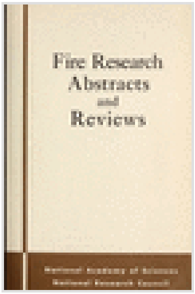

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FIRE RESEARCH ABSTRACTS AND REVIEWS

Robert M. Fristrom, Editor

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The Committee on Fire Research

FIRE RESEARCH ABSTRACTS AND REVIEWS will abstract papers published in scientific journals, progress reports of sponsored research, patents, and research reports from technical laboratories. At intervals, reviews on subjects of particular importance will be published. The coverage will be limited to articles of significance in fire research, centered on the quantitative understanding of fire and its spread.

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Fire Research Abstracts and Reviews

Committee on Fire Research
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ABSTRACTS AND REVIEWS

A. Prevention of Fires and Fire Safety Measures

Eisner, H. S. (Safety in Mines Research Establishment, Sheffield, England) "Ensuring Safety in Flammable Atmospheres," *Electrical Times* (1969)

Section: A

Subjects: Safety; Flammable atmospheres; Testing

Reprint of Safety in Mines Research Establishment Abstract, By Permission

This article describes the work of the Flammable Testing Section and the Intrinsic Safety Testing Section at the Safety in Mines Research Establishment.

Jin, T. (Fire Research Institute of Japan, Tokyo, Japan) "Visibility through Fire Smoke: Visibility of Monochromatic Signs through Fire Smoke," *Fire Research Institute of Japan, Report No. 33*, 31 (1971)

Section: A

Subjects: Visibility; Smoke obscuration; Signs, monochromatic

Author's Summary

Introduction

The visibility of signs through smoke in a fire is an important problem on fire-escaping. It can not be determined only by the smoke density, but varies depending on the brightness of signs and the conditions of illumination in corridors or rooms. With the same smoke density, the visibility depends on properties of smoke. The author reported in the previous issue as to the visibility of signs with smoldering smoke of filter-paper (white smoke). In this paper, the visibility of signs through various smoke such as generate from wooden and various plastic building materials is described. Measurements of the intensity of scattered luminous flux due to smoke particles which greatly affect the visibility, as well as of the size distribution of smoke particles, are also described. According to these results, the visibility of signs through the smoke generating from various building materials in a fire can be calculated.

Conclusions

Visibility of signs with a certain smoke density increases almost linearly, following logarithmically proportional increase of the brightness of the signs.

The value of k obtained from the total scattered luminous flux in smoke, that is, the ratio of the total scattering coefficient to the extinction coefficient will be 1.0 on smoldering smoke of wooden and plastic materials. But, the value of k on flaming smoke varies depending on the kind of building materials and the burning conditions, and as to black smoke, it may not cause so great error when calculating the visibility through smoke using $k=0.5$.

The smoke particle size influencing the total scattered luminous flux does not so largely depend on the kind of building materials and heating temperature with smoldering smoke, and the particles are almost spherical ones of less than 1 μ; the smoke particles of flaming burn are of spherical and of irregular shapes, and the size distributes over a considerably wide range; most of them are, however, of 1–20 μ.

The threshold contrast (δ_c) varies depending on the visual distance, the intensity of luminous flux from an illuminating light in a room and the properties of smoke, but it is presumed to be $\delta_c \doteqdot 0.01$–0.02 under the conditions of the visual distance of 5–15 meters and the room illumination of usual lights.

The visibility of signs (black letters on white background or the reverse) can be calculated according to the equation (7) as to the smoke generating from various building materials under various burning conditions, if the brightness of signs and the intensity of an illuminating light in a room are given.

The product of the visibility of signs and the smoke density (the extinction coefficient) is almost constant under the same conditions of the smoke properties, the brightness of the signs, and the illuminating light in the room (within the range of $5\text{ m} \leqq V \leqq 15\text{ m}$). The product depends mainly on the reflection coefficient of a placard, about 2–4 in a case of a placard; in a case of back-lighted sign, it mainly varied depending on the brightness of the sign and the intensity of luminous flux from an illuminating light in a room, about 5–10. Accordingly, the visibility at the obscuration threshold of signs is

about 2–$4/\sigma$ (m) in a case of a placard, and

about 5–$10/\sigma$ (m) in a case of a back-lighted sign.

The visibility of materials of other than signs through smoke, for example, the visibility of other materials such as walls, doors, pillars, stairway, etc., in an underground place or a long corridor varies depending on the structure of a building and the state of the wall, but it may be considered that the minimum value of the placard above shall be mostly employed.

In the experiments in this report only the visibility of round signs at the obscuration threshold was researched, but the values of the visibility of smaller signs or that of signs when place of the sign is unknown for an observer, are a little smaller than that in this experiment.

In this experiment, the observer was outside of the smoke chamber (free from smoke) and observed through a glass window, so he was free from the influence of the lachrymatic and irritant effect. The color of signs useful in smoke may be investigated later.

Jones, D. H. (Safety in Mines Research Establishment, Buxton, England) "Flameproof Enclosures: New Cylindrical Test Vessels of Variable Volumes and Flange Breadth," *E.R.A. Technical Report No. 5261* (1969)

Section: A

Subjects: Flameproof enclosures; Test vessels

Reprint of Safety in Mines Research Establishment Abstract, By Permission

The test vessels described in this report were designed to enable studies to be made of safe gaps for enclosures with volumes and flange widths smaller than those of earlier test vessels. The new vessels are cylindrical in shape and the volume is determined by the position of a piston inside the cylinder. The force of a gas explosion inside the vessel is transmitted to an outer frame. The need to separate the flanges with shims and compress them with an external counter force is therefore eliminated. Interchangeable cylinders cover a volume range of 250 to 5 ml and a range of flange breadths from $\frac{1}{2}$ in. (12.7 mm) to $\frac{1}{8}$ in. (3.2 mm). The flange gap can be determined accurately to 0.00025 in. (0.0064 mm). The vessels can be easily adapted to fit flamepath configurations other than plane gaps, e.g., threaded or spigoted joints.

Jones, D. H. and Woodhead, D. W. "Flameproof Enclosures: Maximum Safe Flange Gaps with Gas Mixtures Related to Town Gas," *E.R.A. Technical Report No. 5208* (1969)

Section: A

Subjects: Flameproof enclosures; Gaps; Town gas; M.E.S.G.; Quenching

Reprint of Safety in Mines Research Establishment Abstract, By Permission

A study was made of the effects on the M.E.S.G. of the variations that occur in the composition of town gas in its content of hydrogen, methane, carbon monoxide, nitrogen, and unsaturated compounds, with special reference to modern methods of production and new natural sources.

Whilst a linear relation was found between the M.E.S.G. and the relative proportions of hydrogen (M.E.S.G.: 0.011 in.) and methane (0.046 in.) in straight mixtures of these gases, the effect of the addition to hydrogen of carbon monoxide (0.036 in.) was different in that the M.E.S.G., for instance, of water gas (comprising about equal volumes of the two gases) was the same as for hydrogen alone. Group III of B.S. 229 is shown to be still appropriate for town gas if the hydrogen and carbon monoxide contents are not greater than about 55 per cent and 18 per cent, respectively. The normal content of unsaturated compounds does not present a special hazard in view of the experimental result with 5 per cent of admixed acetylene.

Hosono, Y. (Fire Research Institute of Japan, Tokyo, Japan) "Hydrological Investigation on Unconfined Water as a Source for Fire Fighting," *Fire Research Institute of Japan, Report No. 30,* 74 (1969).

Section: A

Subjects: Hydrological; Water sources; Fire fighting water source; Aquifier; Ground water table; Water table

Author's Abstract

A series of the hydrological investigation has been carried out with a view to seek the practical methods by which the probable occurrence of the unconfined aquifer from which the desirable amount of water may be used for the fire-fighting can be determined.

The results obtained have revealed that the unconfined aquifer which satisfies the above-mentioned requirement is in the hydrological environments specified by the following conditions.

1) The coefficient of transmissibility is in the order of about 10^4 cm^2/min as confirmed by the aquifer test.
2) The ground-water table shows recess in the ground-water table contour map.
3) The amplitude of annual cycle of the ground-water level is extremely large.
4) The amount of fluctuation of the ground-water level caused by the rainfall is relatively small or, in the extreme case, negligible.

As the technique of boring for making the well, an efficient pumping capacity and a large transmissibility may be obtained by the installation of a suitable strainer covering the whole depth of the aquifer.

Miller, R. L. E. and Wilford, G. P. (Royal Aircraft Establishment, Farnborough, England) "Simulated Crash Tests as a Means of Rating Aircraft Safety Fuels," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety,* 25 (August 1971)*

Section: A

Subjects: Fuel safety; Aircraft crashes; Aircraft fuel safety

Authors' Summary

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Two tests are described for assessing the fire resistance of Avtur containing polymeric additives which reduce its ability to form flammable mists. In the standard test a tank containing ten or twenty gallons of fuel is propelled on a rocket sled at speeds of 114 or 188 ft/sec and decelerated after contact with an aircraft arrester wire. Fuel is allowed to spill from a slit in the tank onto a series of ignition sources. In the "run on" test the tank travels at speeds up to 240 ft/sec past a series of ignition sources while spilling fuel from a slit on the leading edge.

The velocities of spilled fuel relative to the surrounding air which occur in these tests are shown to be comparable to those occurring during survivable aircraft crashes.

Nilsson, L. (Statens Institut for Byggnadsforskning, Stockholm, Sweden) "Fire Loads in Flats," *National Swedish Building Research Summary Report R34* (1970)

Section: A

Subjects: Fire loads; Apartment fire load; Flats, fire load in

Author's Summary

Report R34:1970 refers to Grant No. C479:2 (Project No. 3) from the National Swedish Council for Building Research to the Division of Structural Mechanics and Concrete Construction at the Lund Institute of Technology.

An essential part of functionally based fire engineering design of load-bearing and fire separating structures is the size of the fire load, determined in such a way that theoretical calculation of the gas temperature-time curve of the fire cell is possible. Theoretical and experimental model investigations, comprising a study of the possibilities of establishing a fire load characterisation based on combustion engineering considerations, are at present being performed at the Division of Structural Mechanics and Concrete Construction at the Lund Institute of Technology. Some fundamental aspects of the fire load and the results of the statistical processing of a field investigation concerning the fire load in flats, obtained during this study, are put forward in this report.

In the processing of the statistical material, taken from 120 flats selected at random, both individual bedrooms and living rooms and whole flats have been regarded as the fire cell. The mean value and the standard deviation pertaining to the enclosing surface and the opening factor are given for each type of fire cell in addition to representative values of the fire load.

Finally, the question of what value of the fire load should be taken as the fire engineering design criterion is discussed.

Pagni, P. J. and Houck, L. D. (University of California, Berkeley, California) "Prescribed Burning," *Final Report Student-Originated Studies, National Science Foundation Grant No. GY-9112, Report No. TS-71–5, Thermal Systems Division, Mechanical Engineering Department, University of California*

Section: A

Subjects: Prescribed burn; Burns, prescribed; Student fire program

Authors' Abstract

This report summarizes research on quantifying prescribed burning conducted during twelve weeks of the summer of 1971 by fifteen students at the University of California at Berkeley and sponsored by the Student-Originated Studies program of the National Science Foundation. The aim of this project was to quantitatively define prescribed burning so that range and forest managers can predict with certainty that a) a prescribed burn will not become uncontrolled, b) fuel loading will be significantly reduced, and c) the net effect on local ecology will be favorable. This report, as was our project, is divided into three sections: data acquisition, fire modeling, and ecological control. The data acquisition group participated in three range-improvement burns on the Wilbur (San Benito Co.), Guenoc (Napa Co.), and Long (Mariposa Co.) Ranches. At each of these fires, flame characteristics, fuel properties, and weather conditions were recorded. Statistically meaningful measurement techniques were developed and data acquired for the following fuel, topography, and weather parameters: fuel compactness, fuel surface to volume ratio, fuel size, fuel density, fuel loading, fuel moisture content, canopy density, fuel mineral content, ground slope, air temperature, humidity, and wind velocity. Procedures for monitoring flame properties were also developed and data obtained for rate of flame propagation, flame intensity, flame height and geometry, maximum temperatures at fixed heights, time-temperature curves at given positions and tree damage. Numerical results are summarized in the report. In the fire modeling group, each member chose a subproblem related to developing an analytical model of flame spread under prescribed burn conditions. A horizontal flame spread model was derived which predicts the rate of flame propagation through an homogeneous, thermally-thin, porous fuel bed in the absence of wind. The fluid mechanic, thermochemical, and heat transfer problems encountered in a flame model are discussed. The difficulties involved in constructing a model of wood pyrolysis are discussed; circumstances under which certain chemical or physical factors dominate pyrolysis are described, and current models are reviewed. Radiant heat transfer from a propagating flame to the overhead canopy is analysed. The application of modeling principles to wildland arson investigation is discussed; a procedure is developed for determining the location and time of origin of a wildland fire. A vertical flame spread model was developed which delineates the conditions under which a ground fire will make the transition to a crown fire. Time limitations prohibited the combining of these studies into an overall model. The ecological-control group established prescribed burn criteria based on the maximum allowable height at which thermal damage will occur to unignited vegetation due to heat flux from the propagating flame. This group also

examined currently available prescribed burn criteria and compiled general guidelines deciding when, what, where, and how to burn. These guidelines were used to develop, as an example, a prescribed burn plan for an area of Coyote brush (*Baccharis pilularis*) in the Berkeley Hills.

Pluss, E. and Purt, G. A. "Fire Protection in Telephone Exchanges," *PTT No. 6* (1971) issued by the *Swiss Posts, Telephone and Telegraph*

Section: A

Subjects: Telephone exchanges; Fire protection; Detectors

Authors' Summary

The marked changes in the design and operation of telephone exchanges and the wish to know more about the suitability of other detector types called for a re-assessment of the existing, though proven, fire protection concept. Exhaustive fire tests in a modern telephone exchange confirm the universal application possibilities of combustion gas detectors based on the ionisation principle. Test findings also point to the possibility of further improving the fire protection concept by using also optical smoke detectors.

U.S.D.A. Forest Service, Forest Products Laboratory (Madison, Wisconsin) "Evaluation of Fire Retardant Treatments for Wood Shingles," *U.S.D.A. Forest Service Research Paper FPL 158* (1971)

Section: A

Subjects: Shingles, wood; Fire retardants

Report Summary

Wood shingles and shakes are esthetically desirable and durable, but have been restricted for some uses because of their performance under fire conditions. Suitable fire-retardant systems would further improve the utility of shingles and shakes and insure consumer confidence. For this reason, numerous fire-retardant treatment systems were evaluated for their fire performance and durability.

The evaluation used western redcedar shingles in two phases of the study. In the first phase, the fire-retardant treatments were evaluated for method of application and general fire performance under three fire test methods. In the second phase of the study, the more promising treatment systems were evaluated for durability by weathering exposure under two conditions, and then fire tested.

Four treatment systems promised the most fire-retardant effectiveness following weather and leaching exposures. Three were impregnation treatments in which the chemical fire retardants were heat cured in the shingles to reduce their water solubility: (1) Tris (1-aziridinyl) phosphine oxide, (2) tetrakis (hydroxy-methyl) phosphonium chloride with urea and a melamine, and (3) dicyandiamide and phosphoric acid. The fourth treatment was an impregnation with formulation AWPA Type D, followed by coating with a sealer solution containing tricresyl phosphate added as a fire-retardant. A coating of an epoxy paint also gave satisfactory performance, except for resistance to severe flaming ignition.

All four treatment systems need further work to develop optimum treatment levels which give sufficient fire-retardant effectiveness, durability, and acceptable treated-wood properties and yet are economically feasible for the product.

B. Ignition of Fires

Andersen, W. H. (Shock Hydrodynamics, Inc., Sherman Oaks, California) "Theory of Surface Ignition with Applications to Cellulose, Explosives, and Propellants," *Combustion and Science Technology* 2(4), 213 (1970)

Section: B

Subjects: Ignition; Surface ignition; Cellulose; Explosives; Propellants

Reviewed by G. A. Agoston

The analytical problem considered is that of a homogeneous, semi-infinite combustible solid, initially at a uniform temperature T_0, and subjected to a constant non-radiative surface heat flux I_n and radiative flux I_r. The differential equation describing the temperature T at distance x from the surface within the solid at time t, assuming constant thermal diffusivity α, density ρ, and heat capacity C, and including first order exothermic and endothermic chemical reaction is

$$\partial T/\partial t=\alpha(\partial^2 T/\partial x^2)+(\gamma I/\rho C)+(Q/C)(1-f)k_r-(Q_e/C)(1-f_e)k_{re} \qquad (1)$$

where

$$I=I_r(1-r)\exp(-\gamma x) \qquad (2a)$$

$$k_r=Z\exp(-E/RT) \qquad (2b)$$

The extinction coefficient γ and surface reflectivity r are average values over the wavelength band of the radiant source. Q is the heat of exothermic reaction, f is the extent of reaction in time t and k_r is the specific rate constant for the rate determining reaction. The subscript e refers to the endothermic (pyrolysis) reaction. E is the activation energy; Z, the frequency factor; R, the gas constant.

The author combines two published solutions of equation (1) in an intuitive manner to obtain the *ignition time* of the surface-heated material. The first solution is for the heating of an inert material ($Q=Q_e=0$). The temperature of the surface layer ($x=0$) is given by:

$$T=T_0+(1/K\gamma)\exp(\alpha\gamma^2 t)\operatorname{erfc}(\gamma^2\alpha t)^{1/2}+[2(I+I_n)t^{1/2}/(\pi\rho CK)^{1/2}]-(K\gamma)^{-1} \qquad (3)$$

This equation is simplified in this study, where γ is considered large and I_n is disregarded, to:

$$T=T_0+[2I_r(1-r)t^{1/2}/(\pi\rho CK)^{1/2}] \qquad (4)$$

The second solution is that for an adiabatic exothermic reaction [where the first and fourth terms of Eq. (1) apply]. The following expression is obtained for reaction (induction) time t_r at temperature T to which the material is instantaneously heated:

$$t_r=(CRT^2/ZQE)\exp(E/RT) \qquad (5)$$

The author gives the ignition time t_{ig} as

$$t_{ig}=t_c+t_{rc} \qquad (6)$$

where t_c is the time [from Eq. (4)] to heat the surface to T_c, the effective temperature that determines the reaction time t_{rc} [from Eq. (5)] of the exothermic reaction that leads to ignition.

In order to arrive at T_c the author gives as a criterion for ignition

$$(dt_{ig}/dt)_{T=T_c}=[(dt_c/dt)+(dt_{rc}/dt)]_{T=T_c}=0 \qquad (7)$$

This is based on the fact that the surface temperature increases monotonically with time, whereas reaction time decreases with increase in temperature and hence with time. Thus the ignition time should exhibit a minimum, and the controlling ignition reaction should commence at this minimum. Equation (7) is evaluated using Eqs. (4) and (5) yielding

$$T_c=\frac{(E/R)}{\ln\{2R(T_c-T_0)/k_1^2k_2[(1-r)I_r]^2(E-2RT_c)\}} \qquad (8)$$

$$k_1^2=4/(\pi K\rho C) \qquad (9a)$$

$$k_2=CR/ZQE \qquad (9b)$$

After T_c is evaluated, t_c can be obtained from Eq. (4) and t_{rc} from Eq. (5). The ignition time t_{ig} is then obtained from equation (6) and the ignition surface temperature from Eq. (4).

The author obtained a theoretical curve of t_{ig} vs. $(1-r)I_r$ for cellulose, using the following values for the constants: $\rho=0.6$ gm/cm³, $C=0.55$ cal/g°K, $K=2.7(10^{-4})$ cal/cm sec °K, $Q=86$ cal/g, $E/R=16{,}670$°K, and $Z=5.3(10^8)$ sec⁻¹. The curve is in reasonable agreement with the experimental ignition data for cotton cloth of Welker *et al.* (1969) and of Lee and Alvares, except at the lower irradiance levels near the minimum flux threshold required for ignition. The choice of constants was shown not to account for the discrepancy. The author repeated the calculation, assuming that the ignition reaction occurs under essentially isothermal rather than adiabatic conditions and obtained comparable results. He suggests that the discrepancy between experiment and theory is not the result of the adiabatic approximation and that it is likely due to convection losses and/or internal cooling losses resulting from the sample's being thin.

The theory predicts that the surface ignition temperature increases as the absorbed irradiance level is increased. This result is consistent with the analytical studies and the experimental ignition data of Baer and Ryan (1965) for composite propellants. A fit of the present ignition equations to their experimental ignition time vs. heat flux data yielded E of 28 kcal/mole and ZQ of $1.1(10^{11})$ cal/g sec. Baer and Ryan obtained the same value for E from fitting their data with their solution. The author points out that his ignition equations are also qualitatively consistent with the ignition behavior of double base propellants reported by Wachtell and Roth (1962). He adds that the equations should be especially applicable to the surface initiation of secondary explosives, since their thermal decomposition is usually controlled by a single exothermic reaction. Equation (3) should be used to treat data on the initiation of primary explosives by high intensity light.

The author discusses briefly the mechanism of cellulose ignition, following Akita (1959), throwing some light on the influence of pyrolysis. A three-step process is assumed: (1) the endothermic pyrolysis of cellulose into vapors V and carbonaceous material, (2) at sufficiently high temperatures certain components V_1 of the mixture V undergo exothermic reaction to form reactive volatile products V_r, (3) V_r reacts rapidly with air oxygen. Under high heat flux conditions, the surface temperature rises quickly enough for V_r to be formed almost spontaneously with V, and ignition is controlled by the second step. At low heat flux conditions the surface temperature rises slowly, preventing reaction (2) from occurring while the endothermic reactions initially occur. Thus the ignition time is larger than the theoretical time based on an effective exothermic reaction. This is suggested as an additional reason for the discrepancy between experiment and theory. Retention of the endothermic reaction term in the solution of Eq. (1) would probably be preferable, but a numerical integration would be required.

De Soete, G. (Institut Francais du Petrole, Rueil-Malmaison, France) "Influence de la Structure Moleculaire sur Certaines Proprietes d'Auto-Inflammation des Hydrocarbures," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 14 (August 1971)*

Section: B

Subjects: Ignition; Molecular structure; Hydrocarbon-air chemical kinetics

Author's Summary

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

The adiabatic compression method was used to determine delays in self-ignition by different hydrocarbon-air mixtures as a function of pressure and temperature. A comparison of experimental results makes it possible to evaluate the effect of some special molecular structure characteristics on the overall activation energy. In particular, the presence of ternary carbon atoms and double carbon-carbon bonds results in a decrease in this activation energy. Tests made with mixtures of two different hydrocarbons show that the kinetic parameters controlling the dependency of ignition delay on temperature vary in such a way that the delay with a mixture tends to approach that of the pure component having the shortest delay at the temperature considered. This phenomenon was found to be all the greater as the relative concentration of this component in the binary mixture is higher.

Murray, W. L. (Safety in Mines Research Establishment, Sheffield, England) "Further Studies of the Ignition of Methane—Air by Detonating Explosives," *Safety in Mines Research Establishment Research Report No. 262* (1970)

Section: B

Subjects: Methane–air; Explosions; Detonations

Author's Abstract

The paper describes experiments carried out with different types of explosives in order to examine the mechanism of ignition of methane–air. The explosives used included conventional permitted explosives (nitroglycerine–ammonium nitrate–common salt), ion-exchange explosives, and nitroglycerine–common salt explosives. The explosives were detonated when suspended in a small chamber containing methane–air and the subsequent events photographed with an ultra-high-speed framing camera. Measurements of the shock-wave system produced by the explosives were made in separate experiments using schlieren photography and a rotating mirror camera. The observed results support the view that the initial ignition of the gas is brought about by the shock waves and that when the shock system is too weak no ignition occurs.

Powell, F. (Safety in Mines Research Establishment, Sheffield, England) "The Ignition of Gases and Vapours by Friction and Impact," *Industrial and Engineering Chemistry* **61**(12), 29 (1969)

Section: B

Subjects: Ignition; Gases, ignition; Vapour ignition; Friction, ignition by; Impact, ignition by; Review

Reprint of Safety in Mines Research Establishment Abstract, By Permission

This paper is a review of information on the ignition of flammable gases and vapours by friction and impact. A guide to the behaviour of the main materials studied is presented in tabular form.

Sharma, O. P. and Sirignano, W. A. (Guggenheim Laboratories, Princeton, New Jersey) "Ignition of Fuels by a Hot Projectile," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 15 (August 1971)*

Section: B

Subjects: Ignition; Fuels; Projectiles

Authors' Summary

The combustible gaseous mixture, which is present above the surface of certain liquid fuels, may be ignited by a hot projectile. A short modified discussion is given of the results of earlier theoretical investigations performed by approximating, firstly, the flow at the forward end of the projectile to a stagnation flow towards a hot axisymmetric body, secondly, the flow over its surface to a laminar flow over a hot plate, and, thirdly, the flow in the wake of the projectile to a plane laminar mixing of the cold unreacted mixture with the hot combustion products. After the premixed mixture is exhausted, there is a possibility of ignition of unmixed reactants by the hot inert products which are left behind and are sandwiched between the oxidizer and the fuel. A theoretical analysis for the ignition delay time as a function of the temperature and the width of the hot gas region is also presented.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Underwriters' Laboratories, Inc. (Chicago, Illinois) "An Investigation of Fifteen Flammable Gases or Vapors with Respect to Explosion-Proof Electrical Equipment," *Underwriters' Laboratories, Inc. Bulletin of Research No. 58* (April 1970)

Section: B

Subjects: Gases, flammability; Flammability of gases; Explosion proof; Electrical equipment; Explosions

Bulletin Abstract

This Bulletin of Research reports an investigation conducted by Underwriters' Laboratories, Inc. to establish a procedure for classifying additional flammable gases or vapors within Groups A, B, C, and D of Class I hazardous locations as defined by the National Electrical Code. This procedure provides a means of increasing the utility of presently recognized explosion-proof electrical equipment without the necessity of additional expensive and laborious testing of such equipment.

Using a test facility designed and constructed by Underwriters' Laboratories, Inc. comparative experimental data on flame propagation and explosion effects, with special reference to explosion-proof electrical equipment, have been obtained for fifteen gases or volatile chemical materials not previously classified. Features investigated included the maximum explosion pressure developed by the particular gas- or vapor-air mixture under pertinent test conditions, and the widths and clearances in metal-to-metal joints that will arrest flame propagation. The primary explosion chamber, 12 in. in internal diameter with an internal volume of one cu ft, is provided with a variable test joint assembly, means for inducing initial turbulence in the test mixture prior to ignition, and an optional 10-ft section of $1\frac{1}{2}$-in. size conduit for studies of explosion pressure piling effects.

To arrive at the proposed classifications, the flame propagation and explosion effects of each gas or vapor, together with its ignition temperature, were compared with the corresponding characteristics of acetylene (Group A), hydrogen (Group B), diethyl ether (Group C), and gasoline (Group D) as determined under the same test conditions. The Group classification of these four reference materials has long been established within Class I hazardous locations, and each of the four is considered representative of the other gases or vapors classed in the respective Group.

On the basis of the results of this investigation, fourteen gases or vapors have been added to the Group classifications within Class I hazardous locations as follows:

Class I, Group B—Butadiene, ethylene oxide, and propylene oxide.
Class I, Group C—Acetaldehyde, isoprene, and unsymmetrical dimethylhydrazine.
Class I, Group D—Acrylonitrile, ammonia (anhydrous), ethylene dichloride, propylene, styrene, vinyl acetate, vinyl chloride, and para-xylene.

Carbon disulfide, the fifteenth material investigated, would not be classified in any of the four Groups of Class I hazardous locations. Because of its low ignition temperature and the very close clearances between surfaces necessary to arrest its flame propagation, carbon disulfide requires safeguards beyond those required for any of the present Groups.

C. Detection of Fires

Nakajima, K. (Fire Research Institute of Japan, Tokyo, Japan) "Fire Detection by Infrared Resonance Radiation," *Fire Research Institute of Japan Report No. 30*, 61 (1970)

Section: C

Subjects: Detection of fire; Infrared fire detector; Resonance radiation detector

Author's Abstract

The object of this paper is to describe the new type flame detector which is sensitive to infrared resonance radiation.

The first part of this paper reports that flames of burning fuels, such as gasoline, alcohol, candle and city gas commonly emit a considerably strong resonance radiation band of about 4.4 μ, and that the radiant energy of the band amounts to about one-fifth of the entire radiant energy.

The second part is concerned with the flame detector based on the above-mentioned facts. A PbSe photoconductive cell, which has high sensitivity in the above-mentioned wavelength region, and field effect transister (MOS type) are used as detector head in a trial set. Furthermore, an infrared bandpass filter is placed in front of the cell so that only the resonance radiation band can be passed through. The trial set consists of detector head, electric low-pass filter, amplifier, wave-shaping circuit, integrating circuit, etc.

