Updated March, 2013
Prepared August, 2009
E. Metz, NETC Library

Selected Readings

Topic: Fire spread resulting from nuclear explosions

Note: This bibliography consists of some 40 unclassified and unrestricted reports and studies sponsored by federal government agencies over the past six (6) decades. These are organized below in reverse chronological order by year. Titles published in the same year are then arranged alphabetically by author.

Background: From FM 5-8, Section III – Thermal radiation. "Large amounts of electromagnetic radiation in the visible, infrared, and ultraviolet regions of the electromagnetic spectrum are emitted from the surface of the fireball within the first minute or less after detonation. This thermal radiation travels outward from the fireball at the speed of light, 300,000 km/sec. The chief hazard of thermal radiation is the production of burns and eye injuries... Such thermal injuries may occur even at distances where blast and initial nuclear radiation effects are minimal. Absorption of thermal radiation will also cause the ignition of combustible materials and may lead to fires which then spread rapidly among the debris left by the blast. The range of thermal effects increases markedly with weapon yield… Since the temperature of this system is of several tens of million degrees centigrade, it emits enormous quantities of energy in the form of electromagnetic radiation. This radiation is subsequently absorbed by the surrounding atmosphere, which is heated to extremely high temperatures, causing it to emit additional radiation of slightly lower energy. This complex process of radiative transfer of energy is the basic mechanism by which the fireball is formed and expands."

Bibliography

Homeland Security Council (U.S.). (2010). *Planning guidance for response to a nuclear detonation*. Washington, D.C.: Homeland Security Council Interagency Policy Coordination Subcommittee for Preparedness & Response to Radiological and Nuclear Threats. See chapter 1 which discusses nuclear detonation effects in an urban environment including fire. This document examines impact of a terrorist nuclear device with a yield of not greater than 10 KT. Citation | Fulltext

Eden, L. (2004). *Whole world on fire: Organizations, knowledge, and nuclear weapons devastation*. Ithaca, N.Y: Cornell University Press. Excerpt: Recently a small group of researchers has shown that for modern nuclear weapons the destructiveness and lethality of mass fire often—and predictably—greatly exceeds that of blast effects. -

Includes a chapter on nuclear weapons effects. Citation | Available in LRC. Call # UA23 .E22 2004

Federal Emergency Management Agency. (1989). *Attack environment manual: Chapter 3, what the planner needs to know about fire ignition and spread*. Washington, D.C.: The Agency. This description of the fire environment following nuclear attack provides basic information needed to plan realistic actions to reduce fire casualties and loss of property. It presumes that the reader is familiar with the material in chapters 1 and 2 of the manual. Knowledge of the material in subsequent chapters is not a prerequisite; however, reference is made to pertinent issues in the chapters on fallout, the shelter environment, and emergency operations. Citation | Fulltext

Federal Emergency Management Agency. (1987). *Nuclear attack planning base-1990: Final project report*. Wash., D.C: The Agency. The NAPB-90 is an estimate of the potential physical effects of a nuclear attack on the population of the United States in terms of the degree of the potential risk. Three types of potential nuclear attack effects risks and the areas and populations affected by each are defined: The direct effects risk from blast overpressure generated by the explosion of a nuclear weapon; The potential thermal and secondary blast-ignited fire risk created by the combined effects of blast overpressure damage and the thermal pulse or fireball of a weapon, and the fallout risk from radiation generated by surface-burst weapons. Citation | Fulltext

Solomon, F., Marston, R. Q., Institute of Medicine (U.S.), (1986). *The Medical implications of nuclear war*. Washington, D.C: National Academy Press. Chapter 2, from the book entitled Medical implications of nuclear war. See also chapter 1 – Possible fatalities from super fires following nuclear attacks. Citation | Fulltext

National Research Council (U.S.). (1985). *The effects on the atmosphere of a major nuclear exchange*. Washington, D.C: National Academy Press. See chapter 3 – Fires – includes an extensive References section beginning on page 87. Citation | Fulltext

