

HEALTH AND SAFETY EXECUTIVE

RESEARCH AND LABORATORY SERVICES DIVISION

Broad Lane, Sheffield S3 7HQ

An investigation into the number of
people entering the stadium through
Turnstiles A to G and through Gate C

by

G A C Games BA

IR/L/ME/89/34

Issue authorised by: Dr A Jones

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1 INTRODUCTION

I was told by Dr C E Nicholson, a Deputy Director of the Safety Engineering Laboratory (SEL) of the Research and Laboratory Services Division (RLSD) of the Health and Safety Executive (HSE), that on the 15th of April a video recording had been made which showed people entering the Sheffield Wednesday Football Club's (SWFC) stadium through the Leppings Lane turnstiles A, B, C, D, E, F and G and through gate C; the turnstiles served the West Terrace and North-West Terrace and in this report these terraces are called the 'West terraces'. It is my understanding that the video camera had been in a fixed position and had been recording from before 1:00 pm until after 3:00 pm. As part of the HSE investigation of the incident Dr Nicholson asked me to analyse a copy of the recording to:

- i) count the total number of people who had entered through these turnstiles and compare these counts with the counts registered by the Sheffield Wednesday's computerised system for recording admissions.
- ii) measure the rate at which people had entered the stadium through turnstiles A to G throughout the period of the video recording.
- iii) estimate the number of people who had entered the stadium through gate C.

I was assisted by other staff of RLSD working under my supervision and to my instructions. Police Constable (PC) R Watson of the West Midlands Police liaised with me and he provided the copies of the video recordings. He gave me a copy of a statement by Peter John Wilkinson of West Mercia Police TV Unit which gave details of the copy and edit procedure that had been undertaken from the original video tape.

2 VIDEO TAPE RECORDINGS USED FOR ANALYSIS

Dr Nicholson gave me copies of drawings which had been produced by Ralph Brade and Associates. Drawing No 1340/05 titled 'Close Circuit Television Cameras Location Plan' shows 'S.W.F.C. CAMERA 2 GATES A-G' and it is my understanding that the original **VHS** video tape identified as 'RJH2' was produced from signals sent by a camera at this location and that all the video recordings used by RLSD for analysis were copied from this original tape.

The U-matic video tape recordings used for 'turnstile' admission analysis were delivered by PC R Watson on 15 May 89; the individual tapes were labelled RJH2/E/Part 1 Copy A, RJH2/E/Part 2 Copy A, RJH2/E/Part 3 Copy A, RJH2/F/Part 1 Copy A, RJH2/F/Part 2 Copy A, RJH2/F/Part 3 Copy A. The tapes showed the exits of turnstile booths A to G from approximately 12:55 pm until 3:10 pm on 15 April 1989. The '/E/' Tapes showed the exits of turnstiles A, B and C and the '/F/' Tapes showed the exits of turnstiles D, E, F and G. The two Part 1's covered the first hour, the two Part 2's the second hour and the two Part 3's the remaining time. The continuous reference timings on the video tapes were with respect to the start of each tape and not to British Summer Time (BST) but I determined the relationship between these times and BST using specific events in conjunction with West Midlands Police.

The VHS video recording used for 'gate C analysis' was a copy identified as DF1/B and had been produced by Mr D Francis, an RLSD photographer, from a video recording labelled RJH2, loaned to us by PC R Watson. The copy had continuous reference timings which related to the start of the tape and not to

BST. The recording showed the exits of turnstile booths A to G, gate C and the general area on the West Stand side of these turnstiles.

3 LOCATION AND DESCRIPTION OF TURNSTILE BOOTHS A-G AND GATE C

Fig 1 is a schematic plan showing the seven turnstiles A to G and gate C. The location of the turnstile booths and of gate C is shown on the Ralph Brade and Associates drawing No 1340/04A and the aperture of gate C when open is shown as 4115 mm. Gate C, when closed, formed part of the perimeter boundary and was adjacent to turnstile booth G and approximately perpendicular to the row of turnstile booths. Normally gate C was closed and it is my understanding that the main function of gate C was to let people out of the stadium after a match.

The turnstile booth exits consisted of seven doors, designated in alphabetical order from A to G. When viewed from the video camera location door A was on the right and furthest away from the video camera. Doors A and B, D and E, F and G were in pairs and Door C was on its own. Within the booths the exit doors aligned directly with the appropriate turnstile passage, but the internal layout of the turnstile booths did not prevent a person passing through the 'gate' of turnstile A and then emerging from the door of the booth marked B (and vice versa); similarly for the other paired turnstiles. In my opinion, this indirect route may have been used on a few occasions, for example if there was someone standing in the way at the normal 'direct' exit door. Thus the individual counts for the 'paired' turnstiles may be less accurate than the sum of the two counts from the two doors of a pair.

The turnstile mechanisms were not identical in design nor in ease of operation and details are reported by Games and Waterhouse (RLSD report IR/L/ME/89/33).

It is my understanding that on the 15th April these 7 turnstiles served the West terraces which had a designated capacity of 10,100 persons.

4 THE COUNTING METHOD

4.1 TURNSTILES

The counting method used a specially developed computer program and micro-computer. The video recording was played at normal speed and the computer's clock was synchronised with a reference time on the video image. Whenever a person was seen to emerge from a specific turnstile booth an RLSD observer depressed a push button, closing an electrical circuit and sending an electrical pulse signal to the computer. The computer recorded each signal pulse and the elapsed times from the start of playback. People emerging from turnstiles A and B were registered together because the shadows on the video recording image sometimes made it impossible to differentiate between people emerging from the exit door of turnstile A and those from the exit door of turnstile B. People emerging from all other turnstiles were registered separately.

4.2 GATE C

Dr Nicholson was informed by Inspector M Layton of West Midlands Police that gate C had been opened three times and that the 'First Opening' had occurred at approximately 2:48 pm for a duration of about 30 seconds and that the

'Second Opening' had occurred at approximately 2:52 pm for a duration of about 5 minutes 30 seconds. A 'Third Opening' had occurred approximately one minute later when the gate was opened sufficiently to allow the entry of people in single file for approximately 8 minutes.

The position of gate C on the video image and the small distance between adjacent people as they passed through gate C made it impracticable to discern each person as they passed through the open gate. Therefore the method of assessment for the first two openings was to count the number of people passing a reference line drawn on the video display monitor for a recording period of 3 seconds, and then to repeat this process at intervals throughout the period of opening. The reference line was drawn so that any person who had entered through gate C would cross the line, whilst generally being separated from other people by a greater distance than when passing through the open gate, thus making each person more discernable. The path of each person was viewed to ensure that people emerging from turnstiles were not counted. The counting process was repeated several times, by rewinding and replaying the video tape, for each sample, to ensure that the chance of not counting a particular person was reduced to a minimum. The playback speed on the video recorder was adjusted to play the recording slowly enough to optimize the counting.

Four samples were taken during the First Opening and 27 samples were taken during the Second Opening; the longest interval between samples being 15 seconds. The whole of the Third Opening was analysed in one continuous sample.

5 DATA PROCESSING AND RESULTS

5.1 TURNSTILES

5.1.1 Turnstile Total Counts

Table 1 shows how many people had been counted through the turnstiles at intervals of 5 minutes, the bottom row of the table being the final count just before the turnstiles were closed. Each row of the table gives the individual total count for turnstiles C to G, the totals for the three pairs A+B, D+E, F+G and the total for all seven turnstiles.

