. Not shown in this diagram is the fact that apparently the maximum width of this part of the F-102 fuselage is about 6 inches less than that of the C-105. It was stated by Mr. Chamberlin that the front fuselage can not be changed even if the rest of the aircraft is scaled down, and that the weight of this part is about 1,100 lb. This is nearly half the total fuselageweight of the F-102 in spite of the fact that it contains scareely any heavy equipment. Obviously this is one way in which the fuselage size and weight might be reduced, without altering the aircraft balance very radically (the centre of gravity of the Hughes equipment can probably be moved further forward than the amount by which the fuselage is shortened).

5. CONCLUSION

It has been shown above that the question of reducing the gross weight of supersonic fighters below the size proposed by A.V. Roe depends mainly on a reduction in engine size and of fuselage size. The practicability of reducing engine size while keeping the same engine standards is not discussed here, but it is shown that the fuselage size and weight can probably be reduced substantially if enough design effort were put on the problem. This appears to be the case regardless of whether the overall design is changed to accommodate smaller engines.

It is suggested that even if the large engines are retained a decrease of perhaps 1,000 lb. in fuselage weight might be achieved, and if the aircraft is redesigned around two engines of about two-thirds the thrust, the fuselage weight might be reduced by as much as 2,500 lb.

If, together with such reductions, a maximum effort is made to take advantage of these savings throughout the entire structure and in fuel required it is estimated that the gross weight might be reduced by 4,000 lb. if the large engines are retained.

The N.A.E. weight estimate for the small-engine version of this fighter indicates that the gross weight may be reduced as low as 33,000 lb. It must be pointed out, however, that in several respects this weight estimate can not be regarded as conservative. The assumed engines are of a higher standard than any other known engine except the Rolls Royce RB-106 which is so far only in the proposal stage. No penalty for reduced specific fuel consumption has been allowed for in the small engines, and the aerodynamic characteristics of the airframe have been assumed to be equal to those of the large aircraft. Even so it is estimated that this aircraft would only just meet the R.C.A.F. specification in all respects.

It now appears that if the discussions of weight for an aircraft designed around small engines are to be carried further, more detailed work is required from the proponents of the small engine. If it can not be demonstrated that the so-called "30-inch" engine can be designed with a thrust-weight ratio and specific fuel consumption equal to that of the Rolls-Royce RB-106 then it seems clear from the airframe point of view that the R.C.A.F. specification can not be met in all respects even if a maximum effort is put forth to reduce every item of weight to a minimum.

In this connection it is worth pointing out that at the meeting at Malton on August 21, no representatives were present from the Company's Engine Division, but the Aircraft Division had been provided by them with a report of a study of a small engine called (we think) the P.S./11. This engine was of about the required diameter and weight but its total length was almost exactly the same as that of the RB-106, its specific fuel consumption was considerable worse, and its sea level static thrust (unreheated) was only8,800 lb. instead of the 10,000 lb. assumed in the present analysis.

If this is the Engine Division's version of the ultimate 30-inch engine proposal, then it simply is not good enough. As a result of its appearance, considerably more effort will be required on the engine side before all parties can be convinced of the practicability of the 30-inch engine proposal. The R.C.A.F. and A.V. Roe are certainly far from convinced at the present time.

6. REFERENCES

1. Staff of Various Laboratories of the N.A.E. - Examination of Two A.V. Roe (Canada) Proposals for the C-104/1 and C-104/2 All-Weather Interceptor Aircraft. N.A.E. Report LR-38.

2. J. Chamberlin. Supersonic Figther with 2-30" Diameter Engines. A.V. Roe Report P/C105/5. July 29, 1953.

3. M.S. Kuhring. Some Considerations of the Implications of Building Gas Turbine Engines Under License. Unpublished note. July 29, 1953. Revised August 11, 1953.

4. Design Study of Supersonic All-Weather Interceptor Aircraft. A.V. Roe Report No. P/C-105/1. May 1953.

TABLE I

SUMMARY OF WEIGHTS FOR SUPERSONIC INTERCEPTORS

ITEM	CONVAIR F-102	AVRO C-104/1	AVRO C-105/1200	AVRO C-105/30/1000	AVRO C-105/30/800	NAE C-105/30/800	
ENGINE AND AFTERBURNER	5680	4708	9502	7000	6000	6335	(1)
FIXED ITEMS (Power Plant)							
Fuel tanks and system	260	467	720	680	540	480	(1)
Fire Extinguisher			65	65	45	44	(1)
Access. Gears and Drives			15	15	15	10	(1)
Engine Controls	15	10	20	20	20	13	(1)
Group Total	5955	5185	10322	7780	6620	6882	
EQUIPMENT							
Instruments	105	46	50	50	50	50	
Probe			50	50	50	20	(2)
Surface Controls	457	400	700	675	485	466	(1)
Hydraulic System	420	599	680	660	615	604	(3)
Electrical System	500	550	700	700	700	594	(3)
Radar and Electronics	1330	1800	1800	1800	1800	1800	
Ejector Seat)		132	132	132	132	132	
Emergency Provisions)	482	15	15	15	15	15	
Oxygen)		20	20	20	20	20	
Air Condit. and Pneum.)		215	625	625	625	423	(4)
Anti-icing and Deicing		210	300	300	250	200	(1)
Brake Chute	24	45	75	75	53	53	(5)
External Finish		43	75	75	51	51	(5)
Crew	230	207	230	230	230	230	
Oil	119	20	40	40	27	27	(1)
Residual Fuel	60	123	225	225	225	150	(1)
Armament Provisions	244	200	410	410	410	410	
Armament	1071	1250	1312	1312	1312	1312	
Auxiliary Power Plant	6						
Miscellaneous	18						
Group Total	5066	5875	7439	7394	7050	6557	
Fin	393	525	900	675	675	600	(1)
Fuselage	2588	3350	6148	5351	5262	3780	(5)
Group Total	2981	3875	7048	6026	5937	4380	
Wing	3542	4060	8557	7000	5750	4870	(6)
Undercarriage	1258	1205	2109	1800	1565	1406	(4)
Group Total	4800	5265	10666	8800	7315	6276	
Operational Empty Weight	18802	20200	35475	30000	26922	24095	
Fuel	6825	8000	12900	11000	10700	8600	(1)
Gross Weight	25627	28200	48375	41000	37622	32695	

Notes: (See bracketed numbers in N.A.E. column above)

1. Two-thirds of corresponding C-105/1200 item.
2. Probe weight based on N.A.E. Flight Research Section experience.
3. Based on linear (but not proportional) variation with gross weight fitted to data for C-104/1, C-104/2 and C-105/1200.
4. Same ratio of gross weight as corresponding item for C-105/1200
5. Based on ratio of item weight to gross weight, averaged for C-104/1, C-104/2, and C-105/1200.
6. N.A.E. wing weight equation, adjusted to fit all available A.V. Roe delta wing weights (12 in number).

359-11 KEUFFEL & ESSER CO.
10 × 10 to the ½ inch, 5th lines accented.
MADE IN U. S. A.

COMPARISON OF C105/1200 AND DOUGLAS DC-3.