Longinow, A., Waterman, T. E., Takata, A. N., & FEMA. (1982). *Assessment of combined effects of blast and fire on personnel survivability*. Chicago, Ill: IIT Research Institute. The objectives of the research study described in this report were (1) to perform a preliminary analysis of hazards to sheltered personnel in a blast-fire environment produced by the detonation of a 1 MT weapon near the ground surface, and (2) to lay the ground work for developing a consistent, formal methodology for estimating the probability of people survival in a blast-fire environment. The study began by selecting a set of buildings to be used for constructing a variety of realistic city blocks and then portions of cities and towns. The set included four buildings; two framed single family residences, a low-rise multi-family residence, and a high-rise residential building. All are real buildings and represent a realistic sample of residential construction in terms of size, though not necessarily representative of all possible structural systems and building materials. Each of the four buildings was analyzed to determine overpressures necessary to produce incipient collapse and breakup of the building. On the basis of the blast/structural analysis a debris catalog was assembled for each building. A debris catalog contains all of the pieces a

building breaks into when subjected to incipient collapse overpressure. Each debris piece in the catalog is described in terms of the following parameters, i.e., weight, size, largest and smallest projected areas, center of gravity coordinates of the initial position at the time of separation. In addition to building parts, the debris catalog also includes a typical (basic) set of furniture items. Citation | Fulltext

Reitter, T. A., McCallen, D. B., Kang, S.-W., Lawrence Livermore National Laboratory., & FEMA. (1982). *Literature survey of blast and fire effects of nuclear weapons on urban areas*. Livermore, Calif: Lawrence Livermore Laboratory, University of California. The purpose of this literature survey was to determine the state of knowledge of blast and fire effects of nuclear weapons on urban areas. This information should aid the planning of research in improving predictive capabilities and the development of mitigation and hardening measures. This report consists of summaries of our findings in four main areas: (1) attack scenario, thermal radiation and blast wave propagation; (2) ignition; (3) structural response and debris formation; and (4) fire spread and mass fire. Conclusions are given for each section, and our overall conclusions are presented at the end. The first appendix summarizes the relative state of knowledge, while the second appendix is a bibliography of relevant documents. Citation | Fulltext

Sanderlin, J. C. ; Ball, J. A. ; Johanson, G. A. (1981). *Mass Fire Model Concept*. Santa Barbara, CA: Mission Research Corporation. Review of the literature pertaining to mass fire onset and development indicates there exist no models that describe the onset and development of mass fires. The state-of-the-art is such that a low confidence level, parametric model can be developed. The theoretical basis, and a preliminary implementation, are described for a low confidence level, parametric model of mass fire onset and development in an urban environment. Citation | Fulltext

Schmidt, L. A., United States., & Institute for Defense Analyses. (1979). *A parametric study of probabilistic fire spread effects.* Arlington, Va: Program Analyses Division, Institute for Defense Analyses. One of the basic mechanisms governing the magnitude of fire damage in an urban area resulting from a nuclear attack is the fire spread between individual structures. This paper investigates the effects of various methodological assumptions, using the basic physical models of fire spread by radiation and firebrands contained in the IITRI model. As an introduction to probabilistic effects, various regimes of solutions to fire spread by radiation in individual tracts are obtained by simplifying the IITRI model. The spread of fire down rows of buildings and in rectangular grids when each structure has a constant probability of igniting adjacent structures, is followed through a Monte Carlo simulation. Changes in fire spread patterns, as the probabilities are changed, are illustrated. The effects of various complicating features, such as random initial ignitions and varying ignition probabilities for each structure, are studied individually. Finally a Monte Carlo simulation model is developed which contains almost all of the physical features of fire spread in the IITRI model. The spread of fire by firebrands across firebreaks, and the effects of ignition probabilities on the rate of fire spread are illustrated through the use of this model. Citation | Fulltext

Wiersma, S. J., & Martin, S. B. (1975). *The nuclear fire threat to urban areas: Final report*. Menlo Park, Calif: Stanford Research Institute. The nuclear fire threat to urban areas was evaluated in a four-task program. During three previous years of experiments the dynamic behavior of fires in full-scale structures and the nature of magnitude of behavioral changes that result from variations in both structural and environmental factors were studied. This year an attempt was made to integrate the present structural fire behavior knowledge with blast behavior knowledge and to predict the combined blast-fire responses of an urban area to a nuclear attack. Citation | Fulltext

