ELEVATOR PASSENGER TRANSFER TIME STUDY

By

JOHN WILLIAM PERSOHN

Bachelor of Science

The Agricultural and Mechanical College of Texas

College Station, Texas

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Thesis Approved:

Thesis Adviser

Dean of the Graduate School

SUMMARY

Statement of Problem: Accurate determination of the adequate quantity of elevators for any building has become an important economic consideration in building construction costs. The number of elevators required to effectively accomodate the peak passenger traffic demand (usually when the building occupants arrive for work) is related to the traffic handling capacity of one elevator which is inversely proportional to the round trip time of one elevator. Round trip time of an elevator consists of mechanical elements (running and door operation) and variable elements (because of characteristics of human behavior) of passenger transfer time which amounts to 30%-50% of the total. The basic consideration in the system of data taking developed was the use of round trip time to determine passenger transfer time at upper floors. The method of observation employed eliminated human and mechanical variables in passenger reaction to the observer which would have occurred if the observations had been taken in the elevator car.

Procedure: This system of data taking enabled one observer located at the main floor of a building to obtain data from one elevator for (1) main floor passenger transfer time, (2) number of persons entering the elevator, (3) location of upper floor stops to discharge passengers and (4) round trip time. Door-open to door-open times for various lengths of travel were determined for the test building. By combining the field data secured by this procedure and the latter data, the upper floor passenger transfer time can be calculated. The system was employed in a single purpose office building during the morning peak traffic period.

Findings and Conclusions: The variations noted in the results followed statistical laws. Main floor passenger transfer time showed little variation with passenger load-size changes. This indicated that the element was influenced more by the scheduling interval than by the passenger transfer. The sixteen passenger load-size was most frequently observed and was 62% of the rated passenger capacity of the elevators. The load-sizes observed reflected true passenger load-size preference since no attendant was in the loading alcove to direct traffic during this period. In no case was the rated passenger capacity of twenty-six observed. The most significant data in reference to upper floor passenger transfer time was the variations noted in upper floor passenger transfer time per passenger per upper floor stop (UPTT/NS) for different load-sizes. A constant value (K_S) of 0.22 seconds was established for this factor for use in the formula $UPTT = K_S NS$ to compute total upper floor passenger transfer time for a single purpose office building in which the values of N and S are known variables.

PREFACE

In January 1952 the writer contacted Mr. Bill Bruns, Head of the Research Engineering Department of the Otis Elevator Company, to seek his advice for a thesis subject that would be useful to the elevator industry. A study of elevator passenger transfer time was suggested by Mr. Bruns after discussions with Mr. A. W. Paulson, Chief Engineer and Mr. G. Watson, Assistant to the Chief Engineer, both of the Otis Elevator Company. Little actual field information was available on this subject for the new automatic type of operation of elevators in office buildings.

This need led to the research in this thesis which was designed to develop a system of data taking and to utilize the system in one single purpose office building to obtain the types of information that would be useful in calculating expected performance of automatic elevators. The system of data taking developed here will minimize variations due to observer reactions and will produce consistant results although different persons make the observations. It is hoped that the system will be used to obtain further data in all types of office buildings.

The writer wishes to express his appreciation to Mr. G. Watson for his guidance in providing background data on which to start this study, and to Mr. H. G. Thuesen and Dr. G. G. Rose for their helpful advice and constructive criticisms in the writing of the paper. Mr. A. E. Lang, Building Manager of the Southwest Home Office Building of the Prudential Insurance Company of America was most cooperative in making the building available and providing all additional data requested. The writer is grateful to Miss A. Corzelius and Mr. G. D. Cox for competent assistance with the mechanical details; and to the many individuals in the Otis Elevator Company who have offered encouragement and cooperation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

For many centuries hoisting devices have served mankind. The development from primitive hoists to modern passenger elevators has made multi-story buildings practical and thus changed the profile of our cities. Elevators have facilitated intensive use of land in our large business areas where real estate values are high.

Development from cast iron construction to steel frame construction in common use today permitted an increase in building heights. This also created demands for vertical transportation equipment to handle effectively the increased building passenger traffic. These demands for service were met by many advances in elevator control systems. Today we find automatic high speed elevators efficiently handling large volumes of people without car attendants.

Since the elevator portion of the initial investment in a multi-story office building is approximately ten per cent of the total building cost, the problem of determining adequate vertical transportation in an economical manner has become very important. The elevator installation for each building must be capable of effectively accommodating the peak passenger traffic loads. Normally, this peak demand for elevator service in an office building occurs in the morning period when the building occupants are arriving for work. The number of elevators required is determined by the ratio of the expected traffic load at this time to the traffic handling capacity of one elevator. The passenger handling capacity of an elevator is inversely proportional to the round-trip time[1] of the elevator. The total round-trip time of the elevator is the summation of the following elements: (1) passenger transfer time[2] at the main floor (to load passengers), (2) running time in the up direction (includes acceleration and deceleration time), (3) door operation time at each floor (includes time to open and close car and hoistway doors), (4) passenger transfer time at upper floors (to unload passengers), (5) running time in the down direction (includes acceleration and deceleration time). Elements (2), (3), and (5) are mechanically constant and can be determined for various elevator speeds and for various types of door operators. Elements (1) and (4), passenger transfer time, are influenced by human behavior and will vary with each type of elevator operation and building requirement. It is a significant portion of the total round-trip time, and amounts to 30%-50% of the total.

The various elevator companies have developed reliable empirical data for elements (1) and (4) which is used for calculations of elevator performance of attendant operated elevators (in this type of operation the attendant polices traffic, registers passenger floor calls and starts the elevator in motion). The introduction in recent years of high speed automatic elevators in office buildings influenced passenger reaction time. To date, no field data is available to indicate the variation in time caused by the change to non-attendant operation.

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[1] The round-trip time of an elevator is the time utilized to complete a cycle of operation. The cycle commences when the elevator is ready to load passengers at the main floor, extends through the discharging of passengers on one or more upper floors and terminates when the elevator is again ready to load passengers at the main floor.

[2] The passenger transfer time is the passenger loading and/or unloading time of an elevator.

Because of this need, this project was designed to: (1) determine the type of information that would be useful in calculating anticipated performance of automatic elevators, (2) develop a reliable system of data taking that could be used to ascertain passenger transfer time, (3) utilize this sytem of data taking in an office building.

(1) Type of information obtained -

Although there are many variables in passenger reaction time, it was believed that there were constant patterns that could be recognized. The expected passenger handling capacity of an elevator can be accurately established by reliable data on the following factors: (a) average first floor loading time, (b) total upper floor passenger transfer time, (c) upper floor passenger transfer time per passenger loaded at the first floor, and (d) upper floor passenger transfer time per passenger loaded at the first floor per upper floor stop. The data secured in reference to items (a) and (d) above are particularly significant and will be discussed in Chapter VI.

(2) System of data taking -

This was necessarily a study of human reactions. The following general factors apply to human behavior and are significant in explaining wide variations noted in reactions of persons using elevators: (a) people are affected similarly by the same factors but differ in their capacity and manner of performance, (b) people react differently under varying conditions or under the same conditions at different times, (c) their behavior is influenced by other people.[3] The system of data taking was developed to make use of factors

[3]Frederick H. Zurmuhlen, "Engineering With People", American Engineer, (November 1956) p. 20.

that could be observed directly on one elevator during a complete cycle of operation. These were total round-trip time, first floor passenger transfer time, number of passengers loaded on the elevator at the first floor and the number and location of upper floor stops to discharge passengers. This data was combined with typical running time and door operation time in order to calculate upper floor passenger transfer time which was not directly observed. The method of calculation will be explained in Chapter III.

(s) Utilization of the system of data taking -

This system of data taking was employed to obtain information on passenger reaction times in a single purpose office building, the Southwestern Home Office Building of the Prudential Insurance Co. of America in Houston, Texas. All types of buildings having the operatorless[4] type of elevator equipment were not available in the Houston area. No attempt was made to develop data that would meet all needs for calculation of elevator performance for single purpose office buildings but only an example of the use of the system of data taking was given.

[4]Operatorless is the term generally used to describe high speed automatic elevators operating without attendants in the cars.

