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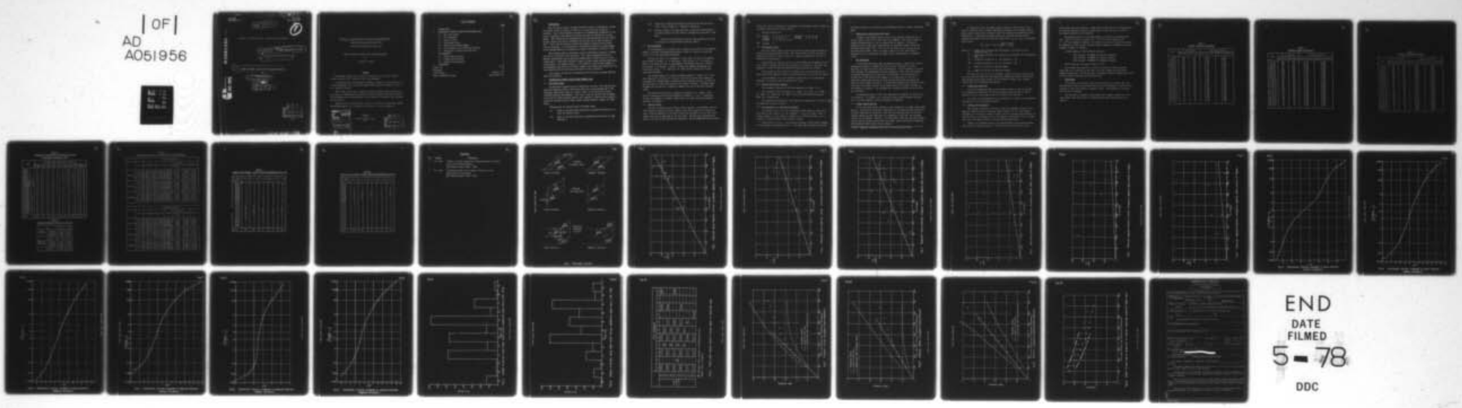

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STUDY OF TRAFFIC PACKING OVER THE NORTH ATLANTIC

by

Rosalind S. Sheil

SUMMARY

This Report updates the work first carried out by P.P. Scott on North Atlantic data for 1967 - data for 1973 is now examined.

Relationships are found between the number of flights in a day and measures of the occupancies of the tracks and flight levels which are adjacent to those of a 'typical' aircraft.

These results are used to construct a flight request pattern required as input data to a simulation model which forecasts the density with which aircraft will be packed into the North Atlantic track system as the traffic flow increases in future years.

Repeated runs of the model with a series of traffic flow rates have enabled the packing density to be expressed as a function of traffic intensity.

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1 INTRODUCTION

Most of the air traffic crossing the North Atlantic is handled by a system of parallel tracks the object of which is to control the risk of mid-air collision. One of the parameters required for a mathematical estimation of this risk is a measure of the density with which aircraft are packed onto a track system. This density may be estimated directly from observations of air traffic control records, and such an estimation was carried out for data obtained in 1967[1]. Since 1967 the system of tracks has slightly altered and the traffic flow has increased. It was desirable to determine the effects of these changes on the packing density by carrying out a similar calculation on data for 1973.

This density based on observation could be extrapolated linearly to higher flow rates to forecast future densities. This linear extrapolation is not, however, satisfactory, and an improved estimate may be found by use of a simulation model[2]. This model requires as input, a flight request pattern which gives a good match to the observed results - the validity of the forecast depends on the assumption that there is no radical change in the design and operation of the track system from that used during the period of data collection.

Only subsonic jet aircraft traversing the North Atlantic between 45°N and 65°N are considered.

2 ESTIMATION OF TRAFFIC DENSITY FROM OBSERVED DATA

2.1 The track system

An aircraft's preferred route is affected by the wind. For both the eastbound and westbound traffic, whose main flows are at early morning and in the afternoon respectively, there is a 'best' track, *ie* one which most closely satisfies aircraft requirements. This 'best' track for the half day is mapped out by the Air Traffic Control Centre, and a system of tracks built up around it. Each track contains several flight levels, making available a number of flight paths.

The paths must be separated from one another thus:-

(i) Paths at the same flight level must be separated laterally by at least 120 nautical miles.

(ii) Paths on the same track must be separated vertically by at least 2000 feet.

(iii) Paths may be separated by 60 miles laterally and 1000 feet vertically. This is known as a 'composite' separation.

(iv) Aircraft flying on the same path must be separated longitudinally by several minutes in their times of passing any given point on the path.

The inter-path separations must be large enough for the risk of collision to be kept within acceptable limits.

2.2 The occupancies

In the estimation of collision risk, a quantity of interest is the expected number of aircraft occupying paths adjacent to that of 'typical' aircraft and close to it in the along-track dimension.

Aircraft are said to be 'proximate' to each other if they are on adjacent paths within a distance Sx of each other. The distance Sx is in practice taken as 120 nautical miles, or approximately the distance flown by a subsonic jet aircraft in 15 minutes. Lateral, vertical and diagonal proximities are illustrated in Fig 1. Sy (STD) and Sz (STD) are the lateral and vertical separation standards.

The average numbers of aircraft occupying segments of length 2Sx of the paths adjacent to the path of a 'typical' aircraft are called the occupancies. For example the average number of same-direction proximate aircraft on laterally adjacent paths is called the same-direction lateral occupancy. 'Average' means averaged over aircraft but occupancy is summed over the two laterally adjacent tracks.

The same-direction lateral occupancy is denoted by Ey (same). Other types of occupancy are similarly denoted with suffices z and d indicating vertical and diagonal (occupancy) respectively, and (opp) indicating opposite-direction (occupancy).

2.3 Source of data

The data is taken from air traffic control records. In accordance with the 1967 exercise, twenty-five traffic samples, each over a period of 24 hours were used. With the exception of two days (no data was available for July 1973) these samples were for the same days as the 1967 study. The days give representative cover to all days of the week and are separated to obtain independent meteorological conditions, with the exception of 25 December and 26 December, both of which are included as they have low density traffic.

The days studied are:

1973	August	1, 7, 9, 13, 25, 31	September	8, 12, 17, 27
	October	2, 7, 12, 22	November	1, 11, 21, 29
	December	1, 11, 16, 21, 25, 26		
1974	January	1.		

2.4 Processing of data

For each 24 hour sample of data the aircraft crossing longitude 20^{o}W are sorted into ascending order of time. This time together with the aircraft's height and latitude are input as data to a computer program which is used to calculate the occupancies.

Each aircraft is taken in turn as it crosses 20^{o}W and the numbers of aircraft within 15 minutes flying time proximate to it laterally, vertically and diagonally in both the same and opposite flying directions are counted.

These counts for each aircraft are summed, and the sums divided by the number of aircraft sampled to give the mean occupancies for each 24 hour period.

For each sample, also, the frequency distribution of the longitudinal separation of aircraft using the same path is found.

2.5 Results from traffic samples

The occupancies observed at 20^{o}W are summarised in Tables 1 to 3.

The estimates of the occupancies Ey (same), Ey (opp), Ez (same), Ez (opp), Ed (same) and Ed (opp) for each 24 hour period are shown in Figs 2 to 7 respectively.

The frequency distribution of the longitudinal separations of aircraft using the same path is given in Table 4.

2.6 The occupancies as distributed variables

It is shown in Ref 1 that the occupancies can be related to the traffic flow rates by the equation $E = AD$ provided D is not too large, where E is the occupancy, D the number of flights in a 24 hour period and A is a constant to be determined by least squares fitting.

Distributions of the E's are formed by applying a 'Monte Carlo' program to this equation as described in Ref 1. The resulting distribution functions are shown in Figs 8 to 13 plotted in non-dimensional form on 'normal' probability paper.

2.7 Comparison of results with 1967 data*

In Table 5 the average lateral, vertical and diagonal occupancies for a traffic sample of 300 in a 24 hour period are compared. This shows a shift to diagonal proximity which is not as large as may be expected. This may be explained by the flight level distributions for westbound traffic during the peak westbound period (1200 - 1900) and for eastbound traffic during the peak eastbound period (0300 - 0900) as shown in Figs 14 and 15, which shows a preference for the traditional odd flight levels, particularly for westbound traffic.

3 THE SIMULATION

It was stated previously that the densities based on observation could be extrapolated linearly to higher flow rates to give a forecast of future densities, but that this would not be satisfactory. This is because as the flow rate increases the extrapolation becomes pessimistic, since with the existence of minimum separations of 15 minutes it is impossible to pack more than two aircraft onto a 240 nautical mile segment of a flight path, so there is a theoretical upper bound of four for each lateral and vertical occupancy and eight for each diagonal occupancy. To attain these bounds every available 'slot' into which an aircraft could be fitted would have to be utilised, and this is not possible in practice. The occupancy must therefore flatten out as the flow rate increases.

The simulation model of Ref 2 was constructed to resemble the system as it is in practice. To bring it up to date with recent events the model was modified to include composite tracks and diagonal occupancies.

3.1 Flight request pattern

One of the items of data required by the simulation is a flight path request pattern. This pattern should give a good match to the observed mean occupancies. The main limitation of the model is that only the westbound half of the North Atlantic system has been simulated; the assumption is made that the eastbound traffic flow is similar. However, it is shown above, that more eastbound flights use the new even flight levels; hence the flight request patterns for eastbound and westbound traffic should differ slightly.

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* Note: 'Composite' separation (section 2.1) was not used in 1967.

To demonstrate this, the flight request pattern as shown in Fig 16 was input to the model with a minimum longitudinal separation of 22 minutes and the hourly arrival patterns as in Tables 7 and 8 for westbound and eastbound traffic respectively. A comparison was made between the resulting outputs and the observed occupancies, the test being the rejection of H_0 $(\mu_1 = \mu_2)$ at 5% significance level

$$|\bar{m}_1 - \bar{m}_2| > 1.96 \times [2 \sqrt{S_1^2/n_1 + S_2^2/n_2}]$$

where $\bar{m}_1$ = sample mean occupancy from observations, an estimate of the population mean μ_1

$\bar{m}_2$ = sample mean occupancy from simulation, an estimate of the population mean μ_2

S_1^2 = estimated variance of m_1 (an estimate of σ_1^2)

S_2^2 = estimated variance of m_2 (an estimate of σ_2^2)

n_1 = number of aircraft in observed sample

n_2 = number of aircraft in simulation sample.

The results of the test on the occupancy results is shown in Table 6, and it can be seen that there are some significant differences between the observed and simulated results particularly for the westbound traffic flow. However, overall the fit is considered satisfactory.

3.2 Flight path preference

One of the assumptions made by the simulation model is that in the event of the requested flight path not being available, then the order of search relative to it for an available path is the same for all aircraft.

The order of path preference used is estimated on a basis of cost penalties incurred by use of an alternative track.

3.3 Results from simulation

The average occupancies (vertical, lateral and diagonal) forecast by the model for same directional flight are shown in Figs 17 to 19. The standard deviation of the average occupancies cannot easily be obtained from the model as the main source of uncertainty is in the validity of the model itself for higher flow rates than those at which it was matched with observation.

However, the standard errors of the coefficients of the functions giving the linear fits shown in Figs 2 to 7 were derived from the scatter of the observations about the functions. Using these standard errors, and assuming that the required standard deviation is proportional to the flow rate, a value for the standard deviation can be deduced.

The standard errors of the coefficients of the linear relationships are 2.45×10^{-4} for vertical occupancy, 3.2×10^{-4} for lateral occupancy and 3.1×10^{-4} for diagonal occupancy. The standard error of mean vertical occupancy is 0.000245D (at flow rate D), of mean lateral occupancy is 0.00032D and of mean diagonal occupancy is 0.00031D.

A rough estimate of 95% confidence limits is:

'best estimate' ±0.00049D for vertical occupancy
'best estimate' ±0.00064D for lateral occupancy
'best estimate' ±0.00062D for diagonal occupancy.

These limits are also shown in Figs 17 to 19.

Fig 20 shows the proportion of aircraft allocated to their preferred flight path, as a function of flow rate, for track systems with and without composite separation. Fig 20 shows that introducing composite separations results in more aircraft receiving their preferred path.

4 CONCLUSIONS

The forecast of the density with which aircraft will be packed onto the North Atlantic track system at high flow rates has been updated to cater for the inclusion in the track system of composite tracks. The estimates of collision risk can also be updated.

The inclusion of composite tracks means that a greater proportion of aircraft obtain their first choice of flight path and thus operating costs are reduced.

Table 1

OBSERVED VERTICAL OCCUPANCIES

Date	No. of aircraft		Vertical occupancy	
	Westbound	Eastbound	Same direction	Opposite direction
1.8.73	196	202	0.869	0.020
7.8.73	186	212	0.955	0.000
9.8.73	181	197	0.783	0.011
13.8.73	211	206	0.782	0.024
25.8.73	194	186	0.789	0.005
31.8.73	198	223	0.746	0.005
8.9.73	186	183	0.721	0.005
12.9.73	182	161	0.676	0.017
17.9.73	177	179	0.888	0.006
27.9.73	157	178	0.681	0.012
2.10.73	162	204	0.743	0.027
7.10.73	167	176	0.764	0.000
12.10.73	173	178	0.650	0.023
22.10.73	143	149	0.644	0.000
1.11.73	158	139	0.492	0.067
11.11.73	107	138	0.571	0.000
21.11.73	110	93	0.512	0.030
29.11.73	103	102	0.459	0.049
1.12.73	111	99	0.390	0.076
11.12.73	84	112	0.500	0.010
16.12.73	98	109	0.522	0.019
21.12.73	118	117	0.383	0.094
25.12.73	41	51	0.196	0.000
26.12.73	71	48	0.303	0.000
1.1.74	90	72	0.457	0.012

Table 2

OBSERVED LATERAL OCCUPANCIES

Date	No. of aircraft		Lateral occupancy	
	Westbound	Eastbound	Same direction	Opposite direction
1.8.73	196	202	0.472	0.000
7.8.73	186	212	0.628	0.000
9.8.73	181	197	0.556	0.000
13.8.73	211	206	0.499	0.000
25.8.73	194	186	0.663	0.000
31.8.73	198	223	0.608	0.000
8.9.73	186	183	0.363	0.000
12.9.73	182	161	0.449	0.000
17.9.73	177	179	0.775	0.000
27.9.73	157	178	0.424	0.000
2.10.73	162	204	0.262	0.005
7.10.73	167	176	0.350	0.012
12.10.73	173	178	0.239	0.000
22.10.73	143	149	0.274	0.000
1.11.73	158	139	0.276	0.007
11.11.73	107	138	0.310	0.000
21.11.73	110	93	0.315	0.000
29.11.73	103	102	0.078	0.010
1.12.73	111	99	0.238	0.000
11.12.73	84	112	0.204	0.000
16.12.73	98	109	0.242	0.000
21.12.73	118	117	0.340	0.000
25.12.73	41	51	0.217	0.000
26.12.73	71	48	0.168	0.017
1.1.74	90	72	0.235	0.000

Table 3

OBSERVED DIAGONAL OCCUPANCIES

Date	No. of aircraft		Diagonal occupancy	
	Westbound	Eastbound	Same direction	Opposite direction
1.8.73	196	202	0.523	0.000
7.8.73	186	212	0.618	0.005
9.8.73	181	197	1.005	0.000
13.8.73	211	206	0.628	0.000
25.8.73	194	186	0.526	0.000
31.8.73	198	223	0.865	0.000
8.9.73	186	183	0.764	0.060
12.9.73	182	161	0.338	0.035
17.9.73	177	179	0.534	0.000
27.9.73	157	178	0.310	0.000
2.10.73	162	204	0.514	0.093
7.10.73	167	176	0.513	0.000
12.10.73	173	178	0.359	0.000
22.10.73	143	149	0.418	0.000
1.11.73	158	139	0.741	0.000
11.11.73	107	138	0.588	0.000
21.11.73	110	93	0.177	0.010
29.11.73	103	102	0.371	0.029
1.12.73	111	99	0.390	0.010
11.12.73	84	112	0.541	0.000
16.12.73	98	109	0.493	0.000
21.12.73	118	117	0.238	0.009
25.12.73	41	51	0.130	0.000
26.12.73	71	48	0.050	0.017
1.1.74	90	72	0.444	0.000

Table 4

INCIDENCE OF LONGITUDINAL SEPARATIONS FOR PAIRS
OF WESTBOUND AIRCRAFT AT 20°W

Date	Reported time separation in minutes									
	0-9	10-11	12-13	14-15	16-17	18-19	20-24	25-29	30-39	40-60
August 1	0	0	0	4	7	9	19	6	26	29
August 7	1	0	0	3	4	11	14	17	21	26
August 9	0	1	0	2	2	2	16	9	21	35
August 13	2	0	1	1	3	9	16	16	32	32
August 25	0	1	0	4	6	6	17	22	25	30
August 31	2	0	1	2	4	13	12	17	22	29
September 8	0	0	1	1	4	4	13	10	15	31
September 12	1	0	0	2	2	3	10	9	13	33
September 17	0	0	0	0	8	9	19	18	16	30
September 27	1	0	0	0	4	1	17	14	14	22
October 2	3	0	0	3	4	6	9	7	18	23
October 7	0	0	0	3	6	3	9	7	23	18
October 12	0	0	0	1	2	6	8	14	17	27
October 22	0	0	0	1	2	4	8	12	12	22
November 1	0	2	0	3	7	2	12	7	11	15
November 11	2	0	0	2	3	3	4	3	7	16
November 21	0	2	0	0	2	2	5	2	6	11
November 29	1	0	0	1	1	3	2	5	2	9
December 1	0	1	0	0	1	3	5	6	4	13
December 11	0	0	0	2	1	1	8	3	6	7
December 16	1	0	0	3	3	4	6	5	9	13
December 21	0	0	1	1	1	1	6	10	10	13
December 25	0	0	0	0	1	0	3	0	2	2
December 26	0	0	1	0	2	0	1	3	5	10
January 1	0	1	0	0	1	0	6	6	6	15
Total	14	8	5	39	81	105	245	228	343	511

Table 5

AVERAGE PROXIMITIES FOR 300 A/C PER DAY

		1967	1973
Same direction	lateral vertical diagonal	0.650 0.785 0.000	0.378 0.625 0.490
	Total	1.435	1.493
Opposite direction	lateral vertical diagonal	0.011 0.021 0.000	0.0017 0.0175 0.0110
	Total	0.032	0.0302

Table 6

COMPARISON OF OBSERVED AND SIMULATION-DERIVED OCCUPANCY

		Westbound aircraft						
	Date	$\bar{m}_1$(obs)	$\bar{m}_2$(sim)	var($\bar{m}_1$)	var($\bar{m}_2$)	5% critical value for $\|\bar{m}_1-\bar{m}_2\|$	$\|m_1-m_2\|$	Decision
	1.8.73	0.8878	0.6375	0.008161	0.000014	0.1772	0.2503	reject
	1.11.73	0.4684	0.5692	0.005181	0.000016	0.1413	0.1008	accept
Vertical	1.12.73	0.3784	0.4507	0.006177	0.000018	0.1543	0.0713	accept
	25.12.73	0.0000	0.2814	0.000000	0.000031	0.0109	0.2814	reject
	1.1.74	0.4444	0.4867	0.011632	0.000024	0.2116	0.0423	accept
	1.8.73	0.5510	0.4091	0.005323	0.000001	0.1431	0.1419	accept
	1.11.73	0.2152	0.3646	0.002431	0.000010	0.0968	0.1494	reject
Lateral	1.12.73	0.2162	0.2813	0.004124	0.000011	0.1260	0.0651	accept
	25.12.73	0.1951	0.1628	0.008590	0.000018	0.1818	0.0323	accept
	1.1.74	0.2667	0.3032	0.005136	0.000015	0.1407	0.0365	accept
	1.8.73	0.2857	0.5829	0.003957	0.000017	0.1236	0.2972	reject
	1.11.73	0.7848	0.5084	0.013086	0.000019	0.2244	0.2764	reject
Diagonal	1.12.73	0.1982	0.3292	0.003217	0.000017	0.1146	0.1310	reject
	25.12.73	0.0000	0.1589	0.000000	0.000021	0.0090	0.1589	reject
	1.1.74	0.4000	0.3643	0.009086	0.000023	0.1871	0.0357	accept

		Eastbound aircraft						
	Date	$\bar{m}_1$(obs)	$\bar{m}_2$(sim)	var($\bar{m}_1$)	var($\bar{m}_2$)	5% critical value for $\|\bar{m}_1-\bar{m}_2\|$	$\|\bar{m}_1-\bar{m}_2\|$	Decision
	1.8.73	0.8515	0.6735	0.007782	0.000014	0.1731	0.1780	reject
	1.11.73	0.5180	0.5745	0.008421	0.000018	0.1801	0.0565	accept
Vertical	1.12.73	0.4040	0.4014	0.007330	0.000018	0.1680	0.0026	accept
	25.12.73	0.3529	0.3372	0.011398	0.000029	0.2095	0.0157	accept
	1.1.74	0.4722	0.3882	0.013107	0.000024	0.2246	0.0840	accept
	1.8.73	0.3960	0.4362	0.003537	0.000009	0.1167	0.0402	accept
	1.11.73	0.3453	0.3636	0.004525	0.000011	0.1320	0.0183	accept
Lateral	1.12.73	0.2626	0.2480	0.004609	0.000011	0.1332	0.0146	accept
	25.12.73	0.2353	0.2025	0.008142	0.000018	0.1771	0.0328	accept
	1.1.74	0.1944	0.2371	0.004876	0.000015	0.1371	0.0427	accept
	1.8.73	0.7525	0.6824	0.009353	0.000019	0.1897	0.0701	accept
	1.11.73	0.6906	0.5035	0.013131	0.000021	0.2248	0.1871	accept
Diagonal	1.12.73	0.6061	0.2716	0.015880	0.000015	0.2471	0.3345	reject
	25.12.73	0.2353	0.2056	0.008142	0.000022	0.1771	0.0297	accept
	1.1.74	0.5000	0.2549	0.016590	0.000020	0.2526	0.2451	accept

Table 7

DIURNAL FLOW PATTERN - HOURLY COUNTS OF WESTBOUND A/C AT 20°W

Date / Hour	1.8.73	1.11.73	1.12.73	25.12.73	1.1.74
00-01	2	0	1	0	0
01-02	1	3	1	0	0
02-03	3	2	0	2	0
03-04	2	2	1	0	0
04-05	1	4	1	2	1
05-06	1	1	2	0	0
06-07	0	0	2	1	0
07-08	2	1	0	0	1
08-09	3	0	0	0	0
09-10	2	1	2	0	0
10-11	2	3	1	1	0
11-12	9	4	5	0	1
12-13	13	10	7	1	3
13-14	23	17	9	7	17
14-15	33	26	16	10	18
15-16	21	28	21	5	17
16-17	18	15	9	8	3
17-18	21	13	13	1	10
18-19	13	7	7	0	5
19-20	8	5	5	1	3
20-21	11	8	3	0	4
21-22	1	4	0	2	3
22-23	3	3	1	0	1
23-24	3	1	4	0	2
Total	196	158	111	41	89

Table 8

DIURNAL FLOW PATTERN - HOURLY COUNTS OF EASTBOUND A/C AT 20°W

Hour \ Date	1.8.73	1.11.73	1.12.73	25.12.73	1.1.74
00-01	1	1	0	1	1
01-02	1	1	1	1	1
02-03	7	1	2	0	0
03-04	23	4	7	1	6
04-05	25	16	12	9	11
05-06	32	23	13	8	15
06-07	33	22	16	11	10
07-08	20	24	13	9	11
08-09	5	13	7	5	4
09-10	11	7	2	0	1
10-11	6	1	0	2	2
11-12	6	3	4	1	1
12-13	6	0	1	0	2
13-14	1	4	3	0	0
14-15	3	2	0	1	0
15-16	3	3	1	0	1
16-17	4	0	2	0	0
17-18	1	2	2	0	0
18-19	4	0	1	0	1
19-20	3	5	4	0	3
20-21	3	3	4	0	0
21-22	3	3	1	1	1
22-23	1	0	0	0	0
23-24	0	1	3	1	1
Total	202	139	99	51	72

REFERENCES

No.	Author	Title, etc
1	P.P. Scott	Studies of traffic packing for estimating mid-air collision risks over the North Atlantic RAE Technical Report 68097 (1968)
2	P.P. Scott	A simulation model of air traffic allocation to the North Atlantic track system RAE Technical Report 73180 (1974)

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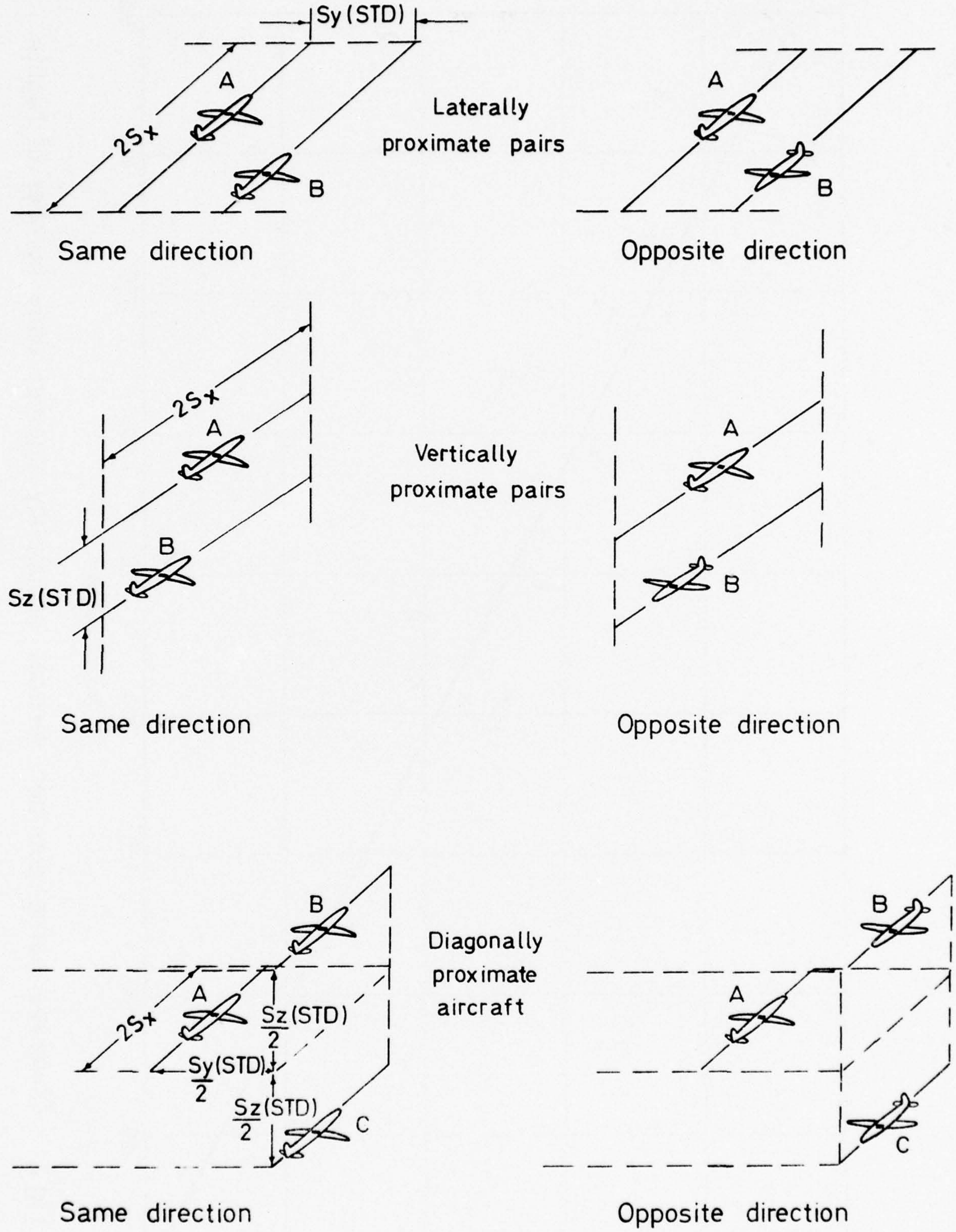

Fig 1 Proximate aircraft

Fig.2

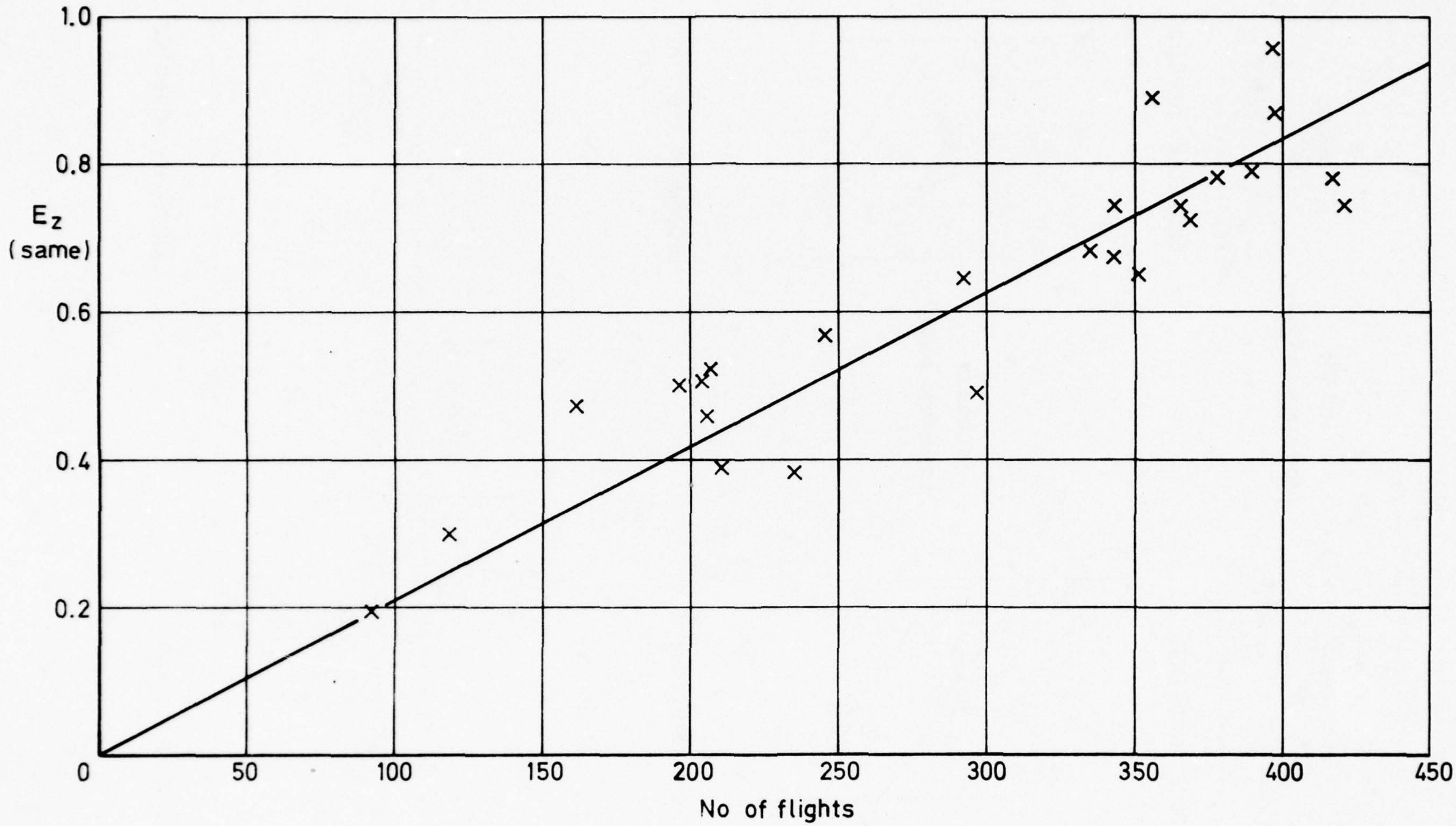

Fig 2 Observed same-direction vertical occupancy against daily number of flights

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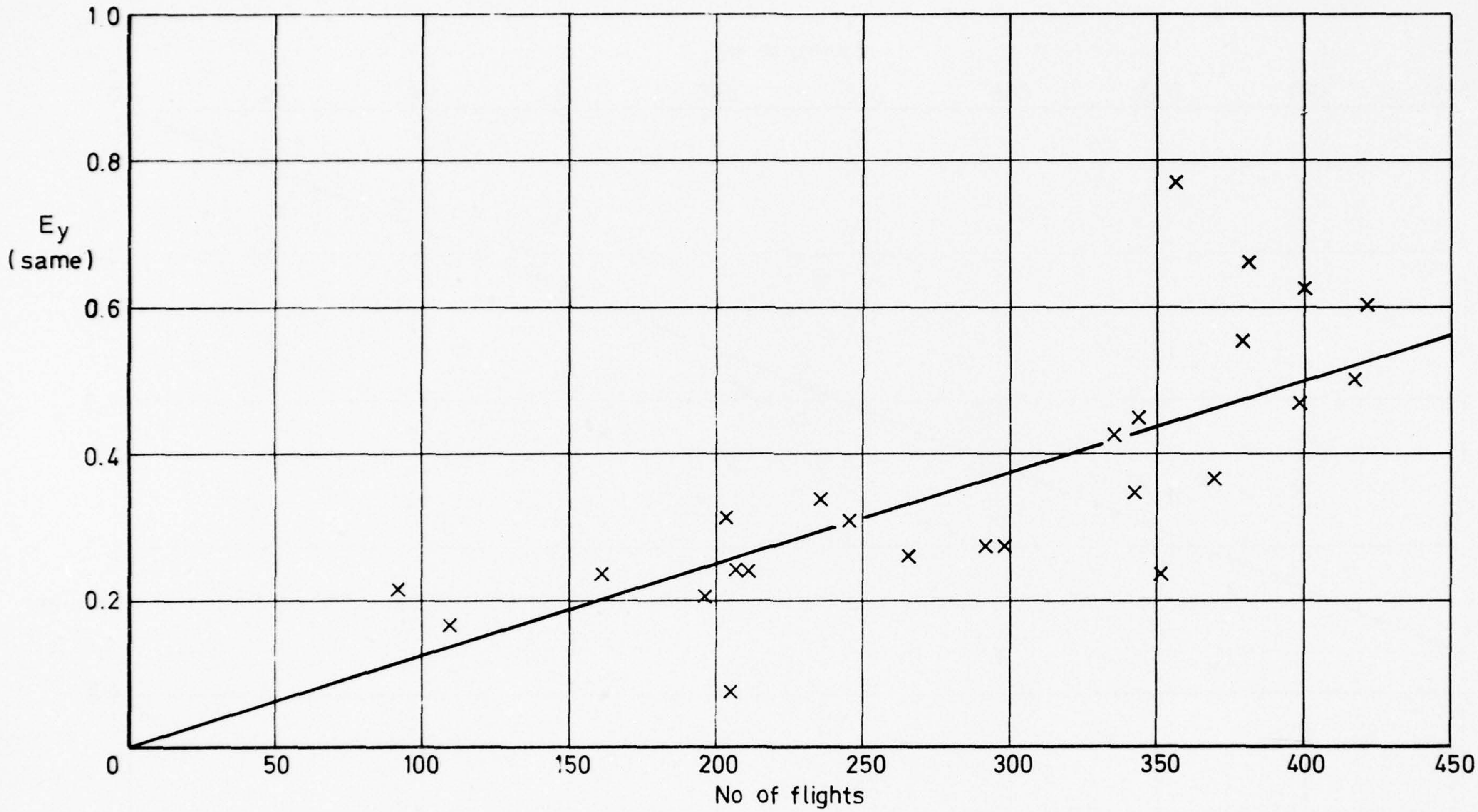

Fig 3 Observed same-direction lateral occupancy against daily number of flights

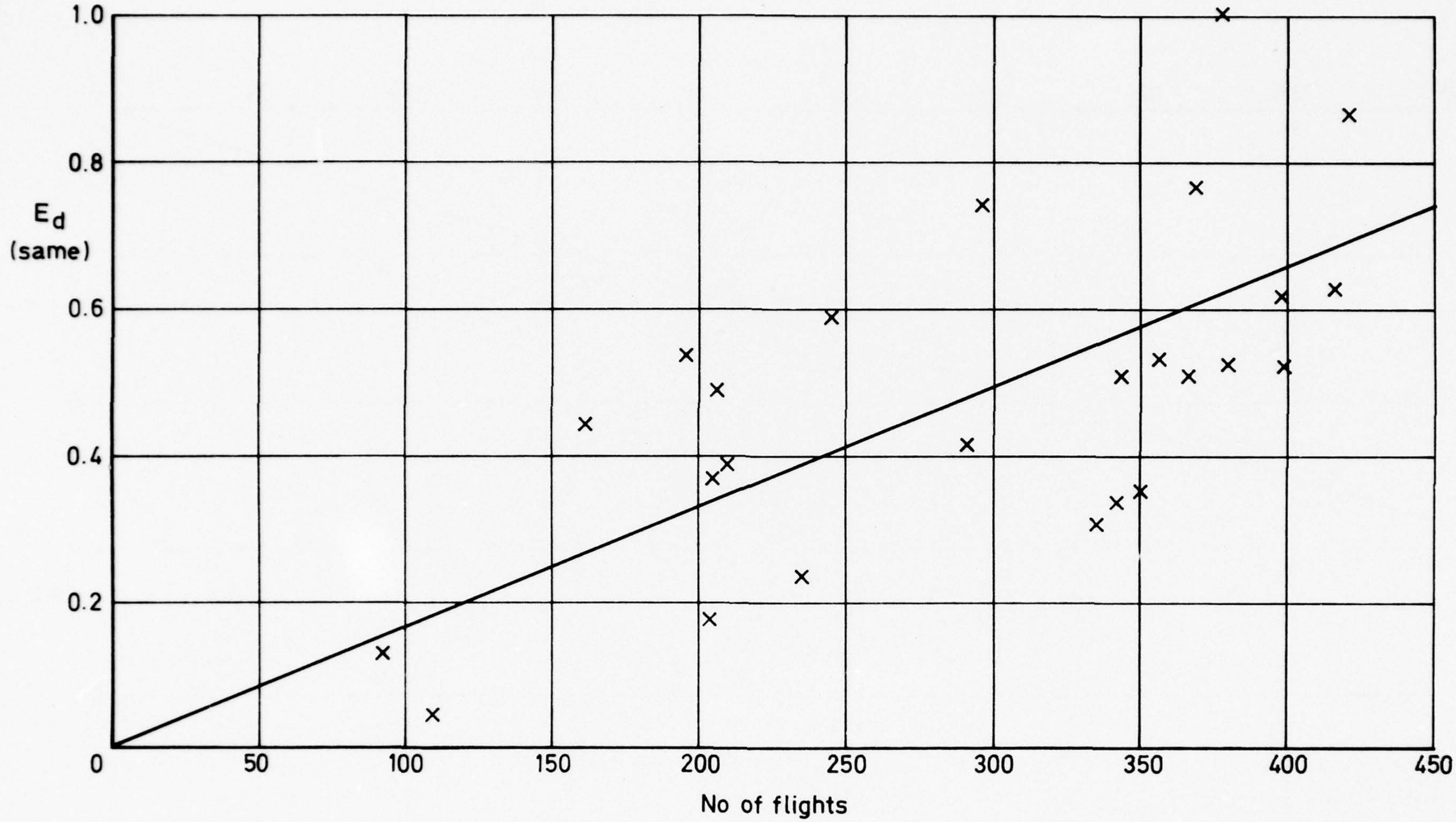

Fig 4 Observed same-direction diagonal occupancy against daily number of flights

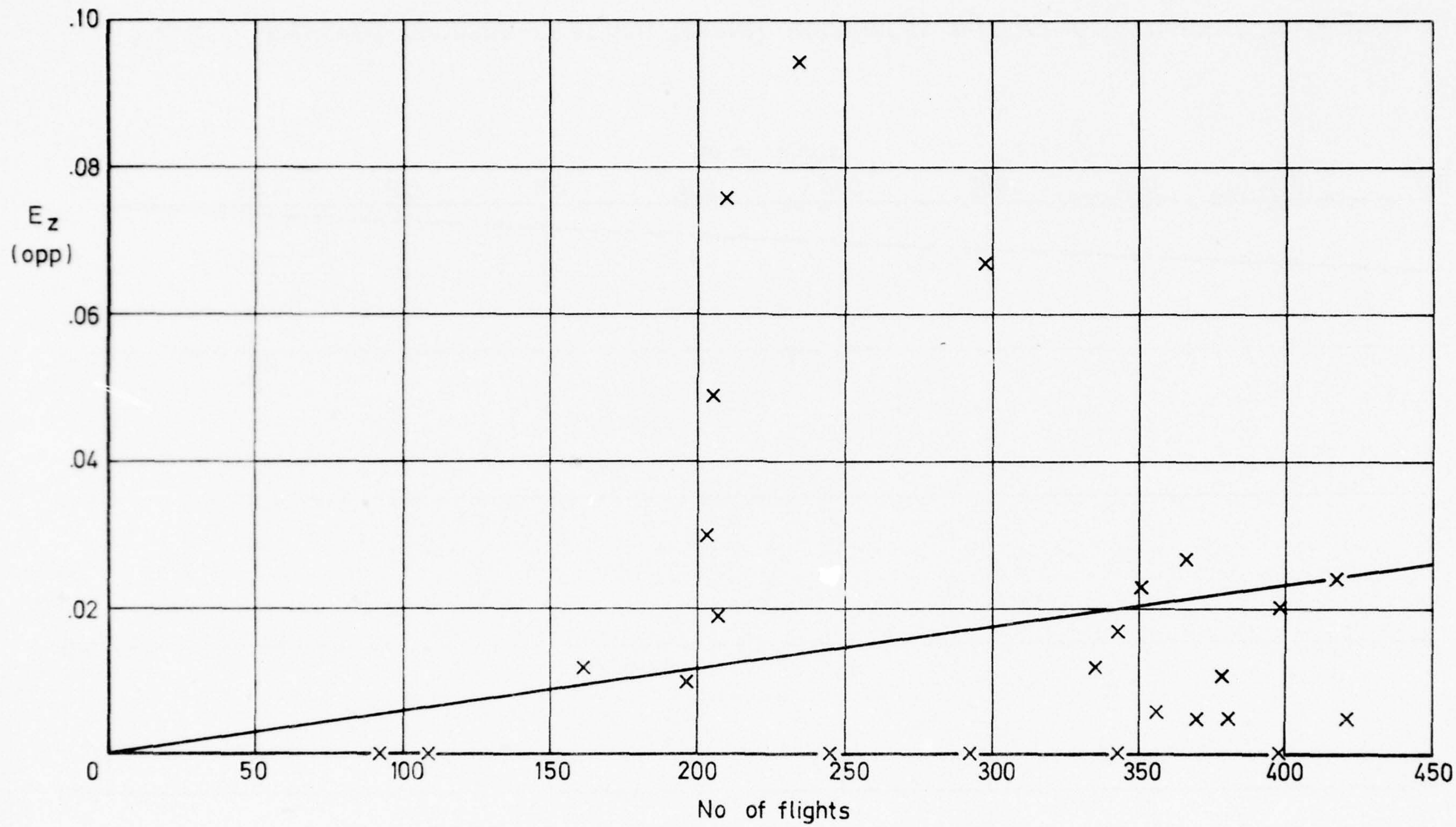

Fig 5 Observed opposite-direction vertical occupancy against daily number of flights

Fig.5

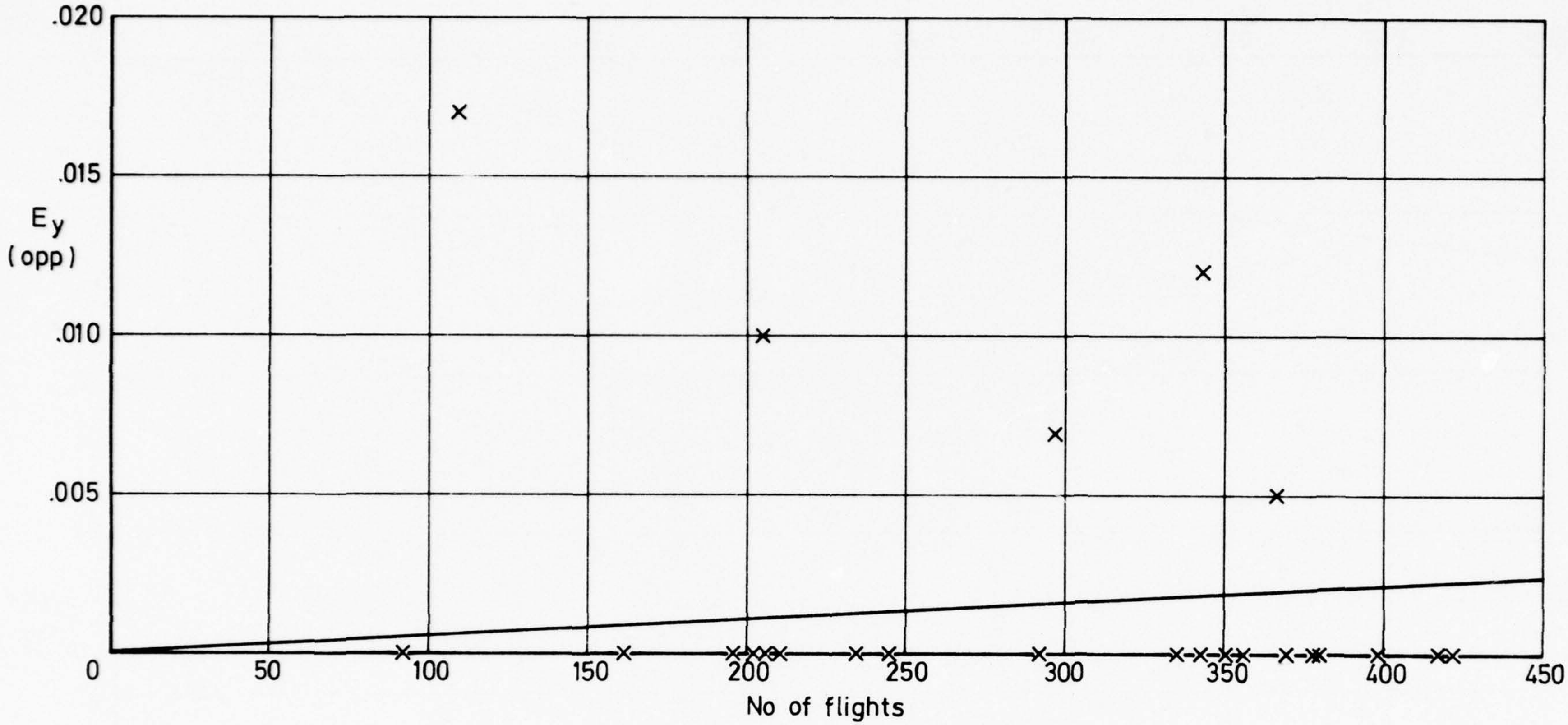

Fig 6 Observed opposite-direction lateral occupancy against daily number of flights

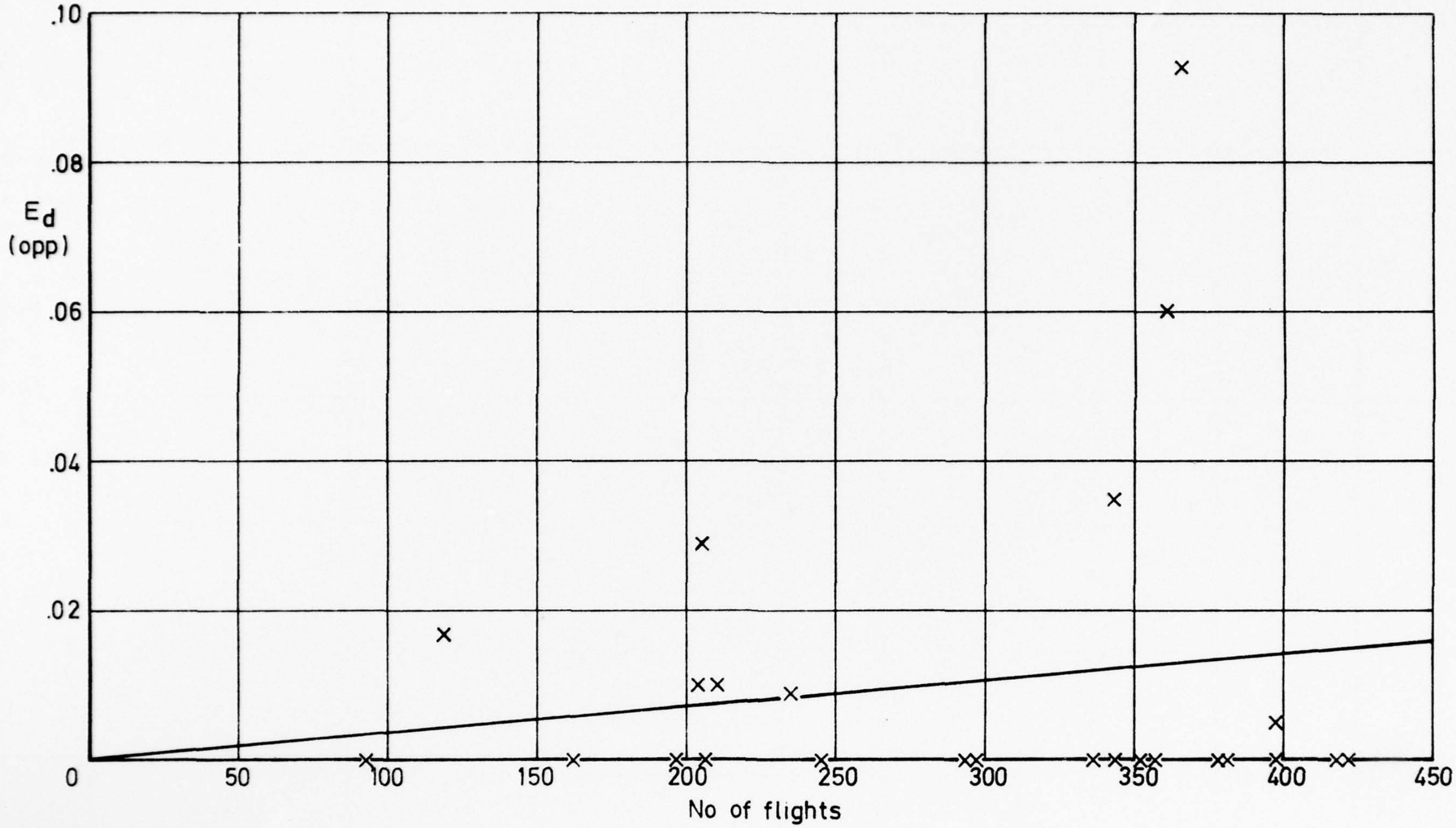

Fig 7 Observed opposite-direction occupancy against daily number of flights

Fig. 8

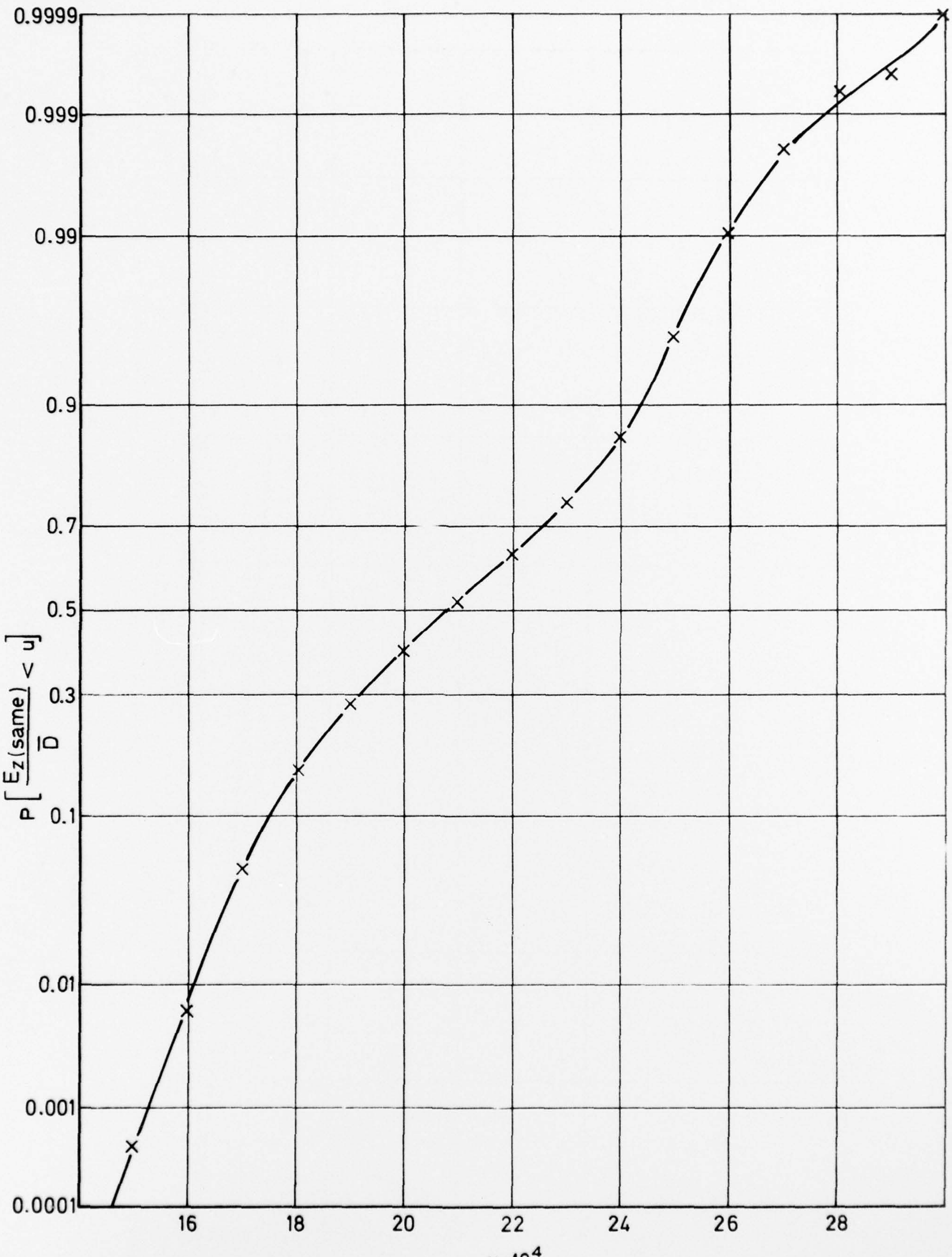

Fig 8 Distribution function assigned to same-direction vertical occupancy

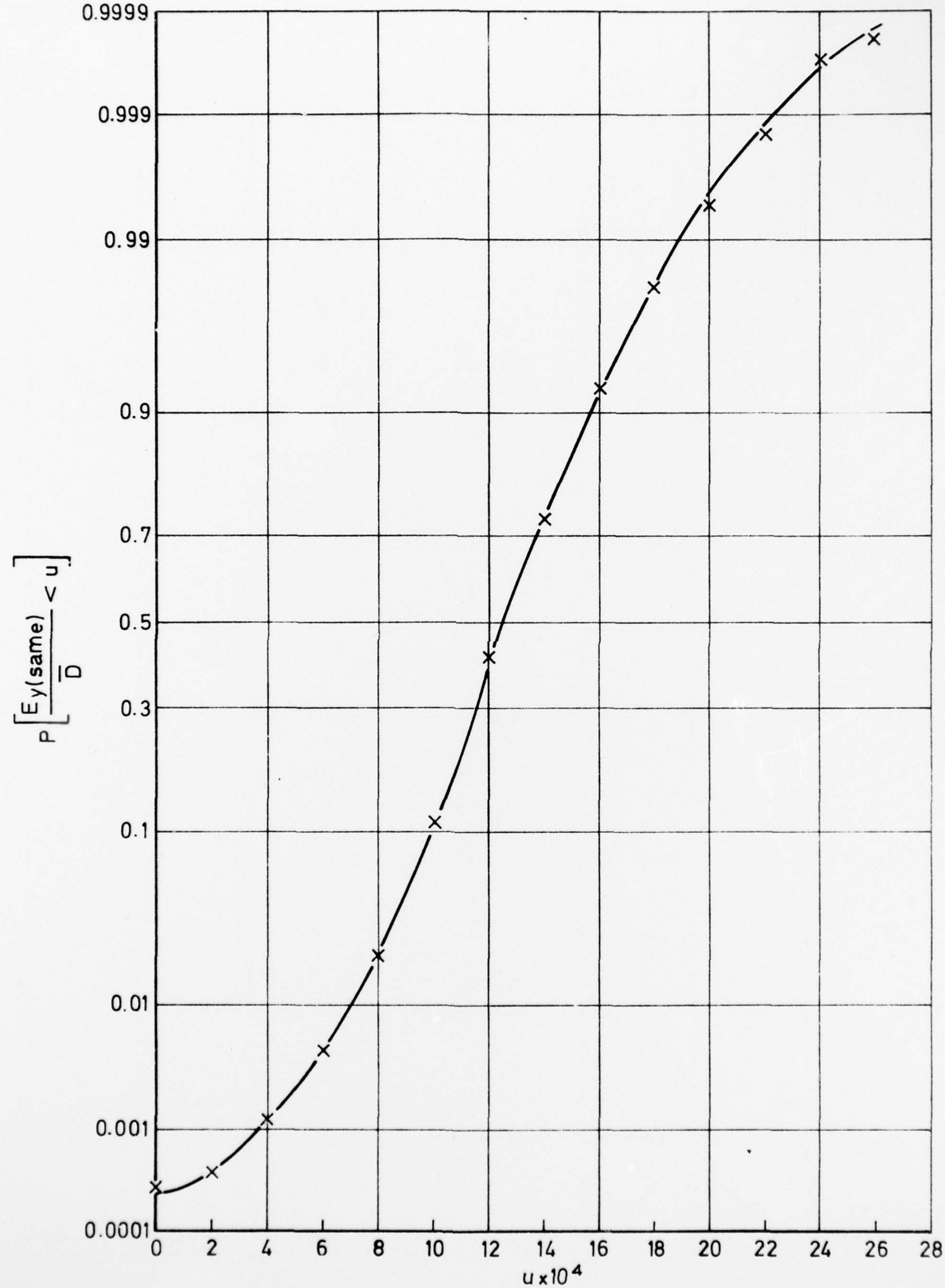

Fig 9 Distribution function assigned to same-direction lateral occupancy

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Fig.10

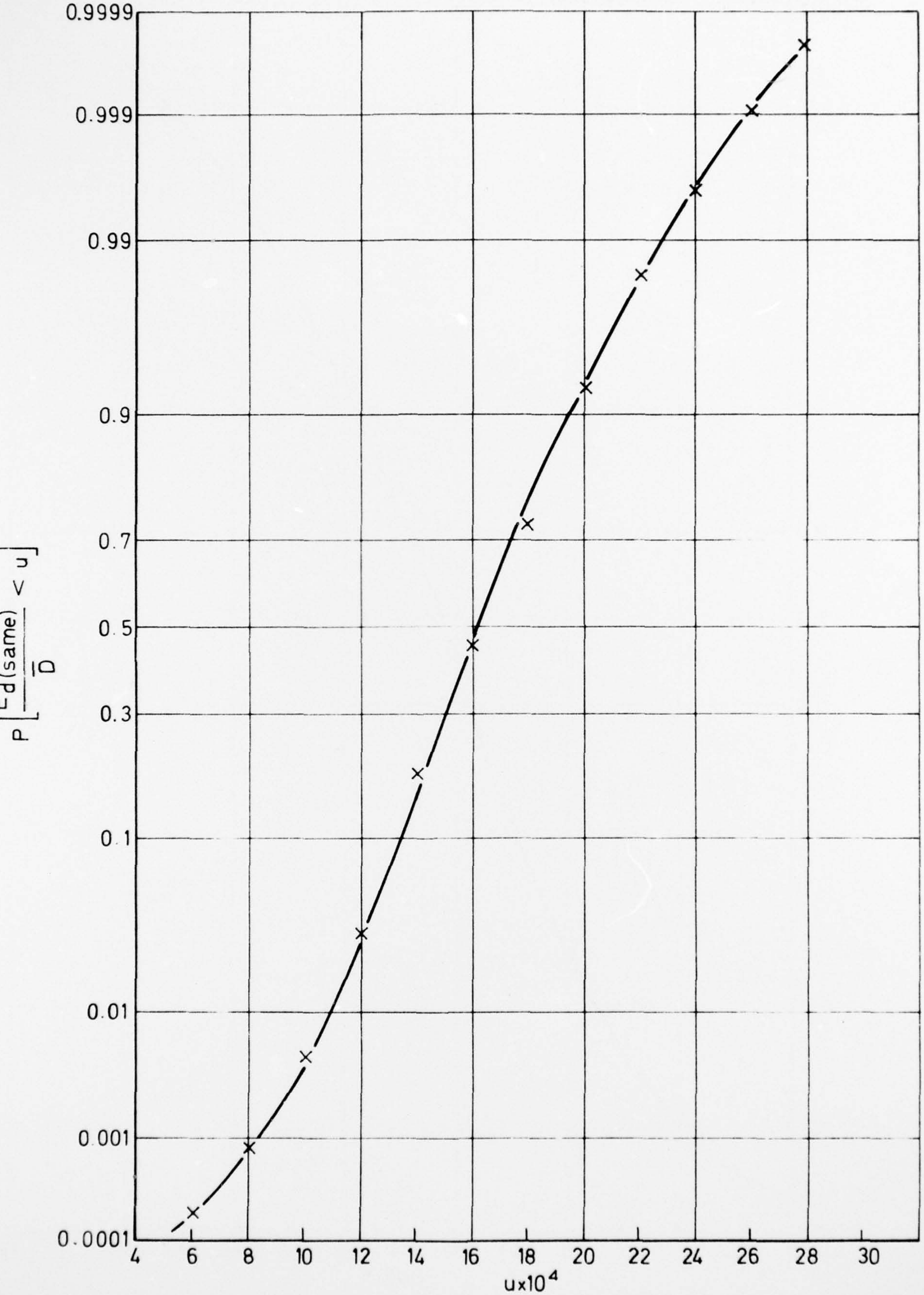

Fig 10 Distribution function assigned to same-direction diagonal occupancy

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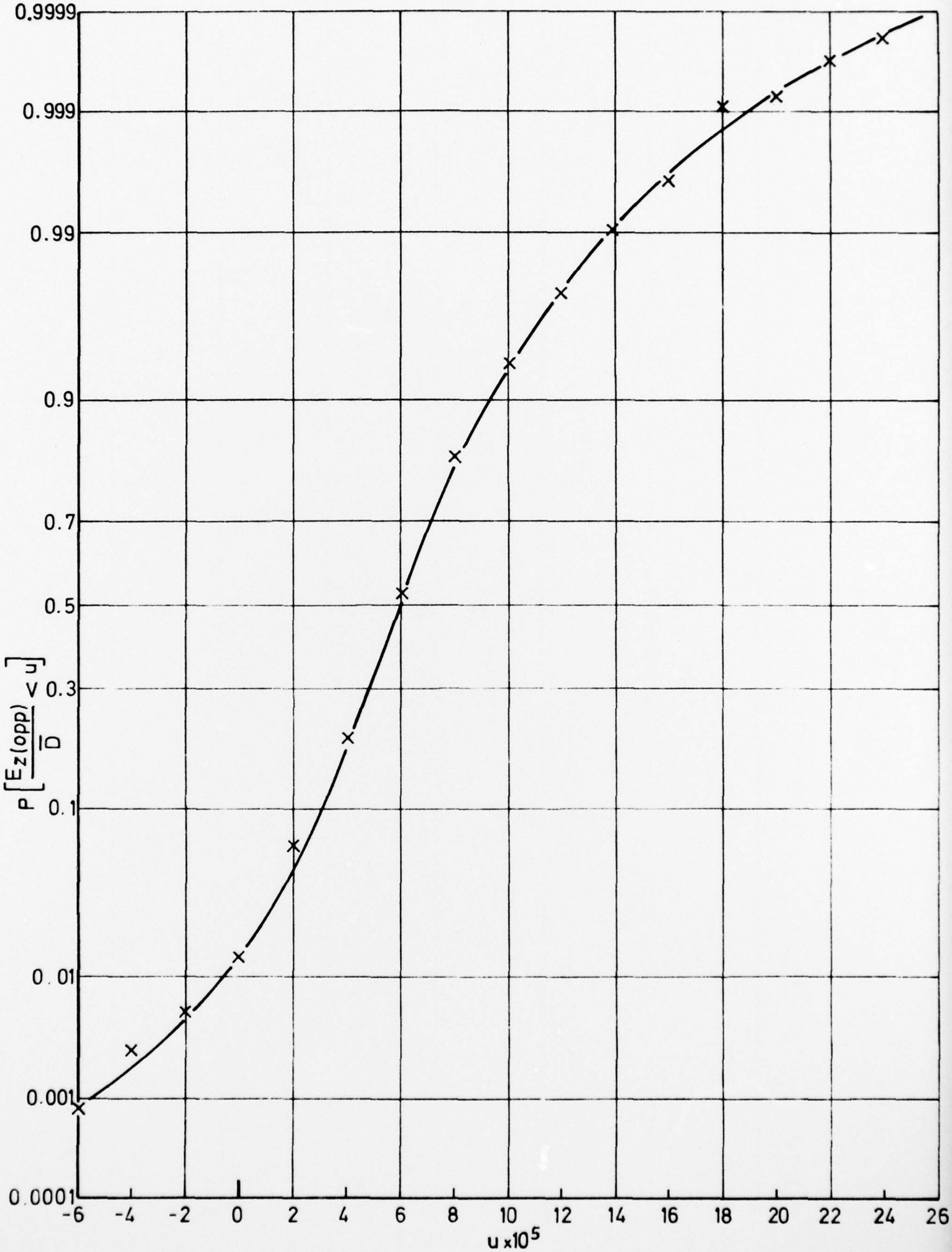

Fig 11 Distribution function assigned to opposite-direction vertical occupancy

Fig.12

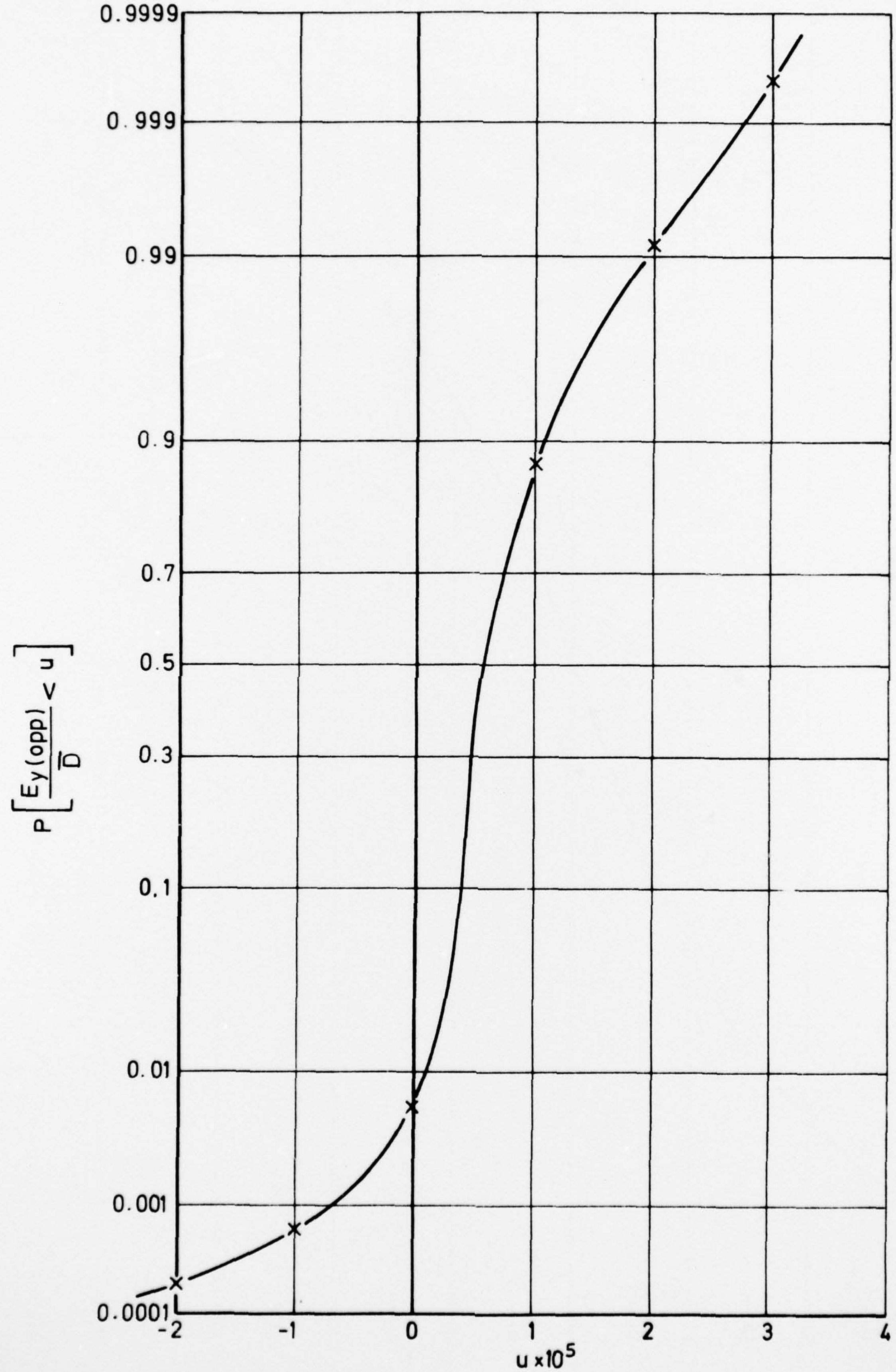

Fig 12 Distribution function assigned to opposite-direction lateral occupancy

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Fig.13

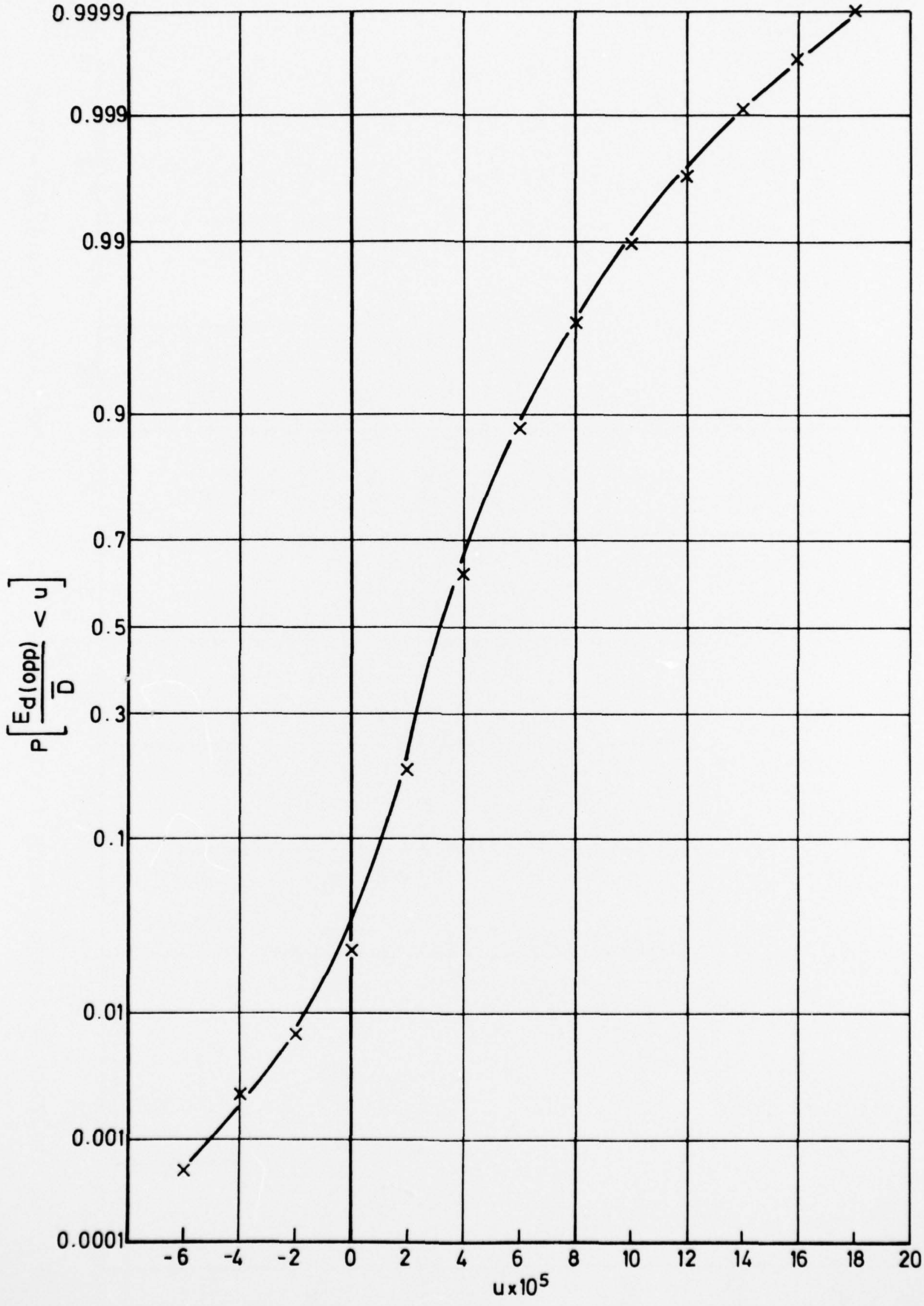

Fig 13 Distribution function assigned to opposite-direction diagonal occupancy

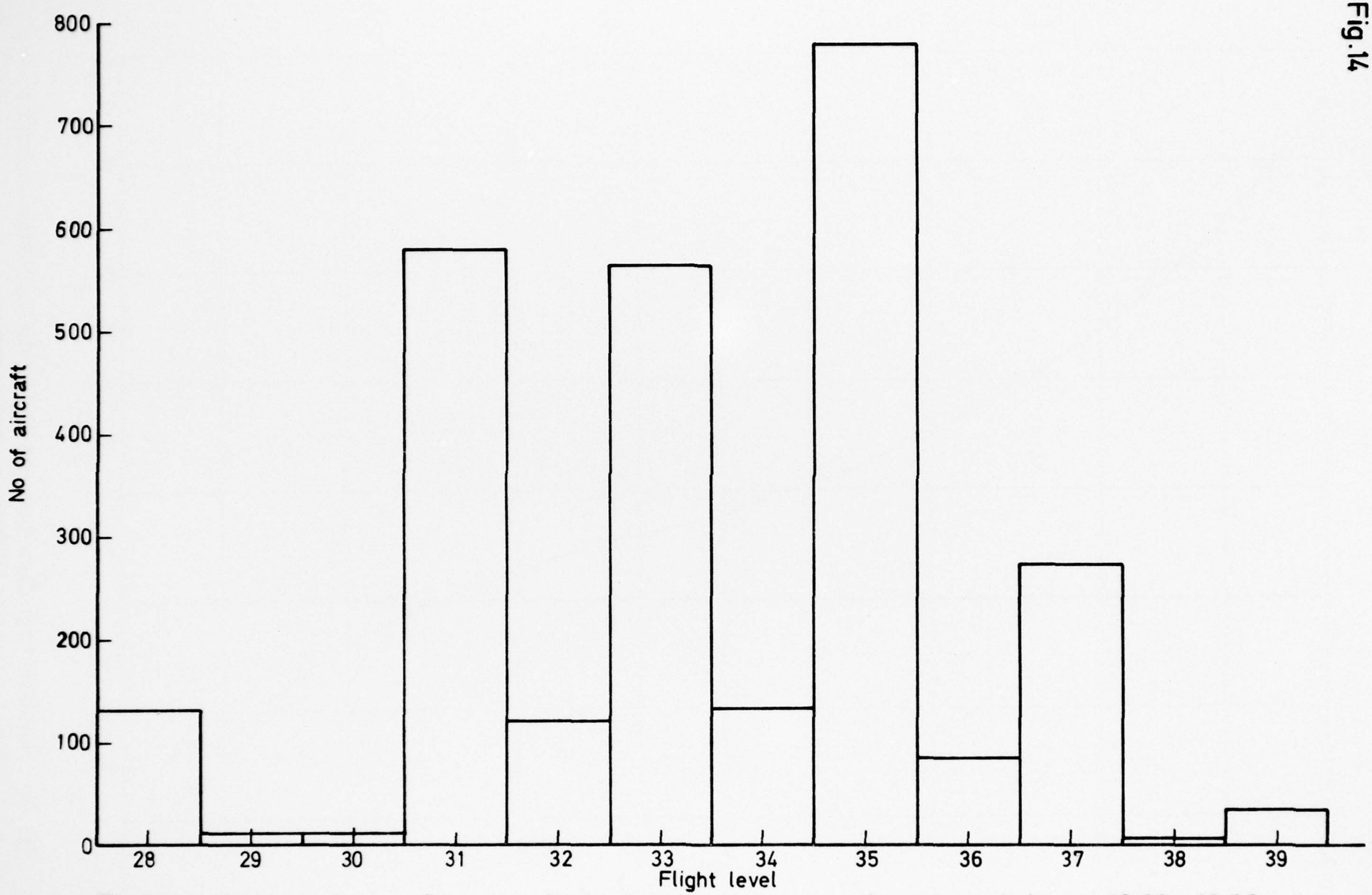

Fig 14 Number of aircraft using flight levels during westbound peak hours 12.00 - 19.00

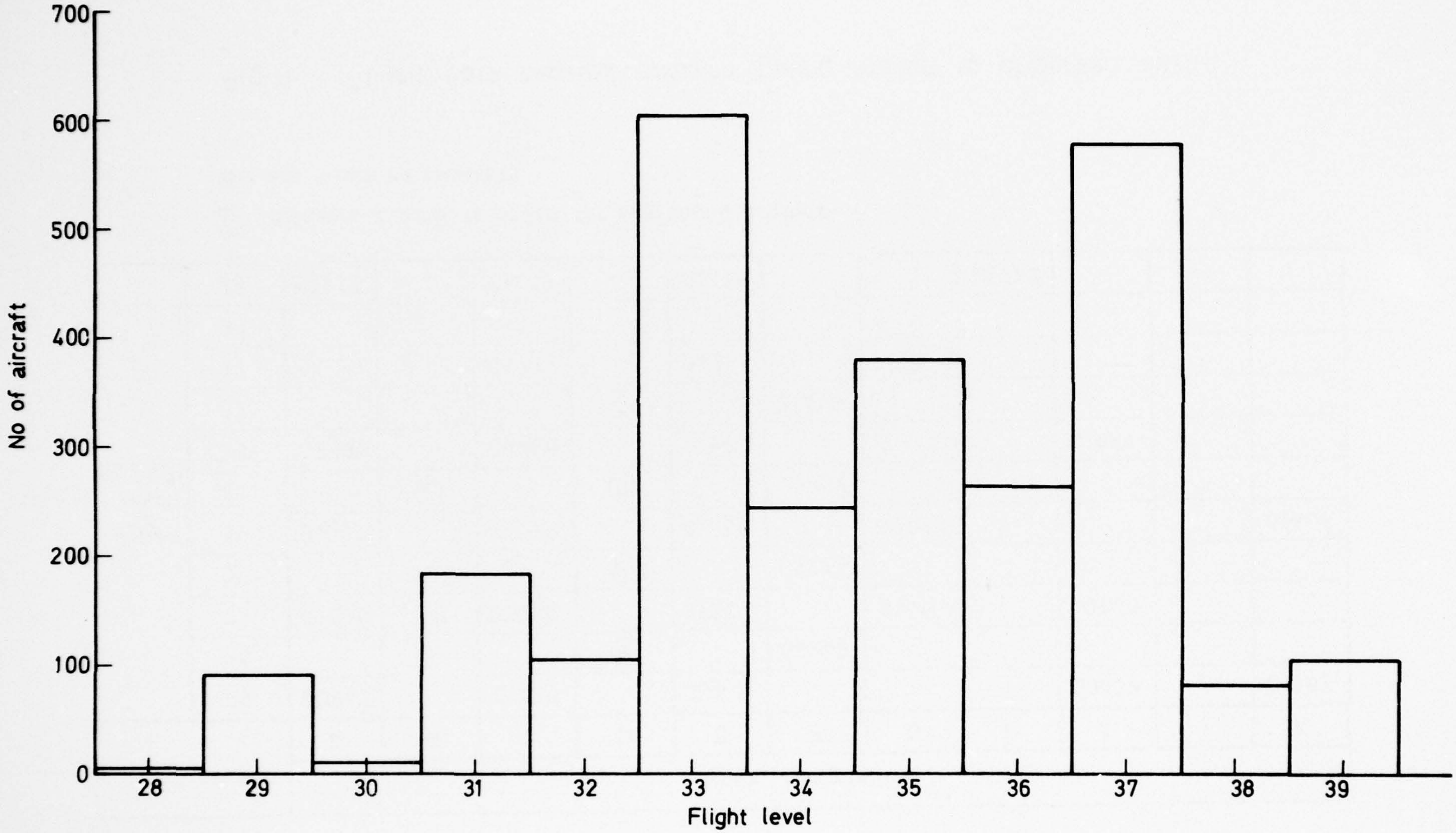

Fig 15 Number of aircraft using flight levels during eastbound peak hours 3.00 - 9.00

Flight level (ft x 10^{-3})		Track designation										
		A	B	C	D	E	F	G	H	I	J	K
	39	.00943		.01415		.01415				.00472		.01887
	38				(E)		.00943					
	37	.02830		.07075		.11377		.01415		.00943		
	36				(E)		.03774					
	35	.01887		.04717		.07132		.02830				.01606
	34		(E)		(E)		.03302					
	33	.02830		.09906		.10906		.01415		.01887		
	32				(E)		.01415					
	31	.01415		.04717		.04358		(E)				
	30											
	29	.01415		.01415		.01415			.00943			

(E) Indicates a path reserved for eastbound aircraft

Blanks mean no requests

Fig 16 Flight path request pattern giving match to observed data

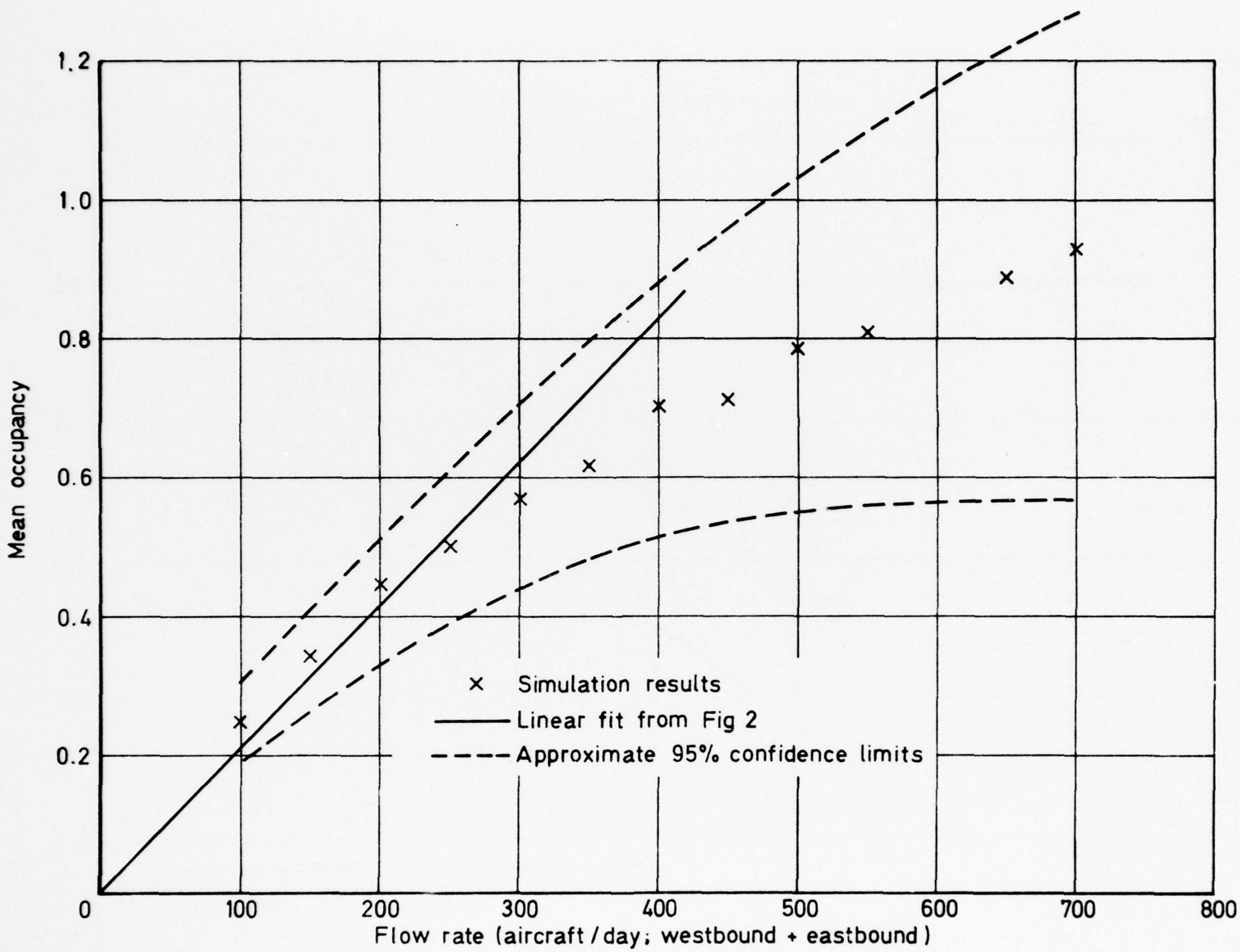

Fig 17 Forecast vertical occupancy (same-direction)

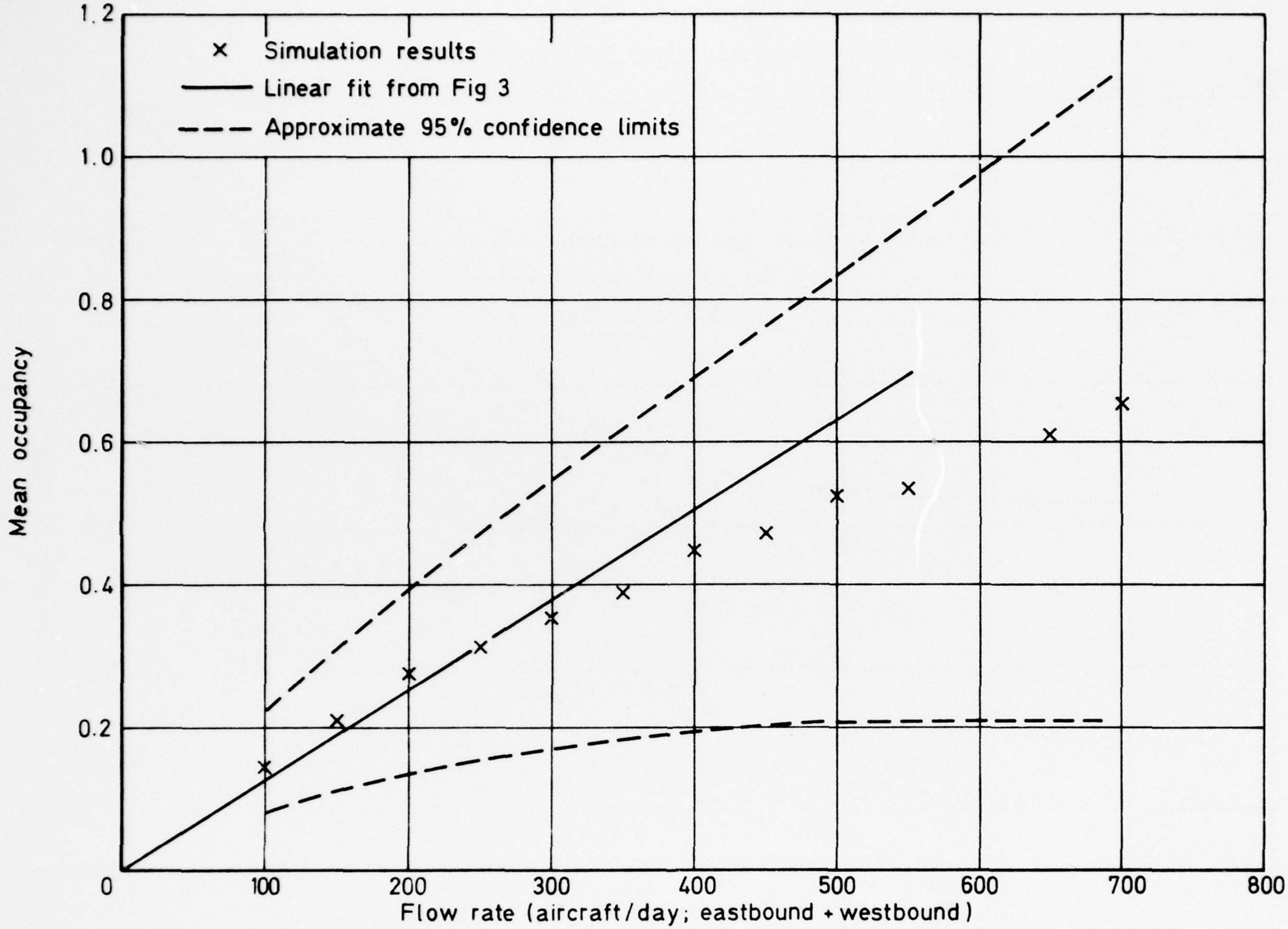

Fig 18 Forecast lateral occupancy (same-direction)

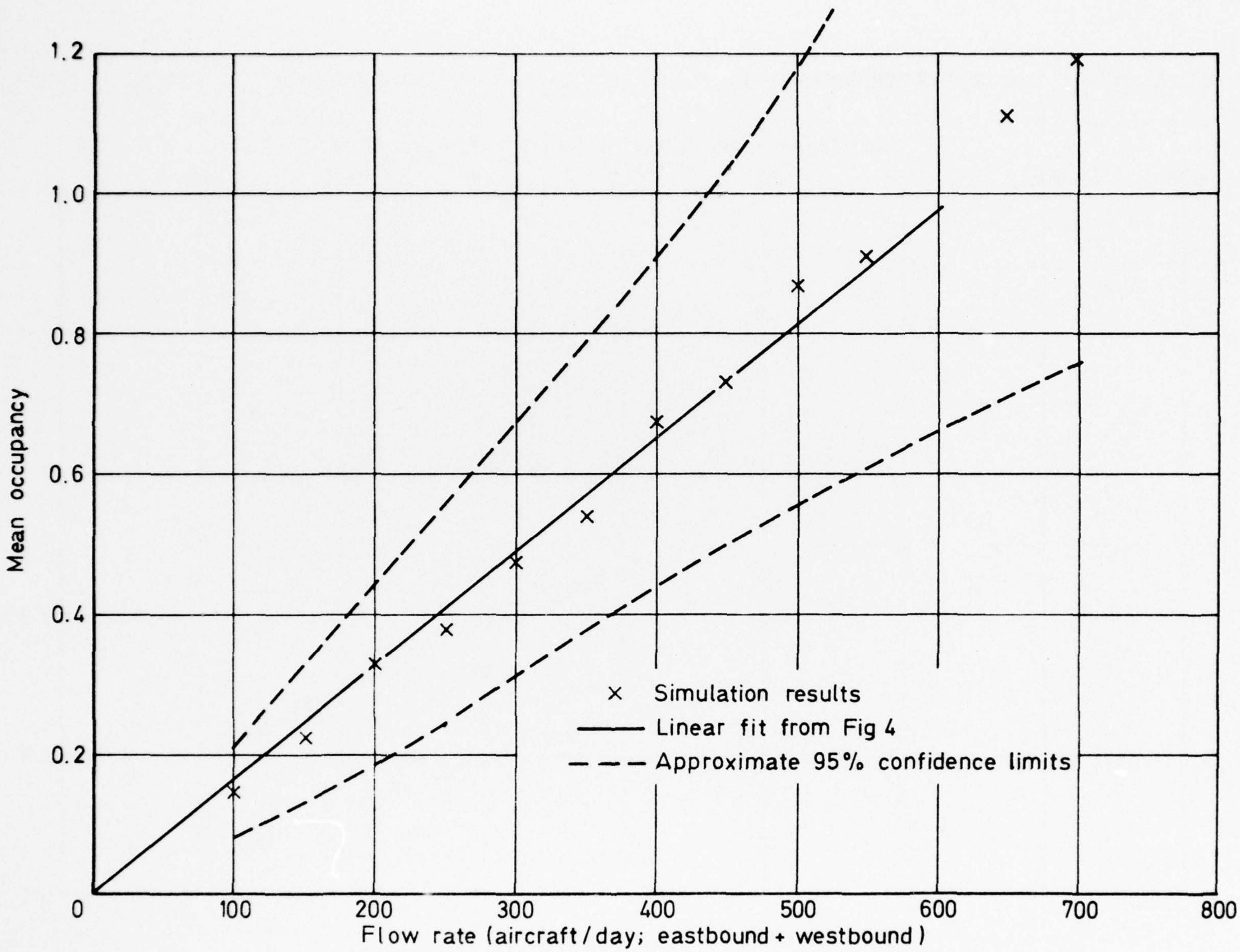

Fig 19 Forecast diagonal occupancy (same-direction)

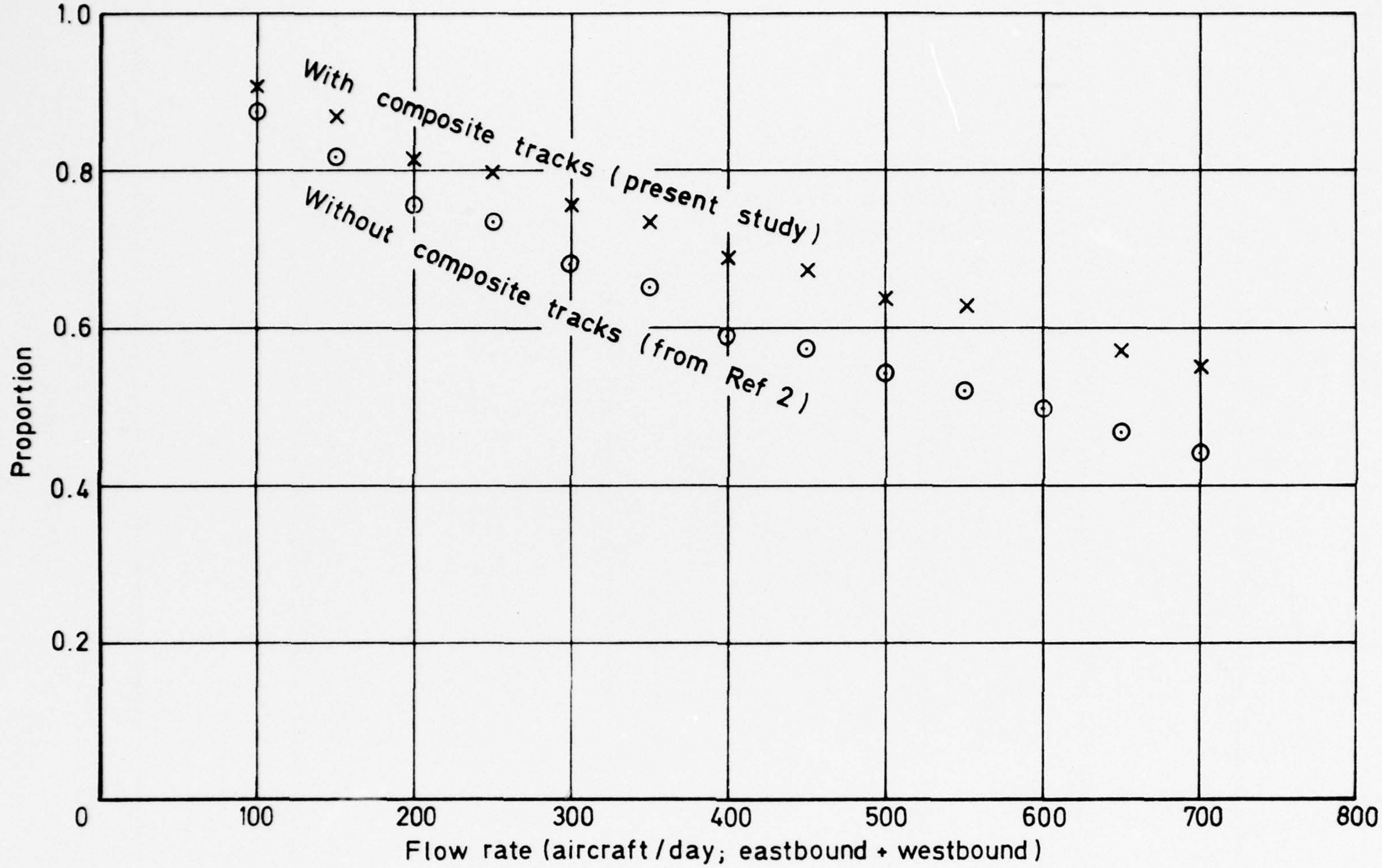

Fig 20 Effect of flow rate on proportion of aircraft receiving preferred flight path

REPORT DOCUMENTATION PAGE

Overall security classification of this page

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15. Distribution statement

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16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Air traffic. Operations. Research. North Atlantic.

17. Abstract

This Report updates the work first carried out by P.P. Scott on North Atlantic data for 1967 - data for 1973 is now examined.

Relationships are found between the number of flights in a day and measures of the occupancies of the tracks and flight levels which are adjacent to those of a 'typical' aircraft.

These results are used to construct a flight request pattern required as input data to a simulation model which forecasts the density with which aircraft will be packed into the North Atlantic track system as the traffic flow increases in future years.

Repeated runs of the model with a series of traffic flow rates have enabled the packing density to be expressed as a function of traffic intensity.

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