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Flight Transportation Laboratory

Report FTL-R68-6

A SIMULATION STUDY OF DYNAMIC SCHEDULING OF A VTOL
AIRPORT FEEDER SYSTEM

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INTRODUCTION

Dynamic Scheduling

In considering ultra short haul, high density transportation systems, it may become feasible to use short term, real time decision making in operating the system. Here the dispatch of vehicles would be based upon actual traffic demands, the passenger waiting times for service, with perhaps some consideration given to expected future demands at the originating and downstream stations. This is called dynamic scheduling, or demand scheduling to differentiate it from the scheduling planning process which uses as input the expected or average demands for the system over some extended period.

An example of pure dynamic scheduling is present taxi service in most urban areas. A fleet of roving or dispersed taxis is controlled by a centralized dispatcher who receives all demands by phone, and assigns a vehicle to a service using a radio communication system. The other extreme is typified by present domestic airline schedules where services, vehicle and crew assignments, etc. are ordained at least a month in advance, and the schedule is followed as closely as possible. Most transportation systems fall in between these extremes with trains adding extra cars or bus carriers making extra sections available at short notice, etc. The EAL shuttle service is partially dynamic in that the guarantee of a seat may force an unplanned extra section, and is partially planned since a continuing study of the patterns

of demand allows planning for most extra sections. The published shuttle timetable remains fixed although departures occur before, on, and perhaps after the scheduled time.

By having a fixed operating plan, the job to be performed becomes deterministic, and adequate planning can ensure good operating efficiencies over the system as measured by load factor, vehicle and crew utilization, ground facility utilizations, etc. With an uncertain operating plan, the system must have above average resources in order to be able to call them into service at peak or above average times. This implies lower load factors and lower utilizations on the average. The higher efficiencies mean lower costs, and presumably lower fares. The lower efficiencies of the dynamic system may mean higher costs, but will be accompanied, presumably, by better service for the traveller. A number of questions are thereby raised: How much will the traveller pay for an improved service? What sort of service improvements can we provide by being responsive to actual real time demands, and what will they mean in operating costs? What type of market will allow most effective use of dynamic scheduling? What kinds of dynamic scheduling strategies can be employed? How do we discover efficient strategies, and how do we test them?

There does not seem to be any clear or well defined set of answers to such questions. This is a report on some preliminary investigations into the problems of dynamic scheduling in very short haul markets which exist in collecting and distributing passengers from a major transportation center.

Dynamic Scheduling Strategies

The decision making process by which the system operates

is called a scheduling strategy. Given the present system state in terms of accurate real time information concerning demands, passenger waiting time, vehicle availabilities, etc. and some short term expectations of future system states, a set of operating rules is established which determine the transportation system response. This set of rules, (or strategy) always exists, either explicitly in the form of management policy directives, or implicitly in the form of the experience and intelligence used by a taxi dispatcher. Whether complex or simple, there are a wide variety of strategies which can be selected for testing in various markets. Each strategy will use certain information about the system state, which assumes that such information will be made readily available. One of the first problems is to discover strategies which allow efficient operation of the system with an economical use of data about the present and projected system states. This report describes the operation of a final strategy which has evolved from reference 1, and further testing during this study.

System Operational Objectives

The classical aim of airline managements is to maximize short term profits. It could easily be minimization of costs, maximization of revenues or aircraft utilization. From the public service point of view or longer term management objectives, it could be minimization of passenger waiting time. It could be some weighted combination of any of these factors. Different situations will dictate deferent objectives, and it is not clear which objectives are preferable, or what type of strategies are most effective in achieving any chosen objective.

Simulation

Simulation models of operations systems have benefited management in the decision making process and in comparing basic alternatives of operating policy. Computer simulation is a technique which provides management with means of testing and evaluating a proposed system under various conditions. In our study the system's behavior is modeled by a computer program which reacts to various scheduling strategies in a manner very similar to the system itself. With the use of the simulation model, management can thus determine the effects of many alternate strategies without tampering with the actual physical system. The result is that we do not risk upsetting the existing physical system without prior assurance to some degree of confidence that the proposed changes in strategies will be beneficial. Computer simulation thus produces a system which is efficient and fulfills the system operational objectives.

Use of simulation can save cost and time. In this study for example, five days of airline operation have been simulated in less than three minutes of computer time using the General Purpose System Simulator on IBM 7094.

The simulation allows us to follow through the system and observe the effects of blocking caused either by the need of time-share facilities or caused by limited capacity of parts of the system. Outputs of the program give information on:

1. The amount of traffic through the system, or parts of the system.
2. The average time and the time distribution for traffic to pass through the system, or between selective points on the system.

3. The extent to which elements of the system are loaded.
4. Queues in the system.
5. A departure schedule.
6. Miscellaneous parameters of interest in the system.

With our simulation model a number of different dynamic scheduling strategies have been examined. The final decision rules are described in chapter 2. The effects of variations in these final decision rules are shown in chapter 3.

Chapter 1

Description of the Simulation Model

The Dynamic Scheduling Problem

The following describes the GPSS III Simulation done to study a new strategy for local helicopter airline operating as a scheduled air taxi carrier between some twenty heli-stops and the local airport. The helistops can be divided into three geographic groupings. See Figure 1. Any of those

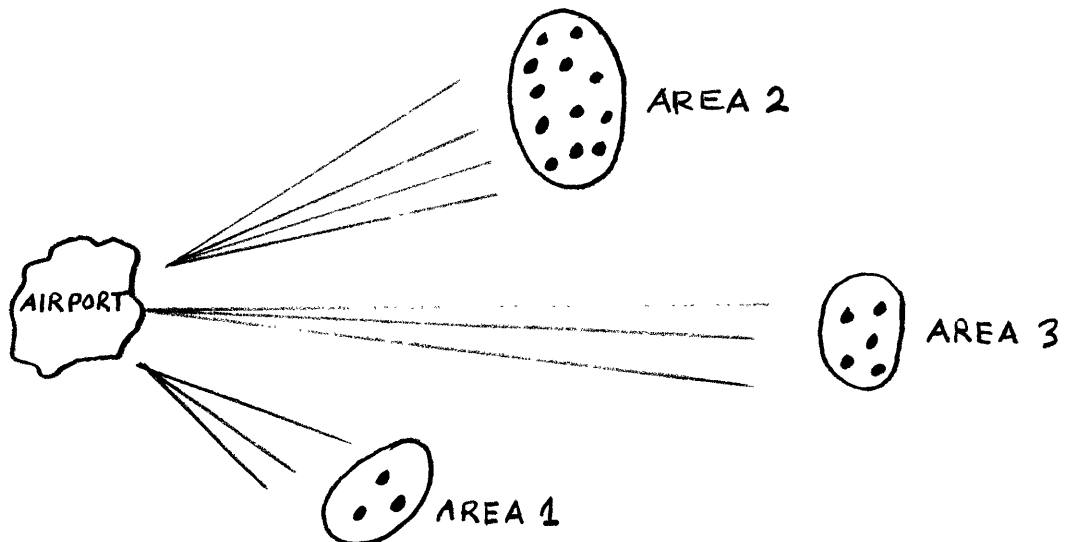


FIG 1 HELICOTER AIR TAXI SERVICE

in group one can be reached in about ten minutes; those in group two require about twenty minutes and those in three about thirty minutes. Fares for the three areas are \$8, \$12 and \$16 respectively.

Demand for travel to and from the airport has been studied and it is felt that Figure 2 is representative of the time of day variations. Passenger arrivals were considered at two points:

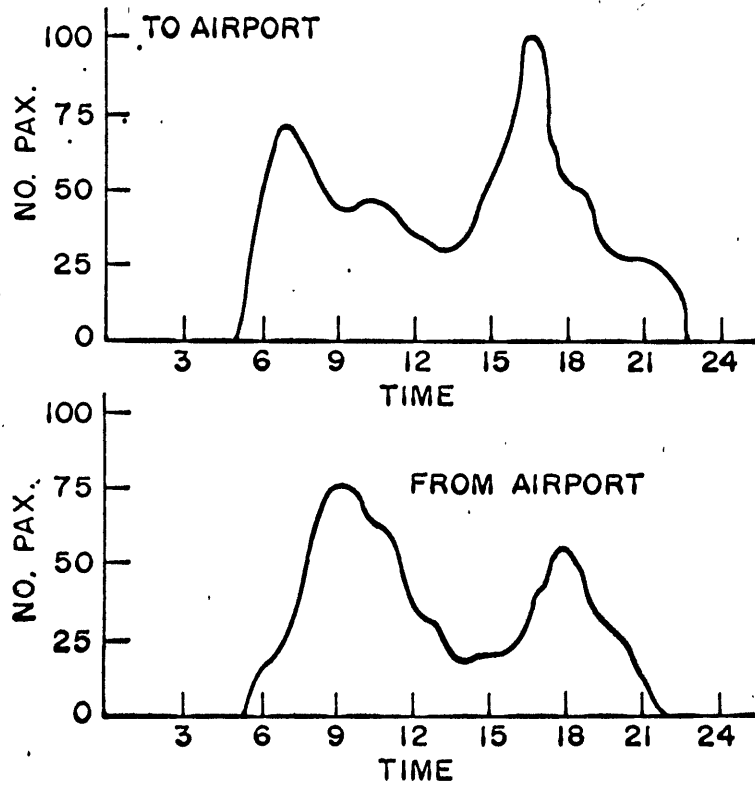


FIGURE. 2. DAILY VARIATION IN DEMAND TO AND FROM AIRPORT

- a) At the airport with the destination being an outstation determined randomly.
- b) At an outstation, also determined in a random manner, with the destination being the airport.

No inter-station travel is considered. The problem may be classified as the "many to one, one to many" collection and distribution problem.

The passenger interarrival time was determined by multiplying the mean interarrival time by the bias. The mean interarrival time was taken to be twenty minutes. The bias on the mean incorporated the time of the day variations in our model. Although the determination of the passenger interarrival time was the same in both directions, the time of the day variations (a bias on the mean) at the two points was different and the respective peak periods were out of phase. See Figure 2.

$$\text{Interarrival Time} = \text{Mean} \times \text{Bias}. \quad (1.1)$$

Passengers are generated simultaneously at the airport and at the outstations. Passengers queue up by area to await satisfaction of one of the dispatching criteria. The length of delay before an aircraft can be dispatched is recalculated each time a departure is considered. Its value depends upon certain expectations with respect to passenger demand at the stations immediately affected and to the current disposition of aircraft in the system.