The detector can detect (1) 20 cm diameter pan fire of gasoline at a distance of 5 m from the head, (2) burning of a sheet of newspaper of about 1000 cm^2 at the same distance, and (3) burning of a match stick at a distance of 50 cm from the head. The false alarm does not occur by flashings of 500W-bulb at a distance of 50 cm from the head.

D. Propagation of Fires

Botteri, B. P. (Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio) "Flammability Properties of Jet Fuels and Techniques for Fire and Explosion Suppression," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety,* 13 (August 1971)*

Section: D

Subjects: Fuels; Suppression of explosion; Flammability

Author's Summary

Because of the large quantity and dispersed storage of fuel on-board aircraft, under combat environment conditions, a high probability exists that gunfire hits will occur in fuel areas with consequent damaging effects of fire, explosion, and/or fuel depletion. One obvious means for enhancing the survivability of an aircraft is to select a fuel which is less susceptible to fire and explosion induced by gunfire. Results of investigative efforts to establish the "practical" flammability envelopes and associated combustion damage potential for conventional jet fuels such as JP-4, JP-8 (similar to JET A-1), and JP-5 under simulated hostile operating environment conditions will be presented. Testing included liquid-space gunfire hits to assess external fire hazard and vertical (liquid to vapor) firing trajectories to determine explosion hazard associated with projectile-induced fuel sprays and mists. All tests were performed in instrumented replica target tanks varying in volume from 15 to 90 gallons. Principal test variables were fuel temperature, pressure, fuel depth, external void space, and internal and external air flow. All tests were conducted utilizing 0.50-caliber armor piercing incendiary projectiles. These tests indicate a considerable extension in the flammability range of all fuels compared to the equilibrium flammability limit values which are commonly utilized for fire safety analysis. In view of the fire and explosion potential exhibited by all conventional jet fuels, additional measures must be employed to achieve an effective fire-protection capability. Accordingly, recent progress in the use of reticulated polyurethane foam, halogenated hydrocarbon chemical extinguishants, and other fuel-tank inerting techniques will also be reviewed.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Glassman, I., Mackinven, R., Sharma, O. P., and Sirignano, W. A. (Guggenheim Laboratories, Princeton, New Jersey) "Flame Spreading Across Liquid Fuels," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 17 (August 1971)*

Section: D

Subjects: Flame spreading; Fuels

Authors' Summary

For fuels below their flashpoint, hydrodynamic currents in the liquid fuel itself play perhaps the dominant role in flame spreading. These currents are induced by either surface tension or buoyancy forces. Since it was concluded then that the physical characteristics of the fuel are important in flame spreading, extensive experiments were performed in which the flame spreading rate across normal decane was measured as a function of fuel temperature, viscosity, depth, pan size, etc. This paper summarizes these results.

The problem of a two-dimensional flame spreading across a horizontal fuel surface has been analyzed when the liquid fuel temperature is below its flash point. It has been demonstrated that the liquid phase convective heat transfer in the direction of the flame propagation occurs when surface tension variation is taken into account. The flow field has been completely analyzed for shallow pools. In the case of deep pools, the boundary layer approximation is valid and it has been shown that the buoyancy terms are of higher order and, hence, negligible compared to surface tension terms. Some velocity profiles in the liquid phase are presented.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Roberts, A. F. and Blackwell, J. R. (Safety in Mines Research Establishment, Sheffield, England) "The Possibility of the Occurrence of Fuel-Rich Mine Fires," *Mining Engineer* **128**, 699 (1969)

Section: D

Subjects: Fires, mines; Mine fires; Fuel-rich fires

Reprint of Safety in Mines Research Establishment Abstract, By Permission

A study has been made of the characteristics of fires that propagate along the timber linings of mine roadways. Initially experiments were conducted in a 0.3-m (1-ft) square refractory-lined duct, which could be ventilated at rates up to 5 m/s

(1000 ft/min). These small-scale experiments demonstrated the possibility of fires of exceptional severity, with characteristics very different from those so far observed in large-scale fires. Furthermore, an analysis of the data from the small-scale experiments indicated that these characteristics could develop in a full-scale mine roadway. A series of experiments in a 2.1-m (7-ft) high roadway, of cross-sectional area 4.1 m^2 (45 ft^2), confirmed this prediction. The characteristics of these severe fires are described and some practical implications of these studies are considered.

Vodvarka, F. J. (IIT Research Institute, Chicago, Illinois) "Firebrand Field Studies," *Final Report under Contract N00228-68-C-2686 for Office of Civil Defense* (September 1969)

Section: D

Subjects: Firebrands; Brands

Author's Abstract

Five residential structures were burned and their firebrand production was sampled by distributing plastic sheets downwind from the structures. Hot brands melted the plastic to leave holes showing their profiles in the sheet. The holes were then traced onto paper, and their areas measured with a planimeter.

Three of the structures were standard frame construction with wood siding. The fourth was asphalt siding applied over sheet rock which covered the original shiplap. The fifth structure was a brick veneer over a wood frame. All five structures were burned under light and variable wind conditions.

The firebrand production was greatest at the time of roof collapse. The firebrands captured ranged from smaller than match-head size to about 15-$in.^2$ They were classified by fractions of the standard "C" brand used for testing roof flammability. Tentative brand densities for distances to 300 ft were determined.

Concurrently with the experimental phase, attempts were made to obtain firebrand data from accidental fires as reported by IITRI's fire consultants. Only four fires were reported, of which only two were unwanted fires. The other two were set to dispose of the buildings.

The firebrand production and the distance of travel as reported appeared to be greater than that measured at the experimental fires. This is attributed to the higher wind velocities and to the use of water sprays to protect exposures.

A firebrand field study questionnaire was sent to the chiefs of approximately 1600 United States communities with populations over 12,000. Almost 500 replies were received, of which 268 provided detailed information.

Geographically, the mountain states provided the fewest replies and those indicated the least difficulty with firebrands. The remainder of the country all indicated about the same degree of occurrence of firebrands.

E. Suppression of Fires

Alger, R. S., Alvares, N. J., Inman, L. H., and Lipska, A. E. (Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland) "The Destruction of High-Expansion Fire-Fighting Foam by the Components of Fuel Pyrolysis and Combustion—Part II," *Naval Ordnance Laboratory Report No. NOLTR 72-93 for Naval Ship Systems Command* (April 1972)

Section: E

Subjects: High expansion foam; Fire-fighting foam; Smoke products; Pyrolysis products; Defoaming agents; Effect of smoke on foam

Authors' Abstract

The object of this research was to develop and test methods which will allow high-expansion foam production when the only air available to the foam-generating nozzle is contaminated from a combustion environment. Many of the chemical products of combustion and pyrolysis which impede foam production were identified during the last year's experimental program. Chemical modification of the foam solution appeared to show promises as a remedial technique for frustration foam destruction by smoke. Also water-spray scrubbing of the air prior to its entrance to the foam generator proved effective in removing chemical foam-breaking agents. However, only the scrubbing procedures would be of use in providing cooling to the combustion heated air.

The operational limits of both the chemical and scrubbing remedial techniques were investigated during the present research for the following changes in foam-generation parameters and procedures. (1) The ambient temperature. (2) The smoke concentration. (3) Foam-generation plenum pressure. (4) Per cent of chemical foam-stabilizing agent in foam solution. (5) The effect of all above parameters on foam formed with salt water.

The significant results of the current work can be briefly summarized as follows: (1) High expansion foam will not efficiently form if the inlet air temperature to the foam generator exceeds 212°F. (2) Water-spray scrubbing successfully cools inlet air from 600°F to 100°F, a temperature at which foam is efficiently produced. (3) The foam-stabilization chemicals all affected increased foam stability for foam made with smoke-contaminated air. (4) Scaling considerations indicate that scrubbing systems compatible with existing foam generators are feasible.

Baldwin, R. (Joint Fire Research Organization, Boreham Wood, England) "The Use of Water in the Extinction of Fires by Brigades," *Joint Fire Research Note No. 803* (March 1970)

Section: E

Subjects: Extinguishing; Water, Fire; Size; Time

Author's Summary

Some American data on the relationship between the rate of application of water and the fire area and between the time taken to control the fire and the fire area are reviewed. Comparison with published British data suggests that in spite of different techniques and conditions, at this level of comparison, the results are very similar. The rate of application of water is about four times as great as in experimental fires, suggesting that the chief problems of fire fighting are operational.

Baratov, A. N., Karagulov, F. A. and Makeev, V. I. "Study of the Inhibition of H_2–O_2–N_2 Mixture Flames by Halo Hydrocarbons," *Fizika Goreniya i Vzryva* **6**(1), 18 (1970)

Section: E

Subjects: H_2–O_2–N_2 flames; Inhibition; Halocarbons; Burning velocity

Authors' Summary Translated by L. Holtschlag

The results of a number of experimental studies of the degree of influence of tetrafluorodibromoethane and ethyl bromide on the development of an explosion in a constant-volume bomb and on the normal flame propagation rate (u_n) in hydrogen–air mixtures are given. The u_n was determined from diagrams of $p=f(\tau)$. The degree of hydrogen combustion was estimated from the change in mixture volume during combustion and also by analyzing the reaction products on a chromatograph. The u_n of H–air mixture flames with additions of $C_2F_4Br_2$ and C_2H_5Br were studied by schlieren photography of the flame cone from a Bunsen burner. The thickness of the laminar flame zone was measured on a microphotometer (10-× magnification of the flame image). The greatest effect of these additives on u_n was observed in rich mixtures. Analysis of the experimental data by the van Tiggelen theory showed that the introduction of halo hydrocarbons into the flame resulted in an increase in the mean molecular weight of the active centers and the mean activation energy of the burning process. A mechanism of H_2–O_2–N_2 flame inhibition by halo hydrocarbons is proposed which includes deactivation of the oxygen-containing radicals as the basic reaction.

Fiala, R. (Deutsche Forschungs und Versuchsanstalt für Luft und Raumfahrt E. V. Institut für Luftstrahlantriebe, Germany) "Contribution to the Selection of Fire Extinguishing Systems and Agents for Aircraft Fires," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 18 (August 1971)*

Section: E

Subjects: Aircraft fires; Extinguishing agents; Fire extinguishing systems

Author's Summary

Aviation is one of those fields of technical activities in which fire hazard is extremely high, because airplanes carry large amounts of fuel and the equipment of the fuselage consists to a large extent of combustible plastics, although they normally are heavily inflammable. Ignition sources are always present, for example, hot engines parts, hot brakes, possible short circuits in the electrical installation, etc. In most cases of fire many lives and great values are immediately in danger. Therefore, firefighting in aviation gains more and more interest. It is, however, complicated by the fact that due to the great variety of materials which can be set on fire, different types of fires will occur, for example, engine fires, fires in the cabin, in cargo rooms and electrical installations, burning of tires, crashfires, metal fires, etc., each of which needs different fighting procedures if optimum results are to be achieved.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Fiala, R. and Winterfeld, G. (Deutsche Forschungs und Versuchsanatalt für Luft und Raumfahrt E.V. Institut für Luftstrahlantriebe, Germany) "Investigation of Fire Extinguishing Powders by Means of a New Measuring Procedure," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 24 (August 1971)*

Section: E

Subjects: Fire extinguishers; Powder extinguishants; Blowoff limits; Damköhler's first number

Authors' Summary

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Fire extinguishing systems in aircraft of high flight Mach numbers (>2, 5) are exposed to such high temperatures within the aircraft that halogenated hydrocarbons normally used as fire extinguishing agents in aircraft, must be replaced by substances which are thermally more stable. These are fire extinguishing powders which are also used for large fuel fires, e.g., crash fires.

In order to optimise fire extinguishing systems it is necessary to compare the extinguishing efficiency of such solid and gaseous (or liquid) extinguishing agents.

A new measuring procedure is described which allows this direct comparison. It makes use of the relationship between the maximum flow velocity at the burning limit of a flame-holder stabilized flame and the laminar burning velocity of the fuel-air-mixture which is given by Damköhler's first number. Comparative results achieved with this procedure for several fire extinguishing agents are given.

Morikawa, T., Shimada, H. and Moriya, T. (Fire Research Institute of Japan, Tokyo, Japan) "Fire Extinguishing Measures for Radioisotope Facilities: Extinguishing Effects of Carbon Dioxide on Liquid Fires in Hoods," *Fire Research Institute of Japan Report No. 30,* 17 (1969)

Section: E

Subjects: Extinguishing measures radioisotope facility fires; Fires in radioisotope facilities; Pool fires

Authors' Abstract

The purpose of this study is to develop the method of extinguishing fires in radio isotope facilities.

In the present report, the study of carbon dioxide extinguishment of the liquid fires in radioisotope handling hoods is presented.

Carbon dioxide is usually applied as extinguishant for the fires in an enclosure only when not ventilated.

But, for the fire in a hood, it must be applied under the ventilating condition, to avoid radioactive contamination of the atmosphere surrounding the hood.

First of all, it was made sure by some experiments that the extinguishing method using carbon dioxide is applicable for extinguishing the fires of this kind.

Secondly, experiments were carried out to see how much carbon dioxide is required to extinguish the fires in the hoods of different scales and different opening areas, changing the rate of carbon dioxide application, the rate of ventilation, and means of carbon dioxide discharge.

The following results were obtained. (1) The extinction time increases with the rate of ventilation and decreases with the rate of CO_2 application in both cases of the discharge methods, one being "vaporized discharge" and the other "direct

discharge". In the former case, carbon dioxide is discharged in the form of gas, and in the latter case it is discharged directly from the CO_2 cylinder, so it was in the form of the mixture of gas and solid. The patterns of the curves in both discharge methods are similar. (2) The concentration of carbon dioxide is generally higher in the upper region than in the lower region of the hood. (3) The dimensionless relations between the rate of carbon dioxide application q/Q and the amount of carbon dioxide required for extinguishing the fires qt/V were obtained from all the data, where q is the rate of carbon dioxide application, Q the rate of ventilation, t_E the extinction time, and V the volume of the hood. The most suitable value of q/Q is 0.5 for extinguishing the fire. The amount of carbon dioxide required is one-fifth as much as the volume of hood. It is very small, despite the hoods being ventilated during the experiments. The minimum carbon dioxide concentration of the extinction limit is known as 29%, when *n*-Hexan is used as the fuel. It may be considered that our result of smaller amount of carbon dioxide for extinguishment is perhaps due mainly to the local application.

Nakakuki, A. and Takahashi, M. (Fire Research Institute of Japan, Tokyo, Japan) "Extinction of Liquid Fuel Fires with Water Sprays," *Fire Research Institute of Japan Report No. 30*, 53 (1969)

Section: E

Subjects: Extinction; Pool fires; Fires, liquid fuel; Sprays; Water sprays

Authors' Abstract

An investigation on the extinction with water sprays of fires of liquids burning in cylindrical vessels was carried out. The blow-off tests by the wind sent from the right above position of burning liquid were also carried out to clarify the effect of the air-flow in the spray on extinction. Eleven vessels of various dimensions were used. From the difference of the extinction process, sixteen different liquids used were divided into three classes.

1) Blow-off

The fires of such liquids as classified in the 1st class, the vapor layers of which are thick from the very initiation of burning, are likely to be extinguished in a very short time (within 5 sec) by the dilution of the vapor zone, by applying the wind faster than the critical wind speed v_c (m/sec). In these liquids, the extinction time is not so much affected by the time of preburning t_p (min) and the distance

h (mm) of the liquid surface from the edge of the vessel wall. In the liquids of 2nd and 3rd classes, the vapor layers in the flames are thin, but become thick at large t_p or small h. At small t_p or large h, stable flames which are very difficult to extinguish are formed with these liquids, whereas, at large t_p or small h, the fires are extinguished in a very short time (within 5 sec) above the critical wind speeds which are smaller than those with the former liquids (1st class) except methanol and dioxane. The size of the stable flame reduces gradually due to the cooling of the liquid surface and the dilution of combustible vapor, and extinction takes a long time after applying the wind. When fire is extinguished in a very short time, the flame is blown off instantly or after vibrating violently. It is observed more frequently with the liquids of 2nd and 3rd classes that the fires are extinguished instantly or simultaneously with the application of the wind. The critical wind speeds of blow-off of some liquids at different levels of the liquid surface are given.

Through these tests, the following two mechanisms are suggested to account for the blow-off:

a) dilution of the flammable vapor from the liquid to a concentration lower than that required to sustain flame;
b) cooling the liquid surface when the stable flame is formed.

2) Extinction with water sprays

Water sprays were produced from a rotating disk, six swirl and two impinging jet nozzles. The spray properties, that is, the flow rate of the spray per unit area, the drop size, the drop velocity, and the entrained air velocity were measured. The distribution of the drop size was analysed by the formula proposed by Nukiyama and Tanasawa. It is shown from the measurements of the drop size for various sprays that the exponents of the formula are approximately constant. It is confirmed that the equation for the downward drop velocity derived for this case, assuming that Newton's formula is applicable, agrees approximately with the experimental data.

The tests of extinction of liquid fires with water sprays projected from the nozzle (which was fixed right above the burning surface) were carried out. The results of the extinction tests with coarse sprays whose Sauter mean diameters $\bar{D}_{32}$ are larger than 1 mm show the same tendency as those of the blow-off tests. With the fine sprays whose $\bar{D}_{32}$ are in the range 0.1–0.5 mm, the blow-off effect by the entrained air is also observed. The influences of t_p and h on extinction are similar to those in the blow-off test. In the case of the 1st class liquid, the extinction time takes an almost constant value at the same entrained-air velocity and drop size, and is independent of the flow rate of the spray. With the liquid of the 2nd class, the extinction time is also determined mainly by the entrained-air velocity and the drop size, but more or less affected by the flow rate of the spray. In these liquids (1st and 2nd classes), the critical entrained-air velocity, which are defined in the same manner as v_c in the blow-off test, decreases with the droplet size. With the water-soluble liquid (3rd class), it was confirmed by experiment that the fire was extinguished due to the dilution of the liquid surface with water sprays, and the cooling of the liquid surface and dilution of the flammable vapor by the entrained air. Therefore, the extinction times of these liquids are very much influenced by the flow rate of the spray. The concentration C_c of the solution at the instant of extinction takes a constant value at the same drop size and entrained-air velocity, and increases with the entrained-air velocity and with the decrease of the drop size. With all liquids, the formation of steam and the cooling of the flames, the liquid, etc., with water sprays contribute to the extinction of the fire, but the splashing caused by the spray at the liquid surface has the reverse effect on the extinction.

As the mechanism of extinction by means of water sprays are considered, the following factors in addition to the above-mentioned mechanisms of blow-off by the entrained air are also considered:

c) dilution of the flammable vapor by steam formation at the flames, the vapor zone, the vessel wall, and the liquid;
d) cooling the flames, the vapor zone, the vessel wall, and the liquid by steam formation and by the direct contact of spray drops;
e) for the water-soluble liquid, dilution of the surface layer of the liquid.

In some cases, extinction occurs by any single factor of those mentioned above but, in most cases, by the combination of some of them.

Thorne, P. F. (Joint Fire Research Organization, Boreham Wood, England) "Flammable Liquid Fuels for Class-B Fire Tests for Portable Fire Extinguishers," *Joint Fire Research Organization Fire Research Note No. 879* (July 1971)

Section: E

Subjects: Fuel, liquid; Extinguishing; Extinguisher; Tests Class-B fires

Author's Summary

TABLE I

List of fuels used in fire tests and the relevant standards

Extinguisher type	Country	National standard for the fire test	Fuel for fire test	National standard for the fuel
Water	France	NF.S. 61–911 soda acid	Essence-F	—
		NF.S. 61–912 gas operated (optional tests)	Paraffin	—
			Light fuel oil	—
Foam	France	NF.S. 61–910 (1965)	Essence-F	—
Carbon dioxide	France	NF.S. 61–914	Essence-F	—
	Germany	DIN.14406: sheet 1 (1964) and sheet 2 (1967)	Motor gasoline	DIN. 51600 (1966)
Vaporizing liquids	France	NF.S. 61–913 (1966)	Essence-F	—
	Germany	DIN.14406: sheet 1 (1964) and sheet 2 (1967)	Motor gasoline	DIN. 51600 (1966)
	Britain	BS.1721 (revised draft 1966)	Motor gasoline	BS. 4040 Part 1 (1967)
Dry powders	France	NF.S. 61–915 (1966)	Essence-F	—
	Germany	DIN. 14406: sheet 1 (1964) and sheet 2 (1967)	Motor gasoline	DIN. 51600 (1966)
	Britain	BS. 3465 (1962)	Motor gasoline	BS. 4040 Part 1 (1967)

TABLE II

Comparison of standards and specifications for Motor Gasoline in Britain and Germany, Aviation gasoline, and French "essence F"

Property╲Flammable liquid	British motor gasoline BS 4040	German motor gasoline DIN 51600	Range of values to be expected for motor gasolines in Europe[a]	Aviation gasoline D.Eng. RD. 2485	French "Essence F"
Specific gravity	Not specified, but typically 0.72–0.77	Minimum 0.72	0.7–0.78	Not specified, but typically 0.725	0.739
Net calorific value (cal/g)	Not specified, but typically 10,400–10,500	Not specified	10,300–10,550	Minimum 10,400	Not specified
Vapour pressure (REID) (R.V.P.) kg/cm² (lb/in²)	Not specified but typically 0.49(7.0)–0.91(13.0)	Minimum 0.7(10.0) Maximum 0.9(12.9)	0.35(5.0) to 0.98(14.0)	Minimum 0.386(5.5) Maximum 0.49(7.0)	Not specified
Initial boiling point °C	Not specified	Not specified	25–45	Not specified	100
Final boiling point °C	Not specified	Not specified	140–220	Maximum 170	158.5
Distillation characteristics	10% distilled at max. temp. 70°C 50% distilled at max. temp. 125°C 90% distilled at max. temp. 180°C	Minimum of 10% distilled at 70°C Minimum of 40% distilled at 100°C Minimum of 95% distilled at 200°C	—	Between 10% and 40% distilled at 75°C Minimum of 50% distilled at 105°C Minimum of 90% distilled at 135°C	Not specified

[a] Data supplied by Shell Petroleum Company.

Yamashika, S. (Fire Research Institute of Japan, Tokyo, Japan) "Studies on the Required Quantity of Various Fire Extinguishing Agents: Part 3. The Case of Open Tray," *Fire Research Institute of Japan Report No. 33*, 5 (1971)

Section: E

Subjects: Extinguishants; Tray fires; Theory of extinguishment

Author's Abstract

The experimental result of extinction of liquid fires in the open tray with various extinguishing agents is described in this report, and compared with the references.

Various agents such as carbon dioxide, dry powder, halogenated hydrocarbons, water, and aqueous solution of potassium carbonate were applied from the nozzles fixed at the four corners of the tub or from a nozzle above the center of the tub. The square tubs of side length 160, 80, 40 cm, and the circular tubs of diameter 128, 64, 32 cm were used. The fuel was hexane and the preburn time was 30 seconds.

The experimental results are shown in the figures. As the critical discharge rate of the agent to extinguish the pan fire is proportional to the fuel supply rate, it can be calculated by the following equation:

$$q_c/U_F = (q/U_F)\{1 - \exp[-(Q/V)(t - t_e)]\}$$

$$Q = U_F/r$$

$$V = SH$$

where q_c (g/s) is the critical discharge rate of the agent, U_F (l/s) the fuel supply rate, q (g/s) the discharge rate of the agent, Q (m^3/s) the air change rate, V (m^3) the flame volume, t (s) the extinction time, t_e (s) the additional extinction time, r the ratio of fuel to fuel-plus-air, S (m^2) the area of flame base, and H (m) the flame height.

The calculated values are shown. They are smaller than the values of the references. The reason is that the extinction mechanism of diffusion flame is different from the explosion in the burette method of the references.

Yamashika, S. (Fire Research Institute of Japan, Tokyo, Japan) "Studies on the Required Quantity of Various Fire Extinguishing Agents Part 4. The Case of Fire-Fighting Foam," *Fire Research Institute of Japan Report No. 33*, 11 (1971)

Section: E

Subjects: Foam; Extinguishment; Theory of extinguishment; Light water

Author's Abstract

The result of fire extinguishing experiments using protein foam and "light water" is described in this report.

The tub and fuel used were the same as mentioned in Part 3 of these serial reports. In this experiment two methods were used. In one method, the foam, generated from a foam nozzle which is fixed horizontally at a corner of the tub, is poured into the tub after hitting the back plate. In the other method, the foaming solution is sprayed by means of a water fog nozzle which is fixed at one meter above the center of the upper surface of the tub.

The experimental results are shown. From these results, the critical discharge rate of the agent per unit surface area can be calculated by the following equation.

$$q_c'/S = (q'/S)\{1 - \exp[-K(t - t_e)]\}$$

where q_c' (l/min) is the critical discharge rate of the foaming solution, S (m^2) the area of the tub, q' (l/min) the discharge rate of the foaming solution, K (1/min) the rate of drainage, t (min) the extinction time, and t_e (min) the additional extinction time.

The calculated values are shown. They are reasonable in comparison with the values of the references. The critical discharge rate of "light water" was 0.7 times as much as that of protein foam.

Yamashika, S. (Fire Research Institute of Japan, Tokyo, Japan) "Studies on the Required Quantity of Various Fire Extinguishing Agents: Part 5. The Planning of Fire Extinguishing Systems," *Fire Research Institute of Japan Report No. 33,* 16 (1971)

Section: E

Subjects: Extinguishment; Theory of extinguishment; Study of fire extinguishment

Author's Abstract

Presented in this report is a procedure for determining the reasonable capacity of a fire extinguishing system on the basis of the critical discharge rate for the extinguishing agent concerned, which was dealt with in the author's preceding reports.

By utilizing the relationship between the extinction time and the discharge rate, both characteristic measurables for an extinguishing agent, the peculiar distribution of the fluctuations for the former can be converted into the normal distribution for the latter. Then, by using the standard deviation of this normal distribution, the probability for the accomplishment of extinction to enter the safety range may be estimated.

The subsequent procedure will be performed according to the following steps:

(1) The critical discharge rate for the extinguishing agent in concern is determined on the basis of either the experimental results or the theoretical method presented in the author's preceding reports.

(2) This critical discharge rate is multiplied by an arbitrary factor x to give a practical discharge rate. The value of x may be determined mainly from the economical point of view.

(3) By using the obtained discharge rate and the probability for the extinction in safety range, the required discharge time is read from a chart. If the chart does not cover the case, an equation may be employed. The procedure of this step may be reversed with the foregoing step (2).

(4) An additive correction should be put to the discharge rate to make for the ineffective fraction of the extinguishing agent that may flow out of the fire zone.

(5) Finally, the required storage quantity of the extinguishing agent is determined as the sum of the corrected discharge rate multiplied by the required discharge time and a certain surplus quantity to make for the inevitable residual agent that will stay in every portion of the system on operation.

F. Fire Damage and Salvage

G. Combustion Engineering

Fulford, G. D. (University of Waterloo, Ontario) and Catchpole, J. P. (Admiralty Materials Laboratory, Dorset, England) "Dimensionless Groups," *Industrial and Engineering Chemistry* **60**(3), 71 (March 1968)

Section: G

Subject: Dimensionless groups

Reviewed by J. Wagner

This paper supplements and extends the authors' earlier compilation on dimensionless groups.[1] The two papers contain a total of 285 dimensionless groups—75 groups in the latest and 210 groups in the earlier article.

The groups are arranged alphabetically in table form according to name or names, if more than one name applies to a single group. The symbols for the group, definition, significance, field of use, reference, and in many cases the origin of the name are included.

Additional tables are included for the purpose of identifying dimensionless groups. This is accomplished by cross-referencing a large number of easily recognized parameters, e.g., surface tension, voltage, temperature, etc., with the dimensionless groups in the former tables. By following the authors' procedure, one can avoid the renaming of the "not so obvious" dimensionless group often obtained in data reduction of complex transport processes or in engineering studies.

This appears to be the most detailed and useful compilation of dimensionless groups available in the literature and will probably remain so for some time.

Reference

1. Catchpole, J. P. and Fulford, G.: "Dimensionless Groups" I&EC, Vol. 58, No. 3, 46–60 (March 1966).

Gross, D. and Fang, J. B. (National Bureau of Standards, Washington, D.C.) "The Definition of a Low-Intensity Fire," *National Bureau of Standards Special Publication 361*, 1, *Proceedings of the Joint RILEM-ASTM-CIB Symposium, May 1972, Philadelphia, Pennsylvania*

Section: G

Subjects: Buildings, calorimetry, combustibility; Fire intensity; Flame spread; Furnishings; Heat release; Thermal radiation; Wastebaskets

Authors' Abstract

A reproducible fire of low intensity may be used for the realistic performance evaluation of interior finish materials and of structural building elements. The burning behavior of furniture and the contents of wastebaskets are defined in terms of the rates of heat release, heat transfer to the surrounding walls, and heat losses by radiation and convection. Experimental measurements of temperature and radiation levels within a room are summarized for a variety of combustible contents and mass loadings. Selected low intensity fires have been examined for repeatability and for potential use in evaluating fire safe requirements for interior finish materials in terms of the spread of flame, generation of smoke, and overall fire growth pattern.

