FIREFLY

A COMPUTER MODEL TO ASSESS THE EXTENT OF NUCLEAR FIRE DAMAGE IN URBANIZED AREAS

Supplemental Report

OCD Work Unit No. 1614B

Contract No. DAHC20-67-C-0147

May 22, 1968

System Sciences

INCORPORATED

SYSTEM SCIENCES, INCORPORATED

4720 Montgomery Lane
Bethesda, Maryland 20014

SUMMARY
OF
RESEARCH REPORT

FIREFLY

A Computer Model To Assess The Extent Of Nuclear Fire Damage In Urbanized Areas

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by

J.W. Crowley, B.R. Smith, H.J. Avise, and N.G. Whitney

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D.C. 20310

May 22, 1968

DEFINITION

The FIREFLY model is a mathematical technique, adapted to computer calculation because of a need for the ability to handle a large amount of data, which will provide estimates of fire damage resulting both directly and indirectly from the detonation of a nuclear weapon.

GENERAL DESCRIPTION

The main task of FIREFLY is to assess the total damage to a real-world set of buildings from the initial thermal pulse of a nuclear weapon and from the subsequent spread of fire from those buildings which are burning. The model reads a great deal of data about the size, construction characteristics, fuel loading, and separation distances of each building, structures some environmental variables concerning wind speed and direction and weapon placement, and calculates the fire destruction in a probabalistic sense.

Two internal quantities are automatically varied to provide a spectrum of fire damage results. The first of these quantities is the probability of exposed room ignition, P_{ri}, and is a function of the total thermal energy delivered directly to a "standard" room sufficient to create a serious enough ignition that would lead to room flashover. The second quantity is the angle of elevation of the weapon fireball. The value for P_{ri} is dependent upon weapon yield, height of burst, atmospheric visibility, room dwelling occupancy, and slant range. By further fixing an angle of fireball elevation, any preset values for P_{ri} and angle clearly represent an infinite number of exogenous conditions. FIREFLY generates five values of P_{ri} (0.1, 0.3, 0.5, 0.7, 0.9) to be used with each of three angles (5^o, 10^o, 30^o). These fifteen cases, each run 100 times to create a statistical sample, constitute one base case operation of the model using one wind velocity. After about three base cases have been conducted, an analyst may specify exact exogeneous conditions (a given yield, HOB, visibility, wind) and interpolate among the data which was presented for the spectrum of variables. The charts and equations necessary to calculate the actual value of P_{ri} will be presented in the final report to be published later this year.

FIREFLY deals with three calculated quantities:

... The probability of the complete ignition and destruction of a flammable building from the thermal pulse, p_{tp}

... The probability that a burning building will create sufficient heat energy to ignite a flammable substance at a given distance (also called the "probability of jump"), p_j.

... The probability of ignition and destruction of a building from fire spread within the building itself (also called the probability of intra-building spread), p_s.

p_{tp}

The quantity p_{tp} is calculated for each building and is defined as

$$p_{tp} = 1 - (1 - p_{ri})^N$$

where N is the number of ignition points and is itself a function of size of the building, percent window openings, size of the windows, degree of window shading (blinds, etc.), and degree of window shielding (a function of the heights of surrounding buildings and the fireball elevation).

$\underline{p_j}$

The value for p_j depends upon a number of characteristics about a burning building (height, roof type, window openings), the separation distance involved, and the wind speed and direction.

$\underline{p_s}$

The quantity p_s is a function of fuel loading, exterior wall type, floor construction, roof construction and height.

The quantities p_{tp} and p_s for a particular building are multiplied together and Monte Carloed against a random number to determine if that particular building is burning. If it is burning, it becomes a candidate to spread the fire to any nearby building. All p_j's are calculated to any unburned structure; each p_j is also compared to a random number. If it is then determined that there is sufficient energy present at any building(s) in the neighboring area, the value(s) for p_s are themselves Monte Carloed to find which of them are destroyed.

The model is limited by present computer capability to a maximum of 27 city blocks or 1080 buildings, whichever is less. Final answers are provided for each of the fifteen variations of p_{ri} and angle as a result of 100 runs per case in terms of the total number, percent of total, and standard deviation of

... buildings destroyed by thermal pulse

... buildings destroyed by fire spread

... total of the above

Revisions and Additions to FIREFLY

August 14, 1968

I. Revision of Section 5 II

I.1 Page 132

I.1.a. Addition after KVW is defined--

Symbol	Dimension	Meaning
KW	1	Code for the wall construction combustibility. See Section 2 VII F.

I.1.b. Replaces first line of fifth symbol, KW--

Symbol	Dimension	Meaning
KWD	1	General term for the distance in feet

I.1.c. Replaces last line of the meaning of KWE1-4--

east. See KWD

I.1.d. Replaces last line of the meaning of KWN1-4--

buildings respectively. See KWD

I.2 Page 133

I.2.a. Replaces last line of the meaning of KWS1-4--

buildings respectively. See KWD

I.2.b. Replaces last line of the meaning of KWW1-4--

buildings respectively. See KWD

II. Revision of Section 6, FIREFLY 1

Page 141

Replaces third statement--

BANK,(0),/BO/,WITH,KV CONS,PERP,(1),/B1/,FIREFLY1,AGNT

III. Revision of Section 6, FIREFLY 2

III.1 Page 167

III.1.a. Replaces third statement--

BANK,(0),/BO/,(1),/B1/,FIREFLY2

III.1.b. Replaces seventeenth statement--

DO 24 K=1,KK

III.1.c. Addition after eighteenth statement--

24 CONTINUE

III.2. Page 168

III.2.a. Replaces ninth statement--

DO 121 K=1,KK

III.2.b. Addition after tenth statement--

121 CONTINUE

III.3. Page 175

III.3.a. Replaces sixteenth statement--

DO 8066 K=1,KK

III.3.b. Replaces seventeenth statement--

IF (KR(I,J,K).EQ.0) GO TO 8066

III.3.c. Addition after twenty-sixth statement--

8066 CONTINUE

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FOREWORD

The FIREFLY Model was developed for the Office of Civil Defense under Contract No. DAHC20-67-C-0147 as part of Work Unit 1614B. The authors gratefully acknowledge the assistance provided by Mr. George N. Sisson, OCD, OCD Project Officer, under whose guidance and direction the project was performed.

Appreciation is also expressed for the assistance provided by personnel at the National Civil Defense Computer Facility, Olney, Maryland where both developmental and production work on FIREFLY was conducted.

References in the text to Gage-Babcock refer to work by B. M. Cohn, et al, Gage-Babcock and Associates in a study entitled, "A System for Local Assessment of the Conflagration Potential of Urban Areas" (AD 616 623). Some work by IITRI, especially "Prediction of Fire Damage to Installations and Built-Up Areas from Nuclear Weapons" (Contract No. DA-49-146-XZ-021, IITRI Proj. N6001, July 1965) and "Shelter Fire Vulnerability--Survey and Analysis of Representative Buildings" (AD 615 391, IITRI Proj. N6005, March 1965) has proved extremely helpful in developing the working model.

ABSTRACT

A computer model called FIREFLY has been developed and written in FORTRAN IV for the CDC 3600. This model may be applied to obtain statistical data on the expected numbers of buildings destroyed by fire from the thermal pulse of a hypothetical nuclear weapon and from any subsequent fire spread. Many variables concerning numbers and sizes of buildings, their construction, and separation distances may be evaluated.

TABLE OF CONTENTS

SECTION 1

FIREFLY

I. GENERAL DESCRIPTION

The urban fire analysis model, FIREFLY, has been developed by System Sciences, Inc., to provide an automated method for assessing the potential damage to shelter buildings from fires which occur as a result of ignition from the thermal pulse of a nuclear weapon or fire spread from nearby buildings. The model consists of three separate segments.

FIREFLY 1 structures the problem for FIREFLY 2 which in turn operates on the data and provides the results. FIREFLY 3 accepts the output of FIREFLY 2 and provides statistical summaries.

FIREFLY 1 performs the following functions:

A. Reads building size and construction data about each building as well as the distance that every building is separated from its closest neighbors.

B. Reads data concerning the wind speed and direction.

C. Determines the potential flammability of a particular building as a function of its use, its contents and its construction.

D. Determines the susceptibility of a particular building to the spread of fire from nearby structures as a function of the size of these structures, their separation and the speed and direction of the wind relative to all neighboring buildings.

E. Writes a tape describing this environment which becomes the input to FIREFLY 2.

FIREFLY 2 performs computing operations on the given set of buildings to determine how many are destroyed for any given set of conditions. In accepting the probabilistic values from FIREFLY 1, it is able to structure a complete problem of exogenous and endogenous variables, to calculate the expected results 100 times in order to create a valid statistical sample, and then to change one of the variables for the calculation of a new set of results. The variables which are changed are a function of moving the fireball closer to the buildings to determine the increasing number of structures which are destroyed by fire due to the thermal pulse. The number of buildings destroyed by fire spread also becomes dependent upon these environmental changes.

FIREFLY 3, a summary program, analyzes each set of the 100 runs processed by FIREFLY 2 and provides the following summary answers for each of those sets:

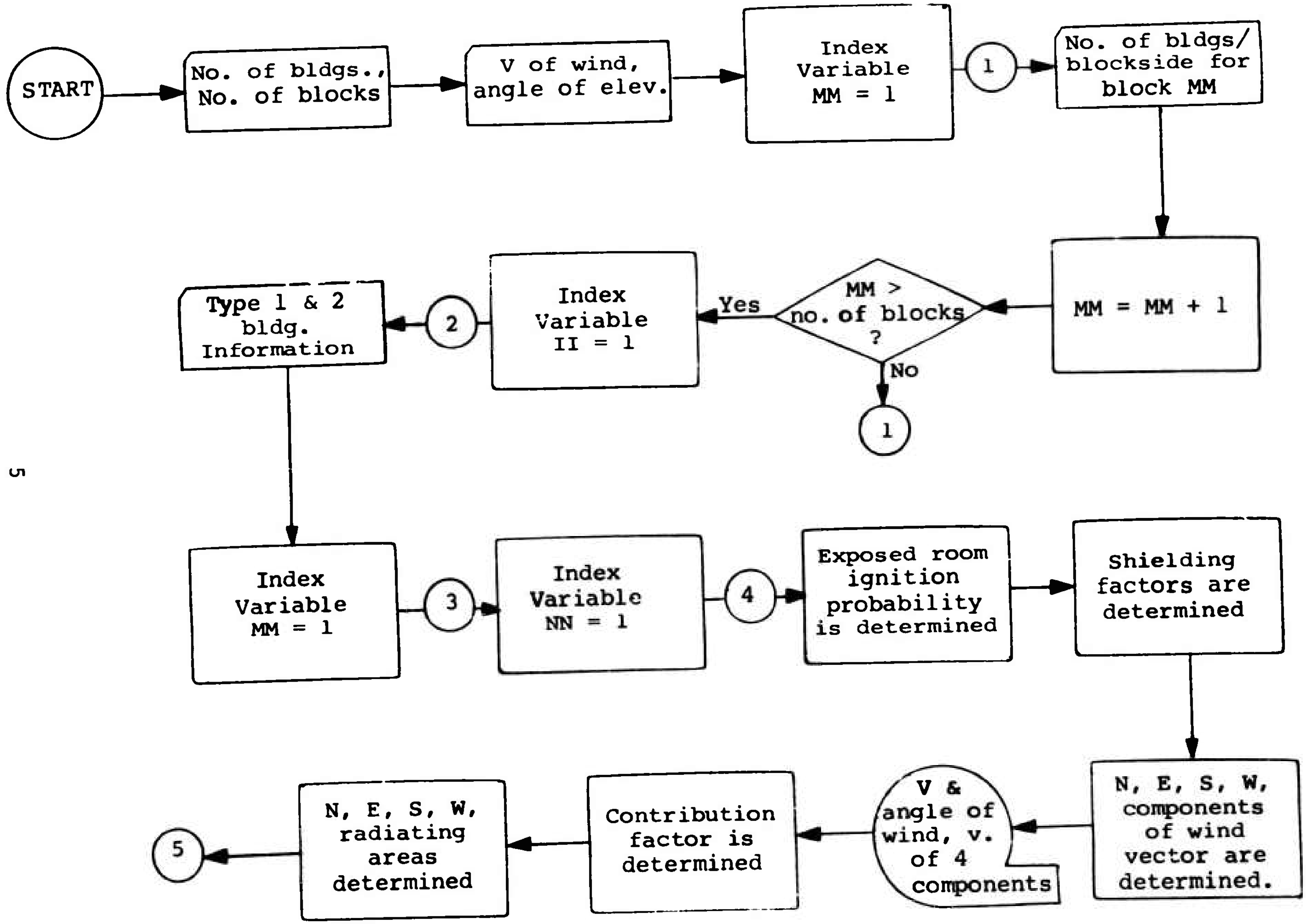
.. average number and percent-of-total buildings destroyed by the thermal pulse.

.. average number and percent-of-total buildings destroyed by fire spread.

.. standard deviations of the above two averages.

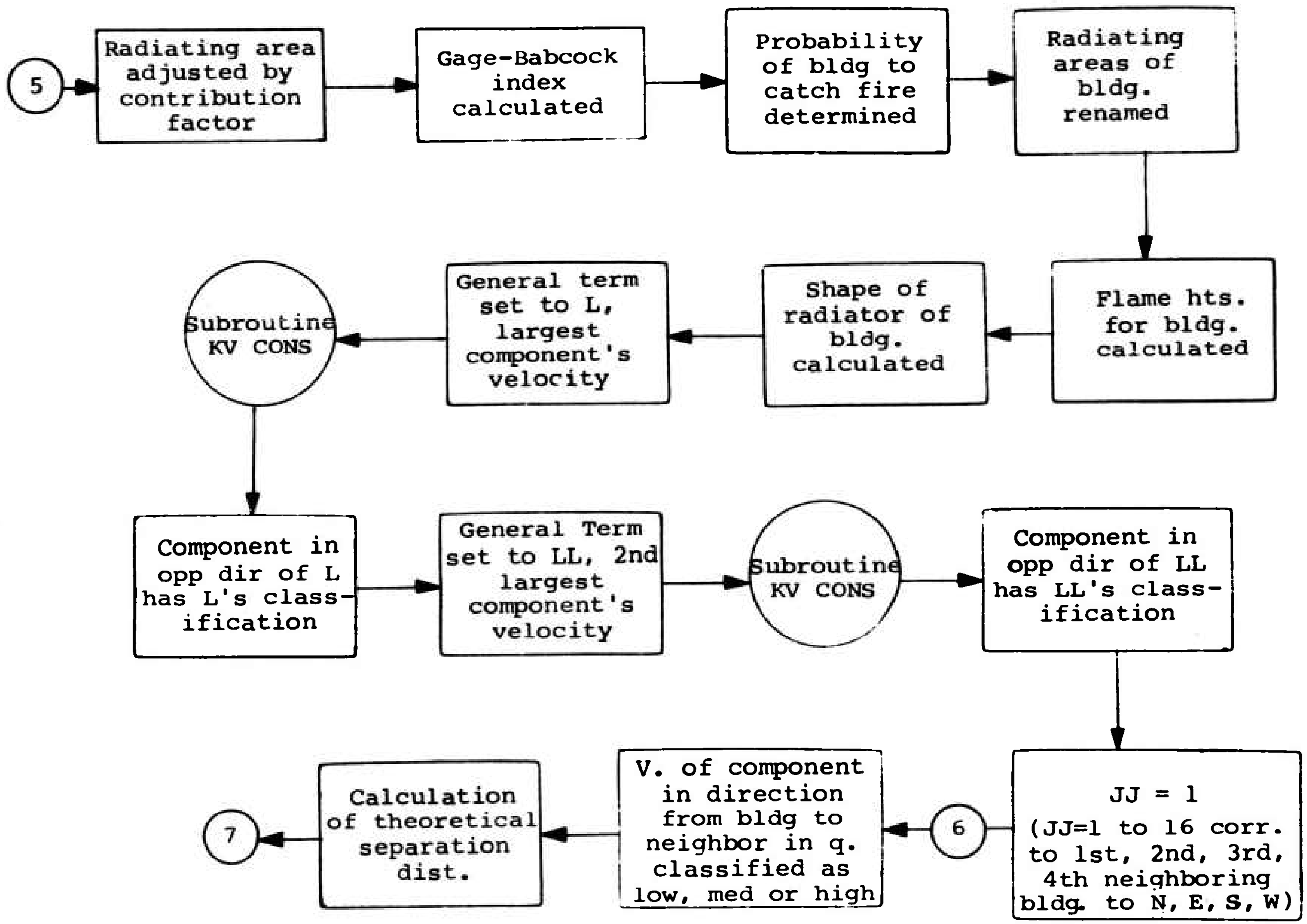
The detailed descriptions of the three segments are contained in the following three sections. An overall flow chart of the FIREFLY system is shown in Figure 1-1.

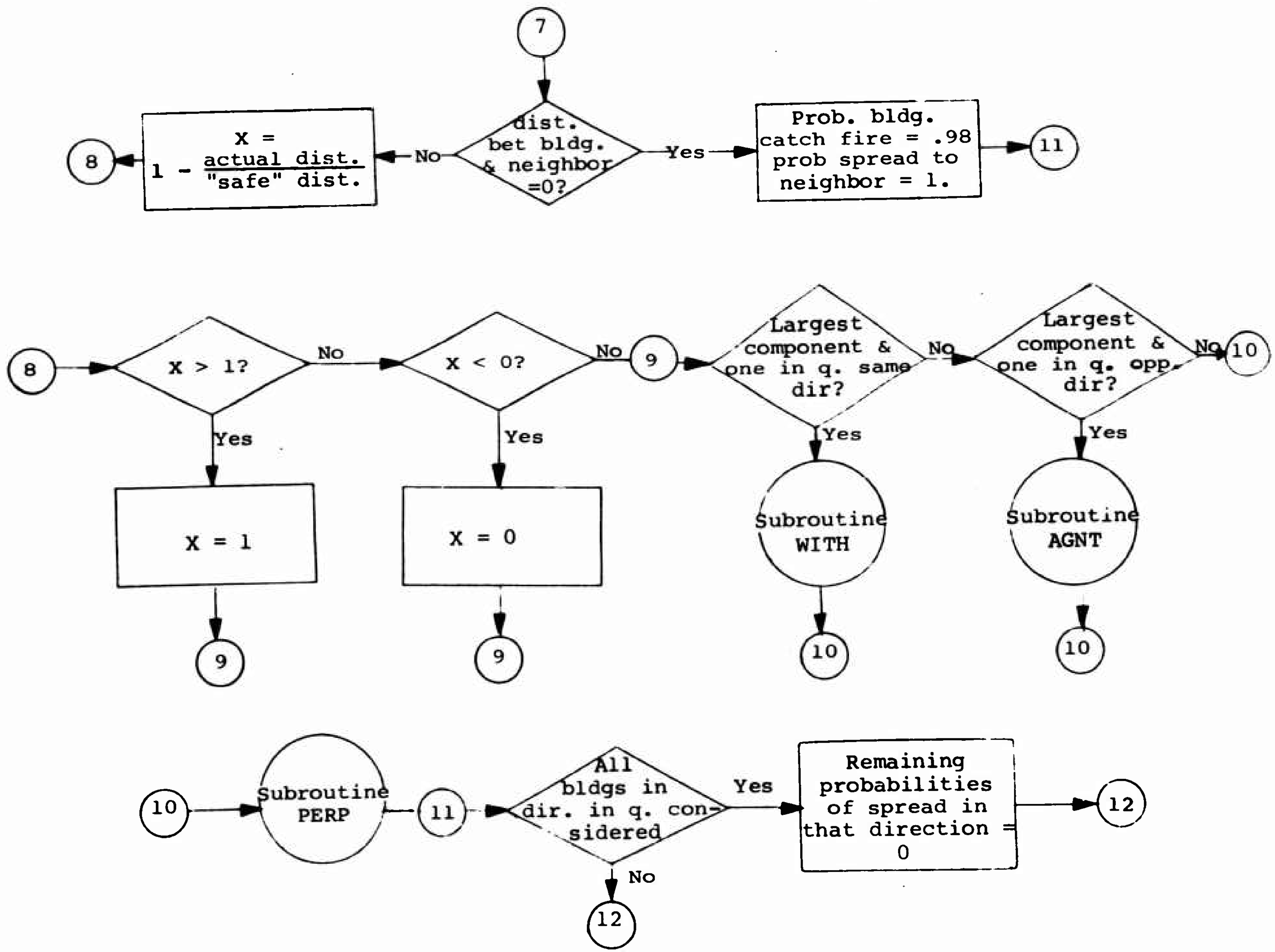
Paragraph II following will give some of the rationale, background, and relationships presented in a manner for the analyst rather than a programmer. Although much of the information will be repeated and expanded in Sections 2, 3, 4, 5, and 6, the reader wishing a general knowledge of the model may omit Sections 2-6.

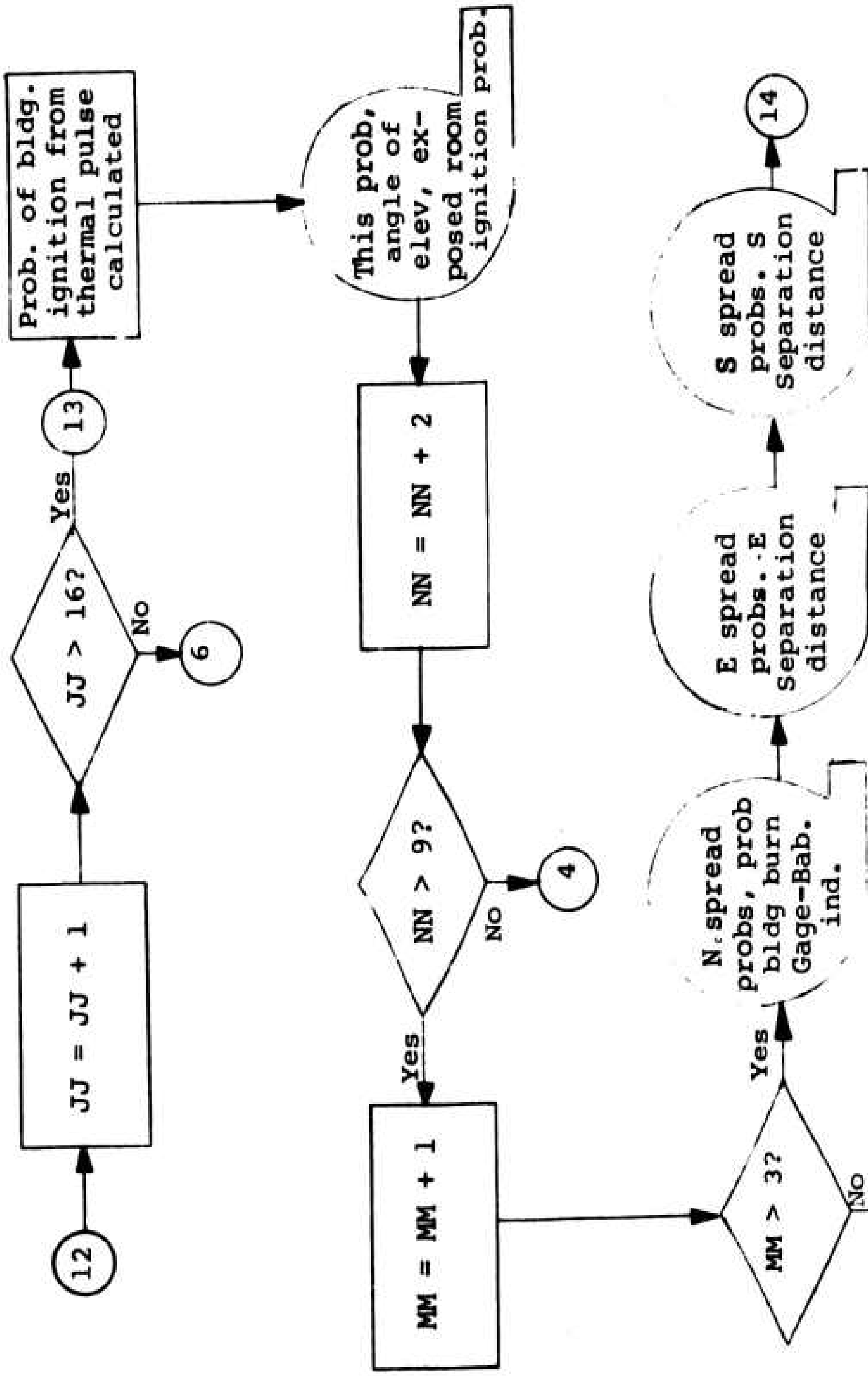


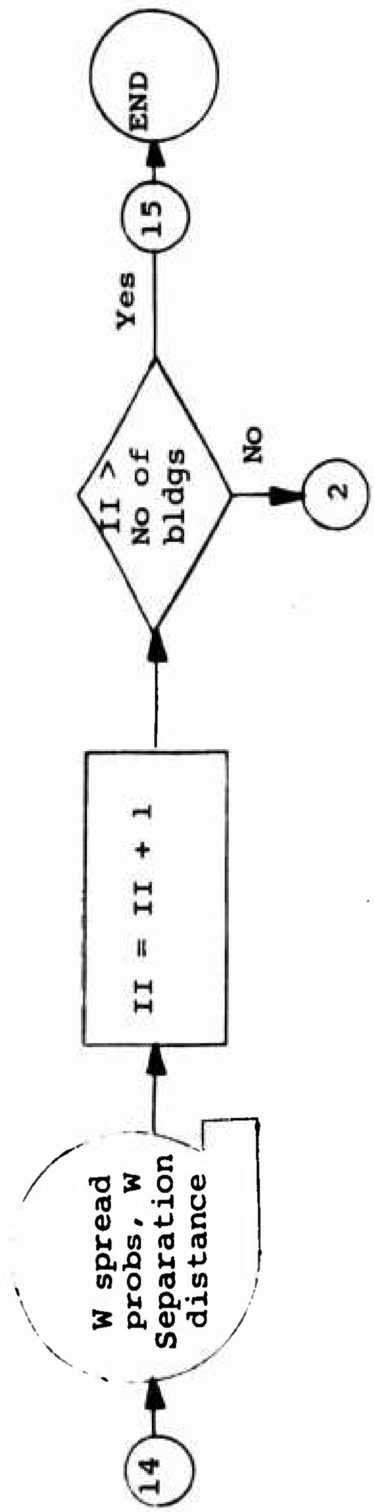
FIREFLY 1

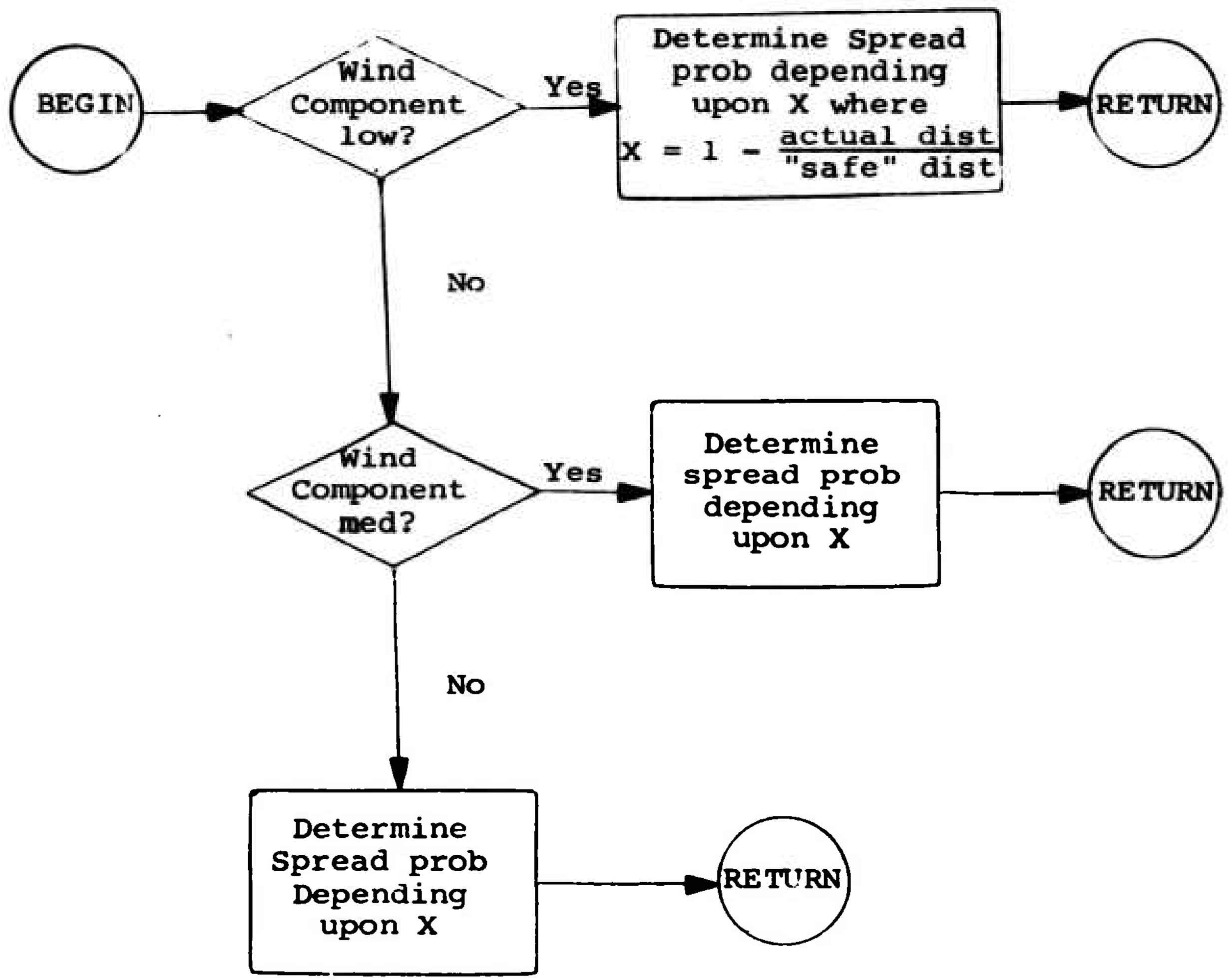
FIGURE 1-1


5
Radiating area adjusted by contribution factor
Gage-Babcock index calculated
Probability of bldg to catch fire determined
Radiating areas of bldg. renamed
Flame hts. for bldg. calculated
Shape of radiator of bldg. calculated
General term set to L, largest component's velocity
Subroutine KV CONS
Component in opp dir of L has L's classification
General Term set to LL, 2nd largest component's velocity
Subroutine KV CONS
Component in opp dir of LL has LL's classification
JJ = 1
(JJ=1 to 16 corr. to 1st, 2nd, 3rd, 4th neighboring bldg. to N, E, S, W)
6
V. of component in direction from bldg to neighbor in q. classified as low, med or high
Calculation of theoretical separation dist.
7


7
dist. bet bldg. & neighbor =0?
No
Yes
X = 1 - actual dist. / "safe" dist.
8
Prob. bldg. catch fire = .98 prob spread to neighbor = 1.
11
8
X > 1?
Yes
No
X = 1
9
X < 0?
Yes
No
X = 0
9
9
Largest component & one in q. same dir?
Yes
No
Subroutine WITH
10
Largest component & one in q. opp. dir?
Yes
No
10
Subroutine AGNT
10
10
Subroutine PERP
11
All bldgs in dir. in q. considered
Yes
No
12
Remaining probabilities of spread in that direction = 0
12

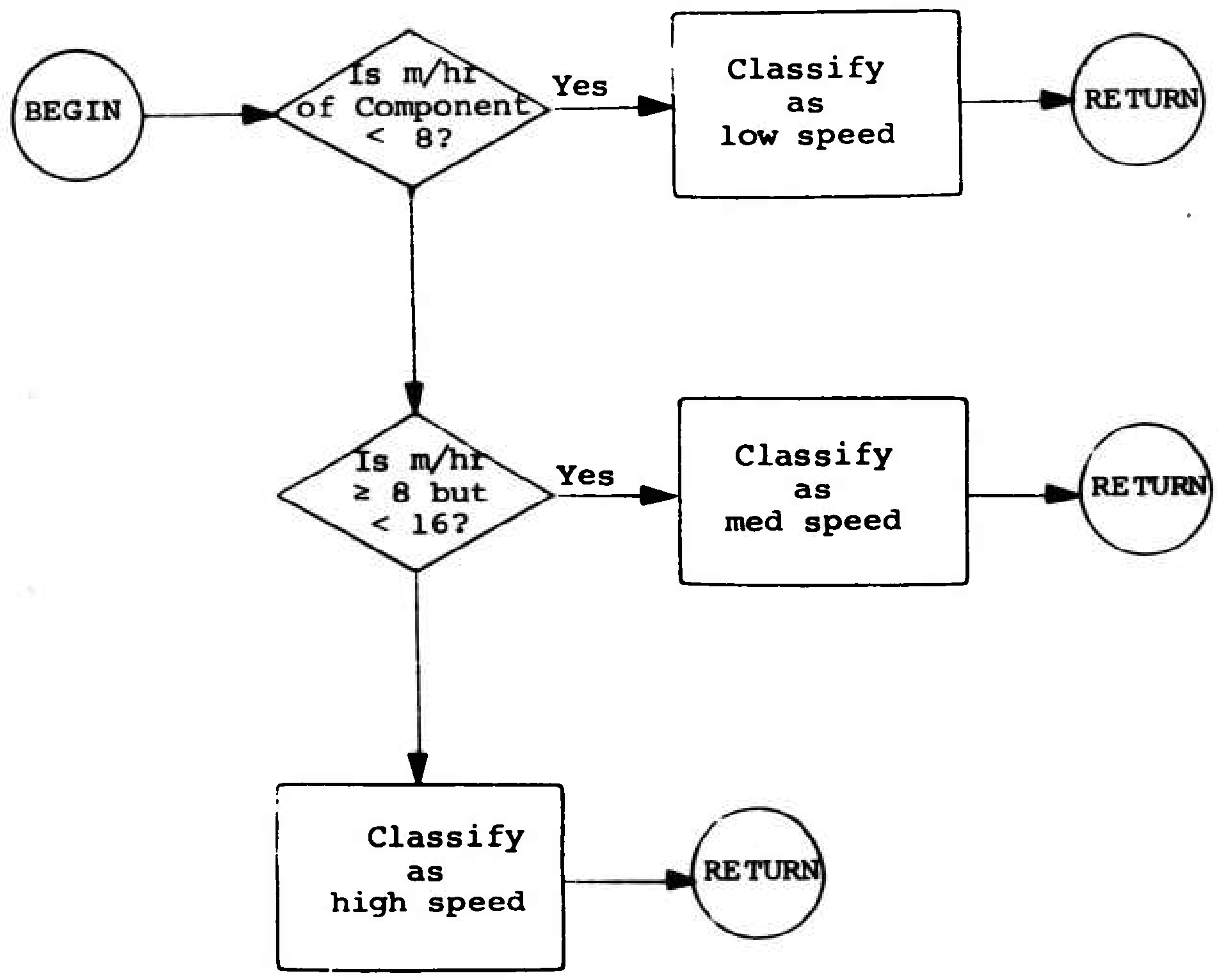

12
JJ = JJ + 1
JJ > 16?
Yes
No
6
13
Prob. of bldg. ignition from thermal pulse calculated
This prob, angle of elev, exposed room ignition prob.
NN = NN + 2
NN > 9?
No
4
Yes
MM = MM + 1
MM > 3?
No
3
Yes
N. spread probs, prob bldg burn Gage-Bab. ind.
E spread probs. E Separation distance
S spread probs. S Separation distance
14


