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Annual Variation of Flight Loads Recorded on Viscount Aircraft by Means of the Fatigue Load Meter

By

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LONDON: HER MAJESTY'S STATIONERY OFFICE

1964

PRICE 7s 6d NET

U.D.C. No. 533.6.048.1 [AI] (42) Viscount

C.P. No. 667

December, 1962

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SUMMARY

Flight load data collected by means of Fatigue Load Meters from Viscount aircraft belonging to British European Airways and Trans-Australia Airlines are presented in full. An analysis is made to determine whether there is any regular annual variation of these flight loads (and consequently, it is believed, of the atmospheric turbulence which causes them). Such an annual variation is shown to exist, and to differ for the two geographical areas concerned.

Replaces R.A.E. Tech. Note No. Structures 322 - A.R.C. 24, 847.

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1 INTRODUCTION

In the past few years a considerable amount of data has been published on the normal accelerations of aircraft, which have been recorded in flight, by means of various instruments such as the Fatigue Load Meter or Counting Accelerometer, or the American V-g-h Recorder; for large transport aircraft these accelerations will be almost entirely due to gusts rather than to pilot-imposed manoeuvres. Comments have been made, notably in J. Taylor's paper[1] on "Fatigue Loading Actions on Transport Aircraft" on the annual variation of the accelerations recorded; the purpose of the present paper is to study such a variation a little more fully, using results gathered over several years from a number of aircraft of the same type operated by two different airlines* in different parts of the world. The data available for this study consist of Fatigue Load Meter readings obtained from Viscount aircraft operated by B.E.A. over routes covering a large part of Europe, and by Trans-Australia Airlines over routes lying mainly over Eastern and Southern Australia. In each case it is evident that there is a pattern of seasonal variation in the loading on the aircraft which is recognisably repeated from year to year. The pattern is obviously different for the north and the south hemispheres.

2 EQUIPMENT AND BASIC DATA

2.1 Description of equipment

The instrument by which the recordings have been made is the Fatigue Load Meter, which is fully described in an R.A.E. Instruction Leaflet[3]. Essentially it consists of a weight whose displacement is proportional to the external load on the aeroplane; a system of electrical contacts operates a series of counters to record whenever preset levels of displacement and therefore of aircraft acceleration are reached. The particular instruments from which these results are taken record the numbers of times at which increments of 0.25g, 0.55g, and 0.95g above and below level flight occur, i.e. the number of distinct occasions on which levels of acceleration of 0.05g, 0.45g, 0.75g, 1.25g, 1.55g and 1.95g are crossed, in the direction away from 1g. Counts from the 0.05g and 1.95g counters are so few in number that they are not used in the present analysis. In order to ensure that all counts recorded are due to true flight accelerations, there is an airspeed switch incorporated in the installation which switches the instrument on at a speed of 125 knots and off at 110 knots, thus cutting out any acceleration due to taxying, take-off or landing. There are two types of instrument which record over the range quoted, the 1A and 1B (including 1BA); the latter is considered to be the more reliable, and accordingly data from 1A instruments were not used. Although the quantity is less than that from the 1B instruments, it is still sufficient to affect aggregated results should there in fact be any appreciable difference in instrument characteristics, and the analysis is already complex enough to deter one from adding another parameter.

2.2 Data collected

The basic data collected by the Fatigue Load Meter consist, therefore, of counts of the number of times crossings in one direction of preset acceleration levels are made in flight; the flight times can be extracted from the aircraft log. We can then calculate the average number of counts per hour for the period between readings, which can be taken as a measure of the frequency of occurrence of stated aircraft accelerations. Since the response of the aircraft is affected by its speed, weight, and altitude, and these factors are not recorded, it is impossible to calculate equivalent gust speeds, and the data are therefore not in detail measures of the turbulence which the aircraft encounters. (From tables given in a report by Heath-Smith on records from Counting Accelerometers installed in Viscounts[4] it appears that the gust velocity required to cause an aircraft acceleration of 0.25g varies from about 8 to 12ft/sec at different stages of a typical flight). We are however dealing with a sizeable fleet of similar aircraft operating over the same set of routes, so we can expect the statistical pattern to

*A report by Bruce and Hooke of the Australian Defence Scientific Services[2] is also based on data from the Australian airline, including most of that used in this Note.

remain reasonably constant throughout the year except for the weather; where we have a sufficiently large sample, the sampling errors will be small compared with the effect being investigated. Thus while the results will be, strictly speaking, the flight loads imposed on the aircraft as a result of atmospheric turbulence, their variation can also be taken as a good indication of the variation of this turbulence.

2.3 Flying covered by records

The records are taken from Fatigue Load Meters installed in practically every aircraft of the fleets of Viscounts belonging to British European Airways and Trans-Australia Airlines. This implies that in each case the flying covers the whole range of operations of the type, both scheduled and charter, over all routes. In other words, the weather whose changes we are hoping to follow is the average weather over quite a considerable geographical area, both in Europe and in Australia. Because of the limitations of the instruments, the flying also covers climbs and descent (apart from a short period near the ground, as noted above) as well as level flight. From the report referred to above[4] it would appear that in an average flight lasting $1\frac{3}{4}$ hours nearly 80% of the counts would be recorded during climb and descent, and the other 20% during cruise.

3 METHOD OF ANALYSIS

3.1 Method of smoothing

The readings of the acceleration counts and flying hours were necessarily made at irregular intervals - operational staff are already very busy, the absences of the aircraft from the home base vary with the schedule of the route they may happen to be on, and during their time on the ground servicing and maintenance demands must be paramount. The information in its original form is therefore not adapted to easy combination of results from different aircraft, for example, or from corresponding periods in successive years, and therefore some smoothing operations will require to be carried out to enable further analysis to take place. The first operation is to estimate the flying time and acceleration counts appropriate to each complete calendar month; when any period between successive readings covers the end of one month and the beginning of the next, it is assumed that the flying time reckoned as occurring in each month (if not otherwise known) is proportional to the number of days covered, and that the counts at all levels allotted to each month are proportional to the flying time whether known or assumed. In other words, the counts per hour are treated as being constant within the period, which is what would be done if a histogram were drawn. The sum total of flying time and of counts for each calendar month is then found. When this treatment is applied to any curve of counts against time, it has the effect of smoothing it out and reducing some of the peaks, but not of altering the position of any peak with regard to the time-scale, as is demonstrated in Fig.1, where the graph of counts at the 1.25g level against time for one particular aircraft has been plotted in both its original and its smoothed out form. A small amount of information is lost, in cases where the period between readings covers long unserviceability, and there is nothing to justify allocation of flying time to any particular month; but this is a small price to pay for the ability to handle the information in statistical units.

A further adjustment has to be made in order to correct for instrument error. The Fatigue Load Meter is subject to a certain amount of zero drift (any practical design is necessarily the result of compromise, and this feature was accepted in order to make provision against other less desirable characteristics) and this appears in some cases to occur very early in the service life of the instrument, in others to be progressive over the whole of the installation life. Since accurate separate totals of positive and negative acceleration counts cannot be obtained, an estimate of the total number of counts at each level is made by taking the geometric mean of the positive and negative counts, rounding it to the nearest whole number (counts of acceleration being necessarily integral) and doubling; this method arises from the fact that the curve of counts against acceleration levels is usually a straight line when plotted logarithmically. The corresponding counts per hours are then found.

No analysis is carried out for the highest level of accelerations (±0.95g) as the counts are too few to permit it.

3.2 Graphical presentation

The curves of counts per hour obtained as described in the previous section are presented in three separate sets; it has been found more convenient to plot on logarithmic paper to reduce the size of large peaks. In order to examine more clearly any annual variation there may be by increasing the concentration of data and reducing the effect of sampling error the variation from aircraft to aircraft and year to year is successively disregarded in Fig.2, where the counts per hour for all aircraft summed are plotted for every month of successive years, and in Fig.3, where the counts per hour for each individual aircraft for each month irrespective of year are plotted against the months: this is done at both the lowest and medium levels in both Figures. Finally, the total counts per hour recorded in each calendar month, summed over all aircraft and all years, are shown in Fig.4, again for both the lowest and medium g levels.

The last diagram (Fig.5) shows the total of aircraft hours flown in each month, for each year separately, summed over all aircraft.

4 DISCUSSION OF RESULTS

4.1 Method of combining results

As mentioned above the method used to combine results for different aircraft in the same month, or for the same month in different years, was to sum all counts at the same level and all aircraft hours, and then take the ratio. This follows in principle the custom applied in all Structures Reports and Technical Notes on gust frequencies, of which that by Heath-Smith on the Viscount has already been mentioned[4]. It might be argued that the counts per hour from all aircraft in any one month is an estimate of the true frequency for the month and therefore a measure of the turbulence, and so is a statistic in its own right; it would follow that when combining data the arithmetical mean of these counts per hour should be taken. It is felt however that what we are after is the total experience of an aircraft, and so it is preferable to adhere to previous practice and take the weighted mean.