Kokurin, A. D. and Polygina, L. G. "Study of the Pyrolysis of Organic Compounds in Laminar Diffusion Flames," *Fizika Goreniya i Vzryva* **5**, 563 (1969)

Section: G

Subjects: Diffusion flame structure; Pyrolysis; Organic polymers

Authors' Abstract Translated by L. Holtschlag

Investigations and some generalizations of the chemical conversion of organic compounds of varying aggregate state in laminar diffusion flames are presented. The gas was tapped from the inner part of the flame jet and the temperature was measured at the points of gas tapping by means of a quartz sampler and a thermocouple introduced axially at the base of a burner (up to 5 mm along the height of the flame jet). The pyrolysis products in the hot upper zone dropped down into the lower zone, where they were cooled (quenched). No flame perturbations were observed at a sampling rate of 0.1 ml/sec, nor was there any appreciable change in the gas composition when the sampling rate was varied, indicating good quenching of the reaction products. The solid materials were burned in the form of grain charges with an opening in the center for insertion of the sampler and were fixed in the tube to a rod so that they could be moved. This method permitted study of the process of high-temperature pyrolysis of such materials (municipal gas, toluene, and utropin). It was found that a pyrolysis zone forms within the laminar diffusion flame after ignition of the gaseous, liquid, and solid fuel; the flame structure, temperature, and quantity of pyrolysis products at various points in the pyrolysis zone depend on the structure, composition, and properties of the original compounds.

Kuchta, J. M., Murphy, J. N., Furno, A. L., and Bartkowiak, A. (Bureau of Mines, Pittsburgh, Pennsylvania) "Fire Hazard Evaluation of Thickened Aircraft Fuels," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 22 (August 1971)*

Section: G

Subjects: Fire hazards; Fuels; Thickened fuels; Aircraft fuels; Spread rate of fuels

Authors' Summary

Various gelled or emulsified fuels have been proposed for reducing the aircraft crash-fire hazard. Results are presented from bench-scale tests for screening the fuels and from large-scale drop tests for evaluating their fire hazard under simulated crash conditions. Jet A and Jet B type thickened fuels were investigated. Their minimum autoignition temperatures and burning rates varied little, whereas their flash points, volatility rates, self-spread rates, and flame spread rates varied noticeably with either the base fuel or thickening agent composition; minimum ignition energies are also compared for liquid sprays. The performance of the thickened fuels, particularly Jet B emulsions, was not very promising under impact conditions. In fuel drops made from a 150-ft three-tower facility, the fireball size and radiation intensity varied with impact velocity, impact angle, and type of fuel container. Generally, the fireball hazard was greatest for the highest volatility fuels.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Macdonald, J. A. and Wyeth, H. W. G. (Royal Aircraft Establishment, Farnsborough, England) "Fire and Explosion Protection of Fuel Tank Ullage," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 23 (August 1971)*

Section: G

Subjects: Fire protection; Explosion protection; Fuel tanks; Ullage

Authors' Summary

This paper examines the conditions that can lead to an explosion within aircraft fuel tank ullages (spaces above liquid fuel) and reviews the need for protection systems. Principles employed in providing the desired degree of protection are outlined (such as oxygen reduction, vapour or mist inerting, and plastics foam fillers) and the results presented of work at the Royal Aircraft Establishment to develop a suitable system for military aircraft. Relevant studies undertaken in the United Kingdom over the last 30 years are summarised and brief descriptions given of prototype and trial installations fitted to aircraft. Comparisons have been made between the various systems and their relative merits discussed.

It is concluded that plastics foam is an effective system provided that the material is compatible with the environment. Liquid nitrogen is also attractive from the weight aspect but could impose logistic problems.

* Available from NTIS 5285 Port Royal Road, Springfield, Virginia 22151.

Nuruzzaman, A. S. M., Siddall, R. G., and Beer, J. M. (University of Sheffield, Sheffield, England) "The Use of a Simplified Mathematical Model for Prediction of Burn Out of Non-uniform Sprays," *Chemical Engineering Science* **26**, 1635 (1971)

Section: G

Subjects: Droplet burning; Sprays; Burn out of sprays

Authors' Abstract

A simple one-dimensional mathematical model is developed which is used to calculate the burning rate of a spray of droplets with an initial Rosin–Rammler size distribution. The model is based on experimental observations of the influence

of temperature, partial pressure of oxygen, and droplet size on the burning rate of a single droplet. In addition, balance equations are employed to determine the time-dependent parameters of the rate equation. The model is used to show the significance of various input parameters on the combustion rate (i.e., evaporation rate) of the spray. The validity of the model is examined by comparing predicted changes in combustion efficiency with those obtained previously from a single tubular turbojet combustor operating with liquid iso-octane over a range of inlet oxygen concentrations.

Russell, R. A., Jr. (Federal Aviation Administration NAFEC, Atlantic City, New Jersey) "Crash-Safety Turbine Fuel Development by the Federal Aviation Administration (1964–1970)," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 20 (August 1971)*

Section: G

Subjects: Fuels; Aircraft crashes; Turbine fuels

Author's Summary

The Federal Aviation Administration is engaged in programs to reduce the probability and/or severity of fire in commercial jet transport aircraft that are involved in ground crash situations. One of the approaches being taken is the development of a modified aviation turbine fuel that will provide a significant reduction in the crash fire hazard. The modified fuels program, initiated in 1964, brought to light that under small-scale simulated crash conditions the fire reduction benefits of fuel thickeners result from their ability to physically bind the fuel and thus reduce the rate of vaporization and the exposed surface area available to support a fire. Dozens of thickened-fuel candidates have undergone cursory screening, and a small percentage of those that looked promising have been subjected to a crash fire rating system designed to provide relative values of candidate fuels. Subsequent efforts to investigate the compatibility of two of the earlier available thickened fuels with an unmodified commercial jet aircraft fuel system indicated that the fuel system could not effectively utilize the modified fuels. If chemical and physical studies, now underway, on two of the leading fuel candidates successfully improve their fluidic property, as well as retain their fire retardative properties, then the agency plans to demonstrate the safe operation of aircraft using the modified fuel and demonstrate the improvement in crash fire safety by conducting full-scale crash tests.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Weatherford, W. D., Jr. (Southwest Research Institute, San Antonio, Texas) **and Schaekel, F. W.** (Aberdeen Proving Ground, Maryland) "Emulsified Fuels and Aircraft Safety," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 21 (August 1971)*

Section: G

Subjects: Fuels; Emulsified fuels; Aircraft safety

Authors' Summary

The U.S. Army has been engaged for several years in a research and development program aimed at improving the post-crash fire safety of helicopter turbine-engine fuels. Primary emphasis has been placed on high-internal-phase-ratio aqueous emulsions. The program background is reviewed, and the present experimental effort is described. Results of current investigations based on existing and newly developed experimental techniques are presented. Interrelations among rheological and physical properties, composition, and fire safety characteristics of various fuel formulations are discussed. Implications of these results on the total safety envelope of rotary wing aircraft are examined, and the future direction of the program is indicated.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Yarin, L. P. "Calculation of the Length of Gas Diffusion Flames," *Fizika Goreniya i Vzryva* **5**(4), 559 (1969)

Section: G

Subjects: Diffusion flames; Jet flames

Author's Abstract Translated by L. Holtschlag

A study is made of the dependence of the length of the gas flame jet on the basic parameters of a number of characteristic types of jet flows. A system of equations describing the development of the gas flame jet is given. Assuming that combustion is localized at the flame front, the aerodynamic analysis is reduced to the determination of the temperature profiles and of the concentrations of the reacting components in the "fuel" and "oxidizer" regions of the flame jet. The expressions show that the length of the laminar diffusion flame depends on the gas exit velocity, while the length of the turbulent flame is governed by the ratio of reagent concentration, the stoichiometric number, and the coefficient of the turbulent structure of the jet. Other types of diffusion flames can be analyzed similarly, e.g., a fan-shaped flame from an annular source and an axisymmetric flame developing along the surface of a cone.

H. Chemical Aspects of Fires

Combourieu, J., Falinower, C., and Denis, G. (Centre de Recherches sur la Chimie de la Combustion et Hautes Temperatures, C.N.R.S., Orleans, France) "Expose N° 16—Influence des Promoteurs (Radicaux Libres) et des Inhibiteurs sur les Flammes de Diffusion," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 16 (August 1971)*

Section: H

Subjects: Flame structure; Acetylene–oxygen; Atomic flames; Inhibition

Authors' Summary

The laminar diffusion flames of acetylene with molecular oxygen and with molecular oxygen partly dissociated were stabilized in a low pressure vessel. A partial dissociation of O_2 into O atoms was produced by a powerful microwave discharge. Concentration profiles of stable species were determined with a microprobe and a mass spectrometer. Temperature profiles were obtained from a silica-coated thermocouple. The intensities of spectral emission were recorded for excited species with a spectrophotometer. The complex structure of these diffusion flames shows that the combustion of C_2H_2 involves several steps. The partial dissociation of O_2 emphasizes the significant role played by O atoms in the combustion of C_2H_2. The influence of halogenated inhibitors is very different according to the kind of inhibitor and whether it is added to the oxidizer or the fuel.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Fristrom, R. M. (The Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland) **and Sawyer, R. F.** (University of California, Berkeley, California) "Flame Inhibition Chemistry," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 12 (August 1971)*

Section: H

Subjects: Suppressants; Inhibition; Flame inhibition; Chemical kinetics

Authors' Summary

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

The suppression of unwanted fires is an important practical problem. Techniques involving diverse mechanisms are employed in extinguishing flames and fires. Mechanisms have commonly been divided into two broad categories: (1) physical mechanisms when mechanical or thermal effects are dominant, and (2) chemical mechanisms when chemical effects are obviously involved. This distinction is somewhat arbitrary since most practical extinguishers utilize both physical and chemical effects. Further, when an effort is made to understand these processes on the fundamental level, the strong coupling between physical and chemical processes is the major characteristic of flames and makes separation academic. The ultimate criterion of flame extinction is the suppression of reaction; therefore, relations are proposed for comparing the various methods for studying inhibition.

A discussion will be given of flame extinguishment viewed from the standpoint of the effects on the elementary reaction processes. A simplified hydrogen–oxygen flame chemistry is used as an illustration. The complications introduced by chemical inhibition are pointed out. The published chemical kinetic information in the area of hydrogen atom scavenging and oxygen flame radical recombination is surveyed.

Hoshino, M. (Fire Research Institute, Tokyo, Japan) "Studies on Factors Influencing the Deterioration of Fire Fighting Foam Compounds: III. On the Formation of Glycine–Ferric Complexes," *Fire Research Institute of Japan Report No. 31*, 5 (1970)

Section: H

Subjects: Foam deterioration; Glycine-ferric compounds

Author's Abstract

The visible absorption spectra of aqueous red solutions of glycine and $FeCl_3$, $Fe(ClO_4)_3$ at relatively high concentration under acidic conditions were found to exhibit an absorption at 450 mμ which could be explained by the formation of glycine–ferric complexes.

As the pH value was raised, brown-red precipitates were formed.

The precipitates diminished when the content of glycine increased.

The binding ratio of glycine–ferric complexes was found to be 1:1 by means of the molar ratio method, when counter ion of Fe(III) was Cl^- and ClO_4^- respectively.

As the complex forming species which may be considered the cause of absorption at 450 mμ, a glycine zwitterion was chosen.

Both Fe^{3+} and $FeOH^{2+}$ were considered as the complex forming species.

Roberts, A. F. (Safety in Mines Research Establishment, Sheffield, England) "The Kinetic Behavior of Intermediate Compounds during the Pyrolysis of Cellulose," *Journal of Applied Polymer Science* **14,** 244 (1970)

Section: H

Subjects: Kinetics; Cellulose; Pyrolysis; Intermediates of pyrolysis

Author's Abstract

A paper by A. E. Lipska and W. J. Parker (*Journal of Applied Polymer Science* (1966) **10,** 1439–1454) gives data on the rate of conversion of cellulose into products and on the rate of weight loss from the samples. These data suggest a two-stage process whereby cellulose is converted initially into non-volatile intermediate compounds and volatile products, and the non-volatile intermediate compounds are converted to a non-reacting solid residue and a further supply of volatile products. In the present paper, rate equations are derived for the formation and for the conversion of these non-volatile intermediate compounds, and equations are derived giving the variation of their concentration with time, in terms of these rate equations. There is reasonable agreement between concentrations calculated from these equations and the experimental data.

Woolley, W. D. (Joint Fire Research Organization, Boreham Wood, England) "Nitrogen Containing Products from the Thermal Decomposition of Flexible Polyurethane Foams," *British Polymer Journal* **4,** 27 (1972)

Section: H

Subjects: Pyrolysis; Thermal decomposition; Polyurethane foams; Foams, nitrogenous compounds

Author's Abstract

The thermal decomposition of a polyester and a polyether flexible foam in a nitrogen atmosphere has been studied by gas chromatography, mass spectrometry and elemental ultramicroanalysis. It is shown that the decomposition behaviours of the two foams are similar. At low temperatures (200 to 300°C) there is a rapid and complete loss of the tolylene diisocyanate unit of each foam as a volatile yellow smoke leaving a polyol residue. The smoke has been isolated as a yellow solid (common to both foams) which contains virtually all of the nitrogen of the original foams and, under the conditions of test, is stable at temperatures up to 750°C. Nitrogen-containing products of low molecular weight (mainly hydrogen cyanide, acetonitrile, acrylonitrile, pyridine and benzonitrile) observed during the high temperature decomposition (over 800°C) of the foams are shown to be derived from the yellow smokes. At 1000°C, approximately 70% of the available nitrogen has been recovered as hydrogen cyanide.

Woolley, W. D. (Joint Fire Research Organization, Boreham Wood, England) "Decomposition Products of PVC for Studies of Fires," *British Polymer Journal* **3**, 186 (1971)

Section: H

Subjects: Pyrolysis; PVC; Decomposition; Toxic gases

Author's Abstract

Approximately seventy-five organic materials have been detected by gas chromatography in the thermal decomposition products of PVC and are shown by mass spectrometry and retention studies to consist mainly of aromatic and aliphatic hydrocarbons. Weight-loss experiments and time-resolved chromatography indicate that these products are formed mainly during dehydrochlorination. The products are modified by the presence of oxygen but no oxygenated organic species have been detected.

Experiments to specifically monitor the production of phosgene from the decomposition of both a rigid PVC sheet and a PVC polymer in air are recorded. Phosgene has not been detected and direct seeding techniques have been used to investigate the detection limits of this material.

PVC is known to release the toxic gases, carbon monoxide and hydrogen chloride, when involved in fires. It is shown that the minor products, including phosgene, make little or no contribution to the overall toxicity of the decomposition products.

Woolley, W. D. and Wadley, A. I. (Joint Fire Research Organization, Boreham Wood, England) "Experimental and Theoretical Studies of the Dehydrochlorination of PVC in Air and Nitrogen," *Joint Fire Research Organization Fire Research Note No. 795* (January 1970)

Section: H

Subjects: Combustion products; Hydrogen chloride; Toxic gas; Poly(vinylchloride)

Authors' Summary

The release of hydrogen chloride from the thermal decomposition of a sample of a commercial rigid PVC has been studied in air and nitrogen between 200 and 300°C. It is shown that the dehydrochlorination can be represented by a 3/2 order decomposition with activation energies of 36.1 and 41.5 K cals mole^{-1} in air and nitrogen respectively. The report explains how this kinetic data can be used to predict the total release of hydrogen chloride as a function of time from the decomposition of PVC during either isothermal conditions or non-linear temperature increments as in fires. A comparison is shown between the experimental and calculated release of hydrogen chloride during a temperature programmed experiment between 200 and 300°C.

Yumoto, T. (Fire Research Institute of Japan, Tokyo, Japan) "An Experimental Study on Heat Radiation from Oil Tank Fire," *Fire Research Institute of Japan Report No. 33*, 30 (1971)

Section: H, I

Subjects: Radiation; Pool fires; Oil fires; Tank fires

Author's Abstract

An experimental study was made to explore the heat-radiative behavior of oil-tank fires under windless condition. A variety of model tank fires were effected by burning each of four sorts of hydrocarbon fuels, such as hexane, gasoline, benzene, and Khafji crude oil, in circular tanks with diameters ranging from 0.64 m to 6 m, and the irradiance E was measured at various relative distances from the fires by means of thermopile radiometers. These radiometric data were analyzed for respective fuel employed, taking the behavior of the flame-to-radiometer geometrical factor into account.

The conclusions obtained may be summarized as follows:

(1) The irradiance E at any arbitrary point around the burning open-top oil tank under windless condition may be predicted by means of the following basic expression,

$$E = \phi R_f \qquad (\text{Kcal/m}^2\text{h})$$

where, ϕ is the geometrical factor and R_f (Kcal/m²·h) the radiant emittance of the flame. R_f is reasonably assumed to be constant for individual fuel.

(2) The geometrical factor ϕ in the above expression for E may be calculated by approximating the flame-shape as a finite cylinder having a diameter equal to the tank diameter D and a height $1.5D$, for which an analytical expression of ϕ is known.

(3) The values of R_f for fuels employed which have been introduced on the basis of the radiometric results are given.

(4) R_f for any arbitrary liquid fuel may be predicted by either of following two expressions:

$$R_f = 0.02 V \rho H_c$$

or

$$R_f = 9.1 \times 10^{-5} H_c^2 / H_v$$

where, V is the burning rate, ρ the density, H_c the heat of combustion and H_v the heat of vaporization at boiling point, all for the fuel concerned.

(5) In cases where the horizontal distance L from the center of the tank to the receiving position exceeds three times the tank diameter D, the irradiance E will decrease with L according to the inverse square law.

(6) With the ring- or coronet-type fire, which will practically be seen in the initial stage of a floating-roof petroleum tank fire, the magnitude of radiation is very small as compared with the open-top tank fire of same outer diameter. However, should the floating-roof submerge or rupture, the size of flame and, accordingly, the magnitude of radiation will rapidly increase.

I. Physical Aspects of Fires

Comeford, J. J. (National Bureau of Standards, Washington, D.C.) "The Spectral Distribution of Radiant Energy of a Gas-Fired Radiant Panel and Some Diffusion Flames," *Combustion and Flame* **18**, 125 (1972)

Section: I

Subjects: Spectral distribution; Diffusion flames; Radiant energy; Gas-fired panel

Author's Abstract

Measurements were made of the spectral distribution of energy from radiant sources employed in standard test methods of flammability. Radiant sources examined were a gas-fired radiant panel employed in ASTM Test E-162 and the electric heater employed in the Smoke Chamber Test. To afford a basis for comparison, the emission spectra of several diffusion flames in air were measured. The energy distribution of the flames occurred essentially in two narrow wavelength intervals corresponding to emission of carbon dioxide at 4.4 μm and water at 2.7 μm. Luminous diffusion flames containing large amounts of incandescent carbon, such as occur from the combustion of acetylene-in-air, show a blackbody background continuum with CO_2 and H_2O emission peaks superimposed on the continuum. The radiant test sources exhibited an energy distribution approximating that of a blackbody with atmospheric CO_2 and H_2O absorptions superimposed. The gas-fired radiant panel, in addition, showed a significant emission peak at 4.4 μm due to excited CO_2.

Nii, R. (Fire Research Institute of Japan, Tokyo, Japan) "Studies on Generating Mechanism of High Expansion Air Foam: II. Relationship between the Minimum Static Pressure Required to Generate Single Bubble and Hole Diameter," *Fire Research Institute of Japan Report No. 31*, 12 (1970)

Section: I

Subjects: Foam; High expansion foam; Bubbles

Author's Abstract

In order to elucidate the generating mechanism of high expansion air foam, it is necessary to find out any relationship between the minimum pressure of a blower required to generate it from liquid film, which is formed on a net plane by wetting through the whole net plane, and mesh of a net used. In order to attain this purpose an experimental apparatus was devised by the author. The minimum static pressure required to generate single bubble from a hole can be measured with the apparatus. The schematic diagram and the main parts of the apparatus are shown. The details of foaming solutions used and the experimental conditions are also shown.

Relationships between the maximum height of single bubble generated in case of the hole diameter 1.5 mm and static pressure are shown as examples for sample No. 1 and for sample No. 2. The minimum static pressures of those cases were determined. The relationship between the minimum static pressure required to generate single bubble and hole diameter is shown for each sample.

Now, considering the physical meaning of the minimum static pressure P_{min} obtained under the experimental conditions, the following Eqs. (1)–(3) are obtained.

$$P_{min} = P_1 + P_3 \tag{1}$$

$$P_1 \doteqdot 8\gamma / h_{max} \tag{2}$$

$$P_2 = 8\gamma / d \qquad \text{for } d \geqq 1.5 \text{ mm} \tag{3}$$

where P_1; a pressure difference (dyne/cm^2) required to form single bubble of the maximum height (h_{max}), P_2; a pressure difference (dyne/cm^2) required to make a foaming solution in a hole form a liquid film of a semi-sphere which has a radius of $d/2$, which is a pressure loss for $d \geqq 1.5$ mm, P_3; total pressure loss (dyne/cm^2), $P_3 - P_2$; the other pressure loss for $d \geqq 1.5$ mm, γ; surface tension of the solution (dyne/cm), h_{max}; the maximum height (cm) of single bubble formed and the height is measured from the surface (F surface in *Fig.* 3), d; hole diameter (cm). The relationships of pressures P_{min}, P_1, P_2, P_3 and $P_3 - P_2$ versus hole diameter d are shown.

From the experimental results and some consideration, the following conclusions were obtained:

- A pressure contributing to P_{min} is total pressure loss P_3 and the other pressure loss $P_3 - P_2$ is nearly constant for $d \geqq 3.0$ mm under the experimental conditions.
- It is said that the highest expansion ratio of protein-based foam is about less than 300. It can be presumed that the reason is owing to the surface tension (ca. 55 dyne/cm) and the observed value of h_{max}, which is 1/2 or 1/3 times as much as those of h_{max} in case of the synthetic foaming agents.
- It can be suggested that the required thickness of liquid layer to be supplied onto a net of a practical high expansion foam generator should be maintained at least with a larger thickness than that of the net used.

Packham, D. R. (CSIRO Division of Applied Chemistry, Melbourne, Australia) "Heat Transfer above a Small Ground Fire," *Aust. For. Res.* **5**(1), 19 (no date)

Section: I

Subjects: Heat transfer; Radiation; Convection

Author's Summary

An experiment has been conducted using a horizontal radiometer looking downwards over a small fire lit as a wide line and spreading at constant velocity. The radiation received by the radiometer is a measure of the total radiation produced by the fire, providing a correction is made for some undetected horizontal radiation.

Convection has also been measured, so that the total heat emitted can be compared with the known thermal release of the burning fuel. The heat yields balance to within 22%, and the ratio of convection to radiation, as averaged over the life of the fire, is approximately 3:1.

Strawson, H. and Lewis, A. (Shell Research Limited, Thornton Research Centre, Thornton, Chester, England) "Electrostatic Charging in the Handling of Aviation Fuels," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 19 (August 1971)*

Section: I

Subjects: Electrostatic charging of fuels; Spark ignition

Authors' Summary

Electrostatic charging of the fuel during fueling can result in the possibility of incendive sparking in aircraft tanks; some of the more recent experimental results on the different phases of this process are presented. These results confirm that, in the absence of special precautions, discharges creating a tank explosion hazard can exist during aircraft refueling in certain circumstances. Unless the fuel conductivity is controlled, however, these hazardous circumstances cannot be precisely predicted. The use of a static dissipator additive eliminates the hazard. Methods of introducing the additive and of maintaining the correct conductivity during fuel distribution are discussed, as well as possible side effects and interactions with other fuel additives. On the basis of world-wide airline use over many years, supported by many laboratory tests, it is concluded that the additive provides a safe, simple, and trouble-free solution to the problem.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

Tuve, R. L. (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland) "Surface Active Considerations in Fuel Fires," AGARD Conference Proceedings #84–71, *Aircraft Fuels, Lubricants and Fire Safety*, 26 (August 1971)*

Section: I

Subjects: Fuel fires; Surface activity

Author's Summary

The problem of efficient extinguishment of fires in burning fuels involves chemistry, the characteristics of interfaces, physical properties, and mechanical requirements. Water, our most ubiquitous fire-halting material, is only marginally useful here under restrictive circumstances, but has been shown to be critically important when its properties are modified. When surface chemistry is applied to the problem, the use of low-density water in the form of foam achieves some solutions to the mechanical and physical needs involved. The most recent development in this area utilizes fluorocarbon surfactants which combine foam requirements and fuel–water interfacial activities benefitting fire extinguishing action to an advanced degree. Practical problems of fire protection and a wider control of the variables involved are being solved by continued testing and development of the new material in standard fire protection systems. Future successes in fire research can only evolve from systematic technical study embracing advanced methods and interdisciplinary skills.

* Available from NTIS, 5285 Port Royal Road, Springfield, Virginia 22151.

J. Meteorological Aspects of Fires

Taylor, R. J., Corke, D. G., King, N. K., MacArthur, D. A., Packham, D. R., and Vines, R. G. (CSIRO, Melbourne, Australia) "Some Meteorological Aspects of Three Intense Forest Fires," *Division of Meteorological Physics Technical Paper No. 21, CSIRO, Australia* (1971)

Section: J

Subjects: Meteorology; Forest fires

Authors' Abstract

We report a study of three intense forest fires, all of area about 30 km^2, in which convection extended to heights ranging from 2750 m to 4300 m. The observations taken comprise surface-level wind, temperature, and humidity; mean temperature, temperature fluctuations, and vertical acceleration as measured from an aircraft; the rate of change of height of the aircraft while it was held at constant attitude; and wind profiles from double-theodolite pilot-balloon flights.

Strong inflow into the smoke columns from all directions was observed to heights of at least 300 m. The consequent strong updrafts were manifest in large and rapid changes of the aircraft's height while penetrating the smoke directly above the fire at heights up to about 1 km, where there was intense turbulent activity. At greater heights, and away from the central area of the fire, the turbulence characteristics of the heated air were little different from those of the ambient unheated air.

From heat conservation principles, a mean entrainment rate of 1.037 (standard error 0.002) per 100 m is deduced. Using this entrainment rate a particularly simple method of predicting the height of convection is proposed for situations where the atmosphere is not conditionally unstable; condensation levels derived from simple surface measurements may be used in this calculation. When conditional instability is present, standard meteorological methods of allowing for entrainment must be employed to obtain a satisfactory estimate of the height of convection.

In the hottest fire the latent heat evolved from condensation was almost as great as that produced from the burning fuel on the ground.

Vines, R. G., Gibson, L., Hatch, A. B., King, N. K., MacArthur, D. A., Packham, D. R., and Taylor, R. J. (CSIRO Division of Applied Chemistry, Melbourne, Australia) "On the Nature, Properties, and Behaviour of Bush-Fire Smoke," *Division of Applied Chemistry Technical Paper No. 1 CSIRO, Australia* (1971)

Section: J

Subjects: Smoke; Brush fires; Fires, brush

Reviewed by R. Long

Little is known about the smoke produced by a large natural bush-fire; the quantities involved are uncertain and the extent to which the smoke affects air quality is not known.

In some parts of Australia forest litter is burned as a fire protection measure. Such fires are said to cause no damage to forests, but the areas burnt at one time may be very large (up to 50,000 acres per day) and the smoke columns can be blown many miles downwind.

This paper reports on the approximate quantities and composition of smoke from a series of such prescribed fires, and on the diffusion characteristics of the smoke columns.

Certain equipment was installed in a light aircraft which was flown through the smoke columns to collect samples and gather data. Filters and an electrostatic precipitator collected smoke samples and a continuously recording nephelometer was used to measure scattering coefficients. A thermal precipitator was used to obtain samples for particle sizing; a cascade impactor was used for larger particles. Concentrations of CO_2, CO, SO_2 and NH_3, olefins, oxides of nitrogen, and O_3 were measured by Dräger tubes. The altitude and external air temperature were recorded, and a drift meter measured wind speed. Traverses were made at right angles to the wind at different heights. Although the smoke columns appeared to have clearly defined edges, they were more ragged than they seemed, and the nephelometer revealed numerous 'eddies'.

Smoke analyses were for tar, soot, and inorganic ash. The tar was the chloroform extractable material and the residue was said to contain "soot and inorganic ash (and possibly some insoluble organic compounds)." Perhaps a better term than "soot" might have been carbonaceous residue.

Particulate matter in the smoke was found to amount to less than 2% of the weight of fuel on the ground. The composition was variable but a typical analysis is given as: tar ~55%, soot ~25% and ash ~20%.