14
W spread probs, W Separation distance
II = II + 1
II > No of bldgs
No
2
Yes
15
END



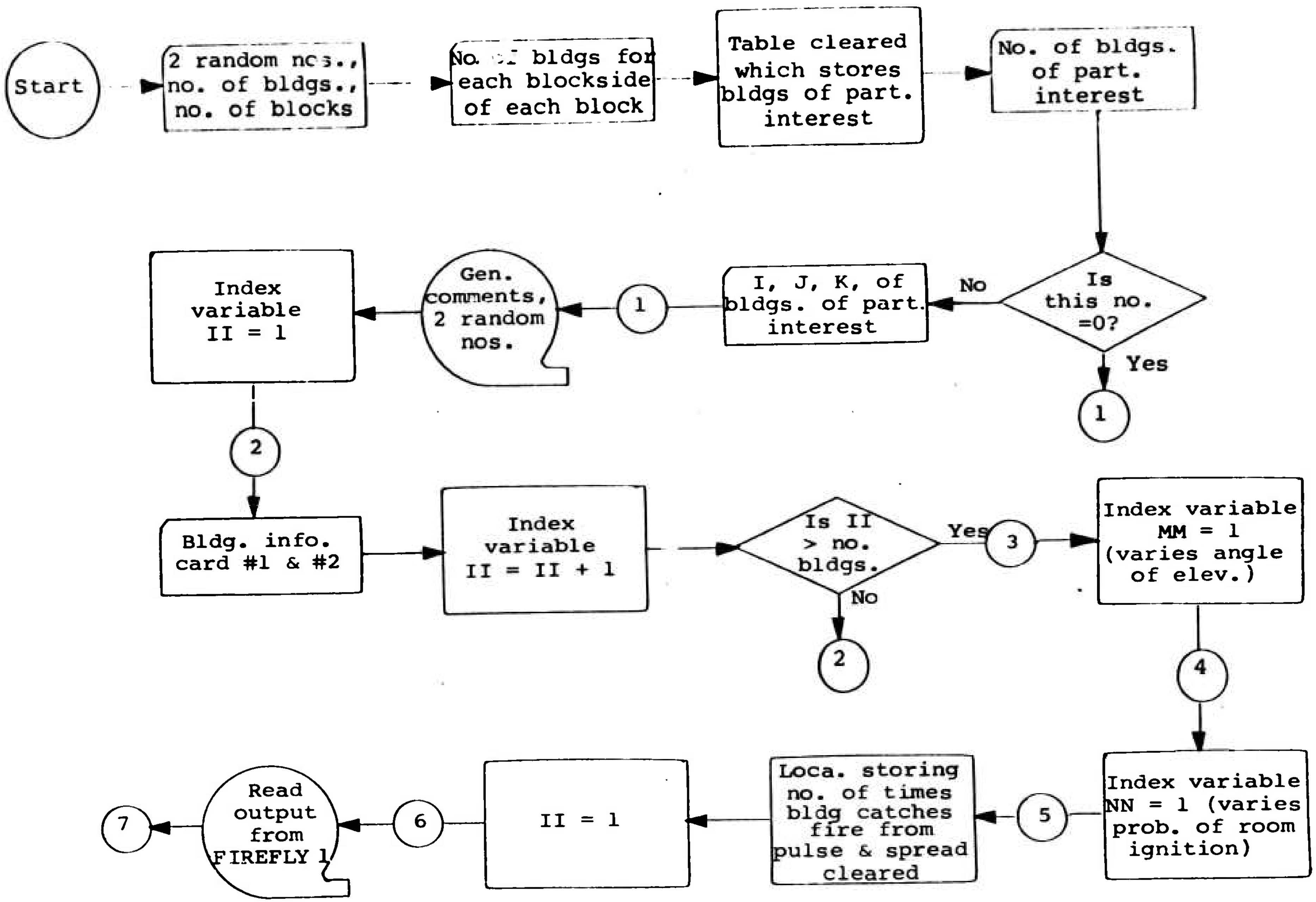
SUBROUTINES AGNT, PERP, WITH

Figure 1-1 (Continued)

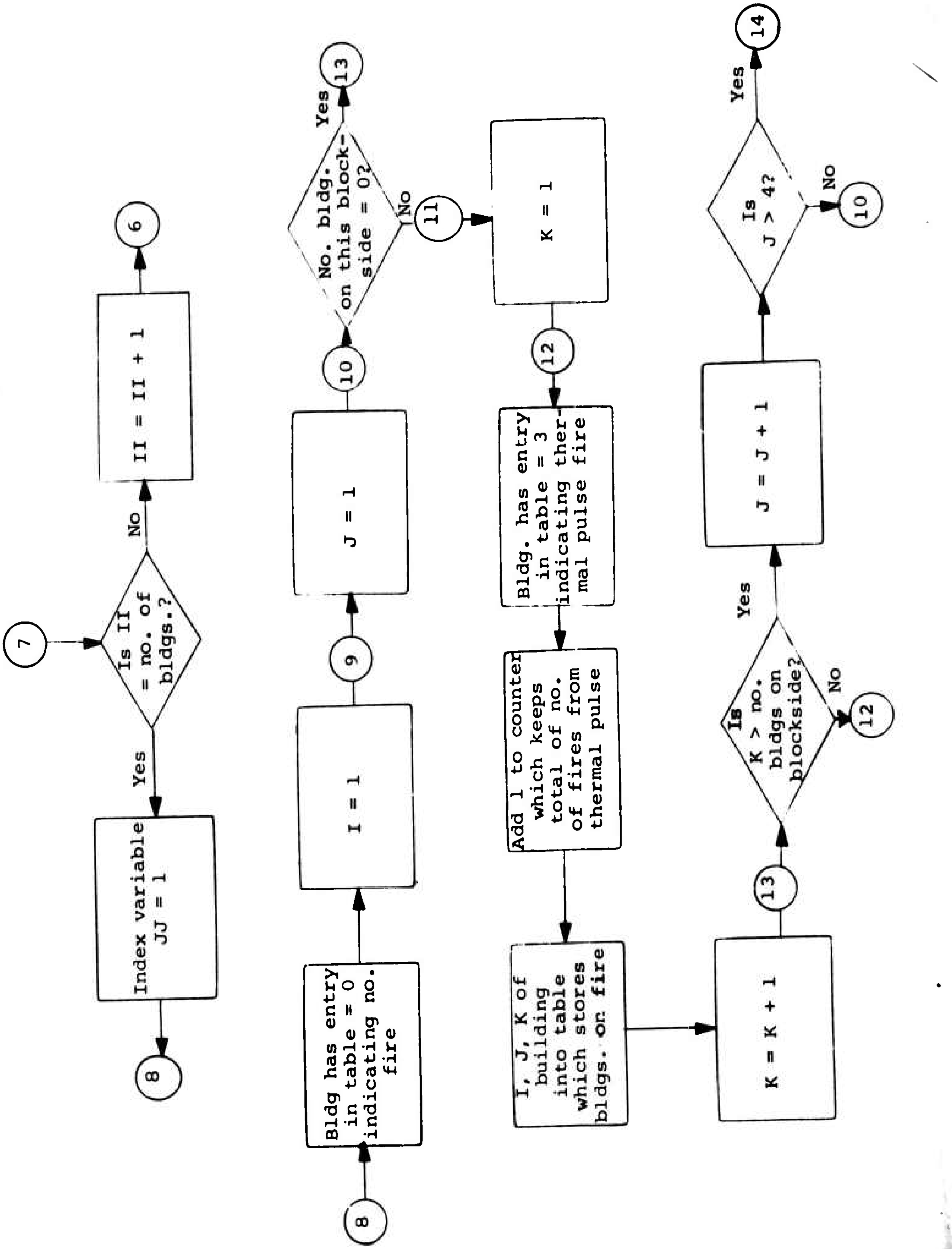


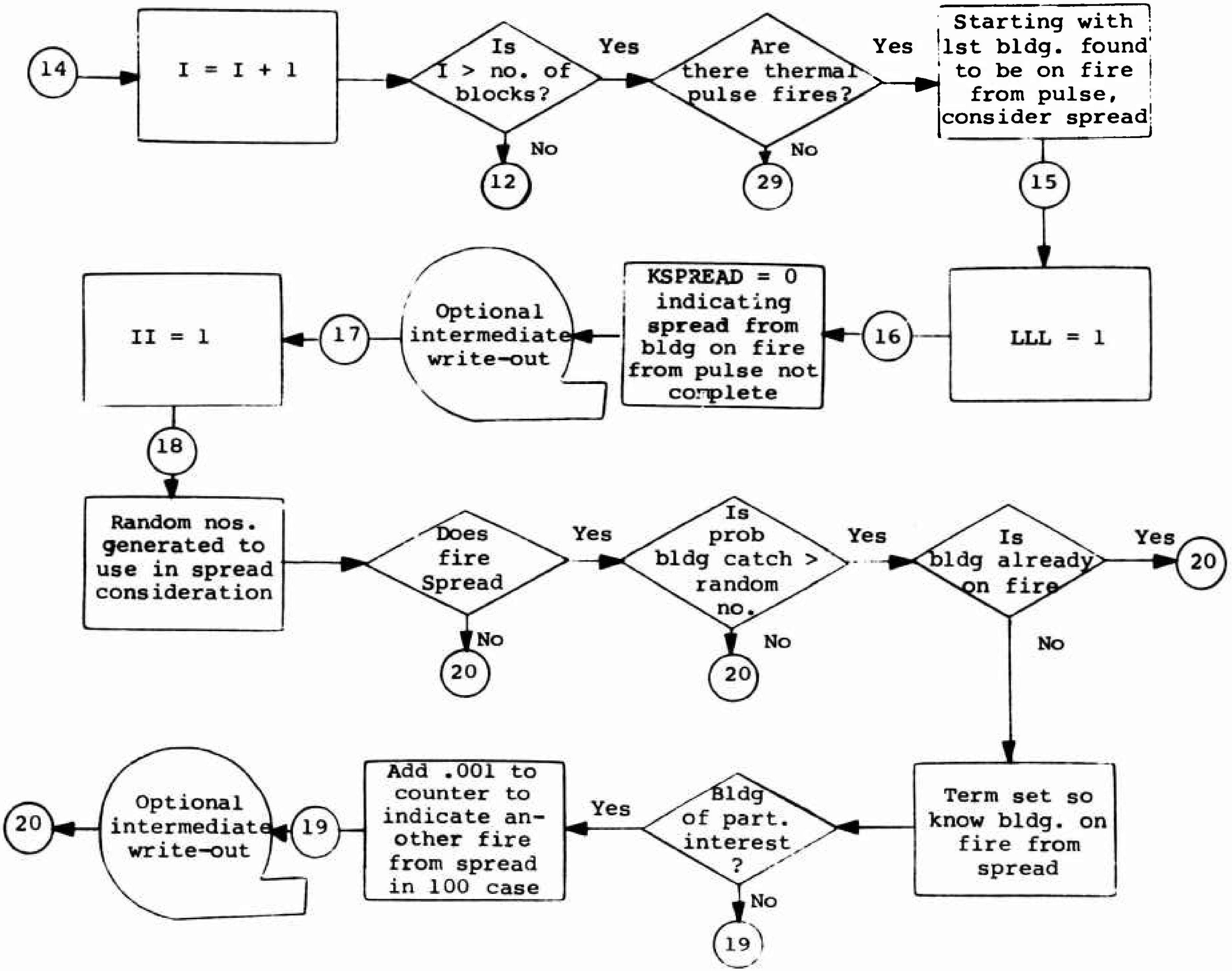
SUBROUTINE KV CONS

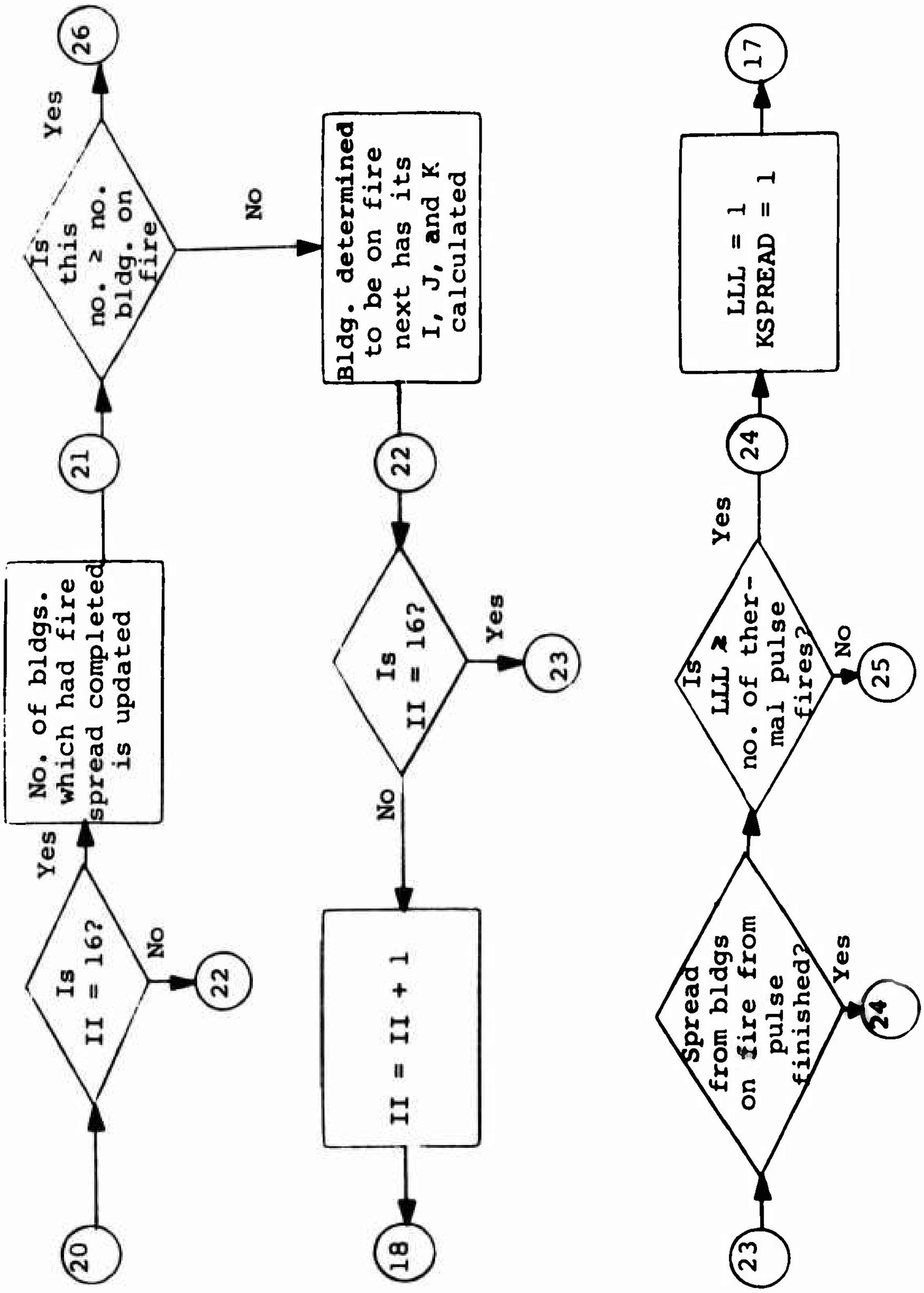
Figure 1-1 (Continued)

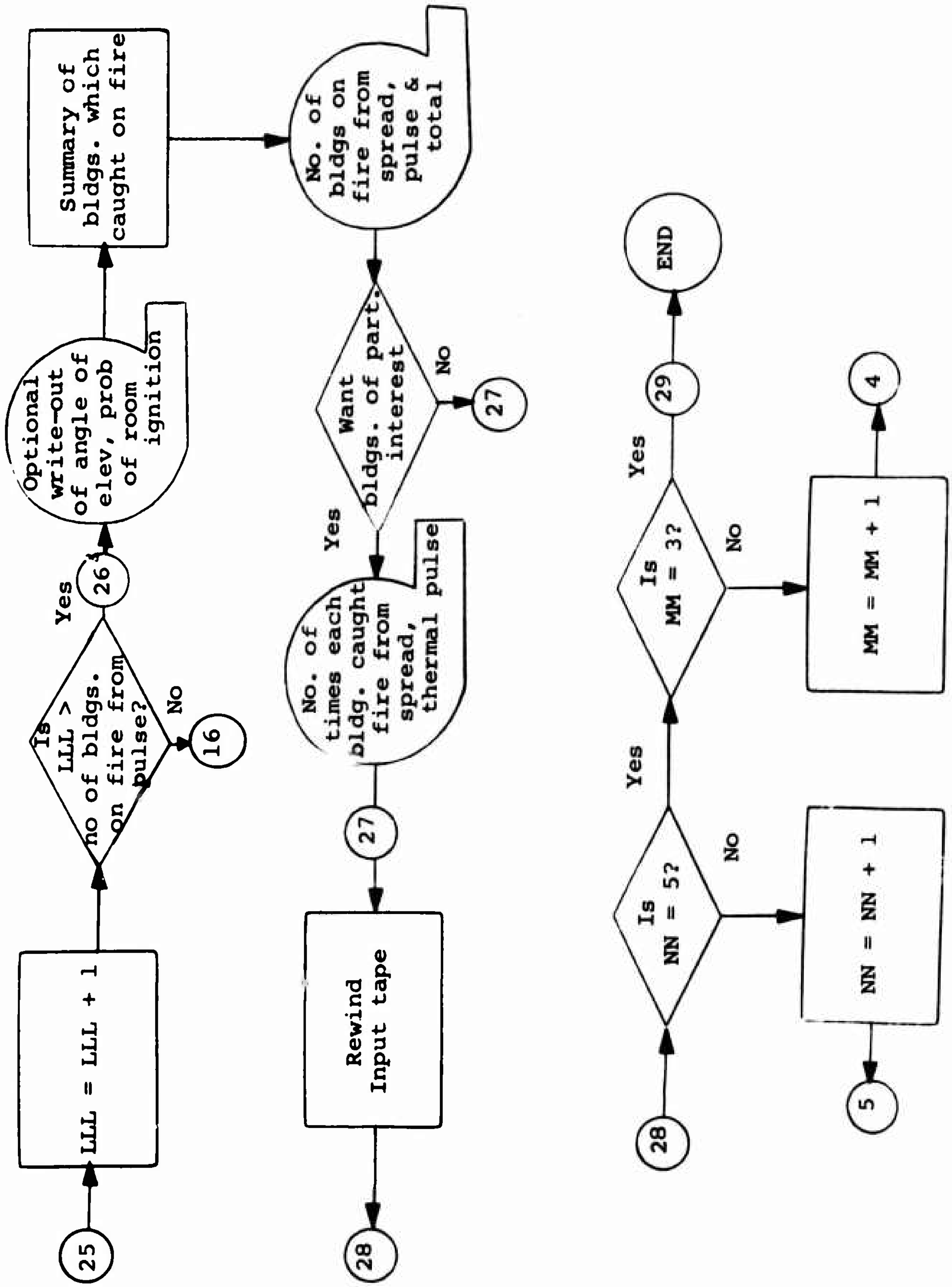


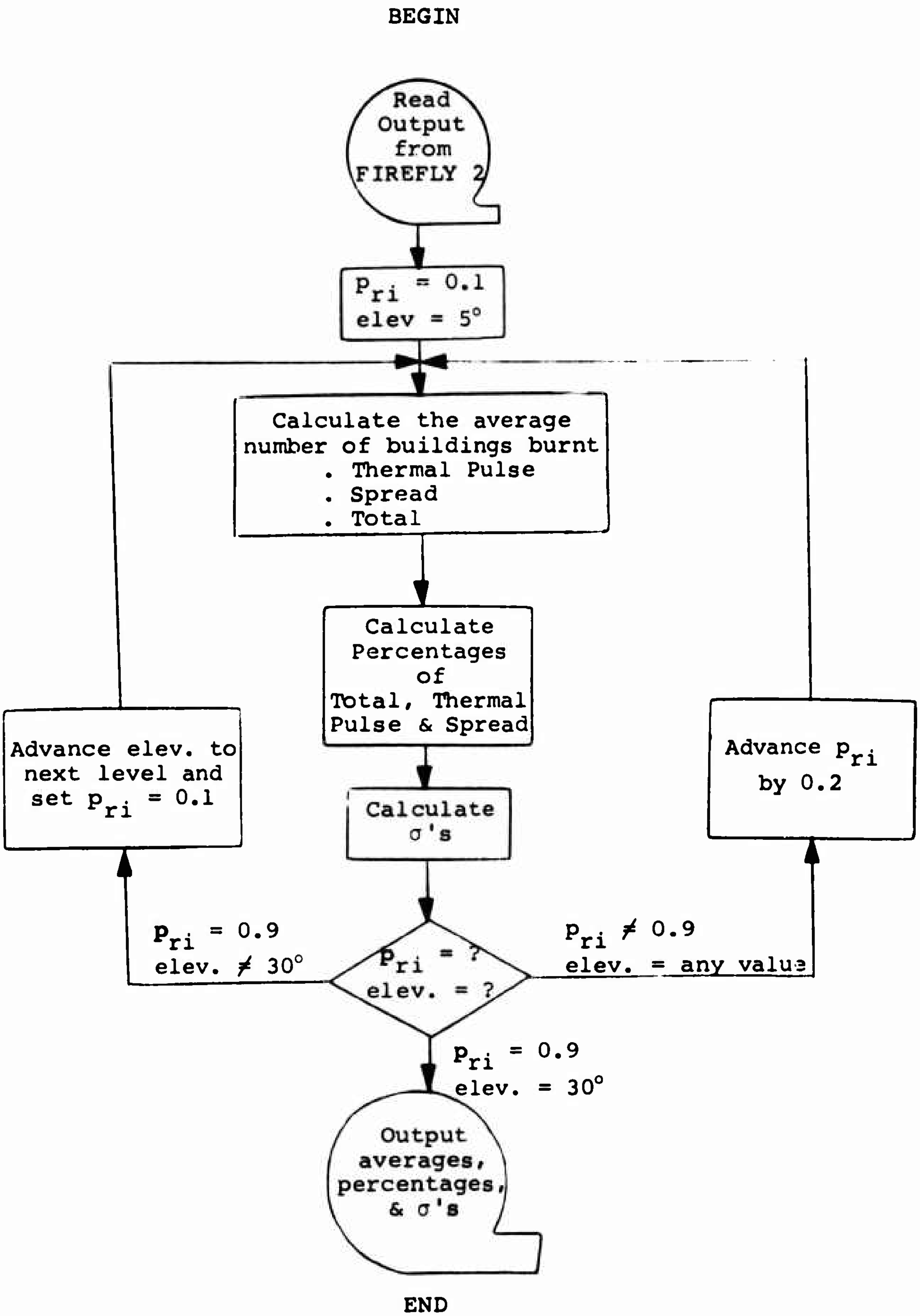
FIREFLY 2
Figure 1-1 (Cont.)


7
Is II = no. of bldgs.?
No
Yes
II = II + 1
6
Index variable JJ = 1
8
8
Bldg has entry in table = 0 indicating no. fire
I = 1
9
J = 1
10
No. bldg. on this block-side = 0?
Yes
13
No
11
K = 1
12
Bldg. has entry in table = 3 indicating thermal pulse fire
Add 1 to counter which keeps total of no. of fires from thermal pulse
I, J, K of building into table which stores bldgs. on fire
K = K + 1
13
Is K > no. bldgs on blockside?
No
12
Yes
J = J + 1
Is J > 4?
No
10
Yes
14


14
I = I + 1
Is I > no. of blocks?
Yes
No
12
Are there thermal pulse fires?
Yes
No
29
Starting with 1st bldg. found to be on fire from pulse, consider spread
15
LLL = 1
16
KSPREAD = 0 indicating spread from bldg on fire from pulse not complete
Optional intermediate write-out
17
II = 1
18
Random nos. generated to use in spread consideration
Does fire Spread
Yes
No
20
Is prob bldg catch > random no.
Yes
No
20
Is bldg already on fire
Yes
20
No
Term set so know bldg. on fire from spread
Bldg of part. interest ?
Yes
No
19
Add .001 to counter to indicate another fire from spread in 100 case
19
Optional intermediate write-out
20


20
Is
II = 16?
Yes
No
22
No. of bldgs. which had fire spread completed is updated
21
Is this no. ≥ no. bldg. on fire
Yes
26
No
Bldg. determined to be on fire next has its I, J, and K calculated
22
Is
II = 16?
Yes
23
No
II = II + 1
18
23
Spread from bldgs on fire from pulse finished?
Yes
24
Is LLL ≥ no. of ther-mal pulse fires?
No
25
Yes
24
LLL = 1
KSPREAD = 1
17


25
LLL = LLL + 1
Is LLL > no of bldgs. on fire from pulse?
Yes
No
16
26
Optional write-out of angle of elev, prob of room ignition
Summary of bldgs. which caught on fire
No. of bldgs on fire from spread, pulse & total
Want bldgs. of part. interest
Yes
No
27
No. of times each bldg. caught fire from spread, thermal pulse
27
Rewind Input tape
28
28
Is NN = 5?
Yes
No
NN = NN + 1
5
Is MM = 3?
Yes
No
MM = MM + 1
4
29
END



FIREFLY 3

Figure 1-1 (Con't)

II. DESCRIPTION OF THE FIREFLY MODEL

A. Rationale and Background

IITRI, Gage-Babcock, URS, SRI, and others have done a great deal of developmental and applied work in the field of fire phenomenology. Attempts have been made at specifying the parameters which have a bearing on the problem, defining some of these parameters in terms of workable expressions, and the construction of fire models. No single study, however, appeared to treat the problem in enough detail that real city blocks under hypothetical attack conditions could be assessed rapidly for all possible conditions of nuclear threat. IITRI's model was by far the most complete attempt at solving the urban fire problem and Gage-Babcock had gone furthest in classifying buildings and separation distances. Some of both methods have been employed.

B. Sample Problem

Since Sections 2-6 present much of the more intricate workings of the model we shall begin with a sample problem of fire ignition and fire spread and work it through to completion much in the same way that FIREFLY itself would.

The buildings, A and B, are shown in Figure 1-2. They are identical in size and used for the analysis to be presented here.

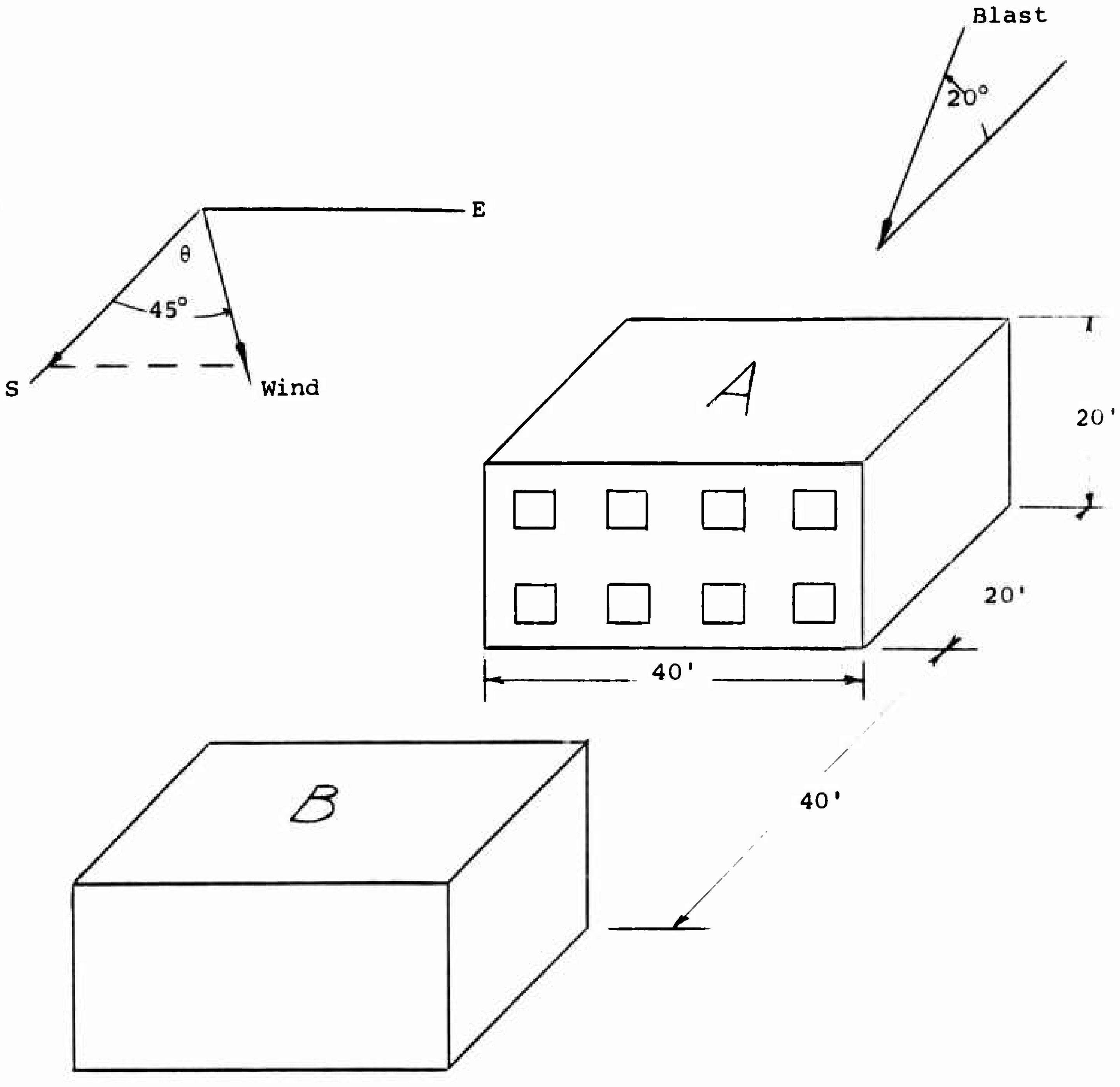


Figure 1-2
Two Building Example

The weather conditions prior to the detonation of weapon show a clear day (visibility of 12 miles or greater), and a wind of 10 mph blowing from the northwest.

The neighborhood is medium-class residential with a typical dwelling occupancy of 0.7 persons per room.

A 1 MT weapon is exploded at 640-foot scaled height of burst creating an angle of elevation of the fire-ball of 20^o at buildings A and B.

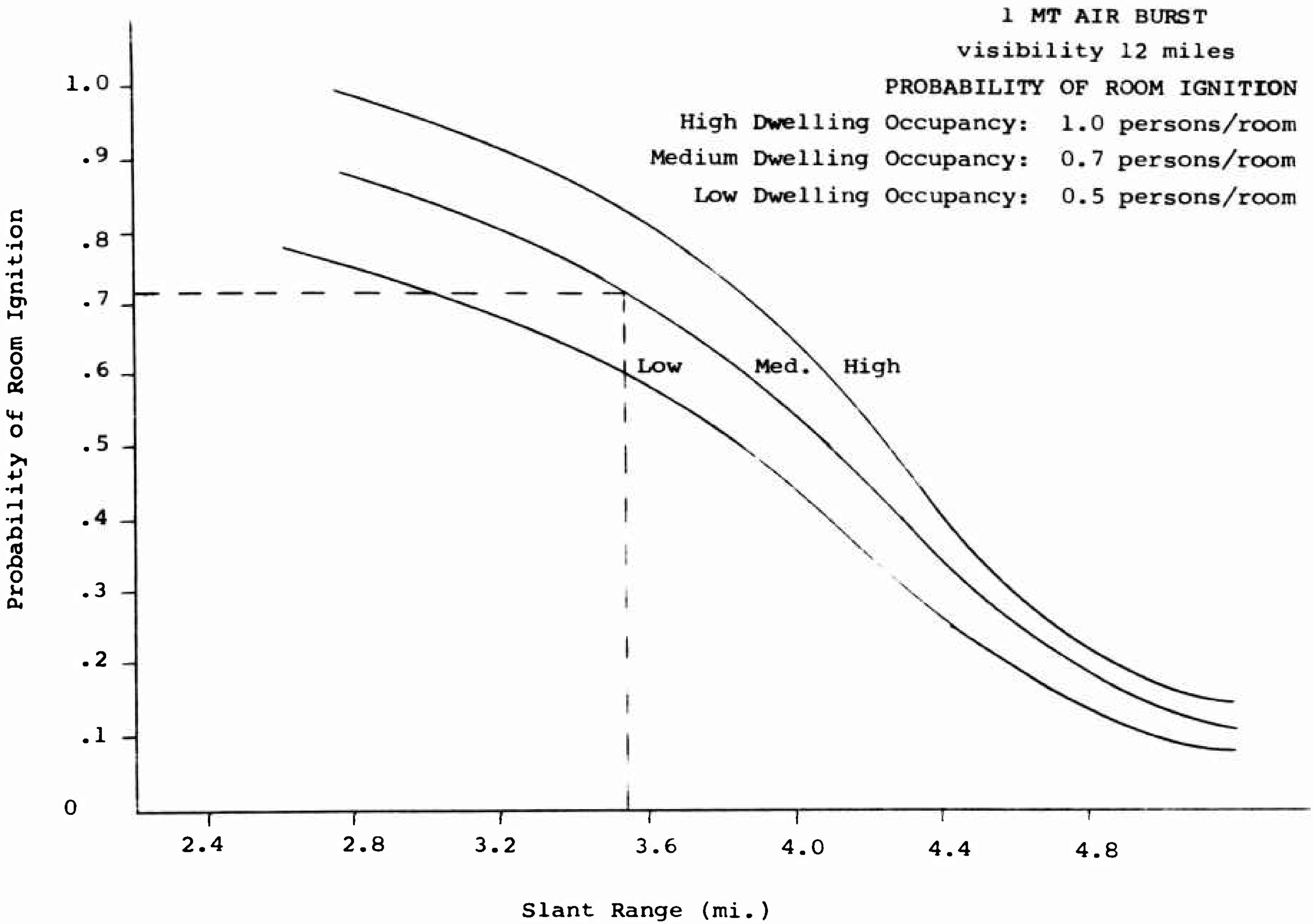
Of first interest is to determine if either building will burn as a result of the thermal pulse* by calculating two distinct quantities. The first of these quantities, called p_{tp}, represents the probability that a completely flammable building will burn and is given by

$$p_{tp} = 1 - (1 - p_{ri})^N$$

We find the value for the probability of room ignition (p_{ri}) from curves such as Figure 1-3 (which have been subsequently reduced to algorithmic form for all yields, heights of burst, and dwelling occupancies).

The actual height of burst for a 1 MT 640-foot scaled is

* It must be borne in mind that FIREFLY does not, at present, take blast effects into account.