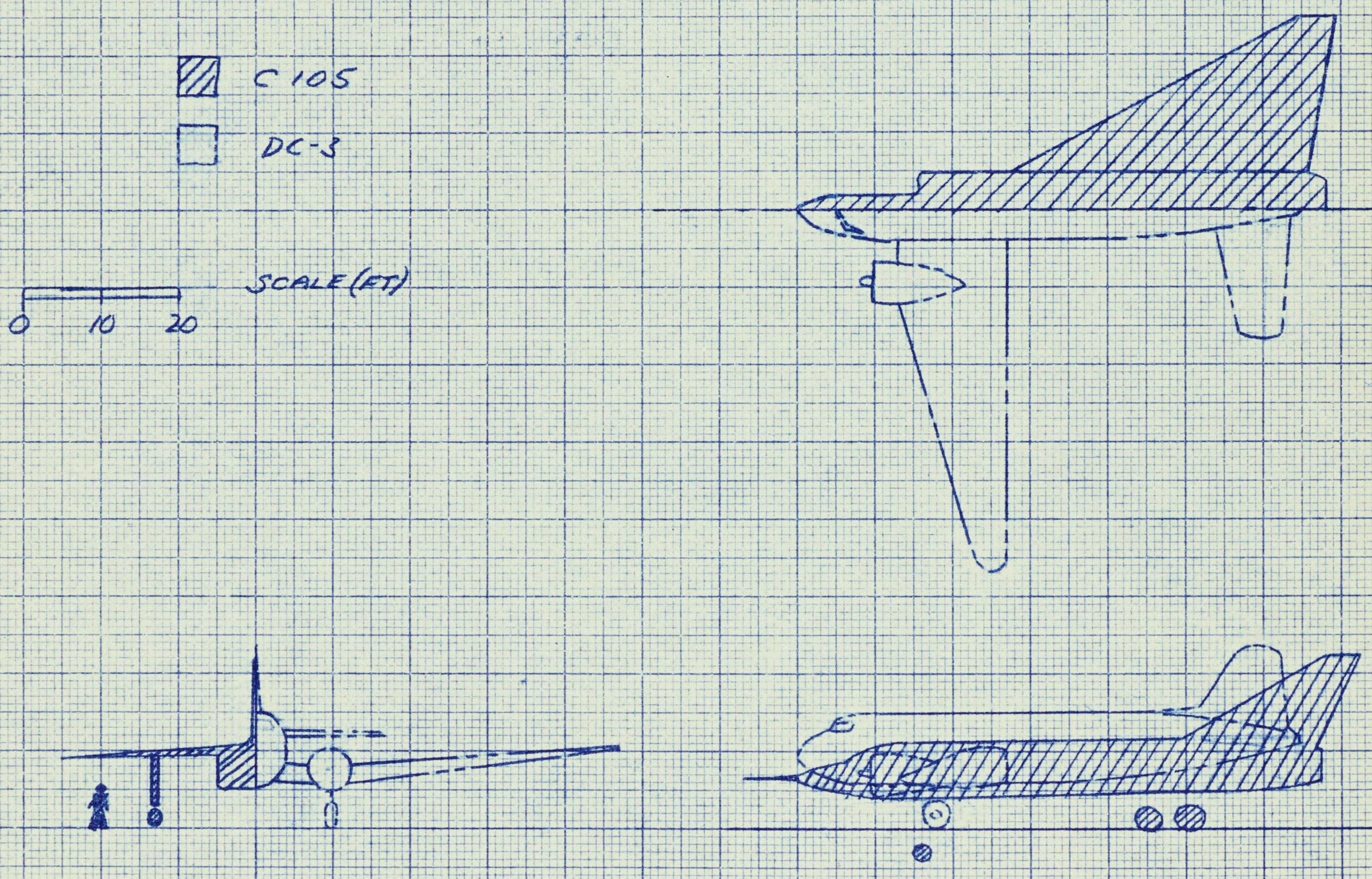


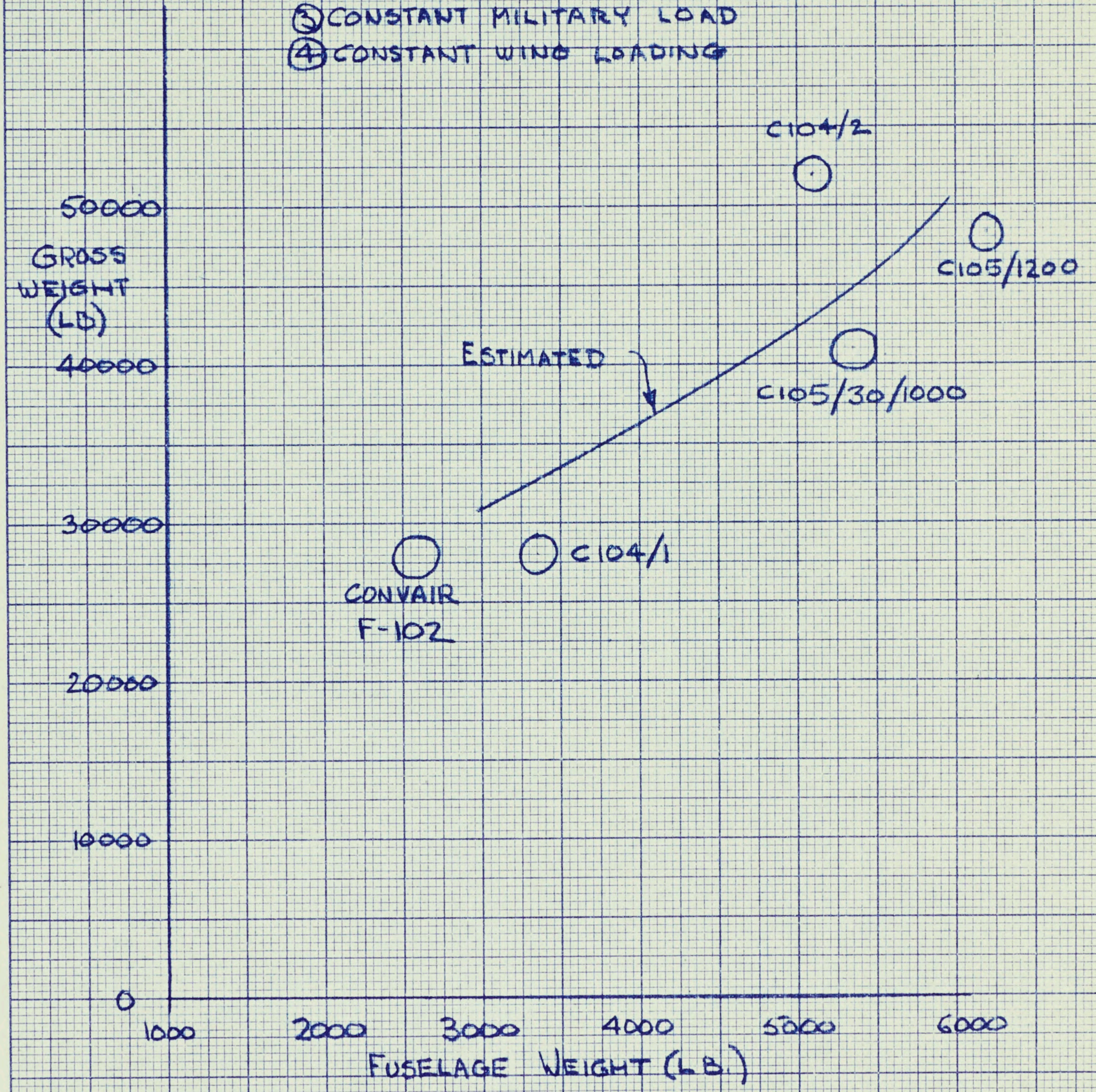
FIG 1

FIG 2

VARIATION OF GROSS WEIGHT WITH FUSELAGE WEIGHT

ASSUMTIONS IN "ESTIMATED" CURVE:

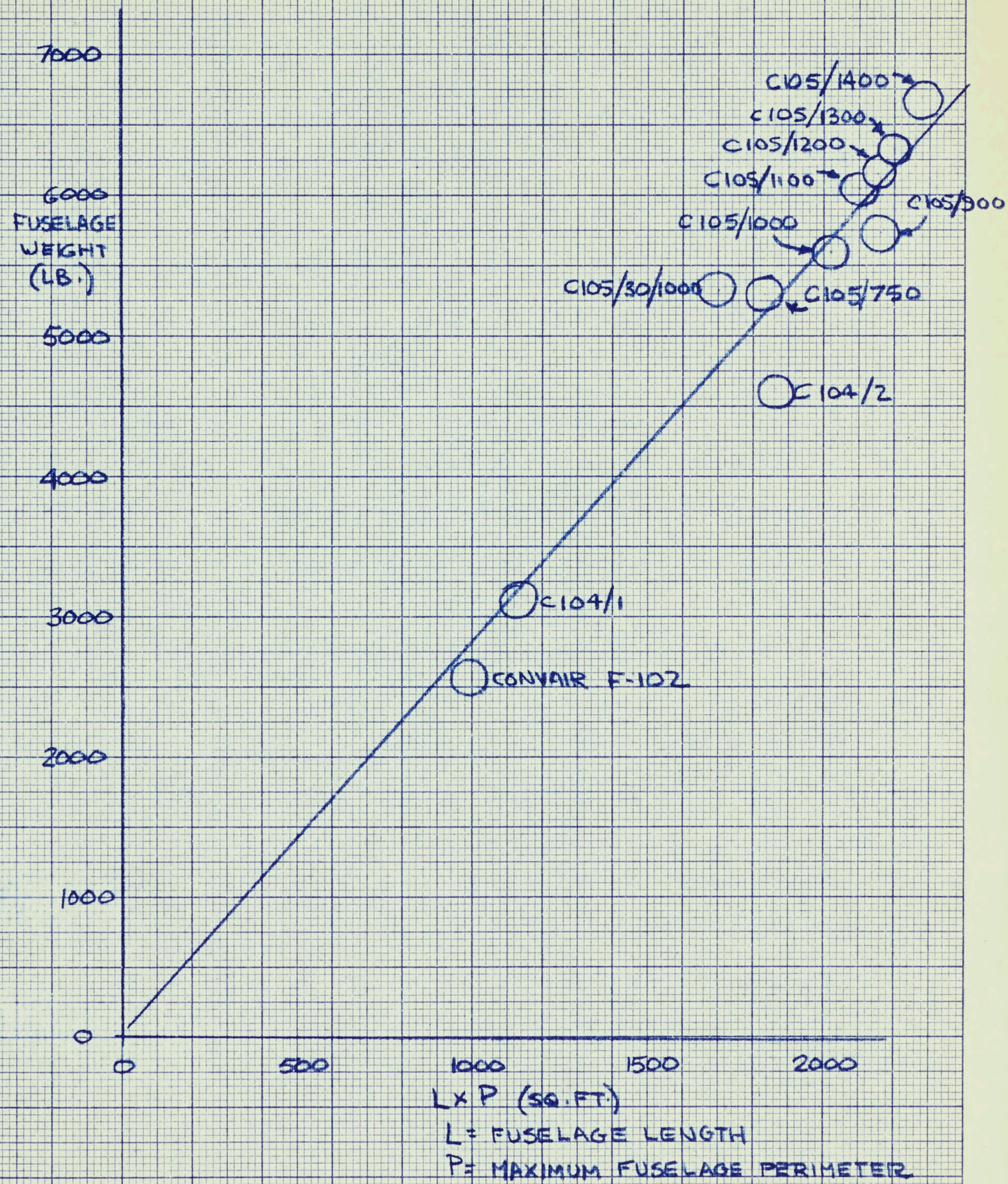
1. ENGINE & FUEL WEIGHT VARY DIRECTLY WITH GROSS WT.
2. WING THICKNESS RATIO VARIES LINEARLY WITH GROSS WT. FROM 0.04 AT 32000 LB TO 0.03 AT 48000 LB.
3. CONSTANT MILITARY LOAD
4. CONSTANT WING LOADING



10 X 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.
KEUFFEL & ESSER CO.
359-11

FIG 3

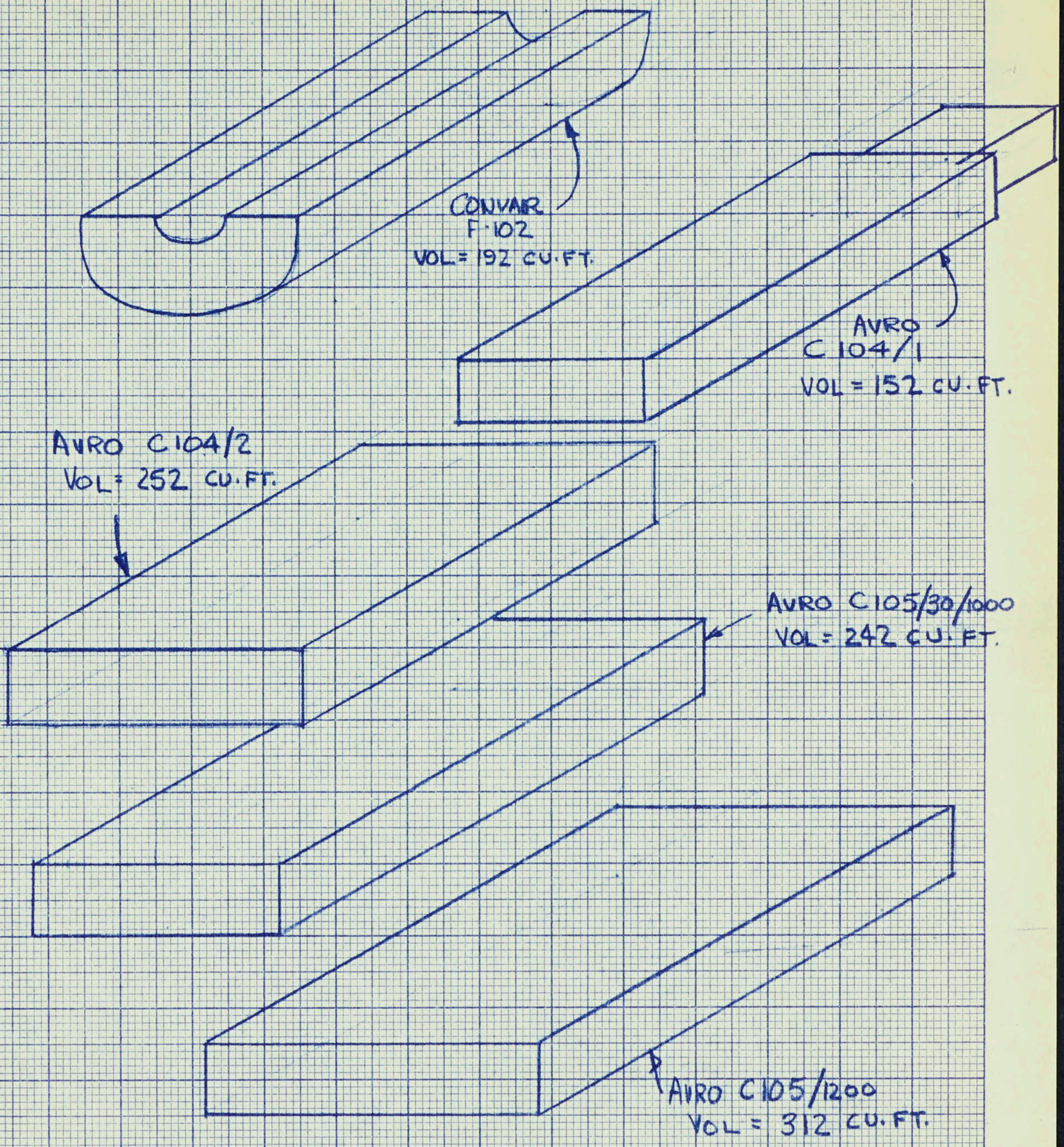
COMPARISON OF FUSELAGE WEIGHTS



KEUFFEL & ESSER CO. 10 X 10 to the ½ inch, 5th lines accented. 359-11 MADE IN U.S.A.