A correlation coefficient of 0.85 is reported between particulate concentrations as measured by the filter and electrostatic precipitator, respectively. There is also a strong correlation between mean scattering coefficients and particulate concentrations, the correlation coefficient being 0.91.

The scattering coefficient per meter (b_s^{550}) is found to be related to smoke density (d in g/m³) by the empirical relationship $d=0.23_5 b_s^{550}$. The visual range in meters Vp is $\sim 0.92/d$ and in the thickest smoke was <250 m.

The measured concentrations of the various gases (by Dräger tubes) are small, typical values being: CO, 0.5–2.0 ppm, CO_2 150 ppm (above clean air level), O_3, 0.02–0.03 ppm (identical with clean air value), NH_3 and SO_2 not detected.

Smoke particles trapped in the thermal precipitator and collected in the impactor were photographed and studied. Round particles (~1/5 μ in dia) are thought to be tar while crystalline particles are thought to be ash and carbon. These were often between 1/20 and 1/30 μm in size. Some very large particles up to 50 μm in diameter are clearly agglomerates and were common if the smoke was of high tar content. It proved impracticable to carry out a particle size distribution, but rough estimates gave total mass concentrations in the thickest smoke of ~1 mg/m³.

As smoke was swept downwind, it became more diffuse but was consistently more concentrated at the higher levels. In all cases the ratio of smoke and fuel was between 1½ and 2%. Variation in smoke quantities downwind and smoke diffusion were studied. With average wind speeds in the smoke column between 15 and 30 knots, and convection limited by an inversion, the smoke was found to spread out from the burning forest block in a narrow fan of included angle from 12–15°. (A NASA satellite photograph of "wild fires" in Queensland shows a similar result.) The observation of no diminution in the angle of spread as the wind speed becomes greater is attributed to the turbulent transfer coefficient being approximately proportional to wind speed.

On the assumption of a Gaussian distribution originating from a continuous point source, the authors calculate the coefficient of turbulent transport in the cross-wind direction; these values of the order of 10^7 cm^2/s are somewhat smaller than those derived by Sutton.

It is pointed out that if such burning techniques are to be used on an increasing scale, it is important to know whether harmful effects can arise, e.g., whether the smoke contains "dangerous" concentrations of gas or particulate matter.

The detected concentrations of gases are said never to be harmful, and it is claimed that even widespread burning would not lead to photochemical smog—although it might be undesirable to produce smoke in air already containing smog. The authors claim, however, that unless prescribed burning is carried out, uncontrolled bush-fires are inevitable.

Inevitable though such smoke may be, the reviewer considers that an opportunity has been lost for gaining valuable information about the tar components and the possible presence of known carcinogens, such as benzo(*a*)pyrene. Programmed-temperature gas chromatography combined with uv spectrometry and/or mass spectrometry might have been employed in a more comprehensive study of the chemical nature of the tar component of the smoke.

K. Physiological and Psychological Problems from Fires

Bentley, R. A. and Bergman, I. (Safety in Mines Research Establishment, Sheffield, England) "Candle or Oil Soot as a Cause of Pneumoconiosis in Coalminers," *Annals of Occupational Hygiene* **13**, 109 (1970)

Section: K

Subjects: Pneumoconiosis; Coal miners; Soot; Candle soot; Oil soot

Reprint of Safety in Mines Research Establishment Abstract, By Permission

The incidence of pneumoconiosis in Scotland has always been low compared with that in other regions. Some years ago, during a systematic investigation of the lungs of miners from all the major British coalfields, it was found that lung dust from Scotland did not fit in with the expected pattern, which was that the dust in the lungs would consist largely of the appropriate seam coal and associated minerals. Further study showed that nearly all the Scottish lung dusts had properties similar to those of soot. It was concluded that almost all the pneumoconiosis found in Scottish coalminers had been caused by soot from naked-light illumination, i.e., open lamps or candles, and that with the changeover to electric lighting, this cause of pneumoconiosis had been eliminated from the pits.

Bott, B., Firth, J. G., and Jones, T. A. (Safety in Mines Research Establishment, Sheffield, England) "The Evolution of Toxic Gases from Plastics," *British Polymer Journal* **1**, 203 (1969)

Section: K

Subjects: Toxicity; Gas toxicity; Plastics, toxic gases from; Pyrolysis

Reprint of Safety in Mines Research Establishment Abstract, By Permission

A brief investigation has been carried out into the nature and quantity of the toxic gases evolved during the thermal decomposition of polyurethane, urea-formaldehyde, nylon, and acrylonitrile in air and in nitrogen. The weight fractions of the polymers evolved as hydrogen cyanide are given, together with the lowest temperatures at which hydrogen cyanide, carbon monoxide, ammonia, and nitrogen oxides are evolved. Apparent activation energies for the evolution of hydrogen cyanide and carbon monoxide have been evolved. A brief discussion of the experimental data is given.

Einhorn, I. N., Seader, J. D., Mihlfeith, C. M., and Drake, W. O. (University of Utah, Salt Lake City, Utah) "Flammability and Toxicological Characteristics of Isocyanurate Foams, Intumescent Coatings, and Fluorel," *University of Utah, UTEC-MSE 71-039* (March 1971)

Section: K

Subjects: Foams; Isocyanurate foams; Toxicology; Flammability intumescent coatings; Fluorel

Reviewed by J. Wagner

A detailed experimental program funded by NASA was conducted to study the thermochemical, flammability, and toxicological characteristics of JP-4 aircraft fuel, isocyanurate foams, intumescent coatings, and fluorel (polyvinylidene fluoride copolymer, hexafluoropropylene elastomer). Various test procedures, such as the XP-2 chamber smoke test, etc., gas chromatography and mass spectrometry, and the LD-50 test on Sprague-Dawley rats were used in evaluating these characteristics. Seventy-eight figures and twenty-one tables are used to illustrate the results. A number of pathological studies were also carried out and are presented in a series of postmortem reports.

Essentially complete combustion (80.4% N_2, 10.8% O_2, and 8.8% CO_2 on a water-free basis) was obtained from the burning of the JP-4 fuel in a fire simulation chamber. Wick burning gave measurable quantities of CO, H_2, CH_4, and butane.

Experimental difficulties prevented one from establishing the desired toxicity baseline from the exposure of rats to the JP-4 combustion products.

Excellent flammability and insulation characteristics were evidenced for the isocyanurate foam, fluorel-coated foam, and the intumescent-coated foams. However, smoke development for all three materials was substantial.

Fifteen different gases, many of which are toxic, were tentatively identified over the temperature range from ambient to 1000 C. For the fluorel refset, a total of twelve effluent gases were tentatively identified and quantified. The two major species present were the monomer vinylidene fluoride (86.9 mol%) and the extremely toxic carbonyl difluoride (COF_2 −2.1 mol%). The HF concentration was 0.06 mol%.

LD-50 values of the above three types of foams were all about 2 gm/ft^3. Because of paralysis, etched eyes, etc., other factors beside the LD-50 values probably require consideration. Further study is recommended in light of the pathologist's reports that the significant cause of animal death is CO from the exposure to the pyrolysis products of the fluorel refset.

Takahashi, S. (Fire Research Institute of Japan, Tokyo, Japan) "Respiratory Protection in High Expansion Air Foam," *Fire Research Institute of Japan Report No. 31*, 33 (1970)

Section: K

Subjects: Respiration in foams; Foam-breathability; Breathability of foams

Author's Abstract

Recently, high expansion air foam has been widely used in fire fighting for building fires in Japan. However, there is a question of safety of people who are closed in the foam. In order to answer this question, a study on oxygen concentration in the foam, where a man is reposing or walking, was performed by the author.

Two simple methods of entering into the foam were tested: (1) using a special mask, which is made of a frame and metal net, has 30 cm×30 cm×50 cm in sizes, and called "net-mask" by the author, and (2) with naked face. The oxygen concentration in each method was measured with Beckmann's oxygen–analyser.

Some conclusions are obtained as follows:

(1) In case of using the net-mask, the net was covered with water film and acted as if it were a large and tough foam cell, and air supply from outside of this cell was considered little, regardless of the stands. The oxygen consumption in walking is twice as much as in reposing.

(2) In case of entering with naked-face, the foam suffocates the nose and mouth, making it unbearable to breathe, but if we sway the hands so as to make a hole in front of our face, we are able to breathe as in the open air at first, but oxygen consumption is larger than the case of "net-walking". It might be due to the smaller space volume around our head than that of the net. But once moved, the O_2-concentration showed normal value.

After all, it is possible to say entering into foam with net-mask or vinyl-bag may be directly connected to death, and when irrespirable gas can be expected, it is better to enter with naked face and move smoothly, or, preferably, use a self-contained breathing apparatus with a communicating device.

Tsuchiya, Y. and Sumi, K. (National Research Council of Canada, Ottawa, Canada) "Evaluation of the Toxicity of Combustion Products," *Fire and Flammability* **3**, 46 (1972)

Section: K

Subjects: Toxicity; Combustion products

Authors' Abstract

Toxic gases and vapors produced from fire are responsible for a large number of fire deaths. The potential danger caused by toxic combustion products may be increasing because of the increasing use of new materials. For the purpose of evaluating and comparing the potential danger from toxic gases produced by combustion of materials, "maximum toxicity index" is proposed. The maximum toxicity index of a material is calculated from experimental data on the quantity of toxic combustion products and the lethal concentration of the products.

L. Operations Research, Mathematical Methods, and Statistics

Alger, R. S. and Nichols, J. R. (Naval Ordnance Laboratory, Silver Spring, Maryland) "Survey of Fires in Hypobaric and Hyperbaric Chambers," *Naval Ordnance Laboratory Report NOLTR 71–128* (July 1971)

Section: L

Subjects: Oxygen-enriched fires; Fire accidents in hyperbaric and hypobaric chambers

Authors' Abstract

The design of fire detection and suppression equipment requires some knowledge of the fire characteristics for the particular fuels and environments involved. In order to provide these characteristics for hyperbaric chambers, evidence from the most recent fires in British, Japanese, and U.S. chambers was examined and summarized. Items of particular interest are (1) the conditions for ignition, e.g., the fuel, environment, and source of heat, (2) the pattern and mechanism of fire spread, (3) the degree of fuel involvement, (4) the time required to develop a lethal environment, and (5) the results of fire suppression and rescue efforts. The evidence suggests a variety of design features and operational procedures which can reduce fire hazards in hypobaric and hyperbaric installations.

Hogg, J. M. (Home Offices Scientific Advisory Branch, London, England) "A Distribution Model for an Emergency Service," *Imperial College of Science and Technology, University of London, Management Engineering Section Report* (September 1970)

Section: L, M

Subjects: Fire house location; Emergency service location; Distribution of emergency services; Model studies

Author's Synopsis

The emergency service considered is the Fire Service. The object is to minimize the total cost of fire, which is made up of the cost of the Fire Service and the value of lives lost and property destroyed by fire.

A more sensitive model would include the cost-effectiveness of fire protection and the costs of administration.

Further study is required to determine the number of firemen and pumping appliances that are needed to cover a given area. The size of the fire-fighting force providing cover is, therefore, assumed to be pre-determined.

The total cost of fire is estimated for the Glasgow of 1990 according to the number of fire stations covering Glasgow. The optimal distribution of stations is determined in each case. Broad limits are obtained for the optimal number of stations, within which a fairly satisfactory guess at the correct number of stations is made.

The best sites for a given number of stations are chosen from a given set of feasible sites. This set of feasible sites is made synonymous with the nodes of the major road network, except where no convenient site can be found within the vicinity of the node.

Each node is also treated as a fire location, with all fires occurring in the area surrounding the node being treated as if they occur at that node. Additional nodes are added to ensure that no node represents too large an area.

All nodes are thus treated as fire locations, but not all are included in the set of feasible sites. Of the set of feasible sites some are treated as fixed sites, already containing stations, while the remaining sites are the variable sites from which the sites for additional stations are to be chosen.

The optimal combination of sites for a given number of stations is obtained using a tree-search algorithm.

The results indicate that very good solutions, not necessarily optimal, would be obtained using a good approximate method which would be considerably cheaper on computer time than the tree-search algorithm.

M. Model Studies and Scaling Laws

Nayuki, K. and Kuroda, Y. (Fire Research Institute of Japan, Tokyo, Japan) "Model Test of Smokeproof Tower under Enforced Heating," *Fire Research Institute of Japan Report No. 31*, 43 (1970)

Section: M

Subjects: Smokeproof tower; Tower, smokeproof; Heating; Stack effect; Ventilation

Authors' Abstract

The smoke ventilation through a smokeproof tower is commonly carried out by natural ventilation or enforced flow with a fan. However, air-flow through the tower does not occur if the inside of the tower is cool and the fan does not work normally due to trouble on electric circuits. Therefore, we planned the method of ventilating the smoke under enforced heating of the inside of the tower. A simple model tower of about 1/40 scale of the actual smokeproof tower was used. Inside the tower, the nichrome heater could be fixed at different heights. We obtained the following information from this test. The efficient ventilation of smoke was observed by heating the air in the tower. When the setting position of the heat source was below one-third of the height of the tower and plaster board was used as the wall material, the best heat efficiency of 80–100% was obtained. The heat quantity which was the most effective for smoke ventilation was about 55.5 kcal/$s \cdot m^2$. We are going to examine the applicability of our results to a real smokeproof tower in the near future.

Roberts, A. F. (Safety in Mines Research Establishment, Sheffield, England) "Fires in the Timber Linings of Mine Roadways: A Comparison of Data from Reduced-Scale and Large-Scale Experiments," *Safety in Mines Research Establishment Research Report No. 263* (1970)

Section: M

Subjects: Scaling; Mine roadways; Fires in mines; Roadways in mines

Reprint of Safety in Mines Research Establishment Abstract, by Permission

The study of any type of combustion system by means of reduced-scale experiments presents problems, since a change in scale can produce major changes in the relative importance of the various physical processes occurring in the system. This paper is concerned with the development of scaling laws based on a simplified mathematical model of the development of fires in the timber linings of mine roadways. The application of these laws to data obtained in reduced-scale experiments predicted that, given a strong enough igniting source, e.g., burning mineral oil, and a continuous timber lining, a previously unreported type of roadway fire could occur in which all the oxygen in the ventilating air is consumed in the fire. A series of large-scale experiments confirmed this prediction. In addition, where detailed comparisons could be made, the relationships between data from large-scale and small-scale experiments were in agreement with the formulated scaling laws.

N. Instrumentation and Fire Equipment

Harris, G. W. (SIMPEDS) "A Laboratory Instrument for Measuring the Turbidity of a Suspension of Dust Particles," *Powder Technology* **3, 107** (1969)

Section: N

Subjects: Dust; Suspensions; Particles; Turbidity

Reprint of Safety in Mines Research Establishment Abstract, By Permission

The basic principles governing the attenuation of a light beam by a suspension of particles are outlined. The paper describes an instrument, developed from a commercially available absorptiometer, that can be used to determine the turbidity produced by a suspension of particles in a liquid. The sources of error in the use of the instrument are briefly discussed.

Lee, T. G. (National Bureau of Standards, Washington, D.C.) "Interlaboratory Evaluation of Smoke Density Chamber," *National Bureau of Standards Technical Note 708* (December 1971)

Section: N

Subjects: Smoke chamber; Building materials; Fire tests; Smoke, optical density; Smoke density chamber; Statistical analysis

Author's Abstract

Results are reported of a interlaboratory (round-robin) evaluation of the smoke density chamber method for measuring the smoke generated by solid materials in fire. A statistical analysis of the results from 10 material-condition combinations and 18 laboratories is presented. For the materials tested, the median coefficient of variation of reproducibility was 7.2% under nonflaming exposure conditions and 13% under flaming exposure conditions. A discussion of errors and recommendations for improved procedures based on user-experience is given. A tentative test method description is included as an appendix.

McCarter, R. J. (National Bureau of Standards, Washington, D.C.) "Apparatus for Rate Studies of Vapor-Producing Reactions," *Status of Thermal Analysis, National Bureau of Standards Special Publication 338* (October 1970)

Section: N

Subjects: Vapor production rate; Pyrolysis

Author's Summary

An apparatus was developed for measuring the rate at which vapors are evolved during the thermal degradation of materials and thereby deriving the kinetics of such reactions. Requisite to the operating scheme of the apparatus is the provision of a high-temperature zone to convert condensable or tarry vapors into noncondensable form.

The apparatus yields a direct measure of reaction velocity, rather than the integrated indication obtained with thermogravimetric analysis. This simplifies the identification and calculation of kinetic parameters. Increases in sensitivity and operating range are also achieved. Flexibility in operation is obtained that permits the separate recording of reactions that tend to overlap.

Although the apparatus has been operated principally with a combustible gas indicator serving to meter the evolved product vapors, a number of options are available for the latter function, including flow meters and various continuous gas analyzers. The applicability of the method appears promising.

Nii, R. (Fire Research Institute of Japan, Tokyo, Japan) "Studies on Generating Mechanism of High Expansion Air Foam: III. About Practical Fixed Net-Fog Nozzle-Blower Type of High-Expansion Foam Generator," *Fire Research Institute of Japan Report No. 31*, 28 (1970)

Section: N

Subjects: Foam generators; Nozzle foam; Net foams

Author's Abstract

A laboratory high-expansion foam generator designed by the author and produced at the factory of the Institute (F.R.I. of Japan) was used in this study. It is the same type as practical one (fixed net-fog nozzle-blower type) of high-expansion foam generator, and renders a great number of experiments about the generating mechanism and the extinguishing ability of foam more economically feasible. The details of the laboratory high-expansion foam generator are shown.

From reference to several reports on generating mechanism of high-expansion foam, it can be convinced by the author, that the expansion ratio of foam depends upon several factors: foaming compound, concentration and temperature of foaming solution, fog nozzle, supply rate of foaming solution, net (width of mesh and weaving method), used area of net, mean wind velocity near front of net in air duct (or wind volume per minute), and distance between fog nozzle and net.

In various combinations of the several factors, a great number of experiments were performed. Furthermore, measurement of static pressure difference between the front and rear of the fixed net in the air duct was also done at the same time both in blowing and in foaming cases. The details of the experimental results are shown.

"Theoretical expansion ratio" E_T was newly defined by the author as shown in Eq. (1).

$$E_T = \frac{w}{Q/60S}\,\frac{S_0}{S} \qquad (1)$$

where w shows mean wind velocity near the front of a used net toward the direction of wind (cm/s); Q supply rate of foaming solution (l/min); S used area of the net $(m)^2$; and S_0 cross section of the air duct used (m^2). Now, a quantity Z is introduced with Eq. (2).

$$Z = Q/60S \qquad (2)$$

where Z (cm/s) shows volume of foaming solution supplied onto the used area of the net per cm^2 per second, or mean thickness of liquid layer or foaming solution supplied onto the used area of the net per second. Substituting from Eq. (2) into Eq. (1), Eq. (3) is obtained.

$$E_T = wS_0/ZS \qquad (3)$$

"Foaming efficiency" $\mathcal{E}$ is defined also by the author as shown in Eq. (4).

$$\mathcal{E}=E/E_T=EZS/wS_0\leqq 1 \quad (4)$$

where E shows an actual expansion ratio of foam generated, and depends upon the net used (mainly upon width of mesh and weaving method), foaming compound, and the concentration and temperature of the foaming solution. Provided that a definite foaming compound and concentration of the foaming solution and net in a high-expansion foam generator are used under a definite wind velocity; and provided that when $Z=Z_0$, we express as follows: $E=E_{max}$, $\mathcal{E}=\mathcal{E}_{max}$, accordingly we get Eq. (5) from Eq. (4).

$$\mathcal{E}_{max}=E_{max}ZS/S_0w \quad (5)$$

where E_{max} expresses the maximum expansion ratio under the definite wind velocity and the conditions as mentioned above. The relationships of maximum foaming efficiency $\mathcal{E}_{max}$ vs. wind velocity w about synthetic foaming compounds, A, B and C are shown.

In consideration of the experimental results following conclusions were obtained by the author.

A relationship as expressed in Eq. (4) exists between foaming efficiency and mean wind velocity with regard to generation of high-expansion foam. In other words, foaming efficiency increases in the following cases: as wind velocity decreases within the lower limit of about 0.9 m/s, which comes from $\mathcal{E}_{max}\leqq 1$, and substituting $E_{max}=1000$, $S/S_0=1.25$, $Z_0=7.0\times 10^{-2}$ cm/s into Eq. (5); as concentration of foaming solution increases in case of the same wind velocity and Z; when $Z=(7.0\pm 1.0)\times 10^{-2}$ cm/s at the same concentration of the same foaming compound. The possible limit of expansion ratio to which we can attain with a practical type of high-expansion foam generator may be at the utmost about 5000.

In order to get a foam of more than 1000 in expansion ratio, the foaming efficiency should be more than 0.25. In order to get a foam of more than 1000 or 2000 in expansion ratio, the active content of more than 0.3 or 1.5 wt% of a foaming compound in water is required, respectively, because such an increase in concentration of the foaming solution causes increased strength of each bubble membrane of foam generated, and consequently decreased break-down rate of foam on the way of its generation.

It is possible for low-expansion type of protein base foam generated with a high-expansion foam generator to attain the maximum expansion ratio of about 400 for a shorter time after foaming. The foam, however, results in low-expansion within 5 minutes after foaming on account of 80% break-down of the initial foam volume. Therefore, foaming compounds of protein base cannot be used for high-expansion foam, because each bubble membrane of the foam is stable for low-expansion, in other words, the foam consists of bubbles which have membranes of larger thickness.

The static pressure difference between the front and the rear of a net of high-expansion foam generator in generation of high-expansion foam, which has an expansion ratio of more than 800, is about 10±2 mm Aq. It does not depend upon any kind of foaming compound and any concentration of foaming solution. It has no direct relation with expansion ratio of foam generated. It is a pressure loss in generation of high-expansion foam.

O'Dell, A. (Safety in Mines Research Establishment, Sheffield, England) "A Tungsten-Wire Resistance Thermometer for Use in Small Gaseous Jets," *Safety in Mines Research Establishment Research Report No. 270* (1970)

Section: N

Subjects: Resistance thermometry; Transient temperatures; Jets

Author's Abstract

Various configurations of a tungsten-wire resistance thermometer are examined with a view to measuring temperatures up to 2000°C in a short-duration pulsed gas jet. Single wires either straddling or immersed in the jet are insufficiently accurate, but better results might be obtained with two wires of different lengths, which allow the end effects to be cancelled. The use of two-wire probes is restricted to jets emerging from narrow slots.

Rae, D., Thompson, W., and Beardshall, D. (Safety in Mines Research Establishment, Sheffield, England) "A Description of the Buxton Full-Scale Surface Coal-Dust Explosion Gallery and Its Instrumentation," *Safety in Mines Research Establishment Research Report No. 260* (1969)

Section: N

Subjects: Buxton; Explosion gallery; Coal dust; Dust; Instrumentation

Authors' Abstract

The structure of the 366-m coal-dust explosion gallery at the SMRE Field Laboratories, Buxton, is described in so far as it has a bearing on the experiments done in the gallery. The paper also deals with the location, response and recording of the three main types of transducers (photocells for flame speed, pressure gauges, and anemometers); the way in which the gallery is used; and the operations of dust production, spreading, and cleaning. The presentation of the results and their accuracy, but not their detailed interpretation, are discussed. The interpretation of the results in relation to the experiments undertaken will be given in other reports.

Wass, C. A. and Lord, H. "A New Plant for Research and Testing Equipment for Flammable Atmospheres," *Electrical Review*, 869 (1970)

Section: N

Subjects: Testing electrical equipment; Flammable atmospheres; Buxton "POLSTAR"; Plant for testing

Reprint of Safety in Mines Research Establishment Abstract, By Permission

This paper describes a new electrical plant which has been installed at the Buxton laboratories of the Safety in Mines Research Establishment, Department of Trade and Industry. It is called "POLSTAR" (Plant for On-Load and Short-circuit Testing And Research), and it is being used to investigate the behaviour of electrical apparatus, especially switchgear, under conditions of full electrical load (including rated overloads) in the presence of flammable gas both within and outside the apparatus. The plant has a maximum output of 50 MVA at 6.6 kV, which can be maintained for 0.2 seconds.

Wraight, H. (Joint Fire Research Organization, Boreham Wood, England) "A Robust Heat Flux Meter for Experimental Building Fires," *Journal of Physics, Series E, Scientific Instruments* **4**, 786 (1971)

Section: N

Subjects: Heat flux; Building fires

Author's Abstract

An instrument has been developed for measuring heat flux in the range 1–80 kW m^{-2}. It is of robust construction, suitable for outdoor use, and designed so that it can be mounted flush with the surface to which the heat transfer is required to be measured. The output of the instrument is nearly proportional to heat flux and the sensitivity is sufficient to enable a change in heat flux of 1 kW m^{-2} to be detected. By using the heat flux meter with and without an infrared transmission window, values of both the radiated and convected heat transfer can be obtained. The instrument is not very sensitive to draughts even without the transmission window, but with it the output is rendered completely unaffected by draught for all practical purposes.

O. Miscellaneous

Belton, M. (Safety in Mines Research Establishment, Sheffield, England) *Safety in Mines Research Establishment Bibliography*, 3rd Edition (1969)

Section: O

Subjects: SMRE; Bibliography, Safety in Mines Research Establishment

Reprint of Safety in Mines Research Establishment Abstract, By Permission

This is a bibliography of the published work of the Safety in Mines Research Establishment and of the Establishment's predecessors, and of publications by other workers for whom these bodies provided facilities, research contracts or grants. The bibliography covers the period from the foundation of organized research in 1908 to the end of 1968. References to over 1700 publications (excluding visual aids) are arranged alphabetically by authors' names. Separate lists of Safety in Mines Research Board papers and SMRE Research Reports are also included. The subject index has been computer-generated and is based upon research work carried out at the Postgraduate School of Librarianship and Information Science, University of Sheffield.

Combustion Laboratory, University of Minnesota, Minneapolis, Minnesota, *Technical Report No. 7, Fire Research, Under Contract No. N0022869C1172 for Office of Civil Defense* (November 1968)

Section: O

Subjects: Mass fire model; Fire spread; Thermal decomposition; Atmospheric diffusion

Mass Fire Model: A sand-filled pan burner is used to study the heat and mass transfer phenomena during various phases of the burning episode for large turbulent fire plumes. The total heat fluxes and radiant heat fluxes to the fuel surface are given for luminous and non-luminous flames as well as fire plume mean optical depths for axially symmetric plumes and fire plumes with fire whirls.

Fire Spread: Heat transfer and burning rates are given for vertically hanging cotton cloth panels as a function of distance from an isothermal wall. The maximum burning rate, radiant heat transfer, and convection heat transfer occurred at 3, 1.5, and 0.75 inches, respectively.

Thermal Decomposition: Combustion of pure α-cellulose cylinders treated with KBr are studied to obtain the effects of size, KBr concentration and heat flux on ignition, mass loss rates, temperature profiles and mode of burning. It is suggested that the effectiveness of fire inhibitor compounds may be limited to a given burning geometry.

Atmospheric Diffusion: A literature review is given for mass coefficients for large sources as they are influenced by atmospheric phenomena.

Schultz, A. G., and Fristrom, R. M. (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland) *"Fire Problems Program, Annual Summary Report, 1 July 1970–30 June 1971," National Science Foundation, RANN Program G1-12, APL/JHU FPP A71* (August 1971)

Section: O

Subjects: Fire problem; RANN; Johns Hopkins University, Applied Physics Laboratory; Education; Dictionary; Colloquia; Systems analysis; Flame inhibition; Polymer attack; Toxic gases; Fire detectors

Authors' Summary

The 21 tasks undertaken by the Fire Problems Group during the first year of its activity fall into six general categories:

1. *Reference works and information dissemination,* in which an effort was made to funnel useful fire information to potential users as early as possible.
2. *Education for the fire service,* in which negotiations were started to explore possibilities of instituting an integrated education program for fire service personnel, ranging from two-year community college programs through graduate school.
3. *Systems analysis and development,* in which a basis was sought for technical analyses of fire problems in order to define the problems quantitatively, determine magnitude and urgency qualitatively, and to undertake problems amenable to solution within the capabilities of the group.
4. *Fire and flame studies,* in which the basic mechanisms of fire, fire suppression, and the evolution and migration of toxic combustion products were investigated.
5. *Equipment and instrumentation studies,* in which attention was devoted to the state of the art of fire detectors, techniques of telemetering fire data, modifica-

tion of laboratory equipment for combustion studies, and development of a cryogenic breathing apparatus.
6. *Medical studies*, in which the main thrust is to determine the lethal agents and biophysical mechanisms in fire deaths.