4.2 B.E.A. Viscounts

4.2.1 When the curves for counts per hour per month at the ±0.25g level for individual aircraft over a period of years* are inspected, it is obvious that there is a considerable variation in each curve with a certain rough regularity, but there is no recognisable "shape" extending over a year which is obviously repeated several times. This is quite understandable, as the number of counts and flying hours for each point on the curves may be under 100, and sampling errors may be therefore large.

4.2.2 In order to get larger samples, and remembering that individual aircraft probably introduce a random error (since the different aircraft are used interchangeably on the various routes, times of day and night, and so forth), it seems logical to aggregate the counts from all aircraft, while showing all years in full, as is done in Fig.2. The first thing we notice about this figure is that the curves for the two acceleration levels are very similar, though there are one or two points where a peak on one curve corresponds to a trough on the other. As these points generally correspond to rather low totals of hours, we can regard these discrepancies as probably due to sampling errors still being appreciable; though it may be true that the more intense gusts are more irregular in occurrence than the less intense ones. These points apart, we get the impression of considerable cyclic regularity in the curves, peaks appearing in the spring (February to April) and in December, and troughs in September or October. At the lower level the spring peaks are the more pronounced, while at the higher level there is less difference between these and the September peaks.

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*Any annual variation there may be.
*(Not reproduced here. See R.A.E. Tech. Note Struct. 322).

4.2.3 The curves of individual aircraft summed over all years (shown in Fig.3(a),(b),(c) and (f)) are not very helpful. As the totals of counts and hours for each point are less than in the last figure, we should expect more scatter in the results, and this is just what we find. The curves at the higher acceleration level in particular are very jagged; they appear to parody rather than copy the curves at the lower level. However, the majority of the pronounced peaks shown at the lower level occur in the spring or in December, and most of the pronounced troughs occur in September or October, or perhaps slightly earlier in the year.

4.2.4 When the data are aggregated for all aircraft and all years, to give the largest samples possible, on the basis that the only significant variable is the calendar month, the curves produced at the two levels have a strong resemblance to each other and to the "shape" that has appeared before, in that there are peaks in the spring and in December, and a trough in the autumn. The spring peak is rather broad, but comes to its highest point in April at the lower level, and as early as February at the higher level, after which it flattens out; the autumn trough is very flat at the lower level, but comes to a sharp lowest point in September at the higher level. On the whole, the evidence does appear to indicate fairly conclusively that there is indeed an annual variation in the frequency of occurrence of gusts, the maximum frequency occurring in the spring, and the minimum in the autumn.

4.2.5 In view of the fact that the "annual shape" for different aircraft summed over all years showed such considerable variation, and yet when the data were summed over all aircraft the result was a fairly definite and convincing curve, some attempts were made to investigate the formal statistical justification for adding data drawn from different aircraft. These were not very successful; in fact, the results would almost indicate that the data for different aircraft were not, statistically, samples drawn from the same population, and therefore should not be summed. It is felt, however, when all the curves are considered, with their different ways of combining the data, that it is not unreasonable to hold to the opinion stated above, that there is an annual variation in the frequency in the occurrence of gust loads which can be detected in spite of the complicating effect of drawing results from different aircraft using different counting instruments, and the difference in weather between one year and another. This point is further discussed in 4.4.2 below.

4.2.6 The aircraft hours flown each month in successive years have been plotted to see if they might have any bearing on the other data. The resulting curve (Fig.5) appears to show no similarity at all to the curves of counts per hour; there would therefore appear to be no correlation between monthly utilisation and turbulence, contrary to the experience related in J. Taylor's paper[1].

It is interesting though to see that this curve possesses almost perfect repetitions of shape from year to year; there is a pronounced summer peak, reaching its highest point in August or September, followed by a steep fall-off in autumn and winter which is interrupted by a slight secondary peak in December and reaches a minimum in February and March. This is as one might expect, the peaks representing summer and Christmas holidays respectively.

It would also appear that variations in the number of aircraft withdrawn for servicing and maintenance have little effect on the pattern of total hours flown (as one would expect in a large fleet) and therefore presumably little effect on the counts per hour calculated from the data.

4.3 T.A.A. Viscounts

4.3.1 The general appearance of the curves derived from readings from the T.A.A. Viscounts shows more consistency between different levels and different aircraft than do the curves from B.E.A. Viscounts. The curves of counts per hour for each aircraft drawn out for all months in successive years* show remarkable similarity between aircraft and repetitiveness from one year to another; the main peak occurs in the early summer, i.e. October to December, and the main trough in the winter, May to July. Other peaks and troughs occur in addition, but this pattern is most marked on nearly all aircraft.

*(Not reproduced here. See R.A.E. Tech. Note Struct. 322).

4.3.2 When the aircraft records are summed (Fig.2(b)), the extended curve over all months and years shows the cyclic pattern in a high degree, as one would expect with so much similarity between aircraft. The curve for the higher acceleration level also agrees at practically all main peaks and troughs, but is slightly more jagged between these points, as one might expect since the curve represents a lower number of counts.

4.3.3 When individual aircraft are summed over all years, in Figs.3(e),(f) and (g), the same thing is seen that practically all aircraft show this pattern, with secondary peaks and troughs superimposed, it is true, but the basic shape is there, at both levels, much more clearly than in the case of the B.E.A. aircraft.

4.3.4 Finally, the annual variation pattern obtained from summing all aircraft over all years shows the same pattern again, a peak in October to December and a trough in May, with a minor peak in July and trough in August. The two acceleration levels show a very similar shape, save that in the broad summer peak the apex is in October at the $\pm 0.25g$ level and in December at the $\pm 0.55g$ level; a larger amount of data might bring even greater similarity.

4.3.5 As one would expect from the greater similarity between the curves for individual aircraft shown by these diagrams, compared with those for the B.E.A. aircraft, the correlation test when applied to the T.A.A. aircraft gave a much more positive reaction.

4.3.6 The results quoted above agree with those given by Bruce and Hooke[2], in showing a peak in summer and a trough in winter, but the months tend to differ; these two investigators have drawn sinusoidal curves to fit their data with the summer peak in December or January, and the winter trough in June or July, i.e. the pattern is about a month later than that shown in this work.

4.3.7 We may note in passing that the Australian Report also points out that four aircraft, VH, VI, VJ, and VL, which are Viscount Type 756, show lower counts per hour than the other aircraft which are Type 720; a similar feature may be noted in Fig.3(a), though not to the same extent as in Bruce and Hooke's work. Aircraft of both series initially carried type 1A instruments, later changed to 1BA (the data on each aircraft being treated as one continuous set) though a larger proportion of the records of series 720 aircraft came from 1A instruments; so there seems to be more behind the difference in readings than a simple change in the type of instrument carried. It is noticeable however that the Type 720 aircraft tend to show a higher rate of counts at 1.3g to counts at 0.7g; in addition, looking at January in successive years as a typical month, the rate of counting drops markedly from 1955 and 56, when 1A instruments were carried, to 1958, and 59, by which time 1BA instruments had been installed; instrument error in the earlier type of instrument cannot therefore be ruled out as a possible cause of this effect. On the other hand, the change in maximum permitted take-off weight quoted by Bruce and Hooke is not sufficient to alter materially the response to gusts of equal strength; nor would a possible change in aerodynamic characteristics account for a change in the counting rate of about 60%. It may be possible to obtain an explanation in a later report discussing results to be gathered under more carefully controlled conditions, which the Australian workers hope to produce.

4.3.8 The curve of aircraft hours per month (Fig.5) does not show nearly such a clear pattern as that from the B.E.A. Viscounts. There is a slight tendency to peak in December and January, which of course are the months of high summer in Australia; but when allowance is made for the build-up of Type 1BA instruments in the fleet, the two years of reasonably full operation, which is all that we have, differ sufficiently to prevent any firm deduction being drawn.

4.3.9 It is not thought that hours flown per aircraft per month would be a more illuminating quantity to portray. When an aircraft is withdrawn for several months for repair or major servicing, it is natural to increase the hours flown by other aircraft if at all possible to maintain the schedules, and so the total hours flown per month will remain fairly constant. Such a curve would therefore probably respond to temporary absence of one or two aircraft more readily than that for total hours flown, and therefore would tend to confuse the issue.

4.4 General remarks

4.4.1 Before discussing the pattern of results just described, and attempting to suggest reasons for the differences, it is as well to consider one or two points which are common to both sets of data. As the aircraft used are essentially the same (though there may be differences in Series or Mark) the operational use should also be similar, such as normal cruise level (of the order of 20,000 ft) climb and descent techniques, and so on. In any case, any individuality in operational or pilot technique would presumably apply throughout the whole year, and therefore should not affect the shape of the annual variation we are looking for, in the sense that a peak would not be transposed to another month, though it might be intensified or somewhat smoothed out. In particular, no Viscounts of the period under review carried Cloud Collision Warning Radar; the extent to which pilots could take action to avoid local convectional disturbances would therefore be limited.