CHAPTER II

BASIC CONSIDERATIONS AND DEFINITIONS

The total round-trip time of one elevator during the morning peak traffic demand period was the primary factor of consideration of this research project. Since this peak load was of short duration (approximately 45 minutes each day), the usual practice was to express both traffic demand and traffic handling capacity of an elevator in terms of the number of persons transported from the main floor in a five minute period.[5] In the formula

$$HC = 300\ N\ /RTT$$

round-trip time was represented by RTT in seconds, total number of persons transported from the main floor during a five minute period by HC and the number of persons entering the elevator at the main floor each trip by N. Round-trip time referred to the expected handling capacity of an elevator in this formula. The calculation of the handling capacity of an elevator thus depended upon an accurate determination of RTT and N. The value of N was established by the weight carrying capacity of the elevator.

Round-Trip Time

Figure 1 illustrated graphically the five elements composing round trip-time. Since the elements of running time (up or down direction) and door operation time were mechanically constant, they were combined to facilitate data-taking. The data shown in Figure 1 was taken from the sample calculations at the end of Chapter III.

[5]The inter-floor and down direction traffic was considered to be negligible during the morning peak traffic period.

(1) Main Floor Passenger Transfer Time - This time measurement was started when the elevator doors were fully open to allow passengers to enter the elevator car and was terminated when the doors commenced to close. The door closing operation was initiated either by the expiration of the normal scheduling interval[6] or the action of a load weighing device.[7]

(2) Door Operation Time - The car and hoistway doors of an elevator operated simultaneously and had to be completely closed before the elevator car would move. The doors were opened as the elevator car approached the floor at slow speed, thus, the car was ready to discharge or load passengers by the time it was level with the floor.

(3) Up Direction Running Time - This was the total time that the elevator moved in the up direction and included the time to accelerate to full speed, the running time at full speed and the time to decelerate to a stop at floor level.

(4) Upper Floor Passenger Transfer Time - This element comprised the total standing time at the upper floors for passenger transfer. As will be shown later, this was an unknown which was computed from the data obtained.

(5) Down Direction Running Time - This was the total time that the elevator moved in the down direction and included the time to accelerate to full speed, the running time at full speed and the time to decelerate to a stop at floor level.

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[6]Groups of elevators were provided with automatic scheduling equipment (variable timed signals to dispatch the elevators) which coordinated the vertical spacing of the elevators to meet the individual building traffic needs. The interval between dispatch signals during the morning peak period exceeded passenger loading time when small numbers of passengers were loaded.

[7]Load weighing devices automatically weighed the passenger load in the elevator and dispatched the elevator when loaded with 80% of its rated weight capacity. Generally during the morning peak period the action of the load weighing device, due to an 80% load, dispatched the elevator before the scheduling interval had expired.

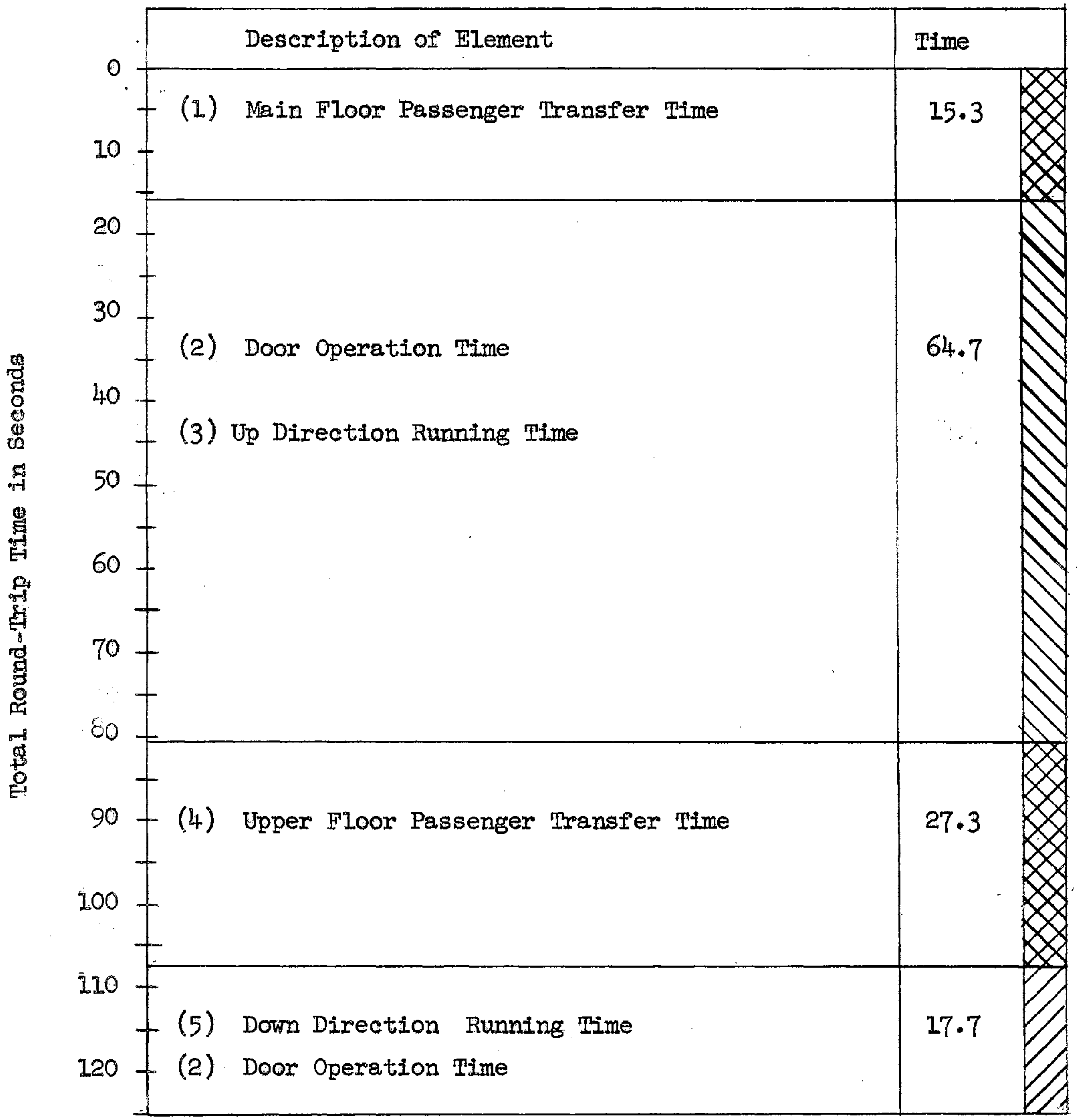

Fig. 1 - Time Chart for total round-trip time

For practical purposes the door operation times and the running times were combined to provide what was known as the "door-open to door-open time". This was the total elapsed time which commenced with the door closing operation at one floor, extended through the running time and terminated when the door again was completely open and the elevator was ready to transfer passengers at another floor. Table I illustrated a form in which the door-open to door-open time was used. This was based on data secured from the building in which this system of data taking was employed.

Table I

Door-Open to Door-Open Time for Test Building

Car Travel From	Car Travel To	Door Open to Door Open Time (Up or Down Direction) in seconds	
1	2	10.2	
1	3	11.5	
1	4	12.4	
1	5	13.4	
1	6	14.5	
1	7	15.5	
1	8	16.6	
1	9	17.7	
1	10	19.1	
2	3	8.8	Same for all typical floor heights.
2	4	10.5	
2	5	11.7	
2	6	12.6	

CHAPTER III

SYSTEM OF DATA TAKING

This system was developed to provide data for the calculation of the upper floor passenger transfer time. This calculation was based on "main floor" observations by one observer of the total round-trip time, the main floor passenger transfer time and the location of upper floor stops of one elevator in a group. This "main floor" method eliminated both human (passenger reaction to the observer) and mechanical (space in the elevator occupied by the observer) variables which would have occurred if observations had been taken in the elevator car. The equipment illustrated in Figure 2 was used to time and record data. Because (1) good architectural arrangement and the system of dispatching of the group of elevators negated the possibility of passenger preference in choice of elevators, (2) walking time in the corridor to each elevator was approximately equal (see Fig. 3), and (3) each elevator in a group had the same capacity and speed characteristics, the assumption that any one elevator in a group could be used to indicate an average performance of the group was permitted.

OBSERVATION PROCEDURE

(1) Main Floor Passenger Transfer Time - The first floor loading time was observed on stop watch "B" and recorded on the data sheet in seconds.

(2) Number of Passengers - The number of persons entering the elevator at the main floor was observed and recorded on the data sheet.