URS Research Company., & US Defense Nuclear Agency. (1974). *The role of fire in nuclear warfare: An interpretive review of the current technology for evaluating the incendiary consequences of the strategic and tactical uses of nuclear weapons*. San Mateo, CA: The Company. Technology pertaining to the incendiary capabilities of nuclear explosions is reviewed and interpreted for military and civil defense planning purposes. Fire, as intentional or collateral effect, is discussed in the contexts of strategic and tactical situations. The report asserts that whereas the use of fire will usually not figure dominantly in targeting considerations, the existence of fire effects should never be overlooked, either defensively or offensively. Fire is the only self-sustaining effect of a nuclear explosion. It can produce damage far beyond the limits of the intended target and it can interface with operations long after the explosion that initiates it. The state-of-the-art of predicting fire effects of nuclear explosions is reviewed. Urban and wildland environments are treated separately as appropriate. Some operationally useful relationships and simplified approximations are developed and offered for use in decision making by civil defense and military planners who may have to cope with fire effects of nuclear explosions some day. Citation | Available in LRC documents collection. Call # 9737.

Martin, Stanley B., and Steve J. Wiersma. *Evaluation of the Nuclear Fire Threat to Urban Areas*. Menlo Park, CA: Stanford Research Institute, 1973. The nuclear fire threat to urban areas was evaluated in a four-task program. During three previous years of experiments the dynamic behavior of fires in full-scale structures and the nature of magnitude of behavioral changes that result from variations in both structural and environmental factors were studied. This year an attempt was made to integrate the present structural fire behavior knowledge with blast behavior knowledge and to predict the combined blast-fire responses of an urban area to a nuclear attack. Full abstract and itation | Fulltext

Murphy, H. L., Rempel, J. R., & Carroll, R. G. (1972). *Slanting for combined nuclear weapons effects: Fire hazard reduction*. Menlo Park, Calif: Stanford Research Institute. Update of previous 1969 report on fire hazard reduction. Citation | Available in LRC documents collection. Call # 2517

Takata, A. N., & Defense Civil Preparedness Agency. (1972). *Fire spread model adaptation*. Chicago, IL: IIT Research Institute. This study involves the continued development of computer codes to predict the initiation and spread of fire in urban areas following a nuclear attack. Specifically, provisions were made in the computer codes to

reflect recent improvements in the state of knowledge in regard to firebrands, effects of blast on ignitions caused by fireball, and shielding of interior building fuels from exposure to the fireball by trees, bushes and awnings. Also allowances were made in the codes for buildings that contain room fires as well as for evaluating the consequences of removing window coverings or room items from exposure to the fireball. Detailed discussions of all the changes are included as well as an overall discussion of major features of the codes. Input/output data are described for each of the codes. Citation | Available in LRC documents collection. Call # 2231.

Takata, A. N., IIT Research Institute., & Defense Civil Preparedness Agency. (1971). *Fire spread in high density high-rise buildings*. Chicago, Ill: IIT Research Institute. The program had the objective of developing a computer routine to determine the initiation and spread of fire in high density high-rise areas following a nuclear detonation, and its effects on the street environment. The result of this endeavor is a computer code that evaluates the probable number and floor locations of fires, the rate of heat generation from built-up areas, the radiant intensities in the streets, and the induced winds as functions of time. Provisions were made to keep the code sufficiently flexible to allow for improved data and information as they become available. Also, provisions were made to simplify the problem of incorporating the routine in a more general code for an entire urban area. Preliminary calculations were conducted to gain an appreciation of how the fires develop in time, the threats to personnel in the streets and the possibility of a fire storm. Citation | Fulltext

