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# Routine for Analysis of the People Movement Time for Elevator Evacuation

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*Prepared for:*
General Services Administration
Public Buildings Service
Office of Real Property Management and Safety
Washington, DC 20405

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# Routine for Analysis of the People Movement Time for Elevator Evacuation

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## Abstract

This paper is part of a project sponsored by the U.S. General Services Administration (GSA) to study occupant use of elevators during building evacuations. A detailed method of analysis of people movement by elevators during emergency building evacuation is presented including the time for people to enter and exit elevators and the equations of elevator car motion. Also a computer program for people movement during elevator evacuation and examples. Runs of this are listed in appendices. The method and computer routine presented in this paper are intended to be used in a later part of the GSA elevator project to help study the feasibility of elevator fire evacuation.

## Nomenclature

| | |
|---|---|
| $a$ | acceleration, m/s$^2$ (ft/s$^2$) |
| $J$ | number of elevators |
| $m$ | number of round trips |
| $N$ | number of people entering or leaving the elevator |
| $N_{dw}$ | number of people entering or leaving the elevator during the dwell time |
| $S$ | distance, m (ft) |
| $S_T$ | total floor to floor travel distance for trip, m (ft) |
| $t$ | time, s (s) |
| $t_a$ | elevator evacuation *start* up time, s (s) |
| $t_d$ | time for elevator doors to open and close, s (s) |
| $t_{dw}$ | dwell time for elevator doors, s (s) |
| $t_e$ | evacuation time, s (s) |
| $t_h$ | time for leveling elevator of elevator car, s (s) |
| $t_i$ | time for $N$ people to enter elevator car, s (s) |
| $t_{io}$ | time for one person to enter elevator car, s (s) |
| $t_o$ | travel time from elevator lobby to outside or to other safe location, s (s) |
| $t_r$ | time for elevator car to make a round trip, s (s) |
| $t_s$ | standing time, s (s) |
| $t_u$ | time for $N$ people to leave elevator car, s (s) |
| $t_{uo}$ | time for one person to leave elevator car, s (s) |
| $V$ | velocity, m/s (ft/s) |
| $V_m$ | normal operating velocity, m/s (ft/s) |
| $\alpha$ | basic transfer inefficiency |

$\mu$ total transfer inefficiency, $\mu = \alpha + e + \gamma$
$e$ door transfer inefficiency
$\gamma$ other transfer inefficiency
$\eta$ trip inefficiency

Subscripts

T end of leveling car motion (also end of travel)
1 end of constant acceleration motion
2 end of transitional acceleration motion
3 end of constant velocity motion
4 end of transitional deceleration motion
5 end of constant deceleration motion

## 1. Introduction

Throughout most of the world, signs next to elevators indicate they should not be used in fire situations; stairwells should be used for fire evacuation. These elevators are not intended as means of fire egress, and they should not be used for fire evacuation (Sumka 1987). The idea of using elevators to speed up fire evacuation and to evacuate persons with disabilities has gained considerable attention (Bazjanac 1974, Bazjanac 1977, Pauls 1977, Pauls, Gatfield and Juillet 1991, Gatfield 1991, Degenkolb 1991, and Fox 1991).

This paper is part of a project sponsored by the U.S. General Services Administration (GSA) to study occupant use of elevators during building evacuations. Aspects of emergency elevator evacuation to be addressed in this project are systems concepts, engineering design considerations, and human behavior. Smoke control for elevators has already been addressed under this project (Klote and Tamura 1991).

This paper presents a detailed method of analysis of people movement by elevators during emergency building evacuation, based on principles of elevator engineering (Strakosch 1983). Bazjanac (1977) and Pauls (1977) have developed methods of calculation of evacuation time by elevator, but the method presented here incorporates more detail about elevator motion and elevator loading and unloading. Also a computer program, ELVAC, for people movement during elevator evacuation is described and example calculations are presented. Appendix A is a listing of the ELVAC program, and appendices B, C and D are example applications of the program. The method and computer routine presented in this paper are intended to be used in a later part of the GSA elevator project to help study the feasibility of elevator fire evacuation. Other people wanting to evaluate the extent to which elevators can speed up evacuation may also want to use the methods presented in this paper.

The sequence of elevator operation for emergency evacuation is complicated and has many possible variations. The following general sequence is presented to provide a framework for the method of analysis presented in this paper. Upon activation of emergency evacuation, elevators in normal service will go to a discharge floor where any passengers on the elevators will exit. This discharge floor may either lead to the outside or lead to an area of relative safety where people may stay during the fire. The elevators will make a number of round trips to transfer occupants from other floors to the discharge floor.

During evacuation, the elevators may be under a special emergency evacuation mode of automatic control or under manual control.

The evacuation time addressed in this paper is an idealized time for people movement which does not account for the complex human behavior that often occurs during emergencies. It is believed that the analysis of this paper is about as accurate as that for evacuation by stairs*. There is little guidance available regarding the extent to which actual evacuation time is greater than the idealized times for stairs or elevators, but Nelson and MacLennan (1988) indicate that actual evacuation time can be two or even three times as long. The approximate nature of such calculations should be taken into account in any applications of the methods presented in this paper.

## 2. Evacuation Time

Analysis of people movement during elevator evacuation must take into account the number and arrangement of elevators in a building. Generally elevators are located in groups of up to eight elevators. Elevators in a group are located near each other and are controlled together to efficiently move people. Arrangements of elevator groups are discussed later. The method of analysis and the computer program of this paper are for the calculation of the evacuation time for one group of elevators. For buildings with multiple groups of elevators, the approach presented in this paper can be applied separately to each group of elevators.

Ideally the time to evacuate a number of people using one group of elevators consists of the sum of all the round trip times divided by the number of elevators plus the time needed to start up the elevator evacuation and the travel time from the elevator lobby to the outside (or to another safe location). Accounting for inefficiencies of elevator operation, this evacuation time can be expressed as

$$t_e = t_a + t_o + \frac{(1 + \eta)}{J} \sum_{j=1}^{m} t_{r,j} \tag{1}$$

where $t_{r,j}$ is the time for round trip $j$, $m$ is the number of round trips, $J$ is the number of elevators, $\eta$ is the trip inefficiency, $t_a$ is elevator evacuation start up time, and $t_o$ is the travel time from the elevator lobby to the outside or to another safe location. The round trip time depends on the travel time of the elevator and on the number of people carried by the elevator as discussed later. The travel time from the elevator lobby to a safe location can be evaluated by conventional methods of people movement [i.e. Nelson and MacLennan (1988) or Pauls (1988)]. The trip inefficiency accounts for trips to empty floors and trips to pick only a few stragglers. The elevator evacuation start up time is discussed in the next section.

*For a discussion of times for people movement during emergency evacuation on stairs, readers are referred to Nelson and MacLennan (1988) and Pauls (1988).

The number of elevators, J, used in equation (1) may be less than the number of elevators in the group to account for out-of-service elevators. The probability of elevators being out-of-service depends on a number of factors including the age of the elevators and the quality of maintenance. Because the out-of-service condition can significantly increase elevator evacuation time, any analysis of elevator evacuation should take this condition into account.

## 3. Start Up Time

The elevator evacuation start up time is the time from activation to the start of the round trips that evacuate people. For automatic elevator operation during evacuation, a simple approach is to start elevator evacuation after all of the elevators have been moved to the discharge floor. For this approach, the start up time, $t_a$, consists of the time for elevators to go to the discharge floor plus the time for the passengers to leave the elevators. This can be expressed as

$$t_a = t_T + (t_u + t_d)(1 + \mu) \tag{2}$$

where $t_T$ is the travel time for the elevator car to go from the farthest floor to the discharge floor, $t_u$ is the time for passengers to leave the elevator, $t_d$ is the time for the doors to open and close once, and $\mu$ is the total transfer inefficiency. These terms are discussed in detail later.

An alternative to the simple approach discussed above consists of starting the evacuation operation individually for each elevator when it reaches the discharge floor. This alternative could result in slightly reduced evacuation time. However, this alternative is not discussed further here, because of its limited benefit and added complexity.

For manual elevator operation, the time for elevator operators to be alerted and then get to the elevators must be included in the estimate of start up time. This additional time may be considerably greater than that calculated from equation (2).

## 4. Elevator Round Trip Time

The round trip starts at the discharge floor and consists of the following sequence: elevator doors close, car travels to another floor, elevator doors open, passengers enter the car, doors close, car travels to discharge floor, doors open, and passengers leave the car. The round trip time, $t_r$, is can be written as

$$t_r = 2t_T + t_s \tag{3}$$

where $t_s$ is the standing time and $t_T$ is the travel time for one way of the round trip. This equation is based on the elevator only stopping at one floor to pick up passengers. It is expected that most elevators will fill up on one floor and proceed to the discharge floor. What constitutes a full elevator is discussed later. If an elevator stops to pick up passengers at more than one floor during a round trip, equation (3) can be modified accordingly. However, the trip inefficiency accounts for such multiple stops.

## 4.1 Standing lime

The standing time is the sum of the time to open and close the elevator doors twice, the time for people to enter the elevator, and the time for people to leave the elevator. Considering transfer inefficiencies, the standing time for a round trip can be expressed as

$$t_s = (t_i + t_o + 2t_d)(1 + \mu) \tag{4}$$

where

$\mu = \alpha + \varepsilon + \gamma$

The basic transfer inefficiency, $\alpha$, allows for rounding off of probable stops, door operating time, door starting and stopping time, and the unpredictability of people. Typically a value of 0.10 is used for the basic transfer inefficiency for commonly accepted arrangements of elevator groups as illustrated in figure 1. For each of these arrangements, the configuration of the elevator lobby is such that passengers can recognize which elevator has arrived and get on the elevator without excessive delay. Further, these lobbies have sufficient space so that people exiting one elevator will have a minimal impact on the flow of people leaving another elevator.

Arrangements of elevator groups other than those commonly accepted can be less efficient and require an increased value of the basic transfer inefficiency. These unusual arrangements include cars separated [fig 2(a)], too many cars in a line [fig 2(b)], angular arrangement [fig 2(c)], and cornered arrangement [fig 2(d)]. Separation of elevators results in increased boarding time for passengers waiting by one elevator to walk to another when it arrives. If the separation is too large, some passengers choose to let elevators go by without boarding. Use of too many elevators in a line has similar inefficiencies. With the angular arrangement [fig 2(c)], cars at the narrow end tend to be to close together while cars at the wide end tend to be too far apart. In the cornered arrangement [fig 2(d)], passengers entering or leaving comer cars tend to interfere with each other.

The door inefficiency, e, is used to adjust for any increase in transfer time over that of a 1200 mm (48 in) wide center opening door. Values of e are listed in table 1. The inefficiency, $\gamma$, is used to account for any other inefficiencies in people transfer into or out of elevators, such as increased movement times within an elevator car due to an unusual elevator car shape or limited physical capability of passengers. For example, $\gamma$ often is chosen to be 0.05 for hospital elevators. Generally for office buildings, $\gamma$ is taken as zero.

The time, $t_d$, for the doors to open and close depends on the width and type of the doors as listed in table 1. The kinetic energy of closing doors is limited by elevator safety codes and is usually not more than 0.29 J (7 ft poundal**). This is why doors from different manufacturers take about the same time to open and close. Types of elevator doors are shown in figure 3. Door operating time is important because of the many times that doors open and close during an evacuation. Further, an elevator can not teave a floor before the doors are closed and locked, and passengers can not leave an elevator until the doors are fully opened or nearly fully opened. Generally elevator doors do not open until the car has stopped and is level with the floor. However, some center opening doors start opening while the car is leveling, and the times listed in table 1 should be reduced by one second for these preopening doors.

The time, $t_i$, for people to enter an elevator depends on the number, $N$, of people entering and on the door operation. As previously stated, it is expected that most elevators will fill up on one floor and proceed to the discharge floor. However, elevators will be less than full when there are not enough people waiting in the lobby to fill an elevator or elevators. Thus the analysis must include partially filled elevators. Strakosch (1983) has observed elevator loadings for which passengers will not board an elevator and choose to wait for the next one. These observed values are based on 0.22 $m^2$ (2.3 $ft^2$) of floor space in the elevator car per person. It should be noted that the ASME A17.1 (1987) elevator standard allows a maximum loading at 0.14 $m^2$ (1.5 $ft^2$) per person, but this high density is not achieved in normal practice. For this study, the observed values of Strakosch are used as the number of persons in a full elevator car, and these loadings are listed in tables 3 and 4.

When elevator doors open, the doors remain open for a least fixed time referred to as the dwell-time. $t_{dw}$. The time that the door is open can be extended beyond the dwell-time by blocking of the light beam across the door opening or by pushing the door safety edge. The time, $t_i$, for $N$ people to enter an elevator car can be expressed as

$$t_i = \begin{cases} t_{dw} & \text{for } N \leq 2 \\ t_{dw} + t_{io}(N - N_{dw}) & \text{for } N > 2 \end{cases} \tag{5}$$

where the $N_{dw}$ is the number of people entering the elevator during the dwell time, and $t_{io}$ is the average time for one person to enter the elevator. The number of people entering the elevator during the dwell time is the term $(t_{dw}/t_{io})$ rounded down to the nearest integer. The time for $N$ people to leave an elevator can be expressed in a similar manner.

**The poundal is the unit of force in the pound mass-poundal system of units, and one poundal equals 0.0311 pounds force.

$$t_s = \begin{cases} t_{dw} & \text{for } N \le 2 \\ t_{dw} + t_{uo}(N - N_{dw}) & \text{for } N > 2 \end{cases} \tag{6}$$

For the computer program of this paper, the dwell-time is taken to be 4 seconds, the average time for one passenger to enter an elevator is taken to be 1 second, and the average time for one passenger to leave an elevator is taken to be 0.6 seconds.

## 4.2 Travel Time

Elevator motion is depicted in figure 4 for most trips. Motion starts with constant acceleration, followed by transitional acceleration, and constant velocity motion. Constant acceleration ends when the elevator reaches a predetermined velocity which is typically about 60% of the normal operating velocity ($V_1 = 0.6V_m$). For office buildings, the normal operating velocity is generally from 1 to 9 m/s (200 to 1800 fpm), and acceleration is from 0.6 to 2.4 $m/s^2$ (2 to 8 $ft/s^2$). Deceleration has the same magnitude as the acceleration, and the total acceleration time equals the total deceleration time ($t_2 = t_5 - t_3$). The method of analysis that follows takes advantage of this symmetry.

Analysis of elevator motion that reaches the normal operating velocity is presented next. For short trips elevators do not always reach the normal operating velocity, and methods of analysis for these short trips are presented later.

**Motion Reaching Normal Operating Velocity**

The time to complete constant acceleration motion (going to point 1 on figure 4) is

$$t_1 = \frac{V_1}{a} \tag{7}$$

The distance traveled during constant acceleration is

$$S_1 = \frac{V_1^2}{2a} \tag{8}$$

Transitional acceleration is approximated by considering the product of velocity and acceleration to be a constant. The time to reach the end of transitional acceleration (point 2 of figure 4) is

$$t_2 = \frac{V_m^2 - V_1^2}{2V_1 a} + t_1 \tag{9}$$

The distance traveled by the end of transitional acceleration is

$$S_2 = \frac{1}{3a}\left(\frac{V_m^3}{V_1} - V_1^2\right) + S_1 \tag{10}$$

The one way travel time is

$$t_5 = 2t_2 + \frac{S_T - 2S_2}{V_m} \tag{11}$$

The leveling time must be added to the above time to get the total travel time for a one way trip.

$$t_T = t_5 + t_h \tag{12}$$

Usually elevators do not stop exactly at the desired floor at the end deceleration, so the elevator must be moved slowly up or down to get it nearly level with the floor. For calculations in this paper, leveling time, $t_h$, is taken to be 0.5 seconds.

### Motion Reaching Transitional Acceleration

If the trip is too short for the elevator to reach the normal operating velocity, but it reaches transitional acceleration, the velocity is represented by either figure 5(a). The time, $t_1$, and distance, $S_1$, traveled during constant acceleration are given by equations (7) and (8). The velocity at the end of transitional acceleration is

$$V_2 = \left[V_1^3 + 3aV_1\left(\frac{S_T}{2} - S_1\right)\right]^{1/3} \tag{13}$$

The time at the end of transitional acceleration is

$$t_2 = \frac{V_2^2 - V_1^2}{2aV_1} + t_1 \tag{14}$$

The one way travel time is

$$t_T = 2t_2 + t_h \tag{15}$$

**Motion Not Reaching Transitional Acceleration**

When the trip does not go beyond constant acceleration, the motion is illustrated in figure 5(b). The one way travel time is

$$t_T = 2\sqrt{\frac{S_T}{a}} + t_h \tag{16}$$

Example 1. Round Trip Time in SI Units

A 1600 kg elevator in an office building makes a round trip from the ground floor to pick up a full load of passengers from the 21st floor and return them to the ground floor. The operating velocity is 3 m/s with an acceleration of 1.2 m/s$^2$, and the elevator door is 1200 mm wide center-opening. The distance between floors is 3.2 m, and the total travel distance, $S_T$, is 64 m.