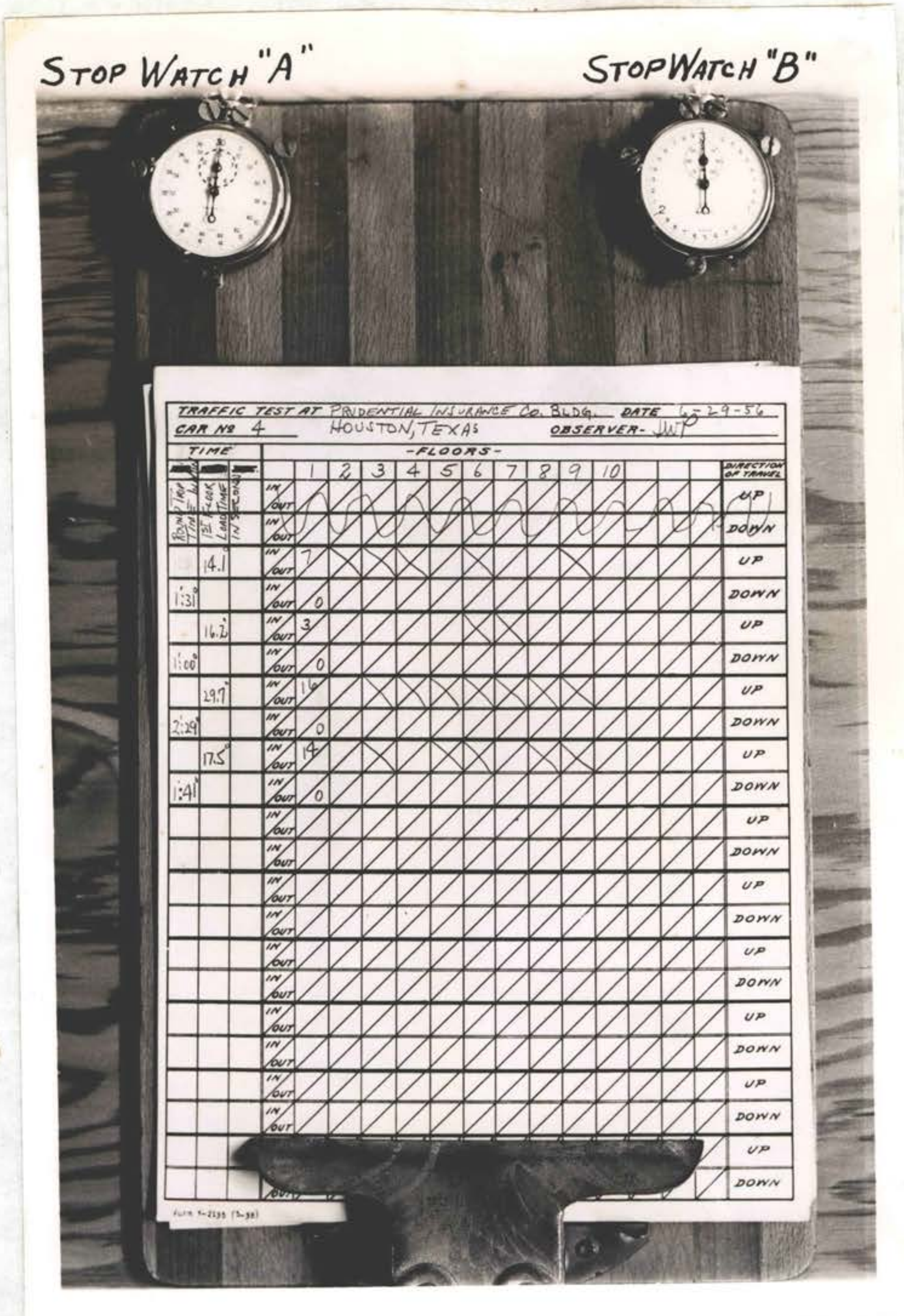

Fig. 2. Equipment utilized in this system of data-taking to time and record data. Stop watches "A" and "B" were attached to the clip board so observer could operate one with each hand.

(3) Upper Floor Stops - This observation was made from the indicator panel in the main floor lobby. The locations of the upper floor stops made by the elevator for passenger transfer were observed and recorded on the data sheet.

(4) Total Round-Trip Time - The total round-trip time of one elevator was observed on stop watch "A" and recorded on the data sheet in minutes and seconds.

Sequence of Observations: The sequence in which the data was observed and recorded was as follows: (1) Both stop watch "A" (to record total round-trip time) and stop watch "B" (to record main floor passenger transfer time) were started simultaneously when the doors of the elevator car were fully open and the car was ready for the loading of passengers. (2) During the loading time the number of persons entering the elevator car were counted. (3) As soon as the doors started to close, stop watch "B" was stopped and the passenger transfer time recorded. (4) An "X" was placed on the data sheet indicating floors where stops were made during the travel in the up and down direction. (5) When the elevator returned to the main floor, the doors opened and the elevator car again was ready to load passengers, stop watch "A" was stopped and the total round trip time recorded in minutes and seconds.

In addition to the above observations it was necessary to obtain the type of data shown in Table I (door-open to door-open time). Since passenger traffic during the morning peak period was predominately in the up direction, observation where stops were made during the trip in the down direction were negligible and, therefore, were not used in any of the calculations. By combining the field test data secured by the procedure outlined above and the data in Table I, the total upper floor passenger transfer time was calculated for each complete round-trip observed (see sample calculation).

SAMPLE CALCULATION:

From an observation on June 27, 1956, sixteen persons entered the elevator at the first floor and upper floor stops were made at the 2nd, 3rd, 4th, 5th, 6th, 8th, and 9th floors (a total of seven stops) to discharge passengers. The first floor loading time was 15.3 seconds. The total round-trip time was 2 minutes 5 seconds.

Total round-trip time		125 seconds
Door and running time 1st to 2nd floor	10.2 seconds	
Door and running time five 1-floor runs	44.0 seconds	
Door and running time one 2-floor run	10.5 seconds	
Total Door and Up Direction running time.....	64.7 seconds	
Door and down direction running time	17.7 seconds	
Total door and running time		-82.4 seconds
Total passenger transfer time		42.6 seconds
First floor passenger transfer time		-15.3 seconds
Total upper floor passenger transfer time at 7 stops		27.3 seconds

CHAPTER IV

CHARACTERISTICS OF TEST BUILDING

This system of data taking was employed to analyze the morning peak traffic in the Southwestern Home Office Building of the Prudential Insurance Company of America located in Houston, Texas. The portion of the building which was studied was classified as a single purpose office building.[8]

The building consisted of a lower section of ten floors and a tower section of eight floors. Each section was served by a separate group of elevators. The tower was not occupied by Prudential Insurance Company employees and was not included in this survey. There was a total of 1019 employees on the second through tenth floors. Of these, 870 were Prudential Insurance Company employees and 149 were employees of other concerns. The net rentable area of this portion of the building was 202,809 sq. feet distributed as noted in Table II. The vertical transportation consisted of four automatic passenger elevators which had a capacity of 4000 lbs. (26 passengers) and a speed of 800 feet per minute. Figure 2 illustrated the physical arrangement of the elevators studied and their location in relationship to the main building entrances.

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[8]A single purpose office building was utilized primarily by a single con-concern whose employees shared common working hours.

Table II. Area Distribution of Prudential Insurance Company Building, Houston, Texas.

Floors	Gross Area Sq. Feet	Rentable Area Sq. Feet Prudential	Tenants
2	30,627	21,831	-
3	30,627	21,982	-
4	30,627	23,953	-
5	30,627	23,813	-
6	30,627	23,813	-
7	30,627	-	23,913
8	30,627	5,019	18,894
9	30,627	23,813	
10	23,306	13,778	
Total	268,322	202,809	

Passenger Load Characteristics - The working hours of all Prudential Insurance Company employees started at 8:15 A.M. Figure 4 indicated the total traffic handled by the four elevators during the morning peak traffic period. Particularly heavy traffic was noted from 8:00 to 8:15, and this was possibly due to an incentive system[9] which Prudential used to encourage promptness.

[9] This incentive system was in the form of a vacation bonus for arrival-to-work promptness.