The Learning Process

During the course of the day, data on demand is compiled and stored away in computer locations or cells, which

have been previously assigned. The address of these storage cells is a unique number indicative of the time of day (in ten minute intervals) and the direction of the demand, i.e., inbound or outbound from the airport. The contents of the cell is the number of passengers travelling in the indicated direction during the particular time interval. Thus, what is in effect a demand distribution is being generated throughout the course of the day. Simultaneously a count is maintained of the total number of passengers travelling in each direction to or from the individual areas. This count is later used to establish relative probabilities.

At the commencement of the simulation run, the demand storage locations and probabilities are initialized with a priori values. These may be based either on past data or our own subjective expectations.

At the termination of the day, the distribution and probabilities are updated using, in essence, a Bayesian approach. For example, at the end of the first day a demand storage location for outbound traffic between 7:00 and 7:10 A.M. would contain a number representing the sum of the a priori value and the number conforming to today's arrivals occurring during that time interval. Although the relative weightings assigned to the priors and the current measures may vary as we choose, here they were considered to be equally weighted. That is, the posterior value of the passenger function

$$= \frac{\text{a priori (or prior)} + \text{current}}{2} \quad (1.2)$$

Therefore, updating at the conclusion of the day requires simply a division by two. The current passenger arrivals

are being added to the prior in real time, but as the distribution is referred to only to determine expectations for future time periods, only the prior (yesterday's posterior) enters into today's calculations.

With the day's operations complete, the program also calculates six probability measures based upon the particular day's performance.

1. Prob (Inbound passenger originates in area 1)
2. Prob (" " " " " 2)
3. Prob (" " " " " 3)
4. Prob(Outbound passenger is destined for area 1)
5. Prob(" " " " " " 2)
6. Prob(" " " " " " 3)

Of course, the first three and the second three probabilities sum to one. These measures are daily average probabilities of traffic flow to or from the individual areas. During the simulation they are used to update the prior (or a prior) probability measures. Here again, an equal weighting was assumed, thus attributing greater importance to the more recent information.

$$\frac{\text{Prior} + \text{Current}}{2} = \text{Posterior} \quad (1.3)$$

The posterior becomes tomorrow's prior and is used in the dispatching decision.

The Dynamic Scheduling Strategy

In general terms, the scheduling strategy used in this report is described as follows:

1. A dispatching delay time is calculated, depending on aircraft disposition, number of passengers waiting in

outbound and inbound queues and passengers expected in the very near future. Generally the first arriving customer is made to wait this calculated time before triggering a departure. This delay time calculation is a parameter of the system.

2. Should a passenger arrive and find that there is a plane leaving to the area where he is destined for, then this passenger will be taken on board without further delay assuming that a seat is available for him on the flight.
3. In all cases when a full capacity load is available, the aircraft will depart immediately.
4. If an aircraft is not available at the outstation where the passenger is and several aircraft are on the ground at other outstations in the area, one on these will be selected and ferried to the desired point of departure. The criterion for this selection is the aircraft which has been grounded the longest.
5. When a passenger arrives at an outstation with no aircraft available in the area and no aircraft en route to the area, he will be held for a calculated amount of time prior to calling for a ferry from the airport.
6. If a flight (either revenue or ferry) is en route to an area no ferry calls from that area will be accepted for additional aircraft until the return flight has departed.
7. If a flight delivers passengers to an area where there are no passengers waiting to return to the airport, it will wait a calculated amount of time (depending on aircraft disposition and traffic flow expectations) before returning to the airport empty. If waiting passengers are in the area they will use this aircraft when it is time for their departure.

There is a maximum waiting time for a passenger built into these delay time calculations. Unless aircraft are busy, the first arriving passenger will depart in less than this guaranteed time. The time to ferry an aircraft from the airport to an area is accounted for in determining the time to call for ferry aircraft.

These decision rules are precisely described in Chapter 2.

Assumptions

1. The flight times are the same in both directions.
2. Every extra stop within a geographic area increases flight time by five minutes.
3. Operating cost is assumed to be \$1.25 per flight minute.
4. The working day is from 6 a.m. to 10 p.m., with units of time in 5 minute intervals.
5. Aircraft seating capacity is three passengers.

Output

a) Normal Departures

Operation of the model yields a resulting departure schedule for the outbound (airport to the outstations) and inbound (into airport) flights. Print out of each departure gives the following information:

1. Time of departure
2. Origin and destination
3. Total flight time
4. Number of passengers on board
5. Number of aircraft remaining at the airport

Throughout the day, data is kept about ferry calls and ferry returns.

b) Ferry Call Departures

A Ferry Call departure can have one of two possible outcomes.

a) An aircraft departs from the airport empty destined for the outstation where the call came from. In this case the print out includes:

1. The area of call
2. The amount of time the passenger waited before his call for an aircraft was accepted
3. The total number of ferries up to and including this call
4. The queue statistics at the areas

b) The aircraft departs from the airport, carrying any waiting passengers to the area where the call came from. In this case the departure is regarded as an ordinary revenue flight.

c) Ferry Return Departures

A Ferry Return departure can have ~~one~~ of the two possible outcomes.

a) If there are no passengers waiting to go to the airport, the aircraft will be held at the outstation for a calculated amount of time. Having waited this time, the aircraft will either: (1) depart empty. In this case the print out would include the area from where the aircraft is leaving, the length of time the aircraft waited before departing for the airport, and the total number of ferries up to and including this departure; (2) Depart with any passengers if they should materialize before the plane departs. In this case, although the departure will be counted as a regular revenue flight, the print out would be of a slightly different format.

b) If there are passengers waiting to go to the airport when the aircraft reaches any one of the outstations in the area, the aircraft will be delayed until it is dispatched in the usual manner due to normal dispatching delay rules.

d) Summary Statistics

The daily print out also includes statistics at the end of each day of the five days of operation. They include the following:

1. The total number of outbound and inbound passengers
2. Distribution of passengers by area
3. Aircraft disposition
4. Total number of ferry flights
5. Total number of outbound and inbound revenue flights
6. Distribution of revenue flights by area
7. Total ferry time
8. Total revenue flight time
9. All six queue statistics up-dated to the current period
10. Profit or loss for the day
11. Probability distribution up-dated to the current period

The Dynamic Scheduling Strategy

Details of Dispatching Rules

Basically there are three criteria comprising the dispatch rule at the airport. For the outstations the same general rules apply except that an additional heuristic criteria is established to govern the decision to call for a ferry flight from the airport. This criterion states that the total number of aircraft at or en route to the area in question are insufficient to meet the current demand. If such is the case, another ferry will be called.

2.1 Outbound Departure Rules

Passengers in any one of the outbound queues can trigger off a departure as long as one of the following rules has been satisfied. We have built into our model, the requirement that there has to be an aircraft available at the airport. Should there be more than one passenger in any one queue destined for the same area, only one passenger is allowed to trigger off a departure. The remaining passengers for that area will be drained off and taken on flight. For example if one passenger has waited long enough to trigger off a departure and two more passengers materialize just prior to the departure, then these two passengers will board the aircraft without further delay.

2.1.1 Capacity Rule

If the number of passengers waiting in any queue exceeds the capacity of the aircraft (at present 3) then provided that there is an aircraft at the airport, it will be dispatched immediately.

2.1.2 Economic Rule

If there are less than three passengers waiting in

any one of the three queues, then the earliest passenger arrival will be delayed by a calculated length of time. When a passenger's waiting time exceeds this value, the flight will be dispatched. The length of the dispatching delay is a function of the weighted average of the following two components.

1. Aircraft Disposition

$$r_1 = \frac{\text{Number of aircraft at or en route to the airport}}{\text{Fleet Size}} \quad (2.1)$$

As r_1 increases the passenger delay at the airport is reduced. Figure 2.1 shows that as r_1 increases, the associated delay component D_1 is assigned lower and lower values.

2. Expected Traffic Flows

$$r_2 = \frac{\text{Expected outbound passengers in the next ten minutes for area } A_i}{\text{Number of inbound passengers waiting in queue } Q_i} \quad (2.2)$$

As r_2 increases the passenger delay at the airport will be increased as shown in Figure 2-2.

The calculated dispatching delay at the airport is made up of these two components. Intuitively the components seem to be reasonable. If most of our fleet is at or en route to the airport, then passenger delay at the airport is small. On the other hand if a good part of our fleet is or on its way to the outstations, then aircraft departures at the airport will be delayed longer. Similarly, if the ratio of expected passengers for the area in the next ten minute interval to the number of passengers at the outstation queue is large, then passengers at the airport will be delayed longer in expectation of these new arrivals.