From table 2, the number of people in the full elevator is approximated at 16. From table 1, $t_d$ is 5.3 s, and e is 0. The elevator shape is not unusual and the passenger capability is normal, so $\gamma$ is 0. The total transfer inefficiency is

$$\mu = \alpha + \varepsilon + \gamma = 0.10 + 0 + 0 = 0.10$$

From equation (5), the time for 16 people to enter the elevator is

$$t_i = N = 16 \mathrm{s}$$

From equation (6), the time for 16 people to leave the elevator is

$$t_u = 4 + 0.6(N - 6) = 4 + 0.6(16 - 6) = 10\,\mathrm{s}$$

From equation (4), the standing time is

$$t_s = (t_i + t_u + 2t_d)(1 + \mu) = (16 + 10 + 2(5.3))(1 + 0.1) = 40.26\mathrm{s}$$

Consider $V_1$ is 60% of $V_m$, then

$$V_1 = 0.6V_m = 0.6(3) = 1.8\,\mathrm{m/s}$$

From equation (7), the time at the end of constant acceleration is

$$t_1 = \frac{V_1}{a} = \frac{1.8}{1.2} = 1.5\,\mathrm{s}$$

From equation (8), the distance traveled during constant acceleration is

$$S_1 = \frac{V_1^2}{2a} = \frac{(1.8)^2}{2(1.2)} = 1.35\,\mathrm{m}$$

From equation (9), the time at the end of transitional acceleration is

$$t_2 = \frac{V_m^2 - V_1^2}{2V_1 a} + t_1 = \frac{(3)^2 - (1.8)^2}{2(1.8)(1.2)} + 1.5 = 2.83\,\mathrm{s}$$

From equation (10), the distance traveled by the end of transitional acceleration is

$$S_2 = \frac{1}{3a}\left(\frac{V_m^3}{V_1} - V_1^2\right) + s_1 = \frac{1}{3(1.2)}\left(\frac{3^3}{1.8} - 1.8^2\right) + 1.35 = 4.62\,\mathrm{m}$$

The one way travel time is calculated from equation (11).

$$t_3 = 2t_2 + \frac{S_T - 2S_2}{V_m} = 2(2.83) + \frac{64 - 2(4.62)}{3} = 23.9\,\mathrm{s}$$

The total travel time is calculated from equation (12).

$$t_T = t_S + t_k = 23.9 + 0.5 = 24.4\text{s}$$

The round trip time is calculated from equation (3).

$$t_r = 2t_T + t_s = 2(24.4) + 40.3 = 89.1\text{s}$$

Example 2. Round Trip Time in English Units

A 3500 lb elevator in an office building makes a round trip from the ground floor to pick up a full load of passengers from the 21st floor and return them to the ground floor. The operating velocity is 600 fpm with an acceleration of 4 $ft/s^2$, and the elevator door is 48 in wide center-opening. The distance between floors is 10.5 ft, and the total travel distance, $S$ , is 210 ft.

From table 3, the number of people in the full elevator is approximated at 16. From table 1. $t_d$ is 5.3 s, and e is 0. The elevator shape is not unusual and the passenger capability is normal, so $\gamma$ is 0. The total transfer inefficiency is

$$\mu = \alpha + \varepsilon + \gamma = 0.10 + 0 + 0 = 0.10$$

From equation (5), the time for 16 people to enter the elevator is

$$t_i = N = 16\text{s}$$

From equation (6), the time for 16 people to leave the elevator is

$$t_u = 4 + 0.6(N - 6) = 4 + 0.6(16 - 6) = 10\text{ s}$$

From equation (4), the standing time is

$$t_s = (t_i + t_u + 2t_d)(1 + \mu) = (16 + 10 + 2(5.3))(1 + 0.1) = 40.26\,s$$

Consider $V_1$ is 60% of $V_m$, then

$$V_1 = 0.6V_m = 0.6(3) = 1.8\text{ m/s}$$

The normal operating velocity is

$$V_m = 600\frac{\text{ft}}{\text{min}}\ \frac{1\ \text{min}}{60\ \text{s}} = 10\ \text{ft/s}$$

From equation (7), the time at the end of constant acceleration is

$$t_1 = \frac{V_1}{a} = \frac{6}{4} = 1.5\ \text{s}$$

From equation (8), the distance traveled during constant acceleration is

$$S_1 = \frac{V_1^2}{2a} = \frac{(6)^2}{2(4)} = 4.5\ \text{ft}$$

From equation (9), the time at the end of transitional acceleration is

$$t_2 = \frac{V_m^2 - V_1^2}{2V_1 a} + t_1 = \frac{(10)^2 - (6)^2}{2(6)(4)} + 1.5 = 2.83\ \text{s}$$

From equation (10), the distance traveled by the end of transitional acceleration is

$$S_2 = \frac{1}{3a}\left(\frac{V_m^3}{V_1} - V_1^2\right) + S_1 = \frac{1}{3(4)}\left(\frac{10^3}{6} - 6^2\right) + 4.5 = 15.4\ \text{ft}$$

The one way travel time is calculated from equation (11).

$$t_5 = 2t_2 + \frac{S_T - 2S_2}{V_m} = 2(2.83) + \frac{210 - 2(15.4)}{10} = 23.6\ \text{s}$$

The total travel time is calculated from equation (12).

$$t_T = t_5 + t_h = 23.6 + 0.5 = 24.1\text{s}$$

The round trip time is calculated from equation (3).

$$t_r = 2t_T + t_s = 2(24.1) + 40.3 = 88.5\ \text{s}$$

## 5. Computer Elevator Evacuation Analysis

A computer program (ELVAC), written in Quick BASIC, for analysis of elevator evacuation is listed in appendix A. This program calculates evacuation time for one group of elevators. For buildings with multiple groups of elevators, the program can be used a number of times to calculate the evacuation time for each group.

Example 3. Elevator evacuation time

Estimate the time needed for elevator evacuation of all the people from the upper 11 floors of a 21 story building to the outside of the building. Additionally, 3% of the people on the other floors are included in the elevator evacuation. The rest of the people on the lower floors will use the stairs. Each floor is occupied by 90 people. A group of six 1600 kg (3500 lb) elevators are used for the evacuation, and the elevator doors are 1200 mm (48 in) wide, center opening. One of the six cars is considered out-of-service, thus only five of the cars are used in the analysis. Other parameters of this example are listed in table 4.

Table 5 lists trip times and the evacuation time calculated by ELVAC. The evacuation time using five elevators is calculated at 1258 s or about 21 minutes.

Discussion of table 5 provides insight into the computer program. The round trip time for floor 21 is 89.1 s (the same as calculated in example 1). In order to move 90 people from floor 21, the elevator trips are considered to consist of five trips with a full car (16 people) plus one trip of a partially filled (10 people) car. The time for the partially filled round trip is 78.6 s (not shown in table 5). Thus the total trip time to move 90 people from floor 21 is 5(89.1) + 78.6 = 524.1 s. This time is listed under the heading "Time per Floor" for floor 21 in the table.

On floor 10 of this example 3% of 90 people are evacuated, this is rounded up to three people. Because this is done by one trip, the round trip time of 45.8 s listed in table 5 is for moving 3 people rather than the full car load of 16. The total round trip time of 5395.6 s is sum of all the round trips to move people from all the floors. The evacuation time of 1258.3 s using 5 elevators was calculated from equation (1).

## 6. Summary

A detailed method of analysis of people movement by elevators during emergency building evacuation is presented. This method is for one group of elevators. For buildings with multiple groups of elevators, the approach presented in this paper can be applied separately to each group. The time to evacuate a number of people using one group of elevators includes the sum of all the round trip times divided by the number of elevators plus the times needed to start up the elevator evacuation and to travel from the elevator lobby to the outside or to another safe location. A trip inefficiency is used to account for trips to empty floors and trips to pick up a few stragglers.

The round trip starts at the discharge floor and consists of the following sequence: elevator doors close, car travels to another floor, elevator doors open, passengers enter the car, doors close, car travels to discharge floor, doors open, and passengers leave the car. The round trip time is the sum of the standing time plus twice the one way travel time. The standing time is the sum of the time to open and close the elevator doors twice, the time for people to enter the elevator, and the time for people to leave the elevator. Elevator travel time is described by equations of motion under conditions of constant acceleration, constant velocity, and transitional acceleration between the first two. The computer program ELVAC can be used to calculate people movement during elevator evacuations.

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Table 1. Door Operating Time and Transfer Inefficiency

| Door Type | Width mm (in) | Time' to Open and Close $t_d$ (s) | Door Transfer Inefficiency e |
|---|---|---|---|
| Single-Slide | 900 (36) | 6.6 | 0.10 |
| Two-Speed | 900 (36) | 5.9 | 0.10 |
| Center-Opening[2] | 900 (36) | 4.1 | 0.08 |
| Single-Slide | 1100 (42) | 7.0 | 0.07 |
| Two-Speed | 1100 (42) | 6.6 | 0.07 |
| Center-Opening[2] | 1100 (42) | 4.6 | 0.05 |
| Two-Speed | 1200 (48) | 7.7 | 0.02 |
| Center-Opening[2] | 1200 (48) | 5.3 | 0 |
| Two-Speed | 1400 (54) | 8.8 | 0.02 |
| Center-Opening[2] | 1400 (54) | 6.0 | 0 |
| Two-Speed | 1600 (60) | 9.9 | 0.02 |
| Center-Opening[2] | 1600 (60) | 6.5 | 0 |
| Two-Speed, Center-Opening2 | 1600 (60) | 6.0 | 0 |

'Time to open and close doon includes 0.5 second. for car to start.
[2]When preopening can be used, the time to open and close these doon can be reduced by 1 second.

Table 2. Car size and observed loading in SI Units

| Capacity kg (lb) | Car Inside (mm) Wide | Deep | Area ($m^2$) | Observed Loading[1] (people) |
|---|---|---|---|---|
| 1200 (2640) | 2100 | 1300 | 2.73 | 10 |
| 1400 (3080) | 2100 | 1450 | 3.05 | 12 |
| 1600 (3520) | 2100 | 1650 | 3.47 | 16 |
| 1600 (alt.) | 2350 | 1450 | 3.41 | 16 |
| 1800 (3960) | 2100 | 1800 | 3.78 | 18 |
| 1800 (alt.) | 2350 | 1650 | 3.88 | 18 |
| 2000 (4400) | 2350 | 1800 | 4.23 | 20 |
| 2250 (4950) | 2350 | 1950 | 4.58 | 22 |
| 2700 (5940) | 2350 | 2150 | 5.05 | 25 |

[1]See footnote on table 3.

Table 3. Car size and observed loading in English Units

| Capacity (lb) | Car Inside (in) Wide | Deep | Area ($ft^2$) | Observed Loading[1] (people) |
|---|---|---|---|---|
| 2000 | 68 | 51 | 24.1 | 8 |
| 2500 | 82 | 51 | 29.0 | 10 |
| 3000 | 82 | 57 | 32.5 | 12 |
| 3500 | 82 | 66 | 37.6 | 16 |
| 3500 (alt.) | 92 | 57 | 36.4 | 16 |
| 4000 | 82 | 73 | 41.6 | 19 |
| 4000 (alt.) | 92 | 66 | 42.2 | 19 |
| 4500 | 92 | 72 | 46.0 | 21 |
| 5000 | 92 | 77 | 49.2 | 23 |
| 6000 | 92 | 90 | 57.5 | 27 |

[1]This loading is given by Strakosch (1983) as that for which passengers will not board an elevator and choose to wait for the next one.

Table 4. Parameters for Example 3

| | |
|---|---|
| Number of Stories | 21 |
| Number of Elevator Cars | 5 |
| Number of People Per Floor | 90 |
| Percent of People Evacuating by Elevators From Floors 2 to 10 | 3 |
| Percent of People Evacuating by Elevators From Floors 11 to 21 | 100 |
| Height Between Floors | 3.2 m (10.5ft) |
| Operating Velocity of Elevator Car, $V_m$ | 3.0m/s (590 fpm) |
| Car Acceleration, $a$ | 1.20 m/s$^2$ (3.94ft/s$^2$) |
| Other Transfer Inefficiency, $\gamma$ | 0 |
| Trip Inefficiency, $\eta$ | 0.10 |
| Car Full Load | 16 people |

Table 5. Elevator trip and evacuation time calculated by ELVAC computer program

| Floor | Elevation (m) | Elevation (ft) | One Way Trip Time (s) | Round Trip Time (s) | People on Floor | Percent Elevator Evacuation | Number of Round Trips | Time per Floor (s) |
|---|---|---|---|---|---|---|---|---|
| 21 | 64.0 | 210.0 | 24.4 | 89.1 | 90 | 100 | 6 | 524.1 |
| 20 | 60.8 | 199.5 | 23.4 | 87.0 | 90 | 100 | 6 | 511.3 |
| 19 | 57.6 | 189.0 | 22.3 | 84.8 | 90 | 100 | 6 | 498.5 |
| 18 | 54.4 | 178.5 | 21.2 | 82.7 | 90 | 100 | 6 | 485.7 |
| 17 | 51.2 | 168.0 | 20.2 | 80.6 | 90 | 100 | 6 | 472.9 |
| 16 | 48.0 | 157.5 | 19.1 | 78.4 | 90 | 100 | 6 | 460.1 |
| 15 | 44.8 | 147.0 | 10.2 | 76.3 | 90 | 100 | 6 | 447.3 |
| 14 | 41.6 | 136.5 | 17.0 | 74.2 | 90 | 100 | 6 | 434.5 |
| 13 | 38.4 | 126.0 | 15.9 | 72.0 | 90 | 100 | 6 | 421.7 |
| 12 | 35.2 | 115.5 | 14.2 | 69.9 | 90 | 100 | 6 | 408.9 |
| 11 | 32.0 | 105.0 | 13.8 | 67.8 | 90 | 100 | 6 | 396.1 |
| 10. | 28.8 | 94.5 | 12.7 | 45.8 | 90 | 3 | 1 | 45.8 |
| 9 | 25.6 | 84.0 | 11.6 | 43.7 | 90 | 3 | 1 | 43.7 |
| 8 | 22.4 | 73.5 | 10.6 | 41.6 | 90 | 3 | 1 | 41.6 |
| 7 | 19.2 | 63.0 | 9.5 | 39.4 | 90 | 3 | 1 | 39.4 |
| 6 | 16.0 | 52.5 | 8.4 | 37.3 | 90 | 3 | 1 | 37.3 |
| 5 | 12.8 | 42.0 | 7.4 | 35.2 | 90 | 3 | 1 | 35.2 |
| 4 | 9.6 | 31.5 | 6.3 | 33.0 | 90 | 3 | 1 | 33.0 |
| 3 | 6.4 | 21.0 | 5.2 | 30.8 | 90 | 3 | 1 | 30.8 |
| 2 | 3.2 | 10.5 | 3.8 | 28.0 | 90 | 3 | 1 | 28.0 |
| 1 | 0.0 | 0.0 | | | | | | |

| | | |
|---|---|---|
| Total round trip time | = | 5395.6 |
| Startup time | = | 41.3 |
| Time to get outside after leaving the elevator | = | 30.0 |
| Evacuation time using 5 elevators | = | 1258.3 |