1 MT AIR BURST
visibility 12 miles
PROBABILITY OF ROOM IGNITION
High Dwelling Occupancy: 1.0 persons/room
Medium Dwelling Occupancy: 0.7 persons/room
Low Dwelling Occupancy: 0.5 persons/room
Probability of Room Ignition
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Low
Med.
High
2.4
2.8
3.2
3.6
4.0
4.4
4.8
Slant Range (mi.)

Figure 1-3

$HOB = 640 \sqrt[3]{W} = 640 \sqrt[3]{1000} = 6400$ ft = 1.21 miles
(W is in kilotons)

The slant range is then

$$\frac{1.21}{\sin 20^{\circ}} = 3.54 \text{ miles}$$

Using Figure 1-3, p_{ri} is found to be 0.72 and represents the probability that an exposed room will sustain sufficient ignition to produce flashover.

The quantity N, the number of ignition points, may be defined as

$$N = \left[\frac{\left(\frac{\ell + w}{2}\right)(h)}{a} \right] \left[p_w, w_s, w_h \right]$$

where

ℓ = building length (ft)

w = building width (ft)

h = building height (ft)

a = average area of a single window (3 x 5 ft normally)

p_w = ratio of window area to total wall area (.20)

w_s = window shading (found to be .50)

w_h = window shielding factor*

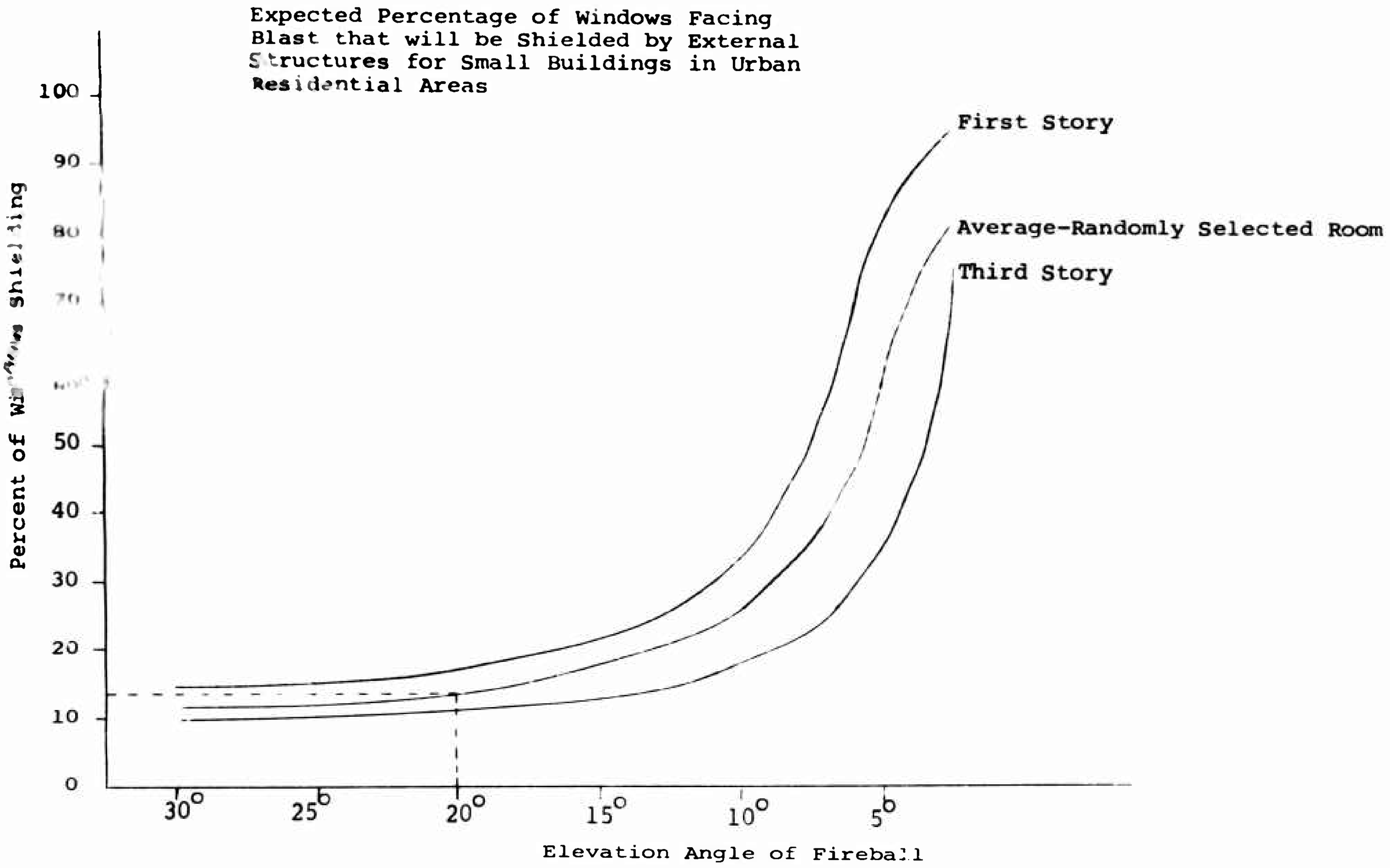
---

* W_h is one minus the percentage shielded. Thus if all windows are totally shielded from the thermal pulse by a neighboring building, then $W_h = 0$.

A note of caution is necessary before N is calculated. Notice that the value for window area, a, is in the denominator. From immediate inspection it appears that if the window size is increased, holding all other values constant, the number of ignition points will decrease which would not be correct. A little interpretation of the case in question is necessary. Take, for example, the case of a modern, all glass front building. If no interpretation of the values is performed, one might mistakenly give "a" a value equal to the entire front area while giving p_w a value of 1.0. The value of "a" must be examined from the standpoint of the number of compartments showing in the front face and using the net average dimension of the compartments. The value of p_w could never be exactly 1.0--allowance must be made for floor and wall divisions. Further, if for the same building the value of "a" were to double, then p_w must also double.

The length and width of the building are averaged since we wish to express the answers in terms of a lateral random orientation of the weapon.

The only quantity remaining to be assessed is the window shielding, w_h. Curves such as Figure 1-4 must be constructed for a typical urban area as a result of sightings from many window levels (such as may be accomplished using Sanborn maps) to determine the obstructions that will occur. Using Figure 1-4 for an elevation angle of 20^o we find that 14% of the windows will be blocked; thus w_h is 0.86. Solving for N, we find



Expected Percentage of Windows Facing Blast that will be Shielded by External Structures for Small Buildings in Urban Residential Areas
First Story
Average-Randomly Selected Room
Third Story
Percent of Wi Shielding
100
90
80
70
50
40
30
20
10
0
30°
25°
20°
15°
10°
5°
Elevation Angle of Fireball

Figure 1-4

$$N = \left[\frac{\frac{40 + 20}{2}(20)}{15} \right] \left[(.20)(.50)(.86) \right]$$

$$N = 3.44$$

Then

$$p_{tp} = 1 - (1 - .72)^{3.44}$$

$$p_{tp} = 0.987$$

The second quantity to be calculated is the probability of interior spread, p_s, and is given by

$$p_s = \sin \left\{ \frac{\pi}{300} \left[H(L + F + W) + R \right] \right\}$$

Before the terms in the equation for p_s are evaluated it must be mentioned that p_s itself is used in two places. Since it is a measure of inter-building spread, reflecting basically the construction characteristics from a flammability standpoint, it is used to "degrade" p_{tp} and a quantity p_j which will be evaluated in a later paragraph.

The values of H, L, F, W, and R are factors which depend on the height and construction characteristics of the particular building. They are explained in detail in Section 2 but must be quantified here for use in the above expression. The following information is estimated using Sanborn maps:

1. Use -- apartment with a moderate fire load (L=20)

2. Exterior Wall Construction--masonry, non-combustible ($W=10$)

3. Roof--class 2, non-combustible ($R=10$)

4. Floor--fire-resistive ($F=0$)

5. Height--2-story ($H=1.0$)

Solving for p_s, we find

$$p_s = \sin \frac{\pi}{300} \left[1.0 \ (20 + 0 + 10) + 10\right]$$

$$p_s = \sin \frac{40\pi}{300} = \sin \frac{\pi}{7.5} = \sin 24^\circ$$

$$p_s = 0.407$$

Now p_s and p_{tp} are combined into the final probability of building ignition, p_{tpn}, by

$$p_{tpn} = p_{tp} \, p_s$$

$$p_{tpn} = (0.987)(0.407)$$

$$p_{tpn} = 0.402$$

The value of 0.402 is compared to a random number (in decimal form) which is generated within FIREFLY. If the random number is equal to or less than the value for p_{tpn}, the building is assumed to have been destroyed by fire.

For purposes of demonstrating the fire spread portion of the model, assume that building A is burning and building B is not (i.e., the random number generated for B was greater than 0.402). It is necessary to calculate the threat that A poses to B as a function of

... The nature of the flame front that A will present.

... The separation distance between A and B.

... The speed and direction of the wind.

1. The Flame Front

The first step in assessing the nature of the flame is to decide upon a value for the "average flame height." This term is a bit misleading but only represents an intermediate calculation, and may be assessed using the Table 1-1.*

Remembering that building A has a class 2 roof, average window openings, and is two stories in height, Table 1-1 gives an "average flame height" of 14 feet. This value is divided into the dimension of building A facing building B to determine into which of three radiating shapes the building will fall (square, rectangular, or long rectangular). The desired ratio is, then

$$\frac{40}{14} = 2.86$$

A ratio of 2.86 classifies building A as a rectangular radiator (the criteria being between 1.6 and 8.0).

---

* Reproduced in total from Table 1 (p. 48) of the Gage-Babcock work referenced in the Foreword.

TABLE 1-1

"Average Flame Heights" For Building Characteristics (in feet)

Class 1 Roof Construction--Fire Resistive, 2-Hour or Better

Story Height	WALL OPENINGS None	Few	Average	Many	All
1	.4	1.8	3.6	7.2	12
2	.7	3.6	7.2	14	24
3	1.1	5.4	11	22	36
4	1.4	7.2	14	29	48
5	1.8	9	18	36	60
6	2.2	11	22	43	72
7	2.5	13	25	50	84
8 & over	2.9	14	29	58	96

Class 2 Roof Construction--Noncombustible or Fire Resistive Less Than 2-Hours

Story Height	WALL OPENINGS None	Few	Average	Many	All
1	10	11	12	14	18
2	10	12	14	17	27
3	10	13	15	21	35
4	10	14	17	24	44
5	10	15	19	28	52
6	10	15	21	32	60
7	10	17	23	35	69
8 & over	10	17	24	39	77

Class 3 Roof Construction--Wood, Flat or Peaked Up to 15 Feet

Story Height	WALL OPENINGS None	Few	Average	Many	All
1	30	31	32	34	38
2	30	32	34	37	47
3	30	33	35	41	55
4	30	34	37	44	64
5	30	34	39	48	72
6	30	35	41	52	80
7	30	36	43	55	89
8 & over	30	37	44	59	97

Table 1-1 (Continued)

Class 4 Roof Construction--Wood, Bow String Truss or Peaked 16-25 Feet

Story Height	WALL OPENINGS None	Few	Average	Many	All
1	45	46	47	49	53
2	45	47	49	52	62
3	45	48	50	56	70
4	45	49	52	59	79
5	45	49	54	63	87
6	45	50	56	67	95
7	45	51	58	70	104
8 & over	45	52	59	74	112

Class 5 Roof Construction--Wood, Peaked 26 Feet and Over

Story Height	WALL OPENINGS None	Few	Average	Many	All
1	60	61	62	64	68
2	60	62	64	67	77
3	60	63	65	71	85
4	60	64	67	74	94
5	60	64	69	78	102
6	60	65	71	82	110
7	60	67	73	85	119
8 & over	60	67	74	89	127

Figure 1-5 is the curve of the "safe distance" relationship for a rectangular radiator as a function of the adjusted radiating area. This safe distance is the distance away from the radiating face of a building under quiescent wind conditions at which ignitions will not occur. The adjusted radiating area is the average flame height (14 feet) multiplied by the width of the face (40 feet), or 560 sq ft. Figure 1-5 shows the safe distance to be 68 feet.

2. The Separation Distance

The actual distance of separation is compared to the theoretical safe separation distance. If the actual distance is zero, the probability of "jump", p_j, (i.e., the probability that the heat from building A will be sufficient to cause one or more ignitions in building B) is set equal to 1.0 for combustible separating walls and 0.95 for fire-resistive walls. If the actual distance is greater than the safe distance, p_j is zero. For cases in between a quantity x is calculated as

$$x = \frac{\text{actual distance}}{\text{safe distance}}$$

$$x = \frac{40}{68} = 0.588$$

3. The Wind

The direction of the wind is shown in Figure 1-2; the speed is 10 mph. Building B is located due south from A, thus the wind component for spread considerations from A to B is

$$\nu_{ab} = \nu_o \cos \theta$$

$$\nu_{ab} = 10 \cos 45^\circ$$

$$\nu_{ab} = + 7.07 \text{ mph}$$

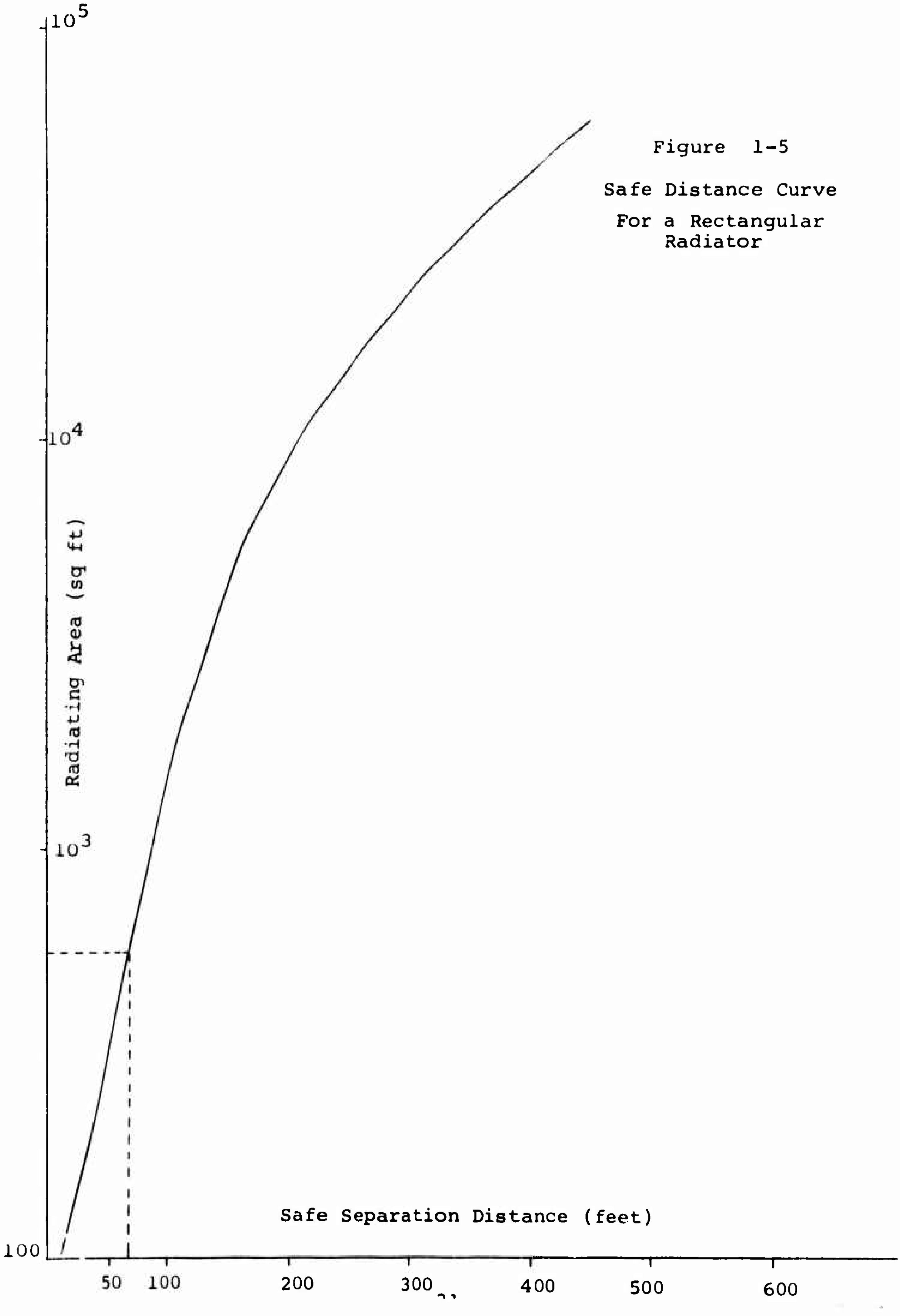


Figure 1-5

Safe Distance Curve

For a Rectangular Radiator

FIREFLY vectors all winds for spread considerations to create any one of nine cases--fire spread with, perpendicular to, or into a low (<8 mph), medium (≥8 but <16 mph), or high wind (≥ 16 mph). The rationale for this may be demonstrated in Figure 1-6.

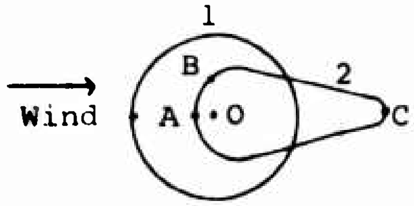


Figure 1-6

Circle 1 represents the safe distance from a radiating point source located at 0 under quiescent conditions. If a wind is blowing as indicated the figure changes as shown by curve 2. Spread from 0 to A will be difficult since both fire brands and the flame inclination will be "pointed" towards C rather than towards A. Spread perpendicular to the wind (O to B) will be greater than that from 0 to A but still less than the original value of the radius of circle 1. As the wind speed increases, OA and OB decrease whereas OC increases. It may be thought then any curve will inscribe an identical area.

Within FIREFLY, the nine curves, which each plot actual/safe distance ratio x versus p_j, fire jump probability, are contained in mathematical form. The expression relating a value of x equal to 0.588 for spread with (building A to B) a low (7.07 mph) wind for x between .45 and .71 is

$$p_j = .96x - .340$$

$$p_j = 0.224$$

The value for p_j is compared to a random number as before. If that random number is less than or equal to p_j, we have sufficient energy present at building B to cause ignition. To determine whether or not B burns, a final random number is compared to p_s (inter-building spread probability) for building B. If B is found to be burning, it then becomes a candidate for causing spread to other nearby structures.

III. OUTPUT

Under normal operating conditions, FIREFLY does not calculate either p_{ri} or the angle of fireball elevation but, instead, "pegs" enough values to create a spectrum of answers. Using one wind vector, p_{ri} takes on values of .1, .3, .5, .7, and .9 for each of the angles of 5°, 10°, and 30°. Since FIREFLY must create a statistical sample, each of the 15 cases of p_{ri} and angle must be run 100 times.

At any one case, an infinite host of conditions are simultaneously represented. A p_{ri} of .5 and an angle of 5°, for example, may represent a small-yield, ground burst weapon at short range on a clear day, a large-yield, air burst weapon far away on a hazy day, and so forth.

Tables 1-2, 1-3, and 1-4 represent actual FIREFLY output from three separate runs (one for each wind speed level) against an actual area in East Boston, Massachusetts. The data may be presented in many ways

... in tabular form as shown

... on curves on linear paper

... on special paper (log-log, linear-probability)

TABLE 1-2

FIREFLY RESULTS

LOW WIND

E. BOSTON, MASS

PROB ROOM IGNITION	ANGLE OF ELEVATION	AVG NO. OF BUILDINGS BURNT (100 CASES)			PERCENT BURNT (200 BUILDINGS)			STANDARD DEVIATION %		
		THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL
0.1	5 DEG	1	2	3	1	1	2	1.4	2.6	3.0
0.3	5 DEG	6	5	11	3	3	6	2.2	3.7	4.4
0.5	5 DEG	10	8	18	5	4	9	3.5	4.2	5.5
0.7	5 DEG	14	11	25	7	6	13	3.3	4.5	5.6
0.9	5 DEG	17	14	31	9	7	16	3.9	4.1	5.7
0.1	10 DEG	3	3	6	2	2	4	1.7	3.3	3.7
0.3	10 DEG	8	9	17	4	5	9	2.6	4.4	5.1
0.5	10 DEG	15	12	27	8	6	14	3.0	4.5	5.4
0.7	10 DEG	20	14	34	10	7	17	3.6	4.4	5.7
0.9	10 DEG	24	17	41	12	9	21	3.9	4.5	5.9
0.1	30 DEG	14	12	26	7	6	13	3.3	4.8	5.8
0.3	30 DEG	38	19	57	19	10	29	4.9	3.7	6.2
0.5	30 DEG	55	20	75	28	10	38	5.9	4.1	7.2
0.7	30 DEG	68	20	88	34	10	44	5.7	4.4	7.2
0.9	30 DEG	79	18	97	40	9	49	5.6	4.1	6.9

TABLE 1-3

FIREFLY RESULTS

MEDIUM WIND

E. BOSTON, MASS.

PROB ROOM IGNITION	ANGLE OF ELEVATION	AVG NO. BUILDINGS BURNT (100 CASES)			PERCENT BURNT (200 BUILDINGS)			STANDARD DEVIATION %		
		THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL
0.1	5 DEG	2	2	4	1	1	2	1.0	2.8	3.0
0.3	5 DEG	6	7	13	3	4	7	2.2	4.9	5.4
0.5	5 DEG	9	10	19	5	5	10	2.8	4.5	5.3
0.7	5 DEG	14	14	28	7	7	14	3.5	4.7	5.8
0.9	5 DEG	17	15	32	9	8	17	3.6	5.1	6.2
0.1	10 DEG	3	4	7	2	2	4	1.4	3.3	3.6
0.3	10 DEG	9	10	19	5	5	10	3.0	4.7	5.6
0.5	10 DEG	14	13	27	7	6	13	3.9	5.0	6.3
0.7	10 DEG	20	16	36	10	8	18	3.9	4.7	6.1
0.9	10 DEG	24	18	42	12	9	21	4.5	4.5	6.3
0.1	30 DEG	14	13	27	7	6	13	3.3	4.8	[illegible].8
0.3	30 DEG	38	22	60	19	11	30	5.1	4.6	[illegible].9
0.5	30 DEG	54	23	77	27	12	39	6.0	4.6	7.5
0.7	30 DEG	67	21	88	34	11	45	5.6	[illegible].5	7.1
0.9	30 DEG	79	21	100	40	11	51	5.4	4.1	6.8

TABLE 1-4

FIREFLY RESULTS

HIGH WIND

E. BOSTON, MASS.

PROB ROOM IGNITION	ANGLE OF ELEVATION	AVG NO. OF BUILDINGS BURNT (100 CASES)			PERCENT BURNT (200 BUILDINGS)			STANDARD DEVIATION %		
		THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL	THERMAL PULSE	SPREAD	TOTAL
0.1	5 DEG	2	2	4	1	1	2	1.7	3.3	3.7
0.3	5 DEG	6	7	13	3	4	7	2.0	4.5	4.9
0.5	5 DEG	9	11	20	5	6	11	2.6	5.1	5.7
0.7	5 DEG	14	16	30	7	8	15	3.7	5.3	6.5
0.9	5 DEG	18	17	35	9	9	18	4.0	4.7	6.2
0.1	10 DEG	3	4	7	2	2	4	1.4	3.6	3.9
0.3	10 DEG	9	11	20	5	6	11	3.0	5.4	6.2
0.5	10 DEG	15	16	31	8	8	16	3.7	4.9	6.2
0.7	10 DEG	19	17	36	10	9	19	3.3	4.6	5.7
0.9	10 DEG	24	21	45	12	11	23	4.7	5.2	7.0
0.1	30 DEG	14	15	29	7	8	15	3.5	5.0	6.1
0.3	30 DEG	38	23	61	19	12	31	5.2	5.2	7.3
0.5	30 DEG	54	24	78	27	12	39	5.0	4.6	6.8
0.7	30 DEG	69	24	93	35	12	47	5.5	4.7	7.2
0.9	30 DEG	80	22	102	40	11	51	5.3	4.0	6.6

using different labels for the axes. Figures 1-7 through 1-9 show typical representations of the output for the run made against Boston.

FIRE DAMAGE   BOSTON, MASS.

High Wind
Angle = 10^{o}
(see also Table 1-4)

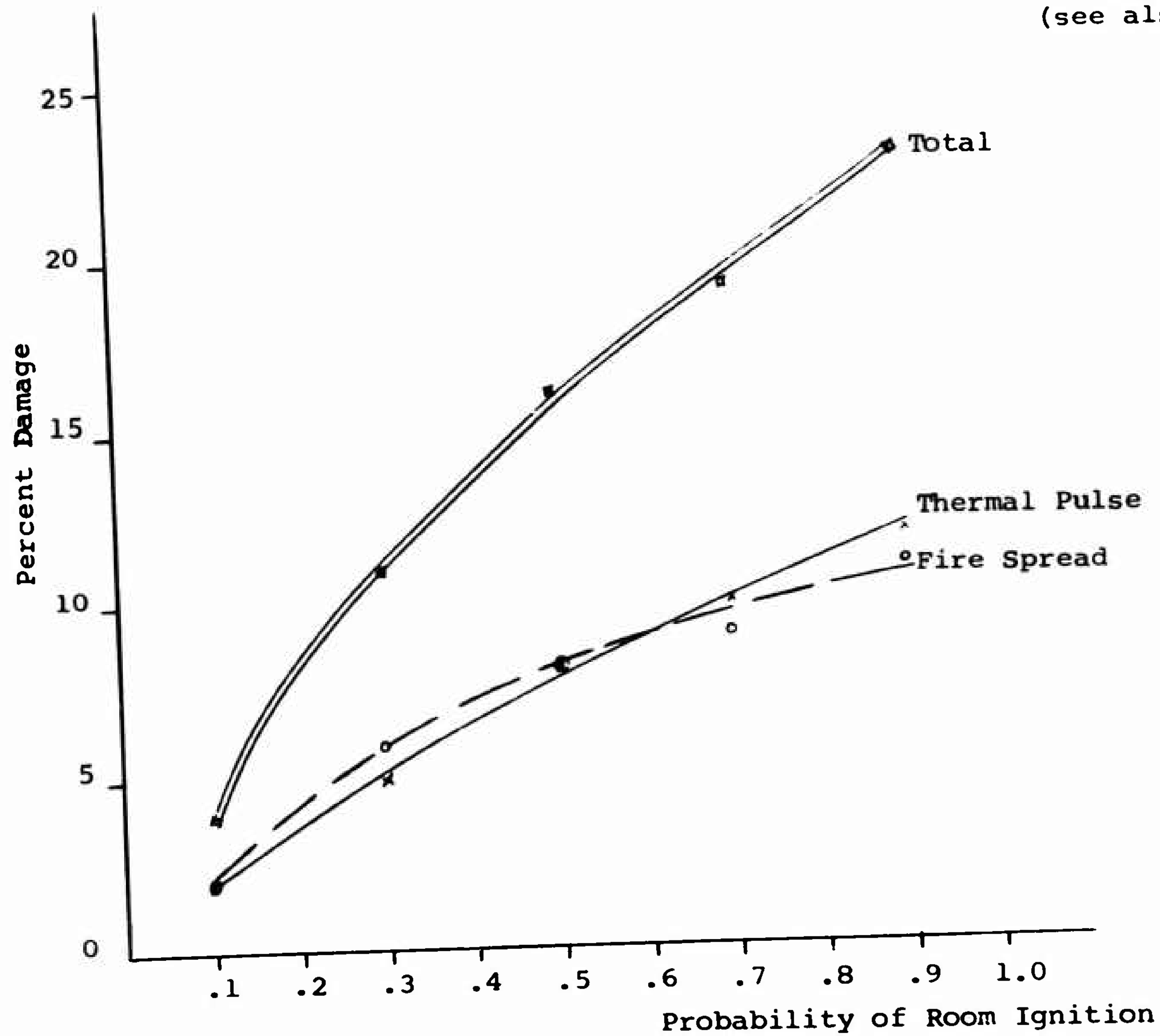


Figure 1-7

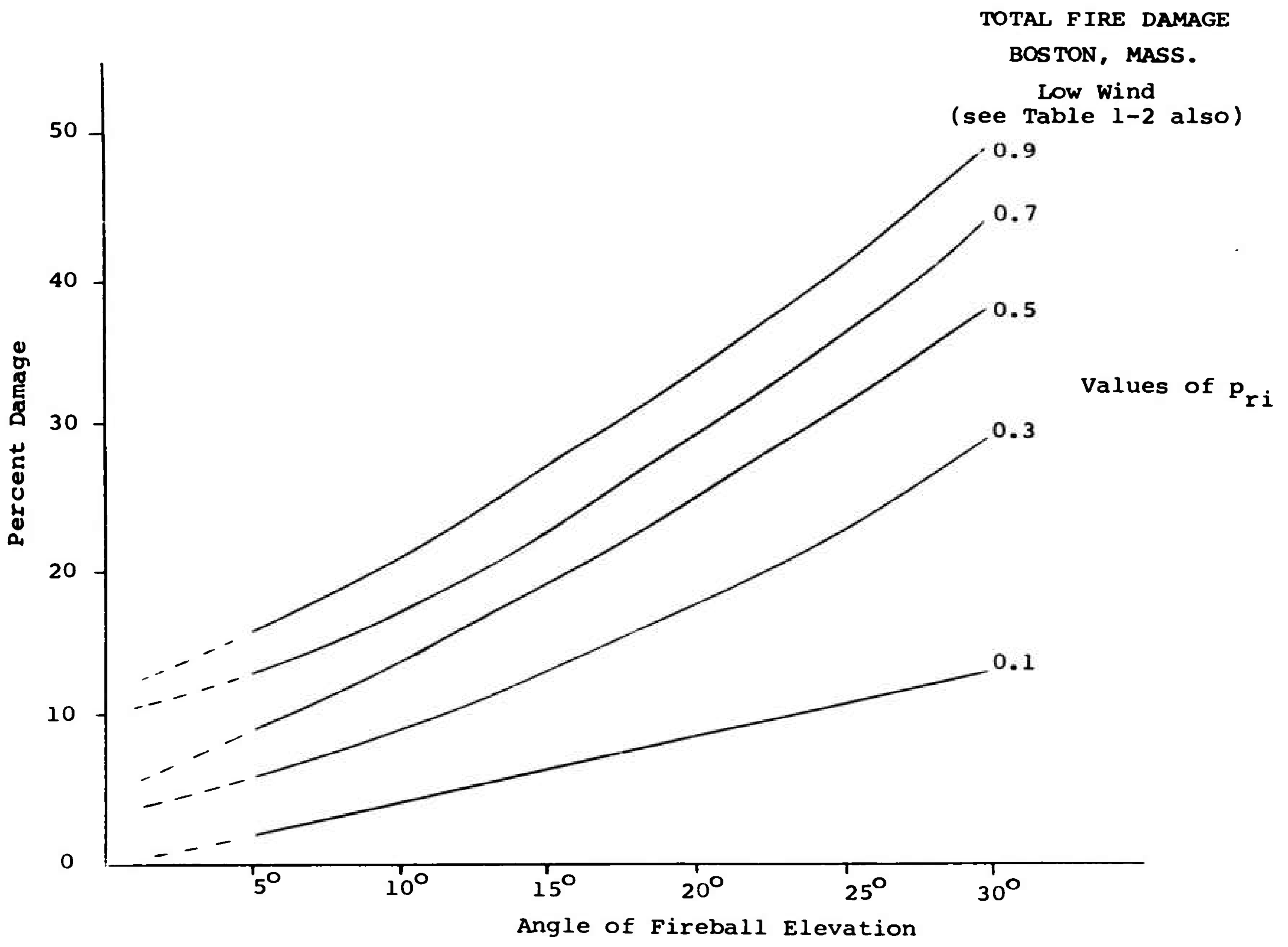

TOTAL FIRE DAMAGE
BOSTON, MASS.
Low Wind
(see Table 1-2 also)
Values of p_{ri}
0.9
0.7
0.5
0.3
0.1
Percent Damage
0
10
20
30
40
50
5°
10°
15°
20°
25°
30°
Angle of Fireball Elevation

Figure 1-8

TOTAL FIRE DAMAGE

BOSTON, MASS.