Fig 2 shows the total number of people who had been counted through all seven turnstiles at any particular time and is a graphical representation of the same data as the final column in Table 1 but every data point has been presented, rather than just the totals at intervals of 5 minutes.

5.1.2 Turnstile Rate Counts

Table 2 shows the number of people counted through the turnstiles in each 5 minute interval. Each row of the table shows the individual 5 minute counts for turnstiles C to G, the 5 minute count for the pairs A+B, D + E, F+G and the 5 minute count for the sum of all seven turnstiles. These counts can be converted to rates of admission, measured as 'people per turnstile per hour', by multiplying by 12 and dividing by the number of turnstiles under consideration.

The last column of Table 3 shows the overall rates of admission for all seven turnstiles for each 5 min period after 2:00 pm and the average (mean) rate of admission measured over the 45 min period from 2:05 pm to 2:50 pm was approximately 660 people/turnstile/hour.

For the period between 2:25 pm and 2:50 pm turnstile C, a single turnstile, achieved a mean rate of admission of 830 people/turnstile/hour whereas the six other 'paired' turnstiles achieved a significantly lower rate of 630 people/turnstile/hour.

A visual representation of the data for turnstiles A+B, C, D, E, F and G is shown in the bar chart in Fig 3.

I analysed the data obtained from the counts from turnstiles A to G in greater detail to give a more continuous measure of the rate at which people were entering the stadium through these turnstiles. The method of analysis used a period of time ('window') of three minutes and calculated the rate of admission for the 'window' from the number of admissions made during its 3 minute duration. The 'window' was then moved forward by an increment of 0.5 minutes and a new rate of admission calculated. This process was repeated until the end of the data was reached and the resulting graph of rate of admission against time is shown in Fig 4. I made analyses using other durations of the 'window'; a longer 'window' gave a smoother curve with some loss of information and a shorter one gave rapid fluctuations which tended to mask more general trends of change in rate of admission. It is my opinion that a 'window' of 3 minutes gave the most representative rates of admission.

5.1.3 Comparison between RLSD counts and Sheffield Wednesday Football Club's computer record

The RLSD final count totals are summarised in the following table and compared with the Sheffield Wednesday Football Club's (SWFC) computer print-out, taken on 15 April 1989 by Mr R J Houldsworth (RLSD report IR/L/ME/89/33).

| Turnstiles | RLSD Count | SWFC Computer | Difference |
|------------|---------------|------------------|------------|
| A+B | 1930 | 2004 | -3.7% |
| C | 1168 | 1206 | -3.3% |
| D+E | 2130 | 2196 | -3.0% |
| A to E | 5228 | 5406 | -3.3% |
| F+G | 2019 | 1632 | +23.7% |
| Total | 7247 | 7038 | |

Dr Nicholson informed me that the turnstiles were open for a period before the start of the video recordings. In my opinion this accounts for RLSD's count of the admissions through turnstiles A to E being approximately 3.3% less than the admissions shown on the print-out taken from the SWFC's computerised system on 15 April. I have therefore concluded that SWFC's count for the total number of admissions through turnstiles A to E is likely to be correct.

5.1.4 Count for turnstiles F+G and error in SWFC count for turnstile G

The SWFC count for turnstile F was 1049, 2% less than the RLSD count of 1071 (Table 1) but this may be attributable to some people passing through

turnstile G but emerging from Exit Door F; in my opinion the SWFC count is probably accurate for this turnstile.

RLSD's count for turnstiles F+G was 23.7% higher than that obtained from SWFC's computerised recording system. RLSD report IR/L/ME/89/33 concluded that there was likely to be persistent under-recording from turnstile G and it is my opinion that under-recording on turnstile G is probably the sole cause of the discrepancy. I have assumed that the RLSD count of 2,019 is less than the true count by the same percentage (3.3%) for turnstiles F+G as for turnstiles A to E, and have estimated that 2,088 is the true total for turnstiles F+G.

My estimate of 2,088 for turnstiles F+G can therefore be divided into a count of 1,049 for turnstile F (the SWFC count) and the remainder of 1,039 for turnstile G. The SWFC count of 583 from turnstile G is therefore 56% of my estimated correct number of admissions through this turnstile.

5.1.5 Estimate of total number of people through turnstiles A to G

It is my opinion that the best estimate for the final total of people admitted through all seven turnstiles is given by adding the SWFC total for turnstiles A to E of 5,406 to my estimate of 2,088 for turnstiles F+G, giving an overall total of 7,494 admissions for turnstiles A to G. In my opinion, based on the tests reported by Games and Waterhouse (RLSD report IR/L/ME/89/33), it is most unlikely that the true total exceeded this value by more than 2% ie a maximum of 7,644 for the number of people who passed through the seven turnstiles.

My estimated total of 7,494 admissions through turnstiles A to G from the time that they were opened is 247 greater than the RLSD count. It is my opinion that this is attributable to people entering the stadium before the start of the video recording.

5.1.6 Estimate of time at which 10,100 people would have entered through turnstiles A to G

RLSD's count at 2:50 pm was 5,868 but an estimated 247 people had entered the stadium before the start of the video recording. Therefore at 2:50 pm the estimated number of people who had entered through turnstiles A to G was 6,115. Based on a capacity of 10,100 for the West terraces there were still 3,985 people yet to enter the stadium for these terraces. The average (mean) rate of admission, measured over a 45 min period, was 660 people/turnstile/hour. If this rate had been maintained I have estimated that it would have taken until approximately 3:40 pm to admit the remaining 3,985 people.

Prior to the 'Second Opening' of gate C at approximately 2:52 pm the highest rate of admission, measured over a period of 5 minutes, for the seven turnstiles was 702 people/turnstile/hour (Table 3 Col 5). If this rate had been constantly maintained it would have taken about 123 minutes to admit 10,100 people. For all these people to have entered the stadium before 3:00 pm the first entrants would have needed to enter before 1:00 pm and continued to enter at this maximum rate.

Prior to the 'Second Opening' of gate C the greatest number of admissions during a period of 5 minutes through turnstile C, a single turnstile, was 76 people, and for any pair of turnstiles it was 141 people (Table 2). On the basis of these values I have calculated a theoretical maximum composite admission for all seven turnstiles (single C and pairs A+B, D+E, F+G) for a 5 min period:

i.e. $76 + (3 \times 141) = 499$ people through 7 turnstiles in 5 minutes, which represents 855 people/turnstile/hour. If this rate had been constantly maintained it would have taken about 101 minutes to admit 10,100 people. For all these people to have entered the stadium before 3:00 pm the first entrants would have needed to enter before 1:20 pm and have continued to enter at this theoretical maximum composite rate of admission.

5.1.7 Turnstile C - Intervals Between Successive Entrants

Turnstile C was the only turnstile where the people necessarily emerged from one door. Therefore the data from this turnstile was further analysed to give the time intervals between the emergence of successive people. The data which was analysed consisted of the times of emergence, rounded to the nearest whole number of seconds, for each person.

The admissions after 2:00 pm were divided into successive groups of 10 minutes duration and the data in each group analysed to give the number of people that had emergence times of 0 second, 1 second, 2 seconds, 3 seconds, etc after the previous person.

There is an anomaly which gives a small number of times for a 0 second interval. The reason for this anomaly is because of the procedure which rounded the actual times to the nearest integer times; for example if a person emerged with an actual time of 97.51 seconds and the next person 0.98 seconds later with an actual time of 98.49 seconds, both of these people would register as 98 seconds and the interval would be calculated as 0 second. A '0 second' interval is therefore occasionally, but not necessarily, recorded for a person who emerged from the door within 1 second of the previous person. These rounding errors were not cumulative and do not affect the average (mean) time of passage.