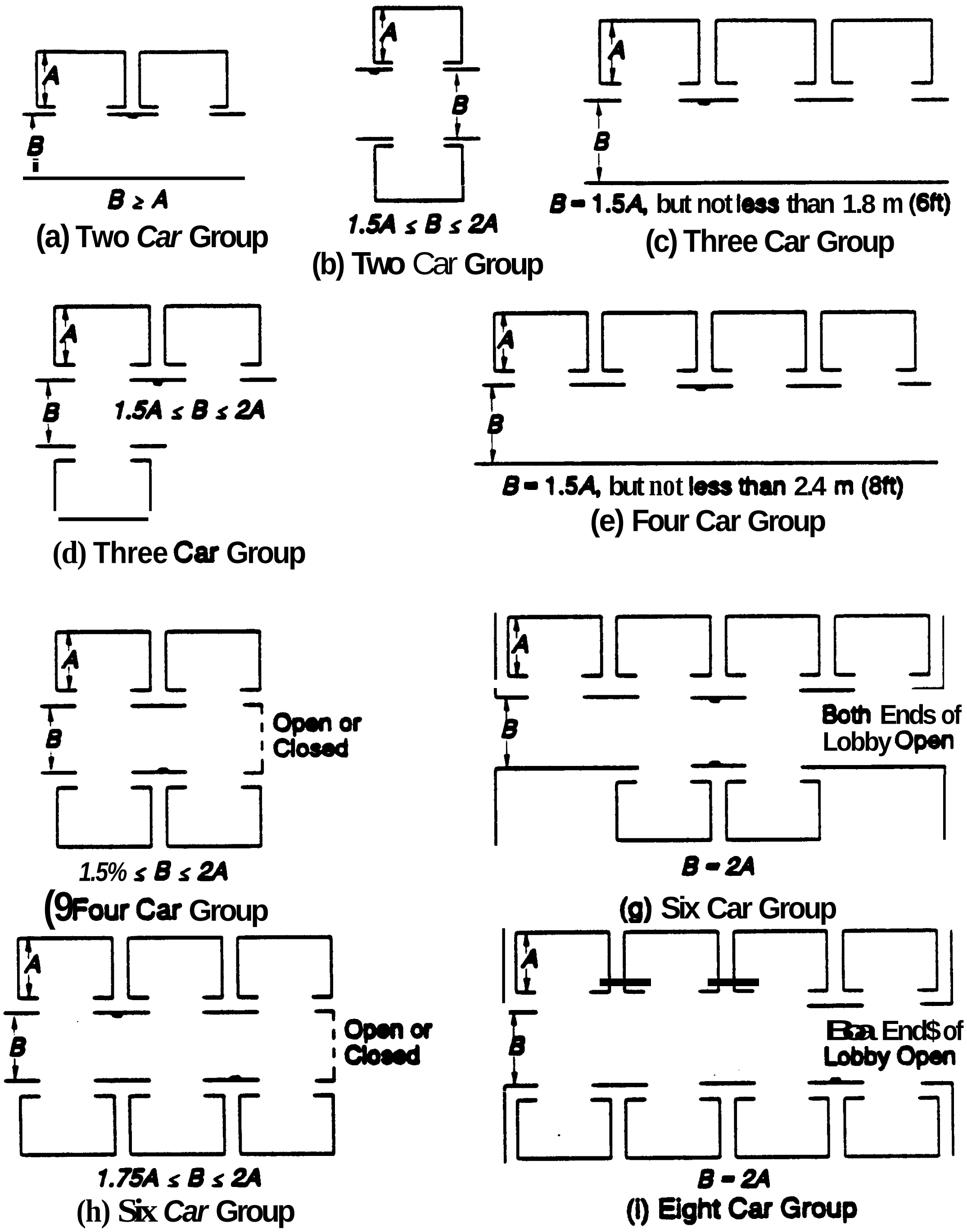


Figure 1. Commonly accepted elevator arrangements

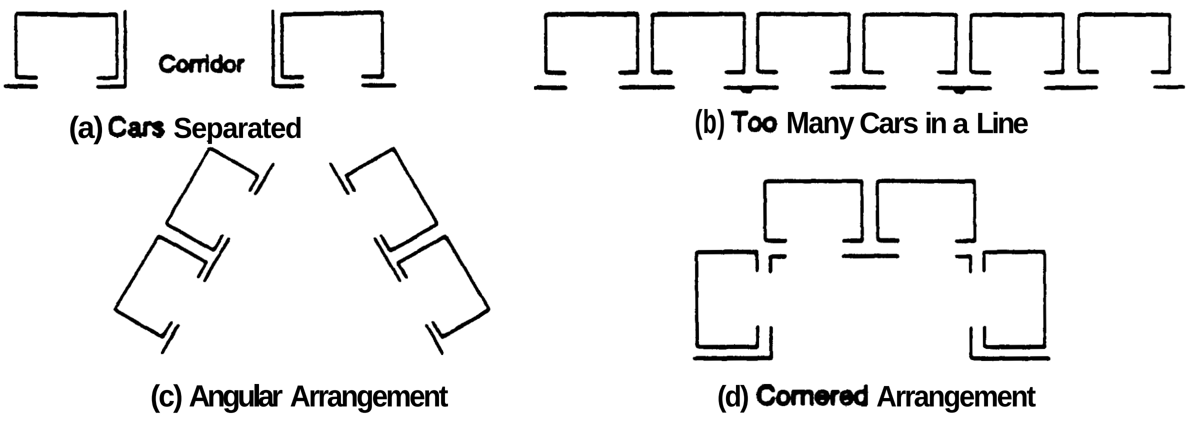


Figure 2. Unusual elevator arrangements resulting in inefficient people movement

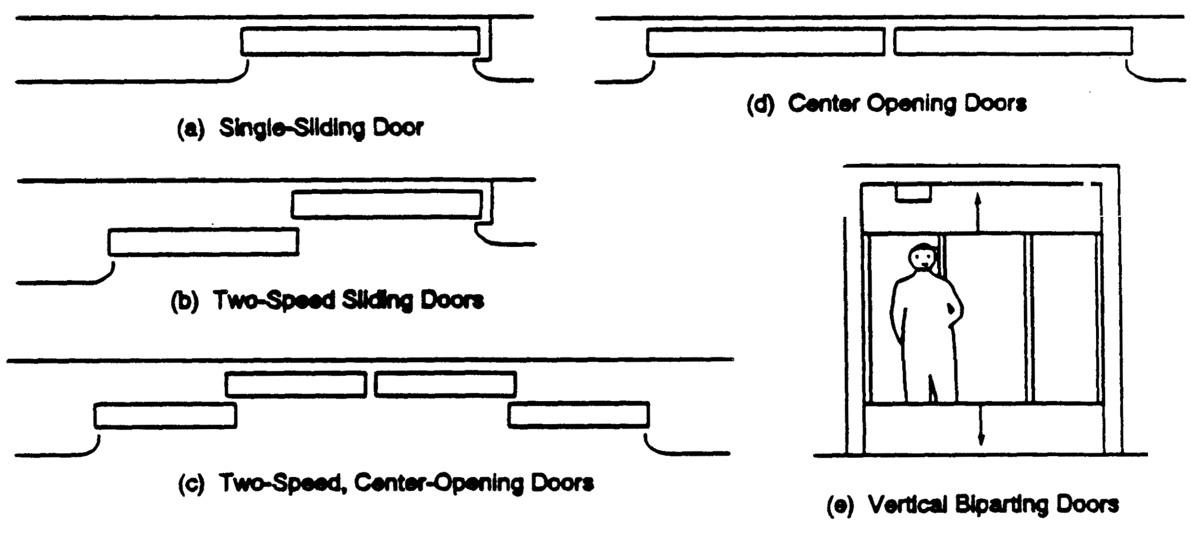


Figure 3. Types of elevator doors

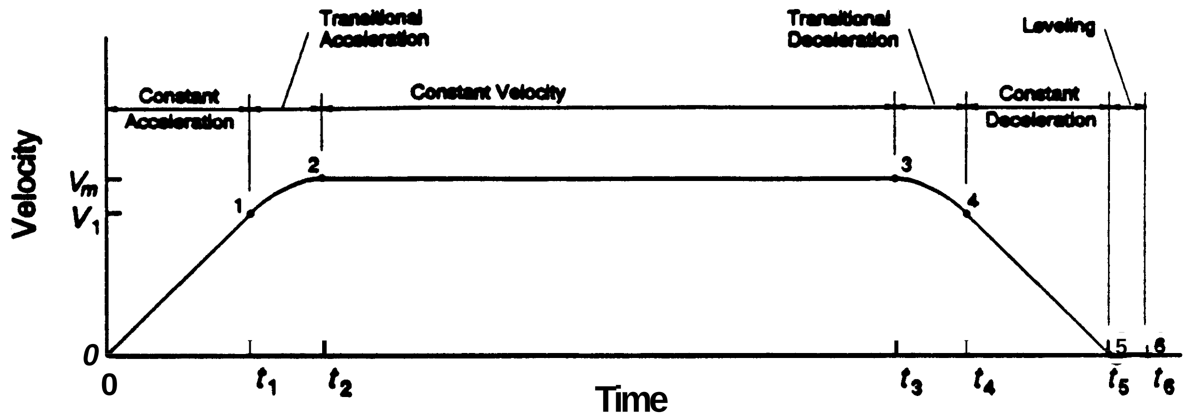


Figure 4. Velocity of elevator reaching normal operating velocity, V

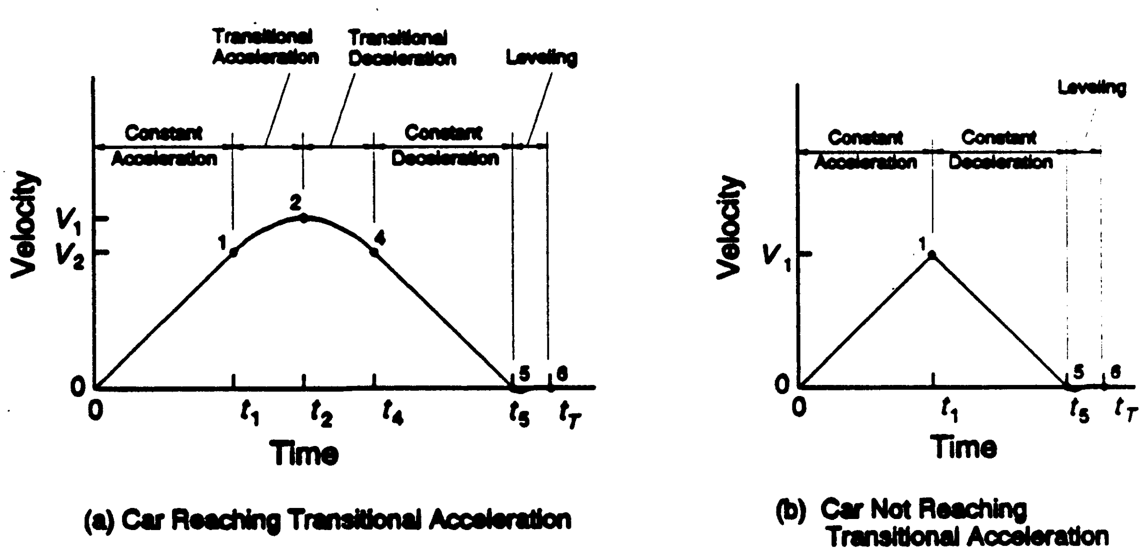


Figure 5. Velocity of elevators not reaching normal operating velocity

## Appendix A Listing of ELVAC Computer Program

```
DEFDBL A-Z
'*****************************
' P R O G R A M   E L V A C *
'*****************************
'
'
'
'--------------------------------------------------------------------------
'
' A             RATE OF CAR ACCELERATION IN FT/S**2.
' ASI           RATE OF CAR ACCELERATION IN M/S**2.
' BASTRANSIN    BASIC TRANSFER INEFFICIENCY. CHOSEN TO 0.1.
' BOTTOEXIT     DISTANCE FROM BOTTOMMOST FLOOR TO EXIT.
' DISTANTFLR    THE NUMBER OF THE FLOOR MOST DISTANT FROM THE EXIT FLOOR.
' DOORINEFF()   DOOR INEFFICIENCY VALUES, SELECTED BY THE USER FROM A TABLE.
' DOORTIME()    TIME IN SECONDS REQUIRED FOR THE OPENING AND CLOSING OF THE
' DOORPTYPESS   DIFFERENT TYPES OF ELEVATOR DOORS, IN A FORMAT USED FOR
'                PRINTING.
' DOORTYPESS    CHARACTER STRING ARRAY WHICH CONTAINS THE DIFFERENT TYPES OF
'                ELEVATOR DOORS AS WELL AS THEIR CHARACTERISTICS.
' DRTIME        TIME (S) REQUIRED FOR THE OPENING AND CLOSING OF THE ELEVATOR
'                CAR DOOR.
' ELCARS        TOTAL NUMBER OF ELEVATOR CARS WITHIN THE GROUP, INPUT BY THE
'                USER.
' ELEVATION(I) ELEVATIONS OF THE VARIOUS FLOORS ABOVE THE LOWEST FLOOR,
'                WHICH IS ASSUMED TO HAVE AN ELEVATION OF 0. I IS Ith FLOOR.
' EXITDELAY     TIME (S) TO OUTSIDE AFTER LEAVING ELEVATOR.
' EXITFLR       POSITION OF'THE EXIT FLOOR RELATIVE TO THE LOWEST FLOOR
'                IN THE BUILDING. FOR EXAMPLE, IF EXITFLR IS 3, IT IS TWO
'                FLOORS ABOVE THE LOWEST ONE.
' EXITIMEFLRI   TIME (S) FOR ALL RESIDENTS OF FLOOR I TO REACH EXIT FLOOR.
' EXITNAMES     NAME OF FLOOR CHOSEN TO BE THE EXIT FLOOR.
' EVACTIME      TOTAL EVACUATION TIME USING ALL ELEVATOR CARS IN THE BANK.
' FINPCTS       SET TO "Y" WHEN THE MODEL USER WISHES TO CONTINUE THE RUN
'                WITH NEW ELEVATOR PERCENTAGE VALUES.
' FLOORS$       THE CHARACTER VARIABLE CONTAINING THE LINE OF FLOOR NAMES.
' FLRNAMES$(I) CHARACTER ARRAY WHICH HOLDS THE FLOOR NAMES AFTER THE RANGES
'                HAVE BEEN EXPANDED BY THE PROGRAM.
' FULLOAD       NUMBER OF PEOPLE THAT FULLY LOAD THE ELEVATOR CAR.
' HGTDIF(I)     HEIGHT DIFFERENCE BETWEEN FLOOR I AND FLOOR I+1.
' INFOPATHS     THE LOCATION WHERE GENERAL INFORMATION ABOUT THE PROGRAM
'                IS SENT.
' KILLEXP       A VARIABLE THAT IS SET TO 1 IF ANY ERRORS ARE FOUND IN THE
'                SPECIFIED LINE OF FLOOR NAMES.
' LEVELTME      TIME (S) REQUIRED FOR THE LEVELING OF THE ELEVATOR CAR. IT
'                CURRENTLY IS SET TO .5 SECONDS.
' METELEV       ELEVATION OF CURRENT FLOOR IN METERS. RECOMPUTED FOR EACH
```

```
'                 FLOOR.
' MTITLE1$       FIRST TITLE ROW FOR OUTPUT TABLE.
' MTITLE2$       SECOND TITLE ROW FOR OUTPUT TABLE.
' MTITLE3$       THIRD TITLE ROW FOR OUTPUT TABLE.
' NPPLELAST      THIS IS THE NUMBER OF PEOPLE IN THE ELEVATOR CAR DURING THE
'                 LAST TRIP, AND IS RECOMPUTED FOR EACH FLOOR.
' NTRIPSFULL     THE NUMBER OF ROUND TRIPS WITH A FULLY LOADED ELEVATOR CAR,
'                 RECOMPUTED FOR EACH FLOOR.
' OPTIONERRORS A FLAG THAT IS SET TO "YES" IF THE OUTPUTOPTION IS NOT
'                 1 OR 2.
' OTHERTRANSIN OTHER TRANSFER INEFFICIENCY VALUE, DUE TO ELEVATOR CAR SHAPE
'                 AND OCCUPANT USE.
' OUTPUTOPTION AN INTEGER BETWEEN 1 AND 2 WHICH IS CHOSEN BY THE USER TO
'                 DETERMINE WHERE STORED OUTPUT IS SENT.
' PATHSELS       "N" IF ONLY SCREEN OUTPUT IS DESIRED,  "PRN" IF THE FINAL
'                 OUTPUT RESULTS ARE TO BE PRINTED, OR A DOS FILENAME IF THE
'                 FINAL OUTPUT RESULTS ARE TO BE SENT TO A FILE.
' PEOPLE(I)      NUMBER OF PEOPLE ON THE Ith FLOOR.
' PERCNT(I)      PERCENT OF PEOPLE ON Ith FLOOR WHO USE ELEVATOR CARS TO LEAVE
'                 THE BUILDING.
' PPLEFLR        TYPICAL NUMBER OF PEOPLE ON A FLOOR, GIVEN BY THE USER.
' PPLEI          ACTUAL NUMBER OF PEOPLE ON Ith FLOOR WHO USE THE ELEVATOR
'                 CAR. IT IS THE PRODUCT OF PEOPLE(I) AND PERCNT(I).
' PRINTINFOS     A FLAG SET TO Y IF THE USER WISHES TO READ ABOUT THE MODEL.
' RERUNPERCNT    FLAG SET EQUAL TO 0 WHEN THE USER WISHES TO LEAVE THE MAIN
'                 DO LOOP, OR 1 WHEN HE WISHES TO RERUN IT WITH NEW ELEVATOR
'                 USAGE PERCENTAGE VALUES.
' RERUNOUTPUT$    SET EQUAL TO Y WHEN THE USER DESIRES TO SEND THE OUTPUT
'                 RESULTS TO THE PRINTER OR A FILE.
' RERUNPROG$     SET EQUAL TO "Y" WHEN THE USER WISHES TO RERUN THE PROGRAM.
' RNDTIMES(I)    TOTAL TIME (a) FOR THE TRIPS REQUIRED TO EVACUATE FLOOR I.
' STARTUPTIME    TIME SPENT BEFORE THE ACTUAL EVACUATION BY ELEVATOR CARS
'                 BEGINS. IT IS COMPUTED FIRST TO BE THE TIME REQUIRED TO
'                 BRING A FULLY LOADED ELEVATOR CAR FROM THE MOST DISTANT
'                 FLOOR TO THE EXIT FLOOR. IF THIS IS NOT SATISFACTORY, THE
'                 USER INPUTS A LARGER VALUE.
' STNDTMEFULL    STANDING TIME CALCULATED FOR A FULLY LOADED ELEVATOR.
' TIMEFULL       SUM OF THE TIMES OF FULLY LOADED ROUND TRIPS. RECOMPUTED FOR
'                 EACH FLOOR.
' TIMELAST       TIME REQUIRED FOR THE LAST ROUND TRIP FROM A FLOOR.
' TIMES(I)       TIME FOR A ONE WAY TRIP TO FLOOR I.
' TITLES         TITLE OF THE CURRENT RUN.
' TOKENS$(I)     NON-BLANK SUBSTRINGS CONTAINED WITHIN EACH PARSED LINE (SEE
'                 PARSING ROUTINE).
' TOPTOEXIT      DISTANCE FROM TOP FLOOR TO EXIT FLOOR.
' TOTFLRS        TOTAL NUMBER OF FLOORS IN THE BUILDING.
' TOTINEFF       BASIC TRANSFER INEFFICIENCY + DOOR INEFFICIENCY +
'                 OTHER TRANSFER INEFFICIENCY.
' TOTTIME        TOTAL TIME TO EVACUATE BUILDING BY ELEVATOR.
' TRANS          TRANSITIONAL COEFFICIENT. V1 = TRANS*VMAX.
' TRIPINEFF      TRIP INEFFICIENCY DUE TO GATHERING STRAGGLERS, TRAVEL TO
'                 EMPTY FLOORS, FLOW RESTRICTIONS, ETC.
```

```
' TRIPS        NUMBER OF ROUND TRIPS NEEDED TO EVACUATE A FLOOR.
' TYPDIF       TYPICAL FLOOR TO FLOOR HEIGHT IN FEET.
' TYPDIFsi     TYPICAL FLOOR TO FLOOR HEIGHT IN METERS.
' TYPPERCNT    TYPICAL PERCENT OF ELEVATOR USAGE.
' UNITS        1 IF SI UNITS ARE DESIRED, 2 IF ENGLISH UNITS ARE REQUESTED.
' VMAX         MAXIMUM ELEVATOR CAR VELOCITY IN ft./second.
' VMAXsi       MAXIMUM ELEVATOR CAR VELOCITY IN m./second.
'------------------------------------------------------------------------------

'      FIRST, DECLARE THE FIVE SUBROUTINES AND THE FUNCTION CALLED BY THE
'      MAIN PROGRAM. THESE SIX SUBPROGRAMS AND THEIR ARGUMENTS WILL BE
'      DESCRIBED BY COMMENT STATEHENTS APPEARING LATER.
    DECLARE SUB CHECK (NUMTOK#, LLIMIT#, UPLIMIT#, ARRPTR#)
    DECLARE SUB PARSE (STORES, NUMTOKS#)
    DECLARE SUB HEIGHTS ()
    DECLARE SUB RANGEEXP (FLRSTRS, FLRSUB1, FLRSUB2, FLR1$, FLR2$, EXPEXCP)
    DECLARE SUB TRIPTIME ()
    DECLARE FUNCTION CALCSTANDX (PEOPX)

'      THESE ARE THE VARIABLES SHARED WITH OTHER ROUTINES.
    DIM SHARED TOKENS$(200), FLOORS$, UNITS
    DIM SHARED FLRNAMES$(200), HGTDIF(200), ELEVATION(200)
    DIM SHARED TIMES(200), people(200), PERCNT(200)
    DIM SHARED KILLEXP, TOTFLRS, EXITFLR
    DIM SHARED TYPDIF, TYPDIFsi, VMAX, TRANS, A, LEVELTME, FULLOAD
    DIM SHARED DRTIME, TOTINEFF

'      DIMENSION THE ARRAYS WHICH ARE NOT SHARED.
    DIM DOORTYPES$(15), Doortime(14), DOORINEFF(14), RNDTIMES(200)
    DIM DOORPTYPES$(13)


'      DATA STATEMENTS INITIALIZING THE DOORTIME AND DOOR TRANFER
'      INEFFICIENCY ARRAY NOW APPEAR.
    DATA 6.6,5.9,4.1,7.0,6.6,4.6,7.7,5.3,8.8,6.0,9.9,6.5,6.0
    DATA .10,.10,.08,.07,.07,.05,.02,0,.02,0,.02,0,0
    FOR I = 1 TO 13: READ Doortime(I): NEXT I
    FOR I = 1 TO 13: READ DOORINEFF(I): NEXT I


'      DATA STATEMENTS USED IN INITIALIZING THE DOOR TYPE ARRAY
'      ARE NOW GIVEN. THE ARRAY IS THEN INITIALIZED.
    DATA" A Single-Slide       900mm (36in)     6.6      0.10"
    DATA" B Two-Speed          900mm (36in)     5.9      0.10"
    DATA" C Center-Opening     900mm (36in)     4.1      0.08"
    DATA" D Single-Slide      1100mm (42in)     7.0      0.07"
    DATA" E Two-Speed         1100mm (42in)     6.6      0.07"
    DATA" F Center-Opening    1100mm (42in)     4.6      0.05"
    DATA" G Two-Speed         1200mm (48in)     7.7      0.02"
    DATA" H Center-Opening    1200mm (48in)     5.3      0    "
    DATA" I Two-Speed         1400mm (54in)     0.0      0.02"
    DATA" J Center-Opening    1400mm (54in)     6.0      0    "
```

```
DATA" K Two-Speed                1600mm (60in)         9.9            0.02"
DATA" L Center —— ning           1600mm (60in)         6.5            0    "
DATA" M Two-Speed,               1600mm (60in)         6.0            0    "
DATA"    Center-Opening                                                    "
DATA" N OTHER                                                              "
FOR I = 1 TO 15: READ DOORTYPES$(I): NEXT I

'    DATA STATEMENTS TO INITIALIZE THE DOOR TYPE PRINTING ARRAY NOW
'    APPEAR. INITIALIZATION OF THE ARRAY IS PERFORMED.
DATA" A Single-Slide                  900mm (36in) wide"
DATA" B Two-Speed                     900mm (36in) wide"
DATA" C Center-Opening                900mm (36in) wide"
DATA" D Single-Slide                 1100mm (42in) wide"
DATA" E Two-Speed                    1100mm (42in) wide"
DATA" F Center-Opening               1100mm (42in) wide"
DATA" G Two-Speed                    1200mm (48in) wide"
DATA" H Center-Opening               1200mm (48in) wide"
DATA" I Two-Speed                    1400mm (54in) wide"
DATA" J Center-Opening               1400mm (54in) wide"
DATA" K Two-Speed                    1600mm (60in) wide"
DATA" L Center-Opening               1600mm (60in) wide"
DATA" M Two-Sped, Center-Opening     1600mm (60in) wide"
FOR I = 1 TO 13: READ DOORPTYPES$(I): NEXT I

'    SET THE DEFAULT VALUES OF SOME OF THE VARIABLES.
BASTRANSIN = .1#
TRANS = .6#
LEVELTME = .5#
RERUNOUTPUT$ = "N"
PATHSELS = "SCRN:"

'    THE MAIN TITLES FOR THE OUTPUT TABLE ARE NOW CREATED.
MTITLE1$ = "                              One      Round     People"
MTITLE1$ = MTITLE1$ + "                          Time"
MTITLE2$ = "Floor      Elevation         Way      Trip        on"
MTITLE2$ = MTITLE2$ + "   Percent  Round     per"
MTITLE3$ = "Name       m        ft       Time s   Time s"
MTITLE3$ = MTITLE3$ + "  Floor   Usage     Trip.    Floor s"


' ************************************************************
' ***   MAIN PROGRAX EXECUTION DO LOOP.
'         THIS LOOP RUNS THE ENTIRE PROGRAM. AT THE END,
'         THE USER IS ASKED IF HE WISHES TO RERUN IT. IF
'         SO, THE PROGRAM IS RERUN. OTHERWISE, THE LOOP
'         IS EXITED AND THE PROGRAM STOPS.
' ************************************************************

DO
```

```
'       INITIALLY SEND COMPUTED OUTPUT TO THE SCREEN.
    CLS
    OPEN "SCRN:" FOR OUTPUT AS #1


    PRINT ""
    PRINT "**********************************************************************"
    PRINT " ELVAC VERSION 1.00                                                  "
    PRINT " WRITTEN BY DANIEL M. ALVORD AND                                     "
    PRINT "        JOHN H. KLOTE                                                "
    PRINT "                                                                     "
    PRINT "CONTRIBUTION OF THE NATIONAL INSTITUTE OF STANDARDS AND              "
    PRINT "   TECHNOLOGY. (U.S.)                                                "
    PRINT "  NOT SUBJECT TO COPYRIGHT                                           "
    PRINT "                                                                     "
    PRINT "FOR COMPILED VERSION ONLY - PORTIONS (C) COPYRIGHT MICROSOFT         "
    PRINT "CORPORATION, 1988. ALL RIGHTS RESERVED.                              "
    PRINT "                                                                     "
    PRINT "DOCUMENTATION: KLOTE,J.H., ALVORD,D.M., AND DEAL,S., ANALYSIS OF"
    PRINT "PEOPLE MOVEMENT DURING ELEVATOR EVACUATION, NATIONAL INSTITUTE      "
    PRINT "OF STANDARDS AND TECHNOLOGY, (U.S.), NISTIR 4730, 1992.              "
    PRINT "**********************************************************************"
    PRINT ""


'       THE USER NOW INDICATES IF HE WISHES TO READ GENERAL INFORMATION
'       ABOUT PARTICULAR CONCEPTS OF THE ELEVATOR MODEL.
    INPUT "Do you want to read about the model (Y or N)?  ", PRINTINFOS
    PRINTINFOS = UCASE$(PRINTINFO$)

'       THE USER NOW SPECIFIES WHERE THE GENERAL INFORMATION SHOULD BE
'       PLACED.
    PRINT ""
    IF PRINTINFOS = "Y" THEN
       PRINT "Where do you wish the general information to appear?"
       PRINT "  (a filename, PRN for printer, or ENTER for output"
       INPUT "   to the screen.)  ", INFOPATHS
       INFOPATHS = UCASE$(INFOPATH$)
       IF INFOPATHS = "" THEN INFOPATHS = "SCRN:"
       OPEN INFOPATHS FOR OUTPUT AS #2
    END IF

'       GENERAL INFORMATION ABOUT THE MODEL AND ITS COMPUTER IMPLEMENTATION
*       IS NOW GIVEN, IF THE USER SO SPECIFIES.
    IF PRINTINFOS = "Y" THEN

    CLS
    PRINT ""
    PRINT #2, " --------------Basic concepts of the model------------------"
    PRINT #2, " Basic tranafer inefficiency- a factor that allows for      "
```

```
PRINT #2, "   rounding off of probable stops, door operating time, door"
PRINT #2, "   starting and stopping time, and the unpredictability of  "
PRINT #2, "   people. A value of 0.10 is ured for commonly accepted    "