Initially these two components were weighted equally

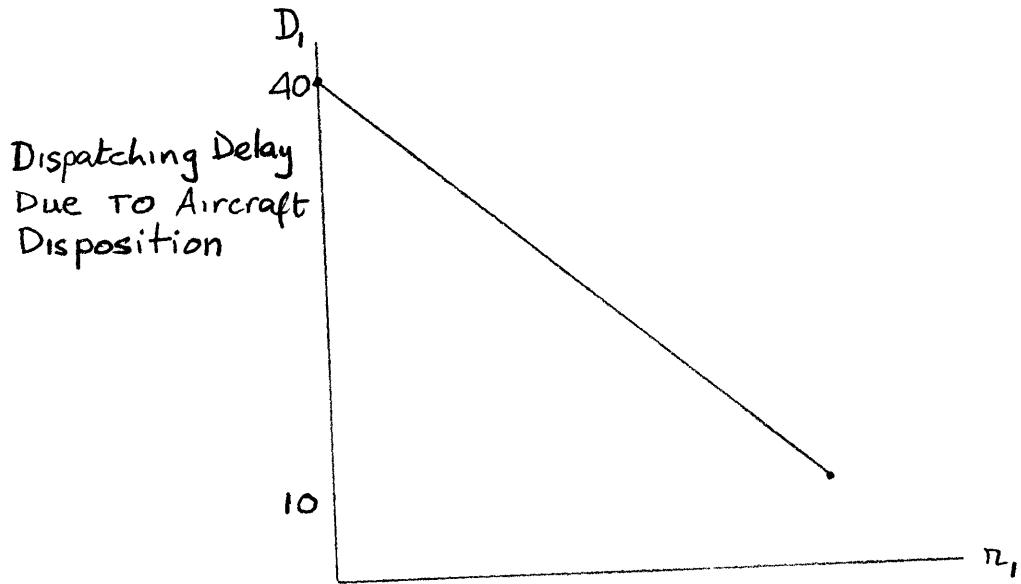


FIG 2.1

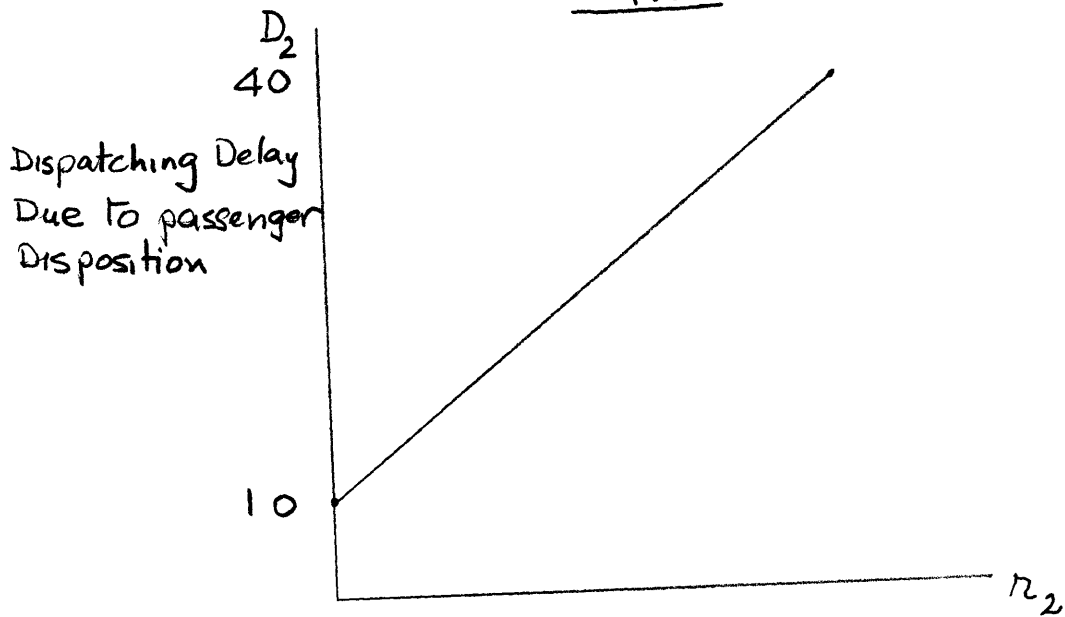


FIG 2.2

DISPATCHING DELAY FUNCTIONS (OUTBOUND)

to obtain the total delay time before an aircraft can be dispatched. The total dispatching delay time in minutes is given by D_0 . See Figures 2.1 and 2.2.

$$D_0 = D_1 + D_2 \quad (2.3)$$

In Chapter 3, Section 3.7 we will vary the weights on these two components of the delay time. As will be seen later the relative weights on these two components do affect flight operations.

2.1.3 Ferry Call Departures

An aircraft will be dispatched if a ferry call has been accepted. Should there be passengers waiting at the airport destined for the area from where the ferry call was made then these passengers will be taken on board the ferry regardless of the time they have waited at the airport. This section complements Section 2.2.3.

2.2 Inbound Departure Rules

As for the outbound case there are three conditions and only one has to be satisfied before an aircraft can be dispatched from any one of the three areas. Once again there is the built-in requirement that there has to be an aircraft at one of the three areas before a departure can take place.

2.2.1 Capacity Rule

This rule is exactly the same as 2.1.1 for the outbound case.

2.2.2 Economic Rule

The length of dispatching delay at an outstation depends on the same two factors as described in Section 2.1.2.

1. The Aircraft Disposition

$$r_3 = \frac{\text{Number of Aircraft in or en route to the area}}{\text{Fleet Size}} \quad (2.4)$$

2. The Expected Traffic Flow

$$r_4 = \frac{\text{Expected inbound passengers in the next ten minutes}}{\text{Number of outbound passengers waiting at the airport}} \quad (2.5)$$

The passenger delay in minutes due to positioning of the aircraft and the expected traffic flow is described by Figures 2.3 and 2.4. Once again if most of our fleet is at or on its way to one of the areas, then passenger delay would be lower than if most of the aircraft were at or on the way to the airport. Similarly if the ratio r_4 was high then the passenger delay at the area would be greater to accomodate these arrivals.

The total dispatching delay is given by D_i which is made up of two components as before.

$$D_i = D_3 + D_4 \quad (2.6)$$

Once again the components were initially given equal weights. An aircraft will be dispatched as soon as any passenger's delay time exceeds D_i .

2.2.3 Ferry Call From An Outstation

When an inbound passenger has waited the calculated delay time D_i less flight time to the area, but there are no aircraft at the area, a ferry call can be made. The ferry call will be accepted at the airport if and only if there are one or more aircraft at the airport.

The ferry call rule also has the built-in requirement that there must be no aircraft en route to the area of call. Once the ferry call has been accepted, whether a pure ferry

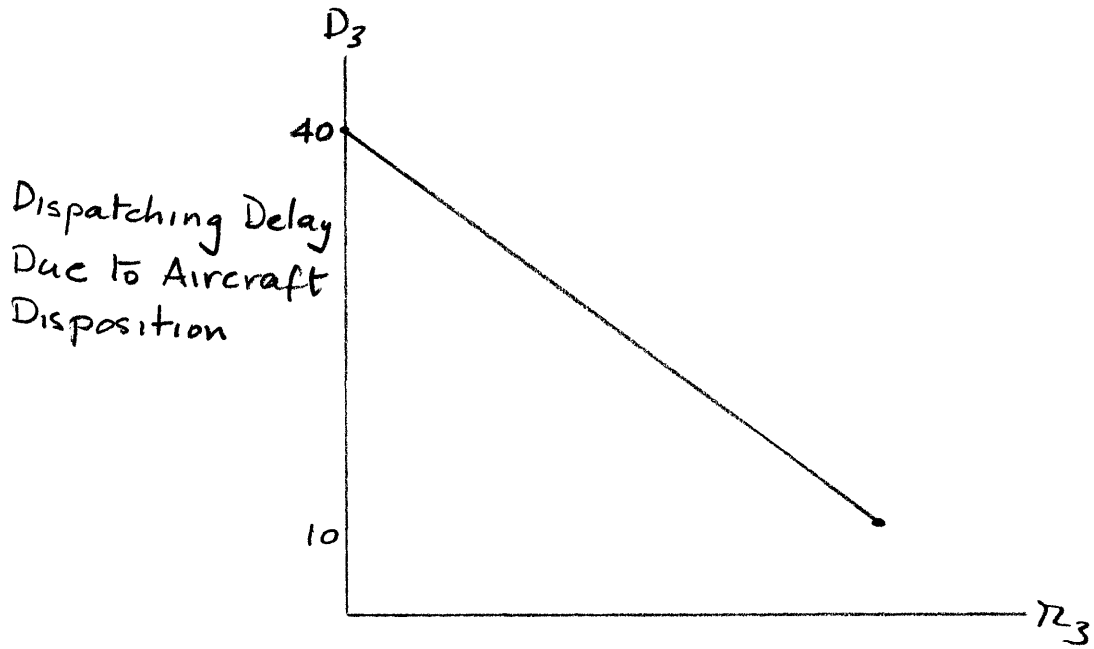


FIG 2.3

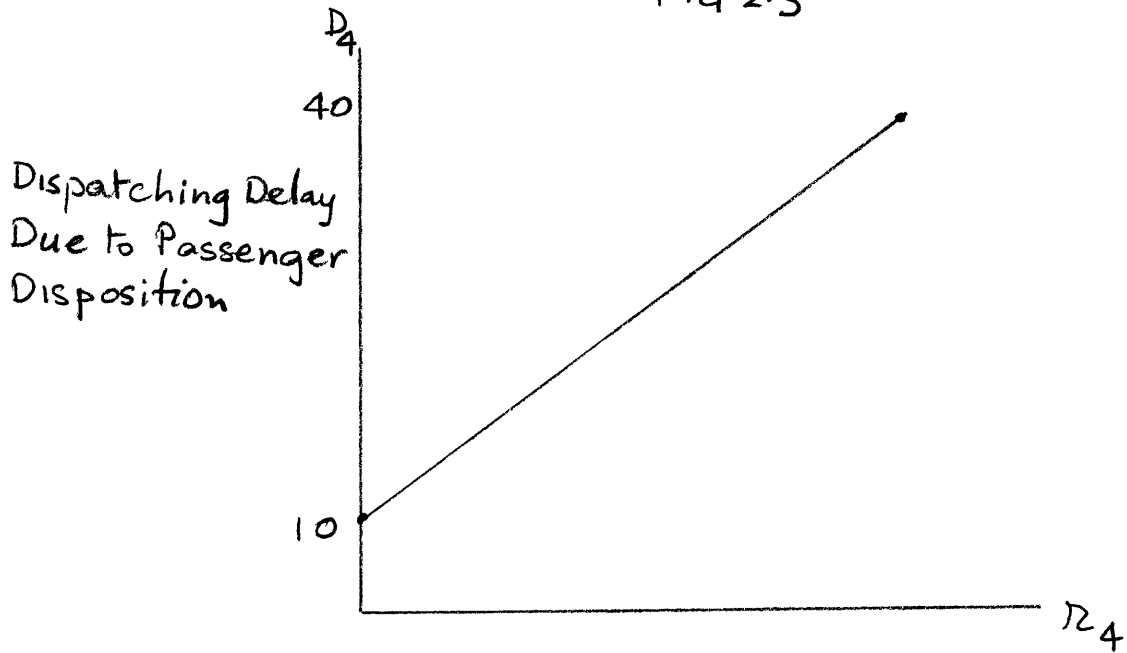


FIG. 2.4

DISPATCHING DELAY FUNCTIONS (INBOUND)

or a ferry with outbound passengers, the caller of the ferry simply waits until the aircraft arrives in the area. On the aircraft's arrival at the outstation a normal departure can take place.