Table 4 shows the number of people having the same time interval of passage through turnstile C and its contents are presented as the bar charts of Fig 5 which show the frequency distribution of the various times; times exceeding 10 seconds are not shown. Both Table 4 and Fig 5 show that the average (mean) time taken to pass through turnstile C was always greater than the most frequently occurring time of passage.

5.2 GATE C

5.2.1 First Opening

I assumed that the rate at which people entered through gate C changed linearly between successive sampling periods. The counts made during each of the 3 second sample periods were therefore used to calculate an estimated number of entries between each sample period. The total number of entries through gate C was obtained from the sum of these estimates, added to the counts made during the sampling periods. The total number estimate was 130 but in my opinion this estimate should be regarded as a minimum because of the likelihood that some people were obscured by others. My best estimate would be that about 150 people entered during the 'First Opening' of gate C and in my opinion the actual number was unlikely to have been greater than 180.

5.2.2 Second Opening

There was an initial surge of people during which a sample was taken and the measured rate for this sample was 10 people/second; the flow soon became

relatively steady and the rates of admission for many of the samples during the remainder of the period were about 6 people/second. Drawing No 1340/04A showed Gate C to be 4115 mm wide and by assuming a shoulder width of 550 mm I calculated that it would allow 7 people to pass abreast when it was fully opened. The measured rate of 6 people/second therefore corresponds approximately to a rate of 1 person per shoulder width per second.

A similar method of analysis was used to that for the 'First Opening' and Fig 6 shows a graph of the number of people who entered through gate C during the 'Second Opening'; the asterisks on the graph denote the individual sample points. The total number estimate was 1800 but in my opinion this estimate should be regarded as a minimum because of the likelihood that some people were obscured by others. My best estimate, based on the assumption that 1 person in 10 may not have been counted, would be about 2000 and in my opinion the actual number was unlikely to have been greater than 2200.

5.2.3 Third Opening

Entries during the 'Third Opening' were at a much lower rate than in the other two openings and a continuous count was made over a period of about 8 minutes. A total of 90 people were counted and in my opinion the actual number is unlikely to have been greater than 100.

6 SUMMARY OF RESULTS

6.1 TURNSTILE COUNTS, ESTIMATES, TOTALS AND RATE OF ADMISSION

The '5 minute totals' and rates for turnstiles A to G are summarised in Table 3.

The third column in Table 3 was obtained from my assumption that the discrepancy of 247 between the RLSD total and final estimated total was due to people entering the stadium before the start of the video recording. This number has therefore been added to all the intermediate RLSD counts to give an estimated count for the intermediate times.

The total entries shown in the fourth column were obtained by adding, at appropriate times, admissions through turnstiles A to G from the third column to my best estimates of the number of entries made through gate C.

6.2 COUNTS AND ESTIMATES FOR THE THREE OPENINGS OF GATE C AND THE FINAL TOTALS

The estimates for gate C and estimated totals for the turnstiles are summarised below:

| | RLSD Count | 'Best' Estimate | Maximum Estimate |
|----------------|------------|-----------------|------------------|
| First Opening | 130 | 150 | 180 |
| Second Opening | 1800 | 2000 | 2200 |
| Third Opening | 90 | 90 | 100 |
| Total gate C | 2020 | 2240 | 2480 |
| Turnstiles | 7247 | 7494 | 7644 |
| Total | 9267 | 9734 | 10124 |

6.3 SWFC COMPUTER COUNTS FOR TURNSTILE A TO G

6.3.1 Turnstiles A to E

The RLSD counts for these turnstiles would indicate that the SWFC counts for turnstiles A to E were accurate and in my opinion SWFC's record of the admissions through these turnstiles would not be in error by more than 2%.

6.3.2 Turnstile G

The SWFC count for turnstile G was low and estimates in this report indicate that the SWFC computer only registered about 56% of the correct number of admissions through this turnstile. Evidence of the turnstile switch malfunctioning is reported by Games and Waterhouse (RLSD report IR/L/ME/89/33) and this would account for errors in the total registered by the SWFC computer.

7 DISCUSSION

7.1 RATE OF ADMISSION THROUGH TURNSTILES A TO G

I consider it reasonable to suppose that, in the absence of crowd forces, the rate at which people entered the stadium would rise until there were queues at all the turnstiles. I would then have expected the rate of admission to remain fairly constant, possibly rising slightly as the match start time approached.

Fig 4 shows that from about 2:05 pm the rate was fairly constant until 2:25 pm, which in my opinion suggests that all turnstiles had queues and people were not having undue difficulty in entering the turnstiles.

After about 2:25 pm turnstile C generally has the highest rate of admission and it is noticeable from Table 2 that the paired turnstiles were performing less well. In particular turnstiles F+G recorded a count of only 86 between 2:45 pm and 2:50 pm and turnstiles D+E a count of 77 between 2:40 pm and 2:45 pm; equivalent to 516 and 462 people/turnstile/hour respectively. The

rate at which people were entering decreased at about 2:35 pm and in my opinion a likely cause was crowd forces acting on the people entering the turnstiles. Even so the lowest overall rate of admission for all seven turnstiles for a 5 minute period of 610 people/turnstile/hour and the corresponding highest overall rate of admission of 702 persons/turnstile/hour were both within 8% of the average rate of 660 people/turnstile/hour that was achieved for the period between 2:05 pm and 2:50 pm.

The theoretical maximum composite rate of admission was 855 people/turnstile/hour and in my opinion this theoretical maximum may have been achievable for these turnstiles operating under ideal conditions, for example with no crowd pressure acting on people entering the turnstile booths and with each person having their ticket ready. In my opinion the maximum measured rate of 702 people/turnstile/hour, achieved over a period of 5 minutes, would have been maintained after 2:35 pm if there had been no crowd forces acting on people entering the turnstiles.

7.2 GATE C OPENINGS

I calculated that an estimated 2000 people entered the stadium during the 'Second Opening', during which significant checking of tickets was not apparent from the video recording. The rate of admission of the turnstiles increased markedly at about the time of the 'Second Opening' of gate C. In my opinion this increase may have been due to two possible causes:

a) the turnstile operators may not have been checking tickets to the same extent as they were before the 'Second Opening'.

b) the 'Second Opening' resulted in decreased crowd forces thus allowing people to enter the turnstiles more easily.

It is my opinion that the number of people who can pass through a given sized opening in a given time will tend to be self-limiting. If a person moves more quickly then more clearance between successive people will be required. If people shuffle through almost touching each other their speed will be limited because of lack of freedom of movement. For example if people walk at a speed of 2 m/sec (4.5 mph) and a spacing of 1.5 m (5 ft) then 80 people per shoulder width would pass a given point in 1 min; if the speed was 1 m/sec (2.2 mph) and the spacing was 0.75 m (2.5 ft) the number of people passing the point in 1 min would be the same.

7.3 TIMES TAKEN TO PASS THROUGH TURNSTILE C

Fig 5 and Table 4 show that between 2:00 pm and 2:10 pm the most frequent time of passage was 5 sec. The time then diminished to 3 sec for the intervals of 2:30 pm to 2:40 pm and 2:40 pm to 2:50 pm, with an approximately equal numbers of admissions taking 2 sec and 4 sec; however the mean times for these intervals were 4.3 sec and 4.4 sec respectively, corresponding to 828 people/hour and 822 people/hour. This shows that the asymmetric distribution of times, caused by a significant number of people taking longer than 5 seconds, gives a mean time that is about 50% greater than the most frequent time for this interval.