PRINT #2, "   arrangements of elevator groups.                         "
PRINT #2, " Discharge floor- When emergency evacuation etarts,         "
PRINT #2, "   elevators will take people to a discharge floor where    "
PRINT #2, "   passengers on the elevators will exit. This floor may    "
PRINT #2, "   lead to the outside or to an area of relative safety.    "
PRINT #2, " Door inefficiency- Adjurtr for any increase in transfer    "
PRINT #2, "   time over that of a 1200 mm (48 in) wid8 center opening  "
PRINT #2, "   door.                                                    "
 IF INFOPATH$ = "SCRN:" THEN
    PRINT ""
    INPUT "Press ENTER to continue.......", junk$
    CLS
    PRINT ""
 END IF
PRINT #2, " Dwell time- The minimum time an elevator car door-remains
PRINT #2, "   open. The time used in this program is 4 seconds.        "
PRINT #2, " Groups- Elevator8 are located in groups of up to eight     "
PRINT #2, "   elevators. The elevators in a group are located near each"
PRINT #2, "   other and are controlled together to move people         ".
PRINT #2, "   efficiently.
PRINT #2, " Elevator evacuation start up time- The time from activation"
PRINT #2, "   of the alarms(for example) to the start of the round trips"
PRINT #2, "   that evacuate people. If the elevators are operated      "
PRINT #2, "   automatically during evacuation, one starts the elevator "
PRINT #2, "   evacuation after all of th8 elevators have been moved    "
PRINT #2, "   to the discharge floor and tho people in them have left. "
PRINT #2, "   In the case Of manual elevator operation, the time for   "
PRINT #2, "   elevators operators to roach the cars must b8 included.  "
PRINT #2, " Motion- Elevator motion starts with conrtant acceleration, "
PRINT #2, "   followed by tranritional acceleration until constant     "
PRINT #2, "   velocity motion at the normal operating velocity of the  "
PRINT #2, "   car is attained.                                         "

 IF INFOPATHS = "SCRN:" THEN
    PRINT ""
    INPUT "Press ENTER to continue....", junk$
    CLS
    PRINT ""
 END IF
PRINT #2, " Other transfer inefficiency- accounts for inefficiencies   "
PRINT #2, "   due to unusual elevator car shape or limited physical    "
PRINT #2, "   capability of passengers. In office building., a value of"
PRINT #2, "   0 is used.                                               "
PRINT #2, " Round trip- a round trip starts at th8 discharge floor and "
PRINT #2, "   consists Of the sequence: elevator doors close, car      "
PRINT #2, "   travels to another floor, door8 open, passengers enter   "
PRINT #2, "   the car, doorr close, car travels to discharge floor,    "
PRINT #2, "   doors open, and passengers leave the car. Alternatively, "
PRINT #2, "   it may b8 defined as two one way trips and a standing    "
```

```
PRINT C2, "   period.                                                          "
PRINT #2, " Standing time- Twice the time required to open and close  "
PRINT #2, "   the elevator doors, plus the time for people to enter the"
PRINT #2, "   elevator, plus the time for people to leave the elevator."
PRINT #2, " Trip inefficiency- a multiplicative factor that accounts   "
PRINT #2, "   for trips to empty floors and for tripe to pick up only a"
PRINT #2, "   few stragglers.                                                  "

 IF INFOPATHS = "SCRN:" THEN
    PRINT ""
    INPUT "Press ENTER to continue...." , junk$
    CLS
    PRINT ""
 END IF
PRINT #2, " -------Concepts inherent to the computer program-----------"
PRINT #2, " Range- A range is a set of floor names that is expanded by "
PRINT #2, "   the program into a set of contiguous floor numbers. For  "
PRINT #2, "   example, the range 2-10 is expanded into 2,3,4,5,6,....,  "
PRINT #2, "   9,10.                                                       "
PRINT #2, " Typical- Used to save effort in the input. It is best shown"
PRINT #2, "   by example. The typical inter floor height of a building "
PRINT #2, "   typical inter floor height of a building is the most     "
PRINT #2, "   commonly occurring height between floors (12 feet is an  "
PRINT #2, "   example). There is a typical inter floor height, a       "
PRINT #2, "   typical number of people on a floor, and a typical       "
PRINT #2, "   elevator uaage percent.                                  "

END IF

IF INFOPATHS = "SCRN:" THEN PRINT "": PRINT "": PRINT ""

'   READ IN THE TITLE OF THE CURRENT RUN.
PRINT "Enter the title of this run. "
LINE INPUT TITLE$

'   ENTER VALUE INDICATING WHETHER METRIC! OR ENGLISH UNITS ARE DESIRED.
DO
   PRINT ""
   INPUT "Enter 1 for SI units or 2 for English units: ", UNITS
   IF UNITS <> 1 AND UNITS <> 2 THEN
      PRINT "  ***INVALID UNIT INDICATOR."
   END IF
LOOP UNTIL UNITS = 1 OR UNITS = 2

'   READ IN THE LINE OF FLOOR NAMES. THE LINE IS EXAMINED BY THE PROGRAM
'   AND, IF ANY ERRORS ARE DISCOVERED, THE USER MUST REENTER THE LINE.
'   IF NO ERRORS ARE FOUND, THE PROGRAM WILL USE THE FLOOR NAME LINE
```

```
'       TO CREATE THE INDIVIDUAL FLOOR NAMES. THE HEIGHTS SUBROUTINE IS THEN
'       CALLED TO READ IN THE TYPICAL FLOOR HEIGHT, ANY HEIGHT EXCEPTIONS,
'       AND THEN TO COMPUTE THE ELEVATIONS OF EACH FLOOR.

     DO
        PRINT ""
        PRINT "Enter floor8 that the elevators serve (for example- B G 1-6)"
        LINE INPUT FLOORS$
        CALL HEIGHTS
     LOOP UNTIL KILLEXP = 0

'       THE USER IS NOW PROXPTED BY THE PROGRAX TO KEY IN THE EXIT (DISCHARGE)
'       FLOOR NAME.  IF THE NAME IS NOT FOUND IN THE LIST OF FLOOR NAMES, AN
'       ERROR MESSAGE APPEARS AND THE USER MUST RETYPE THE EXIT FLOOR NAME.
     DO
        PRINT ""
        INPUT "Discharge floor"; EXITNAMES
        EXITFLR = 0
        FOR I = 1 TO TOTFLRS
           IF EXITNAXES = FLRNAMES$(I) THEN
              EXITFLR = I
              EXIT FOR
           END IF
        NEXT I
        IF EXITFLR = 0 THEN
           PRINT ""
           PRINT "        FLOOR NAME "; EXITNAMES; " NOT FOUND."
           PRINT "          VALID NAMES- "; FLOORS$
        END IF
     LOOP UNTIL EXITFLR <> 0

'       THE EXIT DELAY TIME MUST NOW BE INPUT. IF IT IS NOT WITHIN A CERTAIN
'       RANGE, THE PROGRAM PROMPTS THE USER TO RETYPE IT.
     DO
        PRINT ""
        INPUT "Time to outside after leaving elevator (a)"; EXITDELAY
        IF 0# > EXITDELAY OR EXITDELAY > 10000# THEN
           PRINT " *****TIME TO OUTSIDE IS OUT OF RANGE."
        END IF
     LOOP UNTIL EXITDELAY >= 0# AND EXITDELAY <= 100001

'       THE TRIP INEFFICIENCY FACTOR IS NOW ENTERED.
     DO
        PRINT ""
        INPUT "Trip inefficiency factor (for example .1)?   ", TRIPINEFF
        IF 0# > TRIPINEFF OR TRIPINEFF > 1# THEN
           PRINT " *****TRIP INEFFICIENCY FACTOR IS OUT OF RANGE."
        END IF
     LOOP UNTIL TRIPINEFF >= 0# AND TRIPINEFF <= it
```

```
'       THE TOTAL NUMBER OF ELEVATOR CARS IN THE GROUP IS NOW INPUT.
    DO
       PRINT ""
       INPUT "Number of elevator cars in the group?    ", ELCARS
       IF ELCARS <= 0# OR 100# < ELCARS THEN
          PRINT " *****TOTAL NUMBER OF ELEVATOR CARS IS OUT OF RANGE.'*
       END IF
    LOOP UNTIL ELCARS > 0# AND ELCARS <= 100#


'       THE USER NOW ENTERS THE NORMAL OPERATING VELOCITY OF THE ELEVATOR
'       CAR.
    DO
       PRINT ""
       IF UNITS = 1 THEN
          INPUT "Normal operating velocity of car (m/s)"; VMAXsi
          VMAX = VMAXsi * (1 / .3048#)
       ELSE
          INPUT "Normal operating velocity of car (fpm)"; VMAX
          VMAX = VMAX / 60
          VMAXsi = VMAX * .3048#
       END IF
       IF 0# >= VMAX OR 60000# < VMAX THEN
          PRINT " *****NORMAL CAR VELOCITY IS OUT OF RANGE."
       END IF
    LOOP UNTIL VMAX > 0# AND VMAX <= 60000#


        NOW THE RATE OF ACCELERATION OF THE ELEVATOR CAR IS INPUT.
    DO
       PRINT ""
       IF UNITS = 1 THEN
          INPUT "Car acceleration (m/s**2)"; Asi
          A = Asi * (1 / .3048#)
       ELSE
          INPUT "Car Acceleration (ft/s**2)"; A
          Asi = A * .3048#
       END IF
       IF 0# >= A OR 1000# < A THEN
          PRINT " *****CAR ACCELERATION RATE IS OUT OF RANGE."
       END IF
    LOOP UNTIL 0# < A AND A <= 1000#


        NEXT, ENTER THE DESIRED FULL LOAD FOR THE ELEVATOR CAR. IT MUST BE
'       INTEGER.
    DO
       PRINT ""
       FLAG = 0
       INPUT "Elevator Full Load (people)"; FULLOAD
       IF 0# >= FULLOAD OR S0# < FULLOAD THEN
```

```
      PRINT " *****ELEVATOR FULL LOAD VALUE IS OUT OF RANGE."
      FLAG = 1
   END IF
   IF INT(FULLOAD) <> FULLOAD THEN
      PRINT " *****ELEVATOR FULL LOAD VALUE MUST BE AN INTEGER."
      FLAG = 1
   END IF
LOOP UNTIL FLAG = 0


'    THE TIME REQUIRED TO OPEN AND CLOSE THE ELEVATOR CAR DOORS IS NOW
'    ENTERED.
DO
   PRINT ""
   PRINT "                         ------ MENU OF DOOR TYPES ------   "
   PRINT STRING$(69, "-")
   PRINT " Door type" + STRING$(16, " ");
   PRINT " Door width   Time to Open   Door Transfer"
   PRINT STRING$(39, " ") + " and Close, a    Inefficiency"
   PRINT STRING$(69, "-")
   FOR I = 1 TO 15
      PRINT DOORTYPES$(I)
   NEXT I
   PRINT "      ***Pick one of the door choices A - M.   "
   INPUT "           If you wish to specify another type, enter N.    ", R$
   R$ = UCASE$(R$)
   IF LEN(R$) = 1 THEN
      DOORCHOICE = ASC(R$) - 64
      IF DOORCHOICE < 1 OR DOORCHOICE > 14 THEN
         PRINT ""
         PRINT " *****DOOR CHOICE INVALID."
      ELSEIF DOORCHOICE = 14 THEN
         PRINT ""
         PRINT "      *** ANOTHER DOOR TYPE SPECIFIED***"
         PRINT ""
         INPUT "      New doortime value (s)?  ", Doortime(14)
         DO
            PRINT ""
            INPUT "     New door inefficiency value?  ", DOORINEFF(14)
            MM = DOORINEFF(14)
            IF MM < 0# OR MM > 1# THEN
               PRINT ""
               PRINT "     ***Door inefficiency value is out of range."
            END IF
         LOOP UNTIL MM >= 0# AND MM <= 1#
      END IF
   ELSE
      PRINT ""
      PRINT " *****DOOR CHOICE: CONTAINS MORE THAN ONE CHARACTER."
   END IF
LOOP UNTIL LEN(R$) = 1 AND DOORCHOICE >= 1 AND DOORCHOICE <= 14
```

```
'  THE OTHER TRANSFER INEFFICIENCY FACTOR IS NOW INPUT.
DO
   PRINT ""
   INPUT "Other transfer inefficiency?   ", OTHERTRANSIN
   IF OTHERTRANSIN < 0# OR OTHERTRANSIN > 1# THEN
      PRINT "  *****OTHER TRANSFER INEFFICIENCY IS OUT OF RANGE,"
   END IF
LOOP UNTIL 0# <= OTHERTRANSIN AND OTHERTRANSIN <= 1#


'  THE DOORTIME AND TOTAL TRANSFER INEFFICIENCY ARE NOW COMPUTED.
DRTIME = Doortime(DOORCHOICE)
TOTINEFF = BASTRANSIN + DOORINEFF(DOORCHOICE) + OTHERTRANSIN


'  THE STANDING TIME REQUIRED TO FULLY LOAD AN ELEVATOR CAR IS NOW
'  COMPUTED AND STORED.
STNDTMEFULL = CALCSTAND#(FULLOAD#)


'  NEXT, THE ONE WAY TRIP TIMES ARE COMPUTED FOR EACH FLOOR.
CALL TRIPTIME


'  NOW THE START UP TIME IS COMPUTED OR INPUT. THIS IS THE TIME REQUIRED
'  TO PREPARE FOR THE ACTUAL EGRESS BY ELEVATOR AFTER THE SIGNAL FOR
'  EVACUATION IS GIVEN.
TOPTOEXIT = ELEVATION(TOTFLRS) - ELEVATION(EXITFLR)
BOTTOEXIT = ELEVATION(EXITFLR) - ELEVATION(1)
IF TOPTOEXIT > BOTTOEXIT THEN DISTANTFLR = TOTFLRS ELSE DISTANTFLR = 1
IF FULLOAD > 6 THEN OVER6FACT = .6 * (FULLOAD - 6)
UNLOADTIME = 4# + OVER6FACT
STARTUPTIME = (1 + TOTINEFF) * (DRTIME + UNLOADTIME) + TIMES(DISTANTFLR)
PRINT "The startup time for automatically operated elevators ";
PRINT USING "is ####.## seconds."; STARTUPTIME
INPUT " Do you want to enter another value (Y or N)?   ", NEWFLAG$
NEWFLAG$ = UCASE$(NEWFLAG$)
IF NEWFLAG$ = "Y" THEN
   DO
      INPUT "  ?  ", STARTUPTIME
      IF STARTUPTIME < 0 OR STARTUPTIME > 10000 THEN
         PRINT ""
         PRINT "    VALUE FOR START UP TIME IS NOT IN CORRECT RANGE. "
      END IF
      PRINT ""
   LOOP UNTIL STARTUPTIME >= 0 AND STARTUPTIME <= 10000
ELSE
   PRINT ""
END IF


'  THE TYPICAL NUMBER OF PEOPLE ASSIGNED TO EACH FLOOR MUST NOW BE
```

```
'     ENTERED. IT MUST BE AN INTEGER.
DO
   FLAG = 0
   INPUT "Typical Number of People per Floor"; PPLEFLR
   IF 0# >= PPLEFLR OR 100000# < PPLEFLR THEN
      PRINT " *****TYPICAL PEOPLE PER FLOOR VALUE IS OUT OF RANGE."
      FLAG = 1
   END IF
   IF INT(PPLEFLR) <> PPLEFLR THEN
      PRINT " *****TYPICAL PEOPLE PER FLOOR VALUE MUST BE AN INTEGER."
      FLAG = 1
   END IF
LOOP UNTIL FLAG = 0
FOR I = 1 TO TOTFLRS: people(I) = PPLEFLR: NEXT I

'     NEXT, THE PEOPLE PER FLOOR EXCEPTIONS ARE INPUT. THESE OVERRIDE
'     THE TYPICAL PEOPLE NUMBER.
FOR I = 1 TO 1000
   PRINT "  People per floor exception:"
   PRINT "   Floor Range, people (enter END to atop)"
   LINE INPUT STORES
   CALL PARSE(STORE$, NUMTOKS#)
   CALL CHECK(NUMTOKS#, 0#, 100000#, 2#)
   IF TOKENS$(1) = "STOP" THEN EXIT FOR
NEXT I


'     ******************************************************************
'     * MAIN DO LOOP
'     *      READS IN A NEW SET OF ELEVATOR USE PERCENTAGES. THIS LOOP
'     *      IS RERUN UNTIL THE CURRENT INPUT VALUES TOGETHER WITH THE
'     *      NEW PERCENTAGE VALUES PRODUCE SATISFACTORY RESULTS.
'     ******************************************************************

DO


'     THE TYPICAL ELEVATOR USAGE IS NOW KEYED IN. THIS IS THE PERCENT OF
'     PEOPLE ON EACH FLOOR WHO USE ELEVATOR CARS TO EGRESS. IT MUST BE
'     A VALUE BETWEEN 0 AND 100.
DO
   PRINT ""
   INPUT "Percent of people on typical floor using elevator"; TYPPERCNT
   IF TYPPERCNT < 0# OR TYPPERCNT > 100# THEN
      PRINT " *****ELEVATOR USAGE PERCENT IS OUT OF RANGE."
   END IF
LOOP UNTIL 0# <= TYPPERCNT AND TYPPERCNT <= 100#
FOR I = 1 TO TOTFLRS: PERCNT(I) = TYPPERCNT: NEXT I

'     NEXT, EXCEPTIONS TO THE TYPICAL ELEVATOR USAGE PERCENT ARE ENTERED.
'     THESE OVERRIDE THE TYPICAL PERCENT.
```

```
FOR I = 1 TO 1000
   PRINT "  Percent usage exceptions:"
   PRINT "     Floor Range, Percent (enter END to stop)"
   LINE INPUT STORES
   CALL PARSE(STORE$, NUMTOKS#)
   CALL CHECK(NUMTOKS#, 0#, 100#, 3#)
   IF TOKENS$(1) = "STOP" THEN EXIT FOR