2.3 Ferry Return

Once an aircraft has departed from the airport, reached its destination and deplaned its passenger it would attempt to find passengers eligible to return to the airport. If this aircraft is required by passengers at another outstation in the same area it will be sent there without further delay. However, if there is no need for this aircraft at any of the outstations in the same area, it will wait for a certain length of time at the outstation before it can return empty to the airport. The length of this wait will depend on the following two factors:

1. The Aircraft Disposition r_3 . See Figure 2.5. If the numerical value of r_3 is large, namely most of the fleet is at or on its way to the area in question then the wait before the present aircraft can be returned will be small.

2. As before, the wait will also depend on the ratio of the expected number of inbound passengers in the next ten minute interval to the number of outbound passengers waiting at the airport. If this ratio, r_4 is high then the aircraft will be delayed for a longer period of time before it can be allowed to ferry return empty to the airport. See Figure 2.6. Having waited the calculated time W , the aircraft will be ready to return empty.

Just prior to departing empty, if one or more inbound passengers do materialize, then they will be taken on

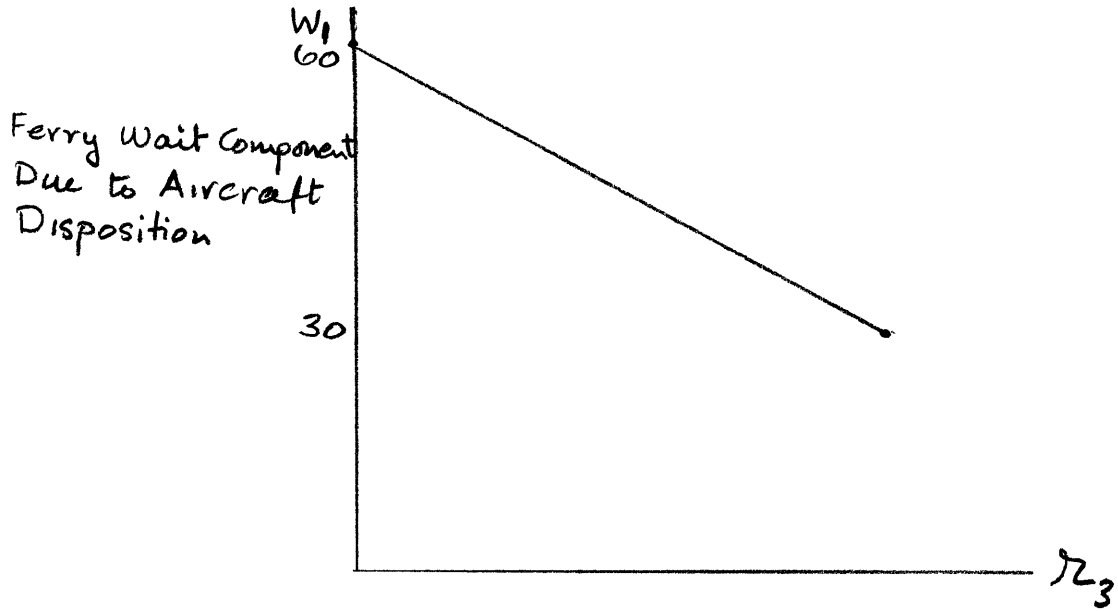


FIG 2.5

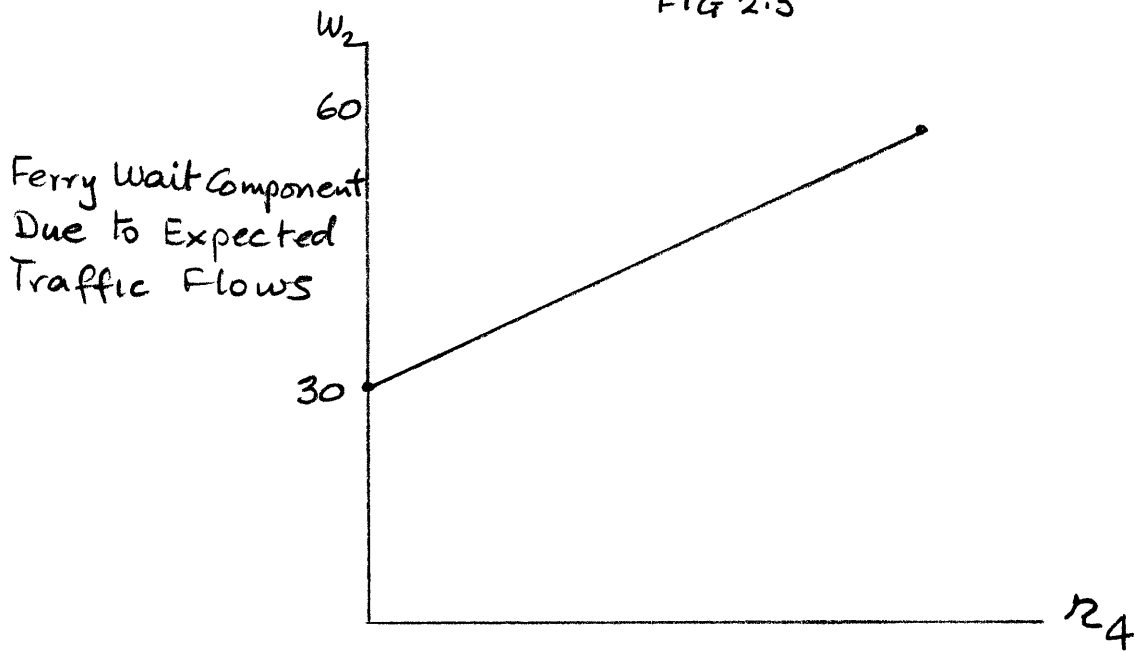


FIG 2.6

$$W = \frac{W_1 + W_2}{2} \dots\dots\dots (2.7)$$

FERRY WAIT DELAY FUNCTIONS (INBOUND)

board without further delay even if they have just entered an inbound queue. In this case although the departure would be regarded as normal, it is however, a ferry return with passengers and would be identified as such in the print out.

Chapter 3

Results of Simulation Runs

In this section we will attempt to show the sensitivity of our model to variation in certain critical parameters in the decision strategy or system operations.

3.1 Fleet Size Variation

The effects of varying the fleet size is seen in Figures 3.1 through 3.6. Average passenger delay, average contents of the queues, daily aircraft utilization and average passenger load factor, all decrease as the number of aircrafts in the fleet is increased. One would expect such results since some of the variables plotted in Figures 3.1 through 3.6 are interrelated. For example, as we increase the number of ferries, the average load factor would decrease. The total number of ferries in the five day run increases with fleet size. Figure 3.5 shows that this relationship is linear.

Profit in our model is defined as total fares less total operating costs which are taken to be \$1.25 per flight minute. Figure 3.6 shows that the current operation is producing a loss. The loss increases linearly with fleet size up to eight aircraft in the fleet. The average daily loss increases at a smaller rate when the number of aircrafts in the fleet exceeds eight.

From Figure 3.1 we see that the average passenger delay varies from about 50 minutes with four aircrafts in operation to about 22 minutes with ten aircraft fleet. From the shape of the curve in Figure 3.1 we notice that increasing the fleet size above ten aircraft will not

produce a significant reduction in the passenger delay. One way of reducing the average passenger delay would be to shift the curve down in Figure 3.1. This can be achieved by changing the delay functions described in Sections 2.1.1, 2.2.2 and 2.3. The important point to observe in Figure 3.1 is the shape of the delay curve and not its relative position on the scale. It is up to management to decide on the quality of service offered to customers. A longer passenger delay would reduce customer patronage. On the other hand a smaller passenger delay would increase the total number of ferries and thereby reduce the average load factor. Thus there exists a trade off between average passenger delay and average load factor.

Average waiting time can be shown ~~(to be taken)~~ (reference 2) to be directly proportional to the average load factor. Our results verify this empirically. Figure 3.7 shows a linear relationship between average waiting time and average load factor.

From reference 2, let

\bar{D} = average waiting time

T_d = total operating time in a day

\bar{T}/C = market density

= number of full plane loads of traffic per day

\bar{LF} = average load factor

$$\bar{D} = \frac{T_d}{2(\bar{T}/C)} \cdot (\bar{LF}) \quad (3.1.1)$$

Since T_d and (\bar{T}/C) can be taken as constants, Equation 3.1.1 simplifies to