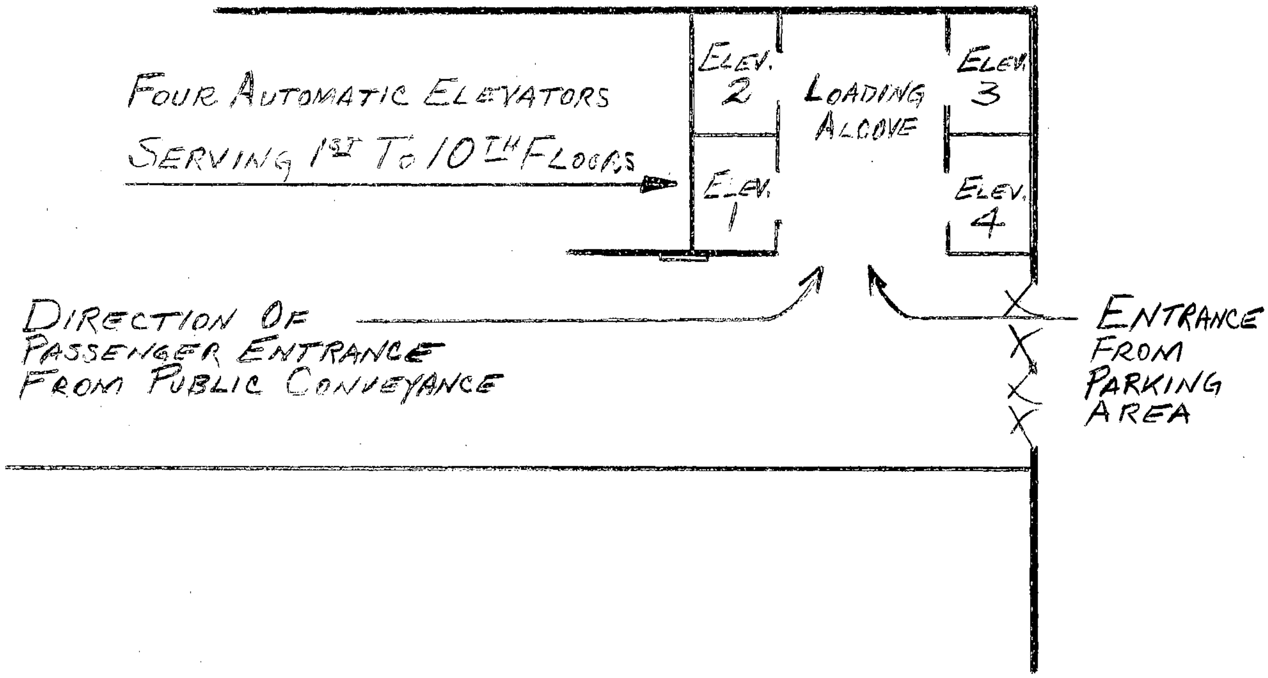


Fig. 3. This plan illustrates that only elevator passengers entered the loading alcove, the arrangement of which did not permit through passenger traffic. This design plus the dispatching system which restricted loading to one elevator until dispatched, equalized elevator usage during the morning peak period.

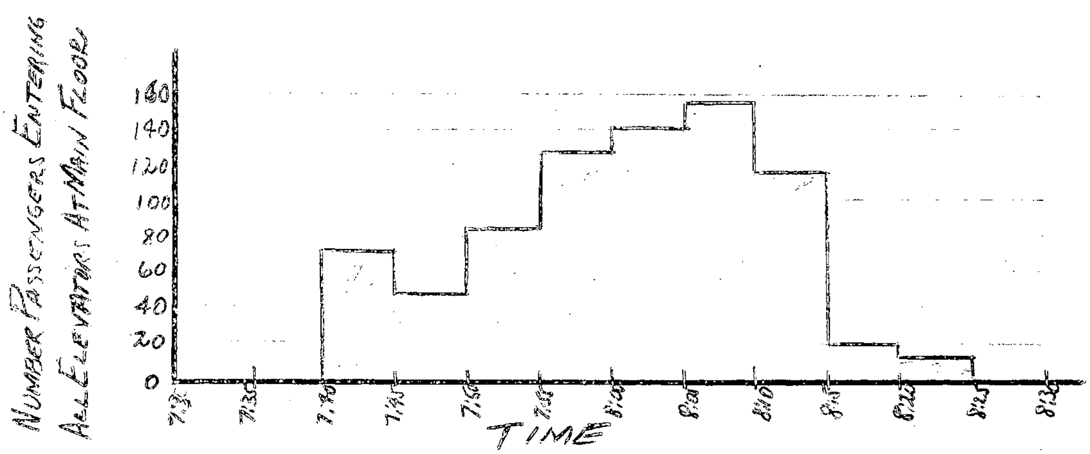


Fig. 4. Time distribution of total traffic entering all elevators at main floor during morning peak period.

CHAPTER V

RESULTS

The data obtained from observations at the test building recorded by this system (Fig. 1, Table 1) were compiled in Table III.

Table III. Compiled results of Data-taking.

RTT - Round trip time.

MPTT - Main floor passenger transfer time.

UPTT - Upper floor passenger transfer time.

N - Number of passengers entering elevator at main floor.

S - Number of stops to discharge passengers above main floor.

TPTT - Total passenger transfer time (MPTT + UPTT).

DATE	RTT	MPTT	UPTT	N	UPTT / N	S	UPTT / S	UPTT / NS	N / 26	TPTT / RTT x 100
6-26-56	100	21.1	23.6	8	2.96	3	7.9	.988	.37	45
	76	13.8	26.4	6	4.4	3	8.8	1.43	.23	52.8
	76	12.8	21.1	8	2.64	4	5.28	.66	.31	72
	81	12.3	26.2	7	3.72	4	6.5	.93	.27	47.5
	125	22.6	37.7	15	2.52	7	5.4	.36	.58	48
	106	15.7	40.2	11	3.65	5	8.05	.73	.42	52.5
	109	10.4	32.9	16	2.05	7	4.7	.294	.62	39.6
	124	16.9	24.7	8	3.1	4	6.2	.77	.31	33.5
	137	12.0	36.7	10	3.67	5	7.34	.734	.38	35.5
6-27-56	117	19.3	30.7	9	3.40	5	6.15	.685	.35	42.6
	119	17.0	37.0	9	4.12	5	7.4	.82	.35	45
	106	17.1	29.7	10	2.97	4	7.42	.74	.38	44
	106	15.4	22.8	11	2.08	5	4.58	.418	.42	36
	103	14.1	28.1	14	2.00	6	4.86	.349	.59	41
	128	15.0	27.5	15	1.83	7	3.93	.33	.58	33.1
	125	15.3	27.3	16	1.7	7	3.90	.244	.62	34
6-28-56	118	12.0	31.1	16	19.5	6	5.2	.325	.62	36.5
	111	27.3	15.9	19	.84	5	3.2	.168	.73	38.8
	116	25.1	16.1	11	1.46	6	2.7	.245	.42	35.5
	47	21.1	2.9	4	.73	1	2.9	.725	.15	51
	91	14.1	9.2	7	1.31	5	1.84	.263	.27	25.7