The relevance of the difference between the mean time and the most frequent time is that the capacity of a turnstile cannot be calculated on the assumption that each person will take the same time of passage.

8 CONCLUSIONS

8.1 My best estimate of the number of people admitted through turnstiles A to G is 7,494 and through gate C is 2,240, i.e. a total of 9,734. It is my opinion that the true total is most unlikely to have exceeded 10,124, i.e. the total admissions were approximately equal to the designated capacity of 10,100 people for the West terraces.

8.2 RLSD measured the average (mean) rate of admission through turnstiles A to G as 660 people/turnstile/hour for the 45 min period between 2:05 pm and 2:50 pm.

8.3 On the basis of RLSD's measured average rate of admission of 660 people/turnstile/hour through turnstiles A to G, and the number of people who had already been admitted through these turnstiles at 2:50 pm, I have estimated that if gate C had not been opened it would have taken until about 3:40 pm to admit a total of 10,100 people through these turnstiles.

8.4 Using RLSD's measured maximum rate of admission of 702 people/turnstile/hour through turnstiles A to G I calculated that people would need to have been continuously entering through these turnstiles at this rate before 1:00 pm to enable 10,100 people to enter the West terraces before 3:00 pm.

8.5 The rate of admission into the stadium increased markedly at about 1:45 pm rising from about 300 to about 550 people/turnstile/hour. The 5 minute rate for all seven turnstiles peaked at 702 people/turnstile/hour for the period 2:30 pm to 2:35 pm and remained within about 8% of the average (mean) rate of 660 people/turnstile/hour between 2:05 pm until 2:50 pm. There was a fall in the rate at about 2:35 pm with no recovery until about the time of the 'Second Opening' of gate C when the rate of admission increased markedly. At this stage the turnstile operators may not have been checking tickets to the same extent and crowd pressure outside the turnstiles may have decreased.

8.6 The distribution of the times of passage through turnstile C, a single turnstile, was asymmetric and the mean time of passage was always significantly greater than the most frequent time. Between 2:30 pm and 2:50 pm the most frequently occurring time of passage was 3 sec but the mean time of passage was 4.4 seconds.

8.7 Turnstile C, a single turnstile, achieved a significantly higher rate of admission of 830 people/turnstile/hour during the period between 2:30 pm and 2:50 pm in comparison with 630 people/turnstile/hour for the other six turnstiles which were in pairs.

8.8 Sheffield Wednesday Football Club's computerised system for recording admissions to the stadium registered only approximately 56% of the people who entered through turnstile G. There is no evidence from the RLSD counting that any of the total counts from turnstiles A to F were registered incorrectly.

Table 1

TOTAL NUMBER OF PEOPLE COUNTED THROUGH TURNSTILES A to G AT DIFFERENT TIMES

| TIME | TURNSTILE | | | | | | | D+E | F+G | TOTAL |
|-----------|-----------|------|------|-----|------|-----|------|------|------|-------|
| | A+B | C | D | E | F | G | | | | |
| pm | | | | | | | | | | |
| 1:00 | 3 | 10 | 5 | 7 | 9 | 8 | 12 | 17 | 42 | |
| 1:05 | 19 | 21 | 24 | 23 | 16 | 21 | 47 | 37 | 124 | |
| 1:10 | 40 | 41 | 39 | 43 | 28 | 40 | 82 | 68 | 231 | |
| 1:15 | 64 | 54 | 56 | 59 | 35 | 44 | 115 | 79 | 312 | |
| 1:20 | 84 | 74 | 76 | 80 | 47 | 53 | 156 | 100 | 414 | |
| 1:25 | 114 | 92 | 98 | 94 | 56 | 60 | 192 | 116 | 514 | |
| 1:30 | 146 | 114 | 131 | 111 | 74 | 85 | 242 | 159 | 661 | |
| 1:35 | 178 | 149 | 151 | 113 | 93 | 102 | 264 | 195 | 786 | |
| 1:40 | 216 | 176 | 185 | 131 | 125 | 124 | 316 | 249 | 957 | |
| 1:45 | 271 | 199 | 217 | 165 | 150 | 141 | 382 | 291 | 1143 | |
| 1:50 | 363 | 241 | 278 | 211 | 189 | 182 | 489 | 371 | 1464 | |
| 1:55 | 448 | 280 | 336 | 270 | 229 | 214 | 606 | 443 | 1777 | |
| 2:00 | 535 | 341 | 390 | 312 | 281 | 262 | 702 | 543 | 2121 | |
| 2:05 | 603 | 399 | 439 | 348 | 331 | 303 | 787 | 634 | 2423 | |
| 2:10 | 690 | 447 | 494 | 399 | 398 | 377 | 893 | 775 | 2805 | |
| 2:15 | 784 | 490 | 546 | 448 | 463 | 444 | 994 | 907 | 3175 | |
| 2:20 | 883 | 537 | 611 | 496 | 532 | 509 | 1107 | 1041 | 3568 | |
| 2:25 | 989 | 587 | 676 | 548 | 589 | 559 | 1224 | 1148 | 3948 | |
| 2:30 | 1097 | 658 | 736 | 603 | 634 | 618 | 1339 | 1252 | 4346 | |
| 2:35 | 1206 | 730 | 790 | 663 | 691 | 676 | 1453 | 1367 | 4756 | |
| 2:40 | 1309 | 796 | 847 | 709 | 758 | 720 | 1556 | 1478 | 5139 | |
| 2:45 | 1415 | 857 | 892 | 741 | 820 | 770 | 1633 | 1590 | 5495 | |
| 2:50 | 1522 | 933 | 946 | 791 | 873 | 803 | 1737 | 1676 | 5868 | |
| 2:55 | 1649 | 1000 | 1015 | 832 | 932 | 840 | 1847 | 1772 | 6268 | |
| 3:00 | 1790 | 1096 | 1098 | 902 | 1005 | 904 | 2000 | 1909 | 6795 | |
| 3:05 | 1911 | 1160 | 1163 | 951 | 1066 | 940 | 2114 | 2006 | 7191 | |
| 3:10 | 1930 | 1168 | 1170 | 960 | 1071 | 948 | 2130 | 2019 | 7247 | |