$$\bar{D} = K (\bar{LF}) \quad (3.1.2)$$

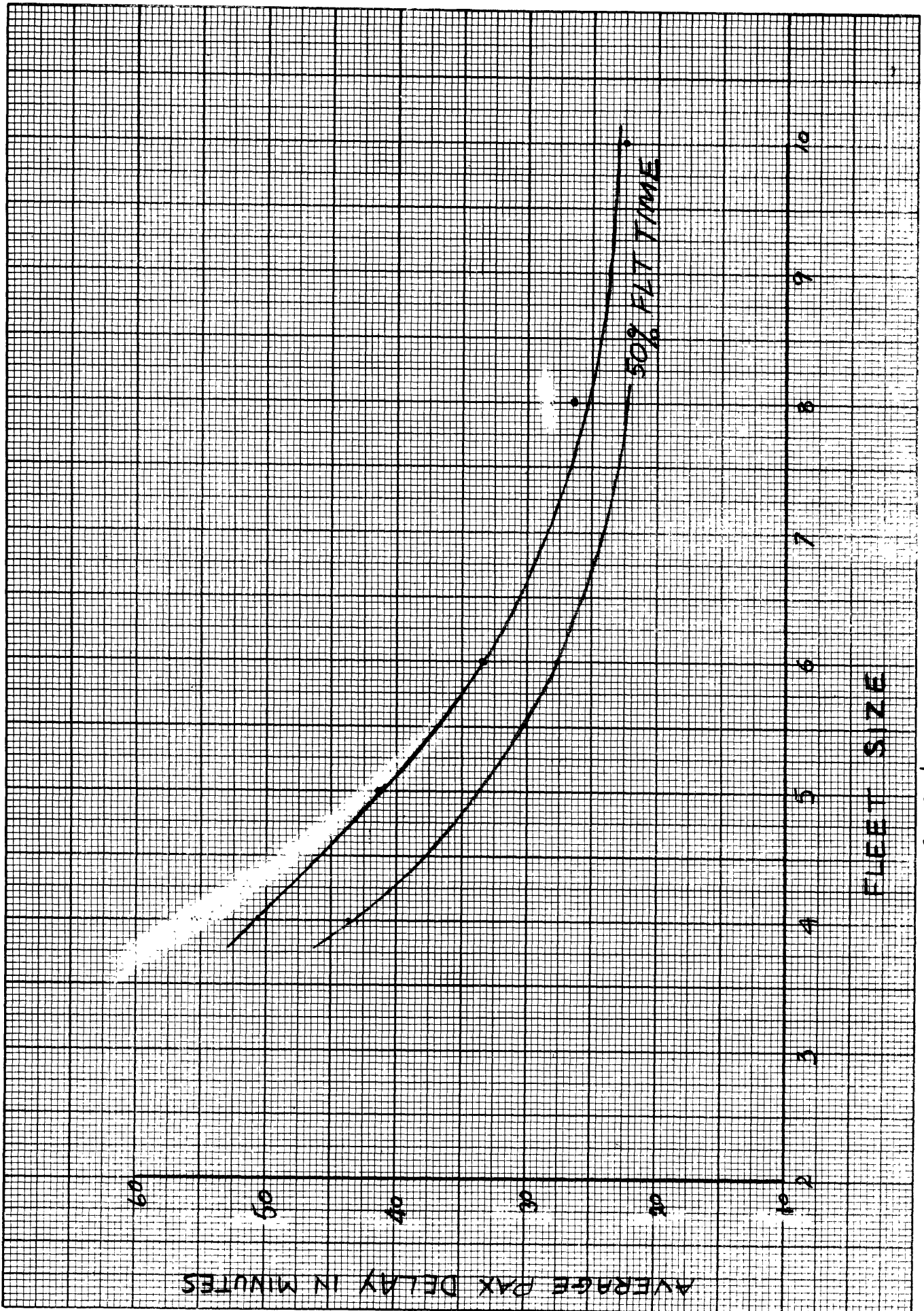


FIG. 3.1

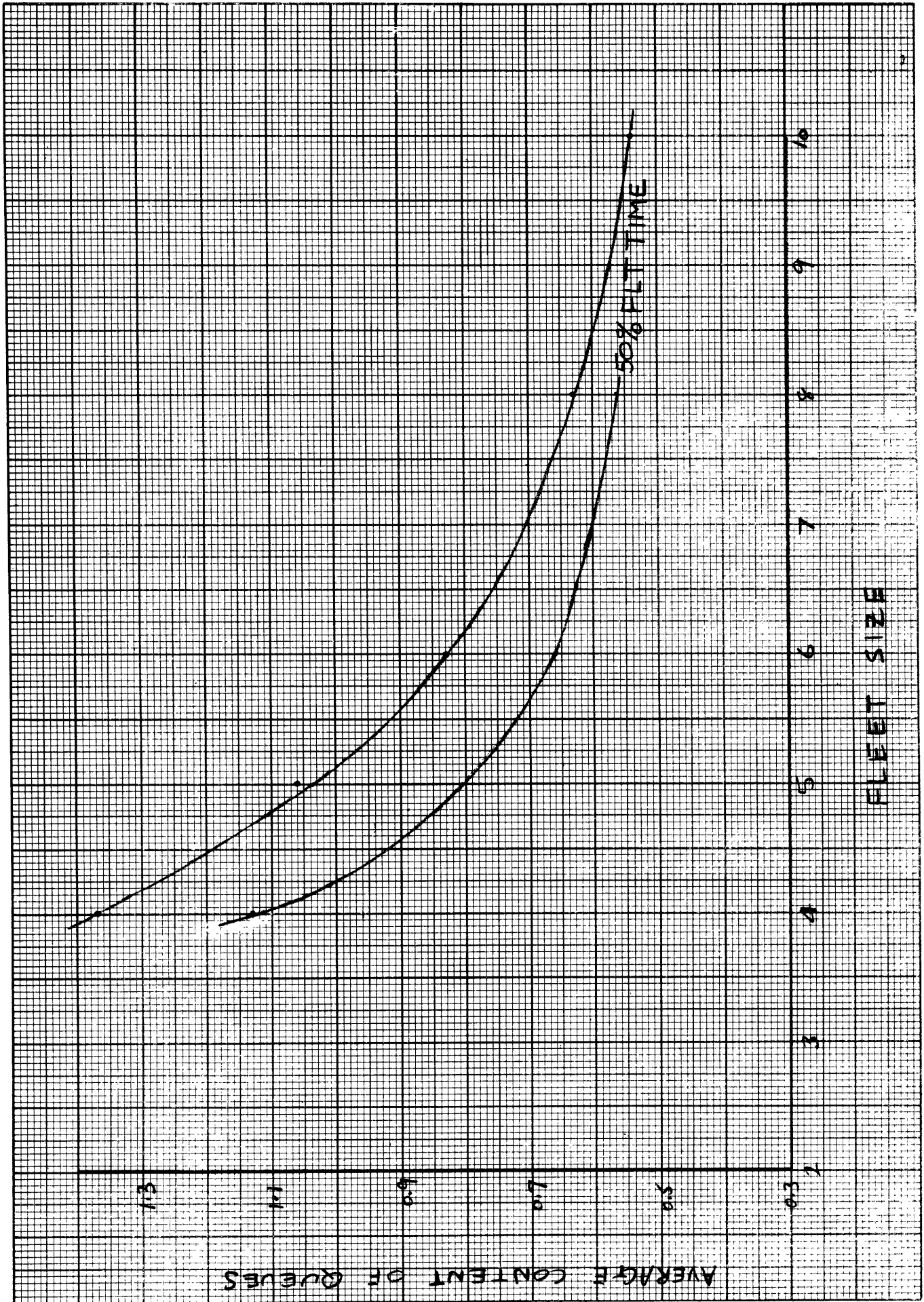


FIG 3.2

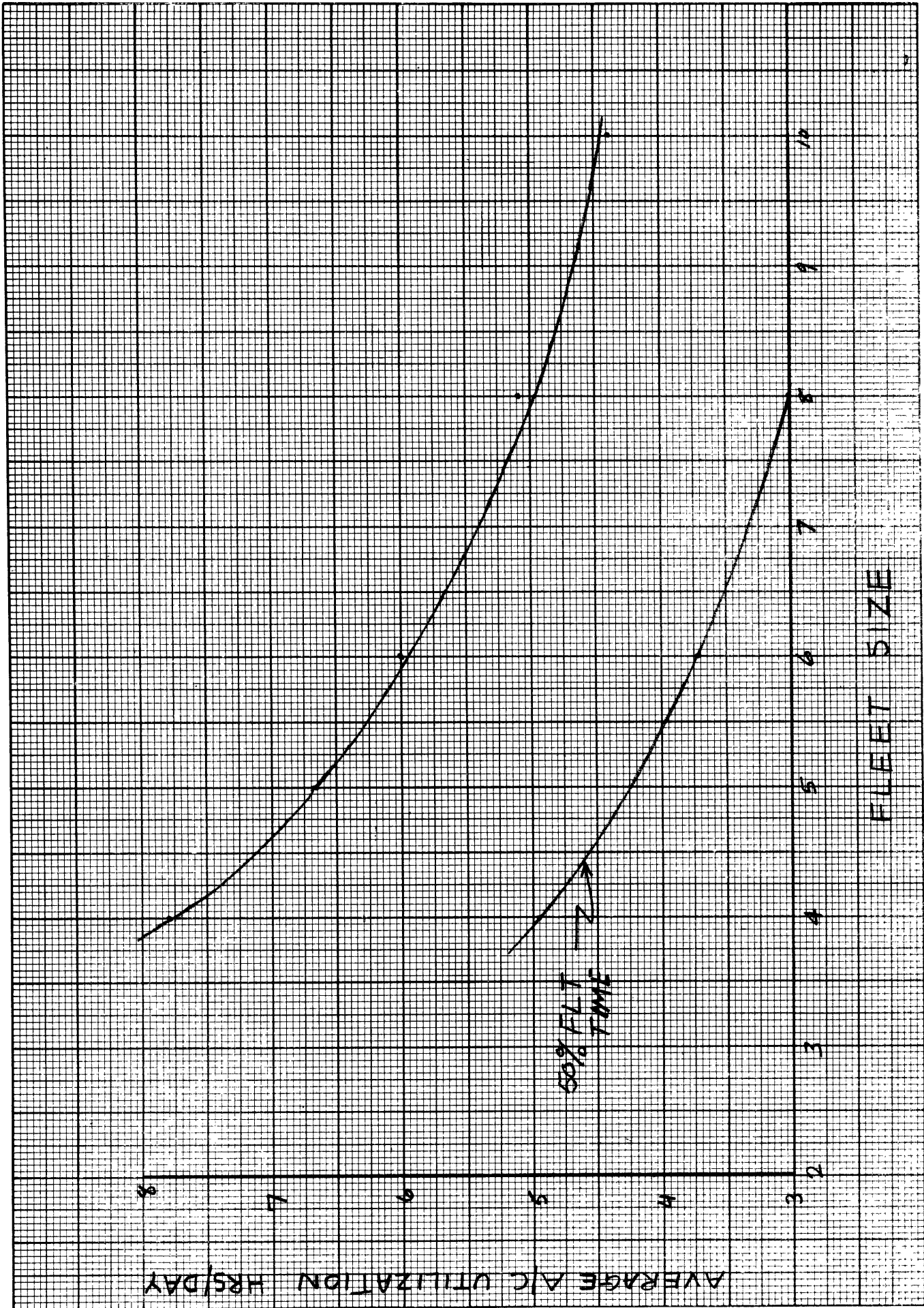


FIG 3.3

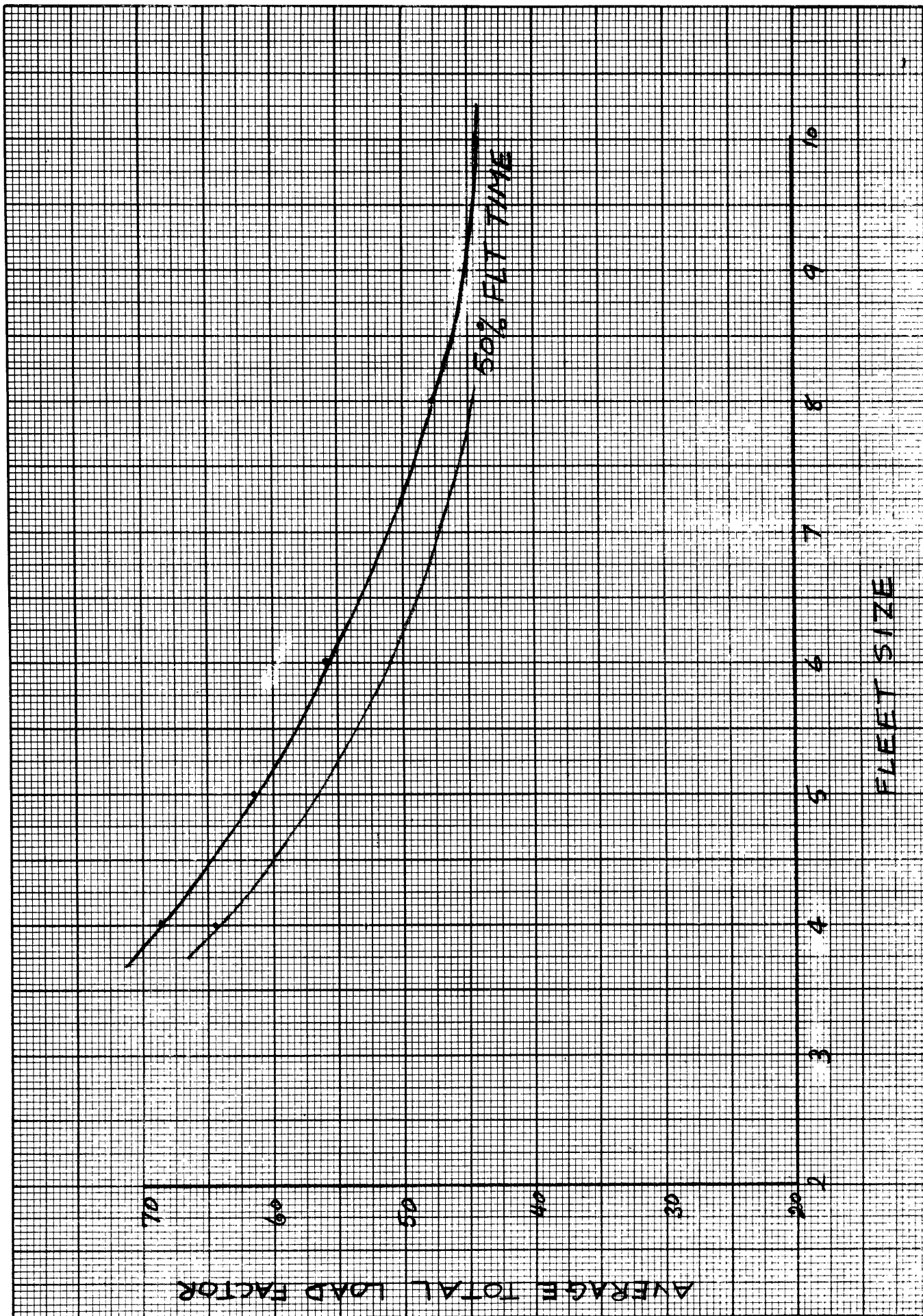


FIG 3.4

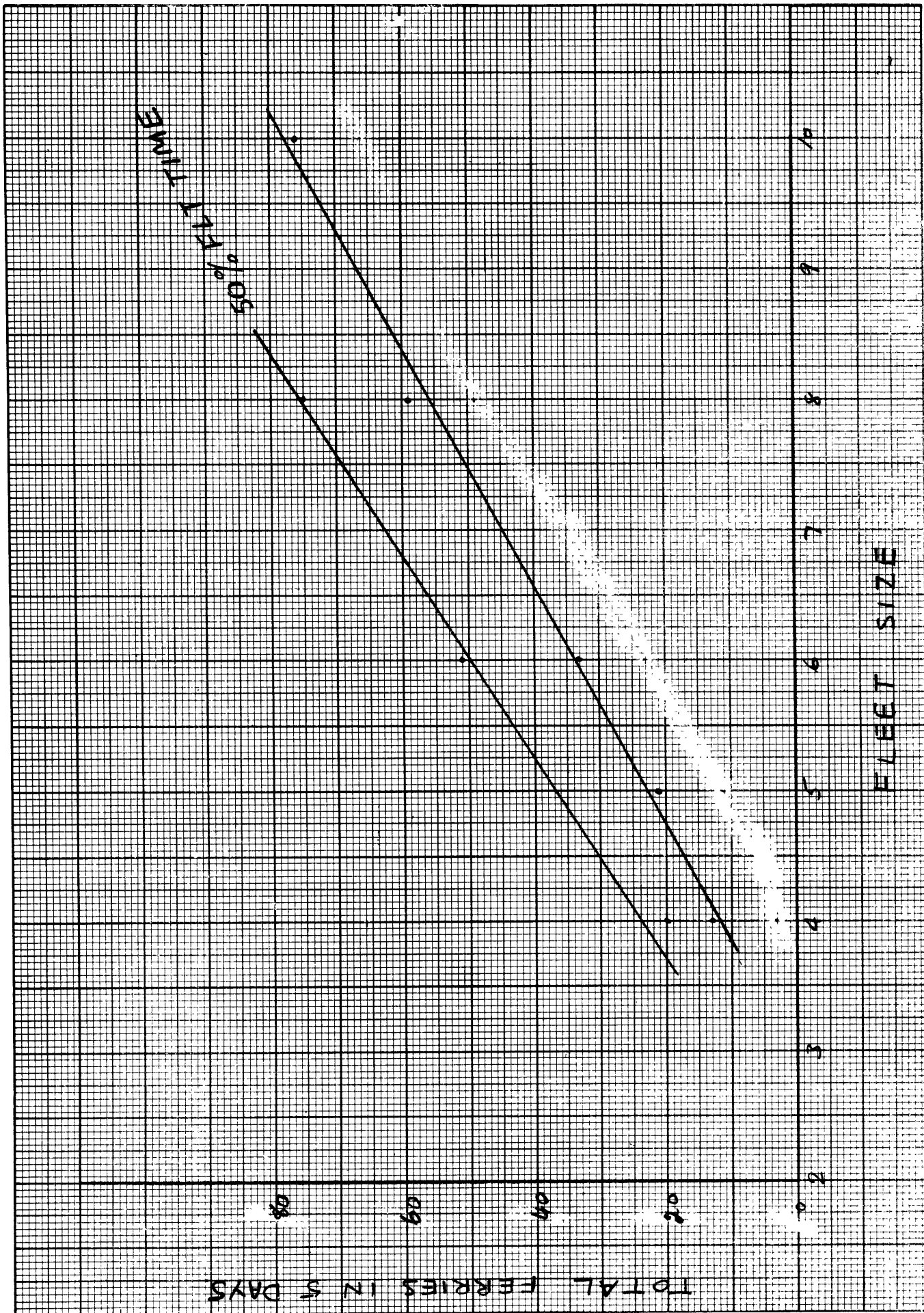


FIG 3.5

π
\$/Day

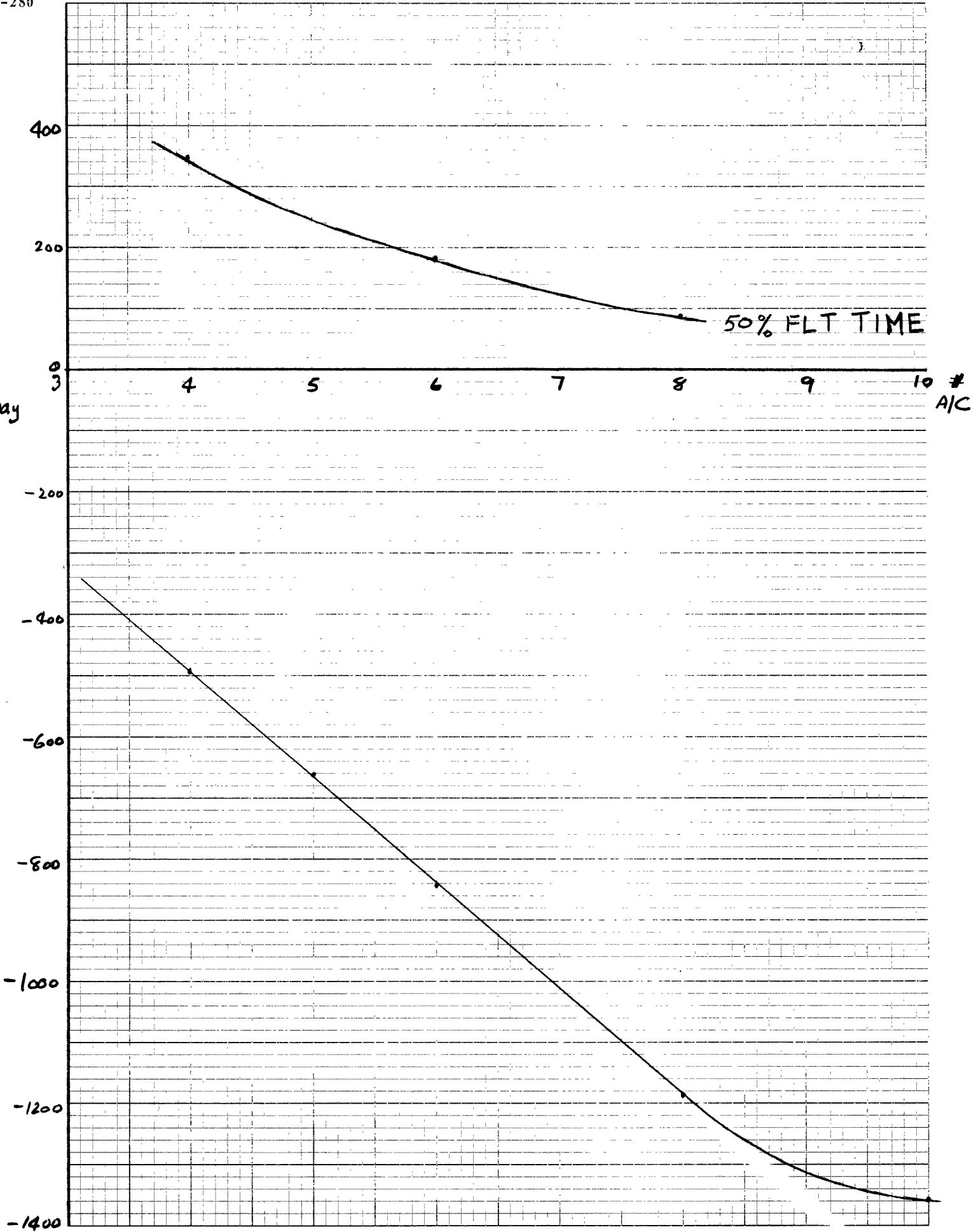


FIG 3.6

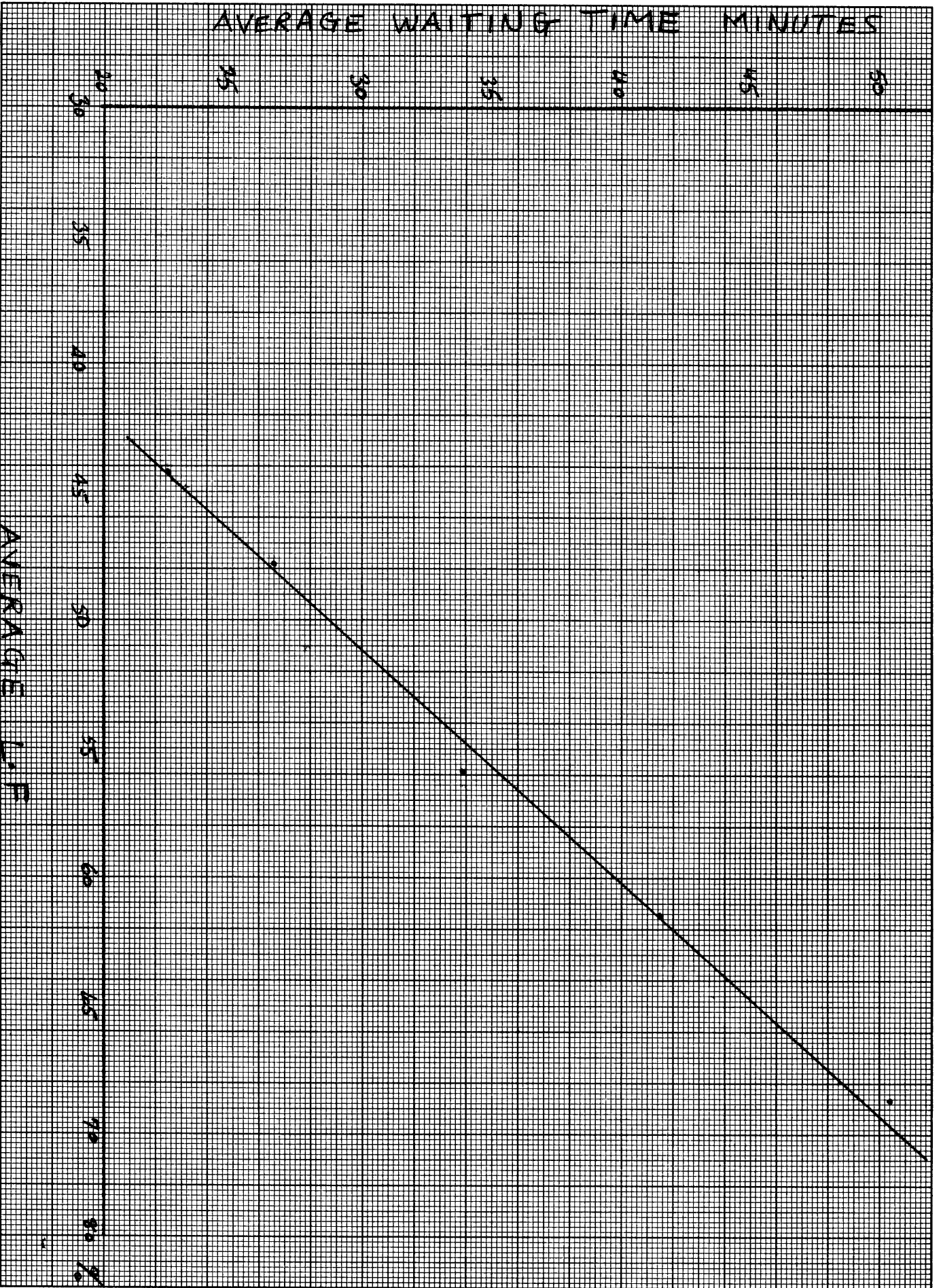


FIG 3.7

It is thus a managerial decision to choose the level of customer service. The level chosen will determine the average load factor and hence profit. The criterion should be to maximize the total profit at the end of the day.

3.2 Flight Time Variation

The second variation in the model was with flight time. Runs were made with flight time reduced by 50 percent. This situation can be envisaged by using aircraft which are twice as fast compared to the present fleet and which have same hourly operating costs. The results of the variation with flight time are seen once again in Figures 3.1 through 3.6. The overall trend remains the same as before. However Figure 3.1 shows that a fleet of ten aircraft with a reduction of 50 percent in flight time does not diminish the average passenger delay by more than two or three minutes.

The model shows that assuming present delay functions, maximum efficiency would be obtained by using five aircraft capable of operating at twice the present speed. This would reduce the average passenger delay to about 30 minutes, a reduction of nearly 8 minutes. Aircraft utilization would decrease by approximately two and one half hours/day. Furthermore decreasing flight time by 50 percent and using five aircraft would mean an increase of only five percent but an increase in daily profit of nearly 900 dollars. Hence under the present fare structure, we would be showing a profit of about 250 dollars a day. This sounds reasonable since we are defining profit as fares less costs and operating costs are directly proportional to the flight time.

3.3 Aircraft Available for Ferry Calls at Airport

Initially we had assumed that a ferry will not be dispatched from the airport unless there are at least two planes at the airport. This condition was relaxed to the requirement for only one aircraft at the airport. Two runs were made one with a fleet of 4 aircraft and the other with a fleet of 8 aircraft. In both cases the results did not show a significant change. See Table 3.1.