A successful series of 14 colloquia, with a total attendance approaching 1000 was conducted, in which speakers discussed problems and results of the most recent work in their respective areas of specialization. The series proved popular and stimulated a lively interchange between practicing fire service personnel and fire science researchers mainly in the Washington-Maryland areas, but also from other states. Several educators and students from local educational institutions attended. Recordings of the colloquia are being widely distributed, with requests being received from all parts of the country.

In order to disseminate information as broadly as possible to the fire community, an energetic publications program was instituted. The book *Rate Constants of Gas Phase Reactions* by V. N. Kondrat'ev was translated, edited, and submitted for publication. Five invited symposium papers were presented and submitted for publication. A number of signed book reviews, abstracts, commentaries, and the like were published during the year. Several internal memoranda on fire problems were prepared by members of the Fire Problems Group, including three state-of-the-art reviews, one of which is scheduled for publication. Manuscripts for a *Fire Science Dictionary and Source Book* and a *Directory of Workers in Fire Research* neared completion, as well as the manuscripts of several papers that will be submitted to appropriate professional journals.

Members of the staff presented invited lectures on fire problems at a number of prominent institutions and participated in the work of the Committee on Fire Research of the National Academy of Sciences and the U.S. Navy Fire Research Committee.

Productive discussions were initiated on fire service education with interested members at the University of Maryland and the University of California (Berkeley). Consultations have been held with fire officials in the States of Maryland, California, Oregon, and Florida. Fire officials in Florida, keenly interested in establishing a state-wide fire data and fire service information system, have invited the APL Fire Problems Group to assist in determining requirements, designing, and implementing such a system.

The APL Fire Problems Group participated in a burn conducted by the University of Maryland Fire Protection Curriculum.

Finally, a biomedical program in fire deaths was recently initiated in collaboration with the Baltimore City Medical Examiner's Office.

Underwriters' Laboratories, Inc., Chicago, Illinois. *Research Bulletins (Available 1972)*

Section: O

RESEARCH BULLETINS

Number

1. Control of Floating Dust in Terminal Grain Elevators.
2. Spontaneous Ignition and Its Prevention.
3. Opacity of Water to Radiant Heat Energy.
4. Effect of Grease in Metal-to-Metal Joints on Safe Operation of Explosion-Proof Electrical Equipment.
5. Fire Exposure Tests of Old Fireproofed Wood Doors.
6. Fire Exposure Tests of Ordinary Wood Doors.
7. Propagation of Flame in Gasoline Vapor-Air Mixtures at Pressures Below Atmospheric.
8. Generation of Static Electricity in Blower Systems.
9. Electrical and Physical Characteristics of Naturally-Aged Rubber-Covered Wire.
10. Electrolytic Oxygen and Hydrogen Plants and Their Operation.
11. Study of Phase Displacement in Electrical Circuits from Linearly Expanded Lissajous Figures.
12. Hydraulic Friction Losses in $1\frac{1}{2}$-in. and $2\frac{1}{2}$-in. Cotton Rubber-Lined Fire Hose.
13. Fire Exposure Tests of Loaded Timber Columns.
14. Electric Shock as It Pertains to the Electric Fence.
15. Fire Exposure Tests of Tin-Clad Fire Doors on Opposite Fire Wall Faces.
16. Oxygen Pressure Method for Accelerated Aging Tests of Rubber Compounds.
17. Noise in Burglary Resisting Vaults Under Normal and Attack Conditions.
18. Fire Exposure Tests of Hollow Metal Fire Doors.
19. Performance of Zinc and Enamel Protective Coatings for Rigid Steel Electrical Conduit.
20. Fire and Explosion Hazards of Ammonium Nitrate Fertilizer Bases.
21. Current-Carrying Capacity of Rubber-Jacketed Cords, Types S, SJ, and SV.
22. Comparative Burning Tests of Common Plastics.
23. Rain Tests of Electrical Equipment—Methods and Apparatus.
24. Effectiveness of a Choke for Arresting Starch Explosions in Wood Box Screw Conveyors.
25. Performance of Rubber Insulation of Building Wire in One-Year Oven Tests.
26. Electrical Conductivity of Snow and Gas Discharged from First-Aid Carbon Dioxide Extinguishers.
27. Clearances and Insulation of Heating Appliances.
28. Fire Exposure Tests of Fire Windows.
29. Classification of the Hazards of Liquids
30. New Bomb for Investigation of Pressures Developed by Dust Explosions.
31. Combustion and Mechanical Noise in Automatic Mechanical-Draft Oil Burners.
32. Fire Hazard Classification of Building Materials.

33. Measurement of Electrical Shock Hazard in Radio Equipment.
34. Reactions of Aluminum and Magnesium with Certain Chlorinated Hydrocarbons.
35. Tests of Some Forms of Window Protection for Minimizing the Flying-Glass Hazard Caused by Air Waves from Explosions.
36. Distribution of Water by Sidewall Types of Automatic Sprinklers.
37. Persistency of Odor of Accidentally Released "Pyrofax" Liquefied Petroleum Gas.
38. Limits of Flammability of Methyl Ethyl Ketone Vapor in Air at Initial Temperatures of 100°, 150°, and 200°C.
39. The Comparative Explosion Hazard of Ammonium Nitrate Containing Organic Matter. (Also Supplement to this Bulletin.)
40. The Visual Study of Nonperiodic Electric Transient Phenomena.
41. Investigation of Overcurrent Protection Devices as Affected by Ambient Temperatures.
42. The Life Hazards and Nature of the Products Formed When Chlorobromomethane Extinguisher Liquid Is Applied to Fires.
43. The Lower Limit of Flammability and the Autogenous Ignition Temperature of Certain Common Solvent Vapors Encountered in Ovens.
44. Heating of Branch Circuit Conductors and Flexible Cords.
45. A Determination of the Acceptability of Magnesium Alloys as Enclosures for Portable Electrical Appliances.
46. An Investigation of Large Electric Motors and Generators of the Explosion-Proof Type for Hazardous Locations, Class I, Group D.
47. The Spontaneous Ignition and Dust Explosion Hazards of Certain Soybean Products.
48. Aluminum Building Wires and Connectors.
49. Fire Door Frames for Thin Walls.
50. A Study of the Corrosion of Vaporizing-Liquid Type Fire Extinguishers.
51. Performance of Type B Gas-Vents for Gas-Fired Appliances.
52. Development of Apparatus and Test Method for Determining Wind-Uplift Resistance of Roof Assemblies.
53. Survey of Available Information on the Toxicity of the Combustion and Thermal Decomposition Products of Certain Building Materials Under Fire Conditions.
54. The Compatibility Relationship Between Mechanical Foam and Dry-Chemical Fire-Extinguishing Agents.
55. Burning, Arcing, Ignition, and Tracking of Plastics Used in Electrical Appliances.
56. Study of Smoke Ratings Developed in Standard Fire Tests in Relation to Visual Observations.
57. Two Versus Three Running Overcurrent Units for the Protection of Three-Phase Motors.
58. An Investigation of Fifteen Flammable Gases or Vapors with Respect to Explosion-Proof Electrical Equipment.

BOOKS

Fire and Buildings by T. T. Lie, Published by Applied Science Publishers Ltd., London, 1972

Author's Abstract

This book deals with various aspects of protection of buildings against spread of fire and collapse. Research in this field has advanced rapidly in the last two decades, and current knowledge and applications of research results to practice are described.

Descriptions are given on the development process of fire and the estimation of the expected temperature and duration of fires in buildings. Also discussed are methods to determine the length of flames from windows, the safe positions of objects exposed to radiation from burning buildings, and the principles of roof venting to remove heat and smoke.

Particular emphasis is placed on preventing the spread of fire by compartmentation of a building with fire-resisting constructions, and consideration is given to experimental and theoretical methods of determining the fire resistance of structural elements such as floors, walls, columns, and beams.

Experimental determination of fire resistance is still the most common method, and detailed information is provided on testing methods and equipment, test results and their interpretation. In the field of theoretical prediction of fire resistance, progress has been significant. Reasonably accurate predictions of the fire resistance of various concrete, steel, and timber structural elements can now be made by calculation, at only a fraction of the cost and time involved in experimental determination of fire resistance.

Attention is also paid to economic aspects of fire. An increasingly important subject is the determination of appropriate fire-resistance requirements for buildings. A rational method based on balancing the cost of providing fire protection against the benefits is discussed.

Chapter Headings

PERIODICALS

Joint Fire Research Organization Fire Research Notes, January 1970–March 1972. Available Department of the Environment and Fire Offices' Committee, Joint Fire Research Organization, Boreham Woods, Herts., England

1. *Fire Research Note No. 796*, January 1970. "The Rates of Spread of Head Fires in Gorse and Heather" by P. H. Thomas.
   Subjects: Fire spread, rate, wildland, wind.

2. *Fire Research Note No. 798*, February 1970. "Street Numbers of Houses Where Fires Occur" by E. D. Chambers.
   Subjects: Area, British, comparison, distribution, domestic, fire prevention.

3. *Fire Research Note No. 799*, March 1970. "Fire Deaths in the Fourth Quarter of 1969" by S. E. Chandler.
   Subjects: Fatalities, fire statistics.

4. *Fire Research Note No. 800*, March 1970. "Specification of Tests for Fire Hazard Associated with Portable Electrostatic Spray Painting Equipment".
   Subjects: Paint, spraying (paint), electrostatic, equipment, specification, tests.

5. *Fire Research Note No. 801*, March 1970. "Exeter Chip Pan Safety Campaign: Effect on Fire Frequency" by E. D. Chambers.
   Subjects: Cooker, cost benefits, domestic, fire prevention, fire statistics, time series.

6. *Fire Research Note No. 802*, February 1970. "Make Leicester Fire-Safe Campaign: Statistics of Fires in Dwellings" by E. D. Chambers.
   Subjects: Cost-benefit, fire prevention, fire statistics, publicity, correlation, time series.

7. *Fire Research Note No. 804*, March 1970. "Fires in Television Sets" by S. E. Chandler.
   Subjects: Casualties, fire cause, fire statistics, television.

8. *Fire Research Note No. 805*, March 1970. "Some Statistics of Damage to Buildings in Fires" by R. Baldwin and G. Allen.
   Subjects: Building, damage, fire statistics.

9. *Fire Research Note No. 806*, March 1970. "A Preliminary Note on the Movement of Smoke in an Enclosed Shopping Mall" by P. L. Hinkley.
   Subjects: Smoke, spread, shopping mall, escape means.

10. *Fire Research Note No. 807*, March 1970. "The Flow of Hot Gases Along an Enclosed Shopping Mall: A Tentative Theory" by P. L. Hinkley.
    Subjects: Smoke, spread, shopping mall, escape means.

11. *Fire Research Note No. 808*, March 1970. "Survey of Fire-Loads in Modern Office Buildings—Some Preliminary Results" by R. Baldwin, Margaret Law, G. Allen, and Lynda G. Griffiths.
    Subjects: Statistics, fire-load, offices.

12. *Fire Research Note No. 810*, March 1970. "The Behavior of Automatic Fire Detection Systems" by J. F. Fry and Christine Eveleigh.
    Subjects: Detector fire, alarm, alarm false, automatic.

13. *Fire Research Note No. 811*, March 1970. "S. I. Units and Their Use at the Fire Research Station" by Margaret Shakeshaft.
    Subject: Units.

14. *Fire Research Note No. 812*, April 1970. "The Prevention of Fire Spread in Buildings by Roof Vents and Water Curtains. Part 2. The Effect of Air Movement on Water Curtains" by A. J. M. Heselden and C. R. Theobald.
    Subjects: Water curtains, fire spread, building, vents, drops.

15. *Fire Research Note No. 813*, March 1970. "Town Gas Explosions in Dwellings" by J. F. Fry.
    Subjects: Explosion, dwellings, gas, town, statistics.

16. *Fire Research Note No. 814*, March 1970. "Fire Tests with Sprinklers on High Piled Stock" by R. A. Young.
    Subjects: Detector, fire, extinguishing, fire spread, high-piled, sprinkler, storage.

17. *Fire Research Note No. 815*, April 1970. "Preliminary Analysis of Fire Reports from Fire Brigades in the United Kingdom, 1969" by S. E. Chandler.
    Subject: Fire statistics.

18. *Fire Research Note No. 816*, April 1970. "The Thermal Movement of Concrete Floor Units under Fire Conditions" by F. C. Adams and T. V. Day.
    Subjects: Building—industrialized, concrete—reinforced, expansion, fire—resistance.

19. *Fire Research Note No. 817*, April 1970. "Fire Risk in Dwellings in Multiple Occupation" by W. N. Daxon.
    Subjects: Fire risk, dwelling, occupation, multiple.

20. *Fire Research Note No. 821*, May 1970. "The Effect of Reactant Consumption on Substantially Sub-Critical Self-Heating" by P. C. Bowes.
    Subjects: Spontaneous heating, self-heating.

21. *Fire Research Note No. 823*, October 1970. "Experiments on the Use of a Laser Beam for Fire Detection. Part 1. Heat Detection" by E. F. O'Sullivan, B. K. Ghosh, and J. Turner.
    Subjects: Detector, fire, heat, laser, investigation, circuitry.

22. *Fire Research Note No. 824*, April 1970. "A Laser Beam Fire Detection System" by D. I. Lawson.
 Subjects: Laser, fire detector

23. *Fire Research Note No. 825*, May 1970. "Fire Deaths in the First Quarter of 1970" by S. E. Chandler.
 Subjects: Fatalities, fire statistics.

24. *Fire Research Note No. 826*, May 1970 (superseding F. R. Note No. 820). "Gas Explosions in Dwellings, 1969: Material Damage and Injuries" by E. D. Chambers.
 Subjects: Casualties, comparison, distribution, domestic, gas explosion, loss.

25. *Fire Research Note No. 842*, November 1970. "Thermal Explosion in Rectangular Parallelepipeds" by P. C. Bowes.
 Subjects: Thermal explosion, self-heating, parallelepipeds.

26. *Fire Research Note No. 848*, November 1970. "Statistical Analysis of Fire Spread in Buildings" by R. Baldwin and Lynda G. Fardell.
 Subjects: Fire statistics, fire spread, building.

27. *Fire Research Note No. 849*, November 1970. "Fire Deaths in the Third Quarter of 1970" by S. E. Chandler.
 Subjects: Fatalities, fire statistics.

28. *Fire Research Note No. 850*, November 1970. "Smoke Tests in the Pressurized Stairs and Lobbies in a 26-Storey Office Building" by T. H. Cottle and T. A. Bailey of Cardiff Fire Brigade; E. G. Butcher and C. Shore of Fire Research Station.
 Subjects: Smoke, movement, tests, building, multi-storey, pressurization.

29. *Fire Research Note No. 851*, December 1970. "The Thermal Decomposition Products of Phenol-Formaldehyde Laminates. Part 1. The Production of Phenol and Related Materials" by W. D. Woolley and Ann I. Wadley.
 Subjects: Polymers; pyrolysis, thermal decomposition, Bakelite, Phenol, formaldehyde.

30. *Fire Research Note No. 852*, December 1970. "The Thermal Decomposition Products of Phenol-Formaldehyde Laminates. Part 2. The Production of Formaldehyde, Carbon Monoxide and Carbon Dioxide" by W. D. Woolley and Ann I. Wadley.
 Subjects: Gas chromatography, pyrolysis, thermoplastic resin, toxic gas.

31. *Fire Research Note No. 854*, December 1970. "Smoke Travel in Shopping Malls—Experiments in Co-operation with Glasgow Fire Brigade—Part 2" By A. J. M. Heselden.
 Subjects: Smoke, spread, shopping mall, tunnel, visibility, temperature.

32. *Fire Research Note No.* 858, February 1971. "Fire Deaths in the Fourth Quarter of 1970" by S. E. Chandler.
    Subjects: Fatalities, fire statistics.

33. *Fire Research Note No. 859*, February 1971. "Intumescent Matrices as Fire Resistant Partitions" by D. I. Lawson.
    Subjects: Columns, doors, partition, ceiling suspended, paint, intumescent.

34. *Fire Research Note No. 862*, March 1971. "Pressure Tests for Fire Extinguishers" by P. F. Thorne.
    Subjects: Extinguishers, pressure tests.

35. *Fire Research Note No. 866*, April 1971. "Some Experimental Studies of the Control of Developing Fires in High-Racked Storages by a Sprinkler System" by P. Nash, N. W. Bridge, and R. A. Young.
    Subjects: Fire detector, fire spread, high-piled, sprinkler, storage.

36. *Fire Research Note No. 867*, April 1971. "Application of the Theory of Thermal Explosion to the Self-Heating and Ignition of Organic Materials" by P. C. Bowes.
    Subjects: Thermal explosion, self-heating.

37. *Fire Research Note No. 868*, April 1971. "Preliminary Analysis of Fire Reports from Fire Brigades in the United Kingdom, 1970" by S. E. Chandler.
    Subjects: Fire statistics, casualties.

38. *Fire Research Note No. 870*, April 1971. "Coupled Gas Chromatography-Mass Spectrometry and Its Application to the Thermal Decomposition Products of Cellulose" by W. D. Woolley and F. N. Wrist.
    Subjects: Fire retardant, gas chromatography, mass spectrometry, pyrolysis.

39. *Fire Research Note No. 871*, April 1971. "The Compaction of Powders by Vibrations—Preliminary Results" by P. F. Thorne.
    Subjects: Dry powders, compaction, vibration.

40. *Fire Research Note No. 873*, May 1971. "Fire Deaths in the First Quarter of 1971" by S. E. Chandler.
    Subjects: Fatalities, fire statistics.

41. *Fire Research Note No. 874*, May 1971. "Thermal Measurements on Unprotected Steel Columns Exposed to Wood and Petrol Fires" by A. J. M. Heselden, C. R. Theobald, and G. K. Bedford.
    Subjects: Columns, fire, heat transfer, temperature.

42. *Fire Research Note No. 875*, May 1971. "Some Notes on the Control of Smoke in Enclosed Shopping Centres" by P. L. Hinkley.
    Subjects: Shopping mall, smoke, ventilation, vents.

43. *Fire Research Note No. 876*, June 1971. "The Fire Propagation Test as a Measure of Fire Spread. Correlation with Full-Scale Fires in Corridors" by H. L. Malhotra, W. A. Morris, and J. S. Hopkinson.

Subjects: Fire propagation test, fire spread, corridor, fire tests, wall lining.

44. *Fire Research Note No. 878*, July 1971. "Fire at Wulfrun Shopping Centre, Wolverhampton, 24.12.70" by A. Silcock and P. L. Hinkley.

Subjects: Fire account, shopping mall, fire spread, smoke, spread.

45. *Fire Research Note No. 881*, August 1971. "The Formation of Nitrogen-Containing Products from the Thermal Decomposition of Flexible Polyurethane Foams" by W. D. Woolley, Ann I. Wadley, and P. Field.

Subjects: Gas chromatography, mass spectrometer, polyurethane foam, pyrolysis, toxic gas.

46. *Fire Research Note No. 882*, October 1971. "The Survey of Fires in Buildings. Fire Survey Group. First Report October 1971" by A. Silcock.

Subjects: Fire, survey, building.

47. *Fire Research Note No. 884*, August 1971. "Fire Spread in Buildings—The Early Stages of Growth" by R. Baldwin, S. J. Melinek, and P. H. Thomas.

Subjects: Fire statistics, fire spread, probability.

48. *Fire Research Note No. 890*, September 1971. "An Instrument for Continuous Weighing of Fires" by M. J. O'Dogherty.

Subjects: Apparatus (measuring), burning rate, detector, fire.

49. *Fire Research Note No. 892*, October 1971. "Intumescent Coated Honeycombs as Fire Resistant Materials" by D. I. Lawson and E. G. Butcher.

Subjects: Fire, damper, honeycomb, intumescent, coating, fire-resistance test, partition, doors.

50. *Fire Research Note No. 896*, November 1971. "Notes on Charring Rates in Wood" by C. P. Butler.

Subjects: Combustion, charring, rate, wood.

51. *Fire Research Note No. 899*, November 1971. "Considerations of the Fire Size to Operate, and the Water Distribution From, Automatic Sprinklers" by M. J. O'Dogherty and P. Nash.

Subjects: Area, burning rate, distribution, fire load, sprinkler, water.

52. *Fire Research Note No. 903*, November 1971. "Frequencies and Causes of Fires in Laundries, Launderettes, and Similar Occupancies" by S. E. Chandler.

Subjects: Fire statistics, fire cause, laundry.

53. *Fire Research Note No. 904*, December 1971. "Fire Extinguishers in Private Dwellings" by E. D. Chambers and Carolyn M. Jessop.

Subjects: British, domestic, extinguisher (hand-operated), extinguishing agent, statistics, survey.

54. *Fire Research Note No. 909*, January 1972. "Some Notes on the Mathematical Analysis of Safety" by R. Baldwin.
Subjects: Safety, analysis.

55. *Fire Research Note No. 910*, January 1972. "Extreme Value Theory and Fire Losses—Further Results" by G. Ramachandran.
Subjects: Large fires, loss, fire statistics.

56. *Fire Research Note No. 911*, December 1971. "Some Electrical Properties of High-Expansion Foam" by P. F. Thorne and D. M. Tucker.
Subjects: Foam, high expansion, electrical shock, expansion, measurement.

57. *Fire Research Note No. 913*, January 1972. "The Thermal Decomposition Behaviour of Some Commercially Available Flexible Polyurethane Foams" by W. D. Woolley, Ann I. Wadley and P. Field.
Subjects: Gas chromatography, polyurethane foam, pyrolysis, toxic gas.

58. *Fire Research Note No. 914*, January 1972. "Experiments with Sprinklers in High-Racked Storages (2) Extinction with Face-Mounted Sprinklers" by P. Nash, N. W. Bridge, and R. A. Young.
Subjects: Fire spread, high-piled, sprinkler, storage.

59. *Fire Research Note No. 915*, January 1972. "The Use of Fire Extinguishers in Dwellings" by G. Ramachandran, P. Nash, and Miss S. P. Benson.
Subjects: Fires, dwellings, extinguishers.

60. *Fire Research Note No. 916*, January 1972. "Experiments with Sprinklers in High-Racked Storages (1) Extinction with Centrally Mounted Sprinklers" by P. Nash, N. W. Bridge, and R. A. Young.
Subjects: Fire spread, high-piled, sprinkler, storage.

61. *Fire Research Note No. 917*, November 1971. "Surface Temperatures of a Diesel Engine and Its Exhaust System" by P. S. Tonkin and C. F. J. Berlemont.
Subjects: Hot surfaces, diesel engine.

62. *Fire Research Note No. 918*, February 1972. "The Effect of the Velocity of Foam Jets on the Control and Extinction of Laboratory Fires" by D. M. Tucker, D. J. Griffiths, and J. G. Corrie.
Subjects: Foam, jets, velocity, extinguishing, fuel, liquid.

63. *Fire Research Note No. 920*, January 1972. "Fires in Oil Refineries and Outdoor Chemical Plants in 1969" by S. E. Chandler.
Subjects: Fire statistics, chemical, oil, industry, extinguishing.

64. *Fire Research Note No. 921*, January 1972. "The Projection of Flames from Burning Buildings" by P. H. Thomas and Margaret Law.
Subjects: Flame, window, size, projection.

65. *Fire Research Note No. 925*, February 1972. "Compatibility of Fluorochemical and Protein Fire-Fighting Foams" by T. B. Chitty, D. J. Griffiths, and J. G. Corrie.
Subjects: Foam, protein, fluorochemical, compatibility.

66. *Fire Research Note No. 926*, February 1972. "Vehicle Fires on Motorways in 1969" by S. E. Chandler.
Subjects: Casualties, crash, extinguishing, fire statistics, vehicle, motorway.

67. *Fire Research Note No. 928*, February 1972. "The Determination of Maximum Permissible Oxygen Concentrations in a Small-Scale Vertical-Tube Dust Explosion Apparatus" by P. S. Tonkin and P. J. Fardell.
Subjects: Dust explosion, prevention, oxygen concentration.

68. *Fire Research Note No. 929*, March 1972. "An Application of the Theory of Extreme Values for Estimating the Delay in the Discovery of a Fire" by G. Ramachandran.
Subjects: Fires, industrial, discovery, delays.

69. *Fire Research Note No. 930*, March 1972. "Geographical Distribution of Large Fires During the Period 1966–1970" by G. Ramachandran.
Subjects: Large, fire, loss, distribution, brigades.

MEETINGS

Tenth Annual Office of Civil Defense Fire Research Contractors Meeting, Asilomar, California (April 23–27, 1972)

Conference Session Summaries

"Civil Defense and Fire Research"—James W. Kerr, Office of Civil Defense, Washington, D.C.

A considerable portion of the generalized discussion periods was devoted to matters that are properly described as administrative, hortatory, or background briefings. The first two categories do not merit recording here, but a few background items help set the tone of the overall meeting.

Foremost is the trend in OCD management toward involvement in natural disaster. Agreement had already been reached with the Office of Emergency Preparedness as to roles of both agencies, foreshadowing the "promotion" of OCD to DCPA, consumated a few days later. Consideration of population movement, i.e., voluntary or mandatory evacuation of damaged or threatened areas, must thus be a routine parameter in civil defense studies.

This is typified in the second major point: emphasis on the interaction of all effects and factors. The most obvious interaction is blast/fire, but an alert analyst picks up interrelations in most studies. For example, if defense depends on fire guards, how can 100% evacuation be contemplated? Do fire countermeasures inhibit defense against EMP? Is EMP a fire threat? Often, a scenario approach can throw light on such relationships.

The following generally accepted conclusions or summary points were gone over in the final hours of the conference:

- There is now sufficient data on behavior of curtains and drapes in the blast/fire environment to permit a confident revision of OCD guidance. Useful publications of greater sophistication and diversity are gradually emerging, e.g., an array of NEOP and NADOP checklists for planners.
- Criteria for determination (or more properly, estimation) of structural survivability are not the same as those used by offensive military planners. The very approach is different. OCD is attempting to protect people, and only incidentally buildings and contents. Survey techniques and hardening guidance are both improving, but secondary fires continue to loom as a major threat.
- Effects of multiple weapons on the blast/fire situation are perhaps least understood of all the various perturbations now conceptualized.
- Self help appears to offer the only real prospect of success in coping with initial ignitions, but it creates a tremendous training and education problem. Crisis activated training programs would probably be too late.
- Operational applications of flame retardants identified in the basic study program now appear ready for the study stage.
- Fire-spread models are taking on new credibility. The idea of re-doing some early specific area studies, using new countermeasure factors, appears attractive.
- There is always a problem in translating research into action. The new peacetime involvement of DCPA seems an ideal vehicle for moving toward a nuclear defense capability, but research on the nuclear case remains an overriding necessity.
- Increased activity was noted among other fire groups:
  —USFS aerial fire suppression.
  —NAS Committee on Fire Research symposia.
  —Presidential Commission hearings.
  —NSF/RANN grants.

"Protective Structures and Their Vulnerability to Blast/Fire Effects"—George N. Sisson, Office of Civil Defense, Washington, D.C.

In a civil defense context, protective structures are any structures which offer some degree of protection against nuclear weapon effects, or even many of the effects accompanying natural disasters. Very few single purpose protective structures are in existence but to the extent that they are, fire problems are generally minimized by designing the structures to be fire resistant and locating them in low fire risk environments. To a considerable extent, the same may be said for shelters deliberately designed into the basements of new buildings. However, the present shelter system in the U.S. consists of some 300,000 conventional buildings plus the basements of some 9,000,000 residences. The pressing need is to define the blast-fire environments which may occur in and around these "shelters" should nuclear war or certain major natural disasters occur.

A basic problem in trying to predict the amount of protection offered by a particular building is to be able to predict the differential loading produced on exterior and interior walls of buildings and the flow patterns within the buildings when subjected to blast effects. Thus far it is possible to define relatively safe areas within a particular room if the outside overpressure time-history is known. Good estimates of the differential load-time histories on exposed interior and exterior walls are not currently available but are being developed. Since many existing shelters which have the best protective capability are in basements of buildings, it is important to understand the flow patterns which might occur in these spaces. Future work will concentrate in these areas.

Present predictions on the strength of existing buildings are being made on the assumption that exterior walls will fail before the building frame is seriously threatened. For buildings in which this is true (believed to be the majority for buildings with frames), a predictive methodology is currently being used which is based on specific test data from individual tests (deterministic data). Since it is known that no two buildings of a given construction are exactly alike from a strength standpoint, estimates are made for various materials parameters to produce a probabilistic estimate for various kinds of walls and floors. Success in understanding the distribution of combustibles in a blast-fire environment depends upon the capability to make these estimates with a satisfactory confidence level. Thus far only a limited capability exists for making these estimates for certain types of walls and slabs. For many common forms of wall construction, the present capability is good.