While on the subject of avoiding action, it is pertinent to remark that airspace in Europe is considerably more crowded than in Australia. One would therefore expect greater liberty to be given to the Australian pilots to change route when thought necessary. This should tend to lower the counts per hour recorded in Australia, compared with those recorded in Europe, a point which should be borne in mind when reading paragraph 4.4.4.

4.4.2 An immense amount of data has had to be handled to obtain the curves given in this Note; in spite of this the inconsistencies in the results are such as to suggest much more data arerequired to produce a reasonable whole. In the first place, the results from B.E.A. aircraft when summed over all years and all aircraft look convincing, and appear to show credible trends, particularly when backed by the results of summation over all aircraft for a succession of years, but the curves for individual aircraft look very different and statistical tests on the data show no apparent correlation. The reason for this is very probably that in view of the number of variables affecting the problem data from each aircraft constitute too small a sample to give reasonably low sampling errors, but their sum is approaching the size of sample required.

4.4.3 On the other hand the results from T.A.A. aircraft, amounting to only one fourth as much data, shows a much more consistent picture, and gives more positive evidence when tested statistically for membership of one population. On the face of it, one would tend to wonder if the flying in Europe is more diverse than in Australia, in terms of variation of hop lengths, and of weather at any one time over the geographical area involved. This is difficult to establish.

Reference to route tables suggests that both airlines cover a fair mixture of stage lengths, though it seems that B.E.A. may fly some stages which are shorter than any flown by T.A.A. But there is unlikely to be enough variation in take-off weight due to differences in fuel requirements to affect the final results materially. On the second point, that of weather, there appears to be more reason for similarity of results over a wide area in Australia than in Europe. Most of the T.A.A. flying is along the east and south-east coasts, where in summer there are periods of intense turbulence, whether associated with the thunderstorm activity of Queensland, or with the "Southerly Bursters" of New South Wales or "Brickfielders" of Victoria; this agrees with the high rate of counts per hour shown in the summer. Turbulence at other periods of the year is probably most marked in Victoria. In Europe, on the other hand, the greatest turbulence in the north west is probably in the late autumn to early spring, in central regions during the summer thermal activity or the winter winds (though there may also be long still cold periods in the latter season) and in the Mediterranean area during early autumn and late winter or spring; thus there is no period when there is liable to be strong turbulence over all that part of Europe covered by the routes concerned. This may well explain why individual aircraft, flying at random to different areas, may not be representative of the pattern which is built up when all flights are summed.

It may also be noted that B.E.A. aircraft fly by night as well as by day, but according to Bruce and Hooke[2] T.A.A. aircraft remain on the ground at night; there may therefore be a difference in the incidence of gusts at night also entering into the results. But we can think of two effects of night flying which would tend to cancel each other out. The general tendency is for there to be less convectional activity at night, but it is more difficult for pilots to see and avoid such cumulo-nimbus clouds as are formed. In other words, fewer large gusts should occur at night, but a higher proportion of those that do should be encountered and counted.

4.4.4 An interesting result which emerges from summing all the counts over all aircraft, all months and all years is that the average turbulence encountered by aircraft, if one can speak of such a thing, is greater in Australia than in Europe; the ratio of counts per hour is 1.7 at the 0.25g level, 2.0 at the 0.55g level. A ratio of this size is too large to be explained away as a sampling error arising out of insufficient data. It may be remarked that the ratio of counts per hour is not uniform for corresponding months, but is least for months of minimum turbulence and highest for months of maximum turbulence. This underlines another fact, that in Australia the ratio of maximum to minimum turbulence is higher than in Europe.

4.4.5 To allow for such a wide range of variables, a full investigation necessitates an instrument which provides the maximum amount of information while requiring the minimum of attention from ground crew, as the frequency of reading required would, if not done automatically, be too heavy a burden on air line staffs, detailed particulars of flights must be obtained, which can be readily linked with the record of counts, and the whole mass of data must be amenable to automatic handling and analysis.

5 CONCLUSIONS

5.1 Flight loads

It would appear that there is an annual variation in the vertical acceleration increments on aircraft as recorded by means of the Fatigue Load Meter; this variation follows a roughly similar pattern in successive years. The pattern, as would be expected, varies in different parts of the world. But it has not always been possible to link up load frequencies with local climatic conditions. In Australia, maximum load frequency occurs in the summer, and minimum in the winter, which broadly agrees with expected gust distributions, though there is also a secondary peak and associated trough in late winter and early spring for which no meteorological reason can be seen. In Europe, on the other hand, the maximum and minimum frequencies occur in the spring and autumn respectively, with a secondary winter peak, and there are no obvious climatic reasons for this. The average level of loads on aircraft arising out of turbulence appear to be greater in Australia than in Europe, and the range from minimum to maximum turbulence is also greater. More data, with relevant information to allow the effect of separate routes to be studied, would therefore be welcomed.

6 ACKNOWLEDGEMENTS

Thanks are due to British European Airways, Trans-Australia Airlines and the Australian Department of Supply for their assistance in the collection of records.

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3	-	R.A.E. Fatigue meter Type 1, 2 and 3 R.A.E. Instruction Leaflet No. Structures 201. June 1954.
4	Heath-Smith, J. R.	Atmospheric turbulence encountered by Viscount aircraft over Europe. A.R.C. Current Paper No. 463. July 1959.

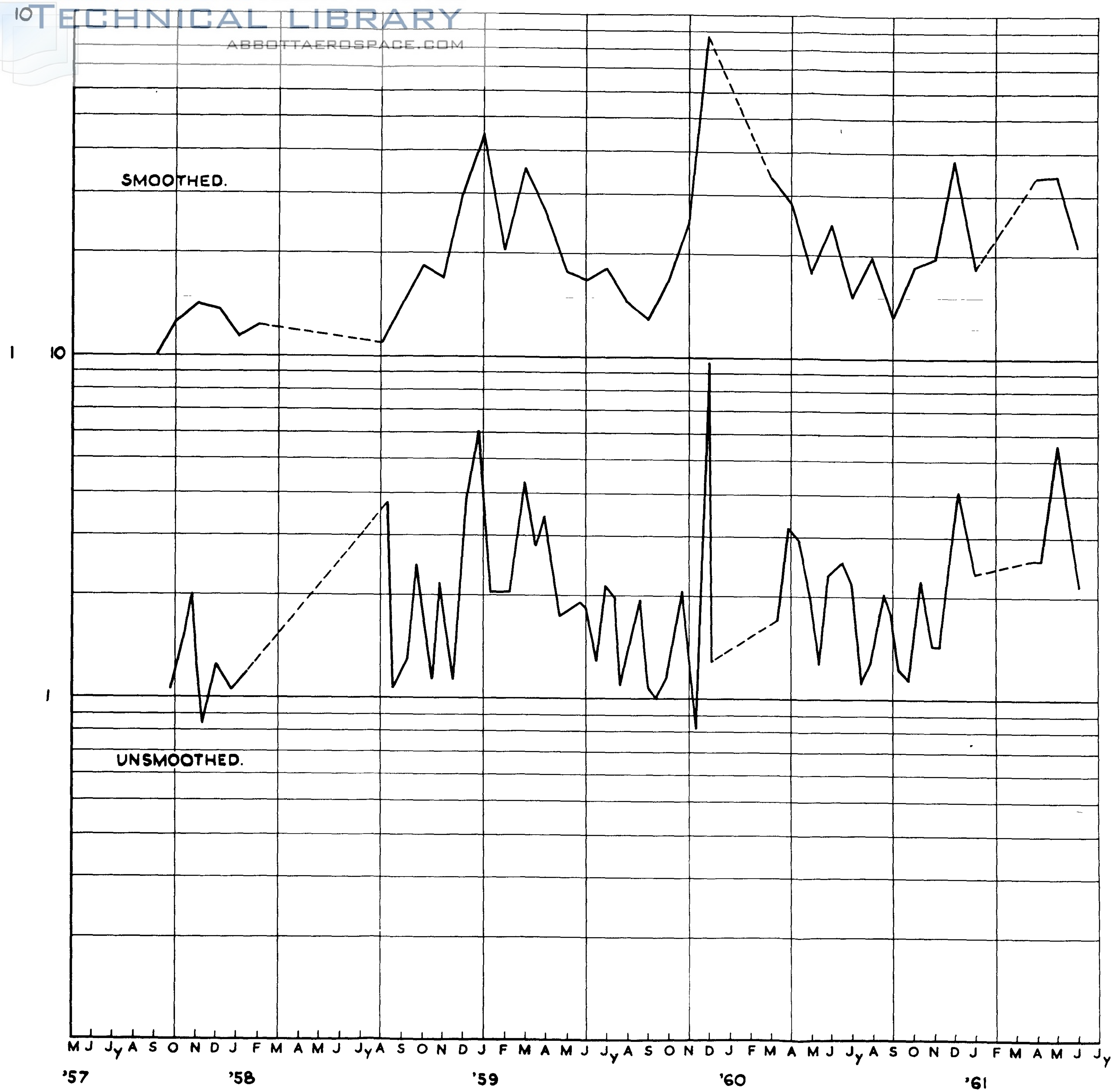

FIG. 1. SMOOTHED AND UNSMOOTHED COUNTS PER HOUR FOR B.E.A. VISCOUNTS G-AMOI AT +0·25g INCREMENT LEVEL.