DATE	RTT	MPTT	UPTT	N	UPTT/N	S	UPTT/S	UPTT/NS	N/26	TPTT/RTT x 100
6-28-56	60	16.2	5.	3	1.67	2	2.50	.833	.11	35.4
	149	29.7	37.3	16	2.33	7	5.33	.355	.62	45
	114	19.5	27.2	11	2.47	5	5.45	.495	.42	41
	101	17.5	15.7	14	1.12	5	3.15	.225	.54	33
6-29-56	128	21.1	34.8	11	3.16	6	5.8	.528	.42	43.5
	145	33.8	29.2	16	1.82	7	4.17	.26	.62	43.5
	112	16.4	20.3	16	1.27	6	3.4	.212	.62	32.8
	96	17.0	19.6	16	1.22	4	4.9	.306	.62	38
	117	21.4	20.8	16	1.30	6	3.47	.217	.62	36
	81	22.0	6.5	3	2.17	3	2.17	.72	.11	35.2
7-13-56	102	21.2	23.7	11	2.16	4	5.9	.53	.42	44
	121	22.6	13.3	12	1.11	7	1.9	.16	.42	29.6
	144	37.2	23.1	19	1.22	6	3.85	.202	.73	42
	166	47.9	43.2	15	2.88	6	7.2	.48	.58	55
	115	24.8	15.3	14	1.09	6	2.56	.183	.54	35.6
	135	28.3	24.3	17	1.43	7	3.47	.204	.65	39
	116	31.6	25.0	6	4.16	4	6.25	1.04	.23	48.8
7-15-56	142	33.5	40.7	9	4.55	5	8.2	.91	.35	52
	159	30.6	46.4	17	2.72	7	6.6	.39	.65	48
	123	28.9	26.3	19	1.34	5	5.3	.277	.73	45
	149	26.8	30.0	12	2.5	8	3.75	.312	.46	38
	107	21.2	26.4	6	4.4	4	6.6	1.1	.23	44
	110	22.2	23.0	13	1.77	6	3.85	.296	.50	41
12-4-56	104	28.9	8.1	13	.62	5	1.6	.123	.50	36
	113	19.1	18.6	19	.98	6	3.1	.163	.73	33
	116	12.9	20.7	15	1.38	7	2.94	.195	.58	28
	111	24.	12.2	17	.718	6	2.0	.118	.65	33
	103	21.8	9.5	19	.5	6	1.6	.084	.73	30
	108	12.5	28.2	19	1.54	5	5.6	.295	.73	38
	126	31.1	19.6	21	.935	6	3.5	.166	.81	40
	59	10.8	15.5	4	3.88	2	7.7	1.92	.15	44
12-5-56	68	17.5	6.8	2	3.4	2	3.4	1.7	.08	46
	122	27.5	16.5	6	2.75	6	2.7	.45	.23	36
	114	18.3	20.8	13	1.6	6	3.4	.262	.50	34
	117	12.9	28.8	9	3.2	6	4.8	.53	.35	35
	113	19.0	26.2	17	1.52	5	5.2	.305	.65	40
	71	10.3	7.9	8	.985	4	1.96	.245	.31	26
	75	10.8	4.8	5	.96	4	1.2	.24	.19	20
	128	29.6	23.5	18	1.3	6	3.9	.216	.69	42
	138	18.3	44.4	14	3.16	6	7.4	.53	.54	45
	120	22.8	22.5	18	1.22	6	3.7	.205	.69	38
	75	12.9	4.3	7	.61	4	1.1	.157	.27	23
12-6-56	109	25.1	17.4	12	1.45	6	2.9	.24	.46	39
	105	15.8	34.1	8	4.27	4	8.5	1.06	.31	48
	73	16.5	5.7	6	.95	3	1.9	.333	.23	30
	66	17.0	3.7	8	.465	3	1.2	.45	.31	31
	121	34.0	12.1	14	.865	6	2.0	.143	.54	38
	133	24.3	16.5	12	1.37	8	2.0	.166	.46	31
	116	17.5	23.6	17	1.39	6	3.9	.23	.65	35
	118	16.8	33.9	17	1.99	5	6.8	.4	.65	43

DATE	RTT	MPTT	UPTT	N	UPTT/N	S	UPTT/S	UPTT/NS	N/26	TPTT/RTT x 100
12-6-56	103	17.6	17.6	16	1.03	5	3.5	.219	.62	34
	119	22.7	21.2	19	1.11	6	3.5	.185	.73	37
12-7-56	86	17.7	8.4	5	1.68	5	1.7	.34	.19	30
	98	26.2	6.8	7	.97	5	1.4	.20	.27	30
	119	27.9	16.2	15	1.08	6	2.7	.18	.58	37
	68	13.0	5.7	7	.81	3	1.9	.27	.27	28
	97	21.7	7.5	8	.94	5	1.5	.188	.31	30
	120	21.9	16.0	12	1.33	7	2.3	.191	.46	31
	90	20.1	10.0	10	1.0	5	2.0	.20	.38	33
	103	22.3	12.9	18	.72	5	2.6	.144	.69	34
	128	36.0	10.0	19	.53	7	1.4	.074	.73	36
	110	13.0	24.5	16	1.53	6	4.1	.256	.62	34
	120	25.8	11.8	13	.91	7	1.7	.13	.50	31
12-11-56	83	16.1	6.7	9	.74	4	1.7	.189	.35	28
	109	25.1	16.1	5	3.22	5	3.22	.65	.19	38
	72	14.7	4.7	3	1.57	3	1.57	.52	.11	27
	98	22.3	23.1	11	2.1	5	4.6	.42	.42	47
	106	22.6	15.6	16	.98	5	3.1	.193	.62	36
	127	15.1	29.9	19	1.57	7	4.3	.226	.73	35
	121	13.5	25.5	14	1.82	7	3.6	.256	.54	32
	109	11.2	22.9	17	1.35	6	3.8	.224	.65	31
	143	18.0	35.5	22	1.61	8	4.44	.20	.85	37
	138	16.2	61.6	20	3.08	4	15.4	.77	.77	56
	141	16.8	34.7	18	1.93	8	4.3	.238	.69	37
	84	18.0	15.7	4	3.94	3	5.2	.13	.15	40
1-31-57	65	27.5	2.2	4	.55	2	1.1	.275	.15	46
	94	28.1	8.5	7	1.21	4	2.1	.30	.27	39
	62	15.0	3.3	5	.66	2	1.6	.32	.19	30
	115	19.2	33.3	8	4.17	6	5.5	.68	.31	46
	76	20.5	6.2	6	1.03	3	2.1	.35	.23	35
	83	18.4	7.5	5	1.5	4	1.9	.38	.19	31
	92	23.6	8.2	5	1.64	4	2.0	.40	.19	35
	123	30.4	20.1	16	1.25	6	3.3	.205	.62	41
	135	27.	42.	18	2.62	7	.6	.33	.69	51
	108	19.5	23.5	14	1.69	5	4.7	.335	.54	40
1-31-57	117	20.0	14.6	15	.97	7	2.1	.14	.58	30
	110	27.5	20.2	14	1.44	5	4.04	.28	.54	43
	151	27.3	34.2	18	1.90	9	3.8	.211	.69	41
	90	25.0	7.6	7	1.08	4	1.9	.27	.27	36
2-5-57	59	12.0	4.5	4	1.1	3	1.5	.375	.15	28
	92	28.1	13.8	9	1.53	3	4.6	.51	.35	45
	121	22.1	17.9	14	1.28	7	2.55	.182	.54	33
	115	27.0	13.1	14	.94	6	2.2	.156	.54	35
	96	20.6	15.2	6	2.53	4	3.8	.635	.23	37
	136	29.0	14.3	14	1.02	8	1.78	.127	.54	32
	146	23.3	47.8	15	3.2	6	8.0	.533	.58	49
	102	24.8	18.0	16	1.12	4	4.5	.281	.62	42
	112	20.0	16.8	14	1.2	6	2,8	.20	.54	33
	108	17.7	30.4	18	1.69	4	7.6	.423	.69	45

DATE	RTT	MPTT	UPTT	N	UPTT/N	S	UPTT/S	UPTT/NS	N/26	TPTT/RTT x 100
2-5-57	136	28.2	15.2	17	.89	8	1.9	.112	.65	32
	80	12.2	10.8	4	2.5	4	2.5	.625	.15	29
	95	15.0	13.1	5	2.6	5	2.6	.52	.19	30
2-6-57	56	15.8	5.6	3	1.87	2	2.8	.93	.11	38
	67	13.8	3.9	5	.78	3	1.3	.26	.19	26
	94	18.2	8.5	7	1.22	5	1.7	.243	.27	28
	88	15.5	5.5	10	.55	5	1.1	.11	.38	24
	126	32.6	12.5	10	1.25	7	1.78	.178	.38	36
	96	27.0	6.8	6	1.13	5	1.36	.227	.23	35
	110	27.6	7.5	10	.75	6	1.25	.125	.38	32
	104	27.3	9.7	5	1.94	5	1.94	.39	.19	36
	115	29.8	12.9	15	.86	6	2.15	.144	.58	37
	107	16.6	23.4	20	1.17	5	4.68	.234	.77	37
	92	20.7	11.1	16	.69	4	2.78	.173	.62	35
	119	30.1	16.4	13	1.26	6	2.73	.21	.50	39
	42	8.2	2.8	3	.93	1	2.8	.93	.11	26
2-12-57	102	18.4	8.7	7	1.24	6	1.42	.208	.27	27
	118	19.3	16.7	17	.98	7	2.40	.141	.65	30
	114	19.2	15.2	15	1.0	7	2.17	.145	.58	30
	149	49.2	20.2	18	1.12	7	2.88	.16	.69	47
	119	28.0	16.1	15	1.07	6	2.69	.179	.58	37
	100	19.9	17.9	12	1.49	5	3.58	.298	.46	38
	98	15.4	16.9	8	2.1	5	3.38	.423	.31	31

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The variations noted in the results of this data taking in a single purpose office building followed statistical laws rather than physical laws and required the establishment of logical trend lines to indicate elevator performance. Previously it was noted that people reacted differently to different conditions or to the same conditions at different times. For example, the multiple occurances of one elevator passenger transfer condition will produce a range of time values rather than a fixed time value because of the inherent variableness of people.

The discussion was divided into the two main catagories which were the object of this investigation: (1) main floor passenger transfer time (loading time) (MPTT) and (2) upper floor passenger transfer time (UPTT) (unloading time).

Main Floor Passenger Transfer Time - The variation in MPTT with different passenger load-sizes was indicated in Figure 5. From this, it can be seen that there was very little variation in MPTT regardless of passenger load-size. This indicated that MPTT was influenced more by the mechanical scheduling interval for the group of elevators than by the time requirement for passenger transfer. The few examples noted of passenger load-sizes of twenty to twenty-two (greater than 80% load) required less MPTT due to the action of the load weighing device.

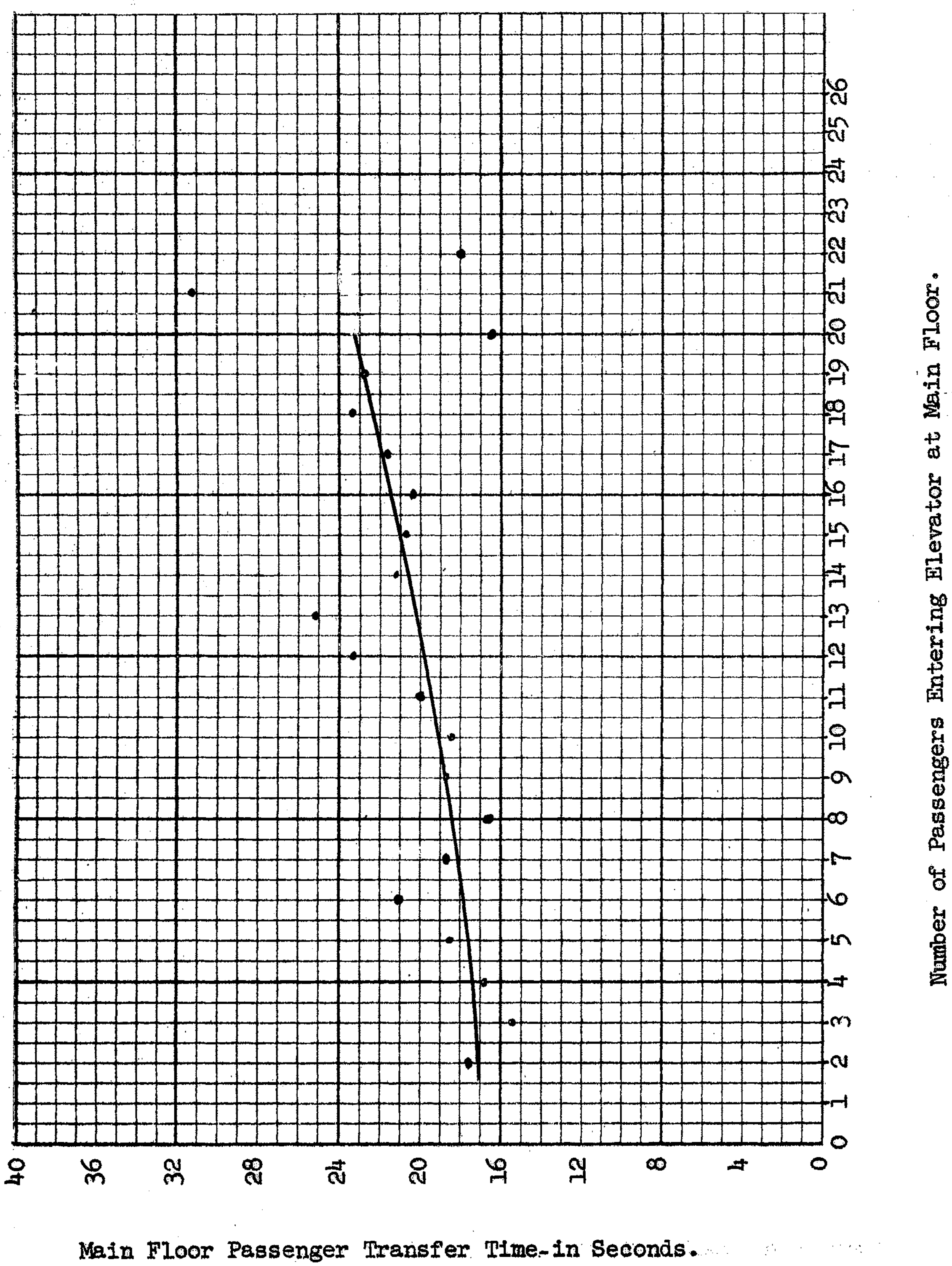


Fig. 5. Main Floor Passenger Transfer Time for various passenger load-sizes.

Figure 6 indicated the frequency distribution of the passenger load-sizes observed. The sixteen-passenger load which was 62% of the rated passenger capacity was most frequently observed (and represented 10% of the total observations during the morning peak period). In no case was the rated passenger capacity of twenty-six observed. Since there was no attendant in the loading alcove to direct traffic or influence elevator loading, this frequency distribution reflected a true passenger load-size preference.

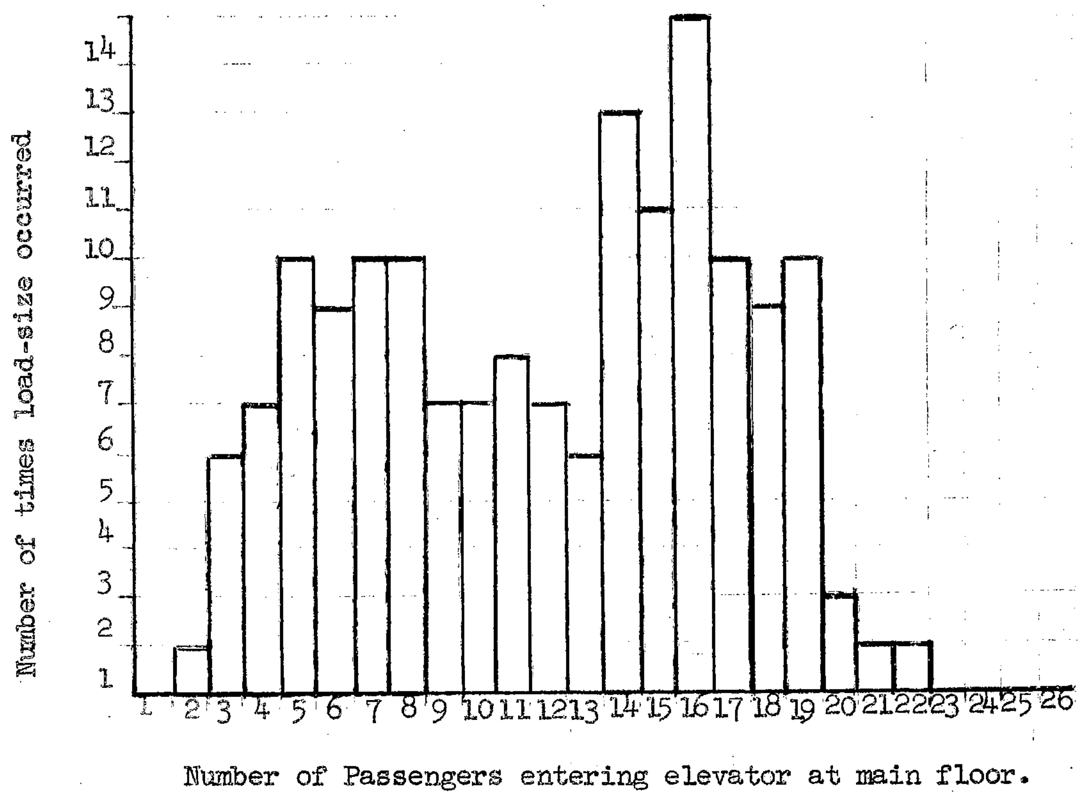


Fig. 6 Frequency Distribution of Passenger Load-Sizes.

The main floor passenger loading in this single purpose office building was characterized by the occupants who (1) moved rapidly, (2) were well acquainted with the automatic elevator operation and door protective devices and (3) preferred to wait for the next elevator rather than crowd into an elevator loaded to about 62% capacity.

Upper Floor Passenger Transfer Time - The variation in total UPTT with different passenger load-sizes was indicated in Figure 7. This showed that UPTT increased directly as the passenger load-size increased within the scope of this data. Insufficient examples of upper-range load-sizes (greater than twenty Passengers) were observed to substantiate a trend line in this portion of the curve. Considerable variation in UPTT was noted for some load-sizes and this was due to variations in (1) the number of stops made above the main floor to discharge passengers and (2) the number of passengers discharged at each stop.

Figure 8 indicated for different passenger load-sizes the variations in upper floor passenger transfer time per upper floor stop (UPTT/S). Because no trend line could be established from these values to produce a useful conclusion, this negative data was shown in the form of a bar graph.

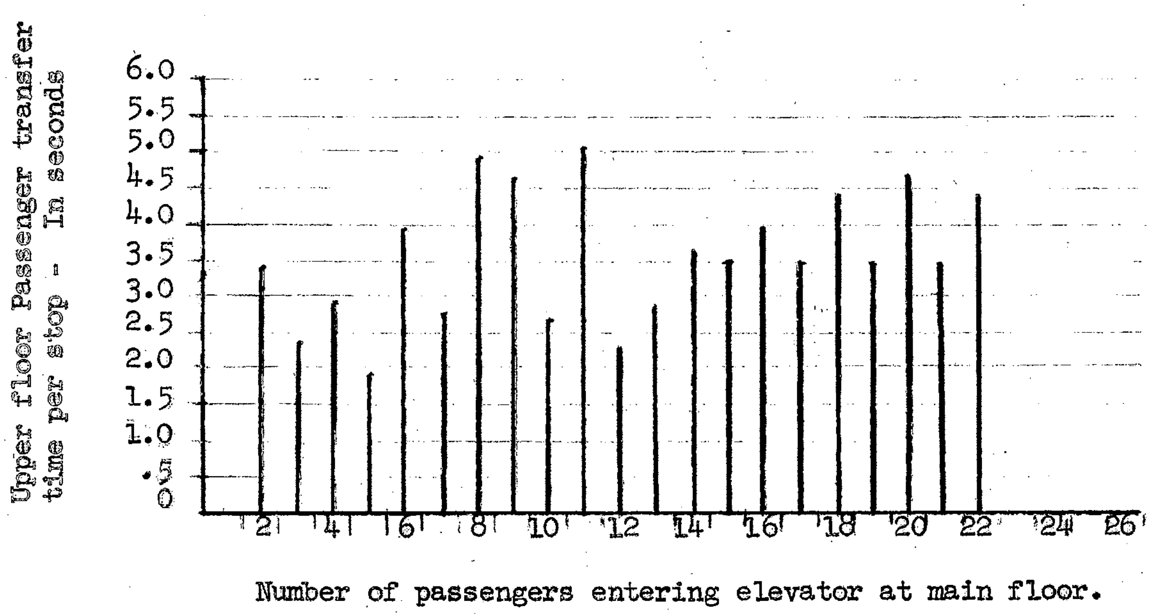


Fig. 8. Graph showing variation in Upper Floor Passenger Transfer time per stop.

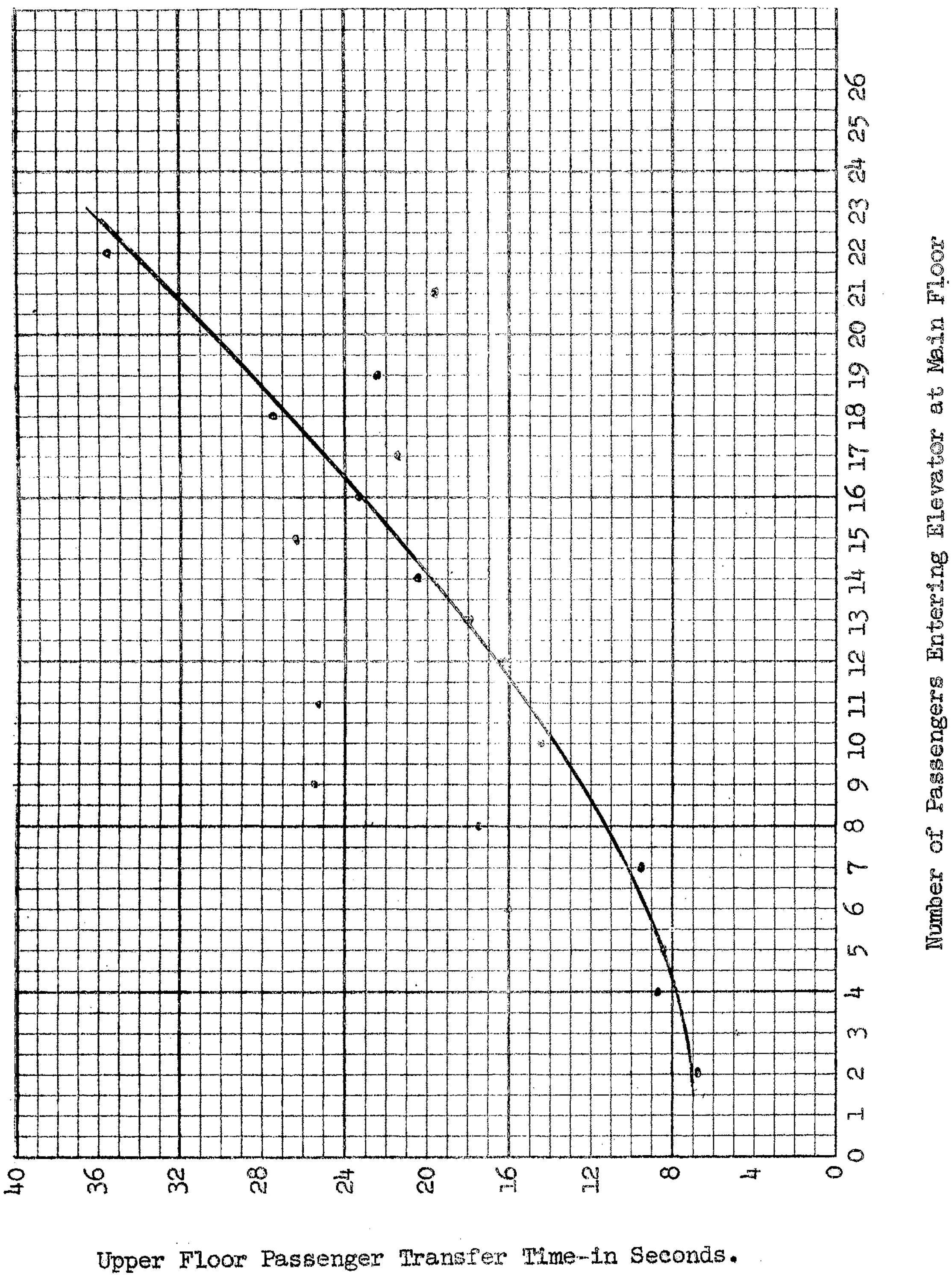


Fig. 7. Upper Floor Passenger transfer time for various passenger load-sizes.

As the total number of passengers loaded on the elevator at the main floor increased, the upper floor passenger transfer time per passenger (UPTT/N) decreased. This was because more passengers left the elevator at each stop. This relationship was indicated in Figure 9 and also was subject to variations produced by the difference in (1) the number of stops made above the main floor to discharge passengers and (2) the number of passengers discharged at each stop.

The most significant data in reference to UPTT was indicated in Figure 10. This showed the variation in the upper floor passenger transfer time per passenger loaded on the main floor per upper floor stop (UPTT/NS) for different load-sizes. The value of UPTT/NS to discharge one passenger at one stop was 1.5 seconds. This value of 1.5 seconds was the minimum door-open time at any upper floor stop. UPTT/NS decreased rapidly as the passenger load-size increased up to about 50% of the rated capacity and then remained constant at 0.22 seconds regardless of greater load-size increase. This constant value of UPTT/NS was termed K_s (constant value of UPTT/NS in single purpose office buildings) and was approximately one-third the K computed and presently used for calculations of expected elevator performance in office buildings with attendant operated elevators.

$$\text{Since:} \quad UPTT/NS = K_s$$

$$\text{Then:} \quad UPTT = K_s NS$$

This established a method of computing the UPTT for any proposed single purpose office building in which values of N and S were known variables. Similarly, the UPTT of any type of office building could be determined once its particular K value had been established by the method of data taking presented herein.

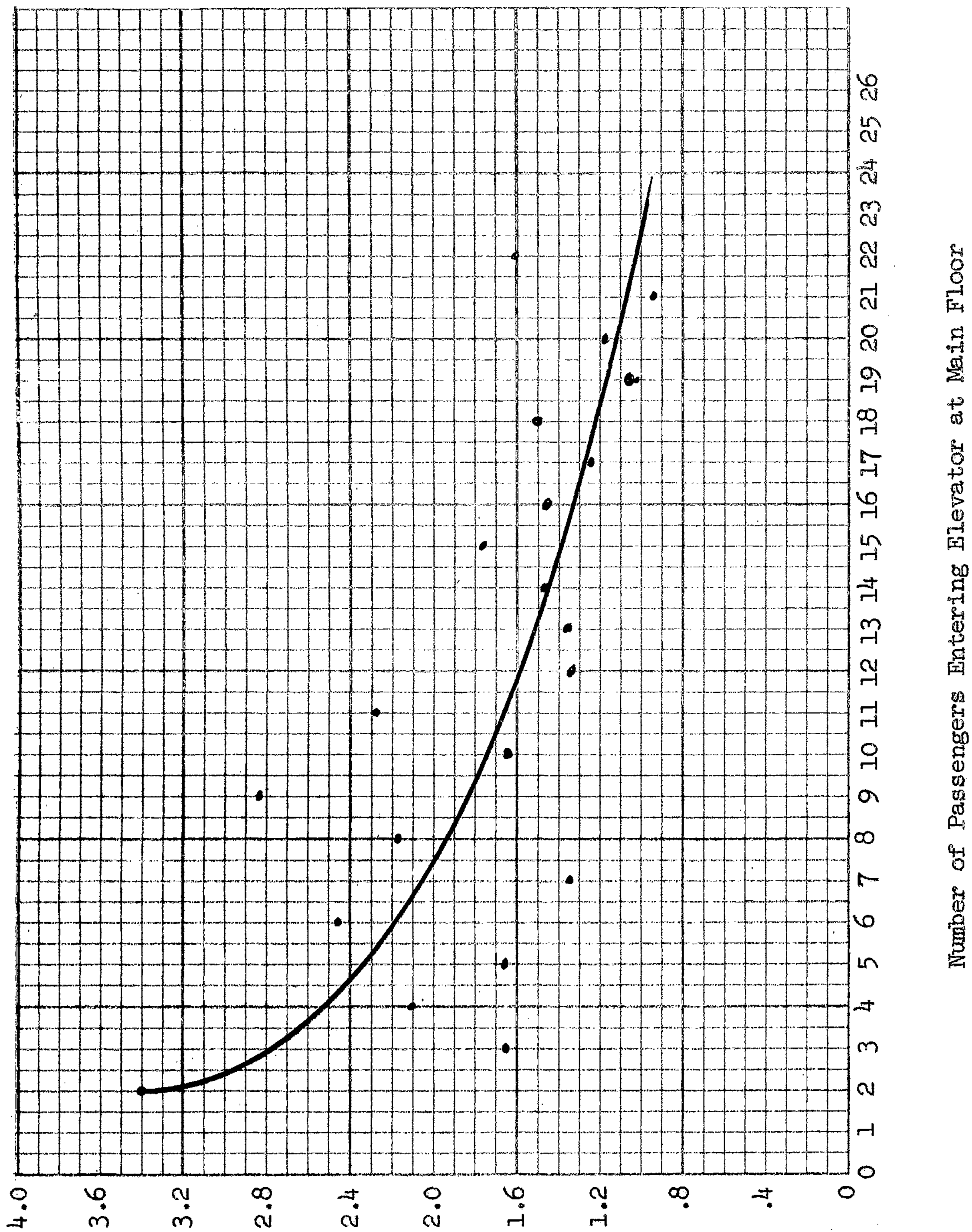
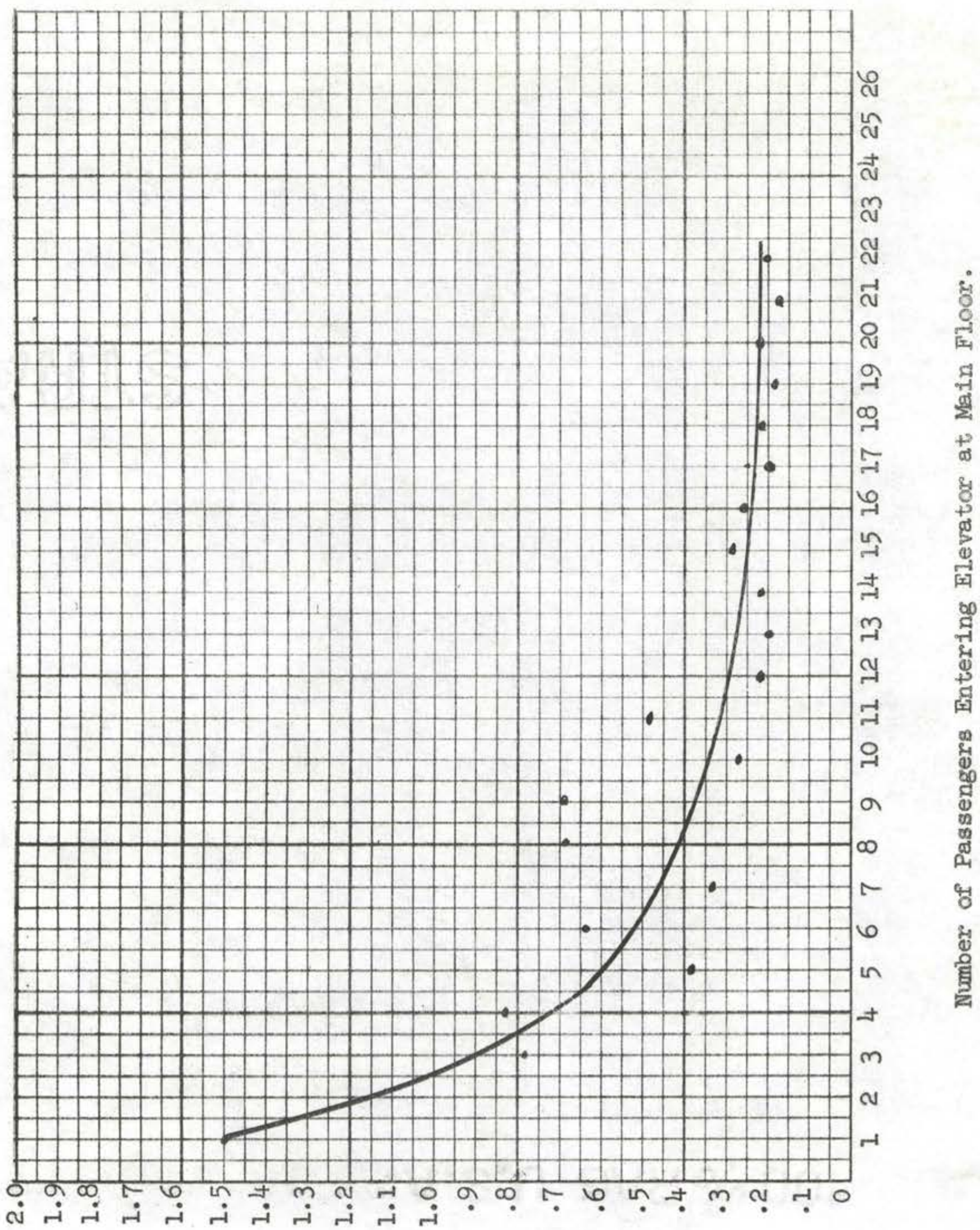


Fig. 9. Upper floor passenger transfer time per passenger loaded at main floor for various passenger load-sizes.



Upper Floor Passenger Transfer Time per passenger loaded at main floor per upper floor stop-in seconds.

Fig. 10. Upper floor passenger transfer time per passenger loaded at the main floor per stop for various load-sizes.

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VITA

John William Persohn
Candidate for the Degree of
Master of Science

Thesis: ELEVATOR PASSENGER TRANSFER TIME STUDY

Major: Industrial Engineering and Management.

Biographical and Other Items:
Born: November 23, 1920 at Keller, Texas.
Undergraduate Study: Agricultural & Mechanical College of Texas, 1938-1942, B. S. in E. E.
Graduate Study: Oklahoma Agricultural & Mechanical College, 1951-1957.
Experience: Army Signal Corps in United States and Pacific area 1942-1946; Employed by Otis Elevator Company as Engineer 1946-1951; Army, Oklahoma Agricultural & Mechanical College R. O. T. C. Staff 1951-1953; Otis Elevator Company 1955-1957. Registered Professional Engineer July 1950.

Member of National Society of Professional Engineers, San Jacinto Chapter of Texas Society of Professional Engineers, Houston Engineers Club, and Eta Kappa Nu.

Date of Final Examination: May 13, 1957.

THESIS TITLE: Elevator Passenger Transfer Time Study.

AUTHOR: John William Persohn

THESIS ADVISER: Mr. H. G. Thuesen

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TYPIST: (Miss) Adelaide Corzelius