NEXT I


'    ***********************************
'    * MAIN OUTPUT LOOP
'    ***********************************

'     FIRST, CLEAR THE SCREEN. NEXT, EXECUTE THE OUTPUT LOOP UNTIL THE
'     VALUE OF RERUNOUTPUTS IS Y. THE VALUE OF THIS VARIABLE IS 1 ONLY WHEN
'     THE USER WANTS TO PRINT OR STORE THE OUTPUT RESULTS.
CLS


DO


'    IMPORTANT PROGRAM PARAMETERS ARE NOW PRINTED. THESE APPEAR BEFORE
'    THE TABLE OF FLOOR INFORMATION.
PRINT #1, ""
PRINT #1, TITLE$
PRINT #1, ""
PRINT #1, USING "People per floor is ######.      "; PPLEFLR
PRINT #1, USING "Distance between floors is  ####.## m"; TYPDIFsi;
PRINT #1, USING "  or ####.## ft.          "; TYPDIF
PRINT #1, USING "Elevator usage percent is ###.###%" ; TYPPERCNT
PRINT #1, USING "Normal car velocity is      ###.## m/s "; VMAXsi;
PRINT #1, USING "or ####.## fpm."; VMAX * 60
PRINT #1, USING "Car acceleration is           ##.## m/s2"; Asi;
PRINT #1, USING " or ##.## ft/s2."; A
PRINT #1, USING "Car full load is ### people."; FULLOAD
PRINT #1, USING "Full load rtanding time is ###.## s."; STNDTMEFULL
PRINT #1, USING "Other transfer inefficiency is #.####"; OTHERTRANSIN
PRINT #1, USING "Trip inefficiency is #.###  "; TRIPINEFF
IF DOORCHOICE <> 14 THEN
   PRINT #1, "Door type:"; DOORPTYPES$(DOORCHOICE)
   PRINT #1, USING "   Doortime s ###.###   "; Doortime(DOORCHOICE);
   PRINT #1, USING " Door inefficiency  ###.### "; DOORINEFF(DOORCHOICE)
ELSE
   PRINT #1, "Door type:  OTHER  "
   PRINT #1, "   Doortime s ";
   PRINT #1, USING "###.###    Door inefficiency "; Doortime(14);
   PRINT #1, USING "#.### "; DOORINEFF(14)
END IF
PRINT #1, ""
PRINT #1, STRINGS(78, "-")
```

```
'       NOW THE VALUES FOR THE OUTPUT TABLE ARE COMPUTED AND PRINTED. THE
'       FIRST ROW CORRESPONDS TO THE TOP FLOOR OF THE BUILDING, THE NEXT
'       ROW TO THE FLOOR BENEATH THE TOP FLOOR, ETC.
     PRINT #1, MTITLE1$
     PRINT #1, MTITLE2$
     PRINT #1, MTITLE3$
     PRINT /1, STRING$(78, "-")
     TOTTIME = 0#
     FOR I = TOTFLRS TO 1 STEP -1
        PPLEI = people(I) * PERCNT(I) * .01#
        IF INT(PPLEI) <> PPLEI THEN PPLEI = INT(PPLEI + .5#) + 1
        TRIPS = PPLEI / FULLOAD
        IF INT(TRIPS) <> TRIPS THEN TRIPS = CINT(TRIPS + .5#)
        NTRIPSFULL = INT(PPLEI / FULLOAD)
        NPPLELAST = PPLEI - NTRIPSFULL * FULLOAD
        RNDTIMES(I) = 2# * TIMES(I)
        IF NTRIPSFULL = 0# THEN
           TIMELAST = RNDTIMES(I) + CALCSTAND(NPPLELAST#)
           RNDTIMES(I) = TIMELAST
           TIMEFULL = 0#
        ELSEIF NTRIPSFULL > 0# AND NPPLELAST = 0# THEN
           TIMELAST = 0#
           RNDTIMES(I) = RNDTIMES(I) + STNDTMEFULL
           TIMEFULL = NTRIPSFULL * RNDTIMES(I)
        ELSEIF NTRIPSFULL > 0# AND NPPLELAST > 0# THEN
           TIMELAST = RNDTIMES(I) + CALCSTAND(NPPLELAST#)
           RNDTIMES(I) = RNDTIMES(I) + STNDTMEFULL
           TIMEFULL = NTRIPSFULL * RNDTIMES(I)
        END IF
        IF PPLEI = 0# THEN
           EXITIMEFLRI = 0#
        ELSE
           EXITIMEFLRI = TIMEFULL + TIMELAST
        END IF
        PRINT #1, USING "\      \ "; FLRNAMES$(I);
        METELEV = ELEVATION(I) * .3048#
        PRINT #1, USING "####.#  ####.#   "; METELEV; ELEVATION(I);
        IF I = EXITFLR THEN
           PRINT #1, " "
        ELSE
           PRINT #1, USING "####.#   ####.#   "; TIMES(I); RNDTIMES(I);
           PRINT #1, USING "######   ###.#    "; people(I); PERCNT(I);
           PRINT #1, USING "####   #####.#"; TRIPS; EXITIMEFLRI
           TOTTIME = TOTTIME + EXITIMEFLRI
        END IF
     NEXT I
     PRINT #1, STRING$(78, "-")
     EVACTIME = (TOTTIME / ELCARS) * (1# + TRIPINEFF) + EXITDELAY
     EVACTIME = EVACTIME + STARTUPTIME
```

```
'       THE TOTAL BUILDING EVACUATION TIME NOW APPEARS.
     PRINT #1, STRING$(43, " ");
     PRINT #1, "Total round trip time=";
     PRINT #1, USING "  #######.#"; TOTTIME
     PRINT #1, STRING$(51, " ");
     PRINT #1, "Start up time=";
     PRINT #1, USING "     ####.#"; STARTUPTIME
     PRINT #1, STRING$(11, " ");
     PRINT #1, "Time to get to the outside after leaving the elevator=";
     PRINT #1, USING "      ###.#" ; EXITDELAY
     PRINT #1, STRING$(30, " ");
     PRINT #1, USING "Evacuation time using ## elevators="; ELCARS;
     PRINT #1, USING "  #######.#"; EVACTIME
     PRINT #1, STRING$(53, " ");
     PRINT #1, USING "(Or ######.# minutes)"; EVACTIME / 60


'       DETERMINE IF THE PROGRAM USER WISHES TO SAVE THE OUTPUT SHOWN ON THE
'       SCREEN. IF THIS IS THE CASE, THE OUTPUT LOOP IS RERUN. THE USER MAY
'       PRINT THE OUTPUT, SEND IT TO A FILE, OR DO BOTH.
     PRINT ""
     IF PATHSELS = "SCRN:" THEN
        INPUT "Do you want to save the output (Y or N)?  ", RERUNOUTPUTS
     ELSE
        INPUT "Do you want to save the output again (Y or N)?  ", RERUNOUTPUTS
     END IF
     RERUNOUTPUTS = UCASE$(RERUNOUTPUT$)
     IF RERUNOUTPUTS = "Y" THEN
        DO
            OPTIONERRORS = "NO"
            PRINT ""
            PRINT " The options for saving the output now follow.          "
            PRINT " Enter a number corresponding to one of the following: "
            PRINT "     1.   Send the output to the printer.               "
            PRINT "     2.   Store the output in a file.                   "
            PRINT ""
            INPUT "Output option?  ", OUTPUTOPTION
            IF OUTPUTOPTION < 1 OR OUTPUTOPTION > 2 THEN
               PRINT ""
               PRINT "  *** Incorrect option number.  Must be 1 OR 2. ***"
               OPTIONERRORS = "YES"
            END IF
            IF OUTPUTOPTION = 1 THEN
               PATHSELS = "PRN"
               CLOSE #1
               OPEN PATHSELS FOR OUTPUT AS #1
            ELSEIF OUTPUTOPTION = 2 THEN
               PRINT ""
               INPUT "   What is the filename?  ", PATHSELS
               PATHSELS = UCASE$(PATHSEL$)
               CLOSE #1
```

```
                OPEN PATHSELS FOR OUTPUT AS #1
             END IF
          LOOP UNTIL OPTIONERRORS = "NO"
       ELSE
          PATHSELS = "SCRN:"
          CLOSE #1
          OPEN PATHSELS FOR OUTPUT AS #1
          RERUNOUTPUTS = "N"
       END IF

'        ***************************
'        * END OF MAIN OUTPUT LOOP
'        ***************************
      LOOP UNTIL RERUNOUTPUTS = "N"


'        DETERMINE IF THE USER WISHES TO RERUN THE PROGRAM WITH NEW ELEVATOR
'        USAGE PERCENTAGES.
      PRINT ""
      INPUT "Rerun program with new usage percentages (Y or N)?  ", FINPCTS
      FINPCTS = UCASE$(FINPCT$)
 .    IF FINPCTS = "Y" AND PATHSELS <> "SCRN:" THEN
         CLOSE #1
         OPEN "SCRN:" FOR OUTPUT AS #1
      END IF
      IF FINPCTS = "Y" THEN RERUNPERCNT = 1
      IF FINPCT$ <> "Y" THEN RERUNPERCNT = 0


'     ***************************
'     *** END OF MAIN DO LOOP
'     ***************************

      LOOP UNTIL RERUNPERCNT = 0


' ***********************************
' *** END OF PROGRAM EXECUTION LOOP
' ***********************************

      PRINT ""
      INPUT "Do you wish to rerun the entire program (Y or N)?  ", RERUNPROG$
      RERUNPROG$ = UCASE$(RERUNPROG$)
      CLOSE #1

    LOOP UNTIL RERUNPROGS = "N"


      END

'-----------------------------------------------------------------------
```

```
'   F U N C T I O N   C A L C S T A N D
'-----------------------------------------------------------------------------
'          THIS FUNCTION COMPUTES THE STANDING TIME PORTION OF AN ELEVATOR'S
'    TRIP. IT IS DEFINED AS FOLLOWS:
' STANDING TIME = (1 + TOTINEFF) * (2*DOORTIME+LOADING TIME+UNLOADING TIME)
'-----------------------------------------------------------------------------
'            LOCAL VARIABLES:
'      LOADTIME    TIME (s) TO LOAD AN ELEVATOR CAR.
'      PEOP#       NUMBER OF PEOPLE FOR WHICH THE STANDING TIME IS COMPUTED.
'      OVER6FACT   EXTRA TIME REQUIRED WHEN PEOP# IS OVER 6.
'      UNLOADTIME  TIME (■) TO UNLOAD AN ELEVATOR CAR AT THE EXIT FLOOR.
'            GLOBAL VARIABLES:
'      DRTIME      TIHE (a) REQUIRED FOR THE OPENING AND CLOSING OF THE
'                   ELEVATOR CAR DOOR.
'      TOTINEFF    TOTAL TRANSFER INEFFICIENCY.
'-----------------------------------------------------------------------------
    FUNCTION CALCSTAND# (PEOP#)

    OVER6FACT = 0
    IF PEOP# > 6# THEN OVER6FACT = .6# * (PEOPX - 6)
    IF PEOP# <= 2# THEN LOADTIME = 2# ELSE LOADTIME = PEOPX
    UNLOADTIME = 4# + OVER6FACT

    CALCSTAND# = (1# + TOTINEFF) * (2# * DRTIME + LOADTIME + UNLOADTIME)

    END FUNCTION

'-----------------------------------------------------------------------------
'   S U B R O U T I N E   C H E C K
'-----------------------------------------------------------------------------
'                 THIS SUBROUTINE CHECKS HEIGHT, PEOPLE PER FLOOR, AND
'           ELEVATOR USAGE PER FLOOR EXCEPTIONS. THESE EXCEPTIONS ARE
'           ENTERED IN THE FORM nm,val , WHERE nm IS A FLOOR NAME AND val
'           IS AN EXCEPTION VALUE. THE STRING VALUE "END" STOPS EXCEPTION
'           INPUT FOR EACH OF THE THREE CATEGORIES OF EXCEPTIONS.
'-----------------------------------------------------------------------------
'                 ARGUMENTS:
'      NUMTOK#    NUMBER OF STRINGS FOUND ON THE CURRENT LINE BY THE PARSING
'                  ROUTINE. THIS IS PASSED TO CHECK.
'      LLIMIT#    LOWER LIMIT FOR THE SECOND ITEM ON THE LINE.
'      UPLIMIT#   UPPER LIMIT FOR THE SECOND ITEM.
'      ARRPTR#    EITHER 1, 2, OR 3. IT DETERMINES THE ARRAY TO WHICH THE
'                  SECOND ITEM IS PASSED.
'-----------------------------------------------------------------------------
    SUB CHECK (NUMTOK#, LLIMIT#, UPLIMIT#, ARRPTR#)

    IF NUMTOK# = 0 THEN
       PRINT "      BLANK LINE HAS BEEN ENTERED OR GENERATED."
       EXIT SUB
    END IF

'      IF THE INFORMATION ON THE LINE IS SUCH THAT NO FURTHER ANALYSIS
```

```
'        IS POSSIBLE, EXIT THE SUBROUTINE.  IF THERE IS ONE ITEM, AND IT IS
'        THE CORRECT END INDICATOR, SET A FLAG TO STOP SUBROUTINE CALLS
'        FOR THIS TYPE OF EXCEPTION.
      IF NUMTOK# > 2 THEN
         PRINT "       MORE THAN TWO ITEMS ON LINE."
         EXIT SUB
      ELSEIF NUMTOK# = 2 AND UCASE$(TOKENS$(1)) = "END" THEN
         PRINT "       TWO ITEMS ON LINE, BUT FIRST ONE IS THE END INDICATOR."
         EXIT SUB
      ELSEIF NUMTOK# = 1 AND UCASE$(TOKENS$(1)) = "END" THEN
         TOKENS$(1) = "STOP"
         EXIT SUB
      ELSEIF NUMTOK# = 1 AND UCASE$(TOKENS$(1)) <> "END" THEN
         PRINT "       ONE ITEM ON LINE, NOT CORRECT END INDICATOR."
         EXIT SUB
      END IF

'        THE FIRST ITEM ON THE LINE SHOULD BE THE FLOOR NAME OR RANGE.  CHECX
'        TO SEE IF IT MATCHES A NAME THAT HAS BEEN PREVIOUSLY SPECIFIED.
'        THE RANGE EXPANSION SUBROUTINE IS CALLED TO CHECX THE FLOOR RANGE
'        SPECIFIED.  IF THE VALUE OF EXPECP IS 0, THE RANGE WAS EXPANDED.
'        IF 1, THE RANGE COULD NOT BE EXPANDED DUE TO CERTAIN ERRORS FOUND
'        IN ITS COMPONENTS.  IF IT IS 2, THE FLOOR NAME IS A SINGLE ITEM.
      CALL RANGEEXP(TOKENS$(1), FLRSUB1, FLRSUB2, FLREXCP1$, FLREXCP2$, EXPECP)

'        PRINT OUT AN ERROR MESSAGE IF ONE OR MORE OF THE NAMES IN THE FLOOR
'        RANGE COULD NOT BE FOUND IN THE FLOOR NAME TABLE.
      IF FLRSUB1 = 0 AND EXPECP = 0 THEN
         PRINT "      FLOOR NAME "; FLREXCP1$; " NOT FOUND."
         PRINT "        VALID NAMES- "; FLOORS$
      END IF
      IF FLRSUB2 = 0 AND EXPECP = 0 THEN
         PRINT "      SECOND FLOOR NAME "; FLREXCP2$; "  NOT FOUND."
         PRINT "        VALID NAMES- "; FLOORS$
      END IF
      IF FLRSUB1 = 0 AND EXPECP = 2 THEN
         PRINT "      FLOOR NAME "; FLREXCP1$; " NOT FOUND."
         PRINT "        VALID NAMES- "; FLOORS$
      END IF


      ERRFLAG = 0

'        DETERMINE IF THE SECOND ITEM IS A VALID NUMBER.
      FOR I = 1 TO LEN(TOKENS$(2))
         PTR$ = MID$(TOKENS$(2), I, 1)
         IF INSTR(".0123456789", PTR$) = 0 THEN
            PRINT "       INVALID NUMBER AFTER FLOOR NAME."
            ERRFLAG = 1
            EXIT FOR
         END IF
         IF INSTR(".", PTR$) = 1 AND ARRPTR# = 2# THEN
```

```
            PRINT "      NO DECIMAL POINTS ALLOWED IN PEOPLE/FLR NUMBER."
            ERRFLAG = 1
         END IF
      NEXT I

'        IF THE ITEM IS A VALID NUMBER, DETERMINE IF IT LIES BETWEEN THE
'        LOWER AND UPPER LIMITS.
      IF ERRFLAG = 0 THEN
         NUMB = VAL(TOKENS$(2))
         IF NUMB < LLIMIT# OR NUMB > UPLIMIT# THEN
            PRINT "      NUMBER AFTER FLOOR NAME IS OUT OF RANGE."
            ERRFLAG = 1
         END IF
      END IF

'        IF ANY ERRORS HAVE BEEN DETECTED, LEAVE THE SUBROUTINE.
      IF ERRFLAG = 1 THEN EXIT SUB

'        SET THE APPROPRIATE ARRAY ROW(S) TO THE VALUE OF THE EXCEPTION.
      FOR I = FLRSUB1 TO FLRSUB2
         IF ARRPTRX = 1# AND UNITS = 1 THEN HGTDIF(I) = NUMB * (1 / .3048#)
         IF ARRPTRX = 1# AND UNITS = 2 THEN HGTDIF(I) = NUMB
         IF ARRPTRX = 2X THEN people(I) = NUMB
         IF ARRPTRX = 3# THEN PERCNT(I) = NUMB
      NEXT I


      END SUB

'-----------------------------------------------------------------------
'     S U B R O U T I N E   H E I G H T S
'-----------------------------------------------------------------------
'           THIS SUBROUTINE FIRST CALLS THE PARSING ROUTINE TO ISOLATE ALL
'       FLOOR NAMES IN THE FLOOR NAME LINE INPUT BY THE USER.  IT CHECKS FOR
'       SITUATIONS WHICH MAKE FURTHER ANALYSIS IMPOSSIBLE.  IT THEN EXAMINES
'       ALL FLOOR NAMES WHICH CONTAIN THE CHARACTER "-". THESE ARE TERMED
'       RANGES (such as 2-10 is the range of floats from 2 through 10). ANY
'       RANCES FOUND ARE EXAMINED CAREFULLY FOR POSSIBLE AMBIGUITIES,
'       INVALID NUMBERS, ETC.  IF NO ERRORS ARE DETECTED, ANY RANGES THAT HAVE
'       BEEN FOUND ARE EXPANDED.  NEXT, THE SUBROUTINE PROMPTS THE USER FOR
'       HEIGHT EXCEPTIONS. AFTER THESE HAVE BEEN ENTERED THE ELEVATIONS ARE
'       COMPUTED AND THE SUBROUTINE IS EXITTED.