Ref SEL1 [300,5]hdtabl.tab

Table 2

NUMBER OF PEOPLE COUNTED THROUGH TURNSTILES IN EACH 5 MINUTE INTERVAL

| TIME pm | TURNSTILE | | | | | | | D+E | F+G | TOTAL |
|--------------|-----------|----|----|----|----|----|-----|-----|-----|-------|
| | A+B | C | D | E | F | G | | | | |
| 12:55 - 1:00 | 3 | 10 | 5 | 7 | 9 | 8 | 12 | 17 | 42 | |
| 1:00 - 1:05 | 16 | 11 | 19 | 16 | 7 | 13 | 35 | 20 | 82 | |
| 1:05 - 1:10 | 21 | 20 | 15 | 20 | 12 | 19 | 35 | 31 | 107 | |
| 1:10 - 1:15 | 24 | 13 | 17 | 16 | 7 | 4 | 33 | 11 | 81 | |
| 1:15 - 1:20 | 20 | 20 | 20 | 21 | 12 | 9 | 41 | 21 | 102 | |
| 1:20 - 1:25 | 30 | 18 | 22 | 14 | 9 | 7 | 36 | 16 | 100 | |
| 1:25 - 1:30 | 32 | 22 | 33 | 17 | 18 | 25 | 50 | 43 | 147 | |
| 1:30 - 1:35 | 32 | 35 | 20 | 2 | 19 | 17 | 22 | 36 | 125 | |
| 1:35 - 1:40 | 38 | 27 | 34 | 18 | 32 | 22 | 52 | 54 | 171 | |
| 1:40 - 1:45 | 55 | 23 | 32 | 34 | 25 | 17 | 66 | 42 | 186 | |
| 1:45 - 1:50 | 92 | 42 | 61 | 46 | 39 | 41 | 107 | 80 | 321 | |
| 1:50 - 1:55 | 85 | 39 | 58 | 59 | 40 | 32 | 117 | 72 | 313 | |
| 1:55 - 2:00 | 87 | 61 | 54 | 42 | 52 | 48 | 96 | 100 | 344 | |
| 2:00 - 2:05 | 68 | 58 | 49 | 36 | 50 | 41 | 85 | 91 | 302 | |
| 2:05 - 2:10 | 87 | 48 | 55 | 51 | 67 | 74 | 106 | 141 | 382 | |
| 2:10 - 2:15 | 94 | 43 | 52 | 49 | 65 | 67 | 101 | 132 | 370 | |
| 2:15 - 2:20 | 99 | 47 | 65 | 48 | 69 | 65 | 113 | 134 | 393 | |
| 2:20 - 2:25 | 106 | 50 | 65 | 52 | 57 | 50 | 117 | 107 | 380 | |
| 2:25 - 2:30 | 108 | 71 | 60 | 55 | 45 | 59 | 115 | 104 | 398 | |
| 2:30 - 2:35 | 109 | 72 | 54 | 60 | 57 | 58 | 114 | 115 | 410 | |
| 2:35 - 2:40 | 103 | 66 | 57 | 46 | 67 | 44 | 103 | 111 | 383 | |
| 2:40 - 2:45 | 106 | 61 | 45 | 32 | 62 | 50 | 77 | 112 | 356 | |
| 2:45 - 2:50 | 107 | 76 | 54 | 50 | 53 | 33 | 104 | 86 | 373 | |
| 2:50 - 2:55 | 127 | 67 | 69 | 41 | 59 | 37 | 110 | 96 | 400 | |
| 2:55 - 3:00 | 141 | 96 | 83 | 70 | 73 | 64 | 153 | 137 | 527 | |
| 3:00 - 3:05 | 121 | 64 | 65 | 49 | 61 | 36 | 114 | 97 | 396 | |
| 3:05 - 3:10 | 19 | 8 | 7 | 9 | 5 | 8 | 16 | 13 | 56 | |

Ref SEL1 [300,5]hdtab2.tab

Table 3

SUMMARY TABLE

| Time | Total Turnstile Count | Total Turnstile Estimate | Total Turnstile + Gate C Estimate | Rate for 5 minutes in people per turnstile per hour |
|---------|-----------------------|--------------------------|-----------------------------------|---|
| 2.00 pm | 2121 | 2368 | 2368 | |
| 2.05 | 2423 | 2670 | 2670 | 517 |
| 2.10 | 2805 | 3052 | 3052 | 654 |
| 2.15 | 3175 | 3422 | 3422 | 634 |
| 2.20 | 3568 | 3815 | 3815 | 673 |
| 2.25 | 3948 | 3948 | 3948 | 651 |
| 2.30 | 4346 | 4593 | 4593 | 682 |
| 2.35 | 4756 | 5003 | 5003 | 702 |
| 2.40 | 5139 | 5139 | 5139 | 656 |
| 2.45 | 5495 | 5742 | 5742 | 610 |
| 2.50 | 5868 | 6115 | 6265 | 639 |
| 2.55 | 6268 | 6515 | 7665 | 685 |
| 3.00 | 6795 | 7042 | 9202 | 903 |
| 3.05 | 7191 | 7438 | 9658 | 678 |
| 3.10 | 7247 | 7494 | 9734 | 96 |

Ref SEL1 [300,5]hdtab3.tab

Table 4

NUMBER OF PEOPLE HAVING THE SAME INTERVAL OF PASSAGE THROUGH TURNSTILE C

| | INTERVAL IN SECONDS | | | | | | | | | | | | Mean Time | Total Count |
|-------------|---------------------|----|----|----|----|----|----|---|---|---|----|-----|--------------|----------------|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | >10 | | |
| 1:50 - 2:00 | 0 | 6 | 11 | 13 | 15 | 19 | 9 | 5 | 3 | 1 | 3 | 15 | 6.0 | 100 |
| 2:00 - 2:10 | 0 | 3 | 7 | 16 | 20 | 23 | 12 | 7 | 3 | 4 | 1 | 10 | 5.7 | 106 |
| 2:10 - 2:20 | 1 | 1 | 4 | 10 | 17 | 20 | 10 | 7 | 4 | 1 | 1 | 14 | 6.7 | 90 |
| 2:20 - 2:30 | 1 | 6 | 20 | 19 | 21 | 12 | 16 | 8 | 6 | 2 | 1 | 9 | 5.0 | 121 |
| 2:30 - 2:40 | 0 | 7 | 26 | 39 | 25 | 17 | 8 | 3 | 5 | 1 | 1 | 6 | 4.3 | 138 |
| 2:40 - 2:50 | 2 | 12 | 23 | 29 | 21 | 14 | 9 | 5 | 7 | 9 | 1 | 5 | 4.4 | 137 |
| 2:50 - 3:00 | 4 | 29 | 47 | 30 | 19 | 7 | 5 | 3 | 1 | 1 | 6 | 11 | 3.7 | 163 |