Martin, S. B., & Office of Civil Defense. (1970). *Civil defense test design and support of operation Flambeau-type fires - annual report*. Menlo Park, CA: Stanford Research Institute. This report describes annual progress in a continuing program to review and appraise potential opportunities for mass-fire tests and other sources of field-test data relevant to the civil defense fire problem and to provide objective and technically sound advice in such matters as required by the Support Systems Division of OCD, Research. Progress for the year is summarized in the following subject-area categories: 1. Review of reports on Flambeau-type fires, 2. Investigation of new sources of data, 3. Conduct of Annual OCD Fire Research Contractors Conference, 4. Participation in the writing of a Handbook on Forest Thermal Effects. Plans for the coming year are also presented. Citation | Fulltext

Butler, C. P., & Office of Civil Defense. (1969). *Operation Flambeau - civil defense experiment and support: Eyewitness accounts of a mass fire*. San Francisco, CA: Naval Radiological Defense Laboratory. Seven men, skilled in fire research, were stationed around the periphery of FLAMBEAU FIRE 769-12 and recorded visual impressions of its magnitude. Their testimony furnishes indices of fire severity which is available to officials immediately. At each of the times when eyewitness accounts are given, instrumental data were taken both inside the fire zone and outside, so that visual magnitudes of this mass fire may be compared with its measured physical parameters. Visual magnitudes for this fire are: a. Flame heights up to 300 feet horizontal flames 100 feet. b. Thermal radiation uncomfortable at 75 feet. c. Able bodied men might escape from

center of fire. d. Cap cloud at 3000 feet. e. Streets filled with smoke. f. Fire whirls lifted bushes 100 feet. g. Downwind side of fire showed much more severe activity than the upwind. h. Firebrands were carried more than 200 feet out of the fire on the downwind side. Citation | Fulltext

Carroll, R. G. and Rempel, J. R. ; Defense Civil Preparedness Agency. (1969). Fire hazard reduction. Menlo Park, CA. Stanford Research Institute. This report demonstrates the extent to which architects and engineers can modify their usual building designs (slanting), thereby providing a protection for people taking shelter in the building, against fire hazard during a nuclear weapon attack. The method chosen to reach this goal has been to describe in some detail the nature of the hazard- as far as it is presently known- and then to set forth as explicitly as possible how the threat may be lessened or eliminated, to the best of present understanding. This means that the report may be used as a prototype guide for architects and engineers wishing to learn about the fire threat accompanying a nuclear weapon detonation and to do something to minimize it. Topics discussed are: locating buildings to reduce the potential for fire-spread among them; biological hazards associated with fires; certain building design countermeasures against fire hazards; and self-help measures to be taken by shelterees. Citation | Available in LRC documents collection. Call # 2517

Pacific Southwest Forest and Range Experiment Station (Berkeley, Calif.), Office of Civil Defense., & Defense Atomic Support Agency. (1969). *Project Flambeau ... an investigation of mass fire (1964-1967): Final report*. Berkeley. Project Flambeau, a research activity of the Pacific Southwest Forest and Range Experiment Station, was an exploratory study into mass fire behavior. Six test fires were burned on isolated sites in California and Nevada. Instrumentation was developed and tested concurrently with the burning of the fires. This summary report of the work of Project Flambeau from 1964 to 1967 outlines our present knowledge of mass fires; suggests some of its characteristics; describes the research approach used and development of instrumentation; discusses the results obtained; suggests a definition of mass fire; and offers a prescription for an experimental mass fire. Citation | Fulltext

Takata, A. ; Office of Civil Defense. (1969). *Mathematical modeling of fire defenses*. Chicago, IL: IIT Research Institute. This study involves the development of techniques to evaluate the effect of fire defenses on building fires caused by a nuclear burst and the incorporation of the fire-defense techniques in a fire-spread model. The resultant computer program allows evaluation of the effectiveness of various numbers of self-help teams, brigades and fire department units in suppressing and containing building fires scattered throughout a tract of several thousand buildings. Preliminary computations indicate that 1/4 of the manpower available in a tract can suppress all fires created by the initial ignition of 1/2 or less of the buildings within a few hours. Most of the manpower, particularly those in the self-help teams, can be diverted to other activities after several minutes of effort. The preliminary results show that ordinary citizens with minimal instruction and training can bring about very pronounced reductions in the total fire damage. Citation | Available in LRC documents collection. Call # 1347.