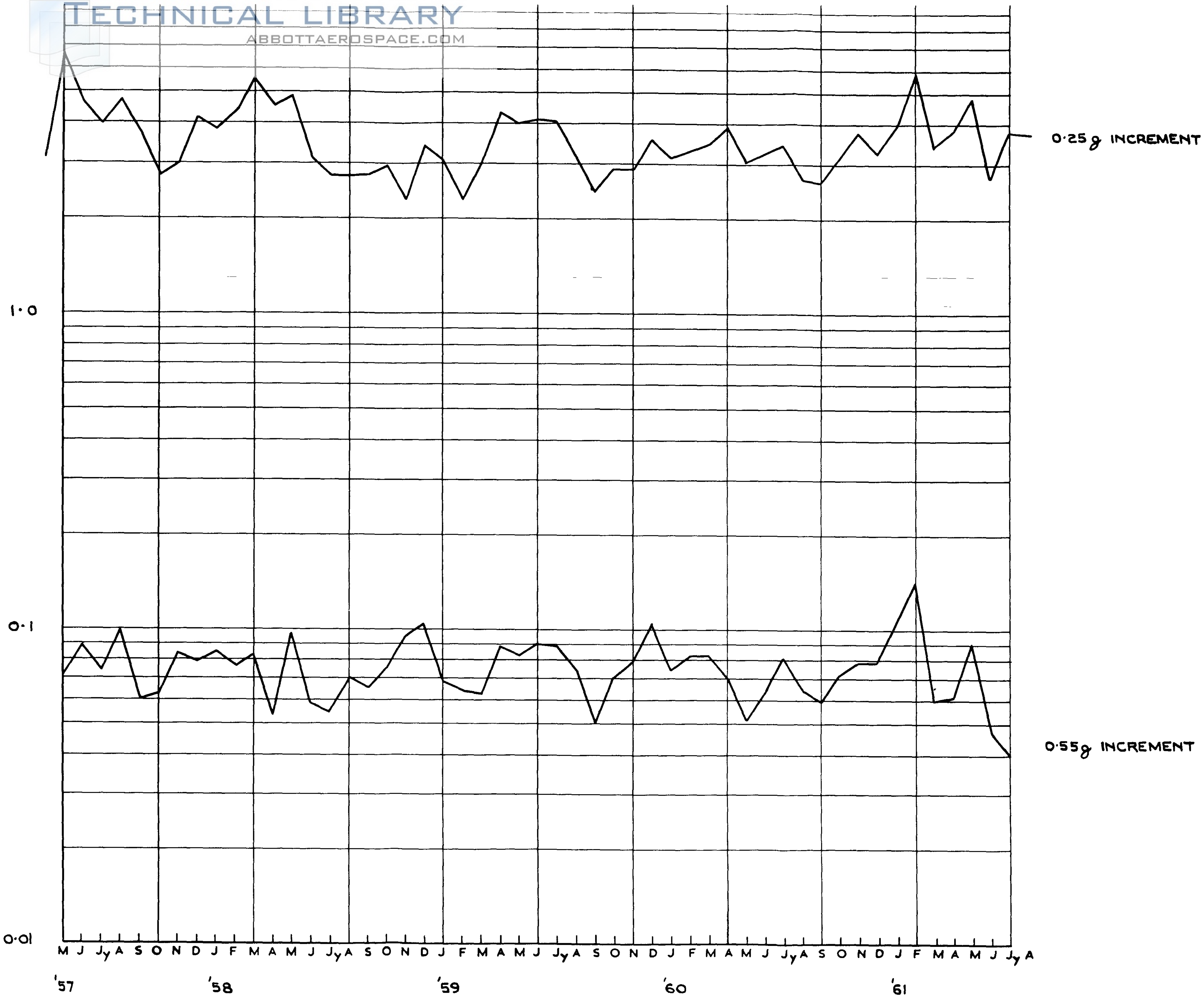

FIG. 2(a) COUNTS PER HOUR SUMMED OVER ALL AIRCRAFT, SUCCESSIVE YEARS, AT 0·25g AND 0·55g INCREMENT LEVELS—B.E.A. VISCOUNTS.

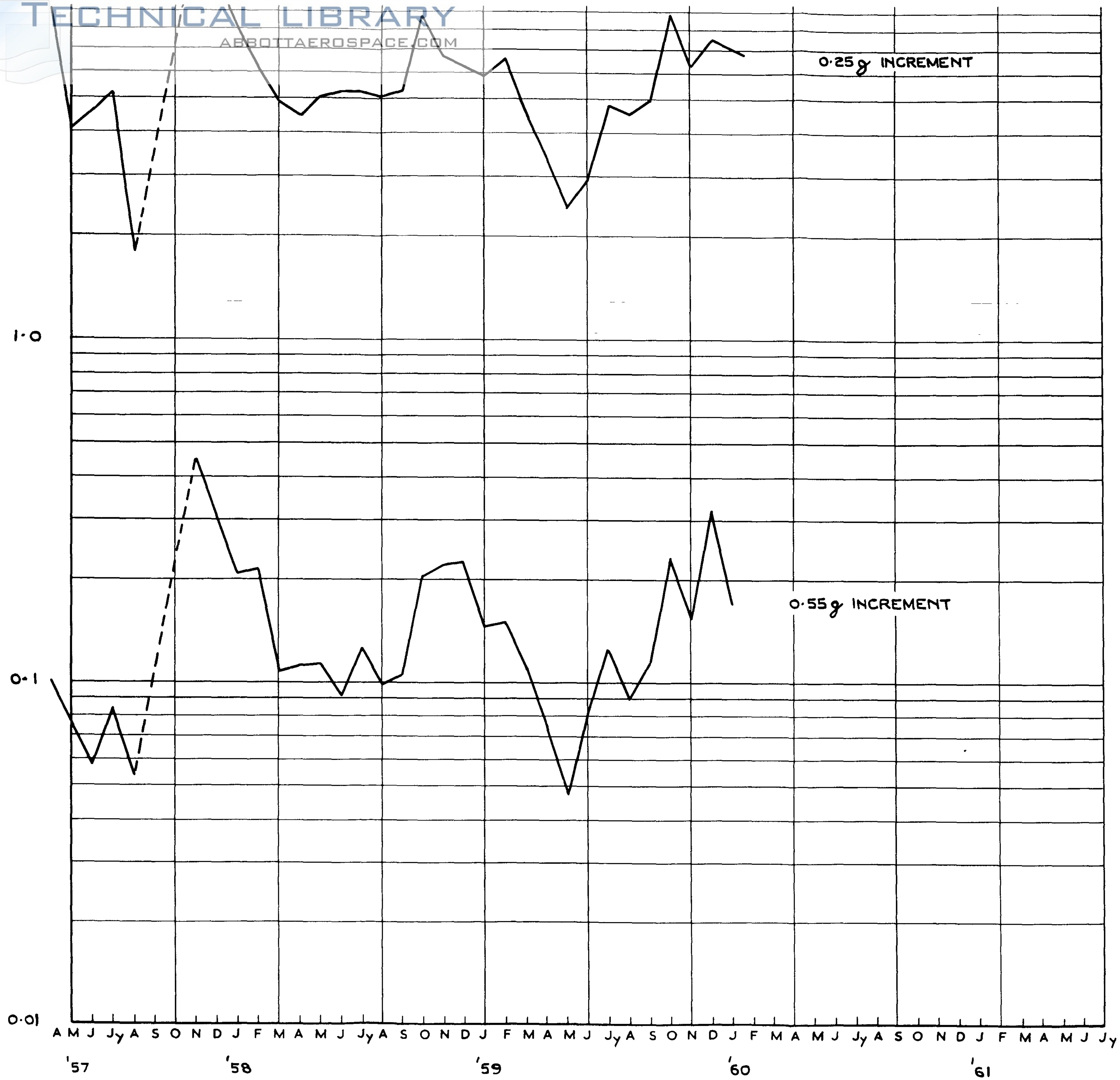

FIG. 2.(b) COUNTS PER HOUR SUMMED OVER ALL AIRCRAFT, SUCCESSIVE YEARS, AT 0·25g AND 0·55g INCREMENT LEVELS – T. A. A. VISCOUNTS.