NB Fig 4 is a visual presentation of the data in this table

Ref SEL1 [3005lhdtab4.tab

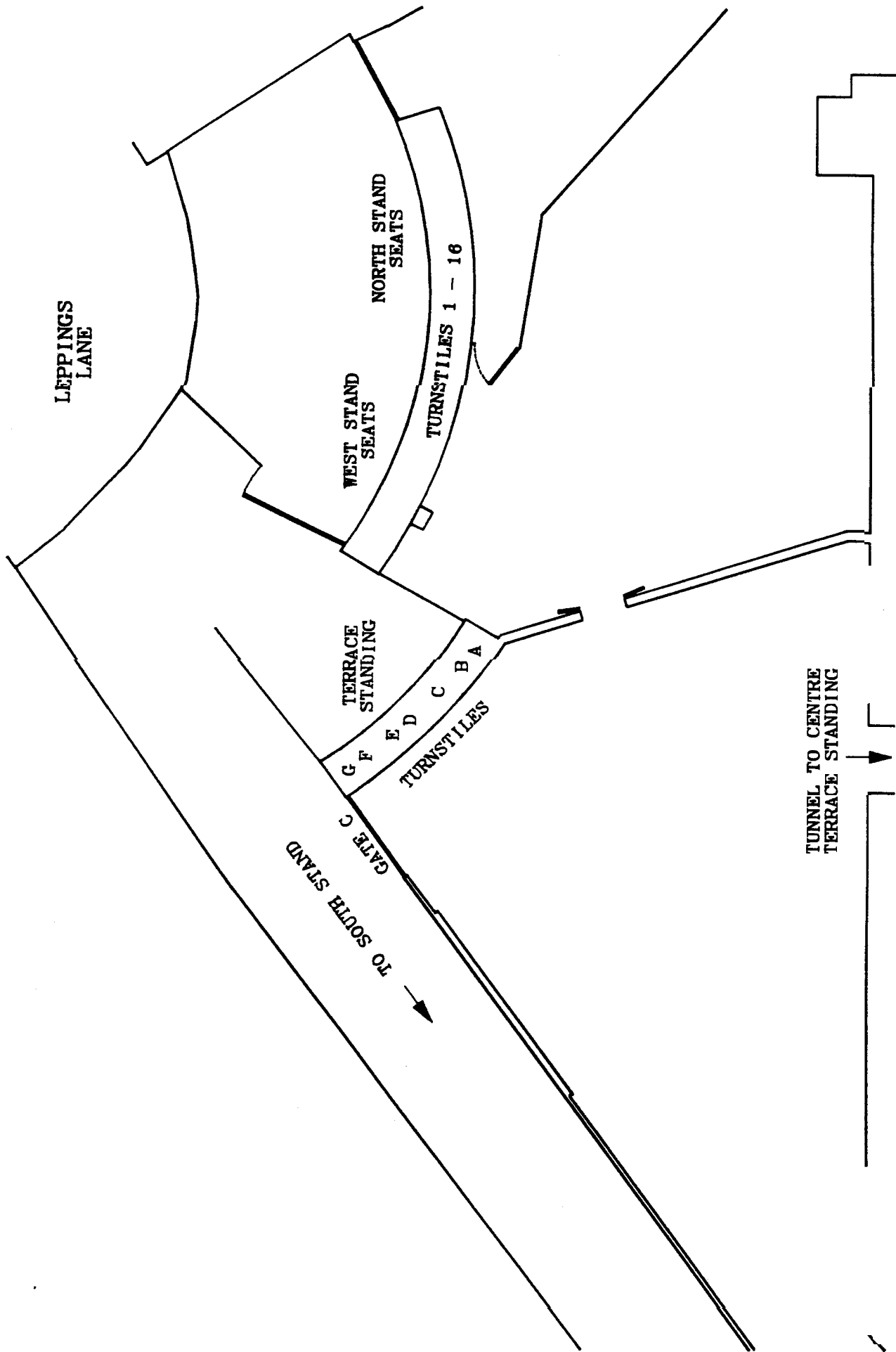


FIG 1 SCHEMATIC PLAN SHOWING TURNSTILES A TO G AND GATE C

RLSD SET TSTIL2/RLLS
 BASED ON
 RALPH BRADY & ASSOCIATES
 TORONTO, CANADA

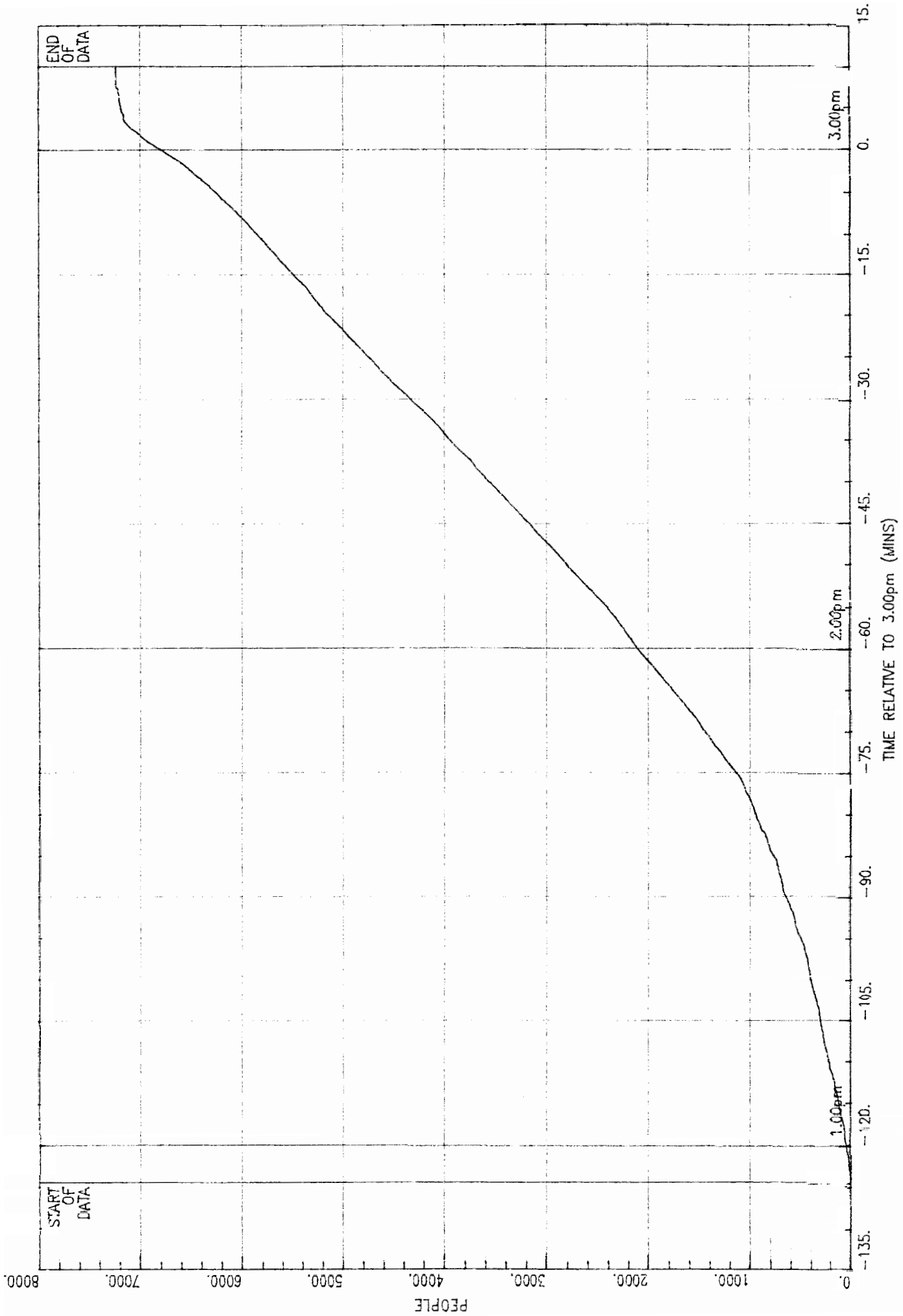


FIG. 2 TOTAL NUMBER OF PEOPLE COUNTED BY RLSD FOR TURNSTILES A TO G

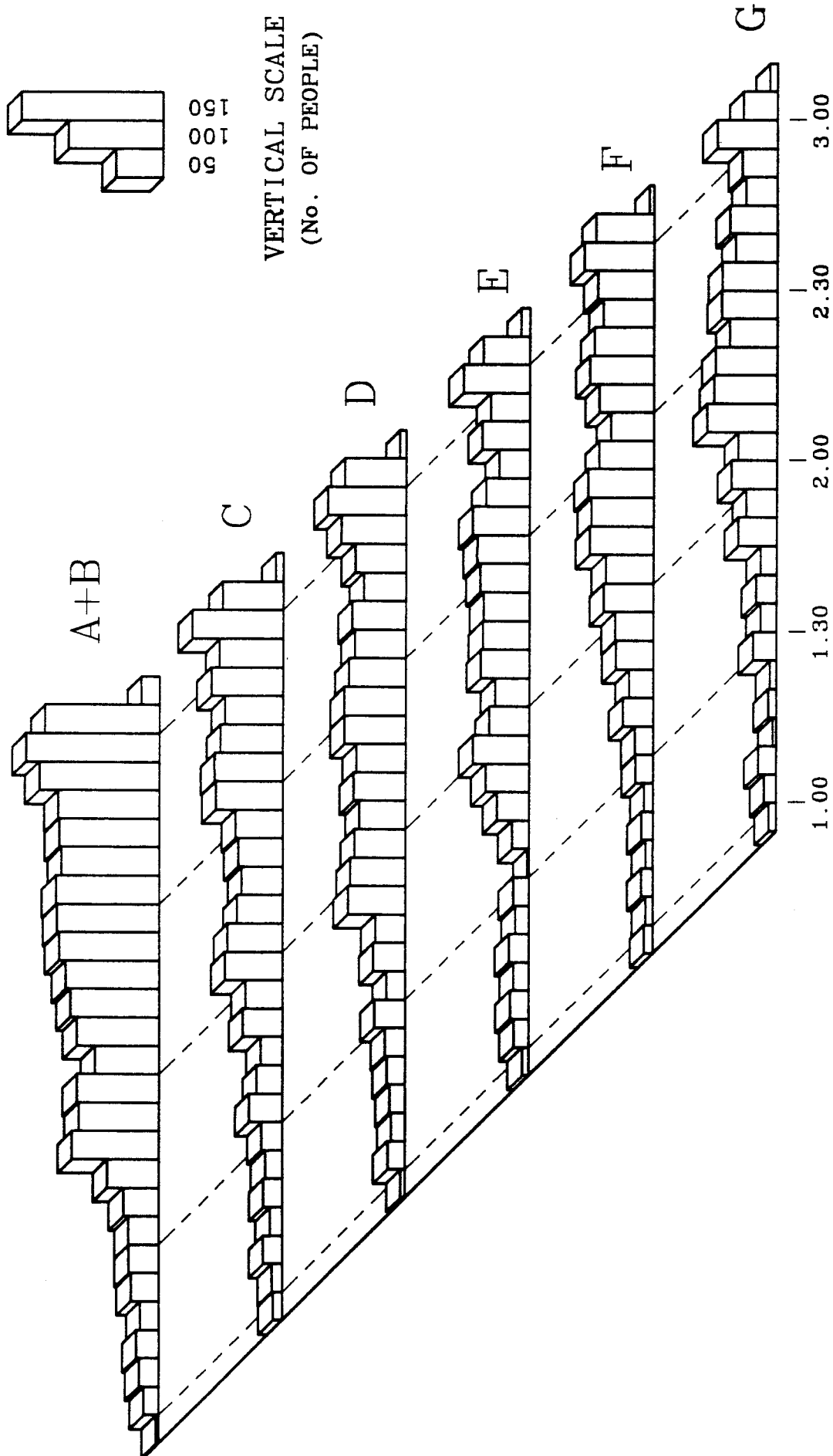


FIG 3 NUMBER OF PEOPLE COUNTED THROUGH TURNSTILES IN EACH 5 MINUTE INTERVAL

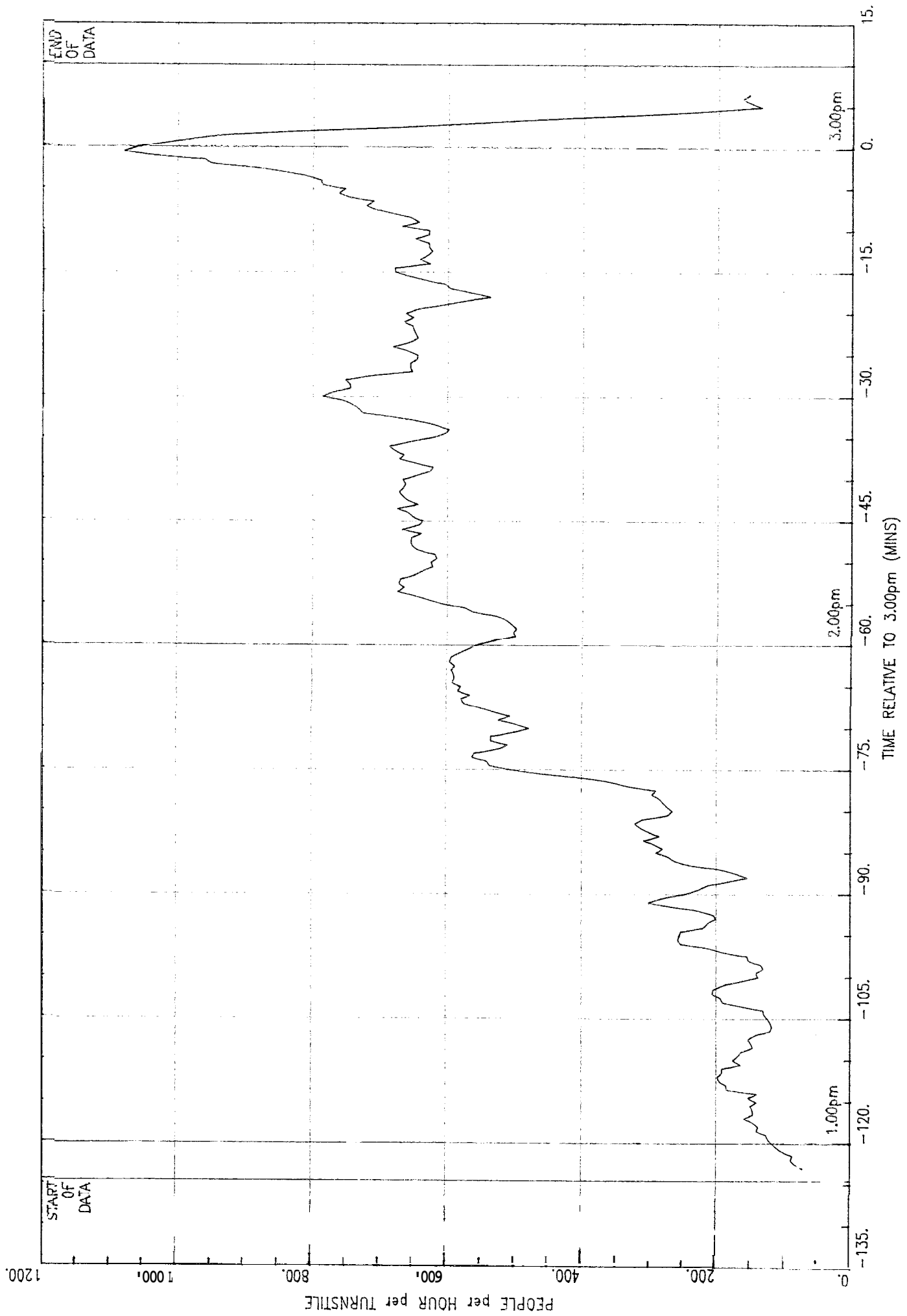


FIG. 4 RATE OF ADMISSION FOR TURNSTILES A to G

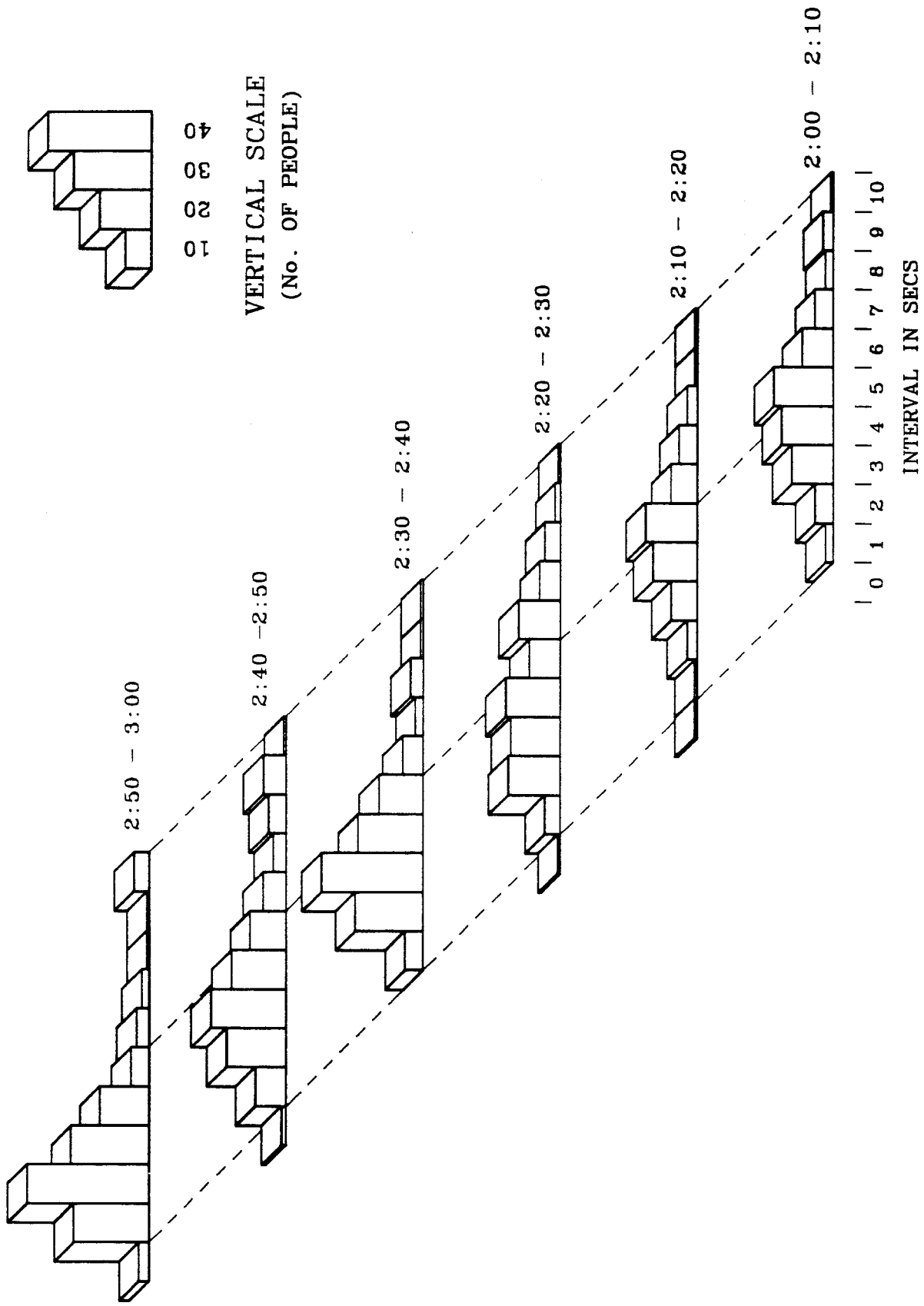


FIG 5 TURNSTILE C - NUMBER OF PEOPLE HAVING THE SAME INTERVAL OF PASSAGE

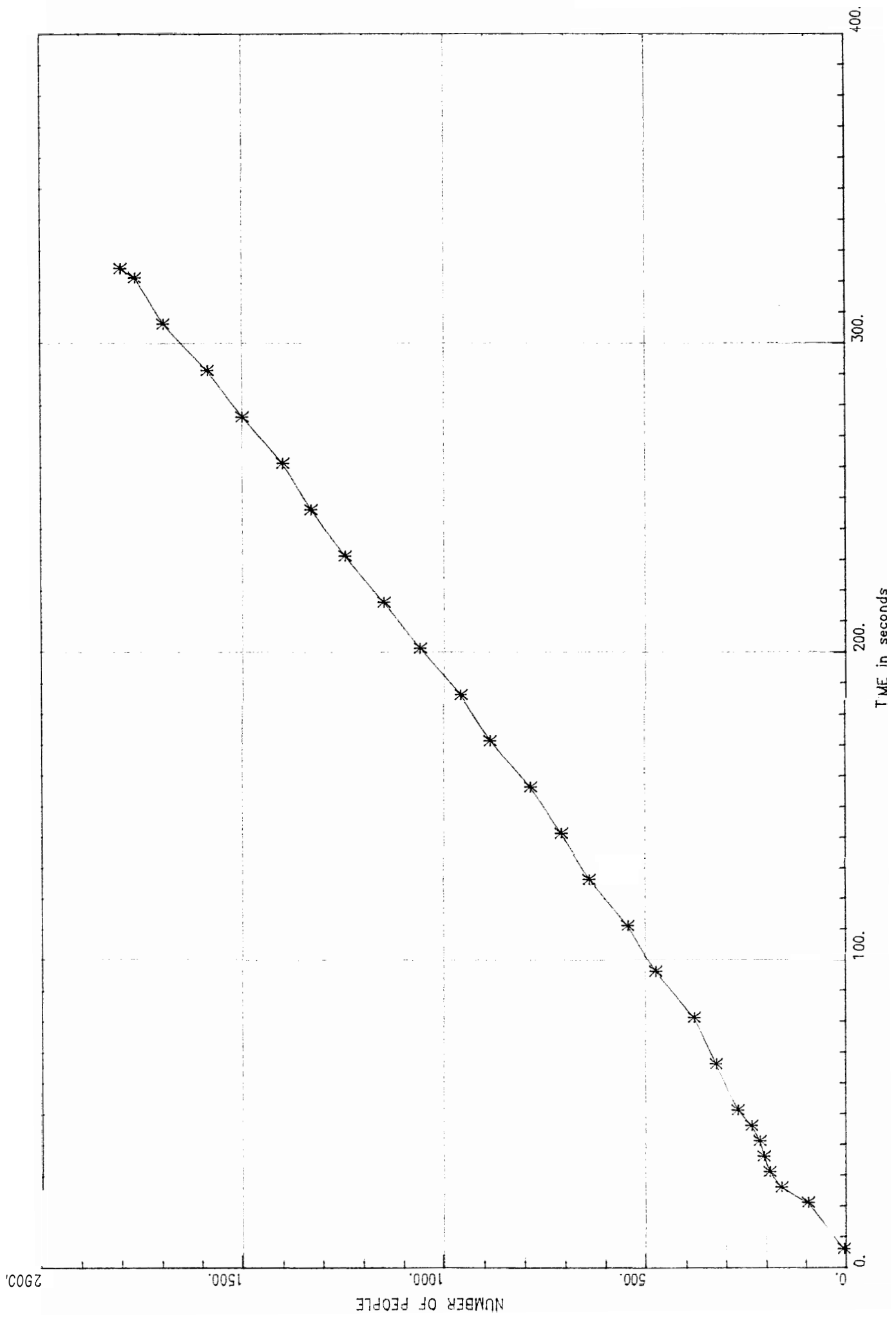


FIG. 6 NUMBER OF PEOPLE EMERGING FROM GATE C AT THE 'SECOND OPENING'