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Bracciaventi, J., Derksen, W., Feldman, S., Defense Atomic Support Agency.(1967). ***A report on the investigation of fire-starts due to nuclear detonations*****. Brooklyn, NY: Naval Applied Science Laboratory.** Technical cooperation program, panel N-3, thermal radiation mass fire research symposium. DASA, Washington, DC. February 6-9, 1967. Citation | Available in LRC documents collection. Call # 6098.

Martin, S. B., Renner, R. H., Jones, R. E., U.S. Naval Radiological Defense Laboratory., & Office of Civil Defense. (1967). ***Application of fire fundamentals to models of macroscale phenomena from nuclear weapon bursts*****. San Francisco, CA: U.S. Naval Radiological Defense Laboratory.** The application of fire fundamentals to macroscale fire phenomena is reviewed to date as part of the OCD program for assessing urban vulnerability to fire caused by nuclear-weapon bursts. Sufficient background information is provided for use in future fire-damage-assessment and fire-protection procedures. Included are the characteristics of fires in enclosures, characteristics of fires in the open (basic processes, techniques for estimating fire spread, and role in fire-spread models) and the interaction (coalescence) of small- and large-scale, free-burning fires. The technical material presented will be useful for determining the importance of each parameter governing macroscale fire phenomena, the synergistic effects of interacting parameters, and what additional information is needed on the sensitive parameters and their interrelations. Citation | Available in LRC documents collection. Call # 826.

Rotz, J., URS Corporation., & Office of Civil Defense. (1967). ***Debris model research with building damage, fire spread, and debris predictions for five-city study -: Final report*****. Burlingame, Calif: URS Corp**. This report is divided into two parts. Part I reports on research work directed toward improvement of the model to predict debris from buildings subjected to the blast and fire effects of nuclear weapons. Part II reports on application of the model in support of the Office of Civil Defense Five-City Study. The research was primarily concerned with the development of multi-yield (other than 20 kt and 20 Mt) building debris charts, and improvement of debris distribution procedures. During work on the multi-yield debris charts, significant inconsistencies in present building damage functions for many building types were discovered. These inconsistencies could not be resolved within the scope of the present study, and therefore charts were prepared only for those building types whose damage functions displayed little or no irregularities. While the charts were in preparation, it was ascertained that overturning can be a significant mode of building damage, especially for tall buildings acted upon by blast from large-yield weapons. Because of lack of quantitative information on building breakup and subsequent debris transport, only a quantitative discussion of debris distribution is included. The Five-City Study work was primarily concerned with predictions of target damage for the city of San Jose resulting from the Five-City Study attack on that city. Predictions were made of initial ignitions and fire spread in wildland fuels, and of debris resulting from the destruction of trees and buildings by the coupled effects of air blast and fire, and detailed descriptions of building damage were provided. These predictions are on file in the Five-City Study Data Bank and are presented for reader convenience in scaled-down and abbreviated form. Citation | Fulltext

John, F. I., Passell, T. O., & Office of Civil Defense. (1966). *Evaluation of nuclear weapon thermal threat.* Menlo Park, CA: Stanford Research Institute. The threat to urban areas from fires produced by the detonation of a nuclear weapon may be measured in terms of the proportion of structures that will contain one or more significant fires, i.e., fires producing a flashover. In the study, this proportion is determined for uncrushed structures in which the ignition of an interior fuel by thermal radiation from a nuclear weapon results in at least one significant. Citation | Available in LRC documents collection. Call # 645.

Ayres, R. U., & Hudson Institute. (1965). *Environmental effects of nuclear weapons*. Harmon-on-Hudson, N.Y: Hudson Institute. Volume I summarizes current knowledge of the effects of nuclear weapons on area targets. Radiological effects are divided roughly into three categories: external Y-radiation from fallout fields; external B-burns and internal hazards due to cycling of Sr-90, Cs-137, and I-131. Vulnerabilities of different classes of targets or "biomes" are considered, e.g. vertebrates, insects, conifer forests, deciduous forests, grasslands and crop lands. Thermal ignition and probabilities of fire spread under various conditions are discussed in Chapter II. Chapter III is concerned with potential meteorological and climatic problems. Chapter IV discusses a variety of "second-order" problems such as epidemics, pest outbreaks, floods, erosion and ecological changes. Volume II is devoted to an analysis of the interactions of these effects with postattack recovery problems, particularly in connection with agriculture. The potential conflicts between short-term and long-term objectives are stressed. A number of specific countermeasures are listed and discussed. Volume III is a short summary of the whole report, bound separately for convenience. Citation | Fulltext Volume 1 ; Volume 2 ; Volume 3 – available in print in LRC

Countryman, C.M. (1965). Mass fire characteristics in large-scale tests. Fire Technology, v1, issue 4, p.303-317. Abstract.