FIG 4

RELATIVE ARMAMENT BAY SIZES



10 X 10 to the ½ inch, 5th lines accented.
359-11 KEUFFEL & ESSER CO. MADE IN U.S.A.

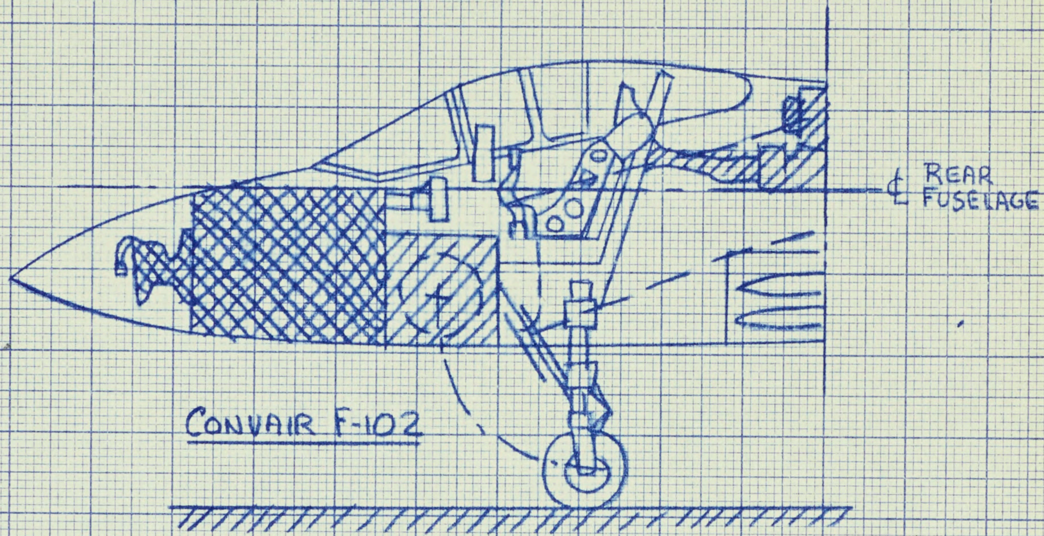
FIG 5

UTILIZATION OF SPACE IN FRONT FUSELAGE

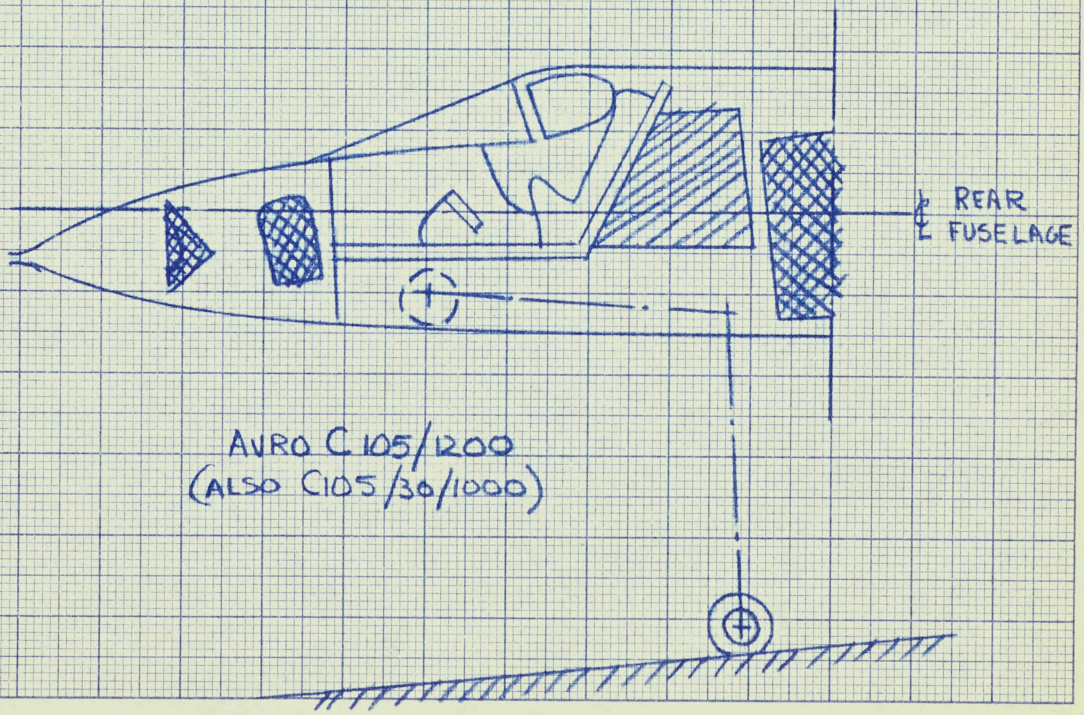
NOTE: DRAWINGS SHOW 20-FOOT LENGTH OF FUSELAGE

SCALE: 1/4 IN. = 1 FT.

- [cross-hatched] HUGHES MX 1179 EQUIP.
- [hatched] OTHER EQUIPMENT.



CONVAIR F-102



AVRO C 105/1200
(ALSO C105/30/1000)

10 X 10 to the 1/2 inch, 5th lines accented. MADE IN U.S.A. KEUFFEL & ESSER CO. 358-11

KEUFFEL & ESSER CO., N. Y. NO. 359-14
Millimeters, 5 mm. lines accented, cm. lines heavy.
MADE IN U. S. A.

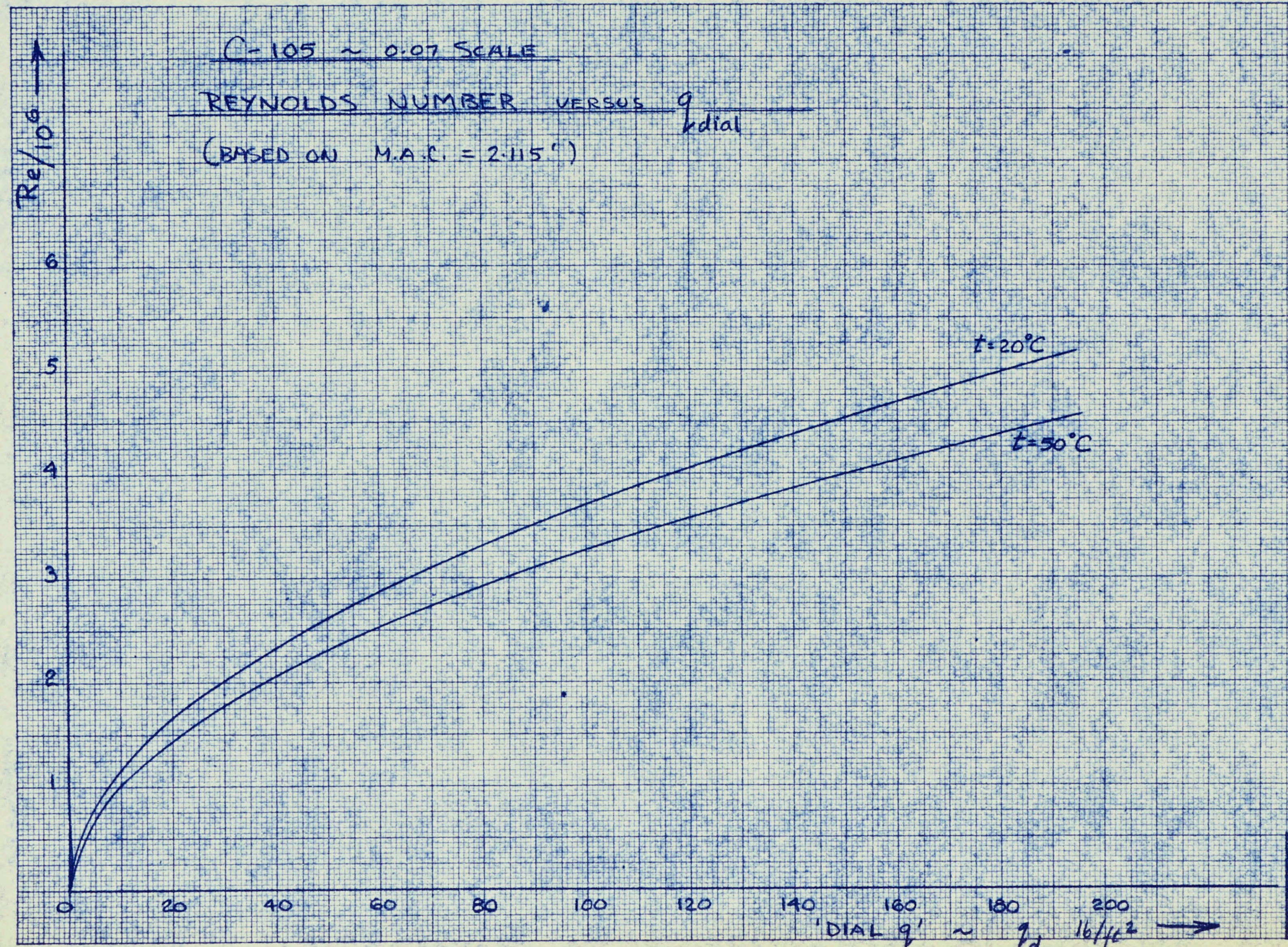
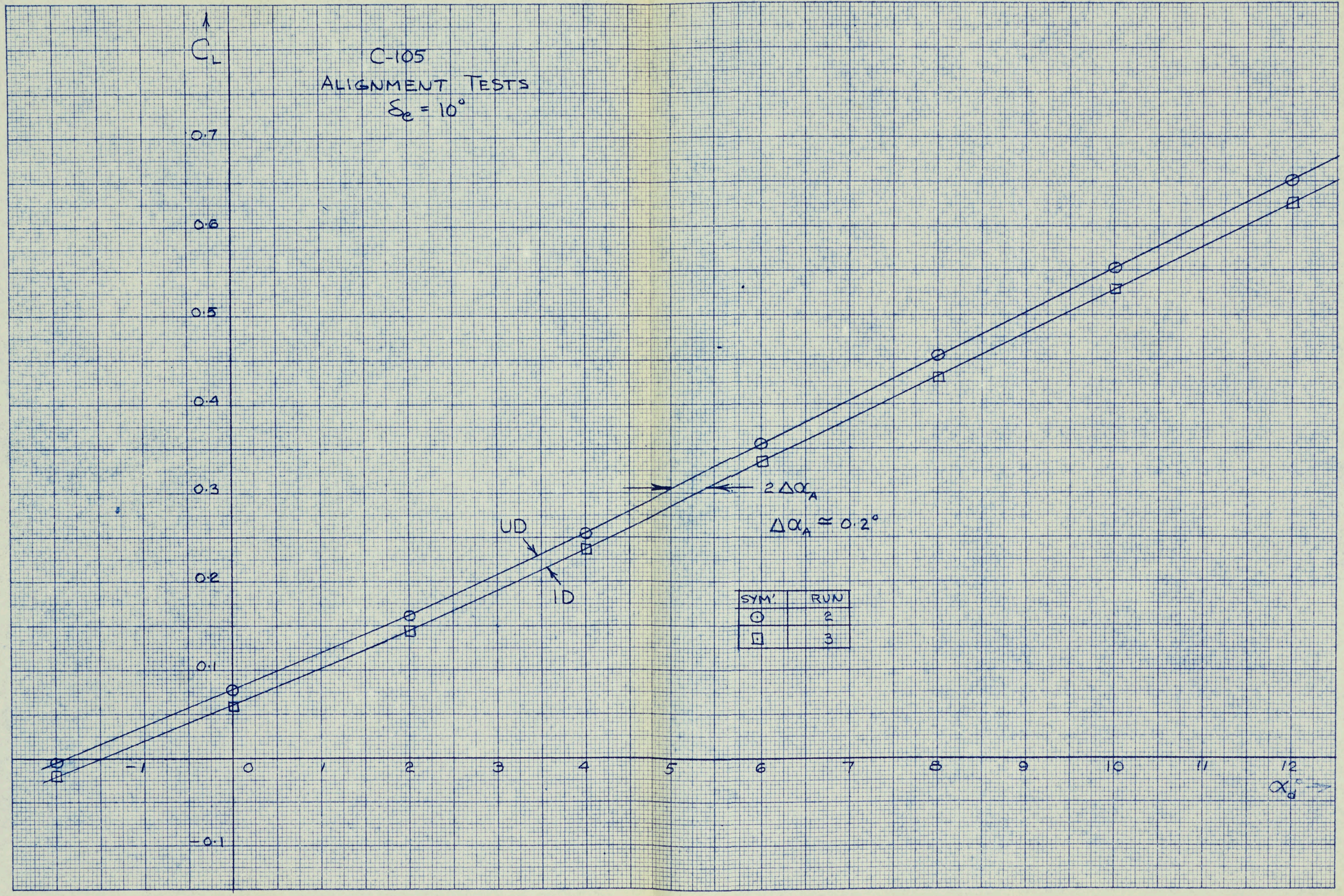