	4 A/C. STD. FLT. TIME FERRY CONDITIONS		8 A/C. STD. FLT. TIME FERRY CONDITIONS	
	2 A/C at A/P	1 A/C at A/P	2 A/C at A/P	1 A/C at A/P
	# of FERRIES	13	11	59
AVER. UTILIZATION	7.8	8.0	5.10	5.10
AVER. DELAY MINS.	50.4	49.0	26.50	26.55
PROFIT (\$/DAY)	-493	-538	-1190	-1180
AVER. LOAD FACTOR	68.6%	67.3%	47.85%	47.5%
AVER. Q. CONTENTS	1.37	1.27	0.63	0.65

TABLE 3.1

3.4 Expected Distribution of Passenger Destinations

Initially it was assumed that when a passenger shows up at the airport, the probability that he is destined for area A_i ($i = 1, 2, 3$) is 33 percent. Similarly the initial probability for all inbound passengers was taken to be 33 percent for each of the areas.

This model, being heuristic, would update these probability distributions at the end of each day. The reader is referred to the "Learning Process" in Chapter 1. As an example suppose that during the first day, of the passengers arriving at the airport, only 5 percent were destined for area 1. For the second day, the probability distribution for A_1 would be 19 percent.

$$\frac{33 + 5}{2} = 19$$

The results of the initial and updated probability distribution for a five day run are shown in Table 3.2. As seen in the table the initial value of 33 percent changes quite significantly by the end of the fifth day. Table 3.5 shows the results when the initial probability distribution was changed to the following.

	<u>Outbound</u>	<u>Inbound</u>
A1	15%	10%
A2	56%	54%
A3	25%	32%

Table 3.3

Results in Table 3.4 show that the probability distribution does not effect the operations at the end of the five

PROBABILITY DISTRIBUTION

UPDATED VALUES AT THE END OF THE DAY						
	AREA 1		AREA 2		AREA 3	
DAY	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND
0	33	33	33	33	33	33
1	22	23	44	44	31	30
2	19	16	51	53	27	28
3	17	15	56	54	23	27
4	15	10	56	54	25	32
5	15	10	56	54	25	32

TABLE 3.2

6 AIRCRAFT, 50% FLIGHT TIME		
	$A_c = 33\%$	$A_c = \text{Per Table 3.3}$
# OF FERRIES	51	53
AVER. UTILIZATION	3.72	3.72
AVER. DELAY MINS	27.85	27.5
PROFIT (\$/DAY)	185	190
AVER. LOAD FACTOR	51%	50.5%