Lommasson, T. E., & Office of Civil Defense. (1965). *Preliminary investigation of firestorm start-criteria*. Albuquerque, NM: Dikewood Corporation. A quantitative hypothesis is developed that relates inrush wind velocity at the edge of a potential firestorm area to the energy release rate of fires within the area and to the size of the area itself. The effects of spread from initial fires are considered and criteria are derived to estimate the way in which the fires are likely to develop with time. The hypothesis was applied to German World War II firestorm and group fire situations and appears to yield reasonable results in predicting the occurrences of each. The hypothesis may be applied to nuclear attacks against urban target areas. Citation | Available in LRC documents collection. Call # 696.

Phung, P. V., Willoughby, A. B., URS Corporation., & United States. (1965). *Prediction models for fire spread following nuclear attacks*. Burlingame, Calif.: URS Corp. In Part I a semi-empirical approach is used to predict fire spread beyond the area directly ignited by thermal radiation from nuclear weapons. Mathematical models, both stochastic and deterministic, describe the progress of fires in two-dimensional or one-dimensional space. Application of each model to appropriate cases is discussed. Empirical

data needed for evaluation of parameters are specified and methods for acquiring these data suggested. Observed data, accumulated over many years in records of past fires, have proved valuable in determining some of the parameters. The remaining parameters require further observed data. At present approximate prediction can be made by use of a specially designed version. Part II presents the results of a statistical study on observed rate of spread data and discusses a number of specific problems that must be worked out before the method can be used for assessing the fire damage from nuclear attacks. Cf. Abstract, p. ix. Citation | Fulltext

Miller, T., Rogers, J. C., & Office of Civil Defense. (1964). *Survey of the thermal threat of nuclear weapons.* Menlo Park, CA: Stanford Research Institute. This paper reviews the current state of knowledge on the thermal effects of nuclear weapons, atmospheric transmissivity, ignition of target elements, and fire propagation and spread. Some of the topics considered are: Importance of attack assumptions (delivery capabilities of the enemy, warhead types and yields, altitude of detonation, timing, and warning) in determining the characteristics of thermal radiation and the susceptibility of targets to thermal damage. Modification of the thermal radiation by the atmosphere, intervening cloud layers or other meteorological features, and target elements, such as trees and topography. Interaction of blast, radioactivity, and thermal radiation phenomena. Response of target elements to direct thermal radiation. Effects of weather and topography on target vulnerability and fire spread. Fire development and spread in target areas. Citation | Fulltext

Countryman, C. M. (1964). *Mass fires and fire behavior*. Berkeley, Calif: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture. Mass fires are being investigated through a series of large-scale test fires. Preliminary results indicate: (a) air flow patterns that create eddies can result in fire vortices when fire is present; (b) the lower part of the convection column consists of a series of small columns that merge well above the combustion zone; (c) air flow for combustion in a large fire may come from a relatively deep layer around and above the fire; (d) flame temperatures are much higher than in small experimental or laboratory fires; and (e) noxious gases occur within, and adjacent to, the fire with no significant concentration in the area between fires when fires are spaced 115 feet or more apart. Citation | Fulltext Part 1 ; Part 2

Brode, H. L. (1963). *Thermal radiation from nuclear explosions*. Santa Monica, Calif: Rand. A description of the explosion phenomena which determine the amount and character of the thermal radiation is presented together with the effects of atmospheric transmission and altitude of burst. The factors governing the response of materials to thermal radiation are outlined, and the nature and extent of large scale fires from nuclear explosions are discussed. The extent of fires caused by the thermal radiation from nuclear explosions is determined by the explosion characteristics, the modifying influences of the atmosphere and transmission through it, and the thermal absorption and combustion nature of the target materials. Citation | Fulltext

Chandler, C. C., Storey, T. G., Tangren, C. D., & Office of Civil Defense. (1963). ***Prediction of fire spread following nuclear explosions.*** **Berkeley, Calif: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture.** Mass fires are likely to follow a nuclear attack. Since it is important to the civil defense program to be able to predict rate, duration, and extent of spread of such fires, the Office of Civil Defense, U. S. department of Defense, issued a joint contract to the Forest Service and to United Research Services, Inc., to study this field. We surveyed the literature, interviewed some 30 urban and wildland fire-control personnel, studied nearly 2,000 fires, collected 1,687 rates of spread, and determined the conditions when fires would not spread significantly and the conditions when fires would be extinguished in the absence of effective firefighting action. Citation | Fulltext

Rogers, J. C., Stanford Research Institute., & Office of Civil Defense. (1963). ***Ignition of materials by large yield nuclear weapons for various burst heights and atmospheric conditions*****. Menlo Park, Calif: Stanford Research Institute.** The purpose of this report is to summarize selected unclassified results derived in a more comprehensive Stanford Research Institute study (Survey of the thermal threat of nuclear weapons) from recently published information on thermal effects of nuclear detonations. The expected ranges are given for ignition of materials by megaton weapons under the assumption of an idealized, transparent atmosphere. From these similar results are developed for real atmospheres. The effects of altitude variation on ignition radii are explored, including surface and outer space bursts. Attenuation of clouds is considered, as well as bursts below clouds and the influence of ground snow cover on the ignition ranges. Finally, recommended research, which would improve some of the estimates of ignition range, is outlined. Cf. Abstract, p. ii. Citation | Available in LRC documents collection. Call # 7.

Martin, S. B., & Office of Civil Defense. (1963?). ***Thermal radiation and fire effects of nuclear detonations*****. Burlingame, CA: URS Corporation.** An unclassified state-of-the-art review of the thermal effects of nuclear weapons, this report summarizes the pertinent information available at the end of 1962. Evidence is presented to show that, in a nuclear weapon attack on targets in urban and rural areas, thermal radiation and fire can be expected to make a major contribution to the destruction of life and property. The characteristics of the emitted thermal radiation, the radiant exposure as a function of distance, and the effects produced by this radiation are summarized. The formation, spread, and control of fires and possibilities for survival in fire zones are discussed. Fire countermeasures which might prove effective in reducing the extent of thermal damage are set forth. Citation | Available in library documents collection. Call #6384 (and related title at 3364).

Atlas, R. A. (1962). ***Factors influencing the fire effects from thermal radiation emitted by a nuclear detonation*****. Seattle, WA: Boeing Aerospace Company.** The general phenomena of mass fires resulting from the thermal radiation emitted by a nuclear detonation are described. Two types of mass fires are considered, conflagrations and fire storms. Either or both types may result from a single detonation. The history of the

formation of a mass fire is followed, from kindling by thermal radiation to ignition of larger fuels, buildup of fires to encompass other structures, and fire spread to the final area. Many variables influence the extent of thermal damage from a nuclear weapon. The following are the most significant and are considered in this study: critical ignition energy; thermal pulse; blast damage; moisture content of materials involved; air temperature; wind; season; kindling pattern; time of day; building density; size of area; topography; fire breaks; and shelters. Certain counter measures to decrease the damage are also described. Citation | Available in library documents collection. Call #5945.

Brown, F. W. (1962). *Ignition of fires and fire spread by thermal radiation*. Port Hueneme, CA: Naval Civil Engineering Laboratory. This report presents a discussion of the problem of primary and secondary fires resulting from a nuclear weapon explosion. The relationship between the incidents of secondary fires and earthquake-produced fires in the United States is discussed. Relationships between the area destroyed by fire and blast as a function of yield of nuclear weapons is presented. It is concluded that the ratio of fire damage area to the blast damage area increases with the yield of the weapon. Primary fire will be a significant factor and the elimination of potential fire sources is of the utmost importance. The probability that a fire storm can be prevented by the use of adequate firebreaks augmented by the use of fire retardant paint is proposed. It is recommended that existing military installations should be resurveyed to see what protective steps are feasible and necessary. Citation | Available in library documents collection. Call #4651.

Hill, J. E., & Rand Corporation. (1961). *Problems of fire in nuclear warfare*. Santa Monica, Calif: Rand Corp. --- Excerpt - Concern has been expressed that fire from nuclear attacks on various targets might spread far beyond the area of serious damage from blast, thus multiplying the area of destruction many times and that free-running fires would spread through forest and grasslands which would burn over such wide areas that the ecological consequences of soil erosion and floods might make postwar recovery impossible. The problem of estimating fire damage from hypothetical nuclear wars involves many difficulties and uncertainties. In very general terms, the procedure would involve making assumptions about the enemy choice **of** time and targets for attack and the number, yield and altitude of burst of weapons delivered on designated ground zeros. These assumptions would be much the same as have been made in previous studies of the effects of blast and fallout, except that one would have to decide whether or not forest and grasslands would constitute a primary target sub-system to which enemy weapons would be assigned or be regarded as a bonus from attacks on other targets such as urban areas or military installations, etc. Citation | Fulltext

Jewell, W. S., Willoughby, A. B., & Broadview Research Corporation. (1960). *A study to analyze and improve procedures for fire damage assessment following nuclear attack*. Burlingame, Calif: Broadview Research Corp., Physical Sciences Division. The two major objectives of this study were to develop a simplified calculational method for predicting the total area of burnout following a nuclear attack based on the 1957 Damage Assessment Study, and to explore possible improved models for predicting the total area of fire spread. In addition, a modest effort was devoted to the development of

visual and computational aids to assist in the simplified damage assessment method. The report itself is divided into two independent parts, with the first part containing the theoretical investigations of both of the above topics; the second part contains the aids, tables, and other implementations of the Simplified Method. Citation | Available in library documents collection. Call #412.

Directorate Of Intelligence, USAF. (1955) *Fire spread in urban areas*. Ft. Belvoir: Defense Technical Information Center. Citation | Fulltext

Arnold, Keith, Chandler, Craig C., Fons, W. L., and Sauer, Fred M. ; Atomic Energy Commission. (1953). Ignition and persistent fires resulting from atomic explosions, exterior kindling fuels. Washington D.C. The Forest Service.
Probability that mass-fires, fire storms, and conflagrations will occur following atomic attack on urban areas depends on the extent and distribution of ignitions as well as fuel, topographic, and weather conditions. Prediction of fire probability is important in military target analysis from both the offensive and defensive standpoints. Furthermore, the factors which affect this probability are also important to civilian defense planning. Project 8.11b, Operation UPSHOT-KNOTHOLE, is part of a research program which is studying extent and distribution of primary ignitions from atomic explosions in urban areas. This project sought to: 1. Determine minimum thermal energies required to ignite those transient exterior kindling fuels found to be dominant by survey of six large representative cities. 2. Study blast effects on persistence of ignition of these fuels. 3. Provide photographic stock-footage demonstration material of the ignition of heavy combustible structures by transient exterior fuels. Previous studies have shown that though solid wood surfaces and other common building materials are not ignited by thermal radiation beyond the range of complete blast damage, thin materials like leaves, paper, and rotted wood are ignited by energies less than 4 cal/sq cm. Surveys have determined kinds and distributions of kindling fuels in urban areas. On Operation UPSHOT- KNOTHOLE, prepared fuel beds were exposed to total energies varying from 1.0 to 31.5 cal/sq cm. Kindling fuels were also arranged adjacent to fence sections to demonstrate fire spread to materials not readily ignited. Conclusions based on results and observations from Operation UPSHOT-KNOTHOLE: 1. Ideal burning conditions at shot time made this experiment completely successful. 2. Minimum ignition energies were established for most urban kindling fuels found to be dominant in urban fuel surveys. 3. The experiment demonstrated that kindling fuels are important agents in igniting combustible structures. Citation | Available in library documents collection. Call #2217.