95% Limits ($\pm 2\sigma$)
Medium Wind
Angle = 30°

(See also Table 1-3)

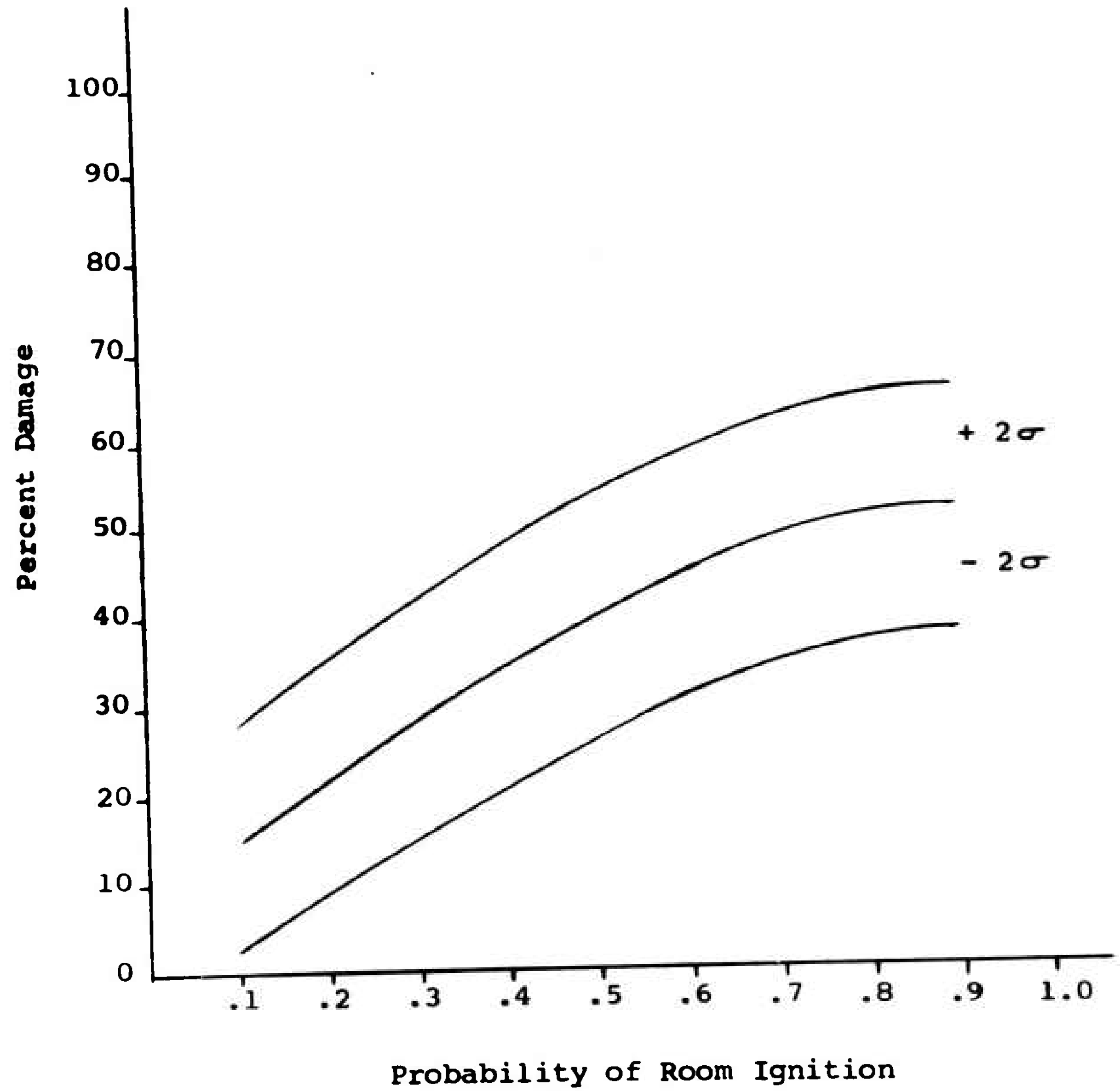


Figure 1-9

SECTION 2

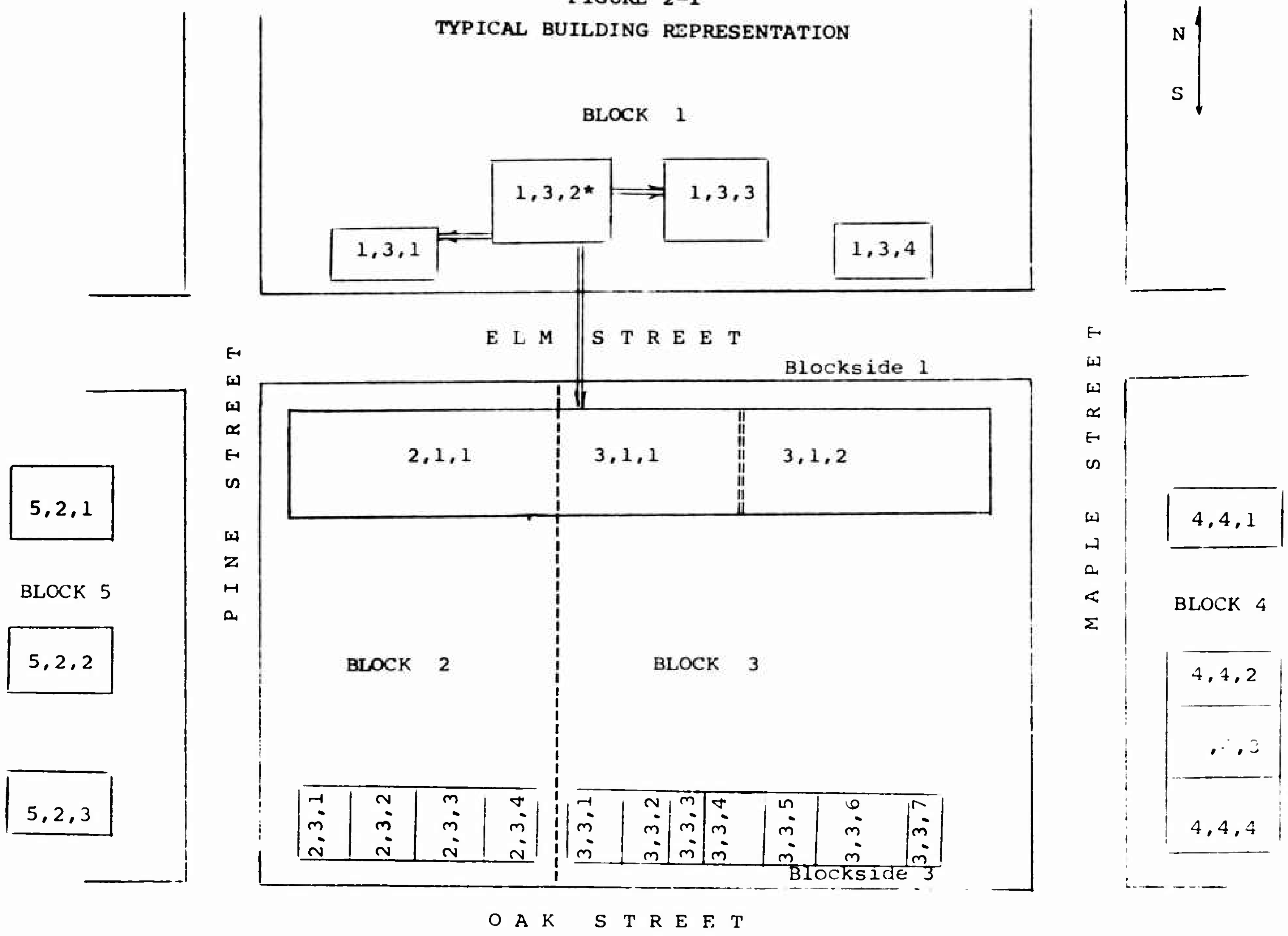
FIREFLY 1

I. INTRODUCTION

The first task of FIREFLY 1 is to read a large amount of information about each building (its size, general construction type, and separation distance from all nearby structures) and a wind vector (given in terms of a wind speed and an azimuth). The model must be structured in terms of the four cardinal directions as all distances, and ultimately all wind vectors, are related to each other in terms of north, east, south, and west. The capacity of the computer's data handling capability limits an area assessment to 27 city blocks, each block containing no more than 10 buildings per side (for a maximum of 40 buildings per block and 1080 buildings per assessment).

Each building is given a three-digit code of the form (i,j,k) where "i" is the block number, "j" is the cardinal direction (1-north, 2-east, 3-south, and 4-west) of the building's location on the block, and "k" is the building number within a particular block; "i" and "k" must be sequentially numbered from one. Figure 2-1 is a typical representation of a city block and a number scheme. It may be noted that the block between Pine Street and Maple Street has been made into two blocks. This was done because of the limitation of 10 buildings per block side. The long building on the

FIGURE 2-1
TYPICAL BUILDING REPRESENTATION



* (1,3,2) uniquely defines the building. The block number is 1, the blockside number is 3 (south), and the lot number is 2.

NOTE: There are more than ten buildings on blockside 3 of the physical block made up of BLOCK2 and BLOCK3 so the physical block must be split to keep within the program's limitations. The building on blockside 1 of BLOCK2 and 3 is split by this division; however, the part of this building in BLOCK3 has more than 4 neighboring buildings to the south. Thus the building is again split.

KEY

====== changes from physical building to those within the limitations of the program

------ changes from physical blocks to those within program's limitations southside of Elm Street has been split into three separate buildings because of a limitation of four neighboring buildings in any one direction.

The input data is described in sub-section 2. Once this data has been read by the program, the first task is to compute the probability that any particular building will ignite as a function of its own construction, the distance to nearby structures that may be burning, and the prevailing wind.

II. BUILDING CONSTRUCTION

A. Ignition from Fire Spread

The assessment of the vulnerability of a building to fire was taken in part from a study by Gage-Babcock and Associates ("A System for Local Assessment of the Conflagration Potential of Urban Areas," March 1965). They recorded quantitative values to be assigned to a city block; these values, based primarily upon number of wall openings, roof, floor, and exterior wall construction, building size, and susceptibility of a particular block. FIREFLY uses these quantities to calculate an index (from 0-100) for each building. This index, called $PRF_{i,j,k}$ becomes the probability of ignition from fire spread when divided by 100. A completely wood-frame residential structure develops a rating near 1.0; a modern fireproof office building, on the other hand, has a very low rating.

The size of the four building walls is also calculated. This is done so that if this building is found to be burning at a later time, the maximum size of the flame front may be calculated to assess the threat to nearby buildings; a large building which is burning obviously presents a greater threat to a neighboring structure than a small building.

B. Ignition from Thermal Pulse

The mathematical treatment of the phenomena of thermal pulse generation and transmission has been thoroughly covered in other documents and will not be discussed here. Actually, FIREFLY does not treat basic weapon parameters at all but is concerned with assessing the change in the probability of building ignition from thermal pulse as a function of only two exogenous variables: the probability of ignition of an exposed "room" and the angle of elevation of the weapon fireball.

Three elevation angles (5°, 10°, 30°) are examined each with five probabilities (.1, .3, .5, .7, .9), thus FIREFLY 1 runs 15 times. The reason for the limits of the angles of elevation is that much below 5° represents little thermal pulse threat and at angles over 30° the fire problem is insignificant since blast is the major agent of damage at this point. By selecting discrete exposed room probabilities, a world of conditions may be represented independent of yield, atmospheric transmissivity, and distance to burst. Thus with the angle of elevation fixed at, say, 10°, a probability of 0.3 may represent a 1MT weapon, 8 miles away, with visibility of 6 miles, a 200KT weapon, 10 miles away on a clear day--clearly the combinations are infinite.

The general expression that is solved is of the form

$$P_b = (1 - (1 - P_r)^N)$$

where

P_b = probability of building ignition

P_r = probability of "room" ignition

N = number of exposed "rooms"

A "room" is now defined as any environment behind a window and an exposed room is any environment which will be "seen" by the fireball. The number of exposed rooms, N, is calculated as a function of

... the fact that only one building side can effectively face the blast

... the number of windows that may be shielded by neighboring buildings given the angle of elevation of the fireball

... the physical size of the building

... the percent window openings to total wall area

... the physical size of the windows

... the average expected number of windows which will be covered by drapes, shades, and blinds

Many of the above items have been standardized within the program but they may be varied.

The probability of building ignition, P_b has to be further modified, however, since the expression $1 - (1 - P_r)^N$ takes no account of different building construction. A series of ignitions in a wooden building is potentially more disasterous than ignitions in a modern reinforced-concrete building. The value of P_b is multiplied by $PRF_{i,j,k}$ which was calculated previously to reflect building construction and contents.

III. SEPARATION DISTANCES

All pertinent separation distances are read and become permanent data within the program. Referencing Figure 2-1 again, building (1,3,2) has three associated physical separations.

IV. WIND

For purposes of analysis any wind speed (in miles per hour) and any azimuth (measured in degrees counter clockwise from due East) may be chosen. For assessment, the wind will be classified within the program as low (< 8 mph), medium (≥ 8 but < 16 mph) or high (≥ 16 mph) and fire spread potential will be assessed in the four cardinal directions to correspond with the normal methods of calculation within the program. Once the wind vector has been split into its two cardinal orthogonal components, counter, mirror images are formed along the two remaining cardinal directions. For instance, if a wind were blowing from the southwest (i.e., into or towards the northeast) there would exist a vertical component due north and a horizontal component due east. If fire spread is being considered from one building to another, more easterly, building, then the fire spread will be aided (i.e., the probability of spread will be higher). If the reverse were true, a westerly spread, the probability of spread will be correspondingly lowered.

Thus nine combinations exist: fire spread with, into, or perpendicular to a low, medium, or high speed wind. These combinations are used in determining the probability that fire will "jump" a gap.

V. PROBABILITY OF FIRE JUMP

Fire jump from one structure depends upon how large the burning building is, how far away it is, and what the wind conditions are. A distance from a given building is calculated which is the "safe distance"--i.e., that distance at which under quiescent wind conditions no ignitions will occur as a result of radiant flux. Then from any one building under question the actual distance to any neighboring building is examined and a quantity, X, is calculated where

$$X = \frac{\text{actual separation distance}}{\text{"safe distance"}}$$

When X is equal to or greater than unity, the probability of fire jump is zero; if X is zero, the probability of fire jump is 1.0. It is when X is between zero and one that any of nine equations are selected which calculate the probability of fire jump as a function of X and the applicable wind vector.

VI. SUMMARY OF OUTPUT DATA

In the output tape which FIREFLY 1 creates for FIREFLY 2 three basic quantities are of interest. It is these quantities which FIREFLY 2 will use in its Monte Carlo routine to assess expected fire damage under various conditions. For each building, FIREFLY 1 contains:

A. The probability of building ignition from the thermal pulse of a nuclear weapon

B. The probability of building ignition from fire spread

C. The probability(ies) that the building will receive sufficient radiant flux from any and all neighboring structures that have themselves been ignited.

Items B and C above are finally combined in Bayesian fashion since B has relevance only if C is met.

VII. DATA DESCRIPTION

The data needed to operate FIREFLY 1 consists of six card types. All values are right justified.

A. Card Type 1--Building Card (1 card)

Cols.	Description
2-5	The total number of buildings, N

B. Card Type 2--Block Card (1 card)

Cols.	Description
2-5	The total number of blocks, M

C. Card Type 3--Wind Information (1 card)

Cols.	Description
1-5	Number of miles per hour of wind
7-10	Angle of the wind in radians from east counterclockwise

D. Card Type 4--Block Information (1 card/block)

Cards should be ordered in ascending block number

Cols.	Description
7-8	The number of buildings on the north block-side of the block in question

Cols.	Description
10-11	The number of buildings on the east blockside
13-14	The number of buildings on the south
16-17	The number of buildings on the west

E. Card Type 5--Building Information Card # 1 (1 card/building)

Cards should be ordered in ascending order number. Every card type 5 must be followed by a card type 6.

Cols.	Description
1-2	The block number of the building A. There are the following limitations: there should be a maximum of twenty-seven blocks of four blocksides each. Each blockside may have a maximum of ten buildings. The blocks must be sequentially numbered from one.
4	The blockside number of building A. The maximum possible number is four. With each block all the blocksides need not contain a building or buildings. Blockside 1 means the northern part of the block, while blockside 2, 3, or 4 means the eastern, southern, or western part respectively.
6-7	The lot number of A. Each blockside which contains a building or buildings must have the lots numbered from one and incremented by one to a maximum of ten. Building information is to be arranged in ascending order according to the order number.
11-13	The width in feet in the east and west direction of building A.
15-17	The width in feet in the north and south direction of building A.

Cols.	Description
18-19	The number of stories.
21-23	The number of feet building A is setback from the street. The setback is only recorded for the side of the building considered the front side.
25	The value assigned for the relative number of wall openings which determines combustibility. If there are no, few, average, many, or all openings, the value is one, two, three, four, or five respectively.
27	The value assigned building A for the roof construction which determines its combustibility. A table of values is presented below; this and subsequent tables have been taken from previously-referenced work by Gage-Babcock and Associates.

ROOF CONSTRUCTION

Category	Value
Protected Noncombustible	0
Unprotected Noncombustible	1
Noncombustible on Combustible Supports	2
Combustible	3

Examples

Protected Noncombustible: reinforced concrete, precast concrete, steel construction protected by metal lath and plaster, or by "fire-rated" acoustical ceilings.

Unprotected Noncombustible: any concrete or gypsum roof on exposed steel supports (without metal lath and plaster of "fire-rated" acoustical ceiling), metal deck or metal on concrete supports, fire-retardant treated lumber.

Noncombustible on Combustible Supports: metal or cement-asbestos panels on wood supports (without wood decking or combustible insulation on the inside).

Combustible: ordinary wood joist construction, mill construction, wood deck on metal or concrete supports, plastic panels on wood or metal supports.

Cols.	Description
40	The number of neighboring buildings to the north of building A. The maximum number is four.
42-44	The distance in feet between the first building to the north of A and building A.
46-48	The distance between the second building to the north of A and building A.
50-52	The distance in feet between the third building to the north of A and building A.
54-56	The distance between the fourth building to the north of A and building A.
58	The number of neighboring buildings to the east of building A.
60-62	The distance between the first building to the east of A and building A.
64-66	The distance between the second building to the east of A and building A.
68-70	The distance between the third building to the east of A and building A.
72-74	The distance between the fourth building to the east of A and building A.
76	The number of neighboring buildings to the south of building A.
80	The number "1" designating building information Card # 1.

F. Card Type 6--Building Information Card # 2 (1 card/building)

Cols.	Description
1-2	The block number of building A.

Cols.	Description
4	The blockside number of building A.
6-7	The lot number of building A.
9-11	The distance between the first building to the south of A and building A.
13-15	The distance between the second building to the south of A and building A.
17-19	The distance in feet between the third building to the south of A and building A.
21-23	The distance between the fourth building to the south of A and building A.
25	The number of neighboring buildings to the west of building A.
27-29	The distance between the first building to the west of A and building A.
31-33	The distance between the second building to the west of A and building A.
35-37	The distance between the third building to the west of A and building A.
39-41	The distance between the fourth building to the west of A and building A.
44-45	The value assigned to building A for the fire load of the building which determines its combustibility. (See below)

OCCUPANCY FIRE LOADING

Category	Value
Negligible	0
Light	10
Moderate	20
High	30

Examples

Negligible: vacant or essentially noncombustible contents, occupancy fire loading not exceeding 5 lbs. per sq. ft.

- Machine shops & metalworking with negligible combustibles
- Stge. of metal implements or machinery, not packed or crated
- Boiler houses, power houses
- Brick storage, stone crushing, etc.
- Water treatment & sewage disposal plants

Light: occupancy fire loading ranging from approximately 6 to 15 lbs. per sq. ft.

- Houses and apartments
- Hotels, hospitals
- Schools, laboratories
- Halls, gymnasiums
- Offices, court houses, jails, banks
- Police and fire stations
- Telephone exchanges
- Libraries (metal shelving)
- Funeral parlors
- Coal storage
- Bulk grain, salt storage
- Bulk fertilizer storage

Moderate: occupancy fire loading ranging from approximately 16 to 25 lbs. per sq. ft.

- Amusement parks, bowling alleys, theaters
- Automobile service stations, repair & parking garages
- Churches
- Laundry & dry cleaning shops
- Restaurants
- Department and variety stores premises not crowded
- Retail stores and shops, general
- Cold storage warehouses
- Drug stores
- Most manufacturing plants (not involving large amounts of combustibles or flammables)
- Storage of grain, fertilizer, etc. in sacks

High: occupancy fire loading exceeding 25 lbs. per sq. ft.

- Aircraft hangars
- Petroleum refineries
- Paint Factories
- Flammable liquids processing
- Whiskey warehouses
- Department and variety stores premises crowded
- Warehouses, general
- Truck terminals
- Plastics manufacturing
- Cotton stocks

Asphalt mixing plants
Rubber tire storage
Stock yards
Junk yards

Textiles, clothing, mattress manufacturing or storage
Woodworking and lumber yards
Feed mills

Cols.	Description
47-48	The value assigned to building A for exterior wall construction. (See below)

EXTERIOR WALL CONSTRUCTION

Category	Value
Standard	0
Substandard Masonry	10
Noncombustible	10
Noncombustible on Combustible Supports	15
Combustible	30

Examples

Standard Masonry: not less than 12 in. brick walls or equivalent in sound condition, with not more than an average number of openings. Equally acceptable are 8 in. brick walls on dwellings, 8 in. concrete block with 4 in. brick facing, 12 in. concrete block, 12 in. stone, 10 in. unreinforced concrete or 6 in. reinforced concrete.

Substandard Masonry: masonry walls of lesser thicknesses than above or in poor condition, or with more than an average number of openings.

Noncombustible: glass store fronts on brick buildings, glass or metal curtain walls on concrete or steel supports, metal sheathing over metal supports, etc.

Noncombustible on Combustible Supports: glass or skeleton metal walls on wood supports, corrugated metal or cement-asbestos panels on wood supports, brick or stone veneer, etc.

Combustible: ordinary wood frame construction, wood store fronts or bay windows in brick buildings, enclosed or open wood porches, wood composition, asbestos, or metal sheathing over wood siding, exterior wood paneling regardless of supports, plastic siding etc.

Cols.	Description
50-51	The value assigned to building A for floor construction (See below).

FLOOR CONSTRUCTION (Exclude Basement)

Category	Value
Fire Resistive or Noncombustible	0
One or more floors, all or partially combustible	10

Examples

Fire Resistive or Noncombustible: reinforced concrete, steel deck with or without concrete topping, concrete or other cementious topping on formboard, etc.--all of the above supported on concrete or steel beams, girders, trusses, columns, etc. Wood flooring over concrete or carpeting should not affect the classification.

Combustible: ordinary wood joists with or without ceilings, mill, and semi-mill construction, wood flooring on steel beams or joists, etc.

Cols.	Description
53-55	"100"
57-59	The value assigned to building A depending upon the angle of inclination of the terrain. (See the following page)

TERRAIN MULTIPLIER

Slope	Multiplier
10% or less	1.0
11% to 20%	1.1
21% to 40%	1.3
41% to 60%	1.6
61% to 80%	1.8
over 80%	2.0

Cols.	Description
61-65	The multiplier for building characteristics given in Table 1-1.
80	"2" for building card # 2

VIII. DESCRIPTION OF PROCESSING SEQUENCE

	STATEMENT NUMBER From	Through
The number of buildings to have lot information read in is input.	(0+3)	(0+3)
The number of blocks to have lot information read in is input.	(0+4)	(0+4)
Wind information card is input.	(5+1)	(5+2)
KSEQ1 contains the sequence number for the previous record read in. Here it is initially set equal to zero.	(1+1)	(1+1)
KPAGNTN, storing the total number of lines of output on the page, is set to one.	(1+2)	(1+2)
The do loop is used to read in the number of buildings per blockside for each block, i.e. KCOUNT (I,J).	(1+3)	(21)
Type 1 of building information is read. There is a check to see if there is a "1" recorded in column 80.	(22+2)	(10+1)
The block, blockside, and lot number are stored in NBLK, NDIR, and NLOT, respectively so that these three can be compared to the block, blockside, and lot number of Type 2.	(10+2)	(10+4)
Type 2 of building information is input.	(10+5)	(10+5)
If the density of all the buildings is 100, "KD=100" should appear here. If the density is not necessarily 100, remove this card.	(23+1)	(23+1)
WB1 is set equal to KWIDTH. WB2 is set equal to KWIDTH2. STY has the same value as KSTY. Thus, three floating point variables are set equal to integer variables.	(23+4)	(23+6)

	STATEMENT NUMBER From	Through
There is a check to see if column 80 contains a "2". The block, blockside, and lot numbers of Type 2 are tested to see if they are the same as Type 1's. If there is a difference, there is a jump to statement (14) which is an error printout.	(23+7)	(23+9)
These two do loops vary the angle of elevation and the probability of ignition of an exposed room. The probability of ignition of an exposed room is modified by its environment. The probability of building ignition is computed.	(23+10)	(24)
If this is not the first time through this part for the building under consideration, the probability of building ignition is computed and the angle of fireball elevation, the exposed room ignition probability, and the probability of building ignition from thermal pulse are written. If this is the first time through this part for the building under consideration, there is a jump to the end of the do loop.	(24+1)	(3715+2)
There is a test to see if the cards are in ascending order. If there is an error, there is a statement written out which indicates a sequence error, and then there is a jump to the end of the program.	(3718)	(25)
The block and blockside number are stored in "I" and "J" respectively for convenience in referencing.	(13)	(13+1)
If the first neighboring building is being considered, the wind vector is broken down into its north, east, south, and west components in miles per hour.	(28)	(46+3)
The number of miles per hour and the angle of the wind are written out as well as the north, east, south, and west components. KPAGNTN is updated.	(15+1)	(17+1)

	STATEMENT NUMBER From	Through
The contribution factor, FC, is computed using the setback distance. The contribution factor is used to adjust the radiating area when the street width is used rather than the distance between the buildings.	(3719)	(150)
The four radiating areas are computed.	(160)	(160+4)
Two factors, KH and KRR, needed to determine the Gage-Babcock index are determined by considering the number of stories, KSTY, and the roof combustibility value, KCR.	(160+5)	(310)
The Gage-Babcock Index, BIN, is determined in these statements. If BIN is greater than 150, it is set to 150.	(320)	(340)
The probability the building with lot number K on blockside J of block I will catch fire is determined here.	(350)	(350)
The radiating areas, WMF (L) where L=1, 2, 3, or 4 are set equal to ARBLDG1, ARBLDG2, ARBLDG3, or ARBLDG4 respectively.	(350+1)	(350+4)
The flame heights for the north-HF1, east HF2, south-HF3, and west-HF4 direction, are determined in these statements.	(3602)	(3602+3)
The shapes of the radiators in the north-S1, east-S2, south-S3, and west-S4 are determined in these statements.	(3602+4)	(3618)
In these statements it is determined which of the four components of the wind vector, DMPHRN, DMPHRE, DMPHRS, or DMPHRW, has the largest positive number of miles per hour of wind and which has the next largest number of miles per hour of wind.	(369)	(1820)

	STATEMENT NUMBER From	Through
If the wind vector in the west direction is largest, and the one in the north is next, these statements are not skipped. The north, east, south, and west components of the wind vector are classified as low, medium, or high wind. KVD*=1 indicates a low wind in the direction D*. The descriptive numbers of north, east, south, and west are "1", "2", "3", and "4" respectively. A "4" is stored in MAJDIR.	(1760)	(1760+9)
If the wind vector in the west direction is the greatest, and the one in the south is next, these statements are not skipped. The north, east, south, and west components of the wind vector are classified as low, medium, or high wind. A "4" is stored in MAJDIR.	(1770)	(1770+9)
If the wind vector in the south direction is the greatest, and the one in the west is next, these statements are not skipped. The north, east, south, and west components of the wind vector are classified as low, medium, or high wind. A "3" is stored in MAJDIR.	(1800)	(1800+9)
If the component of the wind vector in the north direction is the greatest, and the one in the east is next, these statements are not skipped. The north, east, south, and west components are classified as low, medium, or high winds. A "1" is stored in MAJDIR to indicate that the northern wind component is largest.	(1780)	(1780+9)
If the component of the wind vector in the east direction is the greatest, and the one in the north direction is next, these statements are not skipped. The north, east, south, and west components are classified as low, medium, or high winds. A "2" is stored in MAJDIR.	(1790)	(1790+9)

* D = N, E, S, or W indicating north, east, south, and west respectively.

	STATEMENT NUMBER From	Through
If the component of the wind vector in the north direction is the greatest, and the one in the west is next, these statements are not skipped. The north, east, south, and west components are classified as low, medium, or high winds. A "1" is stored in MAJDIR.	(1805)	(1805+9)
If the component of the wind vector in the south direction is greatest, and the one in the east is next, these statements are not skipped. The north, east, south, and west components of wind are classified as low, medium, or high winds. A "3" is stored in MAJDIR.	(1825)	(1825+9)
If the component of the wind vector in the east is greatest, and the one in the south is next, these statements are not skipped. The north, east, south, and west components are classified as low, medium, or high winds. A "2" is stored in MAJDIR.	(1830)	(1830+9)
This do loop is gone through a maximum of sixteen times. This loop determines the probability of spread from the building in question to all its neighboring buildings. The neighboring buildings are taken in the following order; first, second, third, and fourth buildings to the north; first, second, third, and fourth buildings to the east; first, second, third, and fourth buildings to the south; and first second, third, and fourth buildings to the west.	(730)	(730)
These statements test the value of the index variable, JJ, to determine which neighboring building is next to have its probability of spread computed.	(730+1)	(367)
These statements are not skipped if the index variable is not greater than four, i.e. if the spread consideration is to the north. If the value of the index variable is one, there is a check to see if there are any buildings to the north. If there are no buildings, it jumps almost to the end of the loop where all the probabilities of	(2000)	(720+1)

	STATEMENT NUMBER From	Through
spread to the north are set equal to 0, and JJ is set equal to four. If there are neighboring buildings, the general terms S and ARBLDG are set equal to the northern flame height and the northern radiating area respectively of the building from which the spread is being considered. If the index variable is not equal to one, the relative classification of the northern component of the wind is used so this part of the program is skipped. If the index variable is one, the northern component of the wind vector is tested against zero. If the northern component is zero, the relative classification is light wind. If not, the value is compared with eight and sixteen to determine whether it is a light, medium, or high wind.		
These statements are analogous to the statements from (2000) through (720+1) except the southern direction is under consideration rather than the northern and the fifth building is analogous to the first.	(2010)	(750+1)
These statements are analogous to the statements from (2000) through (720+1) except the southern direction is under consideration rather than the northern direction and the ninth building is analogous to the first.	(2020)	(780+1)
These statements are analogous to the statements from (2000) through (720+1) except the western direction is under consideration rather than the northern direction and the 13th building is analogous to the first.	(2030)	(860)
The component of the wind vector which is stored in DMPHR is compared with eight and/or sixteen to classify the wind component as light, medium, or high.	(2028)	(700)
The radiator shape is compared to 1.5. If the flame height is less than 1.5, the classification of the wind component is checked. Otherwise, there is a jump to statement number (1420) or (1425).	(364)	(364)

	STATEMENT NUMBER From	Through
If the wind component's classification is low, and if the radiating area is less than or equal to four hundred and sixty-five, the theoretical separation distance, Y, is determined by a linear equation with the radiating area as its variable afterwhich there is a jump to the part which determines the probability of spread. If the wind component's classification is light, and if the radiating area is greater than four hundred and sixty-five, the following quadratic equation is solved:	(1380)	(1395+1)

$$y^2 - 33.8z - 2.53y + 15.7 = 0$$

where y is the separation distance in feet divided by ten and z is the radiating area in feet squared divided by one thousand. The procedure used here is to solve for y and multiply the resulting y by ten to get the separation distance.

If the classification of the component of the wind is medium, these statements are not skipped. The radiating area is compared to thirteen hundred. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1400)	(1405+1)

$$y^2 - 34.3z - 8.1y + 44.6 = 0$$

If the classification of the wind is high, the following statements are not skipped. The radiating area is compared to two thousand three hundred and eighty. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows	(1410)	(1415+1)

$$y^2 - 29.4z - 13.75y + 69.9 = 0$$

	STATEMENT NUMBER From	Through
The radiator shape is compared to 8. If the flame height is less than 8 but greater than or equal to 1.5 and the classification of the component is low, these statements are not skipped. The radiating area is compared to seven hundred and twenty-five. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1420)	(1435+1)

$$y^2 - 29.3z - 3.35y + 21.2 = 0$$

If the radiator shape is greater than or equal to 1.5 and less than 8, and if the classification of the component of wind is medium, these statements are not skipped. The radiating area is compared to one thousand six hundred and fourty-five. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1440)	(1445+1)

$$y^2 - 30.3z - 9.25y + 49.8 = 0$$

If the radiator shape is greater than or equal to 1.5 and less than 8, and if the classification of the component of wind is high, these statements are not skipped. The radiating area is compared to one thousand one hundred and ten. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1450)	(1455+1)

$$y^2 - 33.2z - 9.4y + 36.8 = 0$$

	STATEMENT NUMBER From	Through
If the radiator shape is greater than 8, and if the classification of the component of the wind is low, these statements are not skipped. The radiating area is compared to one thousand four hundred and twenty. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1460)	(1470+1)

$$y^2 -21.9z -6.32y + 31.1 = 0$$

If the radiator shape is greater than 8, and if the classification of the component of the wind is medium, these statements are not skipped. The radiating area is compared to two thousand three hundred and fifty. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1475)	(1480+1)

$$y^2 -21.4z -10.76y + 50.2 = 0$$

If the radiator shape is greater than 8, and if the classification of the component of the wind is high, these statements are not skipped. The radiating area is compared to two thousand five hundred and ninety. The procedure is similar to that in statements (1380) through (1395+1) except the linear equation differs and the quadratic equation is as follows:	(1485)	(1490)

$$y^2 -24.2z -12.28y + 62.75 = 0$$

If the index variable JJ is one, these statements are not skipped. The spread to the first building to the north from the building in question is calculated in these statements. If the distance between	(1500)	(1368+1)

	STATEMENT NUMBER From	Through
these two buildings is zero, the probability of spread is set equal to one, the probability the building will burn is set equal to .98, and there is a skip to a further point in the program. If the distance is greater than zero, the following steps are performed. A variable x is calculated. If x is greater than 1, it is set equal to one. If x is less than 0, it is set equal to zero. If the distance between the two buildings is greater than the separation distance, the probability of spread is 0. The direction under consideration here is north. North is compared with MAJDIR, the code for the direction which has the largest amount of positive wind. Depending upon whether north is with, against or perpendicular to the major direction of the wind, the subroutines WITH, AGNT, or PERP are called respectively.		
If the index variable is two, these statements are not skipped. The spread to the second building to the north from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1).	(1504)	(1369+1)
If the index variable is three, these statements are not skipped. The spread to the third building to the north from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1).	(1505)	(1370+1)
If the index variable is four, these statements are not skipped. The spread to the fourth building to the north from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1).	(1507)	(1371+1)

	STATEMENT NUMBER From	Through
If the index variable is five, these statements are not skipped. The spread to the first building to the east from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration here is east.	(1508)	(1372+1)
If the index variable is six, these statements are not skipped. The spread to the second building to the east from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is east.	(1510)	(1373+1)
If the index variable is seven, these statements are not skipped. The spread to the third building to the east from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is the east.	(1511)	(1374+1)
If the index variable is eight, these statements are not skipped. The spread to the fourth building to the east from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is east.	(1515)	(1375+1)
If the index variable is nine, these statements are not skipped. The spread to the first building to the south from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is the south.	(1516)	(1376+1)
If the index variable is ten, these statements are not skipped. The spread to the second building to the south from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is the south.	(1518)	(1377+1)

	STATEMENT NUMBER	
	From	Through
If the index variable is eleven, these statements are not skipped. The spread to the third building to the south from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is south.	(1519)	(1378+1)
If the index variable is twelve, these statements are not skipped. The spread to the fourth building to the south from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is south.	(1521)	(1360+1)
If the index variable is thirteen, these statements are not skipped. The spread to the first building to the west from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is west.	(1522)	(1361+1)
If the index variable is fourteen, these statements are not skipped. The spread to the second building to the west from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is west.	(1524)	(1362+1)
If the index variable is fifteen, these statements are not skipped. The spread to the third building to the west from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is west.	(1525)	(1363+1)

	STATEMENT NUMBER From	Through
If the index variable is sixteen, these statements are not skipped. The spread to the fourth building to the west from the building in question is calculated in these statements. The procedure is the same as in statements (1503) through (1368+1) except the direction under consideration is west.	(1527)	(1364+1)
If the number of neighboring buildings to the north of the building in question is less than four, and the index variable equals the number of buildings to the north, the remaining probabilities of spread to the north are set equal to zero. The index variable is set to four.	(1587)	(9040+1)
If the number of neighboring buildings to the east of the building is less than four, and the probabilities of spread to all these buildings to the east have been calculated, the remaining probabilities of spread to the east are set equal to zero. The index variable is set to eight.	(9010)	(9090+1)
If the number of neighboring buildings to the south of the building is less than four, and the probabilities of spread to all these buildings to the south have been calculated, the remaining probabilities of spread to the south are set equal to zero. The index variable is set to twelve.	(9060)	(9140+2)
If the number of neighboring buildings to the west of the building in question is less than four, and the probabilities of spread to all these buildings to the west have been calculated, the remaining probabilities of spread to the west are set equal to zero. The index variable is set to sixteen.	(9110)	(9190+1)
This is the end of the loop which is passed through a maximum of 16 times per building to calculate the probabilities of spread to its neighboring buildings.	(1597)	(1597)

	STATEMENT NUMBER From	Through
The probability of building ignition is computed.	(370)	(370)
The angle of elevation, probability of ignition of an exposed room and probability of building ignition from thermal pulse are not written on a new page of output if the number of lines on the page is less than fifty-five. The number of lines is increased by two.	(3708)	(3711+2)
The angle of elevation, probability of ignition of an exposed room, and probability of building ignition from thermal pulse are written on a new page if the number of lines is greater than or equal to fifty-five. The number of lines is set equal to two.	(3707)	(3715+1)
This is the end of the loop which varies the angle of elevation and the probability of ignition of an exposed room.	(3710)	(3710)
The results are printed out. These results are: the block, blockside and lot numbers, the radiating areas, the flame heights, the radiating shapes, the separation distances and the Gage-Babcock index of the building in question, as well as, the probabilities of spread to its neighboring buildings and the probability the building in question will burn down.	(1270)	(1265)
This is the end of the loop which considers each building singly. When this point is reached, information on the next building is read from cards, and the process continues as described above.	(371)	(371)
This is the end of the program.	(545)	(545)

SUBROUTINE AGNT (KV, X, PR)

This is the subroutine used if the largest wind component of the four basic directions is against the spread direction which is being considered. X and KV are input; PR output. The speed of the wind in the direction of spread consideration and the ratio X are the variables which determine the probability of fire spread from one building to a particular building in a particular direction. On exit, the probability of spread has been computed.