AVER. Q CONTENTS	0.66	0.66

TABLE 3.4

day run. The daily flight schedule does deviate a little from the standard run, but the average statistics at the end of the day remain unaltered when we change this probability distribution.

3.5 Reduction in Ferry Return Time W

The length of time an aircraft is delayed at the outstations before it can ferry return to the airport is calculated using functions 28 and 17 given in Figures 2.3 and 2.4. As seen in Figures 2.3 and 2.4, the aircraft is delayed a minimum of 30 minutes and could conceivably wait as long as one hour before ferry returning to the airport. This delay time was changed to a minimum of 10 minutes and a maximum of 40 minutes. The results of this reduction in delay time are shown in Table 3.5.

6 AIRCRAFT, 50% FLIGHT TIME		
FERRY RETURN MIN-MAX WAIT IN MINS.		
	30-60	10-40
# OF FERRIES	51	69
AVER. UTILIZATION	3.72	3.95
AVER. PAX. DELAY (MINS.)	27.85	24.50
PROFIT (\$/DAY)	185	104
AVER. LOAD FACTOR	51%	48%
AVER. Q CONTENTS	0.66	0.58

TABLE 3.5

As seen in Table 3.5 reducing the ferry return delay time increases the total number of ferries. The average passenger delay is reduced together with the average number of passengers waiting in the queues. As expected the average load factor decreases.

3.6 Reduction in Dispatching Delay Functions - D_1, D_2, D_3, D_4

The delay functions shown in Figures 2.1 through 2.4 were reduced to a minimum delay of 10 minutes and maximum delay of 30 minutes. Comparing the results of Table 3.6 with those of Table 3.5, we note that the total number of ferries has increased. There is no significant reduction in the average passenger delay or the contents of the queues. With total number of ferries increased, the average load factor and daily revenue went down.

6 A/C, 50% STD. FLT. TIME	MIN-MAX DISPATCH DELAY IN MINS. 10-30	MIN-MAX DISPATCH DELAY IN MINS 10-40
# OF FERRIES	71	51
AVER. UTILIZATION	4.02	3.72
AVER. PAX. DELAY (MINS)	24.25	27.85
PROFIT (\$/DAY)	81	185
AVER. LOAD FACTOR	46.5 %	51 %
AVER. Q CONTENTS	0.59	0.66

TABLE 3.6

3.7 Variation In The Weights Given To The Two Components Of The Dispatching Delay

The length of time a passenger is delayed before a departure can be triggered is made up of the following two components.