'-----------------------------------------------------------------------
'                        LOCAL VARIABLES, AND GLOBAL VARIABLES CHANGED HERE:
'        CURTOK$        CONTAINS STRING VALUE BEING TESTED AS A POSSIBLE RANGE.
'        ELEMENT        NUMBER OF SUBSTRINGS FOUND ON THE FLOOR NAME LINE.
'        ELEVATION(I)   ELEVATXON OF Ith FLOOR ABOVE LOWEST FLOOR.
'        FLOORS$        INITIALLY CONTAINS THE FLOOR NAME LINE INPUT BY THE
'                        USER, THEN IT IS COMPRESSED TO REMOVE EXTRA BLANKS.
'        FLRNAMES$(I)   ARRAY CONTAINING THE FLOOR NAMES AFTER RANGE EXPANSION.
'        HGTDIF(I)      ARRAY WHOSE Ith ROW IS THE HEIGHT DIFFERENCE BETWEEN
'                        FLOOR I AND FLOOR I+1, WHERE THE LOWEST FLOOR IS 1.
```

```
'       KILLEXP       IF THIS IS SET TO 1, THE MAIN PROGRAM KEEPS ON PROMPTING
'                      THE USER FOR A NEW FLOOR NAME LINE.
'       PTR           COUNTER USED WHEN FLRNAMESS ARRAY IS CREATED.
'       RANGE1$(I)    CONTAINS THE FIRST RANGE VALUE OF Ith RANGE FOUND. FOR
'                      EXAMPLE, IF THE 4th RANGE FOUND IS 7-10, RANGE1$(4)="7"
'       RANGE2$(I)    SIMILAR TO RANGE1$(I), BUT STORES SECOND RANGE VALUES.
'       RANGEMK       LOCATION OF THE CHARACTER "-" IN A SUBSTRING. IF IT IS
'                      NOT 0, THE SUBSTRING IS ASSUMED TO BE A RANGE.
'       STORES        CONTAINS THE HEIGHT EXCEPTION LINE.
'       TOTFLRS       SET EQUAL TO THE TOTAL NUMBER OF FLOORS FOUND AFTER
'                      EXPANSION.
'       TYPDIF        TYPICAL FLOOR TO FLOOR HEIGHT. CAN BE OVERRIDDEN BY
'                      HEIGHT EXCEPTIONS FOR INDIVIDUAL FLOORS.
'-----------------------------------------------------------------------------
'
    SUB HEIGHTS

    DIM RANGE1$(200), RANGE2$(200)

    KILLEXP = 0

'      PARSE THE LINE OF FLOOR NAMES.
    CALL PARSE(FLOORS$ , NUMTOK#)
    ELEMENT = NUMTOKI

'      IF NO ITEMS ARE FOUND ON THE FLOOR NAME LINE, PRINT ERROR MESSAGE
'      AND EXIT SUBROUTINE.
    IF ELEMENT = 0 THEN
       PRINT "-
       PRINT " BLANK LINE HAS BEEN ENTERED OR GENERATED."
       KILLEXP = 1
       EXIT SUB
    END IF

'      IF ONE ITEM IS FOUND, AND IT IS NOT A RANGE, THEN ONLY ONE FLOOR
'      NAME HAS BEEN INPUT,
    IF ELEMENT = 1 AND INSTR(TOKENS$(1), "-") = 0 THEN
       PRINT ""
       PRINT " ONLY ONE FLOOR IS GIVEN."
       KILLEXP = 1
       EXIT SUB
    END IF

    FLOORS$ = ""

'      CHECK EACH SUBSTRING TO SEE IF IT IS A RANGE. IF SO, TEST FOR COMMON
'      ERROR SITUATIONS.
    PRINT ""

    FOR I = 1 TO ELEMENT
       CURTOK$ = TOKENS$(I)
       CALL RANGEEXP(CURTOK$, SUBS1, SUBS2, FLRVAL1$, FLRVAL2$, EXPRANGE)
```

```
      IF EXPRANGE = 1 THEN
         KILLEXP = 1
      ELSEIF EXPRANGE = 2 THEN
         RANGE1$(I) = ""
         FLOORS$ = FLOORSS + " " + CURTOKS
      ELSEIF EXPRANGE = 0 THEN
         RANGE1$(I) = FLRVAL1$
         RANGE2$(I) = FLRVAL2$
         FLOORSS = FLOORSS + " " + CURTOKS
      END IF
   NEXT I

'     IF ERRORS HAVE BEEN DETECTED, EXIT SUBROUTINE
   IF KILLEXP = 1 THEN EXIT SUB

'     IF NO ERRORS HAVE BEEN FOUND, PERFORM RANGE EXPANSION(IF NECESSARY),
'     AND INITIALIZE THE FLRNAMES$ ARRAY.
   PTR = 1
   FOR I = 1 TO ELEMENT
      IF RANGE1$(I) = "" THEN
         FLRNAMES$(PTR) = TOKENS$(I)
         PTR = PTR + 1
      ELSE
         FOR J = VAL(RANGE1$(I)) TO VAL(RANGE2$(I))
            FLRNAMES$(PTR) = STR$(J)
            FLRNAMES$(PTR) = LTRIM$(FLRNAMES$(PTR))
            PTR = PTR + 1
         NEXT J
      END IF
   NEXT I


'     READ IN THE TYPICAL FLOOR TO FLOOR HEIGHT AND THEN THE HEIGHT
'     EXCEPTIONS.
   TOTFLRS = PTR - 1
   IF UNITS = 1 THEN
      INPUT "Typical floor to floor height (m)"; TYPDIFsi
      TYPDIF = TYPDIFsi * (1 / .3048#)
   ELSE
      INPUT "Typical floor to floor height (ft)"; TYPDIF
      TYPDIFsi = TYPDIF * .3048#
   END IF
   FOR K = 1 TO TOTFLRS: HGTDIF(K) = TYPDIF: NEXT K
   FOR I = 1 TO 1000
      PRINT "   Height exceptions:"
      IF UNITS = 1 THEN
         PRINT "    Floor range, height(m)  (enter END to atop)"
      END IF
      IF UNITS = 2 THEN
         PRINT "    Floor range, height(ft)  (enter END to stop)"
      END IF
```

```
      LINE INPUT STORE$
      CALL PARSE(STORE$, NUMTOK#)
      CALL CHECK(NUMTOK#, 0#, 10000#, 1#)
      IF TOKENS$(1) = "STOP" THEN EXIT FOR
   NEXT I


'     COMPUTE THE ELEVATIONS OF EACH FLOOR, STARTING FROM THE LOWEST ONE.
   ELEVATION(1) = 0
   FOR I = 2 TO TOTFLRS + 1
      ELEVATION(I) = ELEVATION(I - 1) + HGTDIF(I - 1)
   NEXT I


   END SUB

'--------------------------------------------------------------------------
'       S U B R O U T I N E   P A R S E
'--------------------------------------------------------------------------
'            THIS SUBROUTINE IS PASSED THE STRING STORE$, CHANGES ANY
'       COMMAS TO BLANKS, ISOLATES ALL SUBSTRINGS SEPARATED BY BLANKS
'       WITHIN THE STRING, AND COUNTS THEM. THE ARGUMENT NUMTOK# IS SET TO
'       THE COUNTED NUMBER. THE PARSING METHOD DESTROYS ALL SUBSTRINGS
'       WITHIN STORE$ EXCEPT FOR THE RIGHTMOST ONE.
'--------------------------------------------------------------------------
   SUB PARSE (STORE$, NUMTOK#)

   FOR COL = 1 TO LEN(STORE$)
      IF MID$(STORE$, COL, 1) = "," THEN MID$(STORE$, COL, 1) = " "
   NEXT COL
   STORE$ = RTRIM$(STORE$)
   FOR I = 1 TO 200
      STORE$ = LTRIM$(STORE$)
      NEXTBLNK = INSTR(STORE$, " ")
      IF NEXTBLNK = 0 THEN
         TOKENS$(I) = STORE$
         EXIT FOR
      END IF
      TOKENS$(I) = MID$(STORE$, 1, NEXTBLNK - 1)
      MID$(STORE$, 1, NEXTBLNK - 1) = STRING$(100, " ")
   NEXT I
   IF LEN(STORE$) <> 0 THEN NUMTOK# = I: ELSE NUMTOK# = 0

   END SUB

'--------------------------------------------------------------------------
'      S U B R O U T I N E   R A N G E E X P
'--------------------------------------------------------------------------
'          THIS SUBROUTINE IS PASSED A FLOOR NAME OR FLOOR RANGE.  IF IT IS
'     PASSED A RANGE, IT CHECKS THE TWO PARTS OF THE RANGE FOR VARIOUS ERROR
'     SITUATIONS, ISOLATES THE FIRST AND SECOND PART OF THE RANGE, AND
'     FINDS THE LOCATIONS OF THE FLOOR NAMES WITHIN THE FLOOR NAME TABLE.
```

```
'----------------------------------------------------------------------
'                         ARGUMENTS:
' EXPEXCP      AN OUTPUT PARAMETER. ITS VALUE IS 0 IF THE FLOOR ITEM IS A VALID
'              RANGE, 1 IF IT IS AN INVALID RANGE, AND 2 IF THE FLOOR ITEM IS
'              A SINGLE FLOOR NAME.
' FLREXCP1$    AN OUTPUT PARAMETER. THE VALUE OF THE FIRST ITEM IN THE RANGE,
'              OR THE ONLY ITEM IF THERE IS NO RANGE.
' FLREXCP2$    AN OUTPUT PARAMETER. THE VALUE OF THE SECOND ITEM IN THE RANGE,
'              OR THE ONLY ITEM IF THERE IS NO RANGE.
' FLRSTRS      THE CHARACTER STRING PASSED TO THIS SUBROUTINE.
' FLRSUBl      THE LOCATION OF THE FIRST FLOOR NAME WITHIN THE FLOOR NAME TABLE,
'              OR 0 IF THE NAME IS NOT A VALID FLOOR NAME.
' FLRSUB2      THE LOCATION OF THE SECOND FLOOR NAME WITHIN THE FLOOR NAME
'              TABLE, OR 0 IF THE NAME IS NOT A VALID FLOOR NAME.
'----------------------------------------------------------------------

' CURTOKS      CONTAINS THE STRING PASSED TO THE SUBROUTINE.
' RANGEMK      THE LOCATION OF A DASH WITHIN THE FLOOR RANGE.
' TEMPRANGE1$  STORES THE FIRST PART OF THE RANGE.
' TEMPRANGE2$  STORES THE SECOND PART OF THE RANGE.
'----------------------------------------------------------------------
'
   SUB RANGEEXP (FLRSTRS, FLRSUB1, FLRSUB2, FLREXCP1$, FLREXCP2$, EXPEXCP)

'     INITIALIZE SOME OF THE OUTPUT PARAMETERS.
    EXPEXCP = 0
    FLRSUBl = 0
   .FLRSUBZ = 0


'     CHECK THE SUBSTRING TO SEE IF IT IS A RANGE. IF SO, TEST FOR COMMON
'     ERROR SITUATIONS.
    IF FLRNAMES$(1) <> "" THEN PRINT ""
    CURTOK$ = FLRSTRS
    RANGEMK = INSTR(CURTOK$, "-")
    IF RANGEMK = 0 THEN
       TEMPRANGE1$ = ""
    ELSEIF RANGEMK = 1 OR RANGEMK = LEN(CURTOK$) THEN
       PRINT " MISPLACED DASH - NO RANGE EXPANSION PERFORMED. "; CURTOKS
       EXPEXCP = 1
    ELSEIF RANGEMK <> 0 THEN
       TEMPRANGE1$ = MID$(CURTOK$, 1, RANGEMK - 1)
       TEMPRANGE2$ = MID$(CURTOK$, RANGEKK + 1, LEN(CURTOK$))
       FOR J = 1 TO LEN(TEMPRANGE1$)
          IF INSTR("0123456789", MID$(TEMPRANGE1$, J, 1)) = 0 THEN
             PRINT " INCORRECT 1ST RANGE IN  "; CURTOK$; ", POS "; J
             EXPEXCP = 1
          END IF
       NEXT J
       FOR J = 1 TO LEN(TEMPRANGE2$)
          IF INSTR("0123456789", MID$(TEMPRANGE2$, J, 1)) = 0 THEN
             PRINT " INCORRECT 2ND RANGE IN  "; CURTOKS; ", POS "; J
```

```
            EXPEXCP = 1
         END IF
      NEXT J
      IF EXPEXCP = 0 AND VAL(TEMPRANGE1$) >= VAL(TEMPRANGE2$) THEN
         PRINT " 1ST RANGE IS NOT LESS THAN 2ND RANGE IN  "; CURTOK$
         EXPEXCP = 1
      END IF
   END IF


'     IF ERRORS HAVE BEEN DETECTED, EXIT SUBROUTINE
   IF EXPEXCP = 1 THEN EXIT SUB


'     IF THE STRING IS A SINGLE NAME, THEN SET BOTH TEMPORARY RANGES TO IT.
   IF TEMPRANGE1$ = "" THEN
      TEMPRANGE1$ = CURTOK$
      TEMPRANGE2$ = CURTOK$
      EXPEXCP = 2
   END IF

'     PERFORM THE FOLLOWING SECTION ONLY WHEN THE FLOOR NAMES ARRAY
'     HAS ALREADY BEN CREATED.
'      IF NO ERRORS HAVE BEEN FOUND, FIND THE LOCATION OF THE FLOOR NAMES
'      WITHIN THE FLOOR NAMES ARRAY (IF THE PASSED VALUE IS A RANGE),
   IF FLRNAMES$(1) <> "" THEN
      FOR I = 1 TO TOTFLRS
         IF TEMPRANGE1$ = FLRNAMES$(I) THEN FLRSUB1 = I
         IF TEMPRANGE2$ = FLRNAMES$(I) THEN FLRSUB2 = I
      NEXT I
   END IF                    .

'      IF NO ERRORS HAVE BEEN FOUND, AND THE PASSED VALUE IS A SINGLE NAME,
'      THEN FIND ITS LOCATION WITHIN THE FLOOR NAMES ARRAY.
   IF FLRNAMES$(1) <> "" THEN
      FOR I = 1 TO TOT———
         IF TEMPRANGE1$ = FLRNAMES$(I) THEN FLRSUB1 = I
      NEXT I
   END IF


   FLREXCP1$ = TEMPRANGE1$
   FLREXCP2$ = TEMPRANGE2$


END SUB

'---------------------------------------------------------------------------
'     S U B R O U T I N E   T R I P T I M E
'---------------------------------------------------------------------------
'          SUBROUTINE TRIPTIME COMPUTES THE TRAVEL TIME FROM THE DESIGNATED
'    EXIT FLOOR TO EACH OF THE OTHER FLOORS IN THE BUILDING. THE COMPUTED
```

```
'     TIME IS FOR ONE WAY TRAVEL ONLY.  THERE ARE THREE MAIN SITUATIONS WHICH
'     CAN OCCUR. THESE ARE:
'       CASE 1 - DISTANCE TO BE TRAVELLED IS SUCH THAT LINEAR ACCELERATION
'                IS MAINTAINED. THIS OCCURS WHEN DISTANCE IS SMALL.
'       CASE 2 - DISTANCE TO BE TRAVELLED IS SLIGHTLY GREATER. NON-LINEAR,
'                OR TRANSITIONAL, ACCELERATION IS REACHED.
'       CASE 3 - DISTANCE IS GREAT ENOUGH THAT MAXIMUM ELEVATOR CAR VELOCITY
'                IS REACHED. THIS IS THE CONSTANT VELOCITY CASE.
'-----------------------------------------------------------------------------
'                         VARIABLES:
'       A             ACCELERATION RATE OF ELEVATOR CAR.
'       LEVELTME      LEVELING TIME (s).
'       S1            DISTANCE REQUIRED FOR ELEVATOR CAR TO REACH VELOCITY V1.
'       S2            DISTANCE CAR REQUIRES TO REACH VMAX (MAXIMUM VELOCITY).
'       ST            ACTUAL DISTANCE BETWEEN EXIT FLOOR AND FLOOR FOR WHICH
'                      THE TRIPTIME IS BEING COMPUTED.
'       T1            TIME (s) FOR ELEVATOR CAR TO TRAVEL A DISTANCE OF S1.
'       T2            TIME (s) FOR CAR TO ATTAIN VMAX.
'       T2CASE2       TIME (s) FOR CAR TO ATTAIN MAXIMUM VELOCITY IN CASE 2.
'       T5            TIME (s) FOR ELEVATOR CAR TO TRAVEL THE DISTANCE ST,
'                      IN CASE 3, NOT INCLUDING LEVELING TIME.
'       TIMES(I)      ONE WAY TRIP TIMES COMPUTED FOR EACH FLOOR.
'       TOTFLRS       TOTAL NUMBER OF FLOORS.
'       TRANS         TRANSITIONAL COEFFICIENT.  V1=TRANS*VMAX.
'       TT            ONE WAY TRIP TIME FOR THE CURRENT FLOOR.
'       V2            MAXIMUM VELOCITY OF ELEVATOR CAR ATTAINED IN CASE 2.
'       VCUBED        V**3, WHERE V IS AS DEFINED ABOVE.
'       V1            MAXIMUM ELEVATOR CAR VELOCITY TIMES THE TRANSITIONAL
'                      COEFFICIENT.
'       VMAX          MAXIMUM CAR VELOCITY, SPECIFIED BY THE USER.
'-----------------------------------------------------------------------------
'
    SUB TRIPTIME

'      COMPUTE V1, S1, S2, T1, T2. ONLY PERFORMED ONCE.
    V1 = TRANS * VMAX
    S1 = V1 ^ 2# / (2# * A)
    S2 = (1# / (3# * A)) * (VMAX ^ 3# / V1 - V1 ^ 2#) + S1
    T1 = V1 / A
    T2 = ((VMAX ^ 2# - V1 * V1) / (2# * A * V1)) + T1
    PRINT ""
'   PRINT " 2*S1= "; 2 * S1
'   PRINT " 2*S2= "; 2 * S2

'   ***************************************************************************
'   *
'   *   MAIN LOOP OF THIS SUBROUTINE. FOR EACH FLOOR OF THE BUILDING, THE
'   *   DISTANCE ST IS COMPUTED. NEXT, THE LOOP DETERMINES IF CASE 1, CASE
'   *   2, OR CASE 3 IS THE RELEVANT SITUATION, AND IT THEN PERFORMS THE
'       APPROPRIATE CALCULATIONS.
'   ***************************************************************************
    FOR I = 1 TO TOTFLRS
```

```
        ST = ABS(ELEVATION(I) - ELEVATION(EXITFLR))

'   CASE 1    0 <= ST < 2*S1
        IF 0! <= ST AND ST < 2 * S1 THEN
           TT = 2 * SQR(ST / A) + LEVELTME
           TIMES(I) = TT
'          PRINT "   CASE 1 - FLOOR # "; I
        END IF
'   CASE 2    2*S1 <= ST < 2*S2
        IF 2 * S1 <= ST AND ST < 2 * S2 THEN
           VCUBED = V1 ^ 3 + (3 * A * V1 * ((ST / 2#) - S1))
           V2 = VCUBED ^ (1# / 3#)
           T2CASE2 = ((V2 * V2) - (V1 * V1)) / (2 * A * V1) + T1
           TT = 2 * T2CASE2 + LEVELTME
           TIMES(I) = TT
'          PRINT "   CASE 2 - FLOOR # "; I
        END IF
'   CASE 3    2*S2 <= ST
        IF 2 * S2 <= ST THEN
           TS = 2 * T2 + (ST - 2 * S2) / VMAX
           TT = TS + LEVELTME
           TIMES(I) = TT
'          PRINT "   CASE 3 - FLOOR # "; I
        END IF

     NEXT I


     END SUB
```

## Appendix B ELVAC Example of an 11 story building

The example of this appendix was developed to illustrate many of ELVAC's features. ELVAC is an interactive computer program, and Table B. 1 is a listing of all text that appears on the screen during the ELVAC run of this example. Note that in table B. 1 bold type indicates answers typed by the user of ELVAC.

The simulated building has two basement levels, a ground floor, and ten floors above ground level. The typical floor to floor height is 3.7 m (approximately 12 feet). Exceptions to this are the two basement levels and the ground floor, which are somewhat higher. Also, floors 3-5 are somewhat shorter, and it should be noted that the exceptions for these three floors are input into the program in one line.

There are typically 110 people on each floor, with the exceptions being the two basement levels (with fewer), and floors G and 2-3 ( with more). The percent of people on the floors that use elevators to evacuate is typically 85, with the exception of the two basement levels and floors 2-7, where 3 percent of the people use elevators while the rest use stairways. Note again that only one statement is used to input the percent usage exceptions for floors 2-7.

If the user wants the program will list basic concepts about the model as is done in this example.

### Table B.1 Listing of ELVAC Analysis of 11 story building

```
*******************************************************************
ELVAC VERSION 1.00
WRITTEN BY DANIEL M. ALVORD AND
       JOHN H. KLOTE

CONTRIBUTION OF THE NATIONAL INSTITUTES OF STANDARDS AND
   TECHNOLOGY. (U.S.)
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DOCUMENTATION: KLOTE,J.H., ALVORD,D.M., AND DEAL,S., ANALYSIS OF
PEOPLE MOVEMENT DURING ELEVATOR EVACUATION, NATIONAL INSTITUTE
OF STANDARDS AND TECHNOLOGY, (U.S.), NISTIR 4730, 1992.
*******************************************************************

Do you want to read about the model (Y or N)? X

Where do you wish the general information to appear?
  (a filename, PRN for printer, or ENTER for output
   to the screen.)

 --------------Basic concepts of the model-----------------
```

## Table B1. Continued

Basic tranafer inefficiency– **a** factor that allows for rounding off of probable stops, door operating time, door starting and stopping time, and the unpredictability **of** people. A value of 0.10 is used for commonly accepted arrangements of elevator groupr.

Discharge floor– When emergency evacuation starts, elevators will take people to • dimcharge floor where pasaengera on the elevatorm will exit. This floor may lead to the outside or to an area of relative safety.

Door inefficiency– Adjusts for **any** increase in transfer time over that of **a 1200 mm (48** in) wide center oponing door.

. Press **ENTER** to continue.......

**Dwell** time– The minimum time an elevator car door remains open. The time uaed .in this program is 4 seconds.

Groups- Elevators are located in groups of up to eight elevators. The elevators in **a** group are located near **each** other and are controlled together to move people efficiently.

Elevator evacuation atart up time– The time from activation of the alarms(for example) to the start of the round trips that evacuate people. If the elevators arm operated automatically during evacuation, **one** starts the elevator evacuation after all of the elevatorm have been moved to the discharge floor **and** tho people in them havo left. In the case of manual elevator operation, the time for elevators oporatorm to reach the carm must bo included.

Motion– Elevator motion rtarts with constant acceleration, followed by transitional acceleration until constant velocity motion at tho normal operating volocity of the car is attained.

Press **ENTER** to continue....

Other transfer inefficiency– accounts for inefficiencies due to unumual elevator **car** shape **or** limited physical capability of passengers. **In** office building., a value of 0 is used.

Round trip– a round trip starts at the discharge floor and consists of the sequence: elevator doors close, car travels to another floor, doors opon, passengers enter the car, doors close, car travel. to dimcharge floor, doors open, and passengers leave the car. Alternatively, **it** may be defined as two one way trips and **a** atanding period.

## Table B1. Contiaued

Standing time- Twice the time required to open and close the elevator doors, plus the time for people to enter the elevator, plus the time for people to leave the elevator.
Trip inefficiency- a multiplicative factor that accounts for tripe to empty floors and for trips to pick up only a few stragglers.

Press ENTER to continue....

-------Concepts inherent to the computer program-----------
Range- A range is a set of floor names that is expanded by the program into a set of contiguous floor numbers. For example, the range 2-10 is expanded into 2,3,4,5,6,...., 9,10.
Typical- Used to save effort in the input. It is best shown by example. The typical inter floor height of a building typical inter floor height of a building is the most commonly occurring height between floors (12 feet is an example). There is a typical inter floor height, a typical number of people on a floor, and a typical elevator usage percent.

Enter the title of this run.
**11 STORY EXAMPLE BUILDING.**

Enter 1 for SI units or 2 for English units: **1**

Enter floors that the elevators serve (for example- B G 1-6)
**82 B1 G 2-11**

Typical floor to floor height (m)? **3.7**
Height exceptions:
Floor range, height(m) (enter END to stop)
**B2 4.5**

Height exceptions:
Floor range, height(m) (enter END to stop)
**B1 4.5**

Height exceptions:
Floor range, height(m) (enter END to stop)
*G 5.7*

Height exceptions:
Floor range, height(m) (enter END to stop)

## Table B1. Continued

3-5 3.5

Height exceptions:
Floor range, height(m) (enter END to stop)
END

Discharge floor? G

Time to outside after leaving elevator (s)? 30

Trip inefficiency factor (for example .1)? .1

Number of elevator cars in the group? 4

Normal operating velocity of car (m/s)? 3

Car acceleration (m/s**2)? 1.2

Elevator Full Load (people)? 16

------ MENU OF DOOR TYPES ------

| Door type | Door width | Time to Open and Close, s | Door Transfer Inefficiency |
|---|---|---|---|
| A Single-Slide | 900mm (36in) | 6.6 | 0.10 |
| B Two-Speed | 900mm (36in) | 5.9 | 0.10 |
| C Center-Opening | 900mm (36in) | 4.1 | 0.08 |
| D Single-Slide | 1100mm (42in) | 7.0 | 0.07 |
| E Two-Speed | 1100mm (42in) | 6.6 | 0.07 |
| F Center-Opening | 1100mm (42in) | 4.6 | 0.05 |
| G Two-Speed | 1200mm (48in) | 7.7 | 0.02 |
| H Center — ning | 1200mm (48in) | 5.3 | 0 |
| I Two-speed | 1400mm (54in) | 8.8 | 0.02 |
| J Center-Opening | 1400mm (54in) | 6.0 | 0 |
| K Two-Speed | 1600mm (60in) | 9.9 | 0.02 |
| L Center-Opening | 1600mm (60in) | 6.5 | 0 |
| M Two-Speed, Center — ning | 1600mm (60in) | 6.0 | 0 |
| N OTHER | | | |

***Pick one of the door choices A - M.
If you wish to specify another typo, enter N. F

Other transfer inefficiency? 0.0

The startup time for automatically operated elevators is 32.68 seconds.
Do you want to enter another value (Y or N)? N

## Table B1. Continued

```
Typical Number of People per Floor? 110
  People per floor exception:
   Floor Range, people (enter END to stop)
B2 40

  People per floor exception:
   Floor Range, people (enter END to stop)
B1 60

  People per floor exception:
   Floor Range, people (enter END to stop)
2-4 150

  People per floor exception:
   Floor Range, people (enter END to stop)
BND

Percent of people on typical floor using elevator? 85
  Percent usage exceptions:
    Floor Range, Percent (enter END to stop)
B1 3

  Percent usage exceptions:
    Floor Range, Percent (enter END to stop)
B2 3

  Percent usage exceptions:
    Floor Range, Percent (enter END to stop)
2-7 3

  Percent usage exceptions:
    Floor Range, Percent (enter END to stop)
END

11 STORY EXAMPLE BUILDING.

People per floor is    110.

Distance between floors is     3.70 m  or   12.14 ft.
Elevator usage percent is  85.000%
Normal car velocity is        3.00 m/s or 590.55 fpm.

car acceleration is           1.20 m/s2 or  3.94 ft/s2.
Car full load is  16 people.
Full load standing time is  40.48 s.
Other transfer inefficiency is 0.0000
Trip inefficiency is 0.100
Door type: F Center-Opening           1100mm (42in) wide
   Doortime s   4.600    Door inefficiency    0.050
```

Table B1. Coatiautd

| Floor Name | Elevation m | ft | One Way Time a | Round Trip Time a | People on Floor | Percent Usage | Round Trips | Time per Floor e |
|---|---|---|---|---|---|---|---|---|
| 11 | 47.4 | 155.5 | 15.9 | 72.3 | 110 | 85.0 | 6 | 431.7 |
| 10 | 43.7 | 143.4 | 14.7 | 69.8 | 110 | 85.0 | 6 | 416.9 |
| 9 | 40.0 | 131.2 | 13.4 | 67.3 | 110 | 85.0 | 6 | 402.1 |
| 8 | 36.3 | 119.1 | 12.2 | 64.9 | 110 | 85.0 | 6 | 387.3 |
| 7 | 32.6 | 107.0 | 11.0 | 41.7 | 110 | 3.0 | 1 | 41.7 |
| 6 | 28.9 | 94.8 | 9.7 | 39.2 | 110 | 3.0 | 1 | 39.2 |
| 5 | 25.4 | 83.3 | 8.6 | 36.9 | 110 | 3.0 | 1 | 36.9 |
| 4 | 21.9 | 71.9 | 7.4 | 36.9 | 150 | 3.0 | 1 | 36.9 |
| 3 | 18.4 | 60.4 | 6.2 | 34.5 | 150 | 3.0 | 1 | 34.5 |
| 2 | 14.7 | 48.2 | 4.9 | 31.8 | 150 | 3.0 | 1 | 31.8 |
| G | 9.0 | 29.5 | | | | | | |
| B1 | 4.5 | 14.8 | 4.4 | 27.4 | 60 | 3.0 | 1 | 27.4 |
| B2 | 0.0 | 0.0 | 6.1 | 29.7 | 4Q | 3.0 | 1 | 29.7 |

Total round trip time= 1916.1
Start up time= 32.7
Time to get to the outside after leaving the elevator= 30.0
Evacuation time uaing 4 elevators= 589.6
(or 9.8 minutes)

Do you want to save the output (Y or N)? I

Rerun program with new usage percentages (Y or N)? I

Do you wiah to rerun the entire program (Y or N)? I

# Appendix C ELVAC Example of a 21 story building

This appendix presents the ELVAC analysis of the 21 story example in the paper. ELVAC is an interactive computer program and Table C.l is a listing of the computer screen during this ELVAC run. Note that in table B.1 bold type indicates answers typed by the user of ELVAC.

### Table C.l Listing of ELVAC Analysis of 21 Story Building

```
*****************************************************************
ELVAC VERSION 1.00
WRITTEN BY DANIEL M. ALVORD AND
       JOHN H. KLOTE

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   TECHNOLOGY. (U.S.)
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*****************************************************************

Do you want to read about the model (Y or N)?  N

Enter the title of this run.
Example 21 Story Building

Enter 1 for SI units or 2 for English units:  1

Enter floors that the elevators serve (for example- B G 1-6)
1-21

Typical floor to floor height (m)? 3.2
   Height exceptions:
     Floor range, height(m)   (enter END to stop)
END

Discharge floor? 1

Time to outside after leaving elevator (s)? 30

Trip inefficiency factor (for example .1)?   .1

Number of elevator cars in the group?   1

Normal operating velocity of car (m/s)? 3

Car acceleration (m/s**2)? 1.2
```

Table C.1 Continued

Elevator Full Load (people)? 16

------ MENU OF DOOR TYPES ------

| | Door type | Door width | Time to Open and Close, s | Door Transfer Inefficiency |
|---|---|---|---|---|
| A | Single-Slide | 900mm (36in) | 6.6 | 0.10 |
| B | Two-Speed | 900mm (36in) | 5.9 | 0.10 |
| C | Center-Opening | 900mm (36in) | 4.1 | 0.08 |
| D | Single-Slid. | 1100mm (42in) | 7.0 | 0.07 |
| E | Two-Speed | 1100mm (42in) | 6.6 | 0.07 |
| F | Center-Opening | 1100mm (42in) | 4.6 | 0.05 |
| G | Two-Speed | 1200mm (48in) | 7.7 | 0.02 |
| H | Center-Opening | 1200mm (48in) | 5.3 | 0 |
| I | Two-Sped | 1400mm (54in) | 8.8 | 0.02 |
| J | Center-Opening | 1400mm (54in) | 6.0 | 0 |
| K | TWO-Speed | 1600mm (60in) | 9.9 | 0.02 |
| L | Center-Opening | 1600mm (60in) | 6.5 | 0 |
| M | Two-speed, Center-Opening | 1600mm (60in) | 6.0 | 0 |
| N | OTHER | | | |

***Pick one of the door choices A - M.
If you wiah to specify another type, enter N. H

Other transfer inefficiency? 0.0

The startup time for automatically operated elevators is 41.25 seconds.
Do you want to enter another value (Y or N)? N

Typical Number of People per Floor? 100
People per floor exception:
Floor Range, people (enter END to stop)
END

Percent of people on typical floor uaing elevator? 100
Percent uaage exceptions:
Floor Range, Percent (enter END to atop)
END

Example 21 Story Building

People per floor is 100.
Distance between floor. is 3.20 m or 10.50 ft.
Elevator uaage percent is 100.0001
Normal car velocity is 3.00 m/a or 590.55 fpm.
Car acceleration is 1.20 m/s2 or 3.94 ft/s2.
Car full load is 16 people.
Full load atanding time is 40.26 a.
Other tranafer inefficiency is 0.0000
Trip inefficiency is 0.100
Door type: H Center-Opening 1200mm (48in) wide
Doortime a 5.300 Door inefficiency 0.000

---

One Round People Time

**Tabla C.1 Continued**

| Floor Name | Elevation m | ft | Way Time s | Trip Time s | on Floor | Percent Usage | Round Trips | per Floor |
|---|---|---|---|---|---|---|---|---|
| 21 | 64.0 | 210.0 | 24.4 | 89.1 | 100 | 100.0 | 7 | 603.9 |
| 20 | 60.8 | 199.5 | 23.4 | 87.0 | 100 | 100.0 | 7 | S89.0 |
| 19 | 57.6 | 189.0 | 22.3 | 84.8 | 100 | 100.0 | 7 | 574.1 |
| 18 | 54.4 | 178.5 | 21.2 | 82.7 | 100 | 100.0 | 7 | 559.1 |
| 17 | 51.2 | 168.0 | 20.2 | 80.6 | 100 | 100.0 | 7 | 544.2 |
| 16' | 48.0 | 157.5 | 19.1 | 78.4 | 100 | 100.0 | 7 | 529.3 |
| 15 | 44.8 | 147.0 | 18.0 | 76.3 | 100 | 100.0 | 7 | 514.3 |
| 14 | 41.6 | 136.5 | 17.0 | 74.2 | 100 | 100.0 | 7 | 499.4 |
| 13 | 38.4 | 126.0 | 15.9 | 72.0 | 100 | 100.0 | 7 | 484.5 |
| 12 | 35.2 | 115.5 | 14.8 | 69.9 | 100 | 100.0 | 7 | 469.5 |
| 11 | 32.0 | 105.0 | 13.8 | 67.8 | 100 | 100.0 | 7 | 454.6 |
| 10 | 28.8 | 94.5 | 12.7 | 65.6 | 100 | 100.0 | 7 | 439.7 |
| 9 | 25.6 | 84.0 | 11.6 | 63.5 | 100 | 100.0 | 7 | 424.7 |
| 8 | 22.4 | 73.5 | 10.6 | 61.4 | 100 | 100.0 | 7 | 409.8 |
| 7 | 19.2 | 63.0 | 9.5 | 59.2 | 100 | 100.0 | 7 | 394.9 |
| 6 | 16.0 | 52.5 | 8.4 | 57.1 | 100 | 100.0 | 7 | 379.9 |
| 5 | 12.8 | 42.0 | 7.4 | 55.0 | 100 | 100.0 | 7 | 365.0 |
| 4 | 9.6 | 31.5 | 6.3 | 52.8 | 100 | 100.0 | 7 | 350.1 |
| 3 | 6.4 | 21.0 | 5.2 | 50.6 | 100 | 100.0 | 7 | 334.2 |
| 2 | 3.2 | 10.5 | 3.8 | 47.8 | 100 | 100.0 | 7 | 314.7 |
| 1 | 0.0 | 0.0 | | | | | | |

Total round trip time= 9234.9
Start up time= 41.3
Time to get to the outside after leaving the elevator= 30.0
Evacuation time using 1 elevators= 10229.7
(or 170.5 minutes)

Do you want to save the output (Y or N)? N

Rerun program with new usage percentages (Y or N)? N

Do you wish to rerun the entire program (Y or N)? N

# Appendix D ELVAC Example of a building with multiple rises

This building has 38 doors and three rises of elevators: low rise, mid rise, and high rise. Each rise consists of a group of 6 elevators, but it is considered that only 5 of them are being used for evacuation, and one is out of service. The elevator cars in the low rise group travel at 3.10 m/s (610 fpm), and the cars in the mid and high rise groups travel at 5.00 m/s (984 fpm).

The ELVAC program was used to analyze each of the rises individually, and the computer output is listed in tables D1, D2, and D3. In the case of the law rise elevators, all floors serviced by the elevators are shown. For both the mid and high rise elevators, only the doors involved in the evacuation were included in the ELVAC analyses (see tables D2 and D3). The evacuation times are 14.4.22.5, and 25.0 minutes respectively for the low, mid, and high rise elevators. Since these evacuations are concurrent, the building evacuation time is 25 minutes.

## Table D1 38 Story Building: Low Rise Elevators

People per floor is 110.
Distance between floors is 3.70 m or 12.14 ft.
Elevator usage percent is 85.000%
Normal car velocity is 3.10 m/s or 610.24 fpm.
Car acceleration is 1.20 m/s2 or 3.94 ft/s2.
Car full load is 16 people.
Full load standing time is 40.48 s.
Other transfer inefficiency is 0.0000
Trip inefficiency is 0.100
Door type: F Center-Opening 1100mm (42in) wide
Doortime s 4.600 Door inefficiency 0.050

| Floor Name | Elevation m | Elevation ft | One Way Time s | Round Trip Time s | People on Floor | Percent Usage | Round Trips | Time per Floor s |
|---|---|---|---|---|---|---|---|---|
| 13 | 44.4 | 145.7 | 17.5 | 75.5 | 110 | 85.0 | 6 | 451.0 |
| 12 | 40.7 | 133.5 | 16.3 | 73.1 | 110 | 85.0 | 6 | 436.7 |
| 11 | 37.0 | 121.4 | 15.1 | 70.7 | 110 | 85.0 | 6 | 422.4 |
| 10 | 33.3 | 109.3 | 13.9 | 68.3 | 110 | 85.0 | 6 | 408.0 |
| 9 | 29.6 | 97.1 | 12.7 | 65.9 | 110 | 85.0 | 6 | 393.7 |
| 8 | 25.9 | 85.0 | 11.5 | 63.5 | 110 | 85.0 | 6 | 379.4 |
| 7 | 22.2 | 72.8 | 10.3 | 61.2 | 110 | 85.0 | 6 | 365.1 |
| 6 | 18.5 | 60.7 | 9.1 | 58.8 | 110 | 85.0 | 6 | 350.8 |
| 5 | 14.8 | 48.6 | 7.9 | 56.4 | 110 | 85.0 | 6 | 336.4 |
| 4 | 11.1 | 36.4 | 6.8 | 33.3 | 110 | 3.0 | 1 | 33.3 |
| 3 | 7.4 | 24.3 | 5.5 | 30.8 | 110 | 3.0 | 1 | 30.8 |
| 2 | 3*7 | 12.1 | 4.0 | 27.8 | 110 | 3.0 | 1 | 27.8 |
| 1 | 0.0 | 0.0 | | | | | | |

Total round trip time= 3635.4
Start up timer 34.3
Time to get to the outside after leaving the elevator= 30.0
Evacuation time using 5 elevators= 864.1
(or 14.4 minutes)

**Table D2   38 Story Building: Mid Rise Elevators**

People per floor is 110.
Distance between floor. io 3.70 m or 12.14 ft.
Elevator usage percent io 85.000%
Normal car velocity is 5.00 m/r or 984.25 fpm.
Car acceleration is 1.90 m/s2 or 6.23 ft/s2.
Car full load is 16 people.
Full load standing time is 40.48 s.
Other transfer inefficiency is 0.0000
Trip inefficiency is 0.100
Door type: F Center-Opening 1100mm (42in) wide
Doortime a 4.600 Door inefficiency 0.050

| Floor Name | Elevation m | ft | One Way Time s | Round Trip Time s | People on Floor | Percent Urage | Round Trip8 | Time per Floor s |
|---|---|---|---|---|---|---|---|---|
| 26 | 92.5 | 303.5 | 21.7 | 83.9 | 110 | 85.0 | 6 | 501.7 |
| 25 | 88.8 | 291.3 | 21.0 | 82.5 | 110 | 85.0 | 6 | 492.9 |
| 24 | 85.1 | 279.2 | 20.2 | 81.0 | 110 | 85.0 | 6 | 404.0 |
| 23 | 81.4 | 267.1 | 19.5 | 79.5 | 110 | 85.0 | 6 | 475.1 |
| 22 | 77.7 | 254.9 | 18.8 | 78.0 | 110 | 85.0 | 6 | 466.2 |
| 21 | 74.0 | 242.8 | 18.0 | 76.5 | 110 | 85.0 | 6 | 457.3 |
| 20 | 70.3 | 230.6 | 17.3 | 75.1 | 110 | 85.0 | 6 | 440.5 |
| 19 | 66.6 | 218.5 | 16.5 | 73.6 | 110 | 85.0 | 6 | 439.6 |
| 18 | 62.9 | 206.4 | 15.8 | 72.1 | 110 | 85.0 | 6 | 430.7 |
| 17 | 59.2 | 194.2 | 15.1 | 70.6 | 110 | 85.0 | 6 | 421.8 |
| 16 | 55.5 | 182.1 | 14.3 | 69.1 | 110 | 85.0 | 6 | 412.9 |
| 15 | 51.8 | 169.9 | 13.6 | 67.7 | 110 | 85.0 | 6 | 404.1 |
| 14 | 48.1 | 157.8 | 12.8 | 66.2 | 110 | 85.0 | 6 | 395.2 |
| 1 | 0.0 | 0.0 | | | | | | |

| | |
|---|---|
| Total round trip time= | 5830.0 |
| Start up time- | 38.5 |
| Time to get to the outside after leaving the elevator= | 30.0 |
| Evacuation time uaing 5 elevators= | 1351.1 |
| (or | 22.5 minutes) |

## Table D3 38 Story Building: High Rise Elevators

People per floor is 110.
Distance between floors is 3.70 m or 12.14 ft.
Elevator usage percent is 85.000%
Normal car velocity is 5.00 m/s or 984.25 fpm.
Car acceleration is 1.90 m/s2 or 6.23 ft/s2.
Car full load is 16 people.
Full load standing time is 40.48 s.
Other transfer inefficiency is 0.0000
Trip inefficiency is 0.100
Door type: F Center-Opening 1100mm (42in) wide
Doortime s 4.600 Door inefficiency 0.050

| Floor Name | Elevation m | Elevation ft | One Way The s | Round Trip Time s | People on Floor | Percent Usage | Round Trips | Time per Floor s |
|---|---|---|---|---|---|---|---|---|
| 38 | 136.9 | 449.1 | 30.6 | 101.7 | 80 | 85.0 | 5 | 487.8 |
| 37 | 133.2 | 437.0 | 29.9 | 100.2 | 80 | 85.0 | 5 | 480.4 |
| 36 | 129.5 | 424.9 | 29.1 | 98.7 | 110 | 85.0 | 6 | 590.5 |
| 35 | 125.8 | 412.7 | 28.4 | 97.3 | 110 | 85.0 | 6 | 581.7 |
| 34 | 122.1 | 400.6 | 27.6 | 95.8 | 110 | 85.0 | 6 | 572.8 |
| 33 | 118.4 | 388.5 | 26.9 | 94.3 | 110 | 85.0 | 6 | 563.9 |
| 32 | 114.7 | 376.3 | 26.2 | 92.8 | 110 | 85.0 | 6 | 555.0 |
| 31 | 111.0 | 364.2 | 25.4 | 91.3 | 110 | 85.0 | 6 | 546.1 |
| 30 | 107.3 | 352.0 | 24.7 | 89.9 | 110 | 85.0 | 6 | 537.3 |
| 29 | 103.6 | 339.9 | 23.9 | 88.4 | 110 | 85.0 | 6 | 528.4 |
| 28 | 99.9 | 327.8 | 23.2 | 86.9 | 110 | 85.0 | 6 | 519.5 |
| 27 | 96.2 | 315.6 | 22.5 | 85.4 | 110 | 85.0 | 6 | 510.6 |
| 1 | 0.0 | 0.0 | | | | | | |

Total round trip time= 6473.9
Start up time= 47.4
Time to get to the outside after leaving the elevator= 30.0
Evacuation time using 5 elevators= 1501.7
(or 25.0 minutes)

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This paper is part of a project sponsored by the U.S. General Services Administration (GSA) to study occupant use of elevators during building evacuations. A detailed method of analysis of people movement by elevators during emergency building evacuation is presented including the time for people to enter and exit elevators and the equations of elevator car motion. Also a computer program for people movement during elevator evacuation and examples. RuM of this are listed in appendices. The method and computer routine presented in this paper are intended to be used in a later part of the GSA elevator project to help study the feasibility of elevator fire evacuation.

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