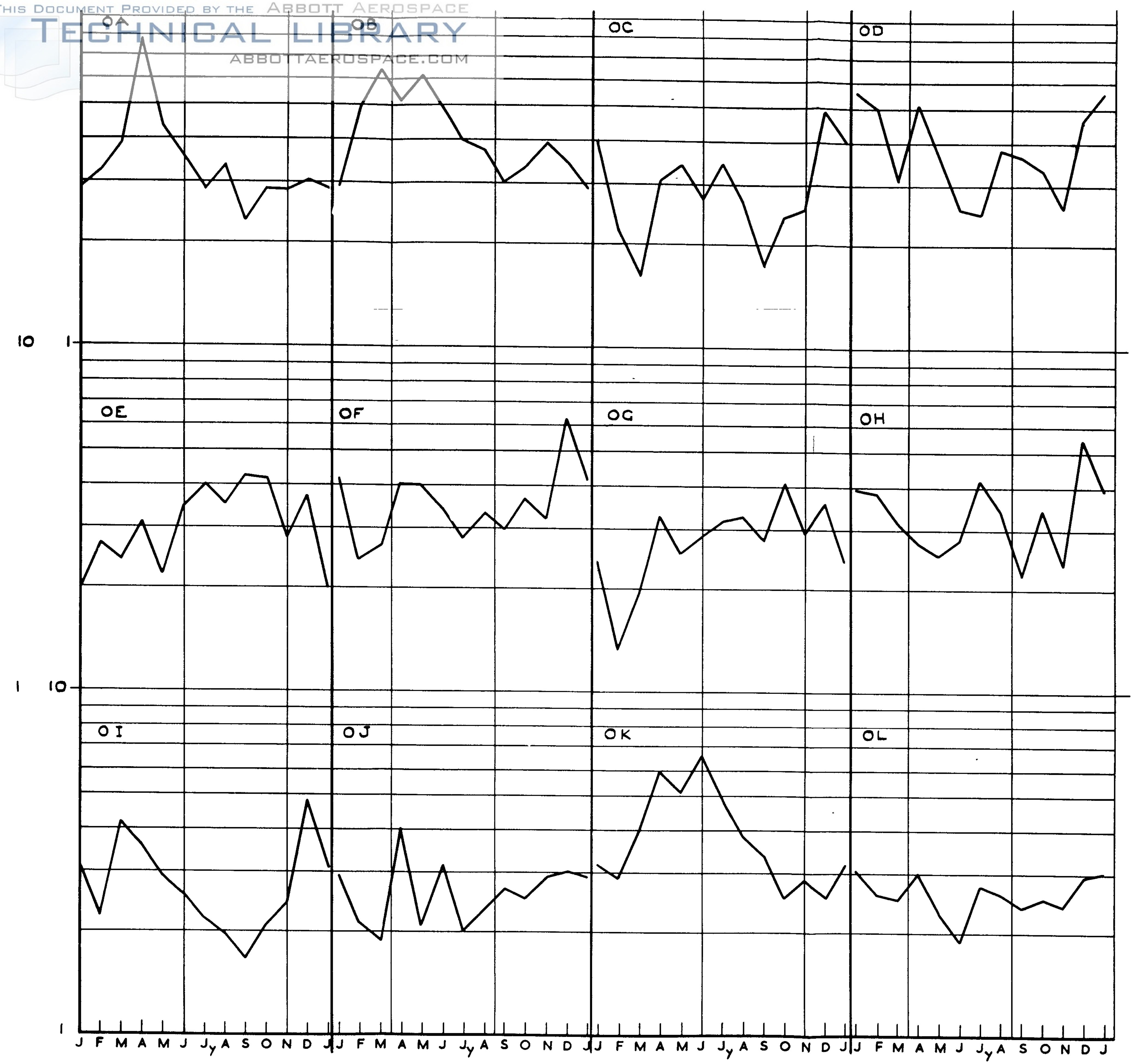

FIG. 3 (a) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·25g INCREMENT LEVEL - B.E.A. VISCOUNTS.

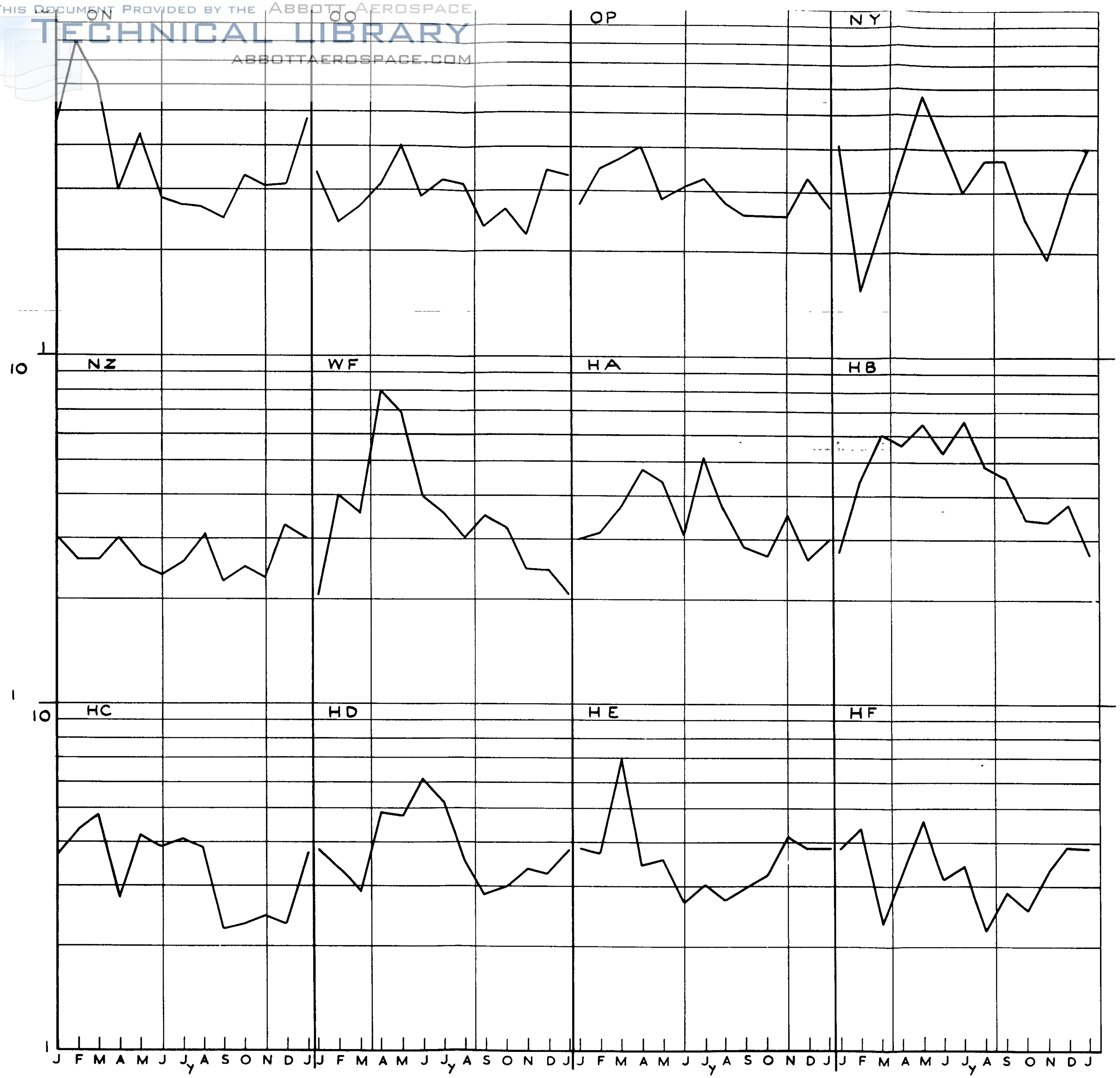

FIG. 3.(b) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·25g INCREMENT LEVEL – B.E.A. VISCOUNTS.