SUBROUTINE PERP (KV, X, PR)

This is the subroutine used if the largest wind component of the four basic directions is perpendicular to the spread direction which is being considered. X and KV are input to the subroutine; PR output. See the subroutine explanation for AGNT above for the variables upon which the probability of spread depends. On exit, the probability of spread has been computed.

SUBROUTINE WITH (KV, X, PR)

This is the subroutine used if the largest wind component of the four basic directions is in the same direction as the spread direction which is being considered. X and KV are input; PR output. See the subroutine explanation for AGNT preceding for variables upon which the probability of spread depends. The result is that the probability of spread has been computed.

SUBROUTINE KV CONS (DMPHR, KV)

This subroutine is to determine from the miles per hour if the wind is light, moderate or high. DMPHR is input; KV output. Thus, there is an exit of general wind classification.

SECTION 3

FIREFLY 2

I. OPERATION

The general calculations of FIREFLY 2 are neither lengthy nor involved. FIREFLY 1 has done most of the work in generating probabilities of ignition from the thermal pulse for fifteen different cases (five exposed room ignition probabilities and three fireball elevation angles) and the complete interaction probabilities that govern fire spread. The basic tasks of FIREFLY 2 are to generate random numbers, compare these random numbers to the various probabilities, and keep a record of the progress of fires from both thermal pulse and spread. As mentioned previously, FIREFLY 2 operates 100 times upon the environment of buildings for a given set of conditions; thus FIREFLY 2 will actually conduct 1500 runs in total.

Assume that a set of four buildings are being examined as shown in Figure 3-1. The values of p_b represent probabilities of building ignitions from the thermal pulse; values of s_{cj} are combined spread probabilities. Table 3-1 is a typical tabulation of random numbers. Reading down the first column and testing the first random number against building # 1, we find the random number (.51772) to be greater than the building ignition probability in which case no ignition takes place. Continuing

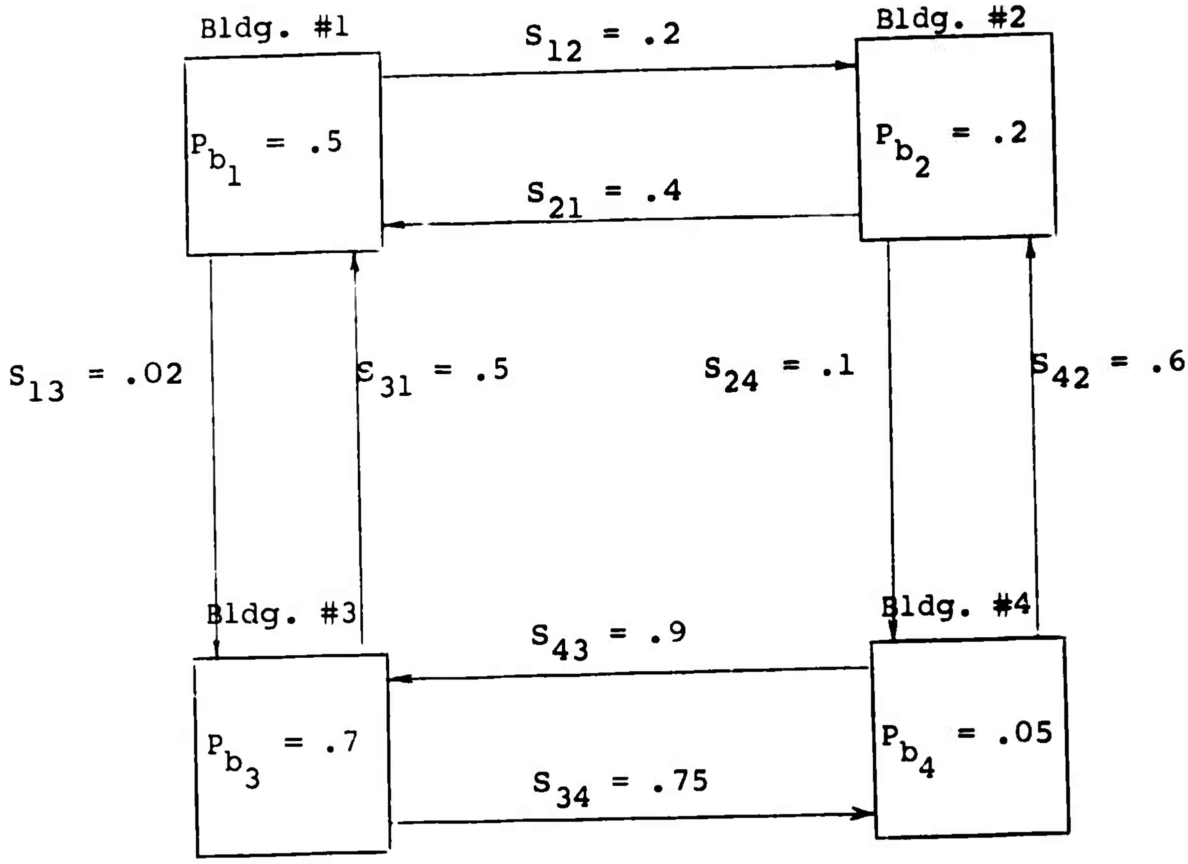


FIGURE 3-1

SAMPLE BUILDING ANALYSIS

51772	74640	42331	29044	46621	62898	93582	04186	19640	87056
24033	23491	83587	06568	21960	21387	76105	10863	97453	90581
45939	60173	52078	25424	11645	55870	56974	37428	93507	94271
305[illegible]6	02133	75797	45406	31041	86707	12973	17169	88116	42187
035[illegible]5	79353	81938	82322	96799	85659	36081	50884	14070	74950
64937	03355	95863	20790	65304	55189	00745	65253	11822	15804
15630	64759	51135	98527	62586	41889	25439	88036	24034	67283
09448	56301	57683	30277	94623	85418	68829	06652	41982	49159
21631	91157	77331	60710	52290	16835	48653	71590	16159	14676
91097	17480	29414	06829	87843	28195	27279	47152	35683	47280
50532	25496	95652	42457	73547	76552	50020	24819	52984	76168
07136	40876	79971	54195	25708	51817	36732	72484	94923	75936
27989	64728	10744	08396	56242	90985	28868	99431	50995	20507
85184	73949	36601	46253	00477	25234	09908	36574	72139	70185
54398	21154	97810	36764	32869	11785	55261	59009	38714	38723
65544	34371	09591	07839	58892	92843	72828	91341	84821	63886
08263	65952	85762	64236	39238	18776	84303	99247	46149	03229
39817	67906	48236	16057	81812	15815	63700	85915	19219	45943
62257	04077	79443	95203	02479	30763	92486	54083	23631	05825
53298	90276	62545	21944	16530	03878	07516	95715	02526	33537

RANDOM NUMBERS

TABLE 3-1

to use random numbers in column 1, we find that only building number 3 is assumed to be burning. FIREFLY 2 would record this event and proceed to assess fire spread.

The probability of fire spread from building # 3 to building # 4 is 0.75; the next random number is 0.03585, hence spread occurs. The spread from 3 to 1 does not occur, however.

Now that building # 4 is burning the only spread probability of interest is $S_{42} = 0.60$. The next random number is 0.15630 and now building # 2 is ablaze. In like manner, S_{21} is 0.40 and is greater than 0.09448 so that building # 1 also burns.

In this example, all buildings were destroyed. As explained earlier, FIREFLY 2 would operate an additional 99 times on this environment saving the results each time in terms of which buildings were destroyed by what agent. After the first 100 passes, a new p_b would be introduced (as a function of a change in the probability of exposed room ignition from 0.1 to 0.3) and another 100 cases run. After 500 cases have been analyzed, the angle of elevation is changed from 5° to 10° and the entire process of 500 runs completed. The final 500 cases are conducted for the 30° angle of elevation.

II. OUTPUT

The output from FIREFLY 2 normally proceeds directly into FIREFLY 3 for summary although the output could be printed in any one of three formats as desired. These formats are:

A. A complete summary case-by-case of every building which was destroyed and the cause of this destruction (See Table 3-2 for sample), giving building address, all probabilities and random numbers used, and the building from which the fire spread, if applicable.

B. A condensed form of A. above shown in Table 3-3.

C. A summary of B. above shown in Table 3-4.

TABLE 3-2

BLOCK	DIREC-TION	LOT NO.	ADDRESS	FIFTH RANDOM NUMBER	THERMAL PULSE	FOURTH RANDOM NUMBER	SPREAD PROBAB-ILITY
16	3	3	33 LONGFLLW WASH, D.C. 22110021	0.7394	0.1175	0.5526	
16	3	5	25 LONGFLLW WASH, D.C. 22110021	0.9597	0.2213	0.5047	
20	1	6	18 LONGFLLW WASH, D.C. 22110021	0.3718	0.2890	0.0082	1.0000
17	1	4	120 LONGFLLW WASH, D.C. 22110021	0.4245	0.2660	0.4336	
17	1	3	122 LONGFLLW WASH, D.C. 22110021	0.4930	0.2660	0.1246	1.0000
18	1	1	118 LONGFLLW WASH, D.C. 22110021	0.8472	0.3144	0.4930	
18	1	2	116 LONGFLLW WASH, D.C. 22110021	0.1284	0.3144	0.6354	1.0000
18	1	4	112 LONGFLLW WASH, D.C. 22110021	0.4343	0.3144	0.5436	
18	1	5	110 LONGFLLW WASH, D.C. 22110021	0.4187	0.3144	0.1425	1.0000
18	1	3	114 LONGFLLW WASH, D.C. 22110021	0.1369	0.3144	0.0403	1.0000
18	1	6	108 LONGFLLW WASH, D.C. 22110021	0.5878	0.3144	0.1369	
18	1	7	106 LONGFLLW WASH, D.C. 22110021	0.8070	0.3144	0.4834	
18	1	8	104 LONGFLLW WASH, D.C. 22110021	0.3993	0.3144	0.0796	
18	1	9	102 LONGFLLW WASH, D.C. 22110021	0.9937	0.3144	0.0415	1.0000
18	2	1	5514 1ST NW WASH, D.C. 22110021	0.4596	0.3995	0.2175	

TABLE 3-2 (Continued)

ADDRESS	FIRST RANDOM NUMBER	BURN PROBABILITY FROM SPREAD	2ND RANDM NUMB.	FIRE	FIRE CAUGHT FROM BLDG BLK	DIR	LOT
33 LONGFLLW WASH, D.C. 22110021	0.0934		0.7394	YES			
25 LONGFLLW WASH, D.C. 22110021	0.7322		0.9597	YES			
18 LONGFLLW WASH, D.C. 22110021	0.6818	0.5878	0.6900	YES	16	3	5
120 LONGFLLW WASH, D.C. 22110021	0.9290		0.4245	YES			
122 LONGFLLW WASH, D.C. 22110021	0.8088	0.9800	0.6842	YES	17	1	4
118 LONGFLLW WASH, D.C. 22110021	0.6701		0.8472	YES			
116 LONGFLLW WASH, D.C. 22110021	0.8819	0.9800	0.2465	YES	18	1	1
112 LONGFLLW WASH, D.C. 22110021	0.9889		0.4343	YES			
110 LONGFLLW WASH, D.C. 22110021	0.2[illegible]	0.9800	0.1381	YES	18	1	4
114 LONGFLLW WASH, D.C. 22110021	[illegible]483	0.9800	0.5886	YES	18	1	4
108 LONGFLLW WASH, D.C. 22110021	0.8623		0.5878	YES			
106 LONGFLLW WASH, D.C. 22110021	0.1618		0.8070	YES			
104 LONGFLLW WASH, D.C. 22110021	0.1598		0.3993	YES			
102 LONGFLLW WASH, D.C. 22110021	0.5176	0.9800	0.4761	YES	18	1	8
5514 1ST NW WASH, D.C. 22110021	0.6210		0.4596	YES			

SUMMARY WITH ANGLE OF ELEVATION=30 AND ROOM IGNITION PROB=0.3

BLOCK	DIR	LOT	TYPE OF FIRE
2	1	1	THERMAL PULSE
2	1	2	SPREAD
3	1	1	THERMAL PULSE
3	1	2	THERMAL PULSE
3	1	6	THERMAL PULSE
4	1	4	THERMAL PULSE
6	1	1	THERMAL PULSE
7	1	4	THERMAL PULSE
11	1	2	SPREAD
11	1	3	SPREAD
11	1	4	THERMAL PULSE
11	1	5	SPREAD
11	1	6	SPREAD
11	1	7	SPREAD
11	1	8	SPREAD
11	1	9	SPREAD
11	1	10	SPREAD
12	1	1	SPREAD
12	1	2	THERMAL PULSE
12	1	3	THERMAL PULSE
13	1	3	THERMAL PULSE
13	1	5	THERMAL PULSE
13	1	7	THERMAL PULSE
13	1	8	THERMAL PULSE
13	1	9	THERMAL PULSE
17	1	2	SPREAD
17	1	3	SPREAD
17	1	4	THERMAL PULSE
18	1	1	THERMAL PULSE
18	1	2	SPREAD

TABLE 3-3

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SUMMARY WITH ANGLE OF ELEVATION=30 AND ROOM IGNITION PROB=0.3 WITH THE NUMBER OF TIMES THROUGH THE LOOP=  1
TOTAL NUMBER OF BLDGS ON FIRE FROM THERMAL PULSE= 196    TOTAL NUMBER OF BLDGS ON FIRE FROM SPREAD=  51

SUMMARY WITH ANGLE OF ELEVATION=30 AND ROOM IGNITION PROB=0.5 WITH THE NUMBER OF TIMES THROUGH THE LOOP=  1
TOTAL NUMBER OF BLDGS ON FIRE FROM THERMAL PULSE= 256    TOTAL NUMBER OF BLDGS ON FIRE FROM SPREAD=  16

SUMMARY WITH ANGLE OF ELEVATION=30 AND ROOM IGNITION PROB=0.7 WITH THE NUMBER OF TIMES THROUGH THE LOOP=  1
TOTAL NUMBER OF BLDGS ON FIRE FROM THERMAL PULSE= 291    TOTAL NUMBER OF BLDGS ON FIRE FROM SPREAD=  11