1. The aircraft disposition
2. The expected number of passengers in the next ten minute interval.

Initially these two components were weighted equally. In this section we will show the results when the two components were given different weights. Table 3.7 shows the results. In row 1 and columns 2 through 4 the first number represents the percentage weight given to component one above. The information in Table 3.7 is shown in the graphical form in Figures 3.8 and 3.9. It is evident from these two graphs that the numerical weightings on the two components of the passenger delay do make a difference to the level of passenger service the carrier offers. Thus the weights on the components represent yet another variable under management control.

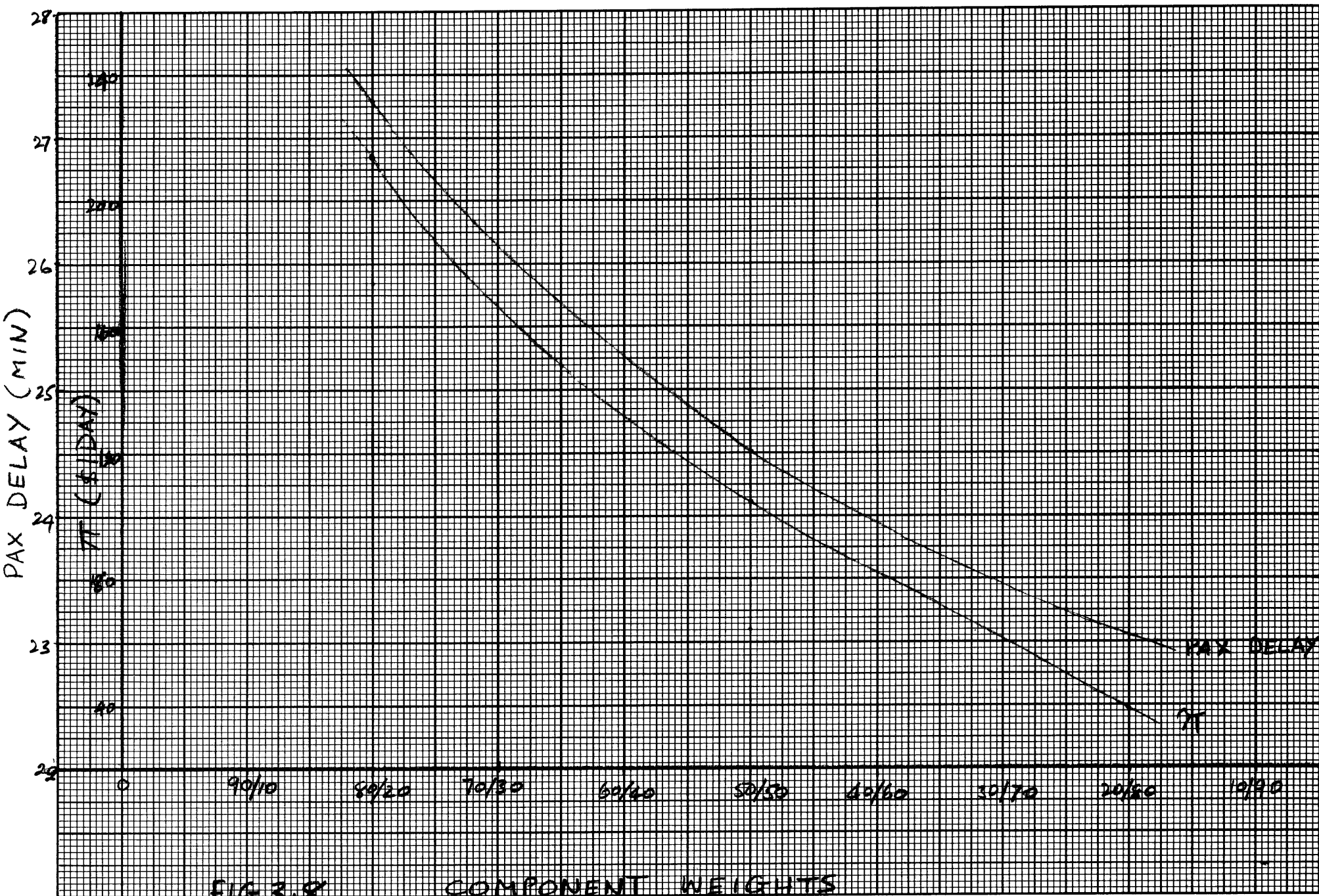


FIG. 3.8

COMPONENT WEIGHTS
A/C DISPOSITION / PAX EXPECTATION

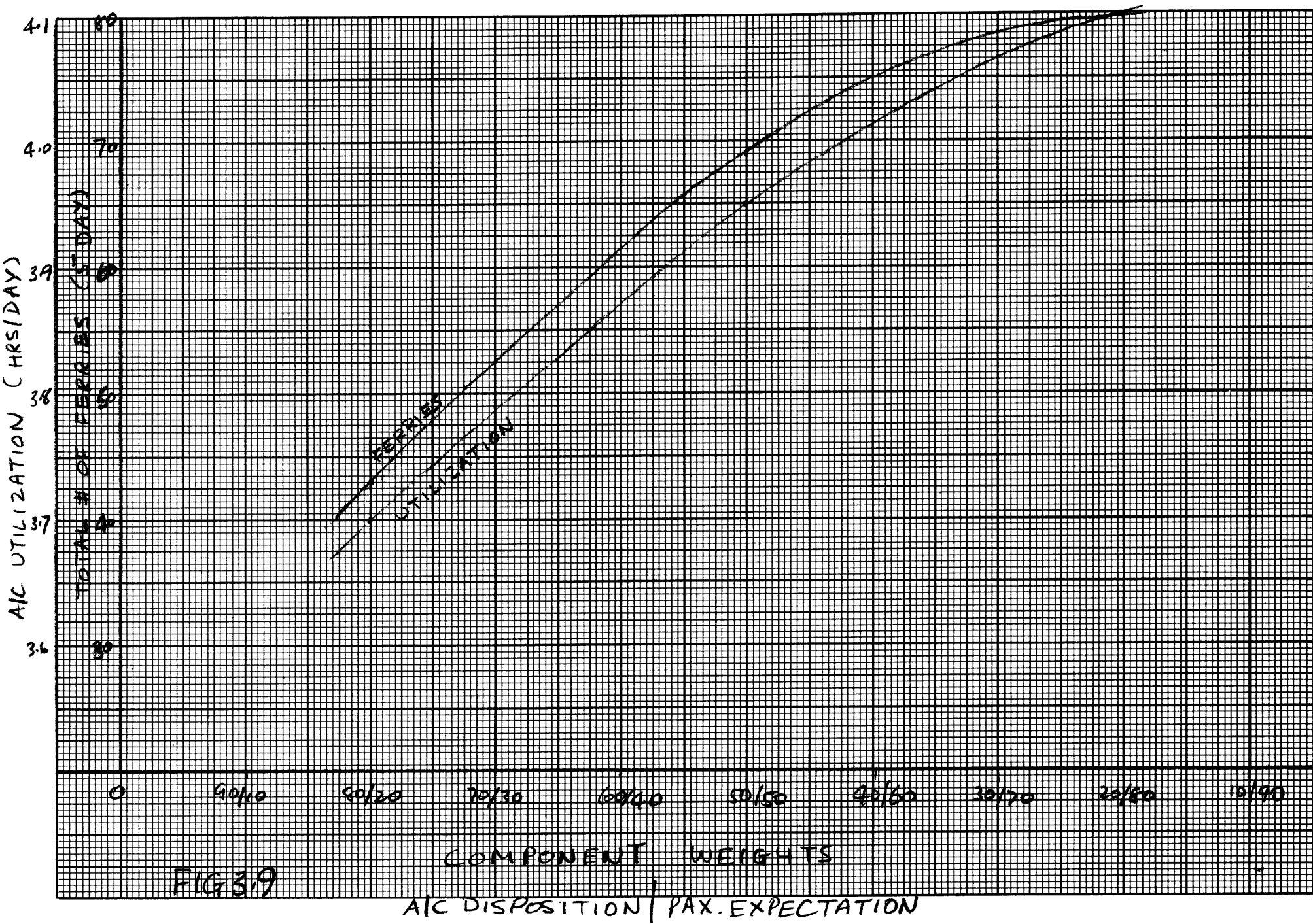


FIG 3.9

A/C DISPOSITION | PAX. EXPECTATION

6 AIRCRAFT, 50% FLT. TIME
FERRY RETURN DELAY (10-40)

WEIGHTS	20/80	50/50	80/20
# OF FERRIES	79	69	43
AVER. UTILIZATION	4.1	3.95	3.7
AVER. PAX. DELAY	23.05	24.05	27.3
PROFIT (\$/DAY)	39	104	214
AVER. LOAD FACTOR	54%	48%	52.6
AVER. Q. CONTENTS	0.56	0.58	0.66

TABLE 3.7

Summary

In Sections 3.1 through 3.7 we show the results when we vary certain critical parameters which are normally under management control. The level of customer service offered by the carrier can be set at any desired level using these parameters. In this report we have investigated some of the parameters which we feel are important. The list is by no means complete.

From the results obtained we can say with confidence that our simulation model is working as expected. The decision rules which we have incorporated in our model are by no means unrealistic. How important are these decision rules relative to each other? We can answer this by quoting the results of one of our standard runs. In this run the input data consisted of the following:

Fleet - 6 aircrafts

Fleet Time - Standard

Initial delay functions as in Chapter 2

At the end of a five day period, out of 217 outbound departures 205 were triggered off having satisfied the Economic Rule, 11 via Capacity Rule and once a ferry call request was accepted at the airport. Out of a total of 192 inbound departures, 32 were triggered off using the Capacity Rule, 6 using the ferry call criterion and 40 departure were ferry return with passengers.

References

1. Akel, O.J., "Dynamic Scheduling in Airline Systems", FTL Report R-67-1, 1967.
2. Neuve-Eglise, M.J., Simpson, R.W., "A Method for Determining Optimal Vehicle Size and Frequency of Service for a Short Haul V/STOL Air Transport System", FTL Report R-68-1, 1968.