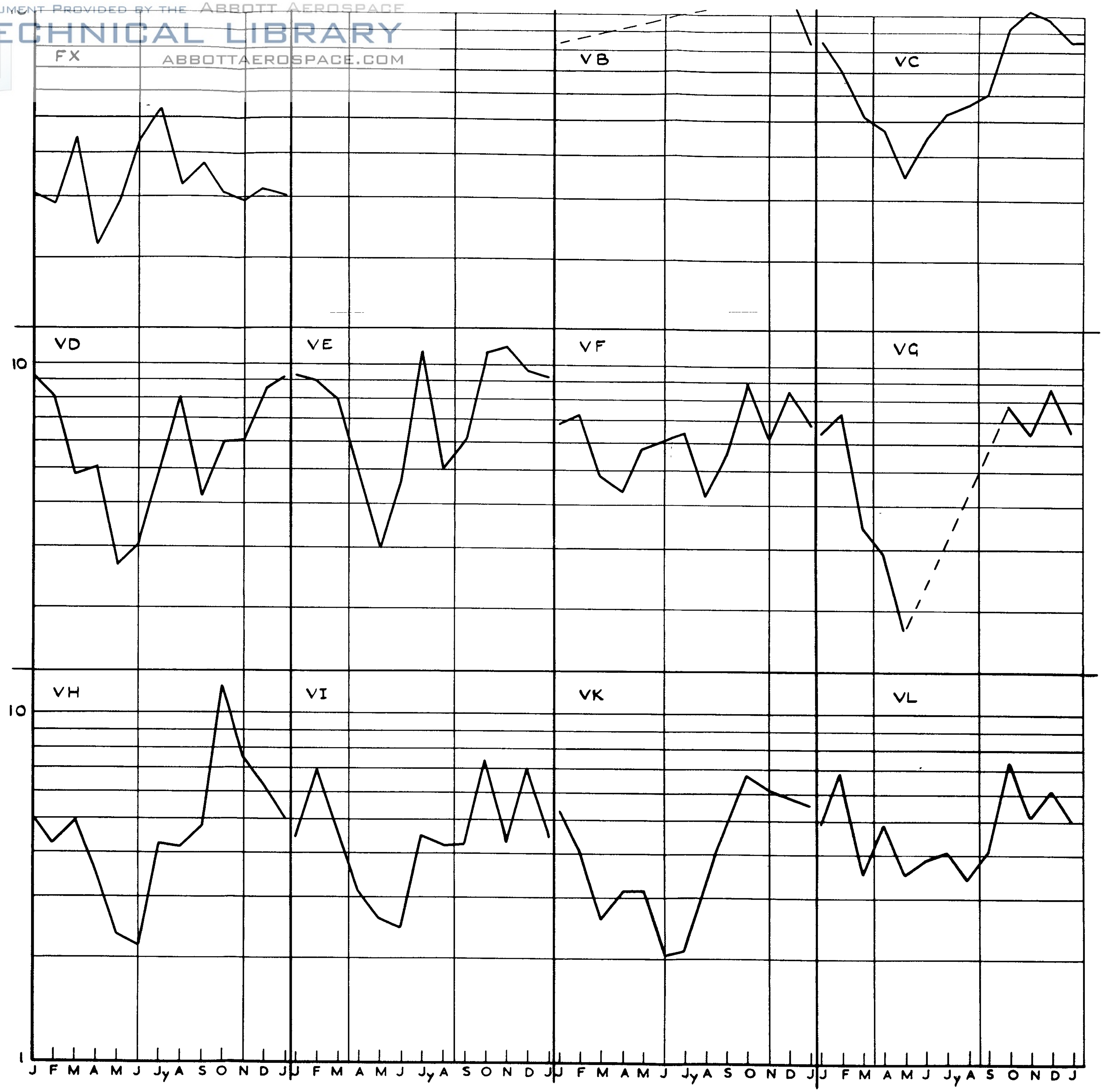

FIG. 3. (c) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·25g INCREMENT LEVEL – B.E.A. AND T.A.A. VISCOUNTS.

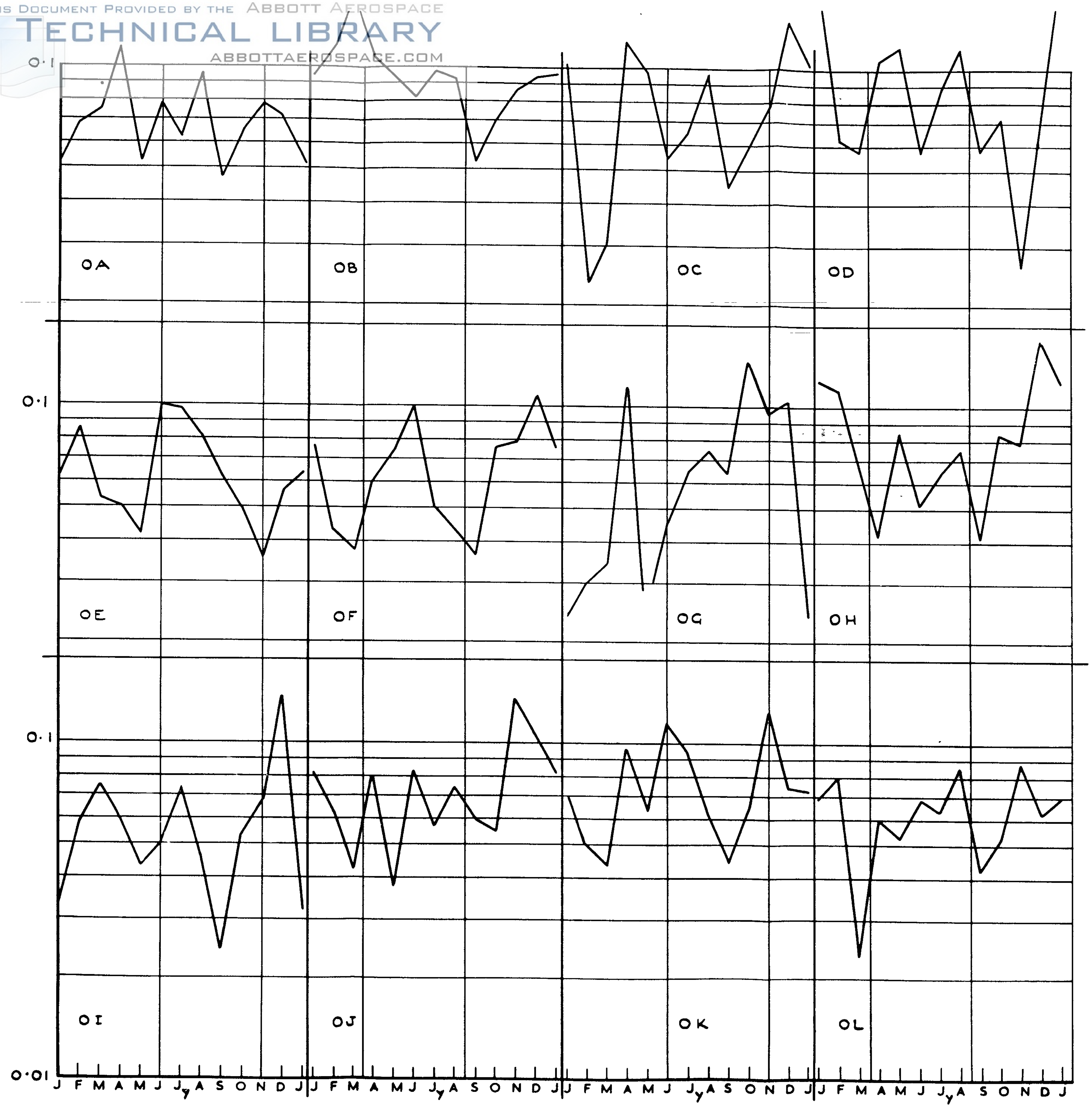

FIG.3.(d) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·55g INCREMENT LEVEL – B.E.A. VISCOUNTS.

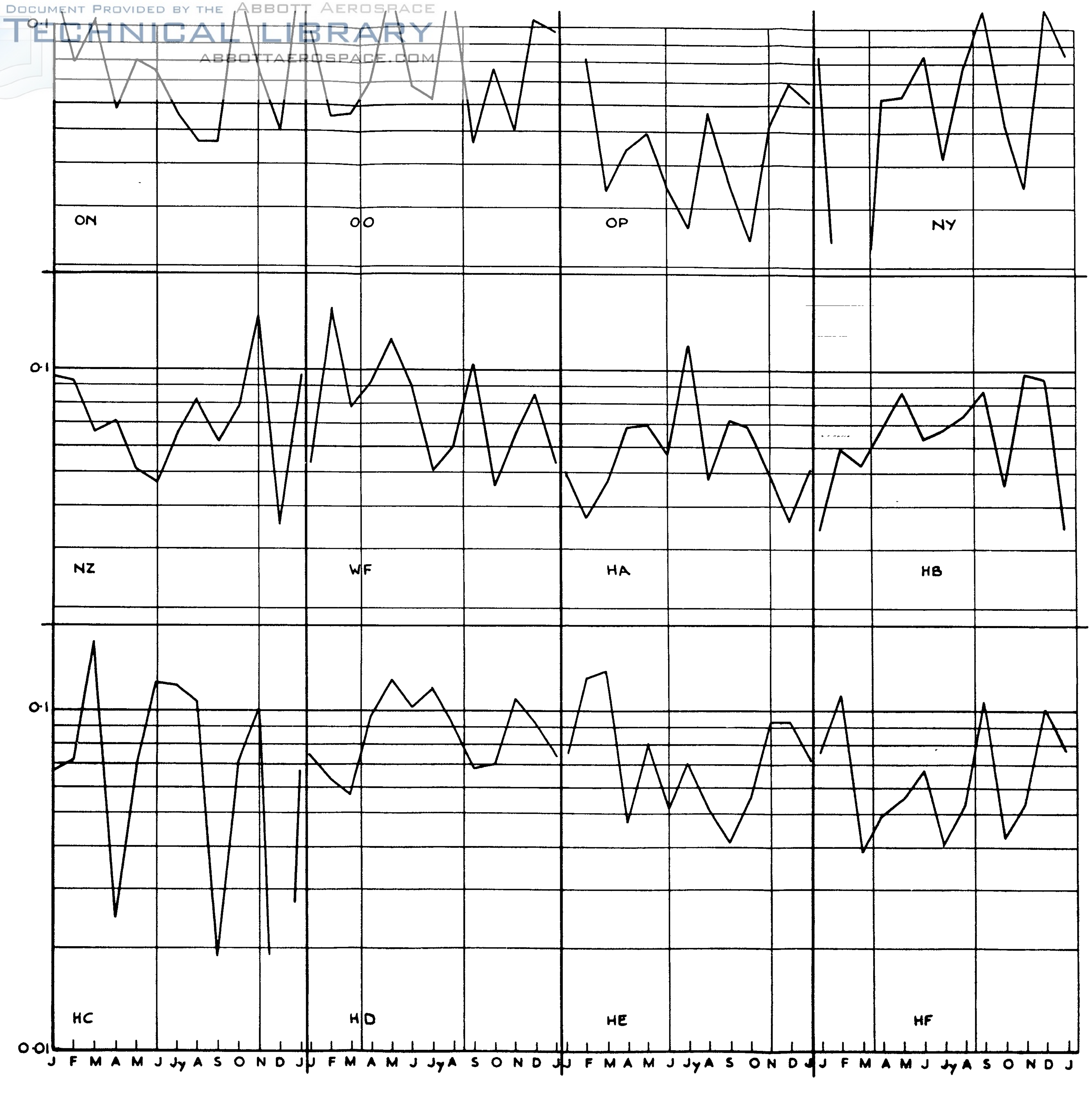

FIG.3 (e) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·55g INCREMENT LEVEL - B.E.A. VISCOUNTS.

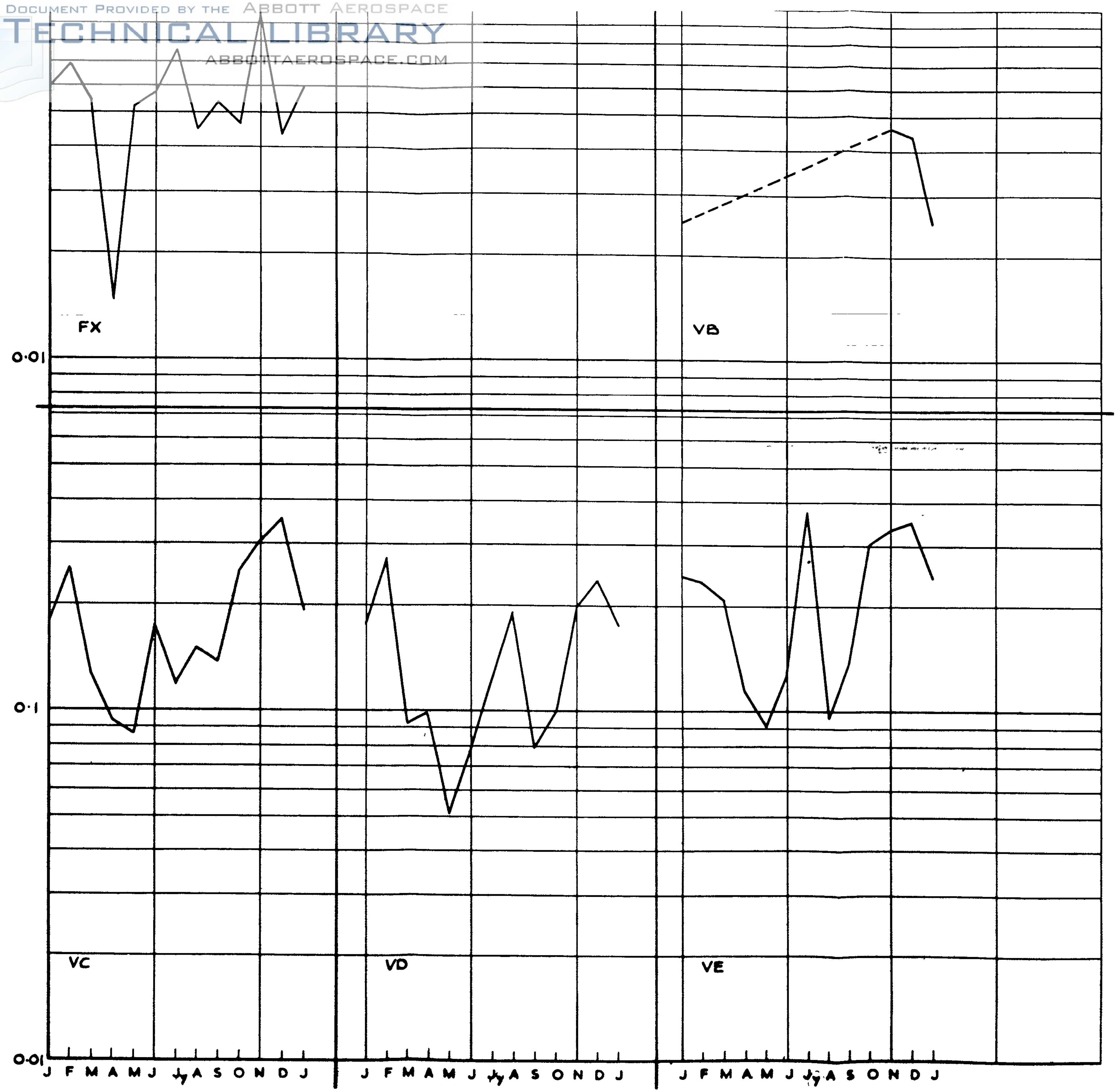

FIG. 3 (f) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·55g INCREMENT LEVELS - B.E.A. AND T.A.A. VISCOUNTS.

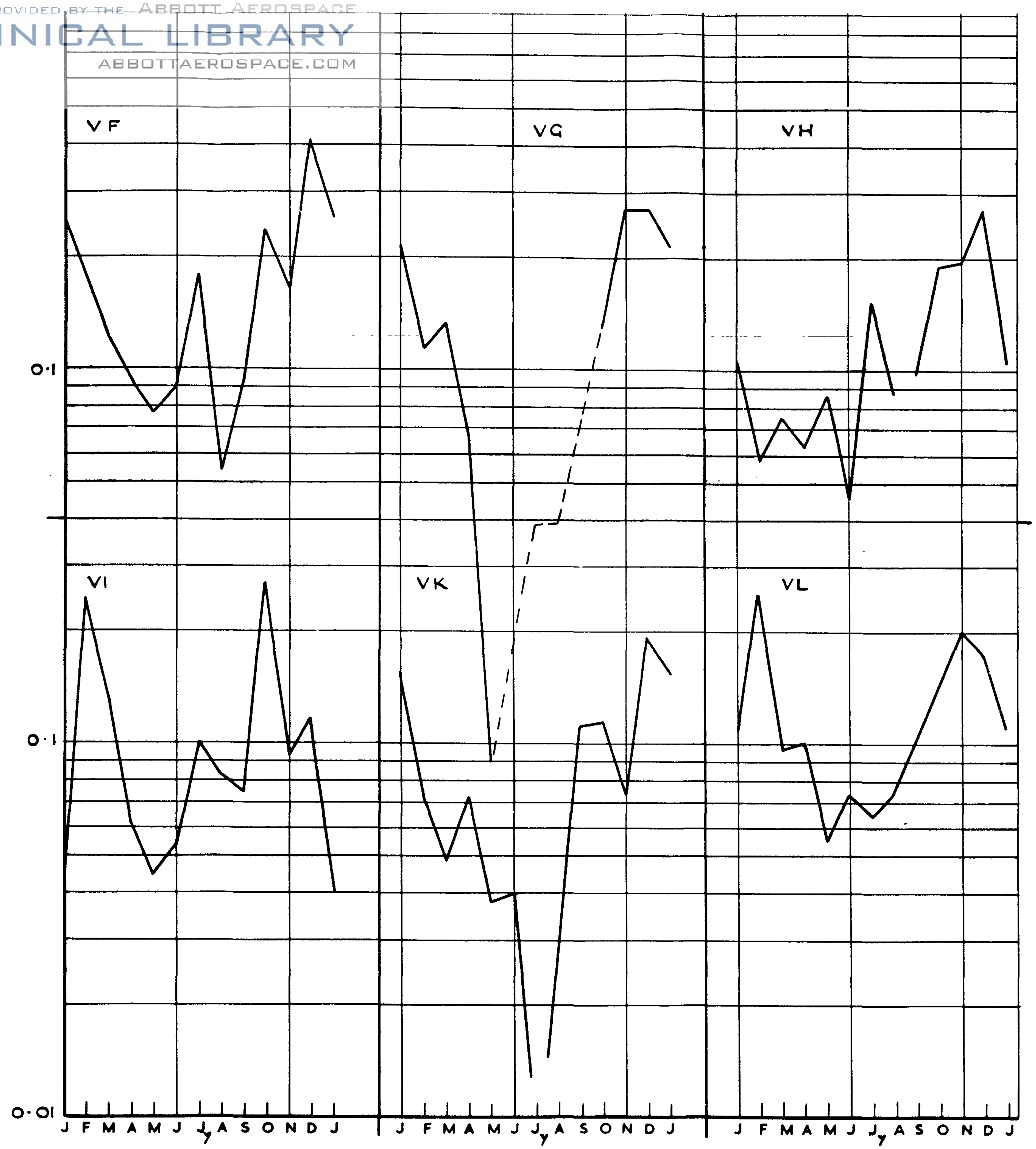

FIG.3.(g) COUNTS PER HOUR FOR INDIVIDUAL AIRCRAFT, SUMMED OVER ALL YEARS, AT 0·55g INCREMENT LEVELS - T.A.A. VISCOUNTS.

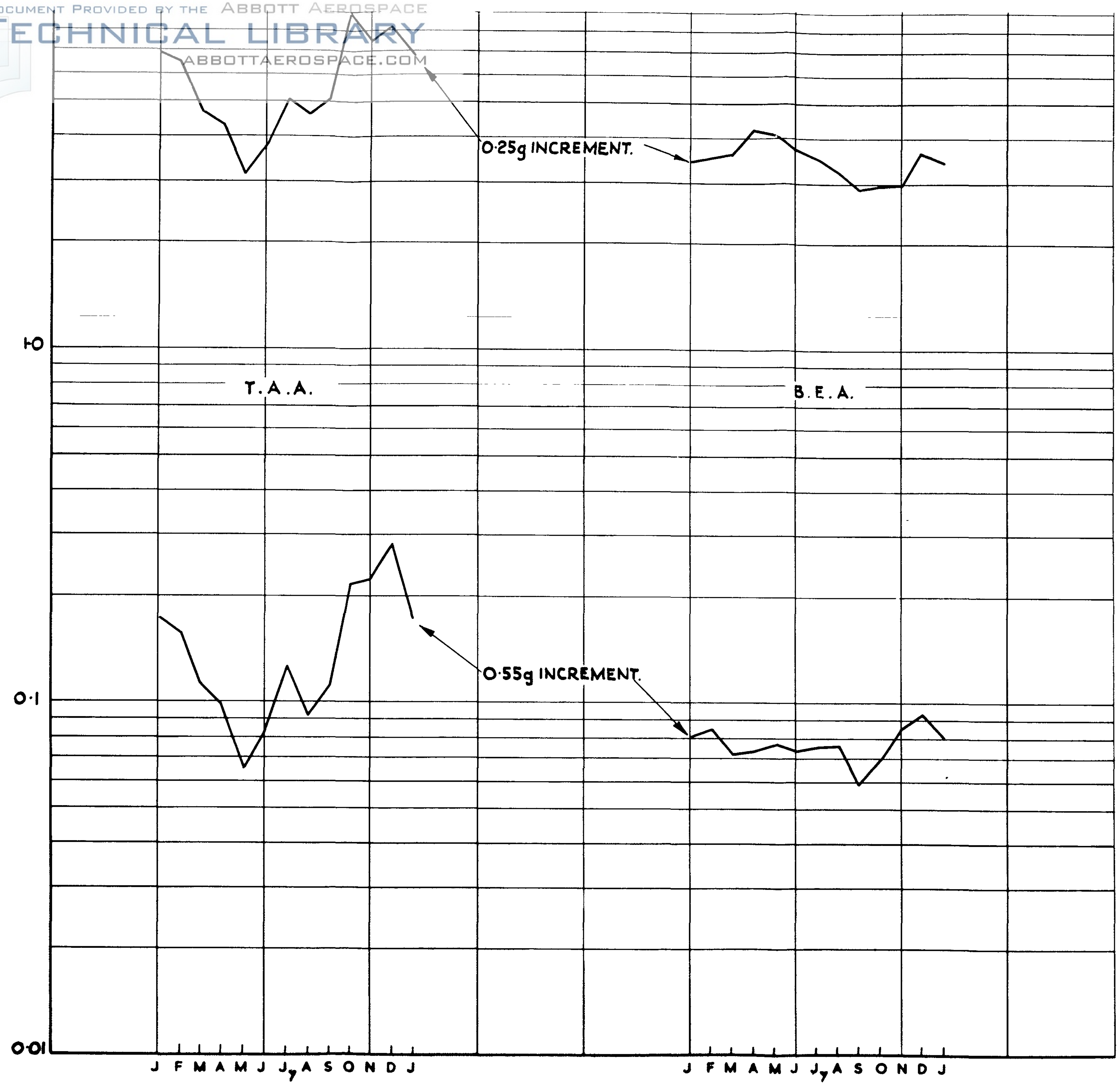

FIG. 4. COUNTS PER HOUR SUMMED OVER ALL AIRCRAFT, ALL YEARS, AT O·25g AND O·55g INCREMENT LEVELS – B.E.A. AND T.A.A. VISCOUNTS.

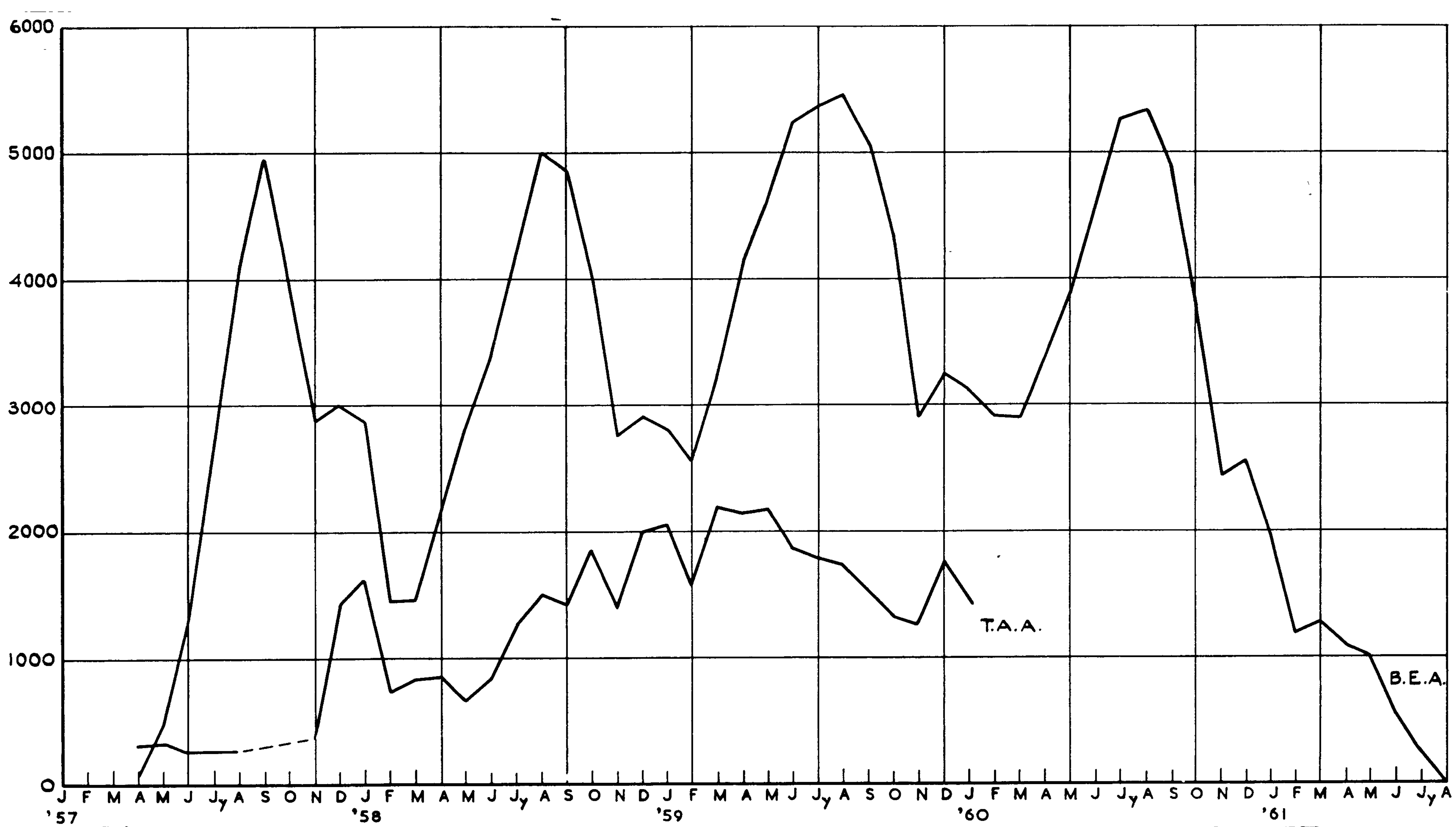

FIG.5. AIRCRAFT HOURS PER MONTH SUMMED OVER ALL AIRCRAFT, SUCCESSIVE YEARS - B.E.A. AND T.A.A. VISCOUNTS.

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S.O. Code No. 23-9013-67