SUMMARY WITH ANGLE OF ELEVATION=30 AND ROOM IGNITION PROB=0.9 WITH THE NUMBER OF TIMES THROUGH THE LOOP=  1
TOTAL NUMBER OF BLDGS ON FIRE FROM THERMAL PULSE= 326    TOTAL NUMBER OF BLDGS ON FIRE FROM SPREAD=   3
```

TABLE 3-4

III. DATA DESCRIPTION

In order to operate FIREFLY 2, the following cards must be prepared. All values are right justified

A. Card Type 1--Random Numbers (1 card)

Cols.	Description
3-8	Any six random digits (may be selected from Table 3-1).
12-17	Any six random digits.

B. Card Type 2--Building Information (1 card)

Cols.	Description
1-4	Total number of buildings.

C. Card Type 3--Block Information (1 card)

Cols.	Description
1-4	Total number of blocks, M.

D. Card Type 4--Number of Buildings Per Blockside

The number M in the above card is the number of cards of this type.

Cols.	Description
7-8	Number of buildings on the north side of a particular block, KC (I,1).

Cols.	Description
10-11	Number of buildings on the east side of this same particular block, KC (I,2).
13-14	Number of buildings on the south side of this same particular block, KC (I,3).
16-17	Number of buildings on the west side of this same particular block, KC (I,4).

E. Card Type 5--Number of Buildings of Particular Interest (1 card)

Cols.	Description
1-3	A value which represents the number of buildings to be summarized in detail in the final output. This option is valuable if in a given analysis, it is desired to examine the number of times a particular building or buildings was destroyed by either pulse or spread (often used when a given urban sample contains shelter buildings).

F. Card Type 6--Buildings of Particular Interest (1 card/ building)

(NOTE: This card must appear if the value in Card Type 5 is not zero, and omitted if the value in Type 5 is zero)

Cols.	Description
1-2	Block number of building of particular interest.
4	The direction number.
6-7	Lot number of the building of particular interest.

G. Card Type 7--Building Information (first of two cards/ building)

Building information is to be arranged in ascending order according to the order number with Card 7 preceding Card 8 of the same number.

Cols.	Description
1-2	Block number of building A with the information on this card and the following card. The limitations on the direction numbers and the lot numbers are the same as specified in the FIREFLY 1 write-up.
4	Direction number of building A with the information on this card and the next card.
6-7	Lot number of building A.
9-13	The order number of the third building to the north of building A.
15-19	The order number of the fourth building to the north of building A.
21-25	The order number of the first building to the east of building A.
27-31	The order number of the second building to the east of building A.
33-37	The order number of the third building to the east of building A.
39-43	The order number of the fourth building to the east of building A.
45-49	The order number of the first building to the south of building A.
51-55	The order number of the second building to the south of building A.

Cols.	Description
57-61	The order number of the third building to the south of building A.
63-67	The order number of the fourth building to the south of building A.
69-73	The order number of the first building to the west of building A.
80	A "3" is punched for identification.

H. Card Type 8--Building Information is to be Arranged In Ascending order According to the Order Number With Card 7 preceding Card 8 of the same Order Number.

Cols.	Description
1-2	Block number of building A with its information on this card.
4	Direction number of building A.
6-7	Lot number of building A.
9-13	The order number of the second building to the west of building A.
15-19	The order number of the third building to the west of building A.
21-25	The order number of the fourth building to the west of building A.
27-32	The first six letters and/or numbers of the street address of building A.
33-38	The last six letters and/or numbers of the street address of building A.
40-45	The first six letters and/or numbers of the city and state part of the address.
46-51	The last six letters and/or numbers of the city and state part of the address.

Cols.	Description
53-60	The Standard Location or any other identification code number.
67-71	The order number of the first building to the north of building A.
73-77	The order number of the second building to the north of building A.
80	A "4" for identification.

During execution, FIREFLY 2 reads the input tape, which is the output from FIREFLY 1. The tape contains information in the form as follows:

First record to be read in which is not blank

Cols.	Description
22-23	The angle of elevation.
61-63	The probability of ignition of an exposed room.

Second record to be read in which is not blank

Cols.	Description
4-5	The block number of building A.
11	The direction number of building A.
18-19	The lot number of building A.
22-27	The probability of spread from building A to the first neighboring building to the north of A.
30-35	The probability of spread from building A to the first building to the east.

Cols.	Description
38-43	The probability of fire spread from building A to the first building to the south of A.
46-51	The probability of spread from building A to the first building to the west of A.
67-72	The probability building A will catch on fire.

Third record to be read in which is not blank

Cols.	Description
22-27	The probability of spread from building A to the second neighboring building to the north of A.
30-35	The probability of spread from building A to the second building to the east.
38-43	The probability of fire spread from building A to the second building to the south of A.
46-51	The probability of spread from building A to the second building to the west of A.

Fourth record to be read in which is not blank

Cols.	Description
22-27	The probability of spread from building A to the third neighboring building to the [illegible] of A.
30-35	The probability of spread from building A to the third building to the east.
38-43	The probability of fire spread from building A to the third building to the south of A.
46-5[illegible]	The probability of spread from building A to [illegible] third building to the west of A.

Fifth record to be read in which is not blank

Cols.	Description
22-27	The probability of spread from building A to the fourth neighboring building to the north of A.
30-35	The probability of spread from building A to the fourth building to the east.
38-43	The probability of fire spread from building A to the fourth building to the south of A.
46-51	The probability of spread from building A to the fourth building to the west of A.

IV. DESCRIPTION OF PROCESSING SEQUENCE

	STATEMENT NUMBER From	Through
A zero in KWRITE indicates no intermediate steps will be printed out for any of the buildings. A one indicates intermediate steps will be written out.	(0+3)	(0+3)
Two random numbers are read in.	(0+4)	(10)
The number of buildings to be considered is read into core.	(10+1)	(10+1)
The number of block to have buildings read in is read into core.	(10+2)	(20)
This is a do loop which reads in the number of buildings per blockside for each block, i.e. KC(I,J).	(20+1)	(35)
This is the beginning of the loop which varies the block number so that there is a clearing of storage location KR(I,J,K) which indicates whether or not a building is to have a running total of the number of times it catches fire from thermal pulse and from spread in the hundred runs where the angle of elevation and the probability of ignition of an exposed room is fixed.	(35+1)	(35+1)
The direction number is varied in this statement.	(35+2)	(35+2)
If the number of buildings on a blockside is 0, there is a jump to the end of the loop. The index variable is the lot number. This loop clears the storage location KR (I,J,K).	(35+3)	(35+5)
Read into core is the card which has the NDETAIL, number of buildings of particular interest. If this number is 0, there is a jump to statement number (48).	(25+1)	(26+1)

	STATEMENT NUMBER From	STATEMENT NUMBER Through
The block, lot, and direction numbers of those buildings of particular interest are read into core and the entry in table KR of "1" indicates that they are to have their total number of times caught on fire from spread and the pulse calculated and written out.	(26+2)	(28)
The general comments and the two initial random numbers are written out.	(48)	(60)
This is a do loop which is gone through N times. The order numbers of the first, second, third, and fourth buildings to the north, east, south and west of the building in question are read in. Also read into core is the address.	(80)	(120)
This is the beginning of the do loop which varies the angle of elevation from 30° to 10° and finally to 5°. This loop includes the rest of the program minus the "STOP" and "END" cards.	(120+1)	(120+1)
This is the beginning of the do loop which initially sets the probability of an exposed room ignition to .1 and then increments it by .2 through .9. This loop also includes the rest of the program excluding the "STOP" and "END" cards.	(120+2)	(120+2)
This is the beginning of the loop which clears the locations in table TPSP so the total number of times a building catches on fire from the thermal pulse or from spread with a fixed angle of elevation and probability of ignition of an exposed room can be computed accurately. The index variable is the block number.	(120+3)	(120+3)
The index variable is the direction number.	(120+4)	(120+4)
A simple variable is set equal to KC(I,J), the number of buildings on the blockside defined by the two index variables above. If this simple variable is zero, there is a jump to the end of the loop. If this variable is not zero, the index variable is the lot number. TPSP(I,J,K) is cleared. This is the end of the loop.	(120+5)	(120+5)

Description	STATEMENT NUMBER From	STATEMENT NUMBER Through
This is the beginning of the loop which reads in the output tape from FIREFLY 1. For a given angle of elevation and a given probability of ignition of an exposed room the results of the FIREFLY 1 run are read for all the buildings.	(1200)	(1205)
If the angle of elevation is 30° and the probability of exposed room ignition is .1, these statements to read in the output tape from FIREFLY 1 are not skipped. The angle of elevation, the probability of exposed room ignition, the probability of building ignition from the thermal pulse, the block, direction, and lot numbers, the probability the building in question will catch on fire and the probabilities of spread from the building in question to its neighboring buildings are read into core. There is a jump to statement number (1310).	(1210)	(1212+1)
If the angle of elevation is 30° and probability of exposed room ignition is .3, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for description of tape information read in).	(1215)	(1217+1)
If the angle of elevation is 30° and the probability of exposed room ignition is .5, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of tape information read in.)	(1220)	(1227+1)
If the angle of elevation is 30° and the probability of exposed room ignition is .7, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of tape information read in.)	(1230)	(1232+1)

	STATEMENT NUMBER From	Through
If the angle of elevation is 30° and the probability of exposed room ignition is .9, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of tape information read in.)	(1235)	(1237+1)
If the angle of elevation is 10° and the probability of exposed room ignition is .1, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1240)	(1247+1)
If the angle of elevation is 10° and the probability of exposed room ignition is .3, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1250)	(1252+1)
If the angle of elevation is 10° and the probability of exposed room ignition is .5, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1255)	(1262+1)
If the angle of elevation is 10° and the probability of exposed room ignition is .7, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1265)	(1267+1)

	STATEMENT NUMBER From	STATEMENT NUMBER Through
If the angle of elevation is 10° and the probability of exposed room ignition is .9, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1270)	(1272+1)
If the angle of elevation is 5° and the probability of exposed room ignition is .1, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1275)	(1282+1)
If the angle of elevation is 5° and the probability of exposed room ignition is .3, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1285)	(1287+1)
If the angle of elevation is 5° and the probability of exposed room ignition is .5, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1290)	(1297+1)
If the angle of elevation is 5° and the probability of exposed room ignition is .7, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the information read in.)	(1300)	(1302+1)

	STATEMENT NUMBER From	Through
If the angle of elevation is 5° and the probability of exposed room ignition is .9, these statements to read in the output tape from FIREFLY 1 are not skipped. (See Description of Processing Sequence for statements (1210) through (1212+1) for the description of the information read in.)	(1305)	(1307)
The probability of building ignition from thermal pulse is put in a table PRB(I,J,K).	(1310)	(1310)
This is the end of the do loop which reads in the output tape from FIREFLY 1. This loop is gone through N times with the information from a particular individual building read into core with each pass through the loop.	(1320)	(1320)
This is the beginning of the do loop which calculates which buildings catch fire as a result of the thermal pulse and fire spread using the Monte Carlo method. This loop is passed through one hundred times for each combination of the angle of fireball elevation and probability of ignition of an exposed room.	(1320+1)	(1320+1)
The two loops included in these statements clear the storage location KFR(I,J,K) which indicates whether a particular building is on fire or not for each of the buildings.	(1320+2)	(127)
These statements clear the locations which store the number of thermal pulse fires NUMTPF, the total number of fires, NTOTAL, and the number of buildings which have had their fire spread completed, NCOUNT.	(127+1)	(127+3)
These statements are skipped if the intermediate step write-out is to be omitted. These statements write-out the heading for the intermediate step printout. The number of lines of printout on the page is set to three.	(127+4)	(130+1)

	STATEMENT NUMBER From	Through
The block, direction, and lot numbers are varied for each building to see if it catches fire from the thermal pulse.	(132)	(132+4)
A random number is generated. If the probability of building ignition from thermal pulse is greater than the newly generated random number, it is assumed by the Monte Carlo method that there is a fire by thermal pulse. If there is a fire from the thermal pulse, the storage location KFR(I,J,K) is set to 3. If the building is one of particular interest, i.e. KR(I,J,K) is not equal to zero, the location TPSP(I,J,K) is increased by one to indicate there is a fire from the thermal pulse. Whether or not the building is of particular interest, NUMTPF is increased by one, NTOTAL is increased by one, and KBDG (NUMTPF) is set equal to the order number of the building just determined to be on fire from the thermal pulse.	(132+5)	(165+2)
Two random numbers are given new values. After it completes all this, there is a return to the beginning of the loop where the block, lot, and direction numbers are varied until all the buildings have been considered for fire from the thermal pulse.	(170)	(180)
These statements are skipped if there are thermal pulse fires. If there are no fires from the thermal pulse, there is a write-out which indicates there are none and a jump to the end of the loop which is passed through one hundred times.	(180+1)	(190+1)
The 3 storage locations which store the block, direction, and lot numbers of the building under consideration are initially set to the block, direction, and lot numbers of the first building which was determined to be on fire as a result of the thermal pulse. These three numbers are computed from KBDG(1). A random number is generated in this statement. The storage location which keeps a running total of the number of buildings on fire from spread, NUMSP, is set to zero.	(200)	(200+5)

	STATEMENT NUMBER From	Through
This is the beginning of the loop which is passed through as many times as there are buildings which catch on fire as a result of thermal pulse and passed through partially as many times as there are buildings which catch on fire from spread.	(200+6)	(200+6)
The storage location KSPREAD in this statement is set to zero and does not vary until the spread of fire from buildings on fire from thermal pulse has been completed.	(200+7)	(200+7)
If the intermediate steps are not to be written out, these statements are skipped. If the number of lines on the page to be written is greater than 60, a new page is begun with the headings written out and the number of lines per page set to three. The block, direction, and lot numbers, the street part of the address, the probability of building ignition from thermal pulse, four random numbers used in the calculation, and the city part of the address are written out. The running total of the number of lines in increased by four.	(200+8)	(230+1)
This loop is gone through 16 times or at least as many times as there are neighboring buildings for each building on fire to see if the fire spreads to other neighboring buildings.	(240)	(240)
The two random numbers used in the Monte Carlo method to determine if the fire spreads, and if the building catches on fire, are generated in these statements.	(240+1)	(250)
The index variable is tested to see if it is less than, equal to, or greater than two.	(260)	(260)
If the index variable is not one, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the first neighboring building to the north.	(270)	(270+2)

	STATEMENT NUMBER From	Through
If the index variable is not two, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the second neighboring building to the north.	(280)	(280+2)
The index variable is tested to see if it is less than, equal to, or greater than 4.	(290)	(290)
If the index variable is not 3, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the third neighboring building to the north.	(300)	(300+2)
If the index variable is not four, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the fourth neighboring building to the north.	(310)	(310+2)
The index variable is tested to see if it is less than, equal to, or greater than six.	(320)	(320)
If the index variable is not five, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the first neighboring building to the east.	(330)	(330+2)
If the index variable is not six, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the second neighboring building to the east.	(340)	(340+2)
The index variable is tested to see if it is less than, equal to, or greater than 8.	(350)	(350)
If the index variable is not seven, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the third neighboring building to the east.	(360)	(360+2)

	STATEMENT NUMBER From	Through
If the index variable is not eight, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the fourth neighboring building to the east.	(370)	(370+2)
The index variable is tested to see if it is less than, equal to, or greater than ten.	(380)	[illegible]
If the index variable is not nine, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the first neighboring building to the south.	390)	(390+2)
If the index variable is not ten, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the second neighboring building to the south.	(400)	(400+2)
The index variable is tested to see if it is less than, equal to, or greater than 12.	(410)	(410)
If the index variable is not eleven, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the third neighboring building to the south.	(420)	(420+2)
If the index variable is not twelve, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the fourth neighboring building to the south.	(430)	(430+2)
The index variable is tested to see if it is less than, equal to, or greater than 14.	(440)	(440)
If the index variable is not 13, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the first neighboring building to the west.	(450)	(450+2)

	STATEMENT NUMBER From	Through
If the index variable is not 14, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the second neighboring building to the west.	(460)	(460+2)
The index variable is tested to see if it is 15 or 16.	(470)	(470)
If the index variable is not 15, these statements are skipped. General terms are set equal to the probability of spread to and the order number of the third neighboring building to the west.	(480)	(480+2)
If the index variable is not 16, these statements are skipped. A general term is set equal to the probability of spread to the fourth neighboring building to the west. If the storage location in KFR associated with the building from which spread is considered is not 3, the location is set to 2 to indicate the spread consideration is complete. Whether or not KFR(I,J,K) equals 3, a general term is set equal to the order number of the fourth neighboring building to the west.	(490)	(495)
This general term which stores an order number is broken down into block, lot, and direction numbers.	(500)	(500+3)
If the order number is zero which implies there are less than 16 neighboring buildings, the spread consideration and write-out is skipped.	(500+4)	(500+5)
The Monte Carlo method is used to see if fire spreads to the neighboring building under consideration. If it does spread, the probability the neighboring building will catch on fire is compared to another random number.	(510)	(510)
The probability the neighboring building will catch on fire is compared to a random number. If the probability the building catches fire is not greater than the random number, the statements which cause the writing-out of the buildings which are	([illegible]0)	(530+1)

	STATEMENT NUMBER From	Through
on fire are skipped. If the probability is greater than the random number, there is a test to see if the neighboring building already caught on fire. If the neighboring building had already caught on fire, statement numbers (535) through (560+1) are skipped.		
The storage location KFR is set equal to "1". The "1" indicates the building caught on fire from spread, but its spread consideration to its neighboring buildings is not complete.	(535)	(535)
If the building is of particular interest, TPSP (I,J,K) is increased by .001 to indicate another fire from spread.	(535+1)	(535+2)
The running total of the number of buildings on fire as a result of spread, NUMSP, is increased by one. The running total of the number of buildings on fire, NTOTAL, is increased by one.	(536)	(536+1)
The table KBDG, which stores the order number of those buildings on fire has entered the order number of the building which was just simulated to be on fire.	(536+2)	(536+2)
If the details are not to be printed out, there is a jump to statement number (610). Otherwise there is a test to see if there are more than 60 lines of write-out on the page. If there are, headings are printed out on the next page, and the number of lines of write-out is set to 3. The block, lot number, and direction number of the building just determined to be on fire from spread, as well as its address, the probability that the building would catch on fire, the probability of building ignition, and the probability of spread from the building which is having its spread determined to a neighboring building are printed. The number of lines of write-out is increased by four.	(538)	(560+1)

	STATEMENT NUMBER From	Through
If the index variable is not 16, there is a jump to statement number (630). When this variable is 16, it indicates that the spread from the building to its neighboring buildings has been completed.	(610)	(610)
The running total of the number of buildings which have had spread consideration completed, NCOUNT, is increased by one.	(610+1)	(610+1)
If the running total number of buildings on fire, NTOTAL, is less than NCOUNT, there is a jump to statement number (690). Otherwise the following occurs: the building determined to be on fire after the one which has just had its spread consideration completed has its block, direction, and lot numbers determined from the order number.	(610+2)	(610+4)
Two random numbers are varied.	(630)	(630+1)
This is the end of the loop which considers the spread from the buildings in question to its neighboring buildings.	(640)	(640)
If the buildings on fire from thermal pulse have been completed, there is a jump to statement number (670) which sets the index variable to one. Otherwise, there is a jump to (660).	(650)	(650+1)
The index variable is compared to the number of buildings on fire as a result of thermal pulse. If the number of buildings on fire from thermal pulse is greater than the index variable, there is a jump to statement number (680).	(660)	(660)
If the number of buildings on fire from the thermal pulse is less than or equal to the index variables, KSPREAD is set to one to indicate that the spread from the buildings on fire from the thermal pulse has been completed. There is a jump to the beginning of the loop which considers spread to the neighboring buildings, (Statement Number 240).	(670)	(670+1)

	STATEMENT NUMBER From	Through
This is the end of the loop which considers the spread of the buildings on fire from thermal pulse. When the buildings on fire from thermal pulse have had their spread considerations completed, the index variable is set to one until all spread considerations are complete.	(680)	(680)
The index variable, NN, is tested to see if it is less than, equal to, or greater than 2. If NN = 1, the probability of exposed room ignition is set to .1, and there is a jump to statement number (6835). If NN = 2, the probability of exposed room ignition is set to .3, and there is also a jump to statement number (6835).	(690)	(6810+1)
There is a test to see if NN = 3, 4, or 5. If NN = 3, the probability of exposed room ignition is set to .5; NN = 4, probability set to .7; NN = 5, probability set to .9. After the probability of exposed room ignition has been set, there is a jump to statement number (6835).	(6815)	(6830)
There is a test to see if the index variable, MM, equals one, two, or three. If the variable is one, the angle is 30°; if 2, the angle is 10°; if 3, the angle is 5°. After the angle of elevation has been evaluated, there is a jump to statement number (695).	(6835)	(6850)
If the write-out of the intermediate steps are to be skipped, there is a jump to statement number (705). Otherwise, the angle of elevation and the probability of exposed room ignition are written out and there is a jump to statement number (708).	(695)	(700+1)
The angle of elevation, the probability of exposed room ignition and the index variable JJ, indicating the number of times the given simulation with the angle and probability fixed has been completed, are written out.	(705)	(706)

	STATEMENT NUMBER From	Through
This is the beginning of the loop which varies the block number. This loop causes the write out of the summary of the block, direction, and lot numbers of the buildings on fire.	(708)	(708)
This is the beginning of the loop which varies the direction number so all buildings will be considered in the summary.	(708+1)	(708+1)
The index variables set in statement numbers (708) and (708+1) determine an entry in the table which stores the number of buildings on the blockside. If the table entry is zero, there is a jump to statement number (785).	(708+2)	(710)
If the number of buildings on the blockside is not zero, this loop is not skipped. The lot number is the variable index.	(710)	(710)
If the location KFR(I,J,K) equals 3, there is a jump to statement number (730). Otherwise, the following occurs: if the intermediate steps are not to be written out, there is a jump to statement number (770).	(710+1)	(710+2)
There is a write-out of the block, direction and lot numbers of the building on fire from the thermal pulse. There is a jump to statement number (770).	(715)	(720+1)
If the building is not on fire from spread, and the spread considerations to its neighboring buildings are not complete, there is a jump to statement number (770).	(730)	(730)
If the intermediate details are not to be written out, there is a jump to (770).	(730+1)	(730+1)
The block, direction, and lot numbers of the buildings on fire from spread are written out only if the intermediate steps are to be written out.	(735)	(740)
This is the end of the loop which has the lot number varied.	(770)	(770)

	STATEMENT NUMBER From	Through
This is the end of the do loop which varies the direction number and writes out the summary.	(785)	(785)
This is the end of the do loop which varies the block number and writes the summary.	(790)	(790)
The number of lines of write-out is cleared. If the total number of buildings on fire is zero, the number of buildings on fire from spread is cleared.	(790+1)	(800+1)
The number of buildings on fire from the thermal pulse and the spread, as well as the total number of buildings on fire, are written out.	(801)	(805)
If NDETAIL equals zero, there is a jump to statement number (807).	(806)	(806)
If this is not the hundredth time through the loop, there is a jump to statement number (807).	(806+1)	(806+1)
This is the beginning of the loop which writes out the number of times those buildings of particular interest catch on fire from the thermal pulse and from spread. The index variable is the block number.	(806+2)	(806+2)
The index variable for this loop is the direction number.	(806+3)	(806+3)
A simple term is set equal to the entry in the table KC. If the simple term is zero, there is a jump to statement number (807). Otherwise, the beginning of the do loop which varies the lot number is encountered.	(806+4)	(806+6)
If the building is not of particular interest, there is a jump to statement number (807). An integer variable is set equal to the floating point number TPSP(I,J,K), which stores the number of thermal pulse fires and one thousandth of the number of spread fires, so that the number of fires from the	(806+7)	(8065+1)

	STATEMENT NUMBER From	Through
thermal pulse is determined. A floating point variable is set equal to the integer variable so arithmetic operations involving floating point variables can be performed. The number of fires from spread is one thousand times the fractional part of the variable storing both thermal pulse and spread. The block, lot, and direction numbers, as well as the number of fires from the thermal pulse and spread are written out. The variable TPSP(I,J,K) is cleared.		
This is the end of the loop which writes out the number of times each building of particular interest catches fire from the thermal pulse and from spread.	(807)	(807)
This is the end of the loop which varies the angle of elevation and the probability of exposed room ignition. The tape being read in is rewound so the information concerning another combination of the angle of elevation and the probability of room ignition can be read into core.	(808)	(808)
This is the end of the program.	(810)	(810+1)

SECTION 4

FIREFLY 3

I. INTRODUCTION

FIREFLY 3 uses as input the output tape from FIREFLY 2. FIREFLY 3 first computes the average of the number of buildings on fire from spread and the thermal pulse, as well as the average of the total number of buildings on fire, for each one hundred case test base where the angle of fireball elevation and the probability of ignition of an exposed room are fixed. Next, the averages just computed are expressed as a percent of the total number of buildings. Finally, the standard deviation of the number of buildings on fire from spread, thermal pulse and total are determined.

II. SUMMARY OF OUTPUT DATA

For each angle of fireball elevation and probability of ignition of an exposed room, FIREFLY 3 contains:

A. The average number and percent of total buildings destroyed by the thermal pulse.

B. The average number and percent of total buildings destroyed by fire spread.

C. The average number and percent of total buildings destroyed from both fire spread and thermal pulse.

A sample of this output is shown in Table 1-2, 1-3, and 1-4.

III. DATA DESCRIPTION

The data needed to operate FIREFLY 3 consist of two card types. All values are right justified.

A. Card Type 1--Records to Skip (15 cards)

Cols.	Description
1-4	KSKIP, number of records to be skipped on the input tape from FIREFLY 2 before each one hundred case writeout of the number of the building on fire from spread, the thermal pulse, and both the spread and the thermal pulse for a particular angle of elevation and probability of ignition of an exposed room.
	KSKIP must be defined for each of the 15 cases of output so that extraneous page, column, and row headings are not erroneously read as data. In a normal operation, that is, when no special building analysis has been performed by defining a value for NDETAIL, the first KSKIP card contains a "7" in column 4 followed by 14 blank cards.

B. Card Type 2--General Information (1 card)

Cols.	Description
1-4	Total number of buildings
6-15	City name (Alphameric)
17-28	The wind speed used in FIREFLY 1. (e.g., "8 mph, east").

IV. INPUT TAPE

During execution, FIREFLY 3 reads the output tape of FIREFLY 2. KSKIP plus one records are by-passed until the following record is encountered:

Cols.	Description
52-55	Number of buildings on fire from the thermal pulse.
103-105	Number of buildings on fire from fire spread.

V. DESCRIPTION OF PROCESSING SEQUENCE

	STATEMENT NUMBER From	Through
The number of records to be skipped on the input tape before each one hundred group is read into the table, KSKIP.	(0+1)	(15)
The number of buildings, the city name, and the wind speed are read.	(15+1)	(20)
The above three items and a heading are written out. The location storing the number of lines per page of output is increased by seven.	(20+1)	(25+2)
This is the beginning of the loop which varies the combinations of the angle of elevation and the probability of ignition of an exposed room so that the averages, percentages, and standard deviations of the number of buildings on fire from spread, thermal pulse, and both spread and thermal pulse for each combination can be performed.	(25+2)	(25+2)
A simple variable is set to KSKIP. If the value of KSKIP is zero, there is a jump to statement (40) so only one record is skipped on the input tape.	(25+3)	(25+4)
This loop causes one record to be skipped for each pass. This loop is gone through KSKIP times.	(25+5)	(35)
The sums of the number of buildings on fire from the thermal pulse and from spread for the hundred case test base is cleared.	(40)	(40+1)
The input tape from FIREFLY 2 is read skipping all but the number of buildings on fire from spread and thermal pulse for each pass. The sums of the number of buildings on fire from spread and the thermal pulse for the hundred case test base is updated. This loop is passed through one hundred times.	(40+2)	(50)

	STATEMENT NUMBER From	Through
The sum of the total number of buildings on fire for the hundred case test base is computed.	(50+1)	(50+1)
The average number of buildings on fire from the thermal pulse is computed and rounded to the nearest integer.	(50+2)	(55)
The average number of buildings on fire from spread is computed and rounded to the nearest integer.	(60)	(65)
The average total number of buildings on fire is calculated.	(70)	(70)
The percent of the average number of buildings on fire from the thermal pulse is computed. This percent is rounded to the nearest integer.	(70+1)	(75)
The percent of the average number of buildings on fire from spread is computed. This percent is rounded to the nearest integer.	(80)	(85)
The percent of the average total number of buildings on fire is computed.	(90)	(90)
The sums of the squares of the absolute values of the differences between the average and the actual number of buildings on fire from spread and the thermal pulse are cleared, i.e. KTOTSQSP = 0, KTOTSQTP = 0.	(90+1)	(90+2)
This loop is gone through one hundred times to determine the squares of the sums of the absolute value of the differences between the average and the actual number of buildings burning from spread and the thermal pulse for a particular angle of elevation and probability of exposed room ignition.	(90+3)	(100)
The standard deviations of the number of buildings on fire from fire spread, the thermal pulse and both spread and the thermal pulse are calculated.	(100+1)	(100+3)

	STATEMENT NUMBER From	Through
If the index variable M (loop beginning in statement number (25+2)) is less than or equal to five, KELEV, angle of elevation, is set to thirty. If M is greater than five but less than eleven, KELEV is set to ten. If M is greater than or equal to eleven, KELEV is set to five. If M equals one, six, or eleven, the probability of exposed room ignition equals.1; if M equals two, seven, or twelve, the probability is .3; if M equals three, eight, or thirteen, the probability is .5; if M equals four, nine, or fourteen, the probability is .7; if M equals five, ten or fifteen, the probability is .9.	(100+4)	(170)
If the number of lines of output on the page of printout is greater than or equal to fifty-five, the title line is printed out at the top of a new page, the number of lines of output on the new page is set to seven and if the exposed room ignition probability is .1, a line is skipped, and the number of lines of output is updated.	(175)	(183+1)
The averages, percents, and standard deviations of the number of buildings on fire from spread, the thermal pulse, and both are written out with the angle of elevation and the probability of ignition of an exposed room specified.	(185)	(190+1)
This is the end of the loop beginning at(25+2). Each pass through this loop compiles the information for a particular combination of the probability of ignition of an exposed room and the angle of elevation.	(200)	(200)
End of program.	(200+1)	(200+2)

SECTION 5

GLOSSARY

I. GENERAL TERMS

BLOCK--	A block is a rectangular or near rectangular area containing at least one building.
BLOCKSIDE--	A blockside is one of four sides of a block--north, east, south, or west.
BUILDING DESIGNATION--	See ORDER NUMBER
CARDINAL DIRECTIONS--	North, East, South, and West
LOT--	The lot number is a number given to each building. On a blockside the lot numbers given to the buildings are values from one and incremented by one to a maximum of ten.
ORDER NUMBER--	The order number, which uniquely designates a building, is defined in the following equation:

$$\text{ORDER NUMBER} = 1000I + 100J + K$$

Where: I = block number
J = blockside number
K = lot number

SETBACK--	The setback is the distance in feet the front side of a building is back from the street, with the following exception: if the distance between the front of the building across the street is used as the separation distance, then the setback is zero. If only the street width is used as the separation distance, then the setback must be defined so that the total separation distance may be calculated.

THEORETICAL SEPARATION DISTANCE--Theoretical separation distance in any of the four basic directions from a particular building is the maximum distance between the building and another building where the probability of spread in the direction under consideration is zero.

II. FORTRAN CONSTANTS AND VARIABLES

GLOSSARY OF TERMS USED IN COMPUTER PROGRAM
(COMPUTER SYMBOLS)

This glossary defines the terms of FIREFLY 1, FIREFLY 2, and FIREFLY 3 which are in common storage. All the terms used in the subroutines in FIREFLY 1 are also used in the main program; therefore, there are no definitions specifically for the subroutines.

Those variables which are not an array name have a "1" as their dimension.

SYMBOL	DIMENSION	MEANING
ADR1-2(I,J,K)	27,4,10	Street part of address of building on block I, blockside J, and lot K
ANG	1	Angle of the wind in radians measured from east counter-clockwise
ARBLDG	1	General term for one of the radiating areas
ARBLDG1	1	Radiating area from the north of the building
ARBLDG2	1	Radiating area from the east of the building
ARBLDG3	1	Radiating area from the south of the building
ARBLDG4	1	Radiating area from the west of the building
AVGSP	1	Floating point variable equal to the average of the number of buildings on fire from spread in a hundred case test base.
AVGTP	1	Floating point variable equal to the average of the number of buildings on fire from the thermal pulse in a hundred case test base
BIN	1	Gage-Babcock Index
CTY1, CTY2	1	City and State
D	1	Floating point variable equivalent to KD (see KD)
DET	1	The part of the solution of the quadratic equation to solve for the separation distance which is under the square root operation
DEVSP	1	Standard deviation of the number of buildings on fire from spread

SYMBOL	DIMENSION	MEANING
DEVTOT	1	Standard deviation of the total number of buildings on fire
DEVTP	1	Standard deviation of the number of buildings on fire from the thermal pulse
DM	1	Multiplier for building characteristics used in calculating the radiating area. It is dependent upon the wall openings, number of stories and type of roof construction. See Section 2 VII E.
DMPHR	1	General term for one of the wind component's number of miles/hour
DMPHRE	1	Number of miles/hour for the eastern component of the wind vector
DMPHRN	1	Number of miles/hour for the northern component
DMPHRS	1	Number of miles/hour for the southern component of the wind vector
DMPHRW	1	Number of miles/hour for the western wind component
EN	1	Probability of room ignition with the environmental factors considered
FC	1	Contribution factor adjusts the radiating area of the side of a building which is the front. The contribution factor is dependent upon the building's setback from the street.
HF1	1	Flame height in the northern part of the building
HF2	1	Flame height in the eastern part of the building
HF3	1	Flame height in the southern part of the building

SYMBOL	DIMENSION	MEANING
HF4	1	Flame height in the western part of the building
I	1	Block number of building. The blocks must be numbered from one and incremented by one with a maximum of 27.
J	1	The side, direction, or blockside number of building. The maximum possible number is four. With each block all the blocksides need not contain a building or buildings. Blockside 1 means the northern part of the block while blockside 2, 3, or 4 means eastern, southern, or western part respectively.
K	1	Lot number of building. Each blockside which contains a building or buildings must have the lots numbered from one and incremented by one to a maximum of ten.
KARD1-4	1	To check to see cards read into core in correct order
KAVGSP	1	Fixed point variable equal to AVGSP (see AVGSP)
KAVGTOT	1	Average of the total number of buildings on fire
KAVGTP	1	Fixed point variable equal to AVGTP (see AVGTP)
KBDG	1080	Table which stores the order numbers of those buildings determined to be on fire. The order numbers of those buildings on fire from thermal pulse appear before those on fire from spread.
KBLK	1	Block number of building
KC(I,J)	27,4	Number of buildings on the blockside J of lot I
KCOUNT(I,J)	30,4	Same as KC(I,J)

SAMPLE	DIMENSION	MEANING
KCR	1	Code for the roof construction combustibility. See Section 2 VII E
KD	1	Density multiplier times one hundred. This will usually be 100.
KDIFSP	100	Absolute value of the difference between the average of the number of buildings on fire from spread and the actual number of buildings on fire from spread for one of the hundred cases. The index corresponds to the index of the actual number of buildings on fire from spread.
KDIFTP	100	Absolute value of the difference between the average of the number of buildings on fire from the thermal pulse and the actual number of buildings on fire from the thermal pulse for one of the hundred cases. The index corresponds to the index of the actual number of buildings on fire from the thermal pulse.
KDIR	1	Blockside number of the building (see J)
KELEV	1	Angle of fireball elevation
KF	1	Code for the floor construction combustibility. See Section 2 VII F
KFR(I,J,K)	27,4,10	Table indicating fire and spread completion information about the building determined by I, J, and K. If the location contains a "0", this indicates there is no fire. If there is a "1", the fire is from spread, but the spread consideration to its neighboring buildings is not complete. If the building is on fire from spread and the spread consideration is complete, the table entry contains a "2". A building on fire from the thermal pulse is indicated by a "3".

SYMBOL	DIMENSION	MEANING
KH	1	Term dependent upon the number of stories in the building. KH is used in the calculation of the Gage-Babcock index.
KK	1	See KC(I,J)
KLOT	1	Lot number of card read in. See K
KO	1	Value assigned to a building for its use which determines its combustibility. See Section 2 VII F
KOW	1	Value assigned for the relative number of wall openings which determines combustibility. If there are no, few, average, many, or all openings, the value is one, two, three, four or five respectively.
KPAGNTN	1	Number of lines of printout on a given page
KPGNTN	1	See KPAGNTN
KPSP	1	Percent of the average number of buildings on fire from spread
KPTOT	1	Percent of the average number of total buildings on fire
KPTP	1	Percent of the average number of buildings on fire from the thermal pulse
KR(I,J,K)	27,4,10	Table which stores whether or not the building is to have the number of times it catches fire from thermal pulse and spread computed and written out, i.e., whether or not it is a building of particular interest. If the table entry is a "1", there is a calculation and printout; whereas, if there is a "0", there is no calculation or printout. This calculation is determined for a fixed angle of elevation and exposed room ignition probability (one hundred case test base).

SYMBOL	DIMENSION	MEANING
KRR	1	Value dependent upon the roof construction code. It is used in determining the Gage-Babcock Index.
KSB	1	Number of feet the building is set back from the street. See setback in glossary
KSEQ1	1	Order number of the building with information read in on previous card
KSEQ2	1	Order number of the building with information read in. A comparison between KSEQ1 and KSEQ2 is performed to determine if the input cards are in the correct order.
KSKIP	15	Number of records to be skipped on output tape from FIREFLY 2 before the one hundred case output of the number of buildings on fire from spread and thermal pulse is encountered. The index equals the number of one hundred cases which have been encountered plus one.
KSMSP	1	Running total of the number of buildings on fire from spread in a particular test base
KSMTOT	1	The total number of buildings on fire in a particular test base
KSMTP	1	Running total of the number of buildings on fire from the thermal pulse in a particular test base
KSP	1	Number of times a building catches on fire from spread with the angle of fireball elevation and the exposed room ignition probability fixed
KSPF	100	Number of buildings on fire from spread for each case of the one hundred under consideration. The number of buildings on fire from spread for the first time through the loop is stored in KSPF(1). The index of KSPF corresponds to the number of times the problem has been simulated with a particular angle of elevation and probability of ignition of an exposed room.

SYMBOL	DIMENSION	MEANING
KSPREAD	1	Indicates whether or not the spread considerations for those buildings on fire from the thermal pulse have been completed. A "0" indicates that the spread consideration is not complete, while a "1" indicates those buildings on fire from the thermal pulse have had their spread considerations completed.
KSQSP	100	Square of KDIFSP with the indices corresponding
KSQTP	100	Square of KDIFTP with the indices corresponding
KSTY	1	Number of stories a building has
KTOTSQSP	1	Running total of KSQSP for the hundred cases
KTOTSQTP	1	Running total of KSQTP for the hundred cases
KTP	1	Number of times a building catches on fire from the thermal pulse with the angle of fireball elevation and the exposed room ignition probability fixed.
KTPF	100	Number of buildings on fire from the thermal pulse for each case of the one hundred under consideration. The number of buildings on fire from the thermal pulse for the first time through the loop is stored in KTPF(1). The index of KTPF corresponds to the number of times the problem has been simulated with a particular angle of elevation and probability of ignition of an exposed room.
KV	1	General term for the classification of one of the four wind components as a light, moderate, or high wind. A component less than 8 miles/hour is a low wind and indicated by a "1" in the location KV. A medium wind from 8 to 16 miles/hour is indicated by a "2" in KV. A "3" in KV indicates there is a high wind, a wind 16 miles/hour or above.

SYMBOL	DIMENSION	MEANING
KVE	1	Classification of the eastern wind component as a light, medium, or high wind. See KV
KVN	1	Classification of the northern wind component as a light, medium, or high wind. See KV
KVS	1	Classification of the southern wind component as a light, medium, or high wind. See KV
KVW	1	Classification of the western wind component as a light, medium, or high wind. See KV
KW	1	General term for the distance in feet between the building and one of its neighboring buildings. If the neighboring building is opposite its front side, the street width may be recorded as the width if the setback distance is recorded.
KWE1-4	1	Distance in feet between the building and one of its neighboring buildings to the east. If there is no neighboring building, distance=0. The "1", "2", "3", and "4" indicate the distance between the building and the first, second, third, and fourth buildings respectively to the east. See KW
KWIDTH1-2	1	Width in feet of the building. The east-west length of the building is stored in KWIDTH 1. The north-south length is stored in KWIDTH 2.
KWN1-4	1	Distance in feet between the building and one of its neighboring buildings to the north. If there is no neighboring building, distance = 0. The "1", "2", "3", and "4" indicate the distance between the building and the first, second, third, and fourth buildings respectively. See KW

SYMBOL	DIMENSION	MEANING
KWRITE	1	Indicates whether or not the intermediate steps are to be written out. If KWRITE=0, there is no intermediate step printout. If KWRITE=1, there is the write-out of the intermediate steps.
KWS1-4	1	Distance in feet between the building and one of its neighboring buildings to the south. If there is no neighboring building, distance=0. The "1", "2", "3", and "4" indicate the distance between the building and the first, second, third, and fourth neighboring buildings respectively. See KW
KWW1-4	1	Distance in feet between the building and one of its neighboring buildings to the west. If th re is no neighboring building, distance=0. The "1", "2", "3", and "4" indicate the distance between the building and the first, second, third, and fourth neighboring buildings respectively. See KW
M	1	Total number of blocks. M is also the maximum block number since M is from one and incremented by one.
MAJDIR	1	Code for the wind component which has the largest number of miles/hour. North, east, south, and west are represented by "1", "2", "3", and "4" respectively.
N	1	Total number of buildings in the area to have buildings on fire considered
NBE1-4(I,J,K)	27,4,10	Order numbers of the neighboring buildings to the east. See NBLDG
NBLDG	1	General term for the order number of a neighboring building. For NBE1-4, NBN1-4, NBS1-4, and NBW1-4 the "1", "2", "3", and "4" indicate the first, second, third, and fourth neighboring buildings respectively.

SYMBOL	DIMENSION	MEANING
NBLK	1	Block number of building. It is used to store the block number read in on the first card of the block information so it can be compared to the block number of the second card.
NBN1-4(I,J,K)	27,4,10	Order numbers of the neighboring buildings to the north. See NBLDG
NBS1-4(I,J,K)	27,4,10	Order numbers of the neighboring buildings to the south. See NBLDG
NBW1-4(I,J,K)	27,4,10	Order numbers of the neighboring buildings to the west. See NBLDG
NCNT	1	NCOUNT + 1 (see NCOUNT)
NCOUNT	1	Number of buildings on fire which have had their spread considerations completed
NDETAIL	1	Number of buildings which are of particular interest
NDIR	1	Blockside number of building. It is used to store the blockside number of the first card of the building information so it can be compared to blockside number of the second card.
NLOT	1	Lot number of building. It is used to compare the lot numbers of the first and second card of the building information.
NTH	1	Order number of building minus the block number times one thousand
NTOTAL	1	Total number of buildings which are known to have caught on fire
NUME	1	Number of neighboring buildings to the east of the building
NUMN	1	Number of neighboring buildings to the north

SYMBOL	DIMENSION	MEANING
NUMS	1	Number of neighboring buildings to the south
NUMSP	1	Number of buildings on fire from spread
NUMTPF	1	Number of buildings on fire from the thermal pulse
NUMW	1	Number of neighboring buildings to the west
PR	1	General term for a probability of spread to one of the neighboring buildings. For PRE1-4, PRN1-4, PRS1-4, and PRW1-4, the "1", "2", "3", and "4" indicate the probability of spread to the first, second, third, or fourth neighboring building respectively in the direction under consideration.
PRB(I,J,K)	27,4,10	Probability of building ignition from thermal pulse
PRE1-4(I,J,K)	27,4,10	Probability of spread to the first, second, third, or fourth neighboring building (see PR) to the east of the building
PRF(I,J,K)	27,4,10	Probability of the building defined by I, J, and K to catch on fire
PRN1-4(I,J,K)	27,4,10	Probability of fire spread to the first, second, third, or fourth neighboring building (see PR) to the north of the building
PROB	1	Probability of building ignition from thermal pulse
PRS1-4(I,J,K)	27,4,10	Probability of fire spread to the first, second, third, or fourth neighboring building (see PR) to the south of the building

SYMBOL	DIMENSION	MEANING
PRW1-4(I,J,K)	27,4,10	Probability of fire spread to the first, second, third, or fourth neighboring building (see PR) to the west of the building
PSP	1	Floating point variable equal to KPSP (see KPSP)
PTP	1	Floating point variable equal to KPTP (see KPTP)
Q	1	Intermediate value used in computing the Gage-Babcock Index
RANDOM1-2	1	Used to generate RANDOM4 and RANDOM5
RANDOM4-5	1	Used in the Monte Carlo method to determine if the building catches on fire from the thermal pulse, if the fire is going to spread to within reach of a neighboring building, and if this neighboring building will catch on fire
RI	1	Exposed room ignition probability
RII	1	See RI
RKTP	1	Floating point variable set equal to KTP (see KTP)
RN	1	Floating point variable set equal to N (see N)
RNN	1	Floating point number set equal to the exposed room ignition probability
S	1	General term for the shape of the radiator
S1	1	Northern radiator shape of the building
S2	1	Eastern radiator shape of the building
S3	1	Southern shape of the radiator of the building

SYMBOL	DIMENSION	MEANING
S4	1	Western shape of the radiator of the building
SHIELD	1	Shielding factor dependent upon the elevation of the fireball angle and the number of stories of the building in question
STY	1	Floating point variable storing the number of stories
T	1	The value assigned to building A depending upon the angle of inclination of the terrain. See Section 2 VII F
TPSP(I,J,K)	27,4,10	Number of times the building of particular interest defined by I, J, and K catches fire from the thermal pulse is stored in the integer part of the floating point number. The number of times the building of particular interest catches on fire from spread is the fractional part times one thousand. These two numbers are totaled for a fixed angle of elevation and exposed room ignition probability.
WB1-2	1	Floating point variables WB1 for KWIDTH1 and WB2 for KWIDTH2
WE1-4	1	Floating point variables WE1 for KWE1, WE2 for KWE2, WE3 for KWE3, and WE4 for KWE4
WIND1-2	1	BCD description of wind, i.e. LOW, MEDIUM, or HIGH WIND
WMF	4	Radiating areas of a building. The subscript 1 indicates the northern radiating area, 2 the eastern area, 3 the southern area, and 4 the western area
WN1-4	1	Floating point variables WN1 for KWN1, WN2 for KWN2, WN3 for KWN3, and WN4 for KWN4
WS1-4	1	Floating point variables WS1 for KWS1, WS2 for KWS2, WS3 for KWS3, and WS4 for KWS4

SYMBOL	DIMENSION	MEANING
WW1-4	1	Floating point variables WW1 for KWW1, WW2 for KWW2, WW3 for KWW3, and WW4 for KWW4
X	1	Term using r=ratio of the distance between two buildings to the theoretical separation distance. The equation follows: x=1-r
Y	1	Theoretical separation distance in any of the four basic directions from a particular building
YE	1	Eastern theoretical separation distance from the building in question
YN	1	Northern theoretical separation distance
YS	1	Southern theoretical separation distance
YW	1	Western theoretical separation distance
YY	1	KTOTSQTP divided by one hundred
YZ	1	YY + ZZ
ZZ	1	KTOTSQSP divided by one hundred

SECTION 6

PROGRAM

FIREFLY 1

PROGRAM

```
      PROGRAM FIREFLY1
      DIMENSION               PRF(30,4,10),WMF(4),KCOUNT(30,4),
     1PRN1(30,4,10),PRN2(30,4,10),PRN3(30,4,10),PRN4(30,4,10),
     1PRE1(30,4,10),PRE2(30,4,10),PRE3(30,4,10),PRE4(30,4,10),
     1PRS1(30,4,10),PRS2(30,4,10),PRS3(30,4,10),PRS4(30,4,10),
     1PRW1(30,4,10),PRW2(30,4,10),PRW3(30,4,10),PRW4(30,4,10)
      COMMON/B0/WMF,       PRF,KCOUNT,PRN1,PRN2,PRN3,
     1PRN4/B1/PRE1,PRE2,PRE3,PRE4,PRS1,PRS2,PRS3,PRS4,PRW1,PRW2,PRW3,
     2PRW4
      BANK,(0),/B0/,WITH,KV CONS,PERP,(1),/B1/,FIRE2,AGNT
C---- TOTAL NUMBER OF BLDGS WITH LOT INFORMATION = N
      READ                    5,N
C---- TOTAL NUMBER OF BLOCKS = M
      READ                    5,M
    5 FORMAT (1H ,I4)
      READ 1,DMPHR,ANG
    1 FORMAT (F5,1,1X,F4.2)
      KSEQ1=0
      KPAGNTN=1
      DO 21 MM=1,M
   21 READ                    22,(KCOUNT(MM,J),J=1,4)
   22 FORMAT     (6X,I2,1X,I2,1X,I2,1X,I2)
      DO 371 II=1,N
      READ                    10,KBLK,KDIR,KLOT,    KWIDTH1,KWIDTH2,KSTY,KSB,K
     1OW,KCR,NUMN,KWN1,KWN2,KWN3,KWN4,NUME,KWE1,KWE2,KWE3,KWE4,NUMS,
     2KARD1
   10 FORMAT (I2,1X,I1,1X,I2,3X,      I3,1X,I3,     I2,1X,I3,1X,I1,1X,I1,
     11X,I1X,                 I1,1X,I3,1X,I3,1X,I3,1X,I3,1X,I1,1X,I3,1X,I3,
     11X,I3,1X,I3,1X,I1,3X,I1)
      IF (KARD1,NE,1) GO TO 14
      NBLK=KBLK
      NDIR=KDIR
      NLOT=KLOT
      READ                    23,KBLK,KDIR,KLOT,KWS1,KWS2,KWS3,KWS4,NUMW,
     1KWW1,KWW2,KWW3,KWW4,KO,KW,KF,KD,T,DM,KARD2
   23 FORMAT (I2,1X,I1,1X,I2,1X,I3,1X,I3,1X,I3,1X,I3,1X,I1,1X,I3,1X,I3,
     11X,I3,1X,I3,2X,I2,1X,I2,1X,I2,1X,I3,1X,F3,1,1X,F5.1,14X,I1)
      KD=100
      WB1=KWIDTH1
      WB2=KWIDTH2
      STY=KSTY
      IF (KARD2,NE,2) GO TO 14
C---- CHECKING TO SEE IF RECORDS IN ORDER
      IF (KLOT,NE,NLOT) GO TO 14
      IF (KDIR,NE,NDIR) GO TO 14
      IF (KBLK,NE,NBLK) GO TO 14
      DO 3710 MM=1,3
      DO 3710 NN=1,9,2
C---- PROB=PROB, OF BUILDING IGNITION FROM THERMAL PULSE
C---- ROOM IGNITION PROB=RII
      RNN=NN
      RII=RNN*,1
      EN=,0333* STY*(WB1+WB2)
      IF (MM-2) 2790,2860,2930
C----
C---- ANGLE OF ELEVATION = 30 DEGREES
```

```
C----
2790 IF (KSTY-14) 2810,2800,2800
2800 SHIELD=.94
     GO TO 2850
2810 IF (KSTY-12) 2813,2812,2811
2811 SHIELD=.90
     GO TO 2850
2812 SHIELD=.83
     GO TO 2850
2813 IF (KSTY-10) 2816,2815,2814
2814 SHIELD=.77
     GO TO 2850
2815 SHIELD=.70
     GO TO 2850
2816 IF (KSTY-8) 2819,2818,2817
2817 SHIELD=.63
     GO TO 2850
2818 SHIELD=.55
     GO TO 2850
2819 IF (KSTY-6) 2822,2821,2820
2820 SHIELD=.48
     GO TO 2850
2821 SHIELD=.42
     GO TO 2850
2822 IF (KSTY-4) 2825,2824,2823
2823 SHIELD=.37
     GO TO 2850
2824 SHIELD=.30
     GO TO 2850
2825 IF (KSTY-2) 2828,2827,2826
2826 SHIELD=.24
     GO TO 2850
2827 SHIELD=.20
     GO TO 2850
2828 SHIELD=.16
2850 P=RII*SHIELD
     KELEV=30
     GO TO 24
C----
C---- ANGLE OF ELEVATION =10 DEGREES
C----
2860 IF (KSTY-14) 2871,2870,2870
2870 SHIELD=.82
     GO TO 2920
2871 IF (KSTY-12) 2874,2873,2872
2872 SHIELD=.69
     GO TO 2920
2873 SHIELD=.58
     GO TO 2920
2874 IF (KSTY-10) 2877,2876,2875
2875 SHIELD=.45
     GO TO 2920
2876 SHIELD=.28
     GO TO 2920
2877 IF (KSTY-8) 2880,2879,2878
2878 SHIELD=.12
```

```
      GO TO 2920
 2879 SHIELD=.11
      GO TO 2920
 2880 IF (KSTY-5) 2883,2882,2881
 2881 SHIELD=.10
      GO TO 2920
 2882 SHIELD=.08
      GO TO 2920
 2883 IF (KSTY-2) 2886,2885,2884
 2884 SHIELD=.05
      GO TO 2920
 2885 SHIELD=.04
      GO TO 2920
 2886 SHIELD=.03
 2920 P=RII*SHIELD
      KELEV=10
      GO TO 24
C----
C---- ANGLE OF ELEVATION =5 DEGREES
C----
 2930 IF (KSTY-14) 2932,2931,2931
 2931 SHIELD=.73
      GO TO 2990
 2932 IF (KSTY-12) 2935,2934,2933
 2933 SHIELD=.62
      GO TO 2990
 2934 SHIELD=.50
      GO TO 2990
 2935 IF (KSTY-10) 2938,2937,2936
 2936 SHIELD=.35
      GO TO 2990
 2937 SHIELD=.20
      GO TO 2990
 2938 IF (KSTY-8) 2941,2940,2939
 2939 SHIELD=.12
      GO TO 2990
 2940 SHIELD=.10
      GO TO 2990
 2941 IF (KSTY-5) 2944,2943,2942
 2942 SHIELD=.10
      GO TO 2990
 2943 SHIELD=.06
      GO TO 2990
 2944 SHIELD=.03
 2990 P=RII*SHIELD
      KELEV=5
   24 IF (MM.EQ.1) GO TO 3706
      GO TO 370
 3706 IF (NN.EQ.1) GO TO 3718
      GO TO 370
 3718 KSEQ2=KBLK*1000+KDIR*100+KLOT
      IF (KSEQ2-KSEQ1) 14,25,25
   14 WRITE (6,20)
   20 FORMAT (1H0,40HTHERE IS AN ERROR IN SEQUENCING OF INPUT)
      GO TO 545
   25 KSEQ1=KSEQ2
```

```
   13 I=KBLN
      J=KDIR
   28 IF (II.NE.1) GO TO 15
      IF (ANG.EQ.0) GO TO 47
      IF (ANG-1.57) 30,32,34
   47 DMPHRE=DMPHR
      DMPHRN=0
      DMPHRS=0
      DMPHRW=-DMPHRE
      GO TO 15
   32 DMPHRN=DMPHR
      DMPHRE=0
      DMPHRS=-DMPHRN
      DMPHRW=0
      GO TO 15
   34 IF (ANG-3.14) 36,38,41
   38 DMPHRW=DMPHR
      DMPHRN=0
      DMPHRE=-DMPHRW
      DMPHRS=0
      GO TO 15
   41 IF (ANG-4.71) 42,43,44
   43 DMPHRS=DMPHR
      DMPHRN=-DMPHRS
      DMPHRE=0
      DMPHRW=0
      GO TO 15
   44 IF (ANG-6.28) 46,48,48
   48 ANG=6.28-ANG
      GO TO 28
C---- CONVERTS VECTOR INTO  NORTH, EAST SOUTH, AND WEST COMPONENTS
C---- BREAKS MPHR VECTOR INTO NORTH AND EAST COMPONENTS
   30 DMPHRE=COS(ANG)*DMPHR
      DMPHRN=SIN(ANG)*DMPHR
      DMPHRS=-DMPHRN
      DMPHRW=-DMPHRE
      GO TO 15
C---- BREAKS MPHR VECTOR INTO NORTH AND WEST COMPONENTS
   36 DMPHRW=COS(3.14-ANG)*DMPHR
      DMPHRN=SIN(3.14-ANG)*DMPHR
      DMPHRE=-DMPHRW
      DMPHRS=-DMPHRN
      GO TO 15
C---- BREAKS MPHR VECTOR INTO SOUTH AND WEST COMPONENTS
   42 DMPHRW=COS(ANG-3.14)*DMPHR
      DMPHRS=SIN(ANG-3.14)*DMPHR
      DMPHRN=-DMPHRS
      DMPHRE=-DMPHRW
      GO TO 15
C---- BREAKS MPHR VECTOR INTO SOUTH AND EAST COMPONENTS
   46 DMPHRE=COS(6.28-ANG)*DMPHR
      DMPHRS=SIN(6.28-ANG)*DMPHR
      DMPHRN=-DMPHRS
      DMPHRW=-DMPHRE
   15 IF (KPAGNTN-55) 18,18,19
   18 WRITE (6,16) DMPHR,ANG,DMPHRN,DMPHRE,DMPHRS,DMPHRW
```

```
   16 FORMAT (1H0,6H M/HR=,F5,1,5H ANG=,F4,2,7H M/HRN=,F6,1,7H M/HRE=,
     1F6,1,7H M/HRS=,F6,1,7H M/HRW=,F6,1)
      KPAGNTN=KPAGNTN+2
      GO TO 3719
   19 WRITE (6,17) DMPHR,ANG,DMPHRN,DMPHRE,DMPHRS,DMPHRW
   17 FORMAT (1H1,6H M/HR=,F5,1,5H ANG=,F4,2,7H M/HRN=,F6,1,7H M/HRE=,
     1F6,1,7H M/HRS=,F6,1,7H M/HRW=,F6,1)
      KPAGNTN=1
C---- FC COMPUTED
 3719 IF (KSB-300) 65,60,60
   60 FC=0
      GO TO 160
   65 IF (KSB-200) 75,70,70
   70 FC=.1
      GO TO 160
   75 IF (KSB-150) 85,80,80
   80 FC=.2
      GO TO 160
   85 IF (KSB-100) 95,90,90
   90 FC=.3
      GO TO 160
   95 IF (KSB-75) 105,100,100
  100 FC=.4
      GO TO 160
  105 IF (KSB-50) 115,110,110
  110 FC=.5
      GO TO 160
  115 IF (KSB-40) 125,120,120
  120 FC=.6
      GO TO 160
  125 IF (KSB-30) 135,130,130
  130 FC=.7
      GO TO 160
  135 IF (KSB-20) 145,140,140
  140 FC=.8
      GO TO 160
  145 IF (KSB-10) 155,150,150
  150 FC=.9
      GO TO 160
  155 FC=1.0
  160 WMF(1)=WB1*DM
      WMF(2)=WB2*DM
      WMF(3)=WMF(1)
      WMF(4)=WMF(2)
      WMF(KDIR)=WMF(KDIR)*FC
      IF (KSTY-2) 210,210,220
  210 KH=1
      GO TO 250
  220 IF (KSTY-5) 230,230,240
  230 KH=2
      GO TO 250
  240 KH=3
  250 IF (KCR-2) 260,270,280
  260 KRR=0
      GO TO 320
  270 KRR=10
```

```
      GO TO 320
  280 IF (KCR-4) 290,300,310
  290 KRR=20
      GO TO 320
  300 KRR=30
      GO TO 320
  310 KRR=40
  320 Q=KH*(KO+KW+KF)+KRR
      D=KD
C---- GAGE-BABCOCK INDEX CALCULATED
      BIN=Q*D*T*.01
      IF (BIN-150.) 350,340,340
  340 BIN=150.
C---- PROBABILITY OF BUILDING TO CATCH FIRE CALCULATED
  350 PRF(I,J,KLOT)=SIN(3.141593*BIN/300.)
C---- CALCULATE RADIATING AREA OF INDIVIDUAL BLDG.
      ARBLDG1=WMF(1)
      ARBLDG2=WMF(2)
      ARBLDG3=WMF(3)
      ARBLDG4=WMF(4)
C---- FLAME HEIGHTS IN 4 PARTS OF BUILDING CALCULATED
 3602 HF1=ARBLDG1/WB1
      HF2=ARBLDG2/WB2
      HF3=ARBLDG3/WB1
      HF4=ARBLDG4/WB2
      IF (HF1.EQ.0) GO TO 3606
C---- SHAPES OF RADIATOR CALCUALTED
      S1=WB1/HF1
      GO TO 3607
 3606 S1=0
 3607 IF (HF2.EQ.0) GO TO 3608
      S2=WB2/HF2
      GO TO 3610
 3608 S2=0
 3610 IF (HF3.EQ.0) GO TO 3616
      S3=WB1/HF3
      GO TO 3617
 3616 S3=0
 3617 IF (HF4.EQ.0) GO TO 3618
      S4=WB2/HF4
      GO TO 369
 3618 S4=0
C---- CLASSIFY COMPONENTS OF WIND VECTOR AS LOW, MEDIUM OR HIGH
  369 IF (DMPHRN) 1740,1740,1745
 1740 IF (DMPHRE) 1750,1750,1820
 1750 IF (DMPHRS-DMPHRW) 1770,1800,1800
 1745 IF (DMPHRE) 1785,1785,1775
 1775 IF (DMPHRN-DMPHRE) 1790,1780,1780
 1785 IF (DMPHRN-DMPHRW) 1760,1805,1805
 1820 IF (DMPHRE-DMPHRS) 1825,1830,1830
 1760 DMPHR=DMPHRW
      CALL KV CONS (DMPHR,KV)
      KVW=KV
      KVE=KV
      DMPHR=DMPHRN
      CALL KV CONS (DMPHR,KV)
```

```
      KVN=KV
      KVS=KV
      MAJDIR=4
      GO TO 730
 1770 DMPHR=DMPHRW
      CALL KV CONS (DMPHR,KV)
      KVW=KV
      KVE=KV
      DMPHR=DMPHRS
      CALL KV CONS (DMPHR,KV)
      KVS=KV
      KVN=KV
      MAJDIR=4
      GO TO 730
 1800 DMPHR=DMPHRS
      CALL KV CONS (DMPHR,KV)
      KVS=KV
      KVN=KV
      DMPHR=DMPHRW
      CALL KV CONS (DMPHR,KV)
      KVW=KV
      KVE=KV
      MAJDIR=3
      GO TO 730
 1760 DMPHR=DMPHRN
      CALL KV CONS (DMPHR,KV)
      KVN=KV
      KVS=KV
      DMPHR=DMPHRE
      CALL KV CONS (DMPHR,KV)
      KVE=KV
      KVW=KV
      MAJDIR=1
      GO TO 730
 1790 DMPHR=DMPHRE
      CALL KV CONS (DMPHR,KV)
      KVE=KV
      KVW=KV
      DMPHR=DMPHRN
      CALL KV CONS (DMPHR,KV)
      KVN=KV
      KVS=KV
      MAJDIR=2
      GO TO 730
 1805 DMPHR=DMPHRN
      CALL KV CONS (DMPHR,KV)
      KVN=KV
      KVS=KV
      DMPHR=DMPHRW
      CALL KV CONS (DMPHR,KV)
      KVW=KV
      KVE=KV
      MAJDIR=1
      GO TO 730
 1825 DMPHR=DMPHRS
      CALL KV CONS (DMPHR,KV)
```

```
      KVS=KV
      KVN=KV
      DMPHR=DMPHRE
      CALL KV CONS (DMPHR,KV)
      KVE=KV
      KVW=KV
      MAJDIR=3
      GO TO 730
 1830 DMPHR=DMPHRE
      CALL KV CONS (DMPHR,KV)
      KVE=KV
      KVW=KV
      DMPHR=DMPHRS
      CALL KV CONS (DMPHR,KV)
      KVS=KV
      KVN=KV
      MAJDIR=2
      GO TO 730
  730 DO 1597 JJ=1,16
      IF (JJ-4) 2000,2000,366
  366 IF (JJ-8) 2010,2010,367
  367 IF (JJ-12) 2020,2020,2030
 2000 IF (JJ.NE.1) GO TO 2007
      IF (NUMN.EQ.0) GO TO 9005
 2007 S=S1
      ARBLDG=ARBLDG1
      IF (JJ.NE.1) GO TO 364
      IF (DMPHRN) 700,700,720
  720 DMPHR=DMPHRN
      GO TO 2028
 2010 IF (JJ.NE.5) GO TO 2017
      IF (NUME.EQ.0) GO TO 9055
 2017 S=S2
      ARBLDG=ARBLDG2
      IF (JJ.NE.5) GO TO 364
      IF (DMPHRE) 700,700,750
  750 DMPHR=DMPHRE
      GO TO 2028
 2020 IF (JJ.NE.9) GO TO 2027
      IF (NUMS.EQ.0) GO TO 9105
 2027 S=S3
      ARBLDG=ARBLDG3
      IF (JJ.NE.9) GO TO 364
      IF (DMPHRS) 700,700,780
  780 DMPHR=DMPHRS
      GO TO 2028
 2030 IF (JJ.NE.13)GO TO 2037
      IF (NUMW.EQ.0) GO TO 9155
 2037 S=S4
      ARBLDG=ARBLDG4
      IF (JJ.NE.13)GO TO 364
      IF (DMPHRW) 700,700,860
  860 DMPHR=DMPHRW
 2028 IF (DMPHR -8.) 2035,2045,2040
 2035 KV=1
      GO TO 364
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 2040 IF (DMPHR -16.) 2045,2050,2050
 2045 KV=2
      GO TO 364
 2050 KV=3
      GO TO 364
  700 KV=1
C---- CALCULATION OF THEORETICAL SEPARATION DISTANCES
  364 IF (S-1.5) 1380,1425,1420
 1380 IF (KV-2) 1390,1400,1410
 1390 IF (ARBLDG-465.) 1393,1393,1394
 1393 Y=5.44*(ARBLDG/1000.)*10.
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-33.8(ARBLDG/1000)-2.53Y+15.7=0.  THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1394 DET=6.4009-4.*(-33.8*(ARBLDG/1000.)+15./)
      IF (DET) 1392,1395,1395
 1392 WRITE (6,393) I,J
  393 FORMAT (1H0,4HBLK ,I2,5H DIR ,I1,1X,21HY HAS NEG DETERMINANT)
      GO TO 3710
 1395 Y=(2.53+SQRT(DET))*5.
      GO TO 1500
 1400 IF (ARBLDG-1300.) 1401,1401,1402
 1401 Y=6.23*(ARBLDG/1000.)*10.
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-34.3(ARBLDG/1000)-8.1Y+44.6=0.    THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1402 DET=65.61-4.*(-34.3*(ARBLDG/1000.)+44.6)
      IF (DET) 1392,1405,1405
 1405 Y=(8.1+SQRT(DET))*5.
      GO TO 1500
 1410 IF (ARBLDG-2380.) 1411,1411,1412
 1411 Y=5.76*(ARBLDG/1000.)*10.
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-29.4(ARBLDG/1000)-13.75Y+69.9=0. THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1412 DET=189.0625-4.*(-29.4*(ARBLDG/1000.)+69.9)
      IF (DET) 1392,1415,1415
 1415 Y=(13.75+SQRT(DET))*5.
      GO TO 1500
 1420 IF (S-8.) 1425,1460,1460
 1425 IF (KV-2) 1430,1440,1450
 1430 IF (ARBLDG-725.) 1431,1431,1432
 1431 Y=4.63*(ARBLDG/1000.)*10.
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-29.3(ARBLDG/1000)-3.35Y+21.2=0.   THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1432 DET=11.2225-4.*(-29.3*(ARBLDG/1000.)+21.2)
      IF (DET) 1392,1435,1435
 1435 Y=(3.35+SQRT(DET))*5.
      GO TO 1500
 1440 IF (ARBLDG-1645.) 1441,1441,1442
 1441 Y=5.62*(ARBLDG/1000.)*10.
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      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-30,3(ARBLDG/1000)+9,25Y+49,8=0,  THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1442 DET=85,5625-4,*(-30,3*(ARBLDG/1000,)+49,8)
      IF (DET) 1392,1445,1445
 1445 Y=(9,25+SQRT(DET))*5,
      GO TO 1500
 1450 IF (ARBLDG-1110.) 1451,1451,1452
 1451 Y=8,46*(ARBLDG/1000,)*10,
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-33,2(ARBLDG/1000)+9,4Y+36,8=0,   THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1452 DET=88,36-4,*(-33,2*(ARBLDG/1000,)+36,8)
      IF (DET) 1392,1455,1455
 1455 Y=(9,4+SQRT(DET))*5,
      GO TO 1500
 1460 IF (KV-2) 1465,1475,1485
 1465 IF (ARBLDG-1420,) 1466,1466,1467
 1466 Y=4,45*(ARBLDG/1000,)*10,
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-21,9(ARBLDG/1000)+6,32Y+31,1=0,  THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1467 DET=39,9424-4,*(-21,9*(ARBLDG/1000,)+31,1)
      IF (DET) 1392,1470,1470
 1470 Y=(6,32+SQRT(DET))*5,
      GO TO 1500
 1475 IF (ARBLDG-2350,) 1476,1476,1477
 1476 Y=4,58*(ARBLDG/1000,)*10,
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-21,4(ARBLDG/1000)+10,76Y+50,2=0, THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1477 DET=115,7776-4,*(-21,4*(ARBLDG/1000,)+50,2)
      IF (DET) 1392,1480,1480
 1480 Y=(10,76+SQRT(DET))*5,
      GO TO 1500
 1485 IF (ARBLDG-2590,) 1486,1486,1487
 1486 Y=4,74*(ARBLDG/1000,)*10,
      GO TO 1500
C---- BELOW IS THE SOLUTION OF THE FOLLOWING EQUATION -
C---- Y**2-24,2(ARBLDG/1000)+12,28Y+62,75=0,THE FINAL Y EQUALS TEN TIMES
C---- THIS Y
 1487 DET=150,7984-4,*(-24,2*(ARBLDG/1000,)+62,75)
      IF (DET) 1392,1490,1490
 1490 Y=(12,28+SQRT(DET))*5,
 1500 IF (JJ-4) 1502,1507,1508
 1502 IF (JJ-2) 1503,1504,1505
 1503 YN=Y
      IF (KWN1) 2605,2600,2605
 2600 PRF(I,J,KLOT)=,98
      PRN1(I,J,KLOT)=1,
      GO TO 1587
 2605 WN1=KWN1
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      X=1.-WN1/Y
      IF (X-1.) 1560,1560,1559
 1559 X=1
      GO TO 930
 1560 IF (X) 925,930,930
  925 X=0
  930 IF (WN1-Y) 1565,6025,6025
 1565 KV=KVN
 1890 IF (MAJDIR-2) 1900,1905,1910
 1910 IF (MAJDIR-3) 1920,1920,1905
 1900 CALL WITH (KV,X,PR)
      GO TO 1368
 1905 CALL PERP(KV,X,PR)
      GO TO 1368
 1920 CALL AGNT (KV,X,PR)
      GO TO 1368
 6025 PRN1(I,J,KLOT)=0
      GO TO 1587
 1368 PRN1(I,J,KLOT)=PR
      GO TO 1587
 1504 YN=Y
      IF (KWN2) 2615,2610,2615
 2610 PRF(I,J,KLOT)=,98
      PRN2(I,J,KLOT)=1.
      GO TO 1587
 2615 WN2=KWN2
      X=1.-WN2/Y
      IF (X-1.) 1506,1506,1512
 1512 X=1
      GO TO 940
 1506 IF (X) 935,940,940
  935 X=0
  940 IF (WN2-Y) 1585,6055,6055
 1585 KV=KVN
      IF (MAJDIR-2) 1925,1930,1935
 1935 IF (MAJDIR-3) 1945,1945,1930
 1925 CALL WITH (KV,X,PR)
      GO TO 1369
 1930 CALL PERP (KV,X,PR)
      GO TO 1369
 1945 CALL AGNT (KV,X,PR)
      GO TO 1369
 6055 PRN2(I,J,KLOT)=0
      GO TO 1587
 1369 PRN2(I,J,KLOT)=PR
      GO TO 1587
 1505 YN=Y
      IF (KWN3) 2625,2620,2625
 2620 PRF(I,J,KLOT)=,98
      PRN3(I,J,KLOT)=1.
      GO TO 1587
 2625 WN3=KWN3
      X=1.-WN3/Y
      IF (X-1.) 870,870,865
  865 X=1
      GO TO 950
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 870 IF (X) 945,950,950
 945 X=0
 950 IF (WN3-Y) 1595,6085,6085
1595 KV=KVN
     IF (MAJDIR-2) 1950,1955,1960
1960 IF (MAJDIR-3) 1970,1970,1955
1950 CALL WITH (KV,X,PR)
     GO TO 1370
1955 CALL PERP (KV,X,PR)
     GO TO 1370
1970 CALL AGNT (KV,X,PR)
     GO TO 1370
6085 PRN3(I,J,KLOT)=0
     GO TO 1587
1370 PRN3(I,J,KLOT)=PR
     GO TO 1587
1507 YN=Y
     IF (KWN4) 2635,2630,2635
2630 PRF(I,J,KLOT)=,98
     PRN4(I,J,KLOT)=1,
     GO TO 1587
2635 WN4=KWN4
     X=1,-WN4/Y
     IF (X-1,) 880,880,875
 875 X=1
     GO TO 960
 880 IF (X) 955,960,960
 955 X=0
 960 IF (WN4-Y) 1605,6115,6115
1605 KV=KVN
     IF (MAJDIR-2) 1965,1975,1980
1980 IF (MAJDIR-3) 1990,1990,1975
1965 CALL WITH (KV,X,PR)
     GO TO 1371
1975 CALL PERP(KV,X,PR)
     GO TO 1371
1990 CALL AGNT (KV,X,PR)
     GO TO 1371
6115 PRN4(I,J,KLOT)=0
     GO TO 1587
1371 PRN4(I,J,KLOT)=PR
     GO TO 1587
1508 IF (JJ-8) 1670,1515,1516
1670 IF (JJ-6) 1509,1510,1511
1509 YE=Y
     IF (KWE1) 2645,2640,2645
2640 PRF(I,J,KLOT)=,98
     PRE1(I,J,KLOT)=1,
     GO TO 1587
2645 WE1=KWE1
     X=1,-WE1/Y
     IF (X-1,) 890,890,885
 885 X=1
     GO TO 970
 890 IF (X) 965,970,970
 965 X=0
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  970 IF (WE1-Y) 1625,6145,6145
 1625 KV=KVE
      IF (MAJDIR-2) 2070,2080,2090
 2090 IF (MAJDIR-3) 2070;2070,2110
 2070 CALL PERP(KV,X,PR)
      GO TO 1372
 2080 CALL WITH (KV,X,PR)
      GO TO 1372
 2110 CALL AGNT (KV,X,PR)
      GO TO 1372
 6145 PRE1(I,J,KLOT)=0
      GO TO 1587
 1372 PRE1(I,J,KLOT)=PR
      GO TO 1587
 1510 YE=Y
      IF (KWE2) 2655,2650,2655
 2650 PRF(I,J,KLOT)=.98
      PRE2(I,J,KLOT)=1.
      GO TO 1587
 2655 WE2=KWE2
      X=1.-WE2/Y
      IF (X-1.) 1622,1622,1623
 1623 X=1
      GO TO 980
 1622 IF (X) 975,980,980
  975 X=0
  980 IF (WE2-Y) 1635,6175,6175
 1635 KV=KVE
      IF (MAJDIR-2) 2095,2100,2105
 2105 IF (MAJDIR-3) 2095,2095,2120
 2095 CALL PERP (KV,X,PR)
      GO TO 1373
 2100 CALL WITH (KV,X,PR)
      GO TO 1373
 2120 CALL AGNT (KV,X,PR)
      GO TO 1373
 6175 PRE2(I,J,KLOT)=0
      GO TO 1587
 1373 PRE2(I,J,KLOT)=PR
      GO TO 1587
 1511 YE=Y
      IF (KWE3) 2665,2660,2665
 2660 PRF(I,J,KLOT)=.98
      PRE3(I,J,KLOT)=1.
      GO TO 1587
 2665 WE3=KWE3
      X=1.-WE3/Y
      IF (X-1.) 895,895,1580
 1580 X=1
      GO TO 990
  895 IF (X) 985,990,990
  985 X=0
  990 IF (WE3-Y) 1644,6205,6205
 1644 KV=KVE
      IF (MAJDIR-2) 2130,2135,2140
 2140 IF (MAJDIR-3) 2130,2130,2145
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 2130 CALL PERP (KV,X,PR)
      GO TO 1374
 2135 CALL WITH (KV,X,PR)
      GO TO 1374
 2145 CALL AGNT (KV,X,PR)
      GO TO 1374
 6205 PRE3(I,J,KLOT)=0
      GO TO 1587
 1374 PRE3(I,J,KLOT)=PR
      GO TO 1587
 1515 YE=Y
      IF (KWE4) 2675,2670,2675
 2670 PRF(I,J,KLOT)=,98
      PRE4(I,J,KLOT)=1.
      GO TO 1587
 2675 WE4=KWE4
      X=1.-WE4/Y
      IF (X-1.) 905,905,900
  900 X=1
      GO TO 1000
  905 IF (X) 995,1000,1000
  995 X=0
 1000 IF (WE4-Y) 1655,6235,6235
 1655 KV=KVE
      IF (MAJDIR-2) 2150,2155,2160
 2160 IF (MAJDIR-3) 2150,2150,2165
 2150 CALL PERP (KV,X,PR)
      GO TO 1375
 2155 CALL WITH (KV,X,PR)
      GO TO 1375
 2165 CALL AGNT (KV,X,PR)
      GO TO 1375
 6235 PRE4(I,J,KLOT)=0
      GO TO 1587
 1375 PRE4(I,J,KLOT)=PR
      GO TO 1587
 1516 IF (JJ-12) 1517,1521,1523
 1517 IF (JJ-10) 1662,1518,1520
 1662 YS=Y
      IF (KWS1) 2685,2680,2685
 2680 PRF(I,J,KLOT)=,98
      PRS1(I,J,KLOT)=1.
      GO TO 1587
 2685 WS1=KWS1
      X=1.-WS1/Y
      IF (X-1.) 1529,1529,1531
 1531 X=1
      GO TO 1010
 1529 IF (X) 1005,1010,1010
 1005 X=0
 1010 IF (WS1-Y) 1665,6265,6265
 1665 KV=KVS
      IF (MAJDIR-2) 2170,2175,2180
 2180 IF (MAJDIR-3) 2185,2185,2175
 2170 CALL AGNT (KV,X,PR)
      GO TO 1376
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2175 CALL PERP (KV,X,PR)
     GO TO 1376
2185 CALL WITH (KV,X,PR)
     GO TO 1376
6265 PRS1(I,J,KLOT)=0
     GO TO 1587
1376 PRS1(I,J,KLOT)=PR
     GO TO 1587
1518 YS=Y
     IF (KWS2) 2695,2690,2695
2690 PRF(I,J,KLOT)=,98
     PRS2(I,J,KLOT)=1,
     GO TO 1587
2695 WS2=KWS2
     X=1,-WS2/Y
     IF (X-1,) 1534,1534,1536
1536 X=1
     GO TO 1020
1534 IF (X) 1015,1020,1020
1015 X=0
1020 IF (WS2-Y) 1675,6295,6295
1675 KV=KVS
     IF (MAJDIR-2) 2190,2195,2200
2200 IF (MAJDIR-3) 2205,2205,2195
2190 CALL AGNT (KV,X,PR)
     GO TO 1377
2195 CALL PERP (KV,X,PR)
     GO TO 1377
2205 CALL WITH (KV,X,PR)
     GO TO 1377
6295 PRS2(I,J,KLOT)=0
     GO TO 1587
1377 PRS2(I,J,KLOT)=PR
     GO TO 1587
1520 YS=Y
     IF (KWS3) 3005,3000,3005
3000 PRF(I,J,KLOT)=,98
     PRS3(I,J,KLOT)=1,
     GO TO 1587
3005 WS3=KWS3
     X=1,-WS3/Y
     IF (X-1,) 1533,1533,1532
1532 X=1
     GO TO 1030
1533 IF (X) 1025,1030,1030
1025 X=0
1030 IF (WS3-Y) 1685,6325,6325
1685 KV=KVS
     IF (MAJDIR-2) 2210,2215,2220
2220 IF (MAJDIR-3) 2225,2225,2215
2210 CALL AGNT (KV,X,PR)
     GO TO 1378
2215 CALL PERP (KV,X,PR)
     GO TO 1378
2225 CALL WITH (KV,X,PR)
     GO TO 1378
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6325 PRS3(I,J,KLOT)=0
     GO TO 1587
1376 PRS3(I,J,KLOT)=PR
     GO TO 1587
1521 YS=Y
     IF (KWS4) 3015,3010,3015
3010 PRF(I,J,KLOT)=.98
     PRS4(I,J,KLOT)=1.
     GO TO 1587
3015 WS4=KWS4
     X=1.-WS4/Y
     IF (X-1.) 915,915,910
 910 X=1
     GO TO 1040
 915 IF (X) 1035,1040,1040
1035 X=0
1040 IF (WS4-Y) 1695,6355,6355
1695 KV=KVS
     IF (MAJDIR-2) 2230,2235,2240
2240 IF (MAJDIR-3) 2245,2245,2235
2230 CALL AGNT (KV,X,PR)
     GO TO 1360
2235 CALL PERP (KV,X,PR)
     GO TO 1360
2245 CALL WITH (KV,X,PR)
     GO TO 1360
6355 PRS4(I,J,KLOT)=0
     GO TO 1587
1360 PRS4(I,J,KLOT)=PR
     GO TO 1587
1523 IF (JJ.EQ,16) GO TO 1527
     IF (JJ-14) 1664,1524,1526
1664 YW=Y.
     IF (KWW1) 3025,3020,[illegible]
3020 PRF(I,J,KLOT)=.98
     PRW1(I,J,KLOT)=1.
     GO TO 1587
3025 WW1=KWW1
     X=1.-WW1/Y
     IF (X-1.) [illegible],1541,1539
1539 X=1
     GO TO 1050
1541 IF (X) 1045,1050,1050
1045 X=0
1050 IF (WW1-Y) 1705,6385,6385
1705 KV=KVW
     IF (MAJDIR-2) 2250,2255,2260
2260 IF (MAJDIR-3) 2250,2250,2265
2250 CALL PERP (KV,X,PR)
     GO TO 1361
2255 CALL AGNT (KV,X,PR)
     GO TO 1361
2265 CALL WITH (KV,X,PR)
     GO TO 1361
6385 PRW1(I,J,KLOT)=0
     GO TO 1587
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1361 PRW1(I,J,KLOT)=PR
     GO TO 1587
1524 YW=Y
     IF (KWW2) 3035,3030,3035
3030 PRF(I,J,KLOT)=,98
     PRW2(I,J,KLOT)=1,
     GO TO 1587
3035 WW2=KWW2
     X=1,-WW2/Y
     IF (X-1,) 1542,1542,1543
1543 X=1
     GO TO 1060
1542 IF (X) 1055,1060,1060
1055 X=0
1060 IF (WW2-Y) 1715,6415,6415
1715 KV=KVW
     IF (MAJDIR-2) 2270,2275,2280
2280 IF (MAJDIR-3) 2270,2270,2285
2270 CALL PERP (KV,X,PR)
     GO TO 1362
2275 CALL AGNT (KV,X,PR)
     GO TO 1362
2285 CALL WITH (KV,X,PR)
     GO TO 1362
6415 PRW2(I,J,KLOT)=0
     GO TO 1587
1362 PRW2(I,J,KLOT)=PR
     GO TO 1587
1526 YW=Y
     IF (KWW3) 3045,3040,3045
3040 PRF(I,J,KLOT)=,98
     PRW3(I,J,KLOT)=1,
     GO TO 1587
3045 WW3=KWW3
     X=1,-WW3/Y
     IF (X-1,) 1544,1544,1546
1546 X=1
     GO TO 1070
1544 IF (X) 1065,1070,1070
1065 X=0
1070 IF (WW3-Y) 1725,6445,6445
1725 KV=KVW
     IF (MAJDIR-2) 2290,2295,2300
2300 IF (MAJDIR-3) 2290,2290,2305
2290 CALL PERP (KV,X,PR)
     GO TO 1363
2295 CALL AGNT (KV,X,PR)
     GO TO 1363
2305 CALL WITH (KV,X,PR)
     GO TO 1363
6445 PRW3(I,J,KLOT)=0
     GO TO 1587
1363 PRW3(I,J,KLOT)=PR
     GO TO 1587
1527 YW=Y
     IF (KWW4) 3055,3050,3055
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3050 PRF(I,J,KLOT)=,98
     PRW4(I,J,KLOT)=1,
     GO TO 1587
3755 WW4=KWW4
     X=1,-WW4/Y
     IF (X-1,) 1547,1547,1548
1548 X=1
     GO TO 1080
1547 IF (X) 1075,1080,1080
1075 X=0
1080 IF (WW4-Y) 1735,6475,6475
1735 IF (MAJDIR-2) 2310,2315,2320
2320 IF (MAJDIR-3) 2310,2310,2325
2310 CALL PERP (KV,X,PR)
     GO TO 1364
2315 CALL AGNT (KV,X,PR)
     GO TO 1364
2325 CALL WITH (KV,X,PR)
     GO TO 1364
6475 PRW4(I,J,KLOT)=0
     GO TO 1587
1364 PRW4(I,J,KLOT)=PR
     GO TO 1587
1587 IF (JJ-NUMN) 1597,9000,9010
9000 IF (NUMN,EQ.4) GO TO 1597
     IF (NUMN-2) 9020,9030,9040
9005 PRN1(I,J,KLOT)=0
9020 PRN2(I,J,KLOT)=0
9030 PRN3(I,J,KLOT)=0
9040 PRN4(I,J,KLOT)=0
     JJ=4
     GO TO 1597
9010 IF (JJ-4-NUME) 1597,9050,9060
9050 IF (NUME,EQ.4) GO TO 1597
     IF (NUME-2) 9070,9080,9090
9055 PRE1(I,J,KLOT)=0
9070 PRE2(I,J,KLOT)=0
9080 PRE3(I,J,KLOT)=0
9090 PRE4(I,J,KLOT)=0
     JJ=8
     GO TO 1597
9060 IF (JJ-8-NUMS) 1597,9100,9110
9100 IF (NUMS,EQ.4) GO TO 1597
     IF (NUMS-2) 9120,9130,9140
9105 PRS1(I,J,KLOT)=0
9120 PRS2(I,J,KLOT)=0
9130 PRS3(I,J,KLOT)=0
9140 PRS4(I,J,KLOT)=0
     JJ=12
     GO TO 1597
9110 IF (JJ-12-NUMW) 1597,9150,1597
9150 IF (NUMW,EQ.4) GO TO 1597
     IF (NUMW-2) 9170,9180,9190
9155 PRW1(I,J,KLOT)=0
9170 PRW2(I,J,KLOT)=0
9180 PRW3(I,J,KLOT)=0
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 9190 PRW4(I,J,KLOT)=0
      JJ=10
 1997 CONTINUE
  370 PROB=(1.-((1.-P)**EN))*PRF(KBLK,KDIR,KLOT)
 3708 IF (KPAGNTN-55) 3709,3707,3707
 3709 WRITE (6,3711) KELEV,RII,PROB
 3711 FORMAT (1H0,20HANGLE OF ELEVATION= ,I2,9H DEGREES ,6X,22H ROOM IGN
     1ITION PROB.= ,F4.2,6X,55H  PROBABILITY OF BUILDING IGNITION FROM T
     2HERMAL PULSE= ,F8.6,3X)
      KPAGNTN=KPAGNTN+2
      GO TO 3710
 3707 WRITE (6,3715) KELEV,RII,PROB
 3715 FORMAT (1H1,20HANGLE OF ELEVATION= ,I2,9H DEGREES ,6X,22H ROOM IGN
     1ITION PROB.= ,F4.2,6X,55H  PROBABILITY OF BUILDING IGNITION FROM T
     2HERMAL PULSE= ,F8.6,3X)
      KPAGNTN=2
 3710 CONTINUE
 1270 WRITE (6,6)
    6 FORMAT (1H0,119HBLOCK  DIREC-  LOT  NORTH   EAST    SOUTH   WEST
     1    RADIATING  FIRE      GAGE-BAB-      FLAME       RADIATOR  SEPARAT
     2ION,/,      1H ,7X,112HTION    NO,   SPREAD  SPREAD  SPREAD   SPREA
     3D       AREA     PROB-     COCK INDEX      HEIGHT          SHAPE     DISTA
     4NCE ,/,1H ,64X,7HABILITY)
 1275 WRITE (6,1260) I,J,KLOT,PRN1(I,J,KLOT),PRE1(I,J,KLOT),PRS1(I,J,KLO
     1T),PRW1(I,J,KLOT),ARBLDG1,PRF(I,J,KLOT),BIN,HF1,S1,YN
 1260 FORMAT (1H0,2X,I2,5X,I1,6X,I2,2X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,
     1F10.3,3X,F6.4,2X,F10.3,2X,F10.3,2X,F10.3,2X,F10.3)
      WRITE (6,1265) PRN2(I,J,KLOT),PRE2(I,J,KLOT),PRS2(I,J,KLOT),
     1PRW2(I,J,KLOT),ARBLDG2,HF2,S2,YE
 1265 FORMAT (1H ,20X,F6.4,2X,F6.4,2X,F6.4,2X,F6.4,2X,F10.3,23X,F10.3,
     12X,F10.3,2X,F10.3)
      WRITE (6,1265) PRN3(I,J,KLOT),PRE3(I,J,KLOT),PRS3(I,J,KLOT),PRW3(I
     1,J,KLOT),ARBLDG3,HF3,S3,YS
      WRITE (6,1265) PRN4(I,J,KLOT),PRE4(I,J,KLOT),PRS4(I,J,KLOT),
     1PRW4(I,J,KLOT),ARBLDG4,HF4,S4,YW
      KPAGNTN=KPAGNTN+12
  371 CONTINUE
  545 REWIND 27
      END
```