Some essentially full-scale data, for large-yield nuclear weapons, and for the initial response of walls and equipment, have been obtained in a large blast tunnel (simulator) in which a large number of tests have been completed. The most notable progress has been made in this test program in demonstrating that no unique overpressure failure value (or even a value with a small standard deviation) can be assumed for, say, an 8-inch brick wall. The same is true for other types of common walls. For some 8-inch brick walls the mean value may vary from 1 psi to perhaps 10 or 15 psi. The failure values depend upon the boundary condition or "confinement" conditions for the walls. The test program must be expanded to include other types of walls and boundary conditions.

Studies have shown that significant protection can be incorporated into the basements of new buildings by a "slanting" technique—i.e., incorporating added strength into the roofs of basements during the design process. Fire can also be minimized by siting the building in a favorable location and incorporating fire protection and fire countermeasures into the construction and use plans for the basements. Such protection, when incorporated during the design process, can be accomplished at modest costs ($4.00 to $8.00 per square foot). Studies to date have been based on a design overpressure of 15 psi. The current guidance must incorporate all recent results of fire-blast interaction research, incorporate recent data on the room filling process created by the blast wave, and a wider range of design overpressures.

Failure of buildings, in terms of thermal pulse entering, nuclear radiation entering, glass broken out, walls failing, and dynamic pressure patterns within the shelters, are basic inputs to survival calculations. Such calculations involve assumptions or knowledge as to the location and position of sheltered people, the interaction of the flow of the gas (dynamic pressure) behind the shock front (and to some extent the shock front) with shelterees as well as the interaction of the shelterees with the debris and various parts of the building. While these calculations can be made with a fairly high confidence level for people in weak-walled buildings, considerable study is needed on strong-walled buildings and basements. In general, basements offer considerably more protection than upper stories.

Slanted basements in well-sited shelters do not seem to be threatened by fire for short times after attack since the heat from overhead fires requires considerable time to manifest itself in the shelters. In densely built-up areas, however, large amounts of burning debris may be created which can create a significant threat in the form of heat and noxious gases. A better understanding of blast-created debris fires is required.

If uncontrolled fires over shelters do occur, the floor slabs may become heat radiators to the people below. A fairly good understanding of the response of people to high temperature ambient environments has been developed, but it appears that the radiant heat from overhead slabs may seriously threaten shelterees unless appropriate countermeasures are taken.

Selected buildings currently in the National Fallout Shelter Survey (NFSS) are being surveyed to determine their protective capability against all weapons effects. Since it is not generally feasible to rule out the possibility of fire in these shelters, the current approach is to estimate the possible fire hazards and attempt to define appropriate fire countermeasures to be incorporated into the plan for use of the space as shelter.

Full-scale buildings equivalent to single family residences have been burned, both in undamaged and damaged states and in single and coupled configurations. Significant differences in burning rates and thermal flux intensities for these sets of conditions suggest that considerably more experimental data are desirable in order to formulate rules for predicting fire interaction, burning rates, flux intensities, and production of noxious gasses for multiple building burns.

If small-scale models of buildings could be used to successfully predict the burn characteristics of full-scale buildings, fire research possibilities would be enormously enhanced. While it is not possible to duplicate all of the characteristics of full-scale buildings with models, careful design of the models can lead to encouraging progress in studying selected parameters. Recent work with models as small as 1/16-scale has yielded moderate-to-poor correlation when comparing burn characteristics with full-scale buildings. It appears that larger models must be considered in order to improve correlation with full-scale data.

Fire retardants in a civil-defense context offer promise in two important respects. These are (1) the treatment of items potentially exposed to the thermal pulse of a weapon to prevent thermal pulse ignitions and (2) the retarding or prevention of subsequent burning. Recent research has shown promise for treating selected wood specimens with a simple low-cost application which is effective in both respects. More study is needed in this area to extend the applications to many common fabrics, develop application techniques applicable to large surfaces and fabrics, and to improve the effectiveness of the retardants.

"Blast Perturbations in Fire-Damage Assessments"—Stanley B. Martin, Stanford Research Institute, Menlo Park, California

For virtually all cases of interest involving fires that result from nuclear attack on urban targets, blast damage in greater or lesser degree will be associated with the fires. We readily perceive two broad situations and three levels of blast damage. The two situations, differing operationally as well as in their direct-effects vulnerability, are (1) the heavily built-up areas typified by central business districts and (2) the lightly built-up areas represented by residential occupancy. Levels of blast damage are conveniently divided into the three enumerated and described by Martin, Longinow, and Sisson at the 9th Annual Conference, to wit:

1. **Modest damage**—exterior walls generally remain in place; buildings remain standing; interior partitions and furnishings have generally been blown in a windward direction but remain on the story of origin; many survivors.
2. **Intermediate damage**—exterior walls and contents are blown from the building, some wall-bearing buildings collapse; few survivors and contents in upper stories, but most people in basements survive.
3. **Heavy damage**—essentially all buildings and frames collapsed; some basements collapsed, but many survivors in those basements above which the first floor maintained some integrity. (In blast-slanted basements, all people would survive and for the most part would remain uninjured.)

Considering the wide variability in structural resistance to air blast, these situations cover a range of free-field shocks from as low as 1 or 2 psi to at least 15 psi and perhaps 20-to-30 psi. Thus the civil defense interesting situations of blast-fire interaction cover a potentially very broad spectrum of initial effect combinations. The breadth of this spectrum must be increased manifoldly when it is recognized that the characteristics of air shocks and resultant flows that enter enclosed spaces of structures are quite diverse and only tenuously related to the free-field blast waves that generate them.

Recent experimental work indicates that fires in enclosures involving flaming combustion are extinguished at incident overpressures as low as 2 psi, at least somewhat irrespective of the intensity of flow during blast filling. While this is probably too much of a generalization to accept with confidence until more confirmatory data are acquired, it suggests strongly that a large proportion of the fires are reduced to smolder in regions of only moderate peak overpressure. This can be very significant operationally because it allows more time for self-help fire fighting. Further, recent studies conducted in the URS shock tunnel suggest that the previously adopted probabilities that window coverings cast into the room by the blast wave will lead indirectly to significant structural fires may be substantially too large because the interval of the burning time during which these coverings must be caught and transported by the blast is short, making the timing coincidence quite critical. The studies also have shown that smoldering fires persist at overpressures approaching 10 psi, and this tenacity of smoldering combustion looms as an important factor in the ultimate fire vulnerability of the areas of an urban target that are exposed to higher overpressures. If at some still higher overpressures smoldering combustion can, in fact, be extinguished, neither this response nor the blow out of flames at lower overpressures is mechanistically understood sufficiently well to predict with confidence the outcome of untested situations. It must be regarded as highly desirable to obtain such mechanistic data. The proposed development of shock tubes specifically for this purpose, as has been proposed by both URS and SRI, is a hopeful sign of intention to acquire these data. The versatility of the proposed SRI shock tube should make it a particularly valuable tool for this study.

Another significant conclusion that seems to arise from the results of recent experiments in blast-wave blowout is that secondary (i.e., blast-caused) fires are the really important ones following attack. This conclusion argues for investing the effort to learn more about secondary fires, which have been relegated to a minor position for many years. But the existing historical evidence on secondary fires, as summarized by McAuliffe and Moll, indicates that such fires are really only exhibited at a low level of incidence, and we are left with the dilemma of explaining the rapid and extensive fire development at Hiroshima. This all suggests that there are some other important kinds of fires which are not included in the classical categories of primary and secondary fires. It seems likely, for example, that there are fires of hybrid origin, that is, combinations of primary and secondary factors. It should be noted, moreover, that for large-yield explosions, enough thermal radiation exposure, delivered at sufficiently high radiation levels, remains after the passage of the blast wave at distances where 5-to-7 psi and greater overpressures are experienced to ignite many kindling materials, including blast-created debris.

Given ignitions, from whatever cause, there remains the task of describing the development of structural and areal fires. Substantial progress has been made here. Experimental data on fire growth and spread dynamics have been acquired in both full-scale and model-scale burns of buildings having varying degrees of blast-damage simulation, but more is needed, especially on spread through debris once its make up can be suitably prescribed.

In summary, although substantial progress is being made, all areas of blast-fire interaction deserve further research attention.

"Operational Plans for Emergencies Involving Fires"—Charles T. Rainey, Stanford Research Institute, Menlo Park, California

A general concept of emergency operation has been developed. This concept is applicable to local operation during an emergency that starts with the recognition of the threat to the time that the hazards no longer present a threat to the community. The concept can be applied to either natural disasters or war emergencies.

The operations concept is based on classifying the potential disaster into two types: (1) those with destructive impact and (2) those with paralyzing effects. Nine Basic Operating Situations (BOS) are defined according to the severity of threats posed by each disaster agent or combination of agents. The severity is judgmental (e.g., negligible, moderate, or severe) and provides the basis for developing a set of contingency plans based on each conceivable triggering event that might occur during the course of the emergency. From these triggering events, a checklist has been developed which will aid in developing sets of plans to respond to each of the emergency situations.

Further work in the same area has been done with the slow-developing natural disaster (such as a hurricane, flood, or forest fire). Although the concept of operations is quite similar to that previously described, the onset of the disaster develops slowly enough to permit adequate time for mobilization of the community's resources to allow concentration of those resources at the area of probable impact as well as to give sufficient time both to evacuate the population from the jurisdiction that may be affected and to make necessary arrangements for assistance from adjacent or outlying jurisdictions. Planning to move the affected population and to care for them in jurisdictions not affected by the potential disaster may be instituted, and populations may be moved from the potential impact areas long before the disaster effects are felt.

Development of the check list for the BRAVO NADOP also includes those measures necessary for survey of the damage after the disaster and measures necessary for rehabilitation of the area in order to alleviate the potential problem of the returning evacuees and to rebuild the area with State and/or Federal assistance when applicable.

The NADOP is based on an emergency organization of a Direction-and-Control function and five emergency operating services (medical, fire, police, shelter, and resource) which may be tailored to the needs of any political jurisdiction, regardless of size, by building on the cadres found in the normal operating organization of the jurisdiction by adding to them the required personnel and equipment and establishing chains of command for operation during the emergency period. These checklists and emergency operating services take into account the requirements imposed on the communities and the assistance available to them under the provision of Public Law 91-606.

Prototype contingency plans are being developed for the shelter complex and multipurpose staging areas described in the previously developed Nuclear Emergency Operations Plan. (ALFA NEOP). The shelter complex (SCX) is an intermediate control level between the individual shelter and the Emergency Operations Center (EOC). Planning for this level seems necessary to reduce the span of control problems and to permit a group of shelters to operate within a broad range of conditions and emergency problems that may be unique to a small area of an operating zone. Prototype contingency plans and checklists must identify conditions and events that require intercomplex support and allocation of resources. These plans must coordinate the operation of the SCX's, service units, and shelter facilities within the SCX.

Parallel development of the plans for the Multipurpose Staging Areas (MPSA) is required because that area is the preselected location for deploying specialized personnel and equipment. The MPSA is the base for coordinated emergency operation in support of the SCX during the emergency, an assembly area for mutual aid entering the afflicted area, and the staging area for postattack recovery activities. Prototype contingency plans must provide criteria for selection of facilities, assignment of personnel and equipment, organization of the personnel and equipment into effective operating units within the scope of their mission, and means for responding to events when required by zone or SCX headquarters.

The Emergency Operations Simulation Training (EOST) program is a potentially effective vehicle to disseminate the emergency plans to the local government personnel. This ongoing OCD-sponsored program also can provide meaningful feedback to the planning research by suggesting countermeasures which are within the feasible capabilities of local government. Work is continuing to improve our abilities to implement the emergency plans.

Credible emergency operation plans together with training and simulation programs are considered essential to the civil defense mission. An understanding of the nature and dynamics of the emergency environment is a prerequisite to developing credible plans and, therefore, the planners are dependent on research. Among the many areas where we feel our understanding of the emergency environment is limited are the following:

a. Preemergency procedures are available for assessing the potential fire risk (conflagration potential) of a facility or group of facilities. Would a similar procedure for assessing potential debris and other blast effects be feasible—or worthwhile?

b. What are the implications of fire research findings on operations—during crisis period and during developing fire? The NEOP calls for every man becoming a fireman to suppress incipient fires. At what point does debris influence this doctrine?

c. Would multiple weapons alter the fire dynamics sufficiently to call for a change in the NEOP doctrine?

d. Entrapment fires. The NEOP calls for evacuating HI-FIRE-RISK shelters before an entrapment fire develops—limiting factor was considered to be the feasibility of moving down streets between burning buildings. Does consideration of blast materially alter this factor?

e. Even with a crisis evacuation doctrine, considerable forces would have to remain in the urbanized areas. This would make selective utilization of best shelter facilities necessary but raises questions—criteria or guidance to planners would be needed—what precautionary measures would be feasible and appropriate during a crisis to reduce vulnerability of the vacated city to fire.

f. Dynamics of fire (in context of damaged city). The central operational decision appears to be whether a facility or area is tenable or untenable, e.g., whether or not it can be protected and occupied by in-place countermeasures. Criteria for identifying potential untenable areas is needed during preemergency period. Operational guidance for decision makers to follow during the emergency would be desirable. Simulation programs, such as the EOST, would provide a potential vehicle for disseminating such guidance.

g. A Fire-and-Blast analog to "Reminder about fallout" (that is the reference section of the NEOP) would be desirable.

Another important problem is incendiarism. A psychologist and a psychiatrist have been pressed into service to organize the meager knowledge that exists in this important aspect of the fire problem. Hopefully these professions will be challenged to explore the problems in greater depth.

The restrictive effect of insurance practices on progress in fire control is a controversial subject that is being reviewed in the expectation that a constructive symposium will result.

The technology and acceptance of fire detectors are the subject of another symposium that is dedicated to asking for a better and more applicable system of early warning of smoke and fire.

The biggest problem that confronts the fire services is the need for an agency to review the research that has been published and ready it for application to real life. This entails testing, validation of concept, collation with other work, and effective publicizing. Without such an agency, most of fire research is destined only to fill already crowded library space.

"Wildland Fire and Tactical Effects"—Major William Shepard, Defense Nuclear Agency, Washington, D.C.

The session "Wildland Fire and Tactical Effects" contained reports from several agencies pertaining to current and projected research that will give the military planner a data base on which to make his evaluations of hazards and obstacles, and then to make his operational decisions.

The data base includes thermal radiation phenomenology in terms of weapons outputs and transmission modes, thermal radiation effects on materials and personnel, combined blast-thermal prompt effects on personnel, combined blast-fire effects at later times, thermal radiation fire effects in a forest environment for strategic planning, air fire suppression techniques, fire spread models, fire data base for Southern California fuels, atmospheric and meteorology models for Santa Ana conditions, techniques for use of water or retardants dropped from fixed-wing aircraft and helicopters, and development of such factors as vegetation penetration, viscosity of air, fuel modeling, and high altitude delivery techniques for the application of air-delivered retardants.

Much of the above data base will be of use to the military commander in formulating his operational plans for tactical operations and control of fires. What remains to be done is to consolidate and correlate the data as it exists into as concise a package as possible with as many of the value judgments (which are independent of the tactical situation) completed in advance. In other words, a tactical operations manual for use in field operations should now be written taking into account the existing data.

Other areas that appear to offer high returns to the application of research efforts at this time are the development of a blast-thermal radiation simulation testing facility to evaluate the response of various structures, followed by improvement in the (then) validated calculational techniques for predicting response to the blast-thermal radiation effects, development of meteorological data and codes applicable to specific areas of concern—which then allows improved predictions for fire spread in urban and wildland areas, and completion of modeling of the wildland fuels and the mechanics of fire spread so that predictions can be made with higher confidence.

The USFS-OCD studies concerning fuels, meteorology, fire spread mechanics, and techniques for controlling fires will have a high value for operational and planning staffs of the military services. The DNA reports concerning thermal radiation, nuclear weapons effects in a forest environment, and the role of fire in nuclear warfare, together with the USFS and OCD studies, when condensed into a tactical operational manual, will be a step forward in understanding and operating successfully in a nuclear environment.

"Fire Research Committee of the National Academy of Sciences"—Dr. Carl Walter, Harvard Medical School, Boston, Massachusetts, and Dr. Robert Fristrom, Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland

The Committee on Fire Research is one of the activities of the Division of Engineering of the National Research Council. Its purpose is to advise government concerning various aspects of the fire problem. It has been particularly active with both the President's Commission and the RANN program of the National Science Foundation.

The formal work of the Committee is indirect as an overview of research published in the *Directory of Fire Research* and *Fire Research Abstracts and Reviews*.

In the past the Committee has viewed the national fire problem with alarm and has 'lobbied' for more formal structuring of the fire services and research activities. It has organized workshops, conferences and symposiums on specific aspects of the fire problem. The workshop on Mass Burns is an example that should be useful to this group. An abstracted version for public use—"Self-help in a Mass Conflagration"—is being edited.

Currently the Committee seems to be changing its stance and is raising questions and assuming a more active role in reviewing proposals for research. I have been delighted to see several proposals funded that explore the cause of death in unburned victims in fire areas. More rational and, hopefully, helpful resuscitation efforts should result. Certainly the most hazardous pyrolysis products will be identified so that the use of products causing them can be banned as finishing materials.

A successful symposium on the Halogenated Fire Extinguishing Agents was held two weeks ago. A surprising amount of research was reviewed describing the toxicology of the compounds, their effectiveness as extinguishing agents, and the optimum methods of use. The proceedings will provide a perspective that defines the use of Halons in the control of fire and explosions in special situations.

Conseiul International du Batiment [C.I.B.] Commission W-14 [Fire Problems], Stockholm, Sweden—May 14–19, 1972

This international group is interested in fire and safety problems in buildings. Meetings have been on a biannual basis with interchange of papers and ideas between representatives of most of the industrialized countries. Included in the present meeting were representatives from Australia, Belgium, Canada, Denmark, Norway, Finland, Sweden, Italy, France, The Netherlands, the U.S.A., U.K., U.S.S.R., Romania, Germany, Greece.

Some eighty-nine papers were exchanged for discussion (see Table I) covering topics in three groups: (1) Fire Endurance; (2) Smoke and Toxic Gases; and (3) Growth of Fire. These groups reported to the main session. Summaries of these reports are after Table I.

The local organizers were Mr. V. S. Sjölin of National Swedish Institute for Building Research and Dr. K. Ödeen of the Swedish Fire Protective Association.

The chairman was Mr. J. Fry of the Fire Research Station, Boreham Wood, England.

R. M. Fristrom

TABLE I

CIB/CTF 72/43

Complete list of papers circulated to delegates since June 1970 meeting

CIB/CTF 70/43(UK)	Fire Research Note No. 824. A laser-beam fire detection system
CIB/CTF 70/44(D)	Wände aus Holz und Holzwerkstoffen unter Feuerangriff
CIB/CTF 70/45(D)	Über den Einfluss der Brandlast auf Brandraumtemperatur und Feuerwiderstandsdauer bei der Prüfung von Beton- und Holzwänden nach DIN 4102. Sonderdruck aus Materialprüfung 11 (1969) Nr. 8 August
CIB/CTF 70/46(UK)	Symposium No. 3. Fire and structural use of timber in buildings
CIB/CTF 70/47(USA)	Fire tests of concrete members: an improved method for estimating thermal-restraint forces
CIB/CTF 70/48(C)	National Research Council of Canada, NRC 11266. Thermal properties of concrete at elevated temperatures
CIB/CTF 70/49(UK)	Ninth Meeting CIB Commission W.14. Summary of decisions on which action is required
CIB/CTF 70/50(D)	Brandverhalten und Feuerschutz von Holz und Holskonstruktionen. Wood and structures of wood, behaviour in case of fire and fire endurance
CIB/CTF 70/51(F)	Centre Scientifique et Technique du Batiment. Essais de resistance au feu (29e serie)
CIB/CTF 70/52(I)	Contribution a la resistence au feu des continus elasto-plasto-visqueux
CIB/CTF 70/53(F)	Centre Scientifique et Technique du Batiment. Essais de resistance au feu (30e serie)
CIB/CTF 70/54(UK)	Fire Research Note No. 832. Smoke travel in shopping malls experiments in co-operation with Glasgow Fire Brigade, Part 1
CIB/CTF 70/55(UK)	United Kingdom fire and loss statistics 1968
CIB/CTF 70/56(C)	National Research Council of Canada. NRCC 11275. Fire endurance of selected non-loadbearing concrete masonry walls
CIB/CTF 70/57(F)	Centre Scientifique et Technique du Batiment. Essais de resistance au feu (31e serie)
CIB/CTF 70/58(UK)	Report of the Ninth Meeting of CIB Commission W.14 at CSTB, Paris, France, 1st–5th June, 1970.
CIB/CTF 70/59(CA)	Technical Record 44/153/392. Department of Works, Commonwealth Experimental Building Station. Ignitability Test for building materials and textiles
CIB/CTF 70/60(C)	National Research Council of Canada. Building Research Note No. 71. Equivalent thickness of concrete masonry units
CIB/CTF 70/61(C)	National Research Council of Canada. Fire Research Note No. 9. Mirror-caused fire
CIB/CTF 70/62(F)	Centre Scientifique et Technique du Batiment. Essais de resistance au feu (32e serie)
CIB/CTF 71/1(D)	Brandschutz im Stahlbau ummantelungen und Verkleidungen. Teil 1. Unterdecken
CIB/CTF 71/2(UK)	FR Note No. 851. The thermal decomposition products of phenol-formaldehyde laminates, Part 1. The production of phenol and related materials

TABLE I—*Continued*

CIB/CTF 71/3(UK)	FR Note No. 852. The thermal decomposition products of phenol-formaldehyde laminates, Part 2. The production of formaldehyde, carbon monoxide and carbon dioxide
CIB/CTF 71/4(UK)	FR Note No. 854. Smoke travel in shopping malls experiments in co-operation with Glasgow Fire Brigade, Part 2
CIB/CTF 71/5(UK)	Papers circulated during 1970
CIB/CTF 71/6(F)	Centre Scientifique et Technique du Batiment. Essais de resistance au feu (33e serie)
CIB/CTF 71/7(D)	Brandverhalten von Bauteilen aus dampfgehärtetem Gasbeton
CIB/CTF 71/8(F)	Tableau recapitulatif des classements relatifs a la resistance au feu
CIB/CTF 71/9(UK)	FR Note No. 856. Fire problems of pedestrian precincts, Part 1. The smoke production of various materials
CIB/CTF 71/10(CA)	Technical Record 52/75/395. Department of Works, Commonwealth Experimental Building Station. Examination of the effect of different types of carpet on fire-spread under fire doors
CIB/CTF 71/11(CA)	Technical Record 44/153/8/393. Department of Works, Commonwealth Experimental Building Station. Smoke generated by building materials supplied by The National Bureau of Standards, U.S.A.
CIB/CTF 71/12(C)	National Research Council of Canada. Research Paper No. 457. Peak-time method for measuring thermal diffusivity of small solid specimens
CIB/CTF 71/13(J)	Building Research Institute of Japan Research Paper No. 45. Charts for estimating the equivalent fire duration on the standard temperature-time curve
CIB/CTF 71/14(J)	Building Research Institute of Japan Research Paper No. 46. Calculation of smoke movement in buildings
CIB/CTF 71/15(CA)	Technical Record 64/16/2/396. Department of Works, Commonwealth Experimental Building Station. Standard fire-resistance tests on windows of wired glass, in frames of galvanized steel, intended to prevent the spread of flames and hot gases through openings
CIB/CTF 71/16(C)	National Research Council of Canada. Research Paper No. 467. Computation of the behaviour of fire in an enclosure
CIB/CTF 71/17(UK)	FR Note No. 869. Collected summaries of Fire Research Notes 1963–1970
CIB/CTF 71/18(D)	Fortschritt-Berichte der VDI Zeitschriften
CIB/CTF 71/19(C)	National Research Council of Canada Technical Paper No. 341. Factors in controlling smoke in high buildings.
CIB/CTF 71/20(CA)	Technical Record 52/75/397 Department of Works, Commonwealth Experimental Building Station. Horizontal projections in the prevention of spread of fire from storey-to-storey
CIB/CTF 71/21(F)	Cahiers du Centre Scientifique et Technique du Batiment No. 122. L'essai ISO d'incombustibilite
CIB/CTF 71/22(C)	National Research Council of Canada Research Paper No. 494. Moisture and heat transport with particular reference to concrete

TABLE I—*Continued*

CIB/CTF 71/23(C)	Canadian Building Digest. Thermal performance of concrete masonry walls in fire
CIB/CTF 71/24(D)	Bauaufsichtliche Brandschutzvorschriften Beispiele für ihre Erfüllung bei Wänden, Brandwänden, und Decken
CIB/CTF 71/25(CA)	Regain of strength after firing of concrete
CIB/CTF 71/26(CA)	Development of a fibrous plaster ceiling/floor system with a rating of one hour for resistance to fire
CIB/CTF 71/27(C)	Canadian Building Digest. Flammability of lining and insulating materials
CIB/CTF 72/1(H)	Safety fire-tests of wooden houses
CIB/CTF 72/2(H)	Calculation of the fire-resistance limit value to be made on the basis of fire-loading in relation to the structures of residential buildings
CIB/CTF 72/3(F)	Statement of the principles of safety in fire
CIB/CTF 72/4(D)	Einwirkung von salzsäurehaltigen PVC-Brandgasen auf Beton
CIB/CTF 72/5(UK)	United Kingdom Fire and Loss Statistics 1969
CIB/CTF 72/6(UK)	Fire Research Note No. 892. Intumescent coated honeycombs as fire-resistant materials
CIB/CTF 72/7(UK)	Fire Research Memorandum No. 38 Loading, restraint, and deformation criteria in fire-resistance tests
CIB/CTF 72/8(UK)	Fire Research Note No. 875. Some notes on the control of smoke in enclosed shopping centres
CIB/CTF 72/9(C)	National Research Council of Canada Research Paper No. 484. Experimental verification of the rule of moisture moment
CIB/CTF 72/10(USA)	Fire Sciences Dictionary and Source Book APL/JHU
CIB/CTF 72/11(USA)	Topical Report flame inhibition chemistry APL/JHU
CIB/CTF 72/12(USA)	National Bureau of Standards Technical Note 708. Interlaboratory evaluation of smoke density chamber
CIB/CTF 72/13(USA)	National Bureau of Standards report 10 691. Flash pyrolysis of polytetrafluoroethylene
CIB/CTF 72/14(USA)	A literature survey of the chemistry of flame inhibition—National Bureau of Standards
CIB/CTF 72/15(USA)	The control of smoke in building fires—a state-of-the-art review—National Bureau of Standards
CIB/CTF 72/16(USA)	Apparatus for rate studies of vapor-producing reactions
CIB/CTF 72/17(USA)	Some observations on experimental fires in enclosures, Part 1: Cellulosic materials, FM
CIB/CTF 72/18(USA)	Aerothermodynamics and modeling techniques for prediction of plastic burning rates, FM
CIB/CTF 72/19(USA)	Some observations on experimental fires in enclosures, Part 2: Ethyl alcohol and paraffin oil, FM
CIB/CTF 72/20(USA)	Cellular and turbulent ceiling fires, FM
CIB/CTF 72/21(USA)	Fire-induced turbulent ceiling-jet. Technical Report, FM
CIB/CTF 72/22(USA)	A heat balance analysis of the standard fire endurance test, U. Calif.
CIB/CTF 72/23(USA)	The role of quantitative measures of combustibility in fire safety design, U. Calif.
CIB/CTF 72/24(UK)	Fire Research Note No. 924. Fire Research in Europe
CIB/CTF 72/25(USA)	National Bureau of Standards Report 10 807. Toxic atmospheres associated with real fire situations

TABLE I—*Continued*

CIB/CTF 72/26(C)	Feasibility of determining the equilibrium moisture condition in fire-resistance test specimens by measuring their electrical resistance
CIB/CTF 72/27(C)	Optimum fire resistance of structures
CIB/CTF 72/28(USA)	The spectral distribution of radiant energy of a gas-fired radiant panel and some diffusion flames
CIB/CTF 72/29(USA)	The definition of a low intensity fire
CIB/CTF 72/30(UK)	Fire Research Memorandum No. 70. Spalling of concrete. Results of a questionnaire
CIB/CTF 72/31(F)	Note sur le reglage de la puissance calorifique des fours de resistance au feu
CIB/CTF 72/32(CA)	Combustible floors and floor coverings in full-scale fires
CIB/CTF 72/33(UK)	The formation of nitrogen-containing products from the thermal decomposition of flexible polyurethane foams (Being published as WOOLLEY, W. D., Nitrogen-containing products from the thermal decomposition of flexible polyurethane foams. *Br. Polym. J.* 4, No. 1, 27–43 (1972).
CIB/CTF 72/34(USA)	Water Fillable Polymers—Ablatine Material for Fire Resistance by J. P. Davidson and R. B. Williamson, U. Calif.
CIB/CTF 72/35(USA)	Experimental Fires in Enclosures (Growth to Flashover), CIB Cooperative Program (CIB 2)
CIB/CTF 72/36(USA)	Research Needs in Fire and Smoke Control
CIB/CTF 72/37(USA)	Operation BREAKTHROUGH—A discussion of the Criteria for Fire Safety
CIB/CTF 72/38(USA)	Development of a Heat Release Rate Calorimeter at NBS
CIB/CTF 72/39(USA)	Fire Spread potential of ABS Plastic DWV Pipe Installation
CIB/CTF 72/40(USA)	A method for the measurement of smoke and HCL evaluation from polyvinyl chloride
CIB/CTF 72/41(J)	Fire resistance design for steel structures
CIB/CTF 72/42	Review of Research

GROUP 1—Fire Endurance

Chairman: Mr. Malhotra
Secretary: Professor Williamson

The discussion covered three categories: the properties of concrete at high temperatures, the spalling of concrete, and the correlation of furnaces for heat transfer.

1. The Properties of Concrete at High Temperatures

Each member of the group gave a brief summary of work in this field being undertaken in his country. It was clearly evident from reviews of work in various countries that the use of computer analysis of fire behavior of structures has led to a need for more information. It was suggested that full interchange of information would be necessary to gain maximum benefit of work presently underway.

T. Z. Harmathy (U.K.) gave a description of the relative importance of the diffusion theory, the capillary flow theory, and the evaporation-condensation theory in explaining the moisture movement in cement paste under applied thermal fields [Ref. 71/22 (C)] and an assessment of the thermal properties of concrete based on both theoretical considerations and some experimental data [Ref. 70/48 (C)]. Prof. Pettersson (Sweden) raised the question of accounting for the strong dependence of the rate of dehydration on heating rate. Mr. Harmathy responded that a compromise was made using an average value, for example, 5 C/min. He noted that a Scanning Differential Calorimeter (SDC) has been developed which might be a useful tool.

A paper on corrosive effects of fire products of PVC on reinforced concrete (at room temperature), document 72/4 (D), was highlighted by Mr. Becker (Germany). The problems appear to apply mainly to facilities which store large amounts of PVC. Recommendations are made for inspecting a suspected structure.

Sven Thelandersson (Sweden) reviewed "Effects of High Temperatures on Tensile Strength of Concrete," [Ref. 72/47 (S)]. The tensile strength of concrete decreases with increasing temperature, with the most rapid deterioration between 300–600 C. At 600 C the tensile strength is only 20-to-30% of the room temperature strength. The residual tensile strength immediately after cooling is somewhat lower than the strength in the hot state, and it was found that the *residual tensile strength of air-cured specimen continued to decrease for some days and weeks following the heating*. The point was made that values of residual strength determined immediately after cooling should not be used to estimate the load-bearing capacity of concrete structures exposed to fire.

2. Spalling of Concrete

Mr. H. L. Malhotra (U.K.) reviewed results of a questionnaire to determine the experience of laboratories with spalling (Ref. 72/30).

Mr. Meyer-Ottens (Germany) presented a summary of his dissertation on spalling. This is a complete study that includes new theoretical considerations, extensive laboratory experiments, and field analysis of spalling in actual fires.

The group discussed spalling. It was emphasized that a rational design methodology should be formulated aimed at prevention of spalling. Since understanding had reached a stage where possible methods of prevention could be presented to the advanced design community, a special symposium on spalling was discussed, and it received strong support of the group.

Working Group 1 recommended that a special symposium be sponsored on *Spalling of Concrete* to be held at the next meeting of the commission.

3. Correlation of Furnaces for Heat Transfer

Dr. J. van Keulen presented a progress report on the cooperative program to compare the heat transport process in different laboratories. The program is aimed at measuring heat influx into a test specimen of refractory "sillimanite" for two emission coefficients. The plan is to measure the coefficient of heat transfer by convection and an average furnace emissivity (ϵ). The comparisons will yield a correlation between fire resistance tests run with different fuels, ventilation, thermocouple and burner locations, and control procedures.

Dr. v. Keulen noted that there were unexpected difficulties in performing the calculations on the raw data. The possible reasons for this were discussed, and the most important appears to be an unexpectedly large variability within any one furnace. Another problem is the loss of the gold reflective film in some furnaces.

"A Heat Balance Analysis of the Standard Fire Endurance Test" (Ref. 72/22) was presented by Prof. Williamson (U.S.A.). Furnace heat transfer was evaluated by using commercially available calorimeters and radiometers, and the heat absorbed by the wall test specimen estimated. A discussion followed on the effect of making these measurements with a water-cooled instrument and the correction for the reradiation of the specimen followed.

Mr. G. Bellisson (France) reviewed "Note sur Le Reglage de La Puissance calorifique des Fours de Resistance au Feu" (Ref. 72/31), in which a spiral calorimeter was used to measure the total heat flux in the test furnace. An informal cooperative program evolved from these discussions.

Other papers included "The Safety Problem of Fire-Exposed Steel Structures—An Application of the Monte-Carlo-Method" by S. E. Magnusson, which presented a probabilistic approach, and "A Fundamental Study of the Structural Behavior and Load-bearing Capacity of Statically Undeterminate Reinforced Concrete Slabs Exposed on One Side to Fires" by Y. Anderberg.

GROUP 2—Smoke and Toxic Gases

Chairman: Dr. A. Robertson
Secretary: Mr. G. Shorter

A questionnaire related to fire deaths, proposed at the 9th meeting of CIB Commission W-14 was discussed, and it became evident that preparation of such a questionnaire was a most difficult task. Dr. Fristrom of the Applied Physics Laboratory/The Johns Hopkins University (U.S.A.) described a project supported by the National Science Foundation. Through cooperation with the State of Maryland Medical Examiner, autopsies are performed in cases of fire deaths occurring in the State of Maryland. In addition to pathological examinations, samples of materials involved in a fatal fire are obtained where possible and analyzed, and the fire scene is studied by a skilled investigator to obtain as complete a picture as possible of the circumstances surrounding a fire death.

Dr. Robertson (U.S.A.) stated that two complementary studies had been undertaken in the U.S.A. The first is the development of fire injury experience, by the U.S. Department of Health, Education, and Welfare with the data developed being analyzed by the National Bureau of Standards under the Flammable Fabrics Act. The second study, under the Fire Research and Safety Act, involves a contract to the N.F.P.A. to carry out investigations in depth of selected fires.

Dr. Fristrom cited two other related projects in the U.S. One is at the University of Utah, supported by the National Science Foundation, under Prof. Einhorn. This study utilizes animal experiments to inquire into nerve and lung damage. The second, by the U.S. Navy, is investigating effects of smoke on small primates.

Members of the group cited legal difficulties in obtaining medical reports of fire deaths. Several members were of the opinion that emphasis should also be placed on studies of actual fires concerned with finding out why people failed to escape as well as studies related to the medical causes of death. Mr. Tofp stressed that studies into fire death should also be concerned with long-term effects of exposure to smoke and gases as opposed to immediate death. Mr. Fry suggested that there should be a greater degree of correspondence between workers in this field.

It was agreed that because of the complexity of the "fire casualty problem" it is premature to prepare a questionnaire concerning the causes of fire death. However, workers in this field should be encouraged. It was suggested that these workers should not only correspond but circulate documents describing the work.

Documents 70/54 (UK) and 71/4 (UK) describe smoke studies undertaken in a tunnel in Glasgow, Scotland, undertaken in cooperation with the Glasgow Fire Brigade, which have provided information concerning the movement and density of smoke both in a confined space and under a canopy. Studies confirmed that a small fire can produce a "smoke logged" situation very quickly in a "mall" or "tunnel."

Col. Cabret (France) described similar studies at the Champs Sur Marne laboratories using the ground floor corridor of a tall experimental building. The height of smoke layers under various ventilation procedures were studied.

Dr. Robertson (U.S.A.) suggested the use of thermal and/or mathematical models for studying the smoke problem. Several members emphasized the need for supplementing model studies with full scale studies.

Paper 72/15 (USA), introduced by Dr. Robertson, dealt with North American smoke production tests. A number of members emphasized the fact that limitations on the smoke production of building materials were only part of the problem. Consideration must also be given to the furnishings and methods for the control of smoke movement. Col. Cabret (France) pointed out that studies related to people's reactions in fire were also very important.

Dr. Harmathy (U.K.) briefly outlined "Factors in Controlling Smoke in High Buildings" (Ref. 71/19 (C)). The factors considered were smoke production, time for evacuation, and stack effect. Smoke control measures must be effective under all climatic conditions.

A review paper, 72/25 (USA), "Toxic Atmospheres Associated with Real Fire Situations," introduced by Dr. Robertson, concerned environmental information of importance to the fire services. It is desirable that methods be developed to provide fire fighters with an indication of the presence of hazardous gases. However, there are so many types of hazardous compounds and mixtures of them that the development of a warning device will not be simple. Col. Cabret (France) stated there were two problems: building occupants and fire fighters. Mr. Becker (Germany) and others broke the problem into two major parts: a) residential and office buildings and b) industrial plants.

Paper 72/33 (UK), "Formation of Nitrogen-Containing Products from the Thermal Decomposition of Flexible Polyurethane Foams," pointed out that this plastic depolymerizes at low temperatures, e.g., 200–300 C, yielding toluene diisocyanate, which contains most of the N in the material. The isocyanate is stable to 700 C. At 1,000 C HCN is liberated. Dr. Høyland (Norway) described similar experiments using air. Here less HCN is evolved than with inert atmospheres. In summary, the group agreed that the situation as represented in the Norwegian experiment would be more typical of conditions in building fires. Although HCN is not produced in large quantities under such circumstances, oxides of nitrogen will be produced which may still pose a problem. On the other hand, it was agreed that situations could arise in building fires where polyurethane might be pyrolyzed in an inert atmosphere.

The Building Research Institute of Japan Research Paper No. 46, "Calculation of Smoke Movement in Buildings," described an analytical approach using computer techniques for smoke protection design systems. The authors assumed that knowledge had been achieved on adequate dimensions of exitways and that a practical state had been reached in knowledge concerning (a) smoke generation from materials, (b) temperatures in burning compartments, and (c) smoke concentrations allowable for the escape of occupants.

The problem becomes one of calculating the smoke flow in buildings. Unfortunately, there was no Japanese delegate, and discussion of this interesting paper was limited.

Mr. Fry introduced 71/9 (UK) F. R. Note No. 856, "Fire Problems of Pedestrian Precincts, Part I: The Smoke Production of Various Materials." A central corrugated steel shed between two brick buildings was used to represent a pedestrian mall. This shed was 24 m long, 9 m wide and 7-1/2 m high. The brick buildings simulated stores opening on to an open-ended mall. The purpose was to compare results of laboratory tests of material with behavior in fire experiments. Discussion followed.

Mr. Fry introduced the final paper, 72/8 (UK) F. R. Note No. 875, "Some Notes on the Control of Smoke in Enclosed Shopping Centres." He stated that it had been prepared to answer some questions which had been asked concerning means of coping with smoke in enclosed shopping centers. It would appear that the most effective way of dealing with this problem would be to remove the smoke from the fire-involved shop. The discussion which followed centered on the use of sprinklers in such complexes for alleviating the smoke problems. Col. Cabret (France) and Mr. Becker (Germany) cited various tests which they had observed whereby sprinklers did not alleviate the smoke problem but aggravated it in some cases. Mr. von Sante stated that a model study was being conducted in the Netherlands concerned with determining the effect of sprinklers on a fire in a large warehouse containing polyethylene beer cartons. In summary, the group extended thanks to J.F.R.O. for this pioneer paper regarding an engineering approach to smoke control in enclosed shopping centers. The group would encourage research into the effectiveness of sprinklers in reducing smoke problems.

Col. Cabret suggested that an International Symposium might be held dealing with aspects of the smoke problem during building fires. The group agreed to submit a recommendation to CIB W-14 asking that consideration be given to organizing an international symposium on "Smoke and Toxic Gases in Buildings."

GROUP 3—Growth of Fire

Chairman: Dr. P. Thomas
Secretary: Mr. Gross

A report of the first cooperative series on fully developed fires, incorporating comments from the cooperating laboratories, has been completed. It will appear shortly as a Fire Research Note (U.K. Building Research Establishment).

A preliminary report on the second cooperative series on fire growth in a compartment has been prepared by Mr. Heselden and Mr. Melinek as "The Results of an International Cooperative Research Programme on the Early Stages of Fire Growth in a Compartment," April 1972, CIB/CTF 72/49 (UK). Over the range of the experiments t_3, the time at which flaming had spread over the top of all the fuel (a) did not differ significantly between the two shapes of compartments, (b) depended to a small extent on continuity of fuel and ventilation opening, and (c) depended to a much larger extent on all the other effects, principally stickspacing, position and area of ignition source, fuel height, and lining. Although the overall effect of the combustible lining was not too great, in certain situations appreciable differences were noted. Supplementary tests by one laboratory with different linings suggested that a correlation with the thermal properties and a flame-propagation index would be worth exploring further. Other supplementary experiments by FMRC suggest scale effects may not be very large. Considerable differences between laboratories in the initial rates of fire spread up to 100 percent were noted.

There is clearly a major need for more basic studies in this field. It was thought desirable to identify some of these needs and Dr. Thomas agreed to initiate the preparations of a note on this on behalf of the group.

Mr. Keough discussed CIB/CTF 71/10 (CA) and 72/32 (CA) regarding the fire performance of carpeting. Based on furnace fire exposure tests, it was concluded that there was as little likelihood of fire spread under a closed door for medium- and short-pile carpeting as for tile and sheet flooring. Also, there did not appear to be a significant fire hazard from fires spreading along floors with or without floor coverings, but the nature and rate of spread differed according to the direction of airflow over the floor. Similarities exist between fire spread in corridors and that in ducts; certain general features are amenable to theoretical studies.

Mr. Smith (U.S.A.) discussed two papers by Dr. Tewarson, CIB/CTF 72/17 (USA) and CIB/CTF 72/19 (USA), emphasizing fire behavior in compartments at relatively low levels of ventilation with reference to gaseous combustion products and application of data for prediction of gas concentrations in large rooms. FMRC plans to extend the program to full-size rooms and relate the results to the toxic effects on animals and humans.

The work was related to the discussions in Group 2: it would be advantageous to compare these combustion-product concentrations with those in the earlier enclosure tests with the aim of developing a generalized combustion model.

Mr. Magnusson (Germany) and Mr. Thelandersson (Sweden) presented a discussion of two papers dealing with analytical prediction of fire growth in an enclosure based on a heat balance model. The model was checked out using data from 30 full-scale tests in Sweden, Japan, and U.K. A generalized computer program was developed for computing time-temperature-varying properties of the materials forming the surrounding structure. The authors offered to make the computer program available on request either in ALGOL or (shortly) in FORTRAN.

In a discussion of the use of wood cribs to represent the basic fire load, it was not noted that work has been started in Germany to relate the burning rates for plastics with wood. Mr. Nilsson has also looked into the question of the effect of plastic wall linings on the burning rate of wood cribs and the interactions due to oxygen deficiency.

Groups engaged in taking fire-load surveys should be encouraged to include important physical factors relating to the building and contents (e.g., ventilation area, surface area).

Mr. Nilsson described a series of model studies involving cubical compartments of three sizes. The parameters investigated included ventilation factor, crib porosity, wall linings, and fire loads. A discussion followed on the design and use of wood cribs and the choice of parameters suitable for relating the burning behavior of cribs and actual furnishings.

The need to look at recent advances in our knowledge of crib behavior would help to extend the usefulness of this work. Knowing how cribs behave in hot and vitiated atmospheres is necessary to interpret experimental data and confirm that cribs can represent building contents.

Mr. Gross (U.S.A.) presented a summary of paper CIB/CTF 72/29 (USA) on the definition of a low-intensity fire. This involved characteristics of wastebasket and upholstered chair fires. Such studies may be useful for evaluating detectors and sprinklers, and also that these two fires represent part of the complete spectrum of fire exposures from which a probabilistic analysis of fire incidence and fire growth could be developed.

Prof. Williamson (U.S.A.) discussed his paper CIB/CTF 72/23 (USA) on quantitative measures of combustibility and noncombustibility. He raised several technical and philosophical questions on the rational basis for building design of interest to the whole Commission's discussion of the principle safety. After discussing the São Paulo fire, the group emphasized the need to translate existing technical knowledge on fire performance of materials into the legal requirements of building codes. More interchange between fire research organizations' architects and engineers and building-regulatory officials would be desirable, treating the whole fire protection system together so that detectors and sprinklers could not be divorced from such discussions.

International Fire Protection Engineering Institute—Sponsored by University of Maryland, N.F.P.A., and T.B.B., College Park, Maryland (October 10-15, 1971)

Mr. Walter Haessler (Rolf Jensen and Associates, Inc., Chatham, New Jersey), "Combustion, Ignition, and Suppression Phenomenon"

Dr. Robert Fristrom (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland), "The Chemistry of Combustion"

Dr. Robert W. Van Dolah (U.S. Bureau of Mines, Pittsburgh, Pennsylvania), "Explosions, Detonations, and Explosive Behavior of Materials"

Mr. Denis J. A. Debuchy (Assurances Nationales, I.A.R.D., Paris, France) "Combustion and Fire Research in Europe"

Mr. Hans G. A. Laufke (Svenska Brandforsvarforeningen, Stockholm, Sweden), "Combustion and Fire Research in Europe"

Dr. Howard W. Emmons (Harvard University, Cambridge, Massachusetts), "The Free Burning Fire"

Dr. William J. Christian (Underwriters' Laboratories, Inc., Northbrook, Illinois), "The Flashover Phenomenon and Significant Parameters"

Mr. Calvin H. Yuill (Southwest Research Institute, San Antonio, Texas), "Flame Spread Evaluation of Materials"

Dr. A. F. Robertson (National Bureau of Standards, Washington, D.C.), "The Development, Similarities, and Differences in North American and European Fire Test Methods"

Dr. John A. Rockett (National Bureau of Standards, Washington, D.C.)—Tour Relative to the Office of Fire Research and Safety

Mr. Irwin A. Benjamin (National Bureau of Standards, Washington, D.C.)—Tour Relative to the Fire Research Section, Building Research Division

Dr. Joseph E. Clark (National Bureau of Standards, Washington, D.C.)—Tour Relative to the Fabric Flammability Section

Mr. John L. Jablonsky (The American Insurance Association, New York, N.Y.), "The Building Code and Fire Protection of the Structure"

Mr. Hank Collins (Underwriters' Laboratories, Inc., Arlington, Virginia), "The Underwriters' Laboratories, Inc., and the Fire Performance of Materials"

Professor Francis L. Brannigan (Montgomery College, Rockville, Maryland), "Empirical Evaluation of Building Construction"

Mr. William H. Haak (Langeveldt de Vos de Waal, Amsterdam, The Netherlands), "Building Codes and Standards in Europe"

Mr. Pekka Oksanen (The State Institute for Technical Research, Otaniemi, Finland), "Building Codes and Standards in Europe"

Mr. Thorsten S. Prossdorf (Allianz Versicherungs, A.G., München, Germany), "Building Codes and Standards in Europe"

Dr. John L. Bryan (University of Maryland, College Park, Maryland), "Human Behavior Factors and Fire Protection in Buildings"

Mr. Richard E. Stevens (National Fire Protection Association, Boston, Massachusetts), "The Fundamentals of Exit Requirements"

Mr. Larry G. Siegel (United States Steel Corporation, Monroeville, Pennsylvania), "Fundamental Principles and Fire Protection Design of Buildings"

Mr. Harold E. Nelson (General Services Administration, Washington, D.C.), "The Measurement of the Smoke Production of Materials"

Dr. Arthur E. Bamert (Brandverhutungsdienst für Industrie und Gewebe, Zurich, Switzerland), "European Building Fire Problems"

Mr. Gerhardus Bayle (Amsterdam-Rotterdam Bank Assurantien, Amsterdam, The Netherlands), "European Building Fire Problems"

Mr. Anton De Vries (Nederlandse Onderlinge, Groningen, The Netherlands), "European Building Fire Problems"

Mr. W. Robert Powers (New York Board of Fire Underwriters, New York, N.Y.), "The High-Rise Building Fire Problem"

Mr. John H. McGuire (National Research Council of Canada, Ottawa, Canada), "Smoke Control in High-Rise Buildings"

Mr. M. Galbreath (National Research Council of Canada, Ottawa, Canada), "Variables of Evacuation in High-Rise Buildings"

Mr. Rudolf J. den Boer (M. van Marle, N.V., Rotterdam, The Netherlands), "The High-Rise Building Fire Problem in Europe"

Mr. Cornelis J. Vlugt (D. Hudig & Company, Rotterdam, The Netherlands), "The High-Rise Building Fire Problem in Europe"

Mr. Anthony R. O'Neill (National Fire Protection Association, Washington, D.C.), "The Federal Government and Industrial Fire Protection"

Mr. Richard E. Wiberg (National Aeronautics and Space Administration, Greenbelt, Maryland), "A Procedure for Determining Detector Location"

Mr. William H. Everard (Alexandria Fire Department Headquarters, Alexandria, Virginia), "Signalling and Communication Systems"

Mr. Hans Gfeller (Swiss Reinsurance Company, Zurich, Switzerland), "Fire Detection Systems in Europe"

Mr. Jan van Katwijk (R. Mees & Zoonen Assurantien, Rotterdam, The Netherlands), "Fire Detection Systems in Europe"

Mr. George J. Grabowski (Fenwal Incorporated, Ashland, Massachusetts), "Explosion Suppression Systems"

Mr. Harry A. van Hoboken (De Grinnel N.V., The Hague, The Netherlands), "Suppression System Developments in Europe"

Mr. Wilhelm E. H. Grimm (Münichre Insurance Company, München, Germany), "Suppression System Developments in Europe"

Dr. Richard L. Tuve (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland), "The Theory of Extinguishment and the Principles of Fire Suppression: Particles, Fluids, and Gases"

Mr. Donald J. Keigher (Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico), "Suppression System Design for Unique Areas"

Mr. Reginald J. Wright (Underwriters' Laboratories of Canada, Scarborough, Ontario, Canada), "Suppression System Applications and Developments: Dry Chemical Systems"

Mr. Robert L. Darwin (U.S. Naval Materiel Command, Washington, D.C.), "Aqueous Film Solution Systems"

Mr. Knut Dessingthon (Forsikrings-Aktieselskabet Norden, Oslo, Norway), "Suppression Agent Research in Europe"

Dr. Derk F. Nijhoff (Gebrs. van Buren, Rotterdam, The Netherlands), "Suppression Agent Research in Europe"

Mr. Edwin J. Jablonski (U.S. Naval Research Laboratory, Washington, D.C.), "Suppression System Applications and Developments: Foam Systems"

Mr. Elmer M. Wetmore (Kemper Insurance Company, Chicago, Illinois), "Carbon Dioxide Systems"

Mr. James M. Hammack (National Fire Protection Association, Boston, Massachusetts), "High-Expansion Foam Systems"

Professor Rolf H. Jensen (Illinois Institute of Technology, Chicago, Illinois), "Halogenated-Agent Systems"

Mr. Allan E. Sheppard (Factory Mutual Engineering Corporation, Norwood, Massachusetts), "High-Rack-Storage Fire Problems"

Mr. Wilbur L. Walls (National Fire Protection Association, Boston, Massachusetts), "Flammable Gas Problems in Industry"

Mr. C. F. Hedlund (Factory Mutual Research Corporation, Norwood, Massachusetts), "Industrial Electrical Hazards"

Mr. Arthur Spiegelman (American Insurance Association, New York, N.Y.), "Fire and Explosion Problems in Chemical Plants"

Mr. Miles E. Woodworth (National Fire Protection Association, Boston, Massachusetts), "Industrial Process Hazards and Flammable Liquids"

Mr. A. Richard Albrecht (The Dow Chemical Company, Midland, Michigan), "An Analytical Approach to Industrial Hazards"

Mr. John J. Ahern (General Motors Corporation, Detroit, Michigan)—Tour of the General Motors Assembly Division Plant, Baltimore, Maryland, and "Industrial Fire Protection Organization"

Mr. William L. Hanbury (National Aeronautics and Space Administration, Washington, D.C.), "Housekeeping and the Industrial Fire Problem"

Mr. Jack S. Barritt (Factory Insurance Association, Hartford, Connecticut), "The 'Highly Protected Risk' Concept and Philosophy"

Mr. Dietrich Beenken (Colonia National Versicherung AG, Köln, Germany), "The Insurance Industry and the European Fire Problem"

Mr. Jean Feron (Compagnie des Proprietaires Reunis, Bruxelles, Belgium), "The Insurance Industry and the European Fire Problem"

Professor Harry E. Hickey (College of Engineering, University of Maryland, College Park, Maryland), "Water Supply Analysis" and "Hydraulic Balanced Design of Automatic Sprinkler Systems"

Mr. Reinier P. F. Nahon (Nagtgas Versteeg, Amsterdam, The Netherlands), "Water Supply Design and Requirements in Europe"

Mr. Svein G. Stubberod (Storebrand, Oslo, Norway), "Water Supply Design and Requirements in Europe"

Mr. Joseph I. deBecker (American International Underwriters, S.A., Brussels, Belgium), "Water Supply Design and Requirements in Europe"

Mr. David M. Hammerman (Office of the Fire Marshal for the State of Maryland, Baltimore, Maryland), "Types of Automatic Sprinkler Systems"

Mr. Abraham Houdkamp (Nagtglas Versteeg, Amsterdam, The Netherlands), "European Experience and Standards for Automatic Sprinklers"

Mr. Peter Kirchhoff (Dansk Tarifforening, Kobenhavn, Denmark), "European Experience and Standards for Automatic Sprinklers"

Mr. Dieter Schwarzwalder (American Foreign Insurance Association, Brussels, Belgium), "The European Concept of the 'Highly Protected Risk' "

Mr. Carl E. Peterson (National Fire Protection Association, Boston, Massachusetts), "The Public Fire Problem"

Mr. James W. Kerr (Support Systems Division, Office of Civil Defense, Washington, D.C.), "Critical Factors in Large Scale Fires"

Mr. Terry C. Hayes (Shreveport Fire Department, Shreveport, Louisiana), "Fire Prevention and the Fire Problem"

Dr. G. Magnus (Chief of City Fire Service, Mannheim, Germany), "The Public Fire Problem in Europe"

Mr. Pieter H. van Veen (Tollenaar and Wegener, Amsterdam, The Netherlands), "The Public Fire Problem in Europe"

Mr. Charles H. Steel (Fire Department Chief, Annapolis, Maryland)—Tour of Annapolis, U.S. Naval Academy

Mr. Harry W. Klasmeier (Chief of Anne Arundel County Fire Department, Millersville, Maryland)—Tour of the Fire Department Facilities, Demonstrations, and Buffet Supper

Mr. Derrick A. Hancock (Department of Works, Commonwealth of Australia, Hawthorn, Victoria, Australia), "The Australian Fire Problem"

Mr. Donald L. Drumm (American Insurance Association, New York, N.Y.), "The American Insurance Association Evaluation of Public Protection"
Mr. David B. Gratz (Chief of Silver Spring Fire Department, Silver Spring, Maryland), "The Organization of Public Protection"
Dr. Edward H. Blum (New York City Rand Institute, New York, N.Y.), "Operations Research and the Public Fire Department"
Mr. Harvey G. Ryland (Public Safety Systems, Inc., Santa Barbara, California), "Systems Engineering and Fire Department Communications"
Mr. Erik J. Saro (Omsesidiga bolaget Industriforsakring, Helsinki, Finland), "The Organization of Public Fire Protection in Europe"
Mr. Oscar Vandevelde (Royale Belge, Brussels, Belgium), "The Organization of Public Fire Protection in Europe"
Mr. Robert H. Merz (Middle Dept. Association of Fire Underwriters, Philadelphia, Pennsylvania), "The Insurance Rating Schedule and Fire Protection"
Mr. Alan I. Gomberg (The Travelers Insurance Company, Hartford, Connecticut), "The Insurance Company and Fire Protection"
Dr. John L. Bryan (College of Engineering, University of Maryland, College Park, Maryland)—Summary and Conclusion

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National Science Foundation Fire Research Program—RANN—Contractors Meeting, Applied Physics Laboratory, The Johns Hopkins University (June 22–23, 1972)

"RANN Fire Research Program," R. H. Long (National Science Foundation)

The objectives of the NSF program of Fire Research are to provide improved understanding of the mechanisms of fire ignition, combustion and spread, and of the flammability of fabrics; and to stimulate the development of technological advances in fire prevention, protection, and suppression.

Fire research efforts supported by NSF focus on understanding and reducing the flammability of structural materials, fluids, fuels, and fabrics. They also include studies on flame propagation mechanisms, fire suppression technology, and physical modeling of fire propagation, as well as research leading toward improved effectiveness of fire fighting systems.

In order to minimize damage due to fires in both existing structures and new facilities, it is necessary to understand the conditions required for ignition and the mechanism of fire spread. The potential hazards of combustion products to humans and to the structures must also be understood. NFS-supported research addresses these and related questions.

In FY 1973, the NSF Fire Research Program will strengthen its focus on fire problems of cities, and increased support will also be provided for problem-focused research that complements that of the Forest Service on forest fires as well as the fire research programs of the National Bureau of Standards and other federal and state agencies.

The correspondence between these objectives and the existing fire research projects may not be obvious in all cases. A little history may help to illuminate the current situation.

NSF has cooperated with the NAS-NRC Committee on Fire Research for many years and funded the 1961 Woods Hole Study of Fire Problems. About ten years ago the Engineering Section (now the Division of Engineering), in cooperation with the Committee on Fire Research, set aside funds for basic research proposals in an attempt to encourage more effort in universities. The response was not great, although several grants were made, and a modest support effort of four-to-six grants per year continued through FY 1971. In FY 1970 the Office of Interdisciplinary Research was formed and subsequently made fire research awards to Johns Hopkins University and the University of California, Berkeley. Early in 1971 the RANN program was established (the Office of Interdisciplinary Research was disestablished), and in May 1971 the existing grants (except for some near completion) and proposals under consideration were placed in the RANN program for administration, which provided the legacy for the fire research effort. The RANN program focuses on problem-oriented research. While the research may be basic or applied, the problem that is being addressed and its significance determine the research needs. In the evaluation of a proposal, a paramount consideration is the potential importance of the research findings, assuming successful completion of the project.

The peer-review method is used for a particular proposal. Reviewers comment on the quality and importance of the proposed program. We also solicit and receive advice from groups involved in fire problems, other federal agencies, technical societies, etc., in order to have an awareness of fire problems, as viewed by a concerned group. Thus a sense of priorities evolves and changes as greater knowledge is developed and the data base is improved. While the current program encompasses a fairly wide spectrum of activities, more worthwhile programs have been proposed than can be supported with the funds available or anticipated in the near future. The President's budget for FY 1973 contains $2.15 million for fire research. About $1.3 million has already been committed for ongoing programs. We won't know the true budget figure until after Congress acts on the appropriation bill.

In addition to providing support for specific research grants, a major need where NSF can play a special role is to develop a few teams of scientists and engineers who can look at a broad portion of the fire problem and maintain a special research and educational capability. Such teams or "centers" require fairly substantial support and could easily consume our budget. We won't let this happen, as we want a balanced program consisting of a few centers in different geographical locations and a greater number of more modest grants to qualified persons.

We are hopeful that this meeting will assist us in our effort to maintain a coordinated fire research effort. The communications value of such an open forum is obvious, particularly if there are frank discussions. I encourage you to interact both at this meeting and in the future in order to expedite your research. Furthermore I urge you to use your ingenuity to develop coupling links with industry, the fire service, and governmental groups where such arrangements may facilitate the research, as well as the transfer of research results to implementation.

"The Home Fire Project" Principal investigators: H. W. Emmons (Harvard University) and R. Friedman (Factory Mutual Research Corporation); staff: K. Min, T. Shen, P. Raj, C. Knight, S. Ubhayakar, F. Tamanini, D. D. Evans, R. Land (Harvard University, Cambridge, Massachusetts) and G. H. Markstein, R. L. Alpert, G. Heskestad, J. de Ris, A. M. Kanury, A. Tewarson (Factory Mutual Research Corporation, Norwood, Massachusetts) NSF Grant No. GI 30957—Combustion Research (Harvard) and NSF Grant The Home Fire Project (Approved; Number Not Yet Assigned)

At Harvard:

1. Pyrolysis Study

This "pyrolysis" study took the simple form of drying a porous medium by radiant heating of one open face. Both theory and experiment show that *all* evaporation occurs at a discontinuous moisture front which moves through the solid and that the moisture flows and diffuses out of the solid at the open heated face and diffuses against the flow further into the solid toward the closed cool face and condenses. Continuation of this work is directed toward finding out the extent to which wood pyrolysis occurs in the same manner. Much information is already available on the nature of pyrolysis products. Our efforts will be directed toward the dynamics and thermodynamics of pyrolysis.

2. Radiant Pyrolysis of Paper Sheets

The "pyrolysis" in air appears to occur at two first order rates. The dominant mode at low temperature appears to be a true pyrolysis but the variation of the radiant properties and the convective heat transfer coefficient mask any small heat of pyrolysis which may be present. The high temperature dominant mode has an exothermic heat of reaction of 360 cal/gm.

3. Transient Convective Flows in an Enclosure

At present, the subproblem of the transient flow out of an opening is under study both experimentally and theoretically. This will be followed by an attempt to clarify the entire dynamic and thermal mechanisms in an enclosure which account for and control fire growth.

4. Measuring the Extinguishment of a Crib by Water

Present effort concentrates on the cooling of the vertical shafts which are the primary control of the burning rate. The cooling water evaporates while flowing down a fiberglass sleeve surrounding the water supply tubes which stick up through the chimneys. This extinguishment study will be enlarged to include the direct effect of water on burning charcoal (perhaps also on a pyrolysing piece of wood), to find the mechanism of action, the extinction effect versus drop size, the absorption (if any), the bounce and splash (if any), the reheating, etc. Both theory and experiment will be attempted.

5. Rate of Destruction of a Home

A special analytical study will be made of the rate of destruction of a home by fire using the best empirical and analytical results currently available to find out what we do and do not understand and hence what additional work yet needs to be done.

At Factory Mutual Research Corporation:

1. Study of Radiation from Fire

The objective is to provide a useful quantitative basis for predicting radiative energy transfer from fires to neighboring fuel elements. This is an extension of a program started with internal funds by FMRC in May, 1971. The first phase, now under way, involves laminar gas-jet diffusion flames and has twin objectives: (1) determining total flame radiation as a function of burning rate, fuel type and geometry; (2) determining absorptivity of the flame for its own radiation, by using a linear array of identical flames (thus modeling a folded combustion zone of a turbulent flame). In this phase apparatus is now operative and calibrated, and the first data are being taken. The next phase will be concerned with turbulent flames of (1) gaseous fuels and (2) flames supported by plastics or wood. While total radiation measurements are emphasized, measurements in selected spectral ranges may be made with band filters. The needed instrumentation is available.

2. Pressure Modeling of Building Fires

The objective is to precisely model enclosure fire behavior by use of high pressure, including fire spread, steady burning, smoke movement, ignition of secondary objects, and, finally, flashover. If scale is varied inversely with the 2/3-power of pressure, Grashof number is preserved. Recent experiments in our laboratory and elsewhere (to be reported, 14th Combustion Symposium) provide confirmation that not only gas phase processes but interfacial processes, such as spread rates, as well as transient effects, may be modeled in this way. We will construct a pressure vessel of 10 times the volume of our present 7.5 cu ft vessel, operating up to 600 psi, and will determine validity of modeling home fire characteristics, including fire growth over scale model furniture, fire spread within a room, flashover, and smoke movement from room to room. The following interactions between the fire and its surroundings will be evaluated, using idealized enclosures and fuels: (1) the initial development of convective flow and build-up of radiation; (2) effect of recirculating combustion products on fire; (3) ignition of noncontiguous objects; (4) flashover. The design, construction, and instrumentation of the pressure facility will be the primary activity during the first year with experiments beginning before year end.

3. Atmospheric Modeling of Building Fires

The objective is to develop approximate atmospheric-pressure methods for modeling enclosure fires. A theoretical approach to modeling of fire in geometrically similar enclosures at constant pressure has been developed (to be reported, 14th Combustion Symposium). This is phenomenological in nature and requires confirmation beyond that already available from crib fires in two enclosures, one twice the scale of the other. In the first phase task, two similar inert enclosures will be built, one three times the scale of the other, with walls selected to model thermal properties, and wood cribs of varying weights and packing densities will be burned. Ventilation will be varied. Temporal variations in burning rates, major gas components, smoke, and temperature will be recorded. In a second phase, after the first year, fuel loads will be reduced from those used in the first phase to make convection time scales comparable to fire duration (instead of much smaller). In a third phase, both burning and non-burning wood elements will be placed in the same chamber and flashover phenomena will be studied, as affected by ventilation.

4. Large Scale Testing

The various tasks in this program seem quite diverse, but the ultimate goal is to understand fire behavior under realistic conditions. As an aid in tying the various tasks to this single goal, we are establishing a separate task—large scale testing. A test room will be constructed and instrumented in the first year. Two test series will be conducted, early in the second year and early in the third year. Tests will be designed and in part instrumented by participation of all project scientists, both Harvard and Factory Mutual. The test room would probably be furnished with real carpets, furniture, etc. The fire source might be a wood crib as studied in the previous task. Presumably all parameters measured in the various individual tasks would be measured here, where practical. Results should stimulate thought and insure relevance. The effort in this task would be controlled so that it will be the smallest of the four Factory Mutual tasks.

"Convective Flows under Conditions Applicable to Building Fires" Principal investigator: E. E. Zukoski; staff: J. B. Cannon (California Institute of Technology, Pasadena, California) NSF Grant No. GI-31892X

Uncontrolled fire spread in complex buildings is strongly affected by natural convection currents set up by the fire itself. Because buoyancy and density differences will strongly influence the mixing of hot and cold gases, and because the flow field is turbulent, it is not possible at present to predict the temperature, velocity, and density fields and the local heat transfer rates resulting from a building fire. The proposed work involves the investigation of the flow and temperature fields set up by natural convection under circumstances similar to those occurring in building fires, and in particular such that buoyancy and density-difference effects are large.

The first flow to be examined was that produced by the motion of low density material into the bottom of a vertical tube closed at the top and filled with a more dense fluid. This situation is related to motion of hot gas up a well-sealed stairwell. Initial experiments have been carried out with water-salt water mixtures so that complications introduced by heat transfer to walls could be avoided in the early experiments. Replacement of high density material in the tube occurs through a turbulent mixing process in which the largest scale coherent motion extends for no more than a few tube diameters. Scaling parameters are being developed, and work with gases and situations where heat transfer is important are being planned.

The second flow to be examined will be the turbulent mixing layer between two parallel strata which are hydrodynamically stable, have greatly differing densities, and a velocity difference such that buoyancy effects are important. The investigation will be primarily experimental, and apparatus is currently being constructed. The mixing regions to be investigated will include the classic turbulent mixing layer between two parallel streams with the additional complexity of large density differences and the presence of large buoyancy forces. In addition, a study will be made of the far field of this region, i.e., the region in which the mixing layer has reached a wall forming the upper boundary of the hot region. This flow will resemble a wall jet.

"Fire Propagation along Solid Surfaces" Principal investigators: F. A. Williams and P. A. Libby (Department of Applied Mechanics and Engineering Sciences, University of California, La Jolla, California) NSF Grant No. P2 I 3061-000

A research project has just been initiated on fire propagation along continuous surfaces of solid combustibles. Experimental measurements are planned for materials such as α-cellulose, polystyrene, and plexiglas. The surfaces will be flat. Propagation in directions varying from downward to horizontal will be studied. Initially, only propagation rates and radiant energy fluxes will be measured. Later plans call for velocity, temperature, and composition measurements. The objective is to ascertain first whether radiant, convective, or conductive heat transfer is primarily responsible for flame spread. A second but central objective of the work is to determine the importance of finite-rate chemical kinetics in flame spread. Consideration will be given to both condensed-phase pyrolysis kinetics and gas-phase diffusion-flame kinetics. It is primarily in connection with this last subject that temperature and composition measurements are needed. Theoretical studies are planned to complement the experimental work. Theoretical calculations of flame-spread rates are intended. In particular, one-step reaction hypotheses will be combined with the assumption of a high overall activation energy to take advantage of asymptotic methods for calculating the effects of finite-rate chemistry on flame spread.

"Flame Spreading over Solid Surfaces" Principal investigator: M. Sibulkin; staff: C. Lee and A. Hansen (Brown University, Providence, Rhode Island) NSF Grant No. 31893X

This investigation, which is in its initial phase, is a study of flame spreading on individual solid fuel elements. Although it is generally understood that there must be feedback of energy from the flame to the unburned fuel for a fire to propagate, quantitative information on the details of the energy feedback processes is needed. The basic experimental configuration being studied is a cylindrical rod of diameter d mounted at an angle θ to the horizontal. Measurements are made for both downward burning (negative θ) and upward burning (positive θ). This experimental arrangement is similar to that specified in a number of small scale flammability tests, and a long range objective of our work is to obtain a more rational method of rating material flammability.

Burning has been studied for rods of wood (maple dowels) and of both extruded and cast polymethylmethacrylate (PMMA). It was found that for wooden rods, flame propagation could only be maintained for θ greater than a critical positive value which increased with the rod diameter. While PMMA rods burn at all values of θ, it was found that extruded rods burn in a dripping mode while cast rods are completely consumed. Because of its complete burning and the reproducibility of the data obtained, cast PMMA rods were chosen for systematic measurements of the (steady) rate of spread V as a function of diameter ($d=1/8''$ to $1/2''$) and orientation ($\theta=-90°$ to $+40°$). For fixed d, V increases monotonically with θ; for fixed θ, V decreases with increasing d. The curves are not parallel, however, with the effect of θ decreasing at smaller values of d.

The average length of the pyrolysis zone $\bar{l}$ has been measured. A study of $\bar{l}/d$ versus θ shows geometrical similarity for negative values of θ but not for positive values of θ, illustrating the danger of generalization from a restricted range of data.

Preliminary measurements of surface temperature T_s exhibit a steep gradient in the vicinity of the leading edge of the pyrolysis zone, showing that the temperature is not constant on all of the burning surface. This result is similar to that found in the burning of paper strips. However, for vertically downward burning the extension of the flame below the visible edge of the pyrolysis zone was significantly less than for paper strips.

Future experimental work will be directed to determining the magnitude and relative importance of heat transfer to the unburned fuel by conduction, convection, and radiation. An analytical study, using approximations suggested by the experimental results, will be undertaken to predict burning rates and criteria for fire extinguishment.

"Experimental Study of the Rate of Spread of Free Burning Fires in a Fine Fuel"

Principal investigator: A. S. Campbell; staff: B. Giguere (Department of Mechanical Engineering, University of Maine, Orono, Maine) NSF Grant No. GK 3764

This project is designed to observe what happens when filter paper burns and, more specifically, to determine the influences of paper thickness and initial temperature on rate of spread.

Rates of spread have been measured for two configurations: downward propagation (both edges inhibited) and horizontal propagation (bottom edge inhibited, top edge exposed). Thickness is varied by glueing sheets together. Initial temperature is varied by external heating. Temperature is measured at the mid-point of thickness. Reproducibility of results is quite good; the uncontrolled factors are variations in surface density and surface roughness.

Data have been correlated using the theoretical result of de Ris and of Magee and McAlvey for rate of spread V_n normal to the burning front;

$$\rho c \tau V_n/k_g \approx (T_f - T_p)/(T_p - T_0)$$

here ρ, c and τ refer to the paper. Conductivity of the gases between flame and paper surface is k_g. T_f is flame temperature, T_p ignition temperature, T_0 is initial paper temperature. Using constant values for T_f, T_p and k_g, results show a pronounced influence due to thickness τ.

Interpreting the equation as a proportionality between heat transfer from flame to paper surface, and heat absorbed by the paper, T_p in the denominator is replaced by T_{ave}, the average temperature between surface and center.

$$\rho c \tau V_n / k_g \approx (T_f - T_p)/(T_{ave} - T_0)$$

To evaluate T_{ave}, we find that the centerline temperature rises linearly with time as the flame front passes over the thermocouple. Denoting the heat flux from the flame as q_f,

$$q_f = \tfrac{1}{2}\rho c \tau (\Delta T/\Delta t)_L$$

the last factor is the measured rate of temperature rise. The temperature distribution between the center and surface of the sheet is then parabolic, and

$$T_{ave} = T_p - (\tau q_f / 6k)$$

so that k, thermal conductivity of the paper, which is absent in the theoretical treatment of thin fuels, enters the analysis.

The resulting correlation is quite good. The discrepancy between vertical and horizontal burning is attributed to convective heating ahead of the flame for the latter.

A simple relationship exists between heat flux from the flame, q_f, and rate of spread, V_n,

$$q_f \approx \log V_n.$$

The experiments cover a three-fold variation in q_f. However, we do not observe at the leading edge of the flame differences in shape, color, or stand-off distance which would account for the range of calculated q_f values.

Using filter paper, we plan to examine the rate of spread in a fuel bed made with sheets standing on edge, with spread taking place from sheet-to-sheet. This arrangement duplicates the work of Emmons and Shen, but the direction of spread is across, rather than along, the sheets.

"Study of Hazards from Burning Apparel and the Relation of Hazards to Test Methods" Principal investigators: W. Wulff and N. Zuber; staff: P. Durbetaki, A. Alkindas, R. W. Hess, W. E. Giddens, E. R. Champion, Jr. (School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia) NSF Grant Nos. GK 27189 (1971) and GI 31882 (1972)

The probability of fabric ignition under given exposure depends on the ratio of fabric ignition time to exposure time; hence the ignition time is an important characteristic required to assess the hazards of fabric-related burn injuries. An experimental and analytical program is being carried out to predict the fabric ignition time as function of exposure parameters and fabric properties.

Of the possible ignition sources radiative ignition was investigated first because the radiative source is most reproducible and free of chemical interaction with the igniting material. Gas flame ignition studies have been initiated.

The objective of the experimental phase is two-fold: first, to measure the ignition times of a selected set of cotton, nylon, polyester, acetate, and wool fabrics and blends, at well defined exposure and fabric conditions; secondly, to measure, on the same fabrics, the thermophysical properties which characterize the ignition process. The properties are the thermal conductance, the specific heat, the mass per unit area, the ignition or melting temperature, the optical properties infrared reflectance and transmittance, and the reaction kinetic parameters activation energy, pre-exponential factor and reaction enthalpy. During the first program period reported, ignition time was measured under radiative fabric heating, and all of the properties were measured, except the reaction kinetic parameters.

The objective of the analytical phase is to predict fabric ignition time as a function of fabric properties and exposure conditions. A complete modeling analysis is being performed to establish the modeling rules necessary for the prediction of fabric ignition time. Partial modeling rules are developed, and error estimates appropriate for partial modeling are derived. Modeling experiments are specified which are required to predict ignition time.

The experiments indicate that:

(1) only approximately 20% of radiative heat is absorbed in a single layer of the above listed fabrics;
(2) ignition time depends strongly on chemical reactions prior to ignition for cellulosic fabrics, but weakly for plastic polymers.

For the selected fabrics listed above the analysis has shown that under radiative heating and free convection heat losses:

(1) a lumped-parameter analysis is adequate to describe the ignition process and to predict ignition time;
(2) thermal conduction within the fabric is insignificant;
(3) the inert heating process leads to an ignition time proportional to the product of areal heat capacity and ignition temperature excess over initial temperature and inversely proportional to the radiative absorptivity;
(4) the proportionality coefficient implied in Item 3 increases with decreasing heating intensity;
(5) convective heat losses increase ignition time significantly;
(6) pre-ignition pyrolysis retards or prevents ignition, except at high-intensity heating.

The program is in its second year. Current program objectives are to determine qualitatively the effect of chemical reactions prior to ignition, including moisture ignition statistics, and to investigate flame ignition. The current program terminated November 1, 1972.

Future plans are to consider fabric assemblies and fabric body interaction.

"Flammability and Burn Potential of Fabrics"—Principal investigator: G. C. Williams; staff: H. C. Hottel, J. B. Howard, A. F. Sarofim, A. K. Mehta, A. S. Padia, F. K. Wong (Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Massachsetts) NSF Grant Nos. GI 31881 and GK 27188

The objectives are the development of the knowledge and measurement techniques needed to predict the burning characteristics and the potential for skin burn injury of clothing fabrics. The flammability study is concerned with prediction of flame propagation rates through fabric and the interaction of the fabric flame with the skin. The burn injury study is concerned with quantitative prediction of the extent of skin damage from measurements of the temperature history of skin simulants exposed to fabric fire.

Approach:

1. Fabric flammability. On the basis of experiments and observations on the effects of orientation, fabric spacing from simulated skin, fabric physical and thermal properties and heat transfer measurements, an attempt is being made to develop a mathematical model for flame propagation in burning cloth that will permit prediction of flame propagation rates and heat transfer to adjacent heat sinks, e.g. skin, from knowledge of the properties of the fabric.

2. Burn injury. An extension of the simple critical thermal history-at-a-critical-depth treatment of Henriques is being made. This extension provides allowance for different values of the frequency factor and activation energy for collagen denaturation and for thermal conductivity and heat capacity in the epidermal, dermal and subcutaneous fat regions of the skin as well as for variation with depth of the diathermancy of the skin and of the blood perfusion rate. With these changes the criterion for severity of burn damage then becomes that of achievement of a particular predicted value of the collagen denaturation (as determined from its temperature history) at a depth in the skin to which biopsy assays have demonstrated damage to occur.

Significant Findings:

1. An analytical solution for a Burke-Schumann type diffusion flame propagating over a cloth surface against an adverse convective velocity predicts the observed flame extension beyond the cloth pyrolysis zone and the convective velocity for flame extinction but cannot predict the correct flame shape.

2. A simulant of skin as a semi-infinite solid of uniform thermal properties has been developed with a depth-stretch factor of 28 for measurement of temperature histories of simulated skin at fractions of a millimeter below the surface.

3. Two criteria for prediction of skin energy have been tested against the earlier experimental data of the University of Rochester on pig burns.

   a. A criterion of a critical thermal dose, e.g., 1 cal/cm^2, of skin surface above a critical skin temperature of 55 C could be fitted to all of the data for burns of severity ranging from 1^+ mild to 3^+ severe (complete destruction of the dermis).

   b. A criterion of a particular degree of destruction of the tissue based on a kinetically controlled rate of tissue destruction at a given depth in the skin has shown promising results in preliminary comparisons with the Rochester data.

4. The effects of cloth weight, material, spacing from the skin, direction of burning and orientation with respect to the vertical, as well as that of combustion of underclothing, have been shown to alter markedly the degree of burn damage to skin underlying burning cloth.

5. There appears to be no char correlation between cloth burning rate and ensuing skin burn damage.

Status and Future Plans

1. Fabric fire.

It is proposed to check the validity of the flame extension model by burning fabrics and measuring the induced convective flow velocity using particle track flow visualization techniques. Upon successful completion of this phase of the work, extinction experiments will be conducted to test the correctness of the extinction criterion.

Once the range of values of variables has been demonstrated experimentally, it is proposed to treat the flame and its extension by using finite difference techniques for the solution of flow and diffusion equations in an attempt to predict a more realistic flame shape than can be expected from an attempt to force the shape into a form tractable for expression as an analytical function.

2. Burn Injury.

The heat transfer model for skin developed here will be tested to see if burn damage can be correlated by a depth criterion such that a damage integral approaches a fixed value for a particular severity of burn at a fixed depth in skin for all the thermal dose data available in the literature. Some of the flexible parameters for this data fitting are the frequency factor and activation energy of the damage rate process, blood flow rates, and the thermal properties of the different tissue layers within a limited range of reported values in literature. Since the critical energy criterion has showed favorable initial results, it will be further examined by means of a physical model in which, in addition to the transient conductive and convective heat transfer, a heat sink term for the latent heat of melting of collagen of the dermis is involved. Finally, the results of this damage criterion study, if favorable, would be applied to the problem of predicting severity of skin burns caused by clothing burning.

"Chemistry of Cellulosic Fires"—Principal investigator: F. Shafizadeh; staff: R. A. Susott, Y. Lai, M. H. Meshreki (Wood Chemistry Laboratory, University of Montana, Missoula, Montana) NSF Grant No. GI 33645X

The initiation and propagation of uncontrolled fires fueled by cellulosic materials such as vegetation, wood and cotton takes place through complex molecular transformations, resulting from the interaction of the fuel with energy and the environment. These pyrolytic transformations include conversion of cellulosic materials[1,2] to flammable, volatile products which support rapidly spreading flaming combustion, and formation of char and water by a competing pathway, which retards the combustion process.[3]

The approach taken for this project involves systematic unravelling of the complex reactions in order to find chemical methods for controlling the pyrolytic transformation and provide a scientific basis for coping with fire problems.

Cottonwood (*Populus trichocarpa*) was selected as a representative of complex cellulosic materials and analyzed to its major components consisting of cellulose, xylan, ligin, extractive and ash. Thermal and chemical investigation of these compounds showed their influence on the pyrolytic properties of the aggregate, with cellulose and xylan forming the major source of the volatile combustible products.[4]

Pyrolytic degradation of these polysaccharides could proceed either through the cleavage of the glycosidic bond or the decomposition of the sugar units. A variety of glycosides, the corresponding free sugars and 1,6-anhydro-β-D-glucopyranose (levoglucosan) were used as model compounds to investigate these reactions.

At lower temperatures these molecules displayed loss of water, breakage of hydrogen bonds, increased heat capacity, phase change and anomerization.[5–10] Calorimetric and wide line NMR measurements showed that 1–6-anhydro-β-D-glucopyranose and related anhydro sugars undergo plastic crystalline transition, involving reorientation of the molecules about their centers of gravity and self-diffusion before melting.[5–8]

At more elevated temperatures the above compounds showed cleavage of the glycosidic group, polymerization of the sugar moiety, decomposition and evaporation of the pyrolysis products.[9–10] Kinetics of this process, including the rates and energies of activation were determined by thermal analysis and ESR spectroscopy. These data indicated that cleavage of the glycosidic bond is directly influenced by variation of its electron density and constitutes the rate determining step in pyrolysis of the carbohydrate compounds.[8,10]

Decomposition of the sugar units was investigated by pyrolysis of levoglucosan and several β-D-xylopyranosides which showed that acidic catalyst promotes dehydration, whereas alkali catalyst leads to fragmentation of the molecule.[11,12] Thermal degradation of levoglucosan-1-^{14}C, -2-^{14}C, and -6-^{14}C gave carbon dioxide, carbon monoxide, and a variety of carbonyl compounds that were isolated and traced to the labeled positions. Variations of the yields and radiochemical patterns of the products on addition of sodium hydroxide or zinc chloride indicated the nature of some of the consecutive and concurrent reactions involved.[13]

Most of the above data have been published in recent literature and reprints are available on request. Current studies involve extension of the data obtained with model compounds to cellulosic materials and finding the effect of nitrogen and phosphorus derivatives on the course of their thermal decomposition.

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"Fire Problems Research and Synthesis"—Principal investigator: R. M. Fristrom; staff: A. G. Schulz, W. G. Berl, N. J. Brown, C. Grunfelder, B. Halpin, B. W. Kuvshinoff, M. M. Robison, R. L. Tuve, G. Fristrom, H. E. Hickey, E. P. Radford, P. Schweda, W. U. Spitz (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland)—NSF Grant No. GI 12

The Fire Problems Program is a multidisciplinary effort dedicated to reducing the problems associated with unwanted fires. It was initiated in July 1970, sponsored by the RANN Program of the National Science Foundation. The effort was renewed for a two year period beginning July 1972.

The work can be divided into four areas: (1) Education and Information; (2) Systems Analysis and Development; (3) Physical and Chemical Studies of Fires and Flames; (4) Medical and Biochemical Studies of Fire Deaths and Casualties.

Education and Information:

Communication among the engineers, scientists, and fire practitioners is a key to an effective program. Program accomplishments include: (1) A *Fire Sciences Dictionary and Source Book* which provides a key to the diverse languages used in Fire Research and Practice. Both definitions and references are provided. This was used as a reference by the National Commission on Fire Prevention and Control. (2) A series of colloquia on fire topics has brought together scientists, engineers, the fire community, educators, and city and governmental officials for meaningful discussions. The audio and video tapes of these sessions have been requested by 76 colleges, government agencies, and fire departments. (3) A Russian chemical kinetic compilation useful for combustion problems was translated and edited. It is used as part of the National Standard Reference Data System. (4) A *Directory of Workers in Fire Research* has been compiled. This volume was used by NASA in their *Directory of Safety Information Systems*. (5) A report system has been developed and twelve topical reports have been prepared including state-of-the-art surveys of detectors, flame inhibition, high rise building hazards, toxic gas evolution by burning plastics, and flame structure. (6) Twenty invited lectures were made by the staff, bringing fire topics to the attention of universities, high schools, the fire community, and scientific societies. As individuals we have undertaken projects in the fire area for the Committee on Fire Research of the National Academy of Sciences; the National Commission on Fire Prevention and Control; the Navy Committee on Fire Research; The Combustion Institute; and the American Association for the Advancement of Science.

Present projects include a survey of Russian Fire Research, the development of classifications of fire literature, the development of course material for teaching programs, and a seminar on Fire Science Education.

Systems Analysis and Development:

These studies have the objective of increasing the acquaintance and the usage of scientific and engineering methods by the Fire Services and the development of specific devices to improve the efficiency of Fire Operations. Critical studