AD-A155 824 LOCAL ASSESSMENT GUIDE FOR CONFLAGRATION ANALYSIS: SYSTEM II(U) INTERNATIONAL ASSOCIATION OF FIRE CHIEFS INC WASHINGTONDC H HICKEY APR 85 EMW-C-0743 1/2

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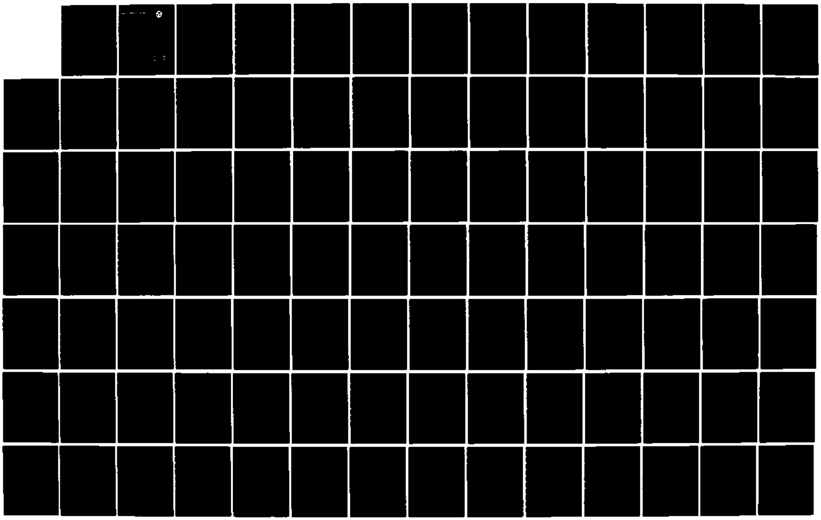

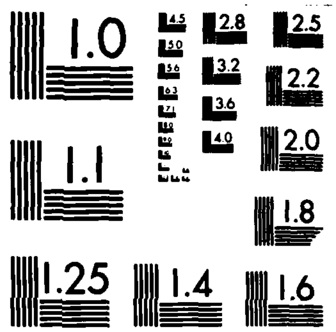

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AREA CODE 202
833-3420

LOCAL ASSESSMENT GUIDE

for

CONFLAGRATION ANALYSIS: SYSTEM II

Final Report

for

Federal Emergency Management Agency, Washington, D.C. 20472

FEMA Award Number EMW-C-0743

FEMA Work Unit Number 6141A

April 1985

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Final Report

by

Harry Hickey

for

Federal Emergency Management Agency, Washington, D.C. 20472

April 1985

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A155 824
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) LOCAL ASSESSMENT GUIDE FOR CONFLAGRATION ANALYSIS: SYSTEM II	5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT SEPTEMBER 1981 - APRIL 1985
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) HARRY HICKEY	8. CONTRACT OR GRANT NUMBER(s) EMW-C-0743
9. PERFORMING ORGANIZATION NAME AND ADDRESS INTERNATIONAL ASSOCIATION OF FIRE CHIEFS, INC. 1329 18th ST., NW WASHINGTON, D.C. 20036	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS WORK UNIT 6141A
11. CONTROLLING OFFICE NAME AND ADDRESS FEDERAL EMERGENCY MANAGEMENT AGENCY WASHINGTON, D.C. 20472	12. REPORT DATE APRIL 1985
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

CONFLAGRATION, MASS FIRE, FIRE SPREAD ANALYSIS, EMERGENCY MANAGEMENT, FIRE PROTECTION MASTER PLANNING, URBAN REDEVELOPMENT, FIRE DEPARTMENT

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study is concerned with the validation of the block assessment program, and the necessity to develop an alternative approach to block risk analysis that may be used to predict the relative potential for mass fire spread after ignition from other than wartime factors.

--continued on next page

BLOCK 20. Continued -

An extensive literature search concerning both the concept and the methodology of the Gage-Babcock block rating analysis strongly suggests the need for modifying the numerical parameters associated with some of the functional analysis items. Further, the literature search indicated the need to expand the scope of the study to encompass fire spread between blocks.

A revised block rating methodology has been constructed based on the literature search findings. The methodology builds on the quantitative analysis developed for the mass fire spread potential in urban blocks. A probability factor of fire spread measure between blocks is introduced based on street gap or open area width, building height ratios, exterior wall surface treatment, and selected wind factors.

An initial validation study of both the original block rating methodology and the revised block rating methodology was conducted during the summer and fall of 1982.

On the basis of the validation program, a number of significant refinements and component changes were made to the local assessment method for measuring mass fire spread potential in urban blocks. Originator-supplied keywords include:

EXECUTIVE SUMMARY

In 1982, a study was initiated by the International Association of Fire Chiefs to determine the current relevance of the Gage-Babcock system for local assessment of the conflagration potential of urban areas. This assessment tool has been used as one evaluation method for determining potential for a devastating fire under wartime conditions in individual urban structural blocks. The assessment process assumes that an ignition takes place in any urban block where 50 percent of the land is built upon. A numerical block rating is determined through a quantitative process to establish a relative measure of conflagration potential given a set of assumptions clearly defined in the assessment methodology.

This new study is concerned with the validation of the block assessment program, and the necessity to develop an alternative approach to block risk analysis that may be used to predict the relative potential for mass fire spread after ignition from a source not connected with wartime causal factors.

An extensive literature search concerning both the concept and the methodology of the Gage-Babcock block rating analysis strongly suggests the need for modifying the numerical parameters associated with some of the functional analysis items.

A revised block rating methodology has been constructed based on the literature search findings. In contrast to the original block rating analysis, the revised block rating method gives new treatments to the following analysis factors:

1. The fuel load and fire severity in compartments;
2. Perimeter building wall construction; and
3. Roof coverings and roof construction.

However, the basic concepts of analysis used in the original block rating method appear basically sound for the purpose of assessing mass fire potential in urban blocks under the condition of a well developed structural fire.

An initial validation study of both the original block rating methodology and the revised block rating methodology was conducted during the summer and fall of 1982. Three separate studies were conducted using senior fire protection engineering students from the University of Maryland; fire officers from the Alexandria, Virginia, Fire Department and selected emergency management personnel from the Washington, D.C., Council of Governments area.

On the basis of the validation program, a number of significant refinements and component changes were made to the local assessment method for measuring mass fire spread potential in urban blocks. The validation program also suggested the need for expanding the study methodology to include a local assessment method for measuring fire spread potential between urban blocks. A second study phase was initiated in 1983 to accomplish this task.

A new guide was prepared, focusing on the probability of fire spread between urban blocks, following a new literature search on the measurable effects of fire spread between structures separated by a defined gap or space interval. The developed methodology builds on the quantitative analysis developed for the mass fire spread potential in urban blocks. A probability factor of fire spread measure between blocks is introduced into the methodology based on street gap or open area width, building height ratios, exterior wall surface treatment, and selected wind factors.

In late 1983 and early 1984, a new round of studies was conducted to validate both phases of the described study. These studies were conducted in Atlantic City, New Jersey; Louisville, Kentucky; and Syracuse, New York. A complete analysis of the validation study process is presented in the primary study document. However, the following conclusions are important to the study process findings.

The block rating concept for quantifying the mass fire spread potential in urban blocks and fire spread potential between urban blocks provides an important urban administration tool for the following applications:

1. Determining the relative fire spread potential within selected urban block configurations;

2. Determining the relative probability of fire spread between urban blocks given a well developed fire in a single block;

3. Determining different quantitative indicators for fire demand zone (FDZ) identification; FDZ identification can be used to -

   a. Assess equipment and personnel resource requirements,

   b. Designate adaptive response criteria, and

   c. Establish public awareness on the potential threat of fire development in urban block areas of a given city;

4. Determining the fire safety impact of urban renewal efforts through the assessment of "before" and "after" results of structural-occupancy changes;

5. Determining structural condition risk assessments as an alternative to the disbanded community structural gradings provided by the Insurance Services Office, and

6. Determining the relative structural risk potentials in a community on a quantitative base; this type of risk assessment appears to be especially useful for -

a. Fire officer education and development at the National Fire Academy in the area of risk management and

b. The integrated emergency management system (IEMS) approach to emergency preparedness for considering the evacuation requirements, communicaton needs, emergency direction and control, continuity of government, resource management, and law and order in the event of a conflagration.

The positive indicators listed above are tempered by an identified list of concerns pertaining to both phases of the stated study. These concerns appear as follows:

1. Both methodologies are very time consuming and are labor intensive because of the large number of calculations that must be completed for a single block rating analysis of mass fire potential;

2. The method of computing fire spread between block areas is excessively complex in the present form for the intended purpose of a local assessment analysis;

3. The local assessment guide supplied to the validation cities does not provide sufficient depth and clarity for use by local governments without further instruction and assistance in specific applications (Note: As indicated above (Item 6, page 3) there appears to be a strong feeling that this program should be incorporated into the Executive Series of course offerings at the National Fire Academy);

4. A computer program should be written to analyze field collected data and compute the numerical block rating or fire spread rating;

5. A number of fire officers, especially in fire prevention bureaus, would like to see an adjustment made to the methodology to account for buildings protected by automatic sprinkler systems, and

6. Fire officers involved in the validation study suggest that impact measures be developed for assessing the value of the responsible fire department and other local government agencies in halting a spreading fire between structural blocks.

It can be concluded that the general scope, methods, and objectives of the local assessment guide for determining mass fire spread potential in urban blocks and the probability of fire spread between blocks is sound and should be advanced to the fire service. One or more programs at the National Fire Academy apprear to offer appropriate and acceptable methods for advancing this program to the fire service. The current documentation on the local assessment guides should be extended to include an impact analysis of automatic sprinkler protection and fire suppression capability in reducing the threat of mass fires and conflagration type fires in urban areas. When all of this is accomplished, the total program should be computerized and implemented into the integrated emergency management system supported by the Federal Emergency Management Agency.

The total study project is presented in three documents as follows:

1. A Study Document for Conflagration Analysis: System II

2. A Local Assessment Guide for Conflagration Analysis: System II

3. Literature Abstracts for Study Phase I and Study Phase II

In addition, a notebook containing the field study data sheets is available at the International Association of Fire Chiefs.

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literature search. The fire loading values presented in Table A of the Appendix section have been determined in accordance with this revised method for use in the mass fire analysis. Structures that have mixed occupancies should be evaluated as outlined in the appropriate appendix section.

2. Structural Information

The structural components of a building have direct relevance to the fire spread phenomenon. Experience has demonstrated that the following factors need to be carefully assessed as they pertain to potential fire spread within blocks and between blocks.

a. Floor Construction

Floor construction may limit or retard the vertical spread of fire in structures. The degree of limitation is a function of the degree of fire resistance of the floor member and the proper protection of vertical openings. The original conflagration determination methodology combines fire resistive and non-combustible construction into one category. These types of construction are now considered significantly different in terms of structural integrity and fuel contribution to a potential fire. This appears to require different operational values for measuring fire growth potential. The floor construction values used with the mass fire assessment are presented in B of the Appendix section.

b. Exterior Wall Construction

The concept of evaluating exterior wall construction created a significant problem in the initial study validation process. There appeared to be a considerable difference of opinion between fire

SECTION IV

A Method of Local Assessment for Measuring Fire Potential

A. Basic Procedures Statement

The basic method of measuring fire potential is based on factual information pertaining to each of the buildings in the designated blocks. The specific information that must be determined is as follows:

1. Occupancy Information

Relative risk based upon occupancy considerations is translated into fuel characteristics or relative fire loading. A considerable amount of research has been conducted in the past 15 years on both the determination of fire loading for specific occupancies and the potential measure of fire severity as a function of fire load parameters. The literature review supporting the approach to occupancy fuel considerations is reported in a companion document. The methodology on fire loading used in the original conflagration analysis study was restricted to an evaluation of the occupancy fire load as a function of pounds per square foot of combustible materials over a defined floor area. Typical occupancies are then categorized into classification schemes of negligible, light, moderate, and heavy or high. The literature search associated with this study clearly indicates that this concept needs to be refined to consider the potential fire severity porduced by an arrangement of combustibles and the potential heat release from these combustibles. One appropriate technique is the determination of relative fire loading measures, which appears to integrate the variables identified. This method is detailed in the supporting mathematical operations. The mathematics can be accomplished by hand but the procedure is long and labor intensive. Future plans call for a computer program that will perform the computational requirements with a minimum of human effort. The actual formula process is given in the following sub-section areas. The series of computations are transferred to one or more Worksheet Forms. These worksheets provide a systematic means for carrying forth both the mass spread analysis and the fire spread between block analysis. Each form is clearly identified under Sections V, VI, and the Appendix to this guide.

are at the suggested scale of 1 inch = 100 feet. Most, if not all, of the information required for both individual block analysis and fire spread between blocks can be gathered from current insurance reports.

d. Actual site visits may be required either to verify existing data against current situations or to finish gathering specific information not detailed on Sanborn maps, fire service inspections, or insurance reports. In most cases site visits will be required to gather specific information about development densities and land slope characteristics. Exterior wall face information may also be lacking on conventional information sheets. Furthermore, a site visit will sharpen the perception of the individual(s) conducting the rating analysis.

B. Step-By-Step Procedures

Both the block rating analysis for mass fire spread indicators and the process for determining spread of fire between blocks follow a defined set of systematic procedures. The process is actually a series of computations carefully formulated to provide a final set of computed values for estimating mass fire spread potential within the confines of a single block and the relative probability of fire spread between urban blocks to manifest a coalescing fire involving two or more urban blocks. A series of basic mathematical formulas is presented to correctly arrange the calculation sequence. It should be noted that the mathematics is not difficult; it simply involves extensive addition, subtraction, multiplication, division, and basic percentage calculations. A calculator is advisable for conducting the

a. Sanborn type maps have long been used by the insurance industry and units of local government to assess individual property risks. Sanborn maps are especially prepared to depict occupancy, structural classifications, installed fire protection features and building exposure conditions for block configurations and individual property in urban areas. The information contained on Sanborn maps is most suitable and complete for the purposes of computing mass fire spread and coalescing fire development in urban areas. However, Sanborn maps need to be carefully evaluated for accuracy and currency. Site checks should be made to update, as necessary. It is important to note that each of the study validation cities had current and accurate Sanborn maps of the blocks used for the assessment study. These maps were extremely useful in preparing the referenced data collection forms for the actual block analysis.

b. Building Information Data (BID) is obtained by fire departments for code enforcement and for pre-fire planning purposes. BID reports containing occupancy and structural information on selected buildings should be most valuable for computing individual block ratings. In many cases the information listed below for the block rating analysis can be obtained directly from fire department survey and inspection reports.

c. At least two major insurance interests, Factory Mutual and the Industrial Risk Insurers, provide municipalities, upon request, with copies of basic building information pertaining to specific industrial and commercial risks in a given city. In most cases this information includes plot plans of buildings under consideration and

SECTION III

Applying Fire Spread Measures to Local Conditions

The block rating analysis and fire spread analysis are calculated from a data base. This data base includes specific sets of data from occupancy conditions, structural conditions and land use conditions. This information must be gathered for all urban blocks that will receive a conflagration assessment. The task can be accomplished by a systematic process. The data collection considerations are outlined below; the application considerations are developed under Sections IV, V, and VI of this guide.

A. Basic Resource Requirements

1. The first item to be obtained in the evaluation is a combined land use and topographic or aerial map of the geographical area under consideration. It is important that this map be prepared on a scale of 1 inch = 100 feet to accommodate other supporting data. The topographic map can be prepared from aerial photographs. Appendix Figure A depicts a typical land use topographic map that has been prepared from aerial photos and is suitable for both block analysis and fire spread analysis between blocks.

2. Occupancy and structural information is needed for each building within the urban block to be evaluated. There appear to be four basic ways to gather the required information to compute an individual block rating. In some cases a combination of the following resource bases will be required to complete all of the required data for selected blocks in an urban area:

comparative analysis could show how local government has improved the quality of life safety within the city.

E. Establishing Public Awareness of the Potential Threat of Fire Development in Urban Areas

Local government has a responsibility to inform citizens of environmental conditions that are injurious to their health and safety and to provide information on the level of protection that can be offered to the owners and occupants of buildings. A higher level of responsibility in these areas is being underscored continually by the courts. The relative indexing system established through the block rating analysis outlined in this guide appears to be one viable method of identifying the potential risk from fire for both the buildings within a given block and the buildings located in a given geographical area within a city. Numerical block ratings plotted on a land use map can be easily understood by both the untrained and the professional: the higher the number, the higher the risk. Categories of risk from "negligible" to "severe" can also be readily understood by citizen groups.

It also appears that the numerical indicators derived from the described methodology might be important to urban planners and citizen groups in setting priorities on urban renewal projects. The relative indicators may also provide a method of matching risk assessment levels to current and projected insurance premiums in selected districts of a given city. This could become a powerful tool for urban administrators.

C. Designating Adaptive Response Criteria Based on Quantitative Projections

The RAND studies conducted with the New York City Fire Department clearly demonstrate the costs and benefits of adapting fire department responses on the basis of risk potential. This concept contrasts with the more cor :ntional approach of dispatching a static or equal response to all fire alarms. Plotting block ratings on a map for a given jurisdiction can be an important method for developing adaptive response programs based on numerical risk potential.

D. Assessing Urban Renewal as a Function of Demolition Selection Based on Relative Risk Indicators

Urban renewal efforts for cities of all population categories continue to be of vital interest to all levels of government; renewal is a direct measure of the quality of life for urban residents. The selection process for determining urban renewal priorities involves complex evaluations based on who benefits and who is deprived in the decision-making process. Important factors in the evaluation equation are the life-threatening situations and potential property damage levels that could occur from a disasterous fire. Individual or continuous structural blocks within a city that present high risk values to life and property should be carefully evaluated relative to the urban renewal process. The local assessment methodology for mass fire and coalescing fire probabilities presents one viable method for making this determination.

The validation study revealed that local government officials feel the guide is most useful for the comparative analysis of individual block risk assessments before and after a block has been demolished and rebuilt. This

A. Prioritizing Fire Demand Zones

It is recognized that different built-up structural blocks in a city have different levels of fire damage risk. One or more high fire risk blocks may be used to identify a fire demand zone (FDZ). An FDZ usually signals the need for a high level of fire department response capability to cope with the problem. Also, an FDZ usually requires a high fire flow from the municipal water system for the same reason. Numerical indicators for FDZ risk levels can be cross-correlated to fire suppression resource requirements.

The block rating numerical system appears to be an excellent way of identifying fire demand zones for computerized deployment allocation programs including the RAND Fire Station Siting Model and the Public Technology, Inc., Fire Station Location Package (1, 2).

B. Determining the Relative Fire Spread Potential Within Selected Sections of Built-up Urban Areas

Computed block ratings and spread probabilities using the study methodology can be plotted on topographic or land use maps. The plotted ratings can be used with referenced figures in the guide to assess risk potentials for a single block or a conflagration potential involving several blocks. The option is also presented for conducting an additional assessment that plots perceived wind directions and wind speeds as a function of fire spread probability between defined blocks.

1. Dormont, Peter, J. Hausner, and Warren Walker. Firehouse Site Evaluation Model: Description and User's Manual. New York. The New York City Rand Institute, R-1618/2-HUD, June 1975.

2. Staff. Fire Station Location Package. Washington, (D.C.). Public Technology, Inc. 1987.

SECTION II

Purpose and Value of Local Assessment Methodology

This local assessment methodology is developed and structured around the thesis that a block rating fire development model carefully constructed and validated will serve as a relative quantitative measure of a selected urban structural block's damage potential after a fire is well developed within the block. Block ratings are also most useful for assessing the potential for urban block fires to form a coalescing fire through the mechanism of fire spread between blocks that may initiate a conflagration situation. It is important to underscore that a common purpose of this guide is to provide a useful tool for the total assessment of potential mass fire and conflagration conditions.

The local assessment guide is divided into two parts as follows:

Part I: Mass fire spread potential within the confines of a single selected structural block and

Part II: Fire spread potential between structural blocks to produce a coalescing fire from a single well developed fire. Further, Part II of the methodology is dependent upon Part I. In other words, the individual block rating forms a baseline for computing the probability of fire spread between blocks. This methodology reduces quantitative analysis to a minimum requirement and avoids a duplication of effort.

The fundamental mission of the Local Assessment Guide for Conflagration Analysis: System II is to provide urban government emergency service managers with a tool for the total assessment of block mass fire and urban conflagration potential conditions. The final tool as described should be useful to accomplish the following objectives.

This document discusses the features of the revised local assessment guide section of the revised methodology. The guide presents a correct and systematic approach for computing numerical index values to mass fire spread potential within and between urban blocks.

A third document presents an annotated bibliography that sets forth the literature reviewed to construct the revised methodology.

It is important to note that a validation study has been completed in three cities to assess this new methodology in the "real world". Findings and conclusions determined from the validation study are reported in the revised study document. Necessary changes and corrections to the January 23, 1984 Local Assessment Guide for Conflagration Analysis: System II used for the validation process are documented in this final edition.

SECTION I

Introduction

In 1965, Gage-Babcock & Associates developed "A System for Local Assessment of the Conflagration Potential of Urban Areas". This assessment tool has been used as one evaluation method for determining a selected urban structural block's potential for a devastating fire under wartime conditions. The assessment process assumes that at least one ignition takes place in any block where 50 percent of the land is built upon. A numerical block rating is computed through a local assessment process to signal a relative measure of conflagration potential given a set of assumptions clearly defined in the documented assessment methodology.

A new study has been completed by the International Association of Fire Chiefs under direct sponsorship of the Federal Emergency Management Agency to determine the relevance of the Gage-Babcock block assessment program and to validate an alternative approach to block risk analysis that can be used to predict the relative potential for mass fire spread after ignition from other than wartime sources.

After an extensive literature search, the International Association of Fire Chiefs study team concludes that the Gage-Babcock approach to the identified analysis of urban fire spread is basically sound but that the analysis factors demand redefinition and, in several analysis categories, different numerical units for computing the relative potential of an urban block to the mass fire phenomenon. The change factors have been formulated into a revised method for the local assessment of conflagration potential in urban areas. A separate document discusses the scope, objectives, methods, conclusions, and recommendations associated with the new study.

APPENDIX

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FIGURES AND TABLES

protection engineers, fire officers, and emergency management personnel regarding the methodology for evaluating exterior wall construction. The concepts concerning the evaluation of wall construction follow. It is important to observe that the selected method for evaluating wall construction is based on the last group validation process and is not approved by all validation study participants. However, it appears to give a higher degree of consistent results than the method proposed for the initial validation study.

The literature search on this subject clearly indicates that a given structural wall face presents an exposure condition to either the fire development in the block of origin and/or fire spread to adjacent blocks. The cited literature on this topic also clearly indicates that wall openings and wall separations, including height ratios, appear very important in considering the fire growth phenomenon. The current conflagration methodology simply considers exterior wall construction as a function of the wall construction types. Based upon the documented literature, this portion of the current methodology appears oversimplified in terms of the variables to be considered. These concerns include the following features for both portions of the study:

1. Exposure wall surface area (i.e., the baseline of the wall times the wall height);

2. Wall openings including those that have non-standard exposure protection features (e.g., plain glass windows, combustible doors);

3. Separation distance between facing walls;

4. Interior block walls in contrast to block perimeter wall sections (Note: To avoid a semantics problem, the following terminology will be consistantly used in this study:)

   a. Exterior wall: Any designated wall exterior to a building;

   b. Interior wall: Any designated wall on the interior of a given building;

   c. Block Interior Wall: Any building exterior wall that faces to the inside of a given block;

   d. Block Perimeter Wall: Any building exterior wall that faces on the outside or street side of a block.

The validation study conducted in Alexandria, Virginia, clearly indicates that the proper approach to wall system evaluation is to follow the basic Gage-Babcock methodology with modification to the wall construction factors and the wall opening factors. Exterior walls require the calculation of individual wall values. Exterior values represent the construction factor times the wall opening factor. All factors pertaining to wall sections are presented in Appendix C. It should be noted that each wall on a building has a prorated value to the entire perimeter wall of the building. The recommended procedure for evaluating exterior walls relative to the assessment methodology is documented on Worksheet A for computational purposes.

c. Height Factor

Both fuel load studies and mass burn analysis indicate that the predominant risk factor is the height of buildings up to 6 stories; beyond this height fire spread and development rates appear independent of the height consideration. Thus, it appears appropriate to modify the current conflagration analysis method to reflect the proportion of building heights in a given block up to 6 stories. This approach gives more emphasis to the relationship of building heights in measuring block analysis. The specific methodology to account for the height consideration is presented in Worksheet B. The concept of evaluating buildings up to 6 stories applies only to block fire spread analysis as a function of block fire density. The probability of fire spread between buildings with heights above 6 stories can be evaluated using Part II of the study which reflects on fire spread between structures.

d. Roof Factor

The current conflagration method of evaluating roof construction focuses on the roof support system and not the roof cover. The historical evidence on conflagrations clearly indicates that the combustible nature of roof coverings is an important factor in measuring fire spread potential. Therefore, it appears necessary to adjust the roof evaluation measure to properly reflect the roof covering materials. Table D in the Appendix depicts a method of evaluating both the roof construction and the roof cover.

e. Block Density

There appears to be almost total agreement that mass fire spread within a block configuration is a direct function of the "block density" of the land face occupied by structures as a function of the total block land area. The total ground area for structural erections within a given block must be computed. This value in relation to the total land area for the entire block gives a percentage of land density. The computational method for this analysis is presented in the case study example and on Worksheet B. For purposes of computing block density, it is important to use the gross area of the block inside of the sidewalk line.

f. Land Slope

It is well documented that fire spreads uphill, given combustible fuels, faster than on a level or in a downward direction. Heat rises and tends to preheat fuel beds as the land slopes upward. Therefore, land slope must be accounted for in assessing fire spread in urban blocks. This is accomplished by a multiplying factor described on the computation chart. The building of fire origin is selected to provide the most severe fire spread case.

B. <u>Calculate the Relative Block Rating Numerical Value</u>

The actual calculation process is orientated to the referenced forms, figures, and tables. These items are located in the Appendix section for easy reference. This material can be laid out on a flat surface in descending order to use more readily during the computation process. Worksheet A is to be completed first. This form outlines the proper methodology for assessing individual building values. The determined or calculated building values serve as a foundation to calculating both mass fire spread within blocks and fire spread between blocks. Worksheet B is the actual worksheet for computing individual block ratings. Form C is the worksheet for computing the fire spread between block fronts. The table of contents references each form, figure, and table by page number.

It should be further noted that Form B provides a systematic method for computing the numerical block rating by the following formula:

$[(O + F + W)(H + R)] D = N$ where:

O is the occupancy fuel load value (Table 1)

F is the floor construction value (Table 2)

W is the exterior wall construction value (Table 3)

H is the height multiplier (See Worksheet B)

R is the roof construction and cover value (Table 4)

D is the construction density multiplier (Table 5)

N is the relative block rating value

C. Obtain Output Data

With the above formula, final relative block rating values are calculated for each block considering prorated factors discussed below. For convenience in recording data for each height category and for performing the arithmetic in the proper sequence, it is suggested that Worksheet B be completed for each block in a given city that has even a remote possibility of suffering a mass fire phenomena.

Even though the many variables involved prevent establishing absolute classifications, "average" climatic and other conditions can be assumed and specific guidelines established. By doing this, blocks can be classified according to their mass fire potential, and in most parts of the United States, where no unusual climatic conditions exist, the following grouping can be used as an approximation of the actual conditions to be expected:

Block Ratings Up to 20: No group fire or mass fire potential, but there is a possibility for fire to spread to an adjacent building.

Block Ratings Between 20 and 60: A low potential exists for group fires and mass block fires, but moderate to high probability of fire to spread to adjacent buildings.

Block Ratings Between 60 and 100: A moderate potential exists for group fires or mass block fires.

Block Ratings Above 100: Indicates a severe threat of mass fire potential.

The nearly 40 evaluators used in the validation study on the local assessment guide agreed that the above indicators are proper benchmarks for examining the relative fire spread within a given block.

SECTION V

Assessment Package I: A Method of Local Assessment for Measuring Mass Fire Potential in Single Urban Structural Blocks

A. Overview

It should be noted that this methodology section focuses on the calculation concepts for determining potential mass fire risk to individual urban block configurations by a modified method to the Gage-Babcock analysis. The following procedural steps depict the systematic process for computing a given block value. The factor values for individual buildings are referenced through a series of tables in the Appendix.

B. Sample Urban Block

A sample urban block is used in this section to illustrate the revised block rating methodology. Figure 1 illustrates the block layout. Figure 2 provides a "Subject Block Description", that matches the block shown in Figure 1. A similar set of information must be determined and computed for each block to be rated. The building analysis illustrated in Figure 2 is transfered to Worksheets A and B as follows for computing individual block ratings.

C. Completing Worksheet A

The starting point for the individual block fire spread analysis is the collection of specific information pertaining to individual buildings. Worksheet A provides a systematic means for collecting and displaying this information for future computations.

FIGURE 1

Block Layout

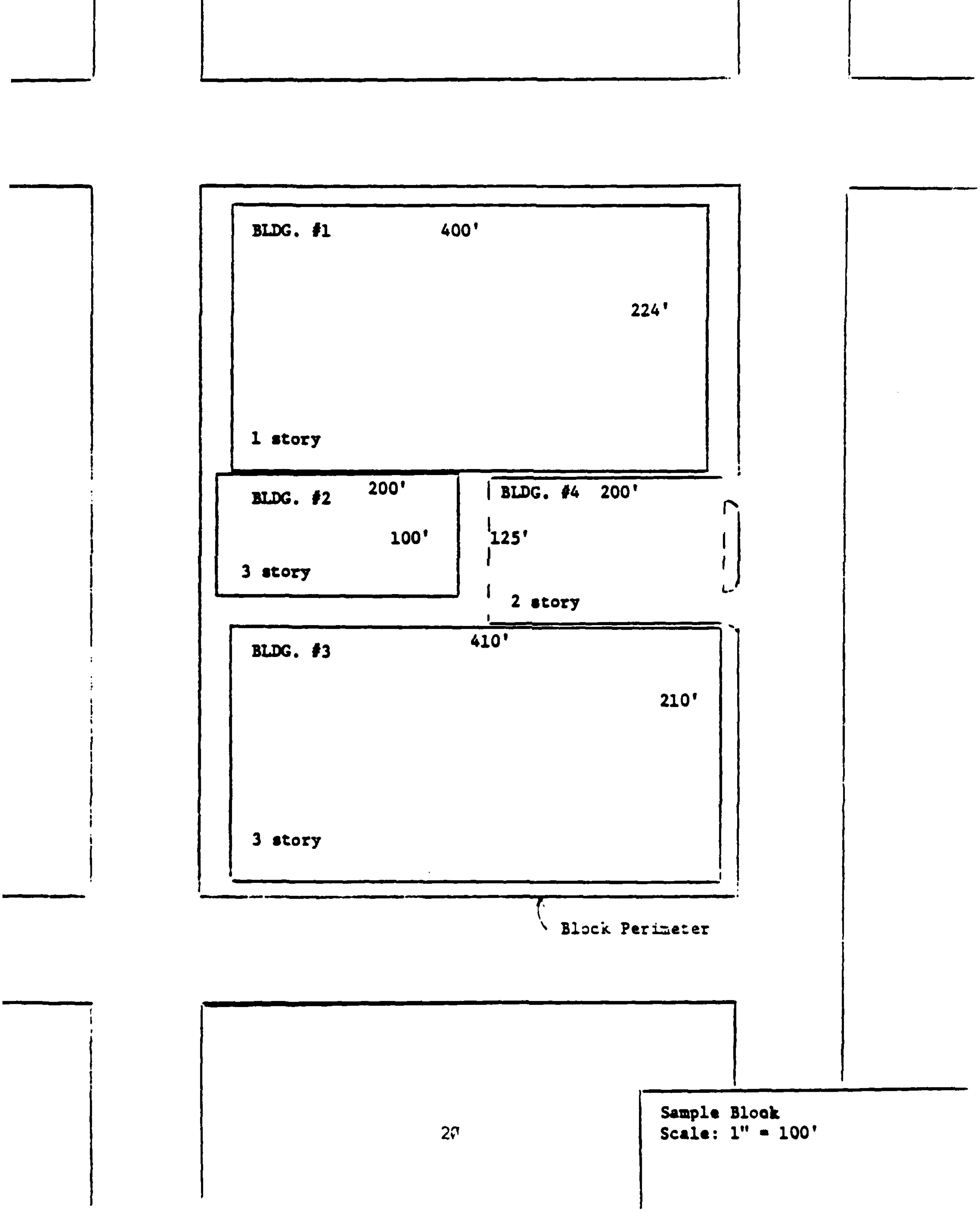


FIGURE 2

Subject Block Description

Building #1:

Occupancy: Hardware and Appliance Store

Basic Dimensions: 400 ft. X 225 ft.

Height: 1 story = 10 ft.

Ground Area: 90,000 sq. ft.

% of the block = 33%

% of 1 story buildings = 100%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 12.1 Table 1

Walls: Concrete Block - Brick Face

Floor: Non-combustible

Roof: Unprotected Non-combustible

Perimeter Wall:

Exterior Block Exposure:	850	feet
Interior Block Exposure:	400	feet
Total	1250	feet

Building #2:

Occupancy: Open Automobile Parking Garage

Basic Dimensions: 200 ft. X 125 ft.

Ground Area: 25,000 sq. ft.

% of the block = 9.2%

% of 2 story buildings = 100%

FIGURE 2 (continued)

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 12.9 Table 1

Walls: Reinforced Concrete Supports - Open Exterior

Floor: Fire Resistant

Roof: Open

Perimeter Wall:

Exterior Block Exposure:	125	feet
Interior Block Exposure:	525	feet
Total	650	feet

Building #3:

Occupancy: Furniture Store (All floors)

Basic Dimensions: 410 ft. X 210 ft.

Height: 3 Story - 30 ft.

Ground Area: 86,100 sq. ft.

% of the block = 32%

% of 3 story buildings = 81.2%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 16.4 Table 1

Walls: Brick Wood Joist

Floor: Combustible

Roof: Unprotected Non-combustible (B)

Perimeter Walls:

Exterior Block Exposure:	830	feet
Interior Block Exposure:	410	feet
Total	1240	feet

FIGURE 2 (continued)

Building #4:

Occupancy: Variety Store on the Ground Floor; Professional Offices on the Second Floor.

Basic Dimensions: 200 ft. X 100 ft.

Height: 3 story - 25 feet

Ground Area: 20,000 sq. ft.

% of the block = 7.4%

% of 3 story buildings = 18.8%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 9.7 Table 1

Walls: Frame

Floor: Combustible

Roof: Combustible (All)

Perimeter Wall:

Exterior Block Exposure:	100 feet
Interior Block Exposure:	500 feet
Total	600 feet

Note that Worksheet A is designed to capture the required information for each building in the subject block.

It is recommended that the block analysis start with the building in the northeast corner of the block and then proceed in a clockwise direction around the block. The analysis buildings 1, 2, 3, and 4 for the sample (Figures 3, 4, 5, and 6) are evaluated in this order.

Refer to Worksheet A for Building 1 (Figure 3). The step analysis in computing the block value is reviewed as follows.

Step 1: Make a plot plan type sketch of the building in the space provided. The sketch can be made from a Sanborn map or a map of the area under consideration. This sketch does not need to be made to scale; it does need the dimensions of the perimeter walls. It is also important to note the construction detail of each exterior building wall on the sketch, and both protected and unprotected openings. Notations can be in the form of standard symbols.

Step 2: Determine the building's relative fire loading value and insert this value on the line provided. Where a mixed occupancy exists, select a value that at least equals the most severe magnitude of the problem. This provides a worst case situation.

A comprehensive list of relative fire load values are found in Appendix Table A.

Step 3: This step is concerned with evaluating each perimeter wall of a given building.

First, the total wall length is inserted on the line provided.

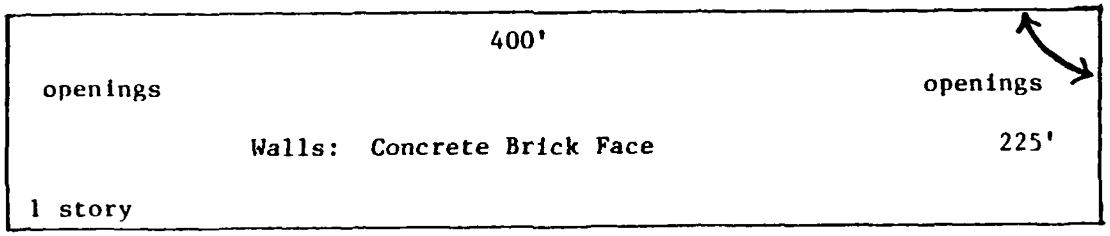
Second, the construction factor, the wall opening factor, and the percent of the perimeter wall is inserted under the proper heading for each wall face.

FIGURE 3

Individual Building

Block I.D. Sample   Building I.D. Building #1   Building Height 1 Stories

Step 1: In the space provided below, draw a sketch of the building being considered. Include notations on perimeter wall construction, height and openings. The sketch should be dimensioned.



Step 2: Fire Loading Value: 12.1

Step 3: Wall Construction Value: Total Perimeter Wall Length 1250 feet

Wall Face	Construction Factor	X	Opening Factor	X	Per Cent of Perimeter Wall	=	Construction Value
NORTH	1	X	10	X	32	=	320
EAST	1	X	10	X	18	=	180
WEST	1	X	10	X	18	=	180
SOUTH	1	X	10	X	32	=	320
					Summary Value	Σ	1000
					Factor = Σ/100	=	10

Step 4: Floor Construction Value 5

Step 5: Roof Construction Value 5

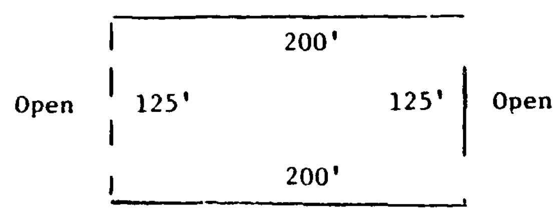
Step 6: Per Cent of Building Height Category 100%

FIGURE 4

Individual Building

Block I.D. Sample Building I.D. Bldg. #2 Building Height 2 Stories

Step 1: In the space provided below, draw a sketch of the building being considered. Include notations on perimeter wall construction, height and openings. The sketch should be dimensioned.



Step 2: Fire Loading Value: 12.9

Step 3: Wall Construction Value: Total Perimeter Wall Length 650 feet

Wall Face	Construction Factor	X	Opening Factor	X	Per Cent of Perimeter Wall	=	Construction Value
NORTH	5	X	10	X	30	=	1500
EAST	5	X	1	X	20	=	100
WEST	5	X	1	X	20	=	100
SOUTH	5	X	10	X	30	=	1500
					Summary Value	Σ	3200
					Factor = $\Sigma/100$	=	32

Step 4: Floor Construction Value 1

Step 5: Roof Construction Value 50

Step 6: Per Cent of Building Height Category 100

It is important to recognize that the exposed building and the exposing building may reverse roles based upon the intervening variables of initial ignition and/or wind conditions. The primary assessment to be made is independent of wind conditions. Supplemental indicators will be provided to compensate for the intervening variables.

2. Exposed Fire Concepts

The building or buildings exposed have fire intensity characteristics that are similar in nature to the exposing building. It follows that the index parameters or quantitative values calculated for an individual building are a reflective measure of either the impact of emitting a fire to a receiver or the act of being a receiver to an emitted fire. While there is some documented evidence to indicate that the exposed variables are slightly different than the exposing variables, it can be assumed for practical analysis purposes that the set of variables is the same.

Expanding on this logic, it should be recognized that the exposing building, given a defined wind factor, may in fact be the exposed building if the wind changes 180 degrees. The wind direction is evaluated in relation to any radiation intensity; not wind swept fire brands. To fail to assume an equality of conditions between an exposing and an exposed building is to introduce a highly complex set of variables that defeats the purpose of local assessment analysis. It follows that index values established for a given block under the mass fire analysis are most suitable for assessing both the relative exposure condition and the relative exposed condition. This reduces the important concern to

1. Exposing Fire Concepts

The exposing block fire has both occupancy and structural factors that relate to a fire intensity that impacts on the exposed structure(s). The variables associated with the exposing structure appear to be the same variables that are analyzed for the mass fire spread phenomenon within a single block. The individual block analysis forms a baseline for the evaluation of the exposing buildings. The variables of concern include:

a. Occupancy fuel load value

b. Floor construction value

c. Exterior wall construction value

d. Building height multiplier

e. Roof construction and cover value

The interrelationship of these values produces a numerical index that is useful for establishing an indicator on the relative potential of exposing fires across a defined open space.

In the individual block analysis, the above variables for the exposing fire area are also the relevant variables for the exposed block configuration. Therefore, it is logical to assume that the numerical ratings for calculated buildings in the exposing block and the exposed block influence the probability of fire spread between blocks. Structures are analyzed in the mass fire spread analysis by examining the exposing face of both blocks under consideration. This numerical value provides the baseline for further computations that address the fire spread over interval distances.

Formatting a Methodology

The underlying objective of this study is to prepare and validate a local ;sessment methodology for assessing the risk of fire spreading between blocks id coalescing to form a conflagration type fire phenomenon. Use of the term .ocal" in the assessment's designation is extremely important to keep in .nd. The application method must be suitable and acceptable for local ›vernment personnel to use. Therefore, the fire spread factor analysis :esented in Appendix Table H must be formatted to provide consistant and :liable results when applied by technical personnel at the local level.

The stated factor analysis clearly indicates that the quantitative and ıalitative measures of fire spread between structures are extensive. Simply :asping the factors requires expertise in the fields of physics, chemistry, ıd engineering. Furthermore, the literature reviewed does not reveal any ingle document source that has completely formulated all of the variables ıto a comprehensive model. Consequently, the formatting of a methodology to ssess fire spread between structures must focus on basic concepts that can be ffectively used to establish relative measures of fire spread potential.

To minimize the work load and to maximize field collection data, it is erceived that the block mass fire spread model and the exposing fire spread odel should have a direct dependent relationship. In other words, the latter odel should build on the former model. To support this premise it should be bserved that several of the variables associated with the block mass fire alculation are the same variables that are associated with the exposing fire henomenon between structural blocks. The following formatting methodology is eveloped around this concept.

Fire spread between structures in adjacent or different blocks needs to be viewed according to a classification scheme. In the past this phenomenon has generally been considered a conflagration or a fire storm. A conflagration is defined by the National Fire Protection Association as a fire that develops moving "fronts" or "heads" under the influence of wind or topography; the hot burning area is usually confined to a relatively narrow depth (3). A fire storm was defined by Rooden, John, and Laurino in 1965 as a fire in which the entire fire area is burning simultaneously (4). Such a fire is essentially stationary, with little outward spread. It is marked by a towering convection column and inflow of air from all sides. This air inflow is believed to be a major reason for the lack of significant outward spread in fire storms reported during World War II (5).

B. Analysis of Variables

A rich and extensive amount of literature focuses on what is termed the "exposure problem". Fire spread between structures occurs when one building exposes a second building across some measurable space. The factors involved in this assessment can be quite complex. It is important to identify these variables and to establish the parameters of each variable. Table H in the Appendix accomplishes this task.

3. National Fire Protection Association. Conflagrations in America Since 1900. Boston, (MA). National Fire Protection Association, 1951, p. 9.

4. Defense Civil Preparedness Agency. Disaster Operations, A Handbook for Local Governments. Washington, (DC). Defense Civil Preparedness Agency, July 1972, p. 3.

5. Ibid., p. 5.

SECTION VI

Assessment Package II: A Method of Local Assessment for Measuring Fire Spread Potential Between Urban Blocks

A. Overview

From their long experience with urban mass fires, fire control agencies have contributed a qualitative description of many aspects of fire behavior. Fire fighters have developed a remarkable degree of skill in predicting fire behavior, developing control techniques and manipulating unwanted fire to attain specified control and extinguishing objectives. But experience has also demonstrated that much of their knowledge is intuitive. This simply means that it has not been converted to the quantitative form needed for generalized application to the problem of fire spread analysis.

The lack of quantitative information has also handicapped theoretical approaches to an understanding of the fire spread phenomenon without any assurance that they were valid. Without quantitative data the applicability of theoretical models formulated from such work to the real-life situation must always remain in doubt.

Accumulation of quantitative knowledge of fire spread characteristics has been hampered by the need to limit experimental work to small-scale fires in the open or in the laboratory. Such studies have proven helpful toward an understanding of the fire phenomena by permitting careful control and measurement of experimental conditions. Further, they allow accurate analysis of some basic fire relationships. But the validity of extrapolating from such studies to large, intense fires is questionable.

multiplier from Appendix Table G. Where percent of slope varies over a one block area, use an average.

Line 16: The final block rating is now computed. Lines 14 and 15 are multiplied to give the final block rating. This completes the calculation process for a given block.

3) Alleys are considered part of the block; surrounding streets, sidewalks, or other boundaries are not.

4) A 150 foot wide block with a 15 foot alley through the block has a density of only 90% even when completely built-up.

5) Select the multiplier value from Table 5.

6) The computation is completed from the information given in Appendix Figure B.

From Appendix Figure B

	Percent of Block
Building #1	33
Building #2	9.2
Building #3	32
Building #4	7.4
	81.6 of the ground area is built upon

7) The factor is 1

Line 14: Follow the directions, multiplying Lines 12 and 13.

Line 15: This item considers the basic land slope throughout the block area. Table F from the Appendix and the following information should be consulted in computing the terrain multiplier.

To estimate the percent of slope in a block or area, sight along a straight edge held horizontally (not parallel to the ground) at eye level. Estimate the distance along the line of sight from the eye to the spot on the terrain seen over the straight edge. Where building exterior construction consists of brick, block, or stone walls with uniform measures, it is possible to estimate elevation differences by counting the difference in block or brick height across the entire block. Select the correct percentage of the slope

Line 8: Follow the directions, adding lines 6 and 7.

Line 9: Height distribution is determined for each of the columns. It must be understood that the computation is looking at the block as a whole unit. Therefore, from Appendix Figure B add the percentage of the block for each height column as follows:

	1 story	2 story	3 story
Building #1	33		
Building #2		9.2	
Building #3			32.0
Building #4			7.4
	33	9.2	39.4

Line 10: Follow the directions, multiplying Lines 8 and 9.

Line 11: It is necessary to divide the value computed on Line 10 by 100 to convert the value from a percent function back to a whole number.

Line 12: Follow the directions, totalling all columns at this point in the calculation.

Line 13: The built-up construction within the confines of the block relates to the construction density. The denser the construction, the higher the risk of fire spread through the block. The following considerations should be observed in computing construction density.

1) Determine density by estimating the percentage of the block within lot lines occupied by buildings, combustible storage, or parking lots.

2) Streets usually extend to include the sidewalk. Thus, lot lines normally are on the inside of the sidewalk. Curb line to lot line distances are considered in the fire spread between block analysis and presented in Part II of the Methodology.

Line 2: Figure the exterior wall values for three-story buildings as follows:

Building #3: 81.2% of three-story bldg. X 70.3 wall values = 5708.36

Building #4: 18.8% of three-story bldg. X 75.9 wall values = 1426.92

7135.28

Factor = 7135.28 - 100 = 71.4

Line 3: Enter the floor construction values computed on Worksheet A for three-story buildings.

Compute the prorated values for three-story buildings as follows:

Building #3: 81.2% of 3 story bldg. X 10 floor construction value = 912

Building #4: 18.8% of 3 story bldg. X 10 floor construction value = 188

1000

Factor Value: 1000 - 100 = 10

Enter 10 on Worksheet B under the three story column.

Line 4: Follow the directions and add lines 1, 2, and 3 for each column.

Line 5: The height multiplier is given to match the number of stories. Note that 5 is the maximum multiplier.

Line 6: Follow the directions, multiplying Lines 4 and 5.

Line 7: Enter the construction values computed on Worksheet A for three-story buildings.

Compute the prorated values for three-story buildings as follows:

Building #3: 81.2% of 3 story bldg. X 15 construction values = 1218.0

Building #4: 18.8% of 3 story bldg. X 1 construction values = 18.8

1236.8

Factor 1236.8 - 10 = 12.4

FIGURE 7

	WORK SHEET B		1 story	2 story	3 story	4 story	5 story
1	Fire Loading		12.1	12.9	15.14		
2	Exterior Wall Construction		10.0	32.0	71.4		
3	Floor Construction		5.0	0	10.0		
4	Add Lines 1, 2, and 3		27.1	44.9	96.54		
5	Height Multiplier		1	2	3	4	5
6	Multiply Line 4 by 5		27.1	89.8	289.6		
7	Roof Construction		5.0	50.0	12.4		
8	Add Lines 6 and 7		32.1	139.8	302.0		
9	Height Distribution		33.0	9.2	39.4		
10	Multinly Line 8 by 9		1059.3	1285.16	118.98		
11	Divide Line 10 by 100		10.59	12.86	118.98		
12	Total All Columns	142.43					
13	Density Multiplier	1					
14	Multiply Line 12 by Line 13	142					
15	Terrain Multiplier	1					
16	Final Block Rating	142					

Notes:

objective of this item is to prorate the values according to building heights. Therefore, any building is simply a percentage of all the buildings in a specified height category. The computation is used in completing Worksheet B below.

It should be noted that Worksheet A needs to be completed for each structure in the block under consideration.

D. Completing Worksheet B

Worksheet B (Figure 7) is provided to summarize the information from the individual building sheets (Worksheet A). This worksheet will be used to complete individual block ratings.

The proper procedure for completing Worksheet B is as follows:

Line 1: Under the respective columns according to the height (number of stories), record the relative fire load values for buildings where the percent of height category applies. (Note: Where there is more than one building in a given height category, it is necessary to prorate values according to the percent of the total ground area for buildings in the height category under evaluation. This concept is applied to the two three-story buildings as an illustration.)

Compute the percentage of three-story buildings:

Building #3: 81.2% of 3 story bldg. X 16.4 relative fire loading index value = 1331.68

Building #4 18.8% of 3 story bldg. X 9.7 relative fire loading index value = 182.36

TOTAL: 1514.04

Divide the added value by 100 to convert the percent value back to a whole number: 1514 - 100 = 15.14

Enter 15.14 on Worksheet B under the three-story column.

Note that the wall faces are identified by direction. The wall factor values are given in Appendix Table C.

The north wall is used to illustrate the correct evaluation procedure on the sample sheet for Building 1. The north wall is noted to be concrete block, brick-faced, giving a dimensional thickness in excess of 12 inches. The corresponding construction factor is 1. The north wall has open windows making the open factor 10. The wall has a length of 400 feet, which is 32 percent of the total perimeter wall length (400'/1250' = 32%). The construction value for the north wall is obtained by multiplying the construction factor, the opening factor and the percent of perimeter wall. The product value for the north wall is 320.

The procedure is repeated for each of the remaining walls. Next, the construction value is added for all walls. Remember, the summary value represents a percent function. Therefore, this summary value must be divided by 100 to convert the value back to a whole number. This is accomplished on the Factor Line.

Step 4: The floor construction value is evaluated under this item. Appendix Table B gives the correct reference for these values. The selected value is inserted on the line provided.

Step 5: The roof construction and the roof covering are evaluated under this item. The combinations of roof construction and roof covering materials are given in Appendix Table D.

Step 6: The last step of the individual building analysis is to record the percent of building height category. This information is found in Appendix Figure C. In this case, Building 1 is the only one-story building in the block and therefore is 100 percent of the one-story buildings. The

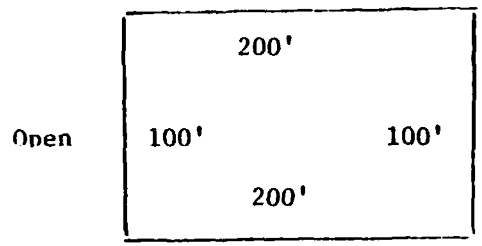
FIGURE 6

WORKSHEET A

Individual Building

Block I.D. Sample   Building I.D. Bldg. #4   Building Height 3 Stories

Step 1: In the space provided below, draw a sketch of the building being considered. Include notations on perimeter wall construction, height and openings. The sketch should be dimensioned.



Step 2: Fire Loading Value: 9.7

Step 3: Wall Construction Value: Frame   Total Perimeter Wall Length 600 feet

Wall Face	Construction Factor	X	Opening Factor	X	Per Cent of Perimeter Wall	=	Construction Value
NORTH	30	X	1	X	33	=	990
EAST	30	X	1	X	17	=	510
WEST	30	X	10	X	17	=	5100
SOUTH	30	X	1	X	33	=	990
					Summary Value	Σ	7590
					Factor = Σ/100	=	75.90

Step 4: Floor Construction Value 10

Step 5: Roof Construction Value 1

Step 6: Per Cent of Building Height Category 18.8

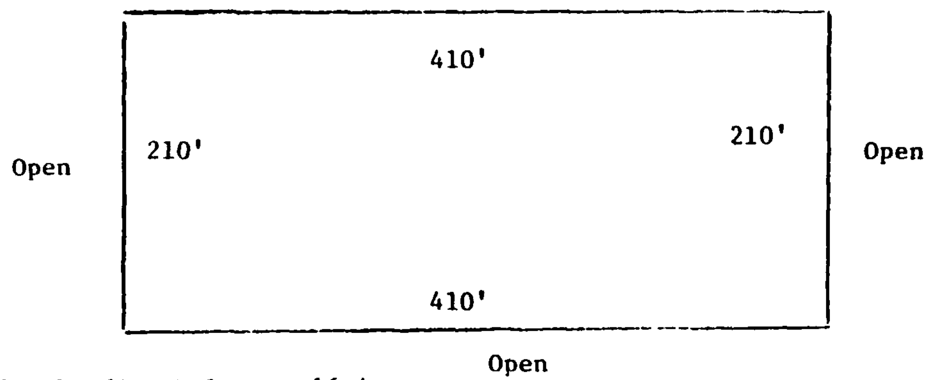
FIGURE 5

WORKSHEET A

Individual Building

Block I.D. Sample Building I.D. Bldg. # 3 Building Height 3 Stories

Step 1: In the space provided below, draw a sketch of the building being considered. Include notations on perimeter wall construction, height and openings. The sketch should be dimensioned.



Step 2: Fire Loading Value: 16.4

Step 3: Wall Construction Value: BW5 Total Perimeter Wall Length 1240 feet

Wall Face	Construction Factor	X	Opening Factor	X	Per Cent of Perimeter Wall	=	Construction Value
NORTH	10	X	1	X	33	=	330
EAST	10	X	10	X	17	=	1700
WEST	10	X	10	X	17	=	1700
SOUTH	10	X	10	X	33	=	3300

Step 4: Floor Construction Value 10 Summary Value Σ 7030

Step 5: Roof Construction Value 15 Factor = Σ/100 = 70.3

Step 6: Per Cent of Building Height Category 81.2

the intervening variables associated essentially with the width of gap and probability of fire spread between structures.

3. Probability of Fire Spread as a Function of Gap Width

The literature documented in this study clearly indicates that the primary consideration of fire spread between structures is the actual width of the gap (street width) between the exposing building and the exposed building. Street width or building gap influences both heat radiation and heat conduction between structural building faces. The mass source, line source, or point source conditions are carefully considered in establishing measurable indicators. The most thorough investigation of this matter appears to have been conducted by Eggleston at Southwest Research which culminated in a "probability between structures" (6). This model concept is based upon the baseline parameters of brick, wood-joisted buildings with unprotected window openings and ordinary occupancy fuel loadings. Higher and lower risk conditions can be assessed from this point. The basic probability index is set forth in the Appendix Table I, based on the referenced Southwest Research studies.

4. Adjustment factors

When there is a defined equality of fire intensity between two structures separated by a defined gap, the analytical analysis of fire spread is a quantitative function of the differential between radiation intensity of the exposure and the defined intervening variables. Reduced

6. Eggleston, Lester. Fire Defense System Analysis. San Antonio, (TX). Southwest Research Institute (Final Report), 1970.

to these parameters, the situation is still very complex. To develop a system of analysis that can be accepted and implemented by local government, it is necessary to reduce the variable analysis to four variable indexes as follows:

a. Index value for the exposing building(s)

b. Index value for the exposed building(s)

c. Width of gap and probability of fire spread

d. The wind direction and speed

Still there are important associations in this variable relationship. It is essential to establish the quantitative interface between the identified variables. This is the essence of this model development. Each of the conditions are discussed in the following subsections.

Before proceeding with actual calculation techniques, it is important to recognize that the variables in each category have been reduced to manageable perspectives determining a quantitative value that expresses the potential fire spread between block structures.

5. Block Spread Model Assumptions

A model of quantifying the potential of fire spread between selected structural blocks in an urban area is developed around a series of basic assumptions. The users of this model need to be made aware of these assumptions in applying the model as intended. The assumptions are developed on the basis of the scope and limitations of fire spread analysis documented in the supporting literature search.

a. The primary assumption of this model is that exposing walls of buildings are separated by designated streets at least 10 feet wide on one side of the building.

b. The model evaluates existing conditions and does not evaluate possible corrective actions to reduce or mitigate the problem.

c. Fire spread between block fronts is dependent upon the following primary physical characteristics:

1) The occupancy-structural interface of exposing buildings. This relationship is quantified in the block fire analysis by the following formula -

[(O + F + W) (H + R)] = RHV where

O is the occupancy fuel load value (Table A - Part I)

F is the floor construction value (Table B - Part I)

W is the exterior wall construction value (Table C - Part I)

H is the height multiplier (See Form B - Part I)

R is the roof construction and cover value (Table D - Part I)

RHV = Relative Numerical Hazard Value for the block.

2) The facing wall area and openings represent the key factors in assessing fire spread (principally by radiation). The wall face impact can be measured as follows -

WFR X PWO = WEV where

WFR = Wall Face Ratio (H/W)

PWO = Percent of wall openings in the wall face that is being evaluated

WEV = Wall Exposure Value

3) The dominant characteristics in fire spread occur with the exposing wall. Therefore, a wall exposure ratio is calculated to determine this relationship. The wall face ratio factor is calculated as follows:

WFR = WE1/WE2 where

WE1 = the exposing wall factor (WEV)

WE2 = the exposed wall factor (WEV)

The ratio factor is especially important for evaluating the potential spread between adjacent high rise structures.

Note: A directional concept is important in this evaluation. The ratios are simply inversed if an opposite direction is assumed. Assumed wind conditions as discussed below enter into the total fire spread evaluation and are used to designate the exposed and exposing conditions.

4) The actual separation distance is important to the assessment of fire spread between blocks. A probability of fire spread based on distance is presented in Appendix Table I.

5) The relative spread index (RSI) per defined facing wall length can be computed by clearly defining the exposing block and the exposed block. Once this designation is made, the following analytical relationship can be applied per unit of block length as discussed below.

Conceptual Numerical Relationship For Determining Fire Spread Between Blocks

Relative Spread Index (RSI) = Exposing Block (RHV X WEV X WRF) X Street Width (Probability value) X

Exposed Block (RHV X WEV)

Form C has been developed to insert the required computational information for any given block. This is discussed in the methodology section.

6) The facing walls of exposing block faces can be set back irregularly from the curb line; this setback can also present an angular exposure. Therefore, it appears necessary to examine the length and separation of facing walls according to an incremental concept. Walls will be divided into 20 foot lengths for this analysis. This concept does not compound the calculation process since calculations for identical exposure fronts can simply be repeated on the analysis form (Form C). A specific example supplied with the methodology section illustrates this point.

7) It is assumed that the parameters identified above can be structured in an analytical manner that will in fact produce a numerical indicator for assessing the risk of fire spread between defined adjacent blocks under prescribed sets of circumstances.

c. The analytical methodology is based on an assumption that direct fire exposure, primarily from radiant heat, is the dominant factor that ignites buildings separated by designated streets or open areas. This portion of the model does not directly consider fire spread as a phenomenon caused exclusively by flying brands.

d. Wind speed and direction have to be most important considerations in assessing fire spread between separately identified blocks. The analysis method developed in this study assumes that the wind is less than five miles per hour and is blowing from the direction of the exposing building to the exposed building. Using the block orientation described in the methodology of a left block and a right block with the designated street running perpendicular to the block fronts, it appears possible to establish a wind orientation index to modify the basic relative block fire spread analysis. Appendix Tables J through L present the wind adjustment factors.

D. Methodology

1. Overview

A systematic process is required to provide consistent results in computing the fire spread potential between buildings in adjacent blocks. A detailed methodology is also required to provide local government personnel with the ability to apply the model. To accomplish these objectives, the following quantitative process for assessing block spread potential is provided in the context of an example.

2. Form C

The key element in the evaluation process is the proper completion of Form C. All of the required calculations for assessing potential fire spread between blocks can be developed directly on this form. For illustration purposes, this form is completed using the identified example according to the steps below. A separate form is used for each step up to step 6 (Figures 8-a through 8-e). This procedure is done for clarity only and does not need to be followed in actual practice. Completed Form C, Figure 8-e, summarizes calculations that are required for the fire spread assessment process.

a. Orientation to Form C

This form is designed to depict the exposing walls separated by a designated street. The form should be orientated so that the exposing block is positioned on the left side of the form. As with any equation process, the computations are carried from left to right by designated rows. Note that the summary column is indexed at the right.

The form uses rows running horizontally on the paper. Two vertical lines are positioned in the center. These vertical lines represent the street boundary or curb lines. The street width is inserted at the top.

The distance between row lines is 20 feet. This permits inserting block fronts up to 500 feet in length on one form. Form sheets may be attached vertically using the reference line for longer blocks.

FIGURE 8-a

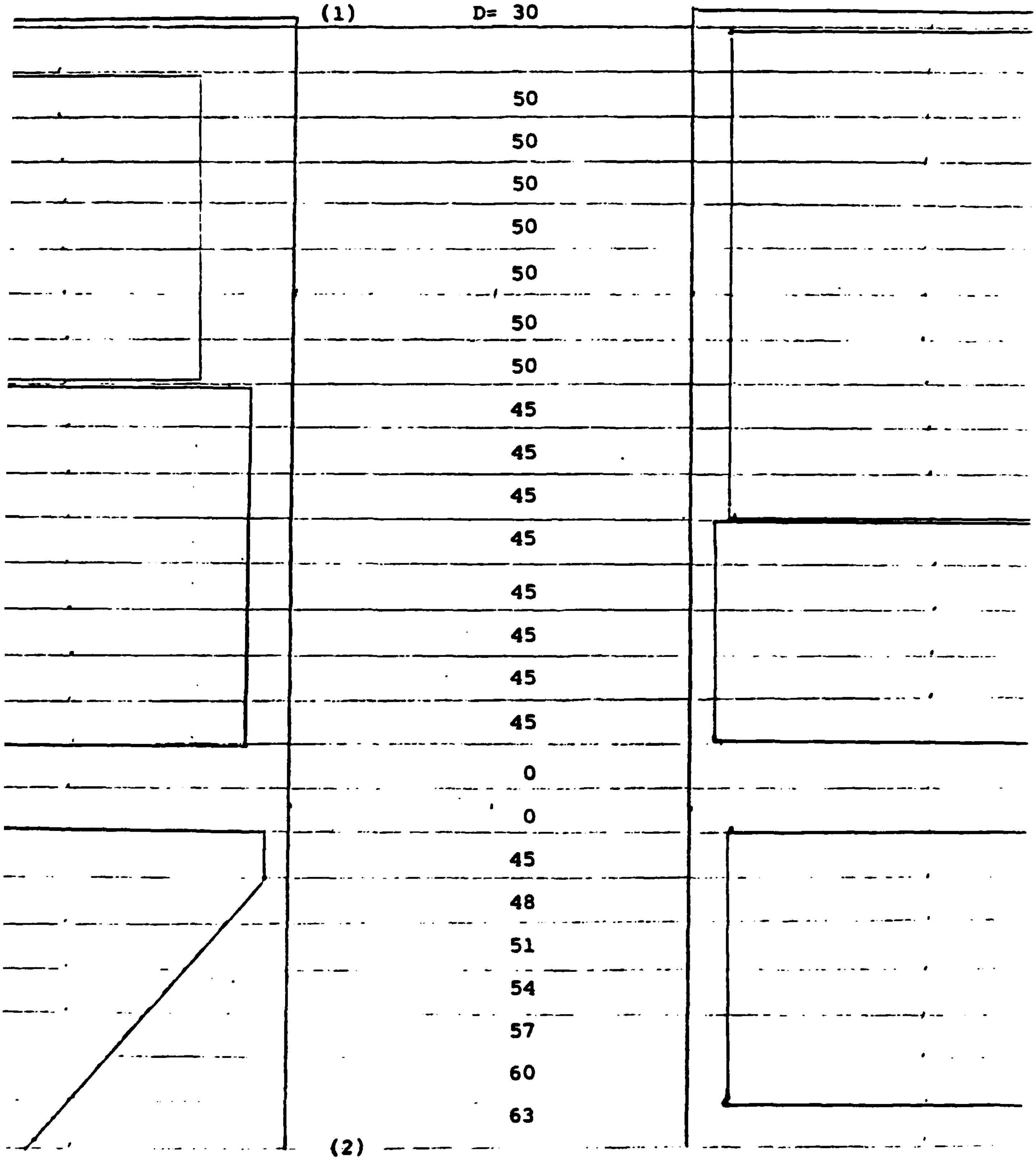

(1)
D= 30
50
50
50
50
50
50
50
45
45
45
45
45
45
45
45
0
0
45
48
51
54
57
60
63
(2)

Figure 8-a shows how the facing walls are drawn on Form C using the 20-foot increment lines. Walls perpendicular to the facing wall are simply drawn back to the margin line. This permits the proper location of setbacks and walls that form angles to the street. These factors are vital to accurate computations.

Building wall lengths, heights, and opening configurations can be taken directly from the information that was gathered for the mass fire spread model. It is important to recognize that this basic information does not have to be collected or analyzed if the mass fire block analysis is completed first. In fact, a common scale permits a simple tracing process for building fronts on to Form C.

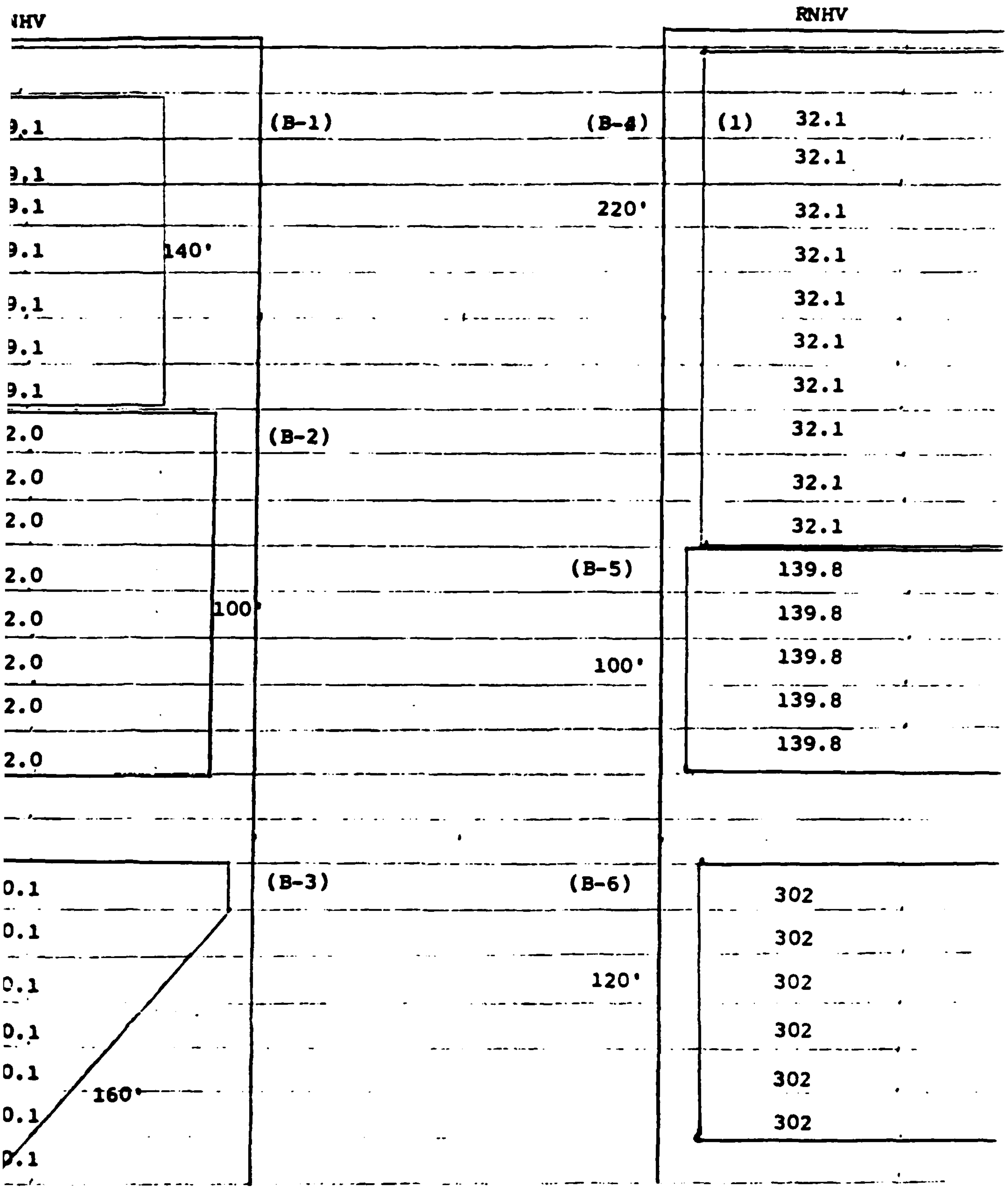
b. Logging in the Individual Building Relative Numerical Hazard Value

Figure 8-b illustrates the proper method of inserting the relative numerical hazard value (RHV) from the calculations performed for the completion of Form A in Part I of the methodology. Note that the RHV is inserted in the proper column on the first row (top to bottom) for each separate building. For proper consistency of application, it is advisable to also insert the number of stories encased by a circle on the first row of each building adjacent to the RHV numerical value.

c. Logging in the Wall Exposure Value

The wall exposure value calculation is a product of the wall face ratio and the percent of wall openings. This information can be calculated from Form A in Part I of the methodology. For

FIGURE 8-b



(B-1)
(B-4)
(1)
RNHV
32.1
32.1
32.1
32.1
32.1
32.1
32.1
32.1
32.1
32.1
220'
140'
(B-2)
100'
(B-5)
139.8
139.8
139.8
139.8
139.8
100'
(B-3)
(B-6)
302
302
302
302
302
302
120'
160'

purposes of clarity the following computations are made for each building in the sample block. Note that an estimated height of 10 feet is used per story height.

Building	WFR	X	PWO	=	WEV
1	.07	X	.70	=	.049
2	.20	X	.70	=	.040
3	.06	X	.60	=	.036
4	.05	X	.50	=	.025
5	.20	X	.20	=	.040
6	.25	X	.30	=	.075

The computed values are inserted on the rows in the proper columns as illustrated on Figure 8-c.

d. Logging in the Wall Exposure Ratio

The exposure ratio to be logged on Form C is determined by dividing the WEVs for the exposing wall faces by the WEVs for the exposed wall face. For the example of Building 1 exposing Building 4 the values would be .049/.025 = 1.96 where these values are constant. The appropriate calculations are also shown on Figure 8-c.

e. Probability Based on Distance

The probability of spread function is based on the separation distance between wall faces. This numerical value is selected from Appendix Table I. Based upon the separation distances noted in Figure 8-a, the spread probabilities are given on Figure 8-d - PFS (Probability of Fire Spread). Note that the distance between wall faces is used, not curbline distances.

FIGURE 8-c

WEV	WER	WEV
.049	1.96	.025
.049	1.96	.025
.049	1.96	.025
.049	1.96	.025
.049	1.96	.025
.049	1.96	.025
.049	1.96	.025
.040	1.60	.025
.040	1.60	.025
.040	1.60	.025
.040	1.0	.040
.040	1.0	.040
.040	1.0	.040
.040	1.0	.040
.040	1.0	.040
	0	
	0	
.036	.48	.075
.036	.48	.075
.036	.48	.075
.036	.48	.075
.036	.48	.075
.036	.48	.075

FIGURE 8-d

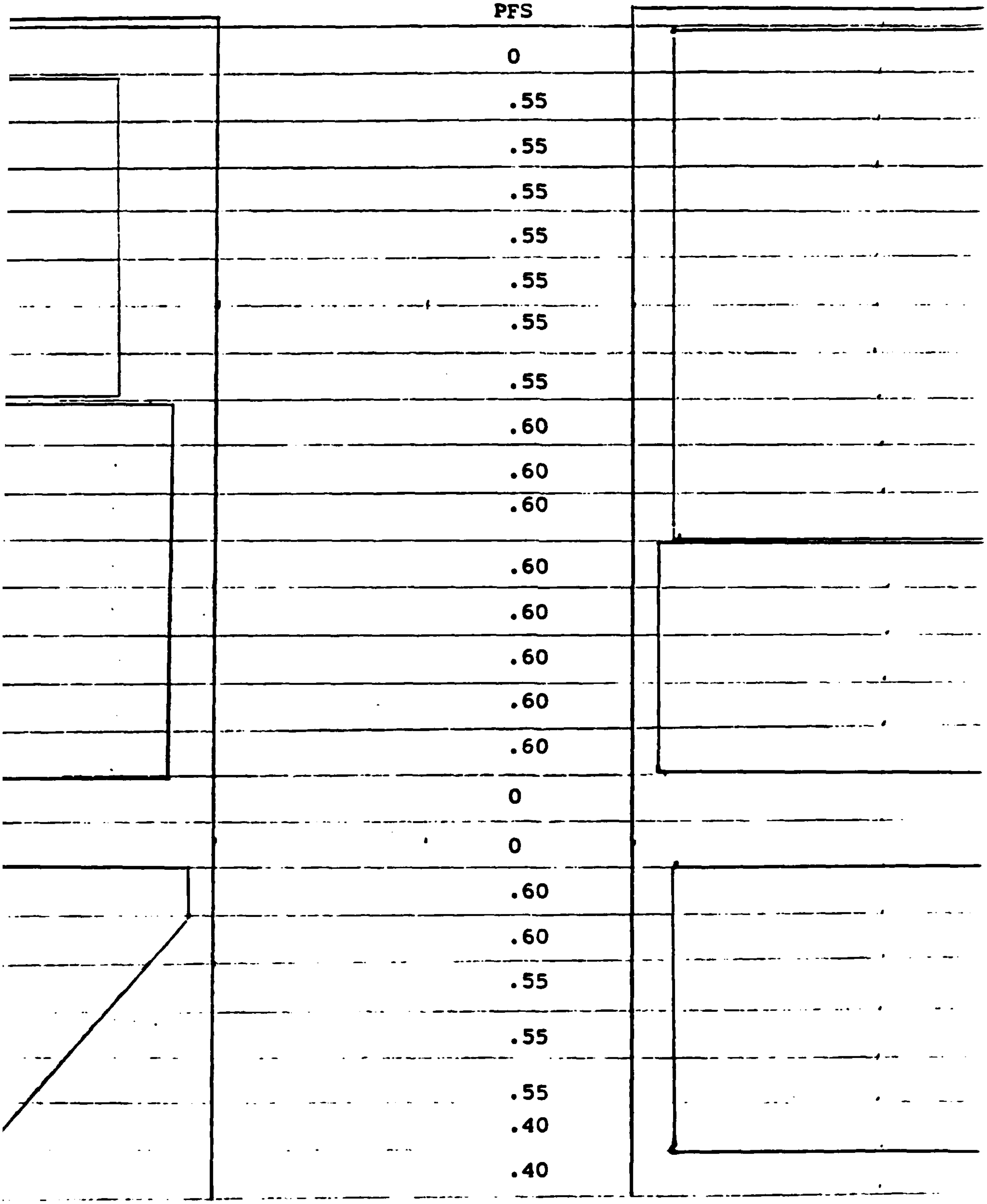

PFS
0
.55
.55
.55
.55
.55
.55
.55
.60
.60
.60
.60
.60
.60
.60
.60
0
0
.60
.60
.55
.55
.55
.40
.40

FIGURE 8-e

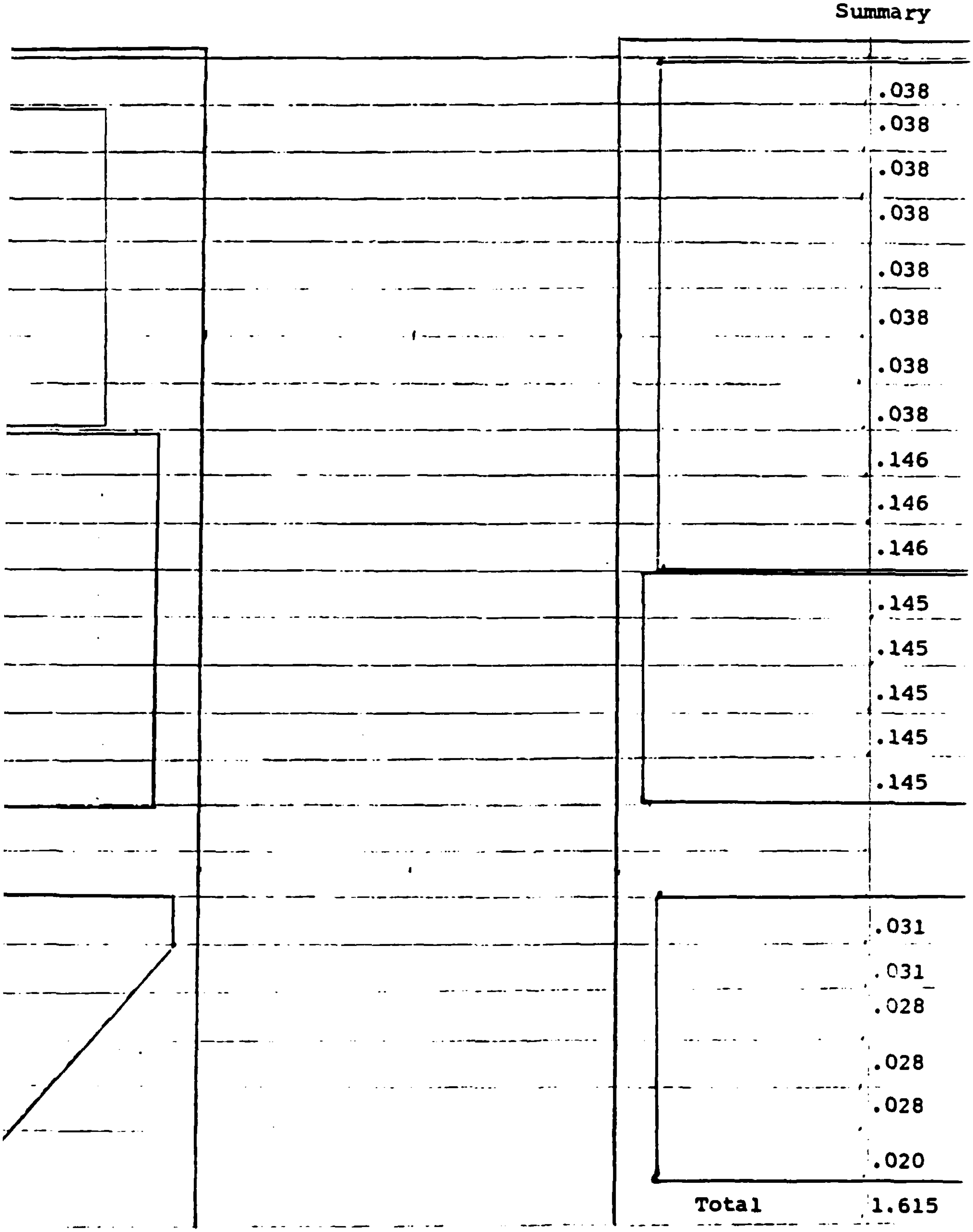

Summary
.038
.038
.038
.038
.038
.038
.038
.038
.146
.146
.146
.145
.145
.145
.145
.145
.031
.031
.028
.028
.028
.020
Total 1.615

TABLE F

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

TABLE E

Construction Density

Category	Multiplier
0 to 5%	0
6 to 20%	0.1
21 to 30%	0.2
31 to 40%	0.4
41 to 50%	0.6
51 to 60%	0.8
61 to 70%	0.9
Over 70%	1.0

TABLE D

Roof Construction Evaluation

f Support System	Roof Cover	Value
e Resistive	Class A Built-up	1
-combustible	Class A Built-up	5
-combustible	Class B Built-up	10
-combustible	Class B Cover	15
k on combustible supports	No listing (UL)	30
bustible Supports	*Combustible	40
-combustible	*Combustible	50

*If more than 25% of the roof in the block under construction has bustible roof covers including wood shingle roofs, assign the value of 50 all column evaluations on Worksheet B.

TABLE C

Exterior Wall Construction Evaluation

ctor

terior Wall Construction

te: Refer to Form A and note that each perimeter wall to a given building is evaluated individually.

ll Construction Factor:

lid Masonry 1
2 inch or greater brick or concrete)

b Standard Solid Masonry 5
ess than 12 inch solid masonry)

ick Wood Joist Construction 10

n-combustible 15

n-combustible Curtain Wall on Combustible Framing 20

mbustible Framing and Exterior Including Metal Clad 30

ll Opening Factor:

wall openings or full exposure protection on openings 1
o other openings)

re glass windows - no other openings 5

protected wall openings 10

It should be noted each wall on a building has a prorated value to the tire perimeter wall of the building. The procedure for this calculation is tlined on Worksheet A.

dividual Wall Value = Construction Factor X Wall Opening Factor

TABLE B

Floor Construction Evaluation

Factor	Values	
Floor Construction	Fire Resistant .... (Equivalent Type A)	1
	Non-combustible	5
	Combustible	10

TABLE A (continued)

Occupancy Designation	Relative Fire Load Value
Open oil quenching	49.7
Solvent cleaning	48.6
Varnish and Paint dipping	49.8

Relative Fire Load Calculation Formulas

$F = K \times W + 0.75\,W + W$

TABLE A (continued)

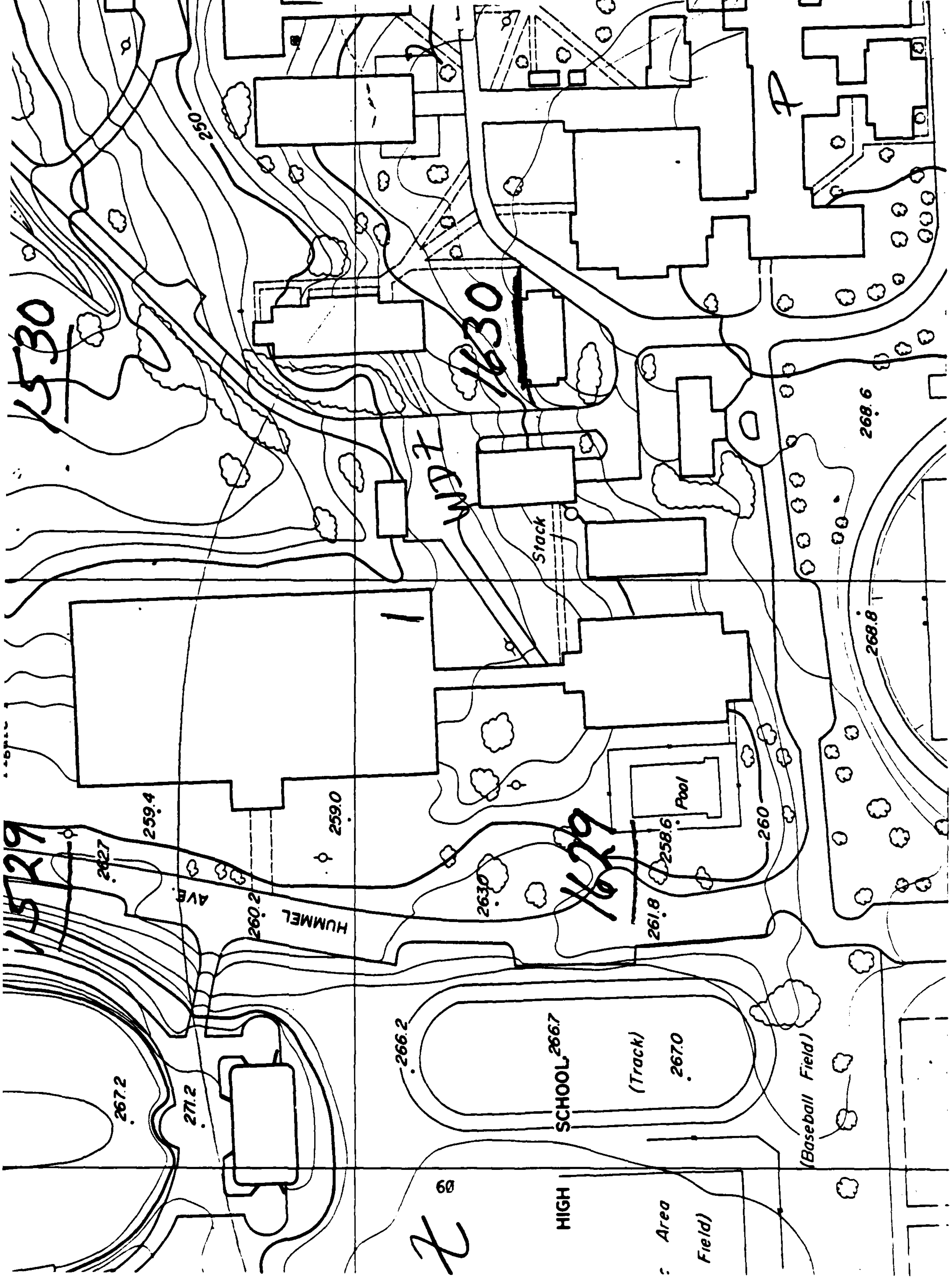
Occupancy Designation	Relative Fire Load Value
Laundries	15.0
Cereal Mills	17.4
Chemical plants	21.7
Machine shops	17.6
Metal working	14.8
Cold storage warehousing	9.8
Confectionary products	12.4
Distilleries	14.8
Leather goods manufacturing	16.7
Mercantile buildings (all)	16.4
Printing and Publishing	19.7
Textile manufacturing	22.0
Tobacco products manufacturing	23.1
Wood products assembly	24.4
Feed mills	27.0
Paper and Pulp mills	28.1
Paper process plants	30.3
Piers and Wharves	25.4
Repair garages	27.9
Fire manufacturing	38.0
All warehousing	18.7
Flammable liquids spraying	34.2
Flow coating	39.1
Modular building assembly	42.1

TABLE A

Relative Fire Loads for Mass Fire Example

Occupancy Designation	Relative Fire Load Value
Church	6.2
Social Club	7.1
Schools, Colleges, other educational institutions	5.9
Hospitals	3.2
Health Care Facilities	3.5
Libraries (stacks less than 12.5 ft.)	12.9
Libraries (stacks over 12.5 ft.)	16.2
Museums	11.7
Office buildings (private)	9.7
Office buildings (government)	19.2
Private residence	3.9
Restaurants (seating areas)	4.0
Restaurants (service areas)	7.7
Theaters and Auditoriums (excluding stages)	10.5
Theaters and Auditoriums (stage areas)	23.6
Automobile parking garages	12.9
Bakeries	14.1
Beverage manufacturing	10.2
Canneries	10.9
Dairy products manufacturing and processing	9.7
Electronic plants	11.2
Glass and glass products manufacturing	13.5

FIGURE A



HUMMEL AVE
Stack
Pool
HIGH SCHOOL
(Track)
(Baseball Field)
Area
Field)
250
259.4
259.0
258.6
260
261.8
263.0
262.7
260.2
271.2
267.2
266.2
266.7
267.0
268.6
268.8
60

APPENDIX

Forms, Worksheets, Figures, and Tables

Condition 2: If the wind increases to 31 miles per hour but maintains the same direction, one would refer to Appendix Table L and read out a new value of .16 or a 16 percent relative probability factor. The factor does not appear to change appreciably even though the velocity has increased by 20 miles per hour. The reason for the observation relates to the low value of the radiating area and the low height-to-width ratio.

Condition 3: If the wind is blowing at 20 degrees to the horizontal, then the adjustment factor from Figure F would be 0.8 or (0.8 X .145 = .1160). This is intended to imply that the probability of fire spread as a function of angular wind is approximately 12 percent instead of 15 or 16 percent.

between buildings is between 50 and 500 feet. There appears to be no constructed values for situations where the structural gap exceeds 500 feet. However, the table values may provide some indicators for making "educated guesses" about the probability of fire spread beyond the 500 foot separation interval.

Second, the probability of fire spread between structures where the wind velocity is over 40 mph is considered to be 1.0 or almost sure probability of spread.

Third, it is assumed in the basic use of these tables that the wind is blowing directly from the exposing building to the exposed building. If the wind velocity is projected at an angle or perpendicular to the wall faces an adjustment must be made to the relative probability factor. These adjustment factors are presented in Appendix Figure D.

Example: The example previously presented in Study Phase II can be extended to illustrate how to apply the wind factor tables and the adjustment for angular velocities.

Condition 1: Let it be assumed that the wind is blowing from the exposing building to the exposed building at a velocity of 10 mph. Start by determining the exposing buidling's height-to-width ratio. The basic information can be obtained from Figure B. The average calculated value is less that .5. Next, read right down in the radiating area column to 5,000 square feet and then index right to read out the value .145. This value implies that there is a relative probability of .145 or approximately a 15 percent chance of fire spread to the adjacent block as a factor of wind conditions.

wind as a primary factor in fire spread between structures. Paradoxically, there is very little quantitative information of the specific effect of different wind velocities on a particular structural fire spread scenario. The amount of research documented in the literature reviewed is almost nil.

There is one important exception to the above observation. A study conducted at Illinois Institute of Technology in 1969 as a follow-up to the original Gage-Babcock local assessment method for measuring conflagration potential discusses a method for determining potential fire breaks. In this study, consideration is given to required separation distances in feet as a function of average wind velocity and shape of the radiating area. Potential wind velocities in this methodology are divided into three increments. The background for this information comes from several forest product studies on fire spread in fuel beds based on artificial wind conditions. From this work, the probability of fire spread, given defined separation intervals, is translated into linear foot separation "requirements". Therefore, it appears quite proper to inverse-ratio the published tables of required separation distances in feet to produce a relative probability of fire spread between structures over a defined gap given a specific wind velocity parameter.

The above concepts have been translated into three separate tables:

Appendix Table J: Relative Probability of Fire Spread with Wind Velocities Under 7 mph;

Appendix Table K: Relative Probability of Fire Spread with Wind Velocities Between 7 and 18 mph; and

Appendix Table L: Relative Probability of Fire Spread with Wind Velocities Between 10 and 40 mph.

Several conditions must be understood clearly and interpreted correctly in the use of these tables. First, the referenced tables apply where the gap

f. Summary Calculations

Figure 8-e presents the summary calculations by row which is the multiplication of all factors on that row. The right column is added to give the relative index of fire spread potential.

The column index is 1.615. It should be recalled that this value is a relative index value. To be meaningful, the index value has to be structured within a scalar value system. The initial estimator of values is given below. It should be recognized that validation studies conducted in three large cities in the United States assessed the benchmarks of the scalar values and possibly suggested new range indicators for this portion of the study. The relative index values are different from the mass fire index for individual blocks.

Relative Index of Fire Spread Potential

Below .20	Slight Probability
.20 to .50	Moderate Probability
.50 to 1.00	Extensive Probability
Above 1.00	High Probability

To be meaningful, the relative index of fire spread potential should be plotted on a city area map with directional arrows showing the potential fire spread between block faces. These factors, in conjunction with the wind indicators given below, provide a powerful quantitative measure of fire spread potential between blocks.

E. Wind Analysis

Without exception, every study reviewed concerning mass fire developemnt and conflagration analysis makes reference to the importance of considering

TABLE G

Estimating Slope

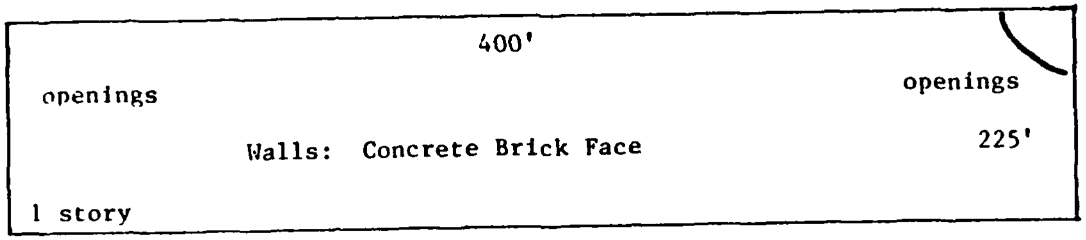
Distance Along Line of Sight	Multiplier
Over 60 ft.	1.0
31 to 60 ft.	1.1
16 to 30 ft.	1.3
10 to 15 ft.	1.6
7 to 9 ft.	1.8
Less than 7 ft.	2.0

WORKSHEET A

Individual Building

Block I.D. Sample   Building I.D. Building #1   Building Height 1 Stories

Step 1: In the space provided below, draw a sketch of the building being considered. Include notations on perimeter wall construction, height and openings. The sketch should be dimensioned.



Step 2: Fire Loading Value: ______

Step 3: Wall Construction Value: Total Perimeter Wall Length 1250 feet

Wall Face	Construction Factor	X	Opening Factor	X	Per Cent of Perimeter Wall	=	Construction Value
NORTH	______	X	______	X	______		______
EAST	______	X	______	X	______	=	______
WEST	______	X	______	X	______	=	______
SOUTH	______	X	______	X	______	=	______
					Summary Value	Σ	______
					Factor = Σ/100	=	______

Step 4: Floor Construction Value ______

Step 5: Roof Construction Value ______

Step 6: Per Cent of Building Height Category ______

WORK SHEET B		1 story	2 story	3 story	4 story	5 story
1 Fire Loading						
2 Exterior Wall Construction						
3 Floor Construction						
4 Add Lines 1, 2, and 3						
5 Height Multiplier						
6 Multiply Line 4 by 5						
7 Roof Construction						
8 Add Lines 6 and 7						
9 Height Distribution						
10 Multiply Line 8 by 9						
11 Divide Line 10 by 100						
12 Total All Columns						
13 Density Multiplier						
14 Multiply Line 12 by Line 13						
15 Terrain Multiplier						
16 Final Block Rating						

Notes:

FORM C

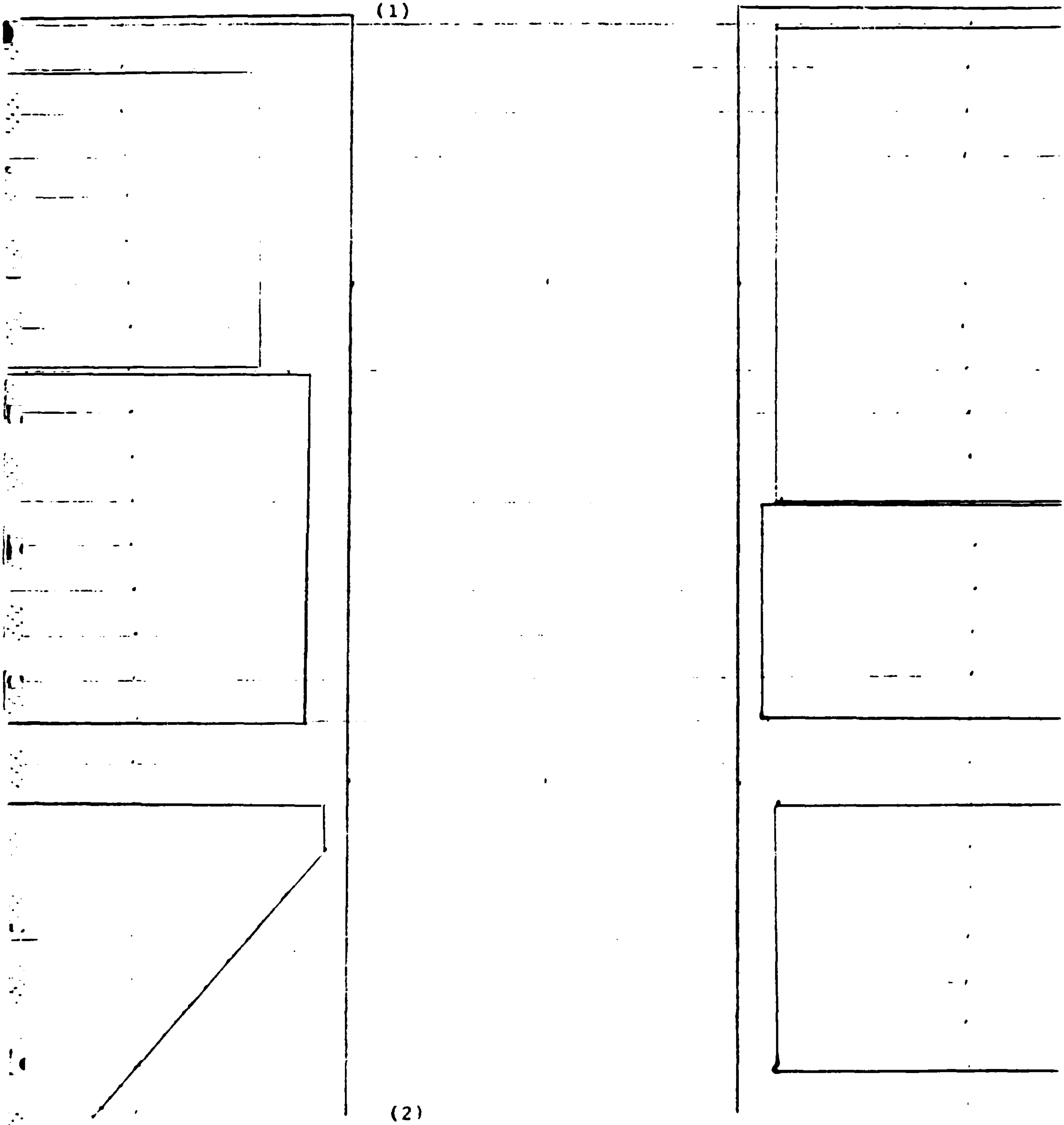


FIGURE B

Block Layout

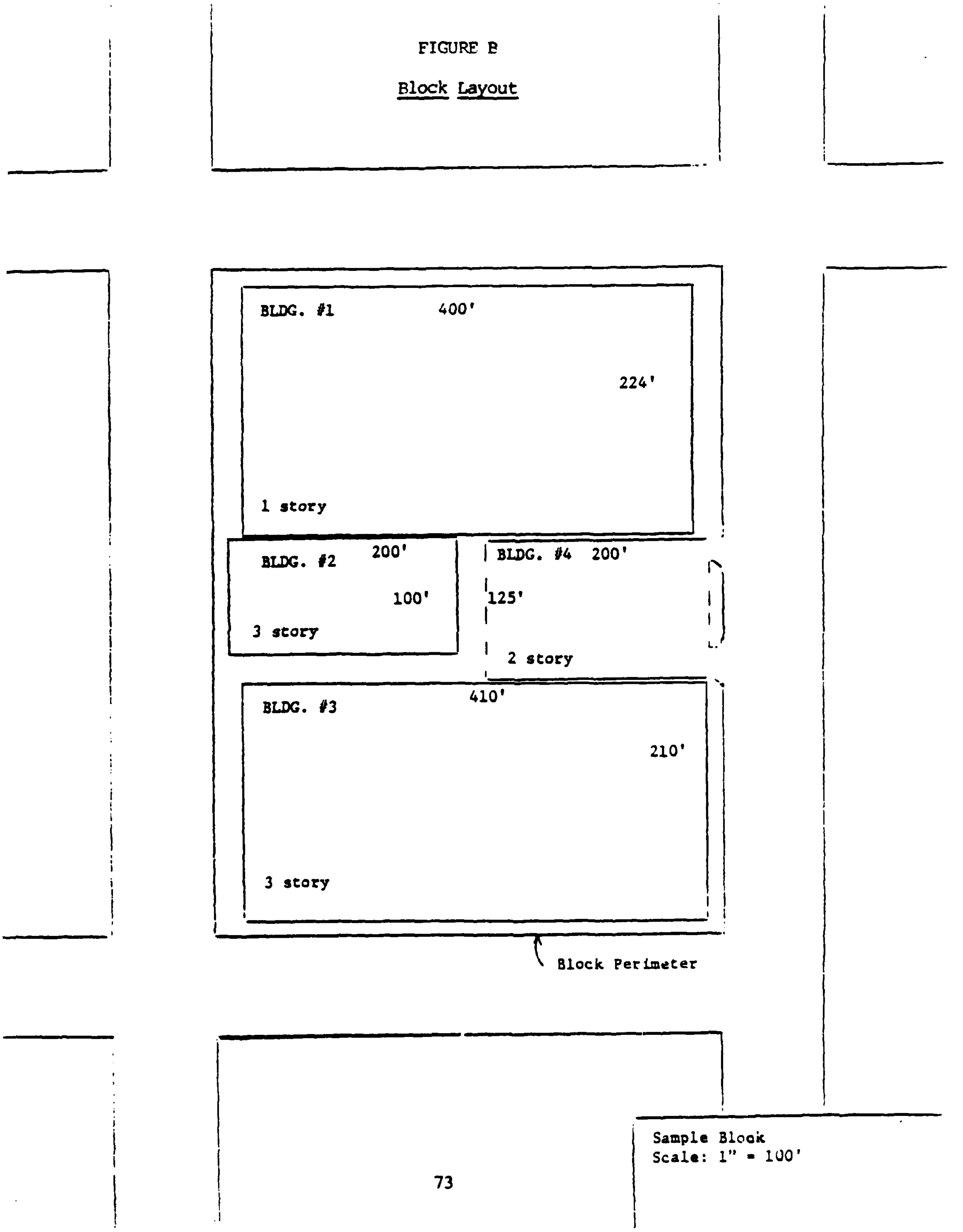


FIGURE C

Subject Block Description

Building #1:

Occupancy: Hardware and Appliance Store

Basic Dimensions: 400 ft. X 225 ft.

Height: 1 story = 10 ft.

Ground Area: 90,000 sq. ft.

% of the block = 33%

% of 1 story buildings = 100%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 12.1 Table 1

Walls: Concrete Block - Brick Face

Floor: Non-combustible

Roof: Unprotected Non-combustible

Perimeter Wall:

Exterior Block Exposure:	850 feet
Interior Block Exposure:	400 feet
Total	1250 feet

Building #2:

Occupancy: Open Automobile Parking Garage

Basic Dimensions: 200 ft. X 125 ft.

Ground Area: 25,000 sq. ft.

% of the block = 9.2%

% of 2 story buildings = 100%

FIGURE C (continued)

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 12.9 Table 1

Walls: Reinforced Concrete Supports - Open Exterior

Floor: Fire Resistant

Roof: Open

Perimeter Wall:

Exterior Block Exposure:	125	feet
Interior Block Exposure:	525	feet
Total	650	feet

Building #3:

Occupancy: Furniture Store (All floors)

Basic Dimensions: 410 ft. X 210 ft.

Height: 3 Story - 30 ft.

Ground Area: 86,100 sq. ft.

% of the block = 32%

% of 3 story buildings = 81.2%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 16.4 Table 1

Walls: Brick Wood Joist

Floor: Combustible

Roof: Unprotected Non-combustible (B)

Perimeter Walls:

Exterior Block Exposure:	830	feet
Interior Block Exposure:	410	feet
Total	1240	feet

FIGURE C (continued)

Building #4:

Occupancy: Variety Store on the Ground Floor; Professional Offices on the Second Floor.

Basic Dimensions: 200 ft. X 100 ft.

Height: 3 story - 25 feet

Ground Area: 20,000 sq. ft.

% of the block = 7.4%

% of 3 story buildings = 18.8%

Hazard Index Level: (1) (Table 1)

(2) Relative Fire Index 9.7 Table 1

Walls: Frame

Floor: Combustible

Roof: Combustible (All)

Perimeter Wall:

Exterior Block Exposure:	100	feet
Interior Block Exposure:	500	feet
Total	600	feet

TABLE H

Factor Analysis for Fire Spread Determination
Between Exposing and Exposed Buidlings

1. Exposing Building: (Emitting the Heat Energy)

   a. Occupancy factor

   b. Type of construction of exterior walls

   c. Height of exposing fire (portion or all of wall height)

   d. Width of exposing fire (portion or all of wall width)

   e. Roof construction and covering

   f. Percent of openings in exposing wall

   g. Ventilation characteristics of exposing buildings fire

   h. The fuel dispersion or surface volume ratio of the fuel

   i. The size, geometry, and surface to volume ratio of the building involved

   j. The thermal properties, conductivity, specific heat, and density of the interior finish

2. Exposed Building: (Receiver of Heat Energy)

   a. Construction classification for exterior wall

   b. Roof cover and construction

   c. Percent of openings in exterior wall area

   d. Protection of openings

   e. Exposure of interior finish and combustibles to the radiation, convection, and flying brands of the exposing fire

   f. Thermal properties, conductivity, specific heat, density, and fuel dispersion of the interior finish materials and the building contents

TABLE H (continued)

3. Intervening Variables

   a. Separation distance between exposing and exposed buildings

   b. Shielding effect of intervening non-combustible construction

   c. Wind direction and velocity

   d. Air temperature and humidity

   e. Accessibility for fire fighting operations

   f. Extent and character of fire department operations

TABLE I

Width of Gap and Probability of Fire Spread

Width of Gap (feet)	Probability of Fire Spread (percent)
0	1.0
12.5	.95
25.0	.80
37.5	.60
50.0	.55
62.5	.40
75.0	.35
87.5	.30
100.0	.25
112.5	.22
125.0	.20
137.5	.15
150.0	.12
167.5	.10
175.0	.08
187.5	.06
200.0	.05
212.5	.04
225.0	.03
237.5	.02
250.0	.01
275.0	.0015
300.0	.0

TABLE J

Relative Probability of Fire Spread

(Wind Velocity 7 mph or less)

ating ea Ft.	Building: Wall Face Ratio (H/W) H/W = 1	H/W = .5 to 1	H/W = Less than .5
30	-	-	-
00	-	-	-
00	-	-	-
00	-	-	-
00	-	-	-
00	-	-	-
00	.120	-	-
00	.125	.120	-
00	.135	.130	.120
00	.150	.145	.130
00	.160	.155	.140
00	.170	.165	.150
00	.180	.175	.160
00	.190	.185	.165
00	.200	.195	.170
00	.210	.200	.180
00	.220	.210	.185
30	.225	.220	.195
00	.235	.225	.200
00	.240	.230	.205
00	.250	.240	.210

TABLE J (continued)

t.	H/F = 1	H/W = .5 to 1	H/W = Less than .5
	.255	.245	.220
	.265	.255	.225
	.270	.260	.230
	.275	.265	.235
	.285	.270	.240
	.290	.275	.245
	.295	.285	.250
	.305	.290	.255
	.310	.295	.260
	.315	.300	.265
	.320	.305	.270
	.325	.310	.275
	.330	.315	.280
	.340	.325	.290
	.350	.335	.300
	.360	.345	.305
	.370	.355	.315
	.380	.365	.320
	.390	.375	.330
	.400	.380	.340
	.410	.390	.345
	.420	.395	.355
	.425	.405	.360
	.435	.415	.365

TABLE J (continued)

H/W = 1	H/W = .5 to 1	H/W = Less than .5
.440	.420	.375
.450	.430	.380
.460	.435	.385
.465	.445	.390
.470	.450	.400
.480	.455	.405
.485	.465	.410
.495	.470	.420
.500	.480	.425
-	.485	.430
-	.490	.435
-	.495	.440
-	.500	.445
-	-	.450
-	-	.460
-	-	.465
-	-	.470
-	-	.475
-	-	.480
-	-	.485
-	-	.490
-	-	.495
-	-	.500

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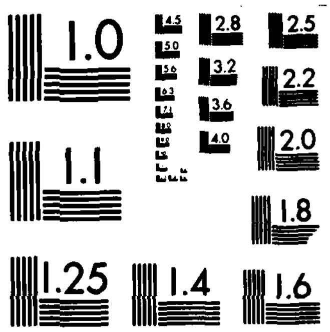


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLF K

Relative Probability of Fire Spread

(Wind Velocity 7 mph to 18 mph)

Radiating Area Sq. Ft.	Building: Wall Face Ratio (H/W) H/W = 1	H/W = .5 to 1	H/W = Less than .5
1,500	-	-	-
1,600	-	-	-
2,200	-	-	-
2,300	.120	-	-
2,600	.125	.120	-
3,200	.135	.130	.120
3,800	.145	.140	.130
4,100	.150	.145	.135
5,000	.160	.155	.145
6,000	.175	.170	.155
7,000	.185	.180	.165
8,000	.195	.190	.175
9,000	.205	.200	.185
10,000	.215	.210	.195
11,000	.225	.220	.200
12,000	.235	.225	.205
13,000	.240	.235	.215
14,000	.250	.245	.220
15,000	.260	.250	.225
16,000	.265	.260	.235
17,000	.275	.265	.240

TABLE K (continued)

Sq. Ft.	H/W = 1	H/W = .5 to 1	H/W = Less than .5
18,000	.280	.270	.245
19,000	.290	.280	.250
20,000	.295	.285	.255
21,000	.300	.290	.260
22,000	.310	.295	.265
23,000	.315	.305	.270
24,000	.320	.310	.275
25,000	.325	.315	.280
26,000	.330	.320	.285
27,000	.340	.325	.290
28,000	.345	.330	.295
29,000	.350	.335	.300
30,000	.355	.340	.305
32,000	.365	.350	.315
34,000	.375	.360	.325
36,000	.385	.370	.335
38,000	.395	.380	.340
40,000	.405	.390	.350
42,000	.415	.395	.355
44,000	.425	.405	.365
46,000	.430	.415	.370
48,000	.440	.420	.380
50,000	.450	.430	.385
52,000	.460	.440	.395

TABLE K (continued)

Sq. Ft.	H/W = 1	H/W = .5 to 1	H/W = Less than .5
54,000	.465	.445	.400
56,000	.475	.450	.405
58,000	.485	.460	.415
60,000	.490	.465	.420
62,000	.500	.475	.425
64,000	-	.480	.430
66,000	-	.490	.440
68,000	-	.495	.445
70,000	-	.500	.450
72,000	-	-	.455
74,000	-	-	.460
76,000	-	-	.465
78,000	-	-	.470
80,000	-	-	.475
82,000	-	-	.480
84,000	-	-	.485
86,000	-	-	.490
88,000	-	-	.495
90,000	-	-	.500
92,000	-	-	-
94,000	-	-	-
96,000	-	-	-
98,000	-	-	-

TABLE L

Relative Probability of Fire Spread

(Wind Velocity 18 mph to 40 mph)

Radiating Area Sq. Ft.	H/W = 1	H/W = .5 to 1	H/W = Less than .5
1,500	.120	-	-
1,600	.120	.120	-
2,200	.130	.130	.120
2,300	.130	.130	.120
2,600	.140	.135	.125
3,200	.150	.145	.135
3,800	.160	.155	.145
4,100	.165	.160	.150
5,000	.180	.170	.160
6,000	.190	.185	.170
7,000	.200	.195	.180
8,000	.210	.205	.190
9,000	.220	.215	.200
10,000	.230	.225	.205
11,000	.240	.235	.215
12,000	.250	.245	.220
13,000	.260	.250	.230
14,000	.270	.260	.235
15,000	.275	.265	.240
16,000	.280	.275	.250
17,000	.290	.280	.255

TABLE L (continued)

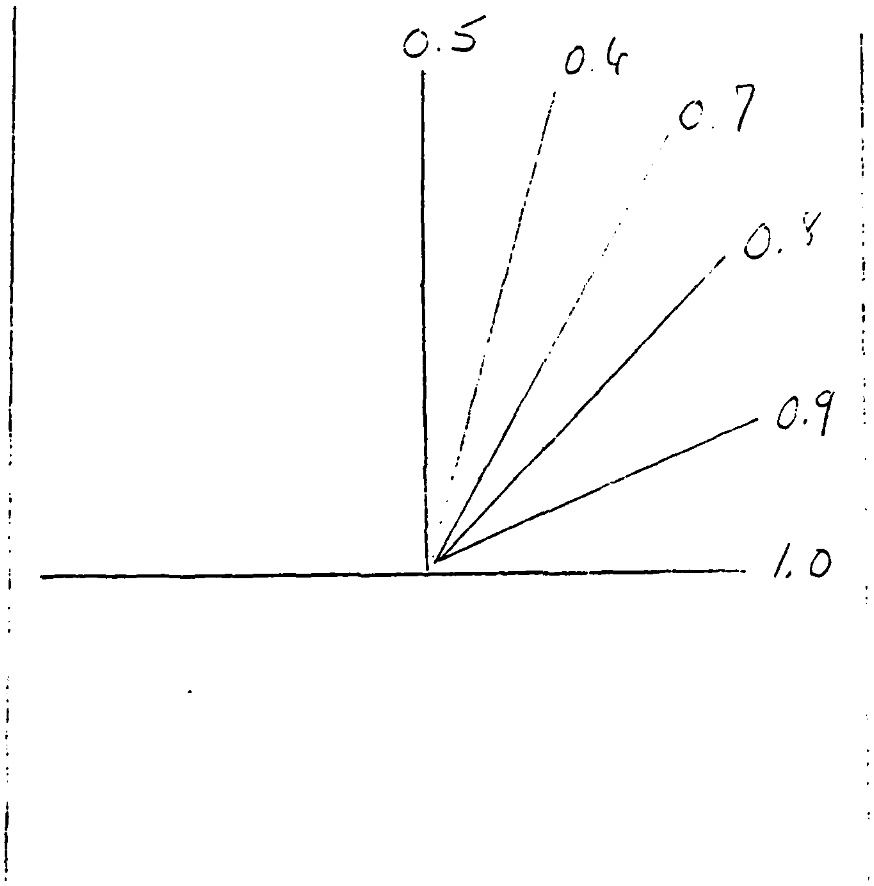
Sq. Ft.	H/W = 1	H/W = .5 to 1	H/W = Less than .5
18,000	.295	.285	.260
19,000	.305	.295	.265
20,000	.310	.300	.270
21,000	.320	.305	.275
22,000	.325	.315	.280
23,000	.330	.320	.285
24,000	.340	.325	.290
25,000	.345	.330	.295
26,000	.350	.335	.300
27,000	.355	.340	.305
28,000	.360	.345	.310
29,000	.365	.350	.315
30,000	.375	.355	.320
32,000	.385	.365	.330
34,000	.395	.375	.340
36,000	.405	.385	.350
38,000	.415	.395	.355
40,000	.425	.405	.365
42,000	.435	.415	.375
44,000	.440	.425	.380
46,000	.450	.430	.390
48,000	.460	.440	.395
50,000	.470	.445	.400
52,000	.475	.455	.410

TABLE L (continued)

Sq. Ft.	H/W = 1	H/W = .5 to 1	H/W = Less than .5
54,000	.485	.460	.415
56,000	.490	.470	.420
58,000	.500	.475	.430
60,000	-	.485	.435
62,000	-	.490	.440
64,000	-	.495	.445
66,000	-	.500	.450
68,000	-	-	.460
70,000	-	-	.465
72,000	-	-	.470
74,000	-	-	.475
76,000	-	-	.480
78,000	-	-	.485
80,000	-	-	.490
82,000	-	-	.495
84,000	-	-	.500
86,000	-	-	-
88,000	-	-	-
90,000	-	-	-
92,000	-	-	-
94,000	-	-	-
96,000	-	-	-
98,000	-	-	-

FIGURE D

Wind Angle Velocity Factors



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