```
      SUBROUTINE AINT(KV,X,PR)
[illegible] IF (KV-2) 420,410,400
  400 IF (X-,85) 405,408,408
  408 IF (6,667*X-5,667) 405,405,409
  409 PR=6,667*X-5,667
      GO TO 430
  410 IF (X-,80) 405,418,418
  418 IF (5,0*X-4,0) 405,405,419
  419 PR=5,0*X-4,0
      GO TO 430
  420 IF (X-,75) 405,428,428
  428 IF (4,0*X-3,0) 405,405,429
  429 PR=4,0*X-3,0
      GO TO 430
  405 PR=0
  430 END
```

```
      SUBROUTINE PFRP(KV,X,PR)
  440 IF (KV-2) 480,442,515
  442 IF (X-.98) 448,448,518
  448 IF (X-.935) 453,453,450
  450 IF (4.4*X-3.35) 553,553,452
  452 PR=4.4 *X-3.35
      GO TO 555
  453 IF (X-.86) 458,458,455
  455 IF (4.0*X-2.94) 553,553,457
  457 PR=4.0*X-2.94
      GO TO 555
  458 IF (X-.79) 463,463,460
  460 IF (2.14*X-1.35) 553,553,462
  462 PR=2.14*X-1.35
      GO TO 555
  463 IF (X-.63) 468,468,465
  465 IF (1.25*X-0.63) 553,553,467
  467 PR=1.25*X-0.63
      GO TO 555
  468 IF (X-.40) 553,553,470
  470 IF (.652*X-.258) 553,553,472
  472 PR=.652*X-.258
      GO TO 555
  480 IF (X-.97) 485,485,518
  485 IF (X-.92) 490,490,488
  488 IF (4.0*X-3.88) 553,553,489
  489 PR=4.0*X-3.88
      GO TO 555
  490 IF (X-.84) 495,495,493
  493 IF (3.75*X-2.67) 553,553,494
  494 PR=3.75*X-2.67
      GO TO 555
  495 IF (X-.75) 500,500,498
  498 IF (1.67*X-.90) 553,553,499
  499 PR=1.67*X-.90
      GO TO 555
  500 IF (X-.52) 505,505,503
  503 IF (1.09*X-.47) 553,553,504
  504 PR=1.09*X-.47
      GO TO 555
  505 IF (X-.36) 553,553,508
  508 IF (.625*X-.235) 553,553,509
  509 PR=.625*X-.235
      GO TO 555
  515 IF (X-.99 ) 520,520,518
  518 PR=1
      GO TO 555
  520 IF (X-.95) 525,525,523
  523 IF (5.*X-3.95) 553,553,524
  524 PR=5.*X-3.95
      GO TO 555
  525 IF (X-.88) 530,530,528
  528 IF (4.*X-3.) 553,553,529
  529 PR=4.*X-3.
      GO TO 555
  530 IF (X-.82) 535,535,533
```

```
533 IF (2,5*X-1,68) 553,553,534
534 PR=2,5*X-1,68
    GO TO 555
535 IF (X-,70) 540,540,538
538 IF (1,5*X-,82) 553,553,539
539 PR=1,5*X-,82
    GO TO 555
540 IF (X-,54) 548,548,543
543 IF (,875*X-.415) 553,553,544
544 PR=,875*X-,415
    GO TO 555
548 IF (X-,44) 553,553,550
550 IF (,5*X-.22) 553,553,551
551 PR=,5*X-,22
    GO TO 555
553 PR=0
555 END
```

```
      SUBROUTINE WITH(KV,X,PR)
  560 IF (KV-2) 563,595,628
  563 IF (X-,95) 566,566,630
  566 IF (X-,91) 573,573,570
  570 IF (4,44*X-3,24) 658,658,571
  571 PR=4,44 *X-3,24
      GO TO 665
  573 IF (X-,81) 578,578,575
  575 IF (3,0*X-1,86) 658,658,576
  576 PR=3,0*X-1,86
      GO TO 665
  578 IF (X-,71) 583,583,580
  580 IF (1,5*X-,71) 658,658,581
  581 PR=1,5*X-,71
      GO TO 665
  583 IF (X-,45) 588,588,585
  585 IF (,96*X-,34) 658,658,586
  586 PR=,96*X-,34
      GO TO 665
  588 IF (X-,27) 658,658,590
  590 IF (,556*X-,156) 658,658,591
  591 PR=,556*X-,156
      GO TO 665
  595 IF (X-,94) 600,600,630
  600 IF (X-,89) 605,605,603
  603 IF (4,0*X-2,76) 658,658,604
  604 PR=4,0*X-2,76
      GO TO 665
  605 IF (X-,77) 610,610,608
  608 IF (2,5*X-1,425) 658,658,609
  609 PR=2,5*X-1,425
      GO TO 665
  610 IF (X-,66) 615,615,613
  613 IF (1,364*X-,554) 658,658,614
  614 PR=1,364*X-,554
      GO TO 665
  615 IF (X-,37) 620,620,618
  618 IF (,862*X-,221) 658,658,619
  619 PR=,862*X-,221
      GO TO 665
  620 IF (X-,17) 658,658,623
  623 IF (,40*X+,01) 658,658,624
  624 PR=,40*X+,01
      GO TO 665
  628 IF (X-,92) 633,633,630
  630 PR=1
      GO TO 665
  633 IF (X-,86) 638,638,635
  635 IF (3,33*X-2,067) 658,658,636
  636 PR=3,33*X-2,067
      GO TO 665
  638 IF (X-,67) 643,643,640
  640 IF (2,143*X-1,036) 658,658,641
  641 PR=2,143*X-1,036
      GO TO 665
  643 IF (X-,58) 648,648,645
```

```
645 IF (1.071*X-.268) 658,658,646
646 PR=1.071*X-.268
    GO TO 665
648 IF (X-.26) 653,653,650
650 IF (.761*X-.103) 658,658,651
651 PR=.761*X-.103
    GO TO 665
653 IF (X) 658,658,655
655 IF (.384*X-.001) 658,658,656
656 PR=.384*X-.001
    GO  TO 665
658 PR=0
665 END
```

```
      SUBROUTINE KV CONS (DMPHR,KV)
      IF (DMPHR-8.) 2035,2045,2040
 2035 KV=1
      GO TO 2060
 2040 IF (DMPHR-16.) 2045,2050,2050
 2045 KV=2
      GO TO 2060
 2050 KV=3
 2060 END
```

FIREFLY 2

PROGRAM

```
      PROGRAM FIREFLY2
      DIMENSION KC(27,4),KFR(27,4,10),PRN1(27,4,10),PRN2(27,4,10),
     1PRN3(27,4,10),PRN4(27,4,10),PRE1(27,4,10),PRE2(27,4,10),
     2PRE3(27,4,10),PRE4(27,4,10),PRS1(27,4,10),PRS2(27,4,10),
     3PRS3(27,4,10),PRS4(27,4,10),PRW1(27,4,10),PRW2(27,4,10),
     4PRW3(27,4,10),PRW4(27,4,10),NBN1(27,4,10),NBN2(27,4,10),NBN3(27,4,
     510),NBN4(27,4,10),NBE1(27,4,10),NBE2(27,4,10),NBE3(27,4,10),
     6NBE4(27,4,10),NBS1(27,4,10),NBS2(27,4,10),NBS3(27,4,10),NBS4(27,4,
     710),NBW1(27,4,10),NBW2(27,4,10),NBW3(27,4,10),NBW4(27,4,10),
     8     KBDG(108),        ADR1(27,4,10),ADR2(27,4,10),PRF(27,4,10),
     9PRB(27,4,10),KR(27,4,10),TPSP(27,4,10)
      COMMON/B0/PRN1,PRN2,PRN3,PRN4,PRE1,PRE2,PRE3,PRE4,PRS1,PRS2,PRS3,
     1PRS4,PRW1   /B1/PRW2,   PRW3,PRW4,NBN1,NBN2,NBN3,NBN4,NBE1,NBE2,
     2NBE3,NBE4,NBS1,NBS2,NBS3,NBS4,NBW1,NBW2,NBW3,NBW4,KC,KFR,KBDG,PRF,
     3PRB,ADR1,ADR2,KR,TPSP
      BANK,(0),/B0/,(1),/B1/,FIRESP
C---- KWRITE=1 IF WANT INTERMEDIATE STEPS WRITTEN OUT,
C---- OTHERWISE KWRITE=0.
      KWRITE=0
      READ                  10,RANDOM1,RANDOM2
   10 FORMAT (F8.6,1X,F8.6)
      READ                  20,N
      READ                  20,M
   20 FORMAT (I4)
      DO 30 I=1,M
   30 READ                  35,(KC(I,J),J=1,4)
   35 FORMAT (6X,I2,1X,I2,1X,I2,1X,I2)
      DO 25 I=1,M
      DO 25 J=1,4
      KK=KC(I,J)
      IF (KK.EQ.0) GO TO 25
      DO 25 K=1,KK
      KR(I,J,K)=0
   25 CONTINUE
      READ 26,NDETAIL
   26 FORMAT (I3)
      IF (NDETAIL.EQ.0) GO TO 48
      DO   28 II=1,NDETAIL
      READ 27,I,J,K
   27 FORMAT (I2,1X,I1,1X,I2)
   28 KR(I,J,K)=1
   48 WRITE (6,50)
   50 FORMAT (1H1,39HGENERAL COMMENTS ON FIRE SPREAD PROGRAM,/,1H0,4X,
     110HDIRECTIONS,/,1H0,6X,7H1=NORTH,/,1H0,6X,6H2=EAST,/,1H0,6X,7H3=SO
     2UTH,/,1H0,6X,6H4=WEST)
      WRITE (6,60) RANDOM1,RANDOM2
   60 FORMAT (1H0,40HTHE FIRST AND SECOND RANDOM NUMBERS ARE ,F8.6,
     15H AND ,F8.6,1H.)
   80 DO 120 II=1,N
      READ                 110,I,J,K,NBN3(I,J,K),NBN4(I,J,K),NBE1(I,J,K),
     1NBE2(I,J,K),NBE3(I,J,K),NBE4(I,J,K),NBS1(I,J,K),NBS2(I,J,K),
     2NBS3(I,J,K),NBS4(I,J,K),NBW1(I,J,K),KARD3
  110 FORMAT (I2,1X,I1,1X,I2,1X,I5,1X,I5,1X,I5,1X,I5,1X,I5,1X,I5,1X,I5,
     11X,I5,1X,I5,1X,I5,1X,I5,6X,I1)
      READ                 115,I,J,K,NBW2(I,J,K),NBW3(I,J,K),NBW4(I,J,K),
     1ADR1(I,J,K),ADR2(I,J,K),CTY1,CTY2,    NBN1(I,J,K),NBN2(I,J,K),
```

```
12? FORMAT (I2,1X,I1,1X,I2,1X,I5,1X,I5,1X,I5,1X,A6,A6,1X,A6,A6,1X,
   1?X,6X,I5,1X,I5,2X,I1)
12? CONTINUE
    DO 6?5 MM=1,3
    DO 5?? NN=1,5
    DO 122 I=1,M
    DO 122 J=1,4
    IF (KC(I,J).EQ.0) GO TO 122
    KK=KC(I,J)
    DO 122 K=1,KK
    TPSP(I,J,K)=0.0
122 CONTINUE
1200 DO 1320 II=1,N
    IF (MM-2) 1205,1240,1275
1205 IF (NN-2) 1210,1215,1220
1210 READ INPUT TAPE 10,1212,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
   1PRE1(I,J,K),PRS1(I,J,K),
   1            PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
   2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
   3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1212 FORMAT (/                  21X,I2,37X,F4,2,61X,F8,6//////////////////
   13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
   1F6,4,2X,F6,4,15X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
   22X,F6.4,2X,F6.4,2X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
    GO TO 1310
1215 READ INPUT TAPE 10,1217,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
   1PRE1(I,J,K),PRS1(I,J,K),
   1            PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
   2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
   3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1217 FORMAT (//                 21X,I2,37X,F4,2,61X,F8,6/ ////////////////
   13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
   1F6,4,2X,F6,4,15X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
   22X,F6,4,2X,F6.4,2X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
    GO TO 1310
1220 IF (NN-4) 1225,1230,1235
1225 READ INPUT TAPE 10,1227,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
   1PRE1(I,J,K),PRS1(I,J,K),
   1            PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
   2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
   3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1227 FORMAT (///                21X,I2,37X,F4,2,61X,F8,6/  ///////////////
   13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
   1F6,4,2X,F6,4,15X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
   22X,F6,4,2X,F6.4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
    GO TO 1310
1230 READ INPUT TAPE 10,1232,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
   1PRE1(I,J,K),PRS1(I,J,K),
   1            PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
   2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
   3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1232 FORMAT (////               21X,I2,37X,F4,2,61X,F8,6/   //////////////
   13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
   1F6,4,2X,F6,4,15X,F6.4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
   22X,F6,4,2X,F6.4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
```

```
      GO TO 1310
 1235 READ INPUT TAPE 10,1237,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
 1237 FORMAT (/////             21X,I2,37X,F4,2,61X,F8,6/    /////////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
 1240 IF (NN-2) 1245,1250,1255
 1245 READ INPUT TAPE 10,1247,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
 1247 FORMAT (//////            21X,I2,37X,F4,2,61X,F8,6/    ////////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
 1250 READ INPUT TAPE 10,1252,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
 1252 FORMAT (///////           21X,I2,37X,F4,2,61X,F8,6/    ///////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
 1255 IF (NN-4) 1260,1265,1270
 1260 READ INPUT TAPE 10,1262,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
 1262 FORMAT (////////          21X,I2,37X,F4,2,61X,F8,6/    //////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
 1265 READ INPUT TAPE 10,1267,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
 1267 FORMAT (/////////         21X,I2,37X,F4,2,61X,F8,6/    /////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
 1270 READ INPUT TAPE 10,1272,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1           PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
```

```
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1272 FORMAT (//////////     21X,I2,37X,F4,2,61X,F8,6/          ////////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
1275 IF (NN-2) 1280,1285,1290
1280 READ INPUT TAPE 10,1282,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1          PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1282 FORMAT (///////////    21X,I2,37X,F4,2,61X,F8,6/           ///////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
1285 READ INPUT TAPE 10,1287,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1          PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1287 FORMAT (////////////   21X,I2,37X,F4,2,61X,F8,6/            //////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
1290 IF (NN-4) 1295,1300,1305
1295 READ INPUT TAPE 10,1297,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1          PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1297 FORMAT (/////////////  21X,I2,37X,F4,2,61X,F8,6/             /////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
1300 READ INPUT TAPE 10,1302,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1          PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1302 FORMAT (////////////// 21X,I2,37X,F4,2,61X,F8,6/              ////
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
     1F6,4,2X,F6,4,15X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
      GO TO 1310
1305 READ INPUT TAPE 10,1307,KELEV,RI,PROB,I,J,K,PRN1(I,J,K),
     1PRE1(I,J,K),PRS1(I,J,K),
     1          PRW1(I,J,K),PRF(I,J,K),PRN2(I,J,K),PRE2(I,J,K),PRS2(I,J,K)
     2,PRW2(I,J,K),PRN3(I,J,K),PRE3(I,J,K),PRS3(I,J,K),PRW3(I,J,K),
     3PRN4(I,J,K),PRE4(I,J,K),PRS4(I,J,K),PRW4(I,J,K)
1307 FORMAT (///////////////21X,I2,37X,F4,2,61X,F8,6/               ///
     13X,I2,5X,I1,6X,I2,2X,F6,4,2X,F6,4,2X,
```

```
     1F6,4,2X,F6,4,15X,F6.4/21X,F6,4,2X,F6,4,2X,F6.4,2X,F6,4/21X,F6,4,
     22X,F6,4,2X,F6,4,2X,F6,4/21X,F6,4,2X,F6,4,2X,F6,4,2X,F6,4)
 1310 PRB(I,J,K)=PROB
 1320 CONTINUE
      DO 807 JJ=1,100
      DO 127 I=1,M
      DO 127 J=1,4
      IF (KC(I,J),EQ,0) GO TO 127
      KK=KC(I,J)
      DO 125 K=1,KK
  125 KFR(I,J,K)=0
  127 CONTINUE
      NUMTPF=0
      NCOUNT=0
      NTOTAL=0
      IF (KWRITE,EQ,0) GO TO 132
      WRITE (6,130)
  130 FORMAT (1H1,119HBLOCK  DIREC- LOT      ADDRESS     FIFTH    THERMAL
     1 FOURTH  SPREAD    FIRST   BURN PROBABILITY  2ND      FIRE    FIRE CAU
     2GHT/1H ,8X,111HTION    NO,                  RANDOM    PULSE    RANDOM
     3PROBAB-  RANDOM     FROM SPREAD     RANDM             FROM BLDG  /1H ,
     434X,6HNUMBER,11X,6HNUMBER,2X,15HILITY    NUMBER,20X,5HNUMB,, 9X,
     511HBLK DIR LOT)
      KPAGNTN=3
C---- THERMAL PULSE CONSIDERATION
  132 DO 180 I=1,M
      DO 180 J=1,4
      IF (KC(I,J),EQ,0) GO TO 180
      KK=KC(I,J)
      DO 180 K=1,KK
      RANDOM5=RANDOM1+RANDOM2
      IF (RANDOM5-1,) 150,140,140
  140 RANDOM5=RANDOM5-1,
  150 IF (PRB(I,J,K)-RANDOM5) 170,170,160
  160 KFR(I,J,K)=3
      IF (KR(I,J,K),EQ,0) GO TO 165
      TPSP(I,J,K)=TPSP(I,J,K)+1,
  165 NUMTPF=NUMTPF+1
      NTOTAL=NTOTAL+1
      KBDG(NUMTPF)=I*1000+J*100+K
  170 RANDOM1=RANDOM2
      RANDOM2=RANDOM5
  180 CONTINUE
C---- IF THERE ARE NO FIRES, THERE IS A JUMP TO THE END OF THE PROGRAM
      IF (NUMTPF,NE,0) GO TO 200
      WRITE (6,190)
  190 FORMAT (1H0,18HTHERE ARE NO FIRES)
      WRITE (6,195)
  195 FORMAT (51X,3H  0,47X,3H  0)
      GO TO 807
C---- THE FIRE SPREAD CONSIDERATION IS INITIALIZED AT ONE OF THE
C---- BUILDINGS WHERE THERMAL PULSE FIRE
  200 I=KBDG(1)/1000
      NTH=KBDG(1)-(I*1000)
      J=NTH/100
      K=NTH-(J*100)
```

```
      RANDOM4=ABS(RANDOM1-RANDOM2)
      NUMSP=0
      DO  680 LLL=1,NUMTPF
      KSPREAD=0
      IF (KWRITE,EQ,0) GO TO 240
      IF (KPAGNTN-60) 220,220,210
  210 WRITE (6,130)
      KPAGNTN=3
  220 WRITE (6,230) I,J,K,ADR1(I,J,K),ADR2(I,J,K),RANDOM5,PRB(I,J,K),
     1R[illegible],RANDOM1,RANDOM2,CTY1,CTY2
  230 F[illegible] (1H0,2X,I2,5X,I1,5X,I2,3X,A6,A6,2X,F6,4,3X,F6,4,2X,F6,4,
     [illegible]X,F6.4,19X,F6.4,3X,3HYES/1H ,20X,2A6/1H )
      KPAGNTN=KPAGNTN+4
C---- THIS LOOP IS GONE THROUGH FOR ALL THE BUILDINGS ON FIRE TO SEE IF
C---- THE FIRE SPREADS TO OTHER BUILDINGS
  240 DO 640  II=1,16
      RANDOM4=ABS(RANDOM2-RANDOM1)
      RANDOM5=RANDOM1+RANDOM2
      IF (RANDOM5-1.) 260,260,250
  250 RANDOM5=RANDOM5-1.
  260 IF (II-2) 270,280,290
  270 PR=PRN1(I,J,K)
      NBLDG=NBN1(I,J,K)
      GO TO 500
  280 PR=PRN2(I,J,K)
      NBLDG=NBN2(I,J,K)
      GO TO 500
  290 IF (II-4) 300,310,320
  300 PR=PRN3(I,J,K)
      NBLDG=NBN3(I,J,K)
      GO TO 500
  310 PR=PRN4(I,J,K)
      NBLDG=NBN4(I,J,K)
      GO TO 500
  320 IF (II-6) 330,340,350
  330 PR=PRE1(I,J,K)
      NBLDG=NBE1(I,J,K)
      GO TO 500
  340 PR=PRE2(I,J,K)
      NBLDG=NBE2(I,J,K)
      GO TO 500
  350 IF (II-8) 360,370,380
  360 PR=PRE3(I,J,K)
      NBLDG=NBE3(I,J,K)
      GO TO 500
  370 PR=PRE4(I,J,K)
      NBLDG=NBE4(I,J,K)
      GO TO 500
  380 IF (II-10) 390,400,410
  390 PR=PRS1(I,J,K)
      NBLDG=NBS1(I,J,K)
      GO TO 500
  400 PR=PRS2(I,J,K)
      NBLDG=NBS2(I,J,K)
      GO TO 500
  410 IF (II-12) 420,430,440
```

```
  420 PR=PRS3(I,J,K)
      NBLDG=NBS3(I,J,K)
      GO TO 500
  430 PR=PRS4(I,J,K)
      NBLDG=NBS4(I,J,K)
      GO TO 500
  440 IF (II-14) 450,460,470
  450 PR=PRW1(I,J,K)
      NBLDG=NBW1(I,J,K)
      GO TO 500
  460 PR=PRW2(I,J,K)
      NBLDG=NBW2(I,J,K)
      GO TO 500
  470 IF (II-16) 480,490,490
  480 PR=PRW3(I,J,K)
      NBLDG=NBW3(I,J,K)
      GO TO 500
  490 PR=PRW4(I,J,K)
      IF (KFR(I,J,K).EQ.3) GO TO 495
      KFR(I,J,K)=2
  495 NBLDG=NBW4(I,J,K)
  500 NBLK=NBLDG/1000
      NTH=NBLDG-(NBLK*1000)
      NDIR=NTH/100
      NLOT=NTH-(NDIR*100)
      IF (NBLDG.NE.0) GO TO 510
      GO TO 610
C---- USE MONTE CARLO METHOD TO SEE WHETHER FIRE MAY SPREAD
  510 IF (PR-RANDOM5) 610,610,520
C---- USE MONTE CARLO METHOD TO SEE IF BUILDING CATCHES ONCE FIRE
C---- EXPOSED TO BUILDING
  520 IF (PRF(NBLK,NDIR,NLOT)-RANDOM4) 610,610,530
  530 IF    (KFR(NBLK,NDIR,NLOT).EQ.0) GO TO 535
      GO TO 610
  535 KFR(NBLK,NDIR,NLOT)=1
      IF (KR(NBLK,NDIR,NLOT).EQ.0) GO TO 536
      TPSP(NBLK,NDIR,NLOT)=TPSP(NBLK,NDIR,NLOT)+.001
  536 NUMSP=NUMSP+1
      NTOTAL=NTOTAL+1
      KBDG(NTOTAL)=NBLDG
  538 IF (KWRITE.EQ.0) GO TO 610
  539 IF (KPAGNTN-60) 550,550,540
  540 WRITE (6,130)
      KPAGNTN=3
  550 WRITE (6,560) NBLK,NDIR,NLOT,ADR1(NBLK,NDIR,NLOT),ADR2(NBLK,NDIR,N
     1LOT),RANDOM5,PRB(NBLK,NDIR,NLOT),RANDOM4,PR,RANDOM1,PRF(NBLK,NDIR,
     2NLOT),RANDOM2,I,J,K,CTY1,CTY2
  560 FORMAT (1H0,2X,I2,5X,I1,5X,I2,3X,A6,A6,2X,F6.4,3X,F6.4,2X,F6.4,2X,
     1F6.4,3X,F6.4,7X,F6.4,6X,F6.4,3X,3HYES,4X,I2,2X,I1,3X,I2/1H ,20X,
     22A6/1H )
      KPAGNTN=KPAGNTN+4
  610 IF (II.NE.16) GO TO 630
      NCOUNT=NCOUNT+1
      IF (NCOUNT-NTOTAL) 620,690,690
  620 NCNT=NCOUNT+1
      I=KBDG(NCNT)/1000
```

```
      NTH=KBDG(NCNT)-(I*1000)
      J=NTH/100
      K=NTH-(J*100)
C---- NTOTAL IS TOTAL NO. OF BLDGS WITH FIRE (RUNNING TOTAL)
C---- THIS IS BOTH THERMAL PULSE FIRE AND SPREAD FIRE
  630 RANDOM1=RANDOM2
      RANDOM2=RANDOM5
  640 CONTINUE
  650 IF (KSPREAD.EQ.0) GO TO 660
      GO TO 670
  660 IF (LLL-NUMTPF) 680,670,670
  670 LLL=1
      KSPREAD=1
      GO TO 240
  680 CONTINUE
  690 IF (NN-2) 6805,6810,6815
 6805 RI=.1
      GO TO 6835
 6810 RI=.3
      GO TO 6835
 6815 IF (NN-4) 6820,6825,6830
 6820 RI=.5
      GO TO 6835
 6825 RI=.7
      GO TO 6835
 6830 RI=.9
 6835 IF (MM-2) 6840,6845,6850
 6840 KELEV=30
      GO TO 695
 6845 KELEV=10
      GO TO 695
 6850 KELEV=5
  695 IF (KWRITE.EQ.0) GO TO 705
      WRITE (6,700) KELEV,RI
  700 FORMAT (1H1,3X,32HSUMMARY WITH ANGLE OF ELEVATION=,I2,24H AND ROOM
     1 IGNITION PROB=,F4.2/1H0,29HBLOCK  DIR  LOT  TYPE OF FIRE)
      GO TO 708
  705 WRITE (6,706) KELEV,RI,JJ
  706 FORMAT (1H0,32HSUMMARY WITH ANGLE OF ELEVATION=,I2,24H AND ROOM IG
     1NITION PROB=,F4.2,43H WITH THE NUMBER OF TIMES THROUGH THE LOOP=,
     2I3,11X)
C---- BELOW IS THE LOOP WHICH GIVES A SUMMARY OF THE BLOCK, DIRECTION
C---- LOT NUMBER OF THE BUILDINGS WHICH CAUGHT ON FIRE.
  708 DO 790  I=1,M
      DO 785  J=1,4
      IF (KC(I,J).EQ.0) GO TO 785
      KK=KC(I,J)
  710 DO 770  K=1,KK
      IF (KFR(I,J,K).NE.3) GO TO 730
      IF (KWRITE.EQ.0) GO TO 770
  715 WRITE (6,720) I,J,K
  720 FORMAT (1H0,1X,I2,5X,I1,4X,I2,2X,13HTHERMAL PULSE)
      GO TO 770
  730 IF    (KFR(I,J,K).NE.2) GO TO 770
      IF (KWRITE.EQ.0) GO TO 770
  735 WRITE (6,740) I,J,K
```

```
740 FORMAT (1H0,1X,I2,5X,I1,4X,I2,2X,6HSPREAD)
770 CONTINUE
765 CONTINUE
790 CONTINUE
    KPAGNTN=0
800 IF (NTOTAL.NE.0) GO TO 801
    NUMSP=0
801 WRITE (6,805) NUMTPF,NUMSP,NTOTAL
805 FORMAT (1H ,50HTOTAL NUMBER OF BLDGS ON FIRE FROM THERMAL PULSE= ,
   1I3,4X, 43HTOTAL NUMBER OF BLDGS ON FIRE FROM SPREAD= ,I3,4X,
   221HTOTAL BLDGS ON FIRE= ,I3,4X)
806 IF (NDETAIL.EQ.0) GO TO 807
    IF (JJ.NE.100) GO TO 807
    DO 807 I=1,M
    DO 807 J=1,4
    KK=KC(I,J)
    IF (KK.EQ.0) GO TO 807
    DO 807 K=1,KK
    IF (KR(I,J,K).EQ.0) GO TO 807
    KTP=TPSP(I,J,K)
    RKTP=KTP
    KSP=(TPSP(I,J,K)-RKTP)*1000.
    KTOT=KTP+KSP
    WRITE (6,8061)
8061 FORMAT (1H1,3X,19HBUILDING DEFINED BY,7X,   31HNUMBER OF TIMES IN
   1100 CASE RUN /1H ,3X, 18HBLOCK   SIDE   LOT ,8X, 28HBUILDING CAUGH
   2T ON FIRE FROM /1H ,29X, 32HTHERMAL PULSE    SPREAD    TOTAL /
   31H ,3X, 5H----- ,3X, 4H---- ,3X, 3H--- ,8X, 13H------------- ,4X,
   4 6H------ ,4X, 5H-----)
8060 WRITE (6,8065) I,J,K,KTP,KSP,KTOT
8065 FORMAT (1H ,5X,I2,6X,I1,5X,I2,14X,I3,10X,I3,6X,I3)
    TPSP(I,J,K)=0.0
807 CONTINUE
808 REWIND 10
810 REWIND 27
    STOP
    END
```

FIREFLY 3

PROGRAM

```
      PROGRAM FIMHELYS
      DIMENSION KSKIP(15),KTPF(100),KSPF(100),KDIFTP(100),KDIFSP(100),
     1KSQTP(100),KSQSP(100)
      DO 10 I=1,15
   10 READ 15,KSKIP(I)
   15 FORMAT (I4)
      READ 20,N,CTY1,CTY2,WIND1,WIND2
   20 FORMAT (I4,1X,2A5,1X,2A6)
      WRITE (6,25) CTY1,CTY2,WIND1,WIND2,N
   25 FORMAT (1H1,29X,2A5,14X,2A6/1H0,64HPROB ROOM    ANGLE OF      AVG NO,
     1 OF BUILDINGS      PERCENT BURNT (,I4,7X,18HSTANDARD DEVIATION/
     21H ,63HIGNITION     ELEVATION      BURNT (100 CASES)           BUILDI
     3NGS)/1H ,23X,22(1H-),3X,22(1H-),3X,22(1H-)/1H ,23X,
     4                72HTHERMAL   SPREAD   TOTAL   THERMAL  SPREAD  TOTAL
     5THERMAL   SPREAD   TOTAL/1H ,24X,5HPULSE,20X,5HPULSE,20X,5HPULSE/)
      KPGNTN=7
      DO 200 M=1,15
      K=KSKIP(M)
      IF (KSKIP(M).EQ.0) GO TO 40
      DO 30 L=1,K
   30 READ INPUT TAPE 10,35
   35 FORMAT (1H )
   40 KSMTP=0
      KSMSP=0
      DO 50 L=1,100
      READ INPUT TAPE 10,45, KTPF(L),KSPF(L)
   45 FORMAT (/51X,I3,47X,I3)
      KSMTP=KSMTP+KTPF(L)
   50 KSMSP=KSMSP+KSPF(L)
      KSMTOT=KSMTP+KSMSP
C---- AVERAGE NUMBER OF BUILDINGS BURNT FROM THERMAL PULSE IN 100 CASES
      AVGTP=KSMTP/100
      KAVGTP=AVGTP
      IF ((AVGTP-KAVGTP)-.5) 60,55,55
   55 KAVGTP=KAVGTP+1
C---- AVERAGE NUMBER OF BUILDINGS BURNT FROM FIRE SPREAD IN 100 CASES
   60 AVGSP=KSMSP/100
      KAVGSP=AVGSP
      IF ((AVGSP-KAVGSP)-.5) 70,65,65
   65 KAVGSP=KAVGSP+1
C---- AVERAGE NUMBER OF TOTAL BUILDINGS BURNT IN 100 CASES
   70 KAVGTOT=KAVGTP+KAVGSP
      RN=N
C---- PERCENT OF TOTAL NUMBER OF BUILDINGS WHICH BURNT FROM THERMAL PULSE
      PTP=AVGTP/RN*100.
      KPTP=PTP
      IF ((PTP-KPTP)-.5) 80,75,75
   75 KPTP=KPTP+1
C---- PERCENT OF TOTAL NUMBER OF BUILDINGS WHICH BURNT FROM FIRE SPREAD
   80 PSP=AVGSP/RN*100.
      KPSP=PSP
      IF ((PSP-KPSP)-.5) 90,85,85
   85 KPSP=KPSP+1
C---- TOTAL PERCENT OF BUILDINGS BURNT
   90 KPTOT=KPTP+KPSP
      KTOTSQTP=0
```

```
      KTOTSQSP=0
      DO 100 I=1,100
      KT=KTPF(I)-KAVGTP
      KS=KSPF(I)-KAVGSP
      KDIFTP(I)=XABSF(KT)
      KDIFSP(I)=XABSF(KS)
      KSQTP(I)=KDIFTP(I)**2
      KSQSP(I)=KDIFSP(I)**2
      KTOTSQTP=KTOTSQTP+KSQTP(I)
  100 KTOTSQSP=KTOTSQSP+KSQSP(I)
      YY=KTOTSQTP/100
      ZZ=KTOTSQSP/100
      YZ=YY+ZZ
C---- STANDARD DEVIATION OF BUILDINGS BURNT FROM THERMAL PULSE
      DEVTP=SQRTF(YY)
C---- STANDARD DEVIATION OF BUILDINGS BURNT FROM FIRE SPREAD
      DEVSP=SQRTF(ZZ)
C---- STANDARD DEVIATION OF ALL BUILDINGS BURNT
      DEVTOT=SQRTF(YZ)
      IF (M-5) 105,105,150
  105 KELEV=30
      IF (M-2) 115,120,125
  115 RI=,1
      GO TO 175
  120 RI=,3
      GO TO 175
  125 IF (M-4) 130,135,140
  130 RI=,5
      GO TO 175
  135 RI=,7
      GO TO 175
  140 RI=,9
      GO TO 175
  150 IF (M-10) 155,155,165
  155 KELEV=10
      IF (M-7) 115,120,160
  160 IF (M-9) 130,135,140
  165 KELEV=5
      IF (M-12) 115,120,170
  170 IF (M-14) 130,135,140
  175 IF (KPGNTN-55) 185,180,180
  180 WRITE (6,25) CTY1,CTY2,WIND1,WIND2,N
      KPGNTN=7
      IF (RI-,1) 185,182,185
  182 WRITE (6,183)
  183 FORMAT (1H0)
      KPGNTN=KPGNTN+1
  185 WRITE (6,190) RI,KELEV,KAVGTP,KAVGSP,KAVGTOT,KPTP,KPSP,KPTOT,
     1DEVTP,DEVSP,DEVTOT
  190 FORMAT (1H ,F4,1,7X,I2,4H DEG,5X,I4,5X,I4,4X,I4,6X,I3,5X,I3,5X,I3,
     14X,F5,1,5X,F5,1,3X,F5,1)
      KPGNTN=KPGNTN+1
  200 CONTINUE
      REWIND 27
      STOP
      END
```

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13. ABSTRACT

A computer model called FIREFLY has been developed and written in FORTRAN IV for the CDC 3600. This model may be applied to obtain statistical data on the expected numbers of buildings destroyed by fire from the thermal pulse of a hypothetical nuclear weapon and from any subsequent urban fire spread. Many variables concerning numbers and sizes of buildings, their construction, and separation distances may be evaluated. (U)

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