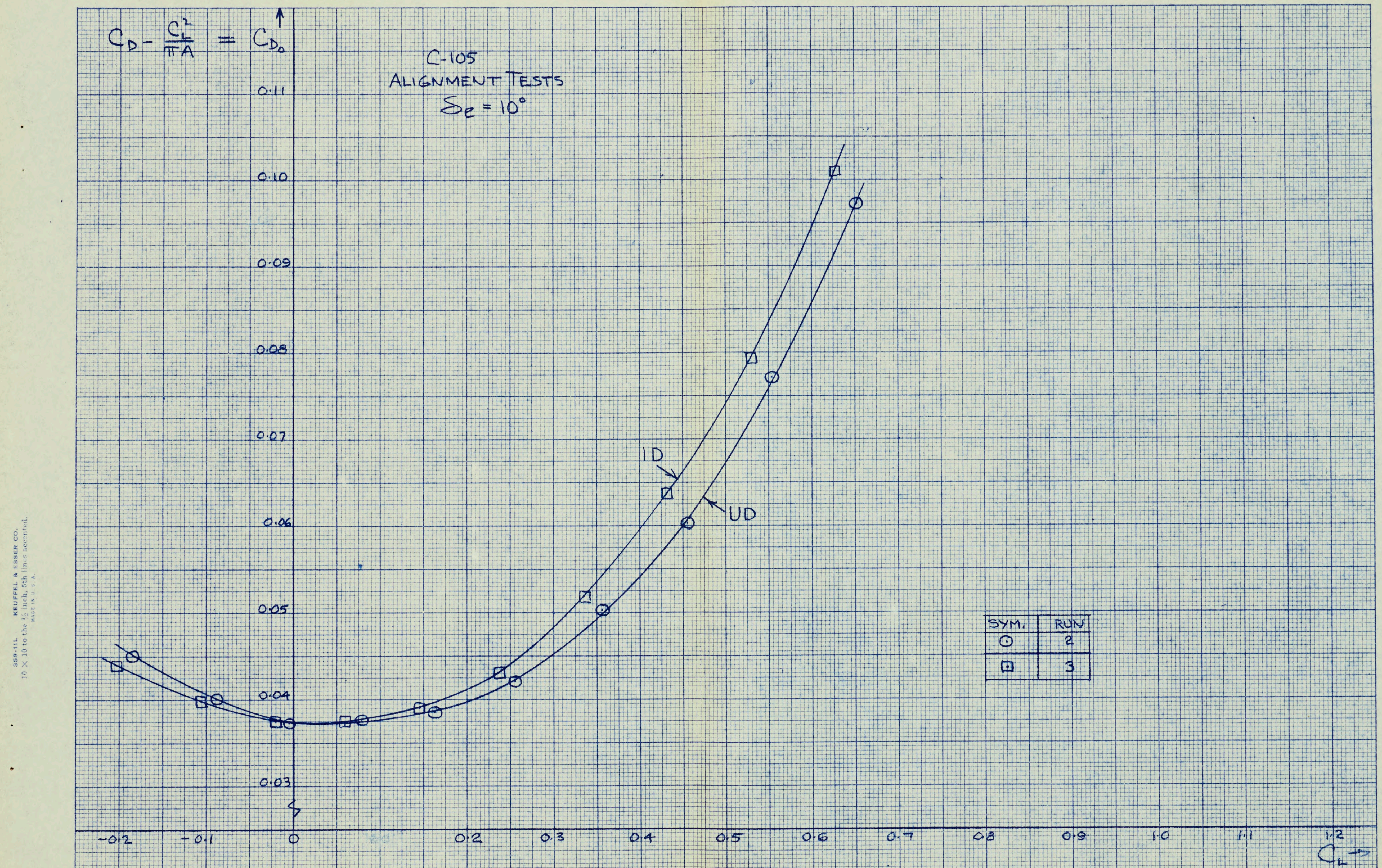
FIG. 6

FIG. 7



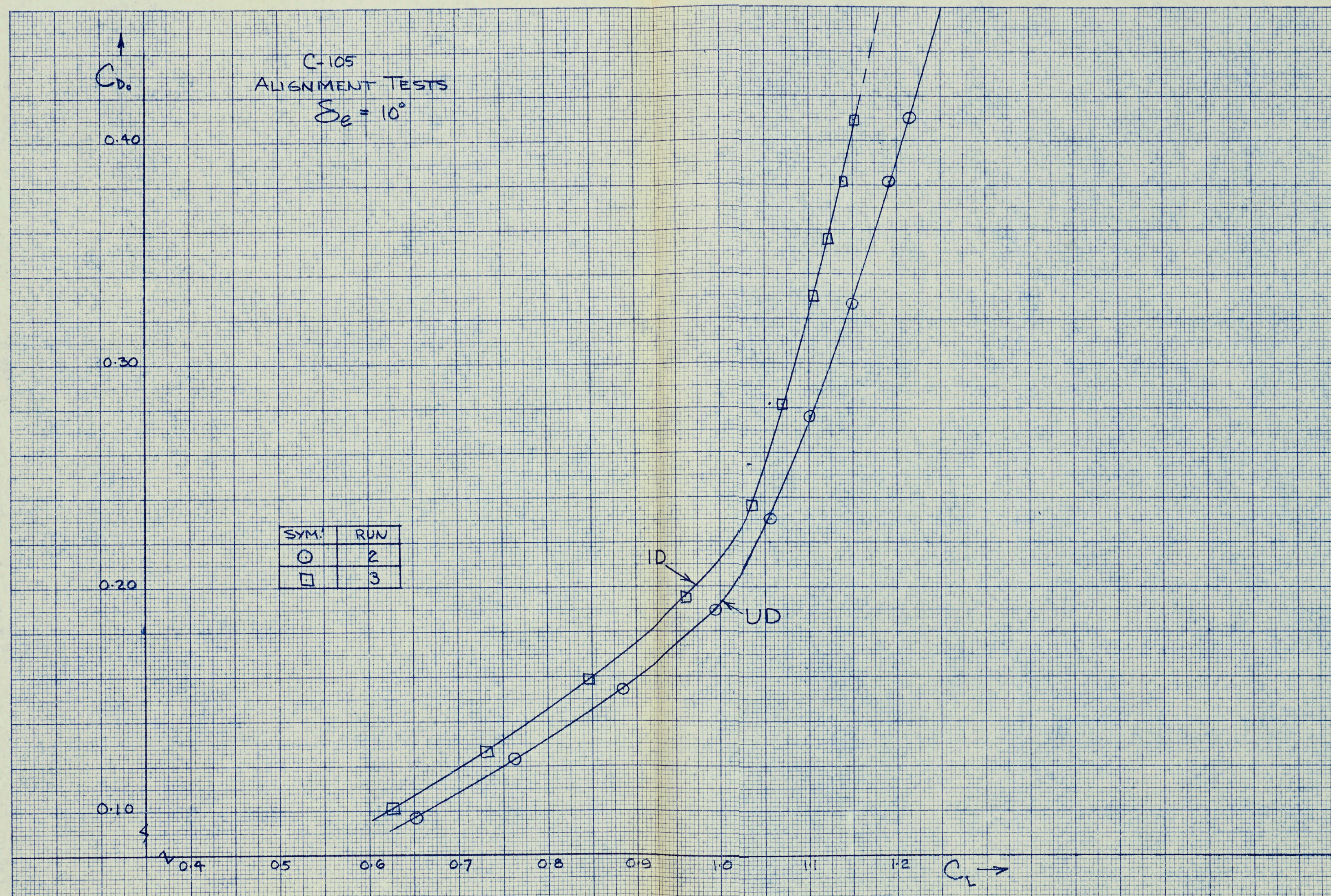
359-11L KEUFFEL & ESSER CO.
10 X 10 to the 1/2 inch, 5th lines accented
MADE IN U.S.A.

FIG. 8



$C_D - \frac{C_L^2}{\pi A} = C_{D_0}$
C-105
ALIGNMENT TESTS
$\delta_e = 10°$
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
-0.2
-0.1
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
C_L
ID
UD
SYM.
RUN
2
3
359-11L KEUFFEL & ESSER CO.
10 X 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.

FIG. 9



359-11L KEUFFEL & ESSER CO.
10 X 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.

FIG. 10

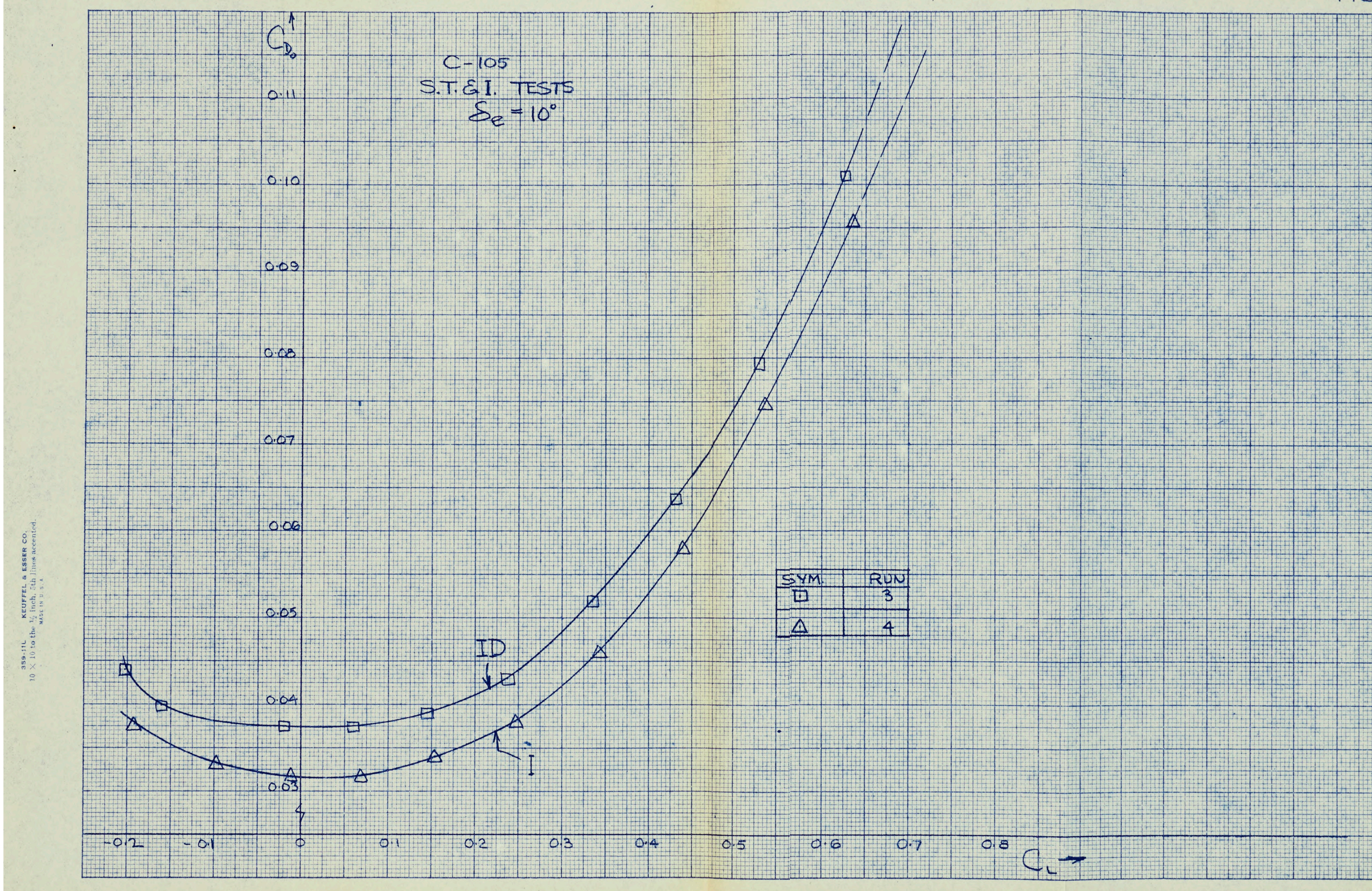
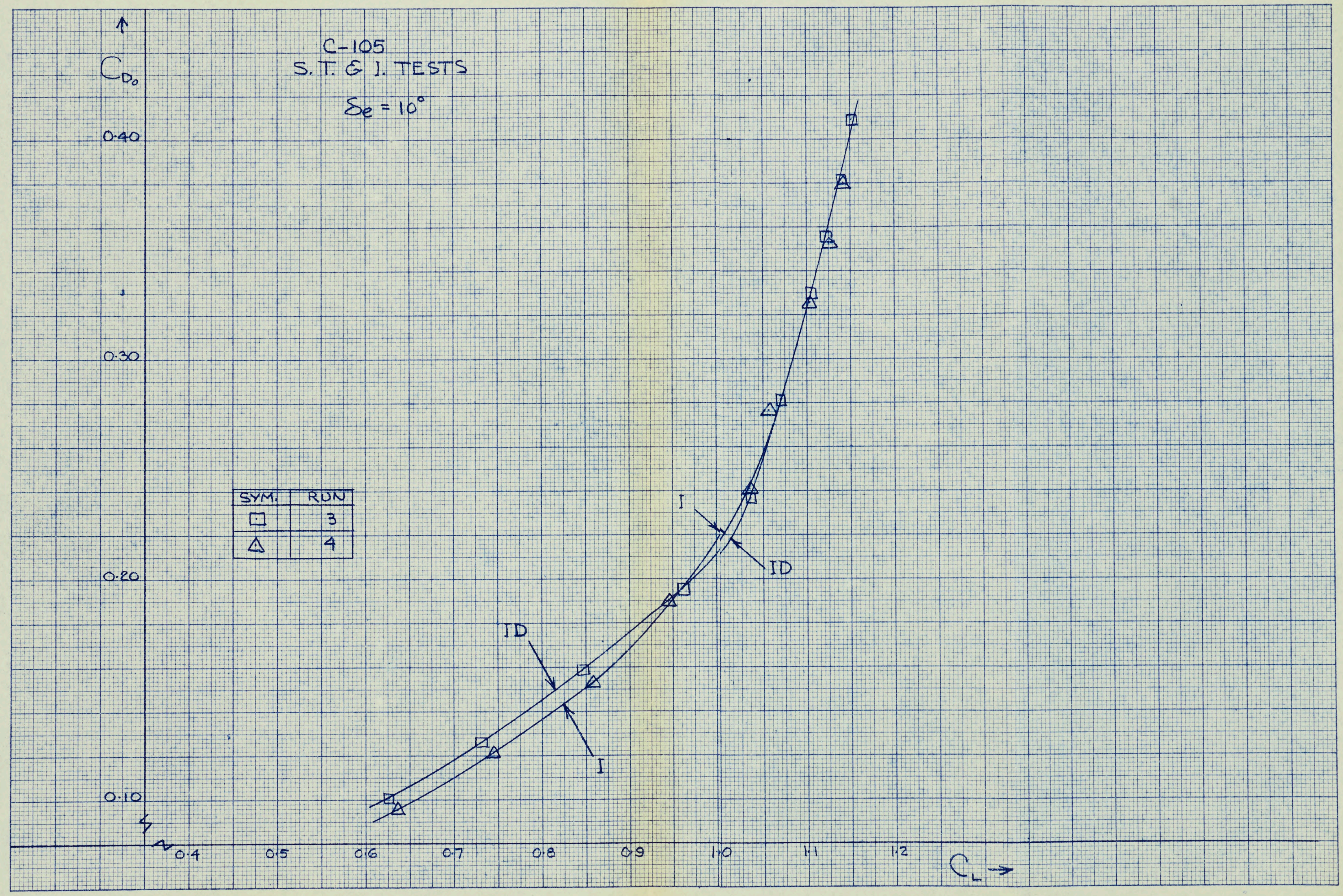
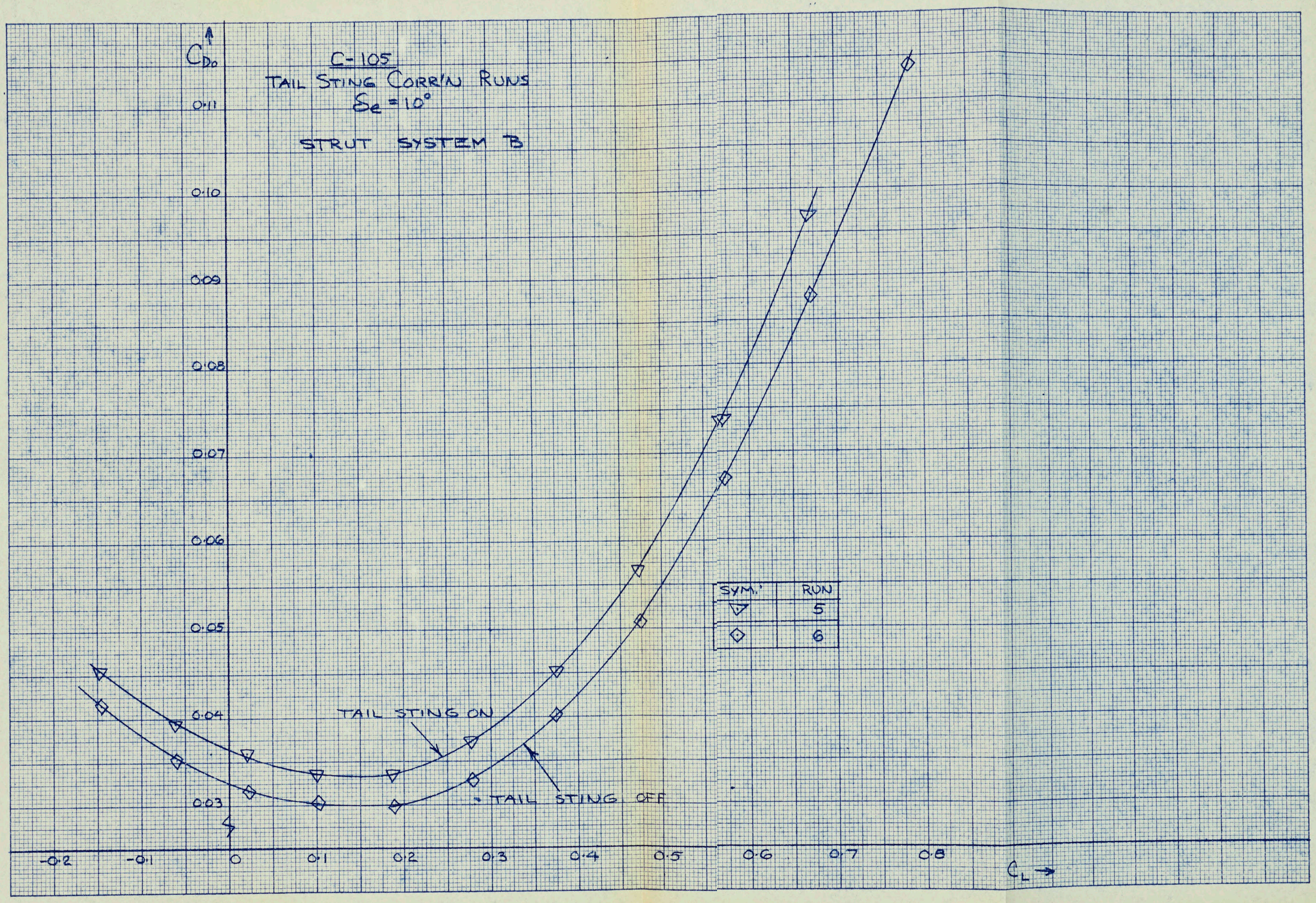

C-105
S.T.&I. TESTS
$\delta_e = 10°$
C_{D_0}
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
C_L
ID
I
SYM. RUN
□ 3
△ 4
359-11L KEUFFEL & ESSER CO.
10 × 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.

FIG. 11.



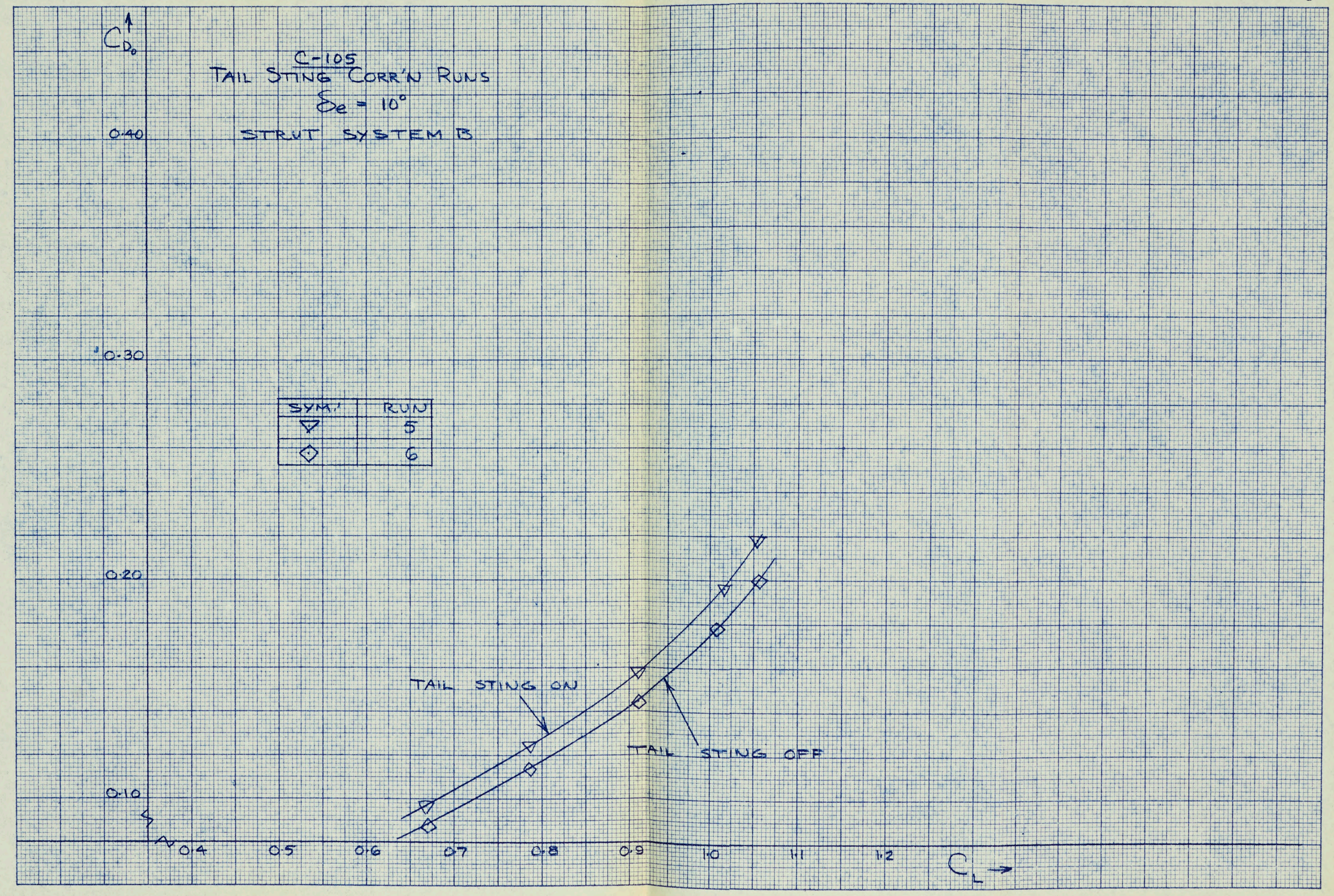
359-11L KEUFFEL & ESSER CO.
10 X 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.

FIG. 12



C_{D_0}
C-105
TAIL STING CORR'N RUNS
$\delta_e = 10°$
STRUT SYSTEM B
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
C_L
TAIL STING ON
TAIL STING OFF
SYM. RUN
5
6

FIG. 13



C-105
TAIL STING CORR'N RUNS
$\delta_e = 10°$
STRUT SYSTEM B
C_{D_0}
0.40
0.30
0.20
0.10
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
C_L
SYM.
RUN
5
6
TAIL STING ON
TAIL STING OFF

FIG. 14

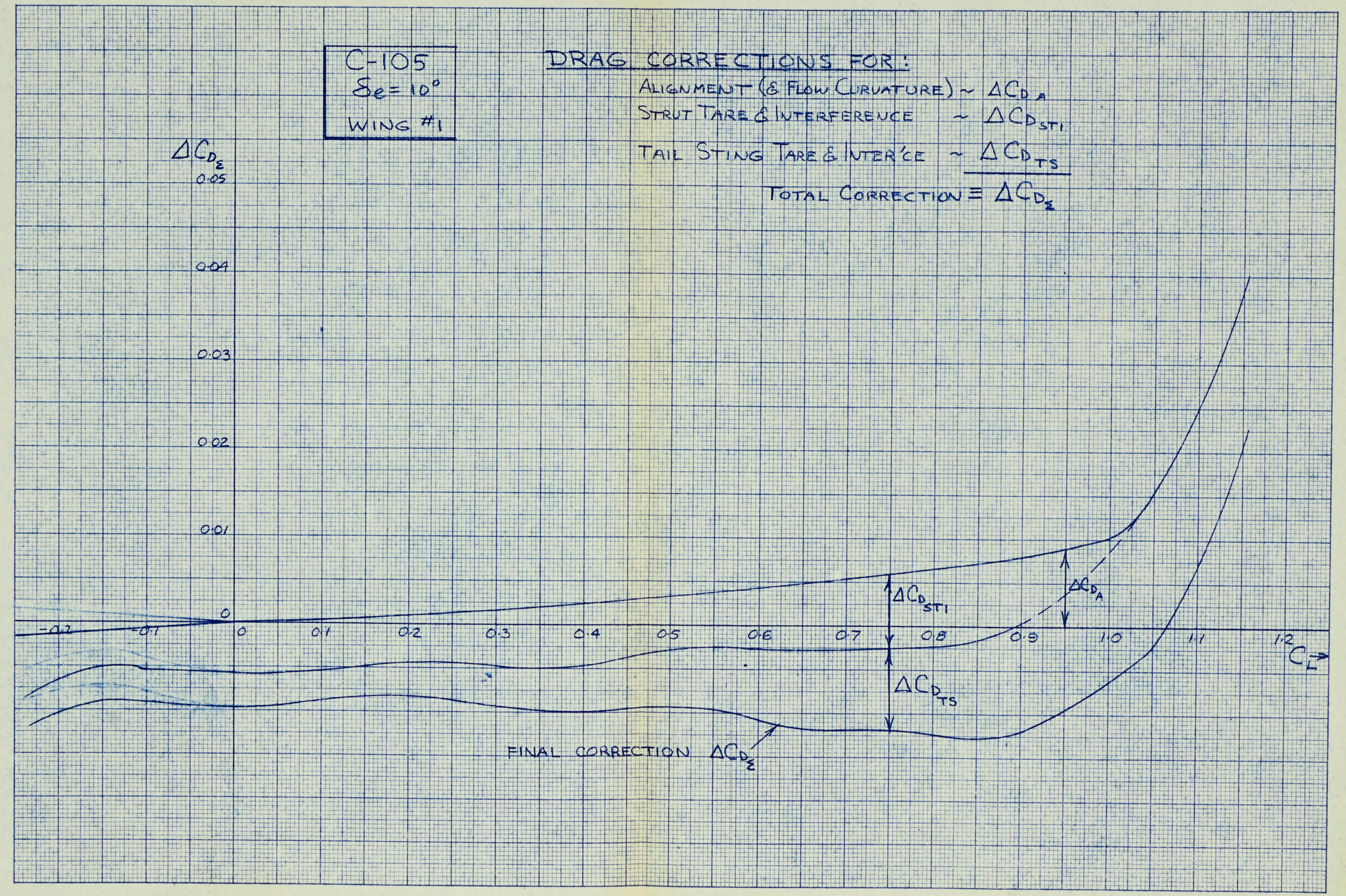
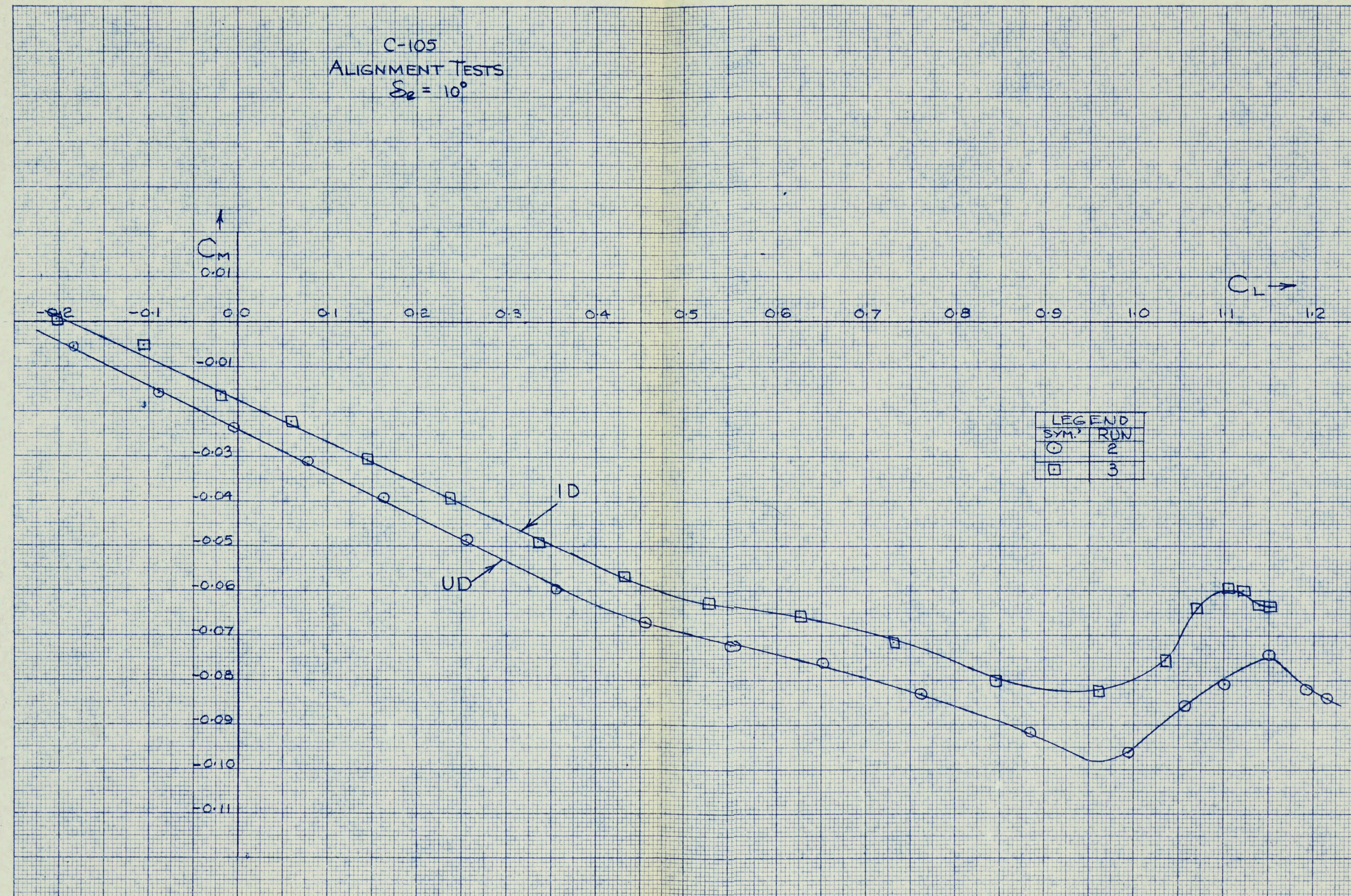
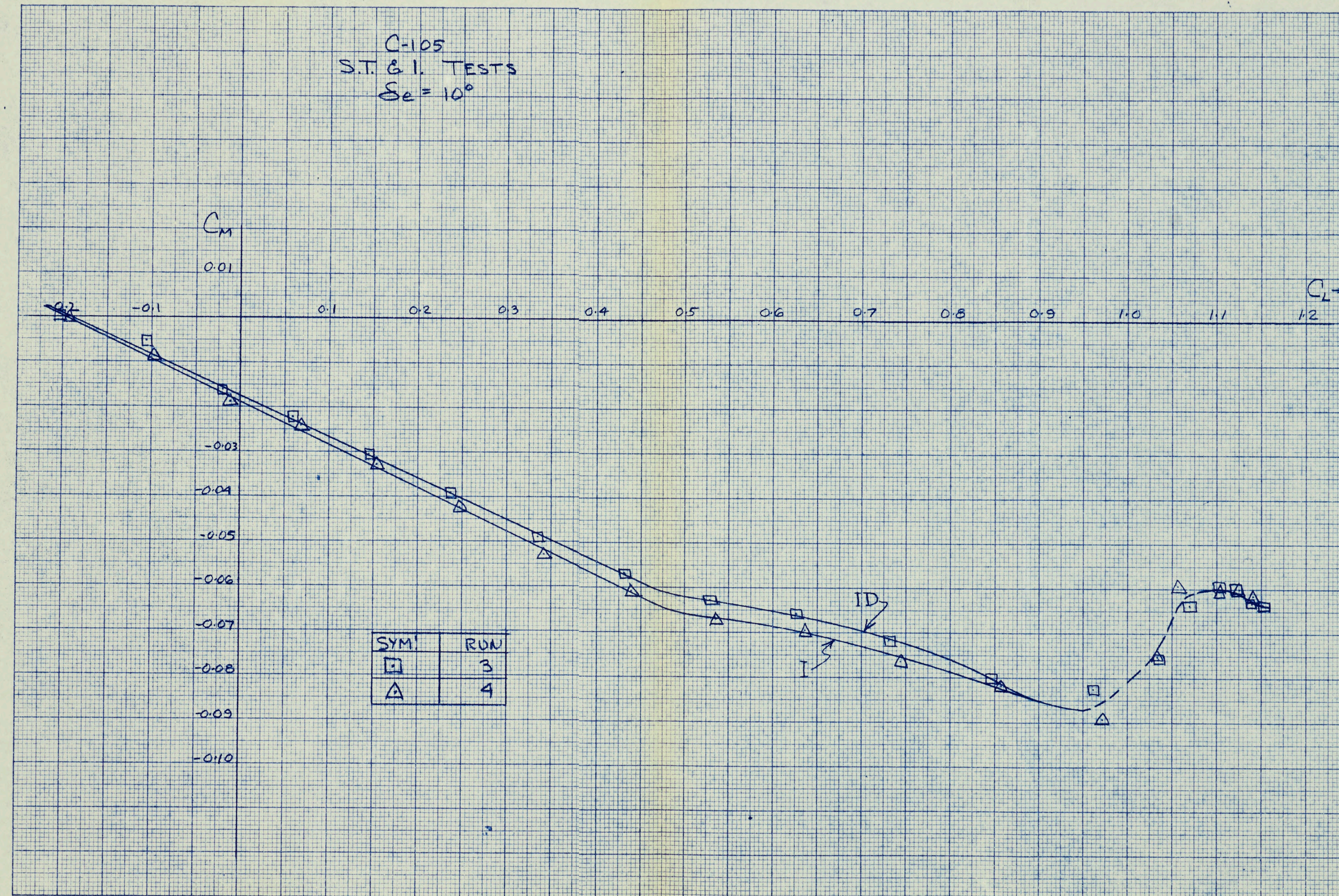

C-105
$\delta_e = 10°$
WING #1
DRAG CORRECTIONS FOR:
ALIGNMENT (& FLOW CURVATURE) ~ ΔC_{D_A}
STRUT TARE & INTERFERENCE ~ $\Delta C_{D_{STI}}$
TAIL STING TARE & INTER'CE ~ $\Delta C_{D_{TS}}$
TOTAL CORRECTION ≡ ΔC_{D_Σ}
ΔC_{D_Σ}
0.05
0.04
0.03
0.02
0.01
0
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
C_L
$\Delta C_{D_{STI}}$
ΔC_{D_A}
$\Delta C_{D_{TS}}$
FINAL CORRECTION ΔC_{D_Σ}

FIG. 15



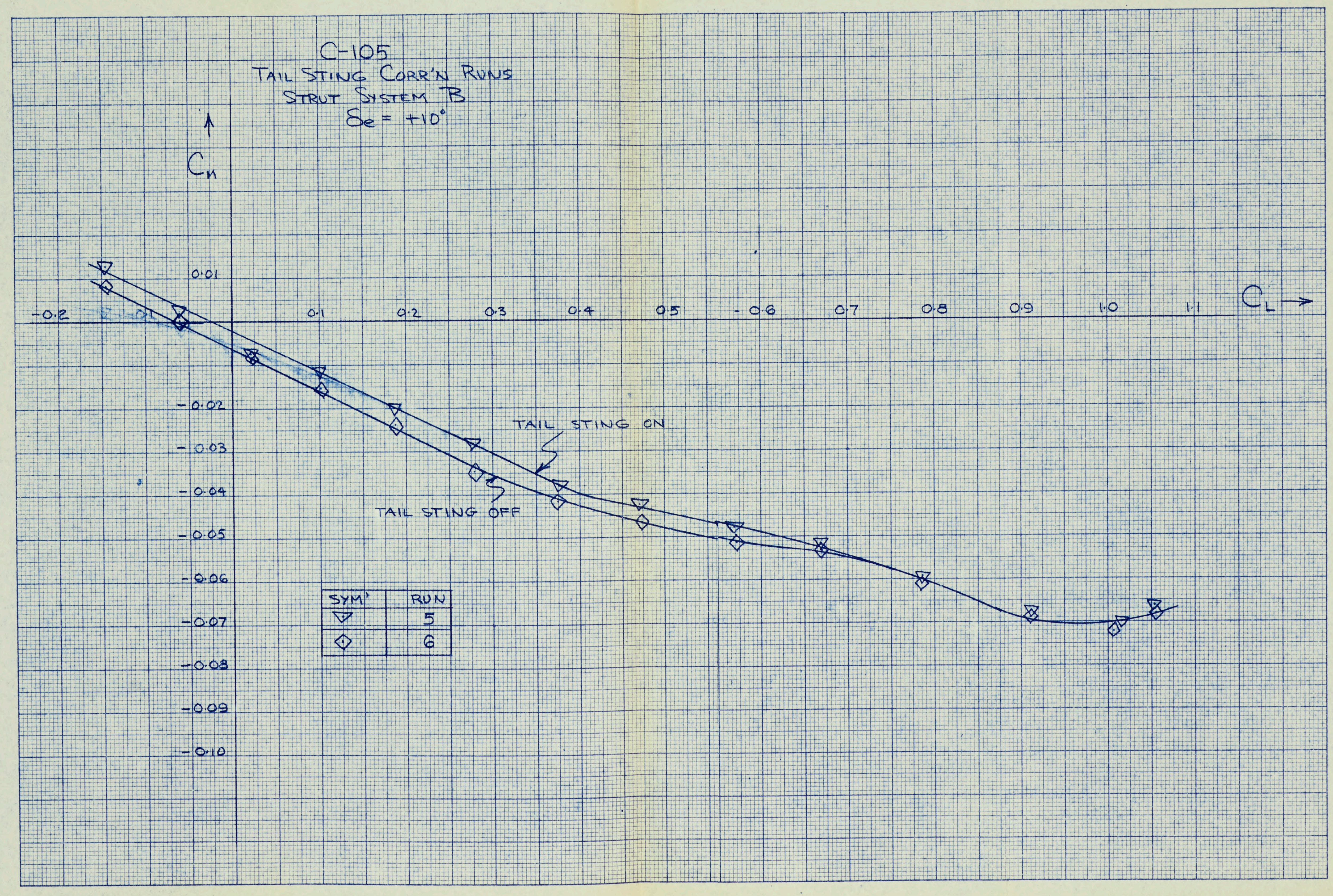
C-105
ALIGNMENT TESTS
$\delta_e = 10°$
C_M
C_L
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
0.01
-0.01
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
-0.11
ID
UD
LEGEND
SYM. RUN
⊙ 2
⊡ 3

FIG. 16



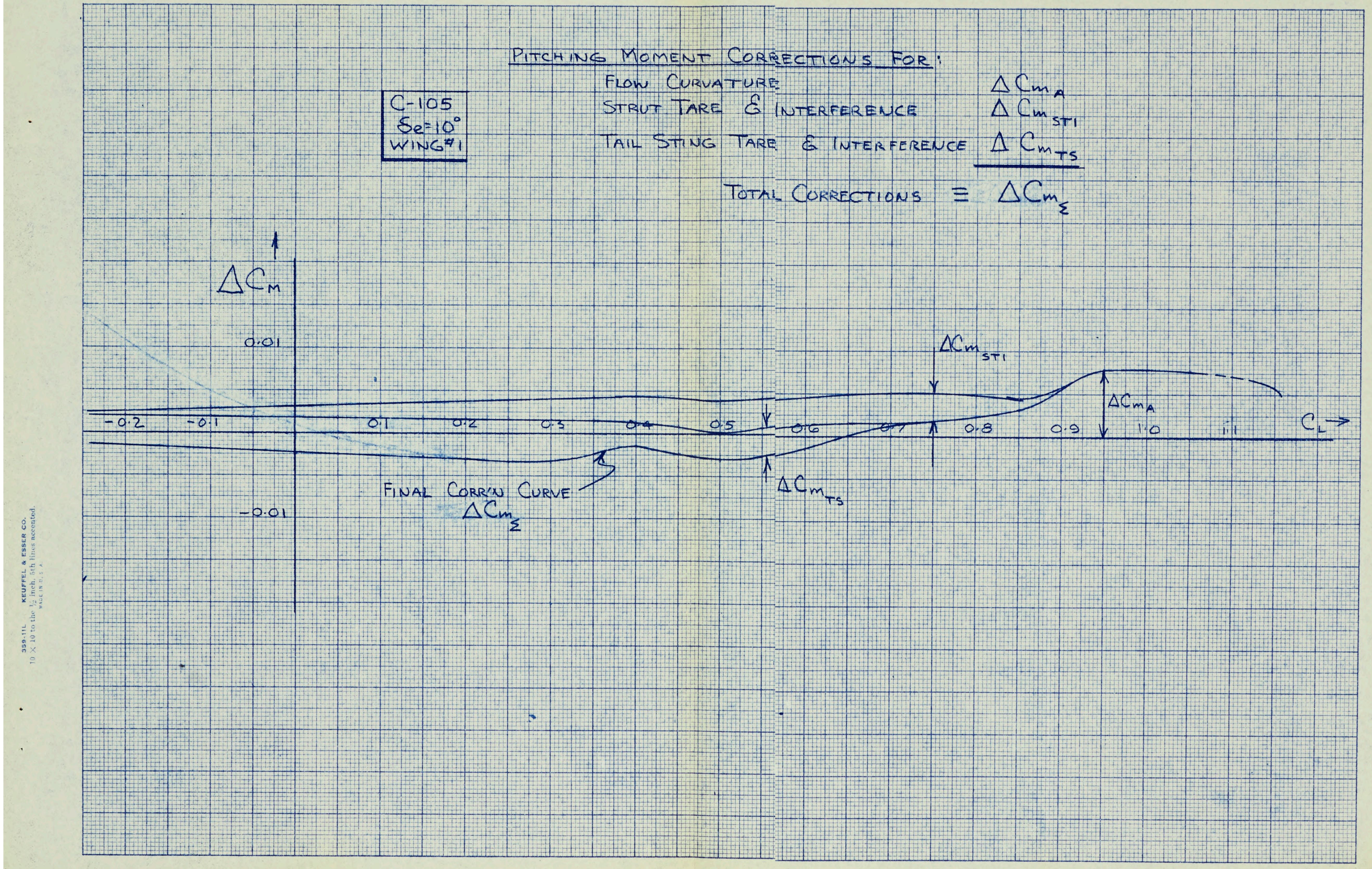
C-105
S.T. & I. TESTS
$\delta_e = 10°$
C_M
C_L
0.01
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
-0.2
-0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
ID
I
SYM. RUN
3
4

FIG. 17



C-105
TAIL STING CORR'N RUNS
STRUT SYSTEM B
$\delta_e = +10°$
C_n
C_L
0.01
-0.2
-0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
TAIL STING ON
TAIL STING OFF
SYM' RUN
5
6

FIG. 18


PITCHING MOMENT CORRECTIONS FOR:
FLOW CURVATURE ΔC_{m_A}
STRUT TARE & INTERFERENCE $\Delta C_{m_{STI}}$
TAIL STING TARE & INTERFERENCE $\Delta C_{m_{TS}}$
TOTAL CORRECTIONS $\equiv \Delta C_{m_\Sigma}$
C-105
$\delta e = 10°$
WING #1
ΔC_M
0.01
-0.01
-0.2
-0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
C_L
$\Delta C_{m_{STI}}$
ΔC_{m_A}
$\Delta C_{m_{TS}}$
FINAL CORR'N CURVE
ΔC_{m_Σ}
359-11L KEUFFEL & ESSER CO.
10 X 10 to the 1/2 inch. 5th lines accented.
MADE IN U.S.A.

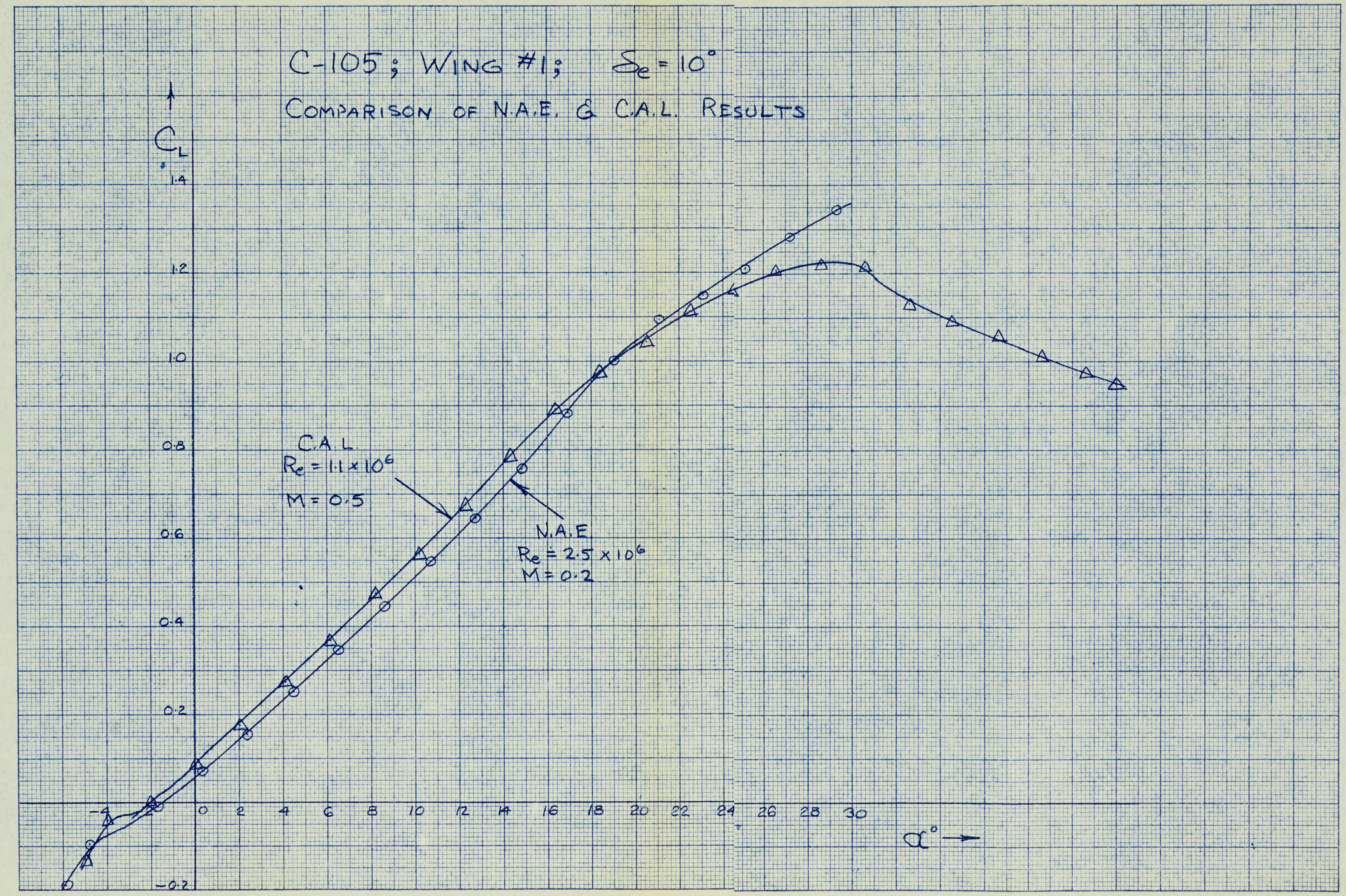

C-105; WING #1; $\delta_e = 10°$
COMPARISON OF N.A.E. & C.A.L. RESULTS
C_L
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-0.2
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
$\alpha°$
C.A.L.
$R_e = 1.1 \times 10^6$
M = 0.5
N.A.E.
$R_e = 2.5 \times 10^6$
M = 0.2

FIG. 20

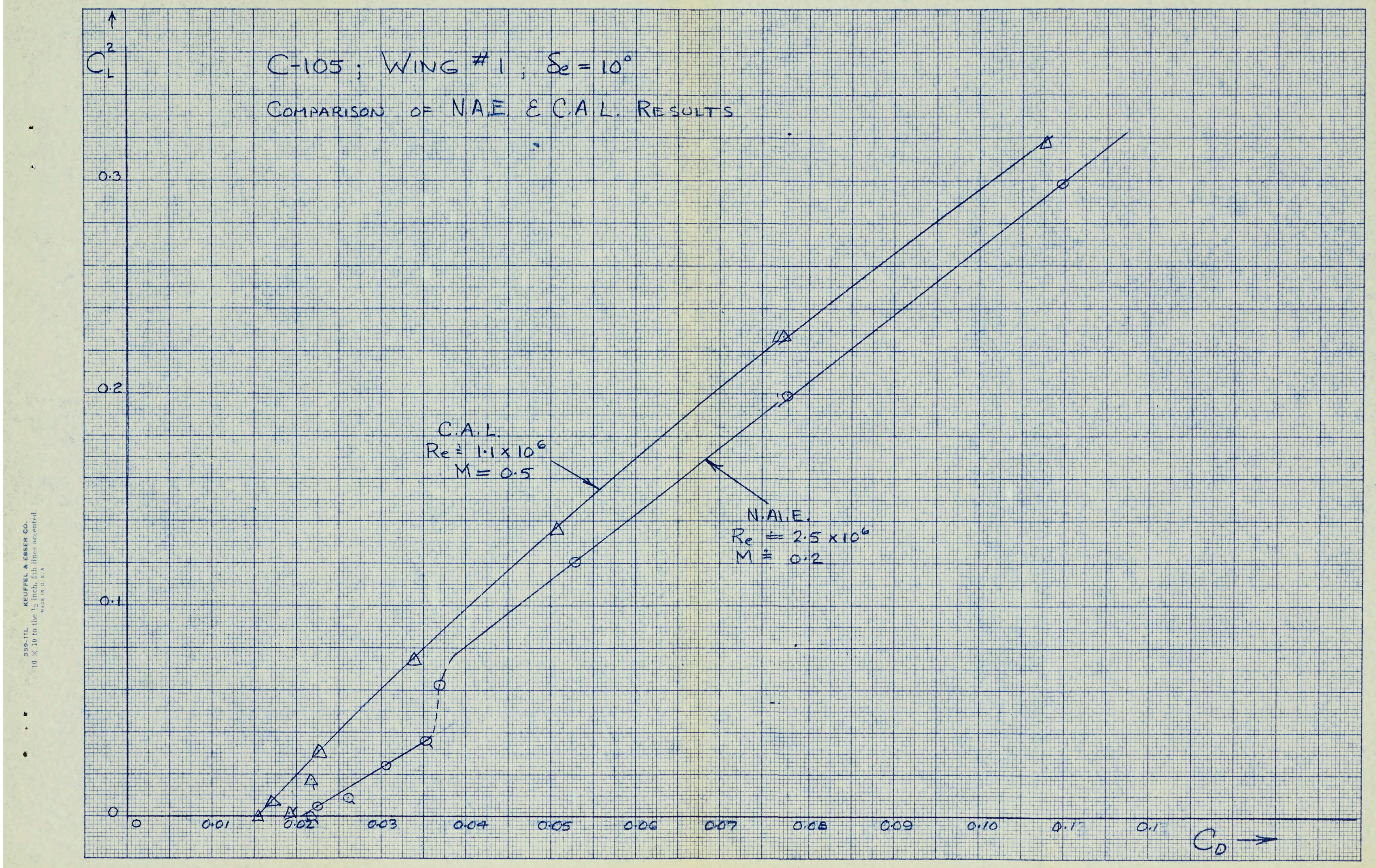
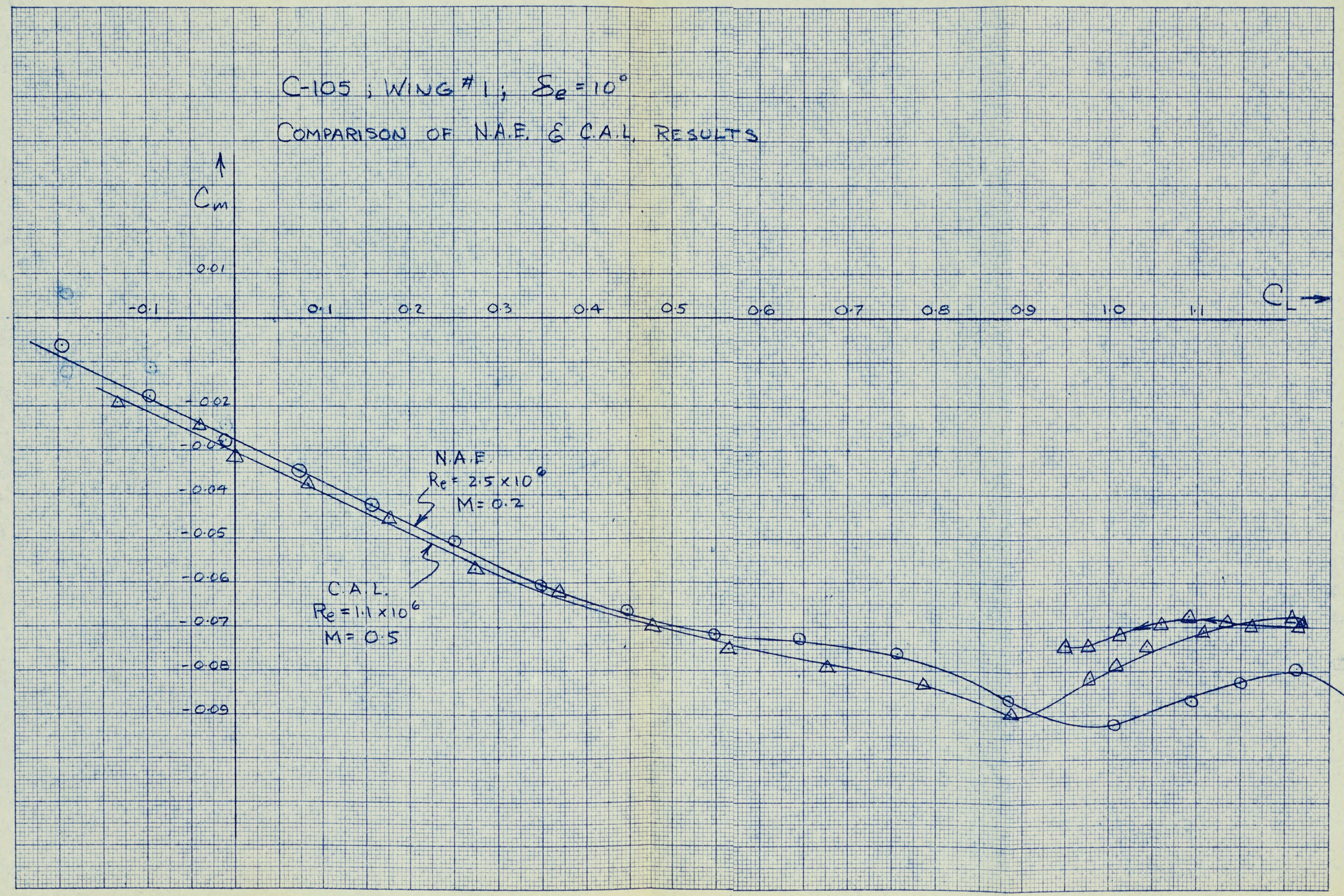

C-105 ; WING #1 ; δe = 10°
COMPARISON OF N.A.E. & C.A.L. RESULTS
C_L^2
0.3
0.2
0.1
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
C_D
C.A.L.
Re ≑ 1.1 x 10⁶
M = 0.5
N.A.E.
Re ≑ 2.5 x 10⁶
M ≑ 0.2
359-11L KEUFFEL & ESSER CO.
10 X 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

FIG. 21



359-11L KEUFFEL & ESSER CO.
10 X 10 to the 1/2 inch. 5th lines accented.
MADE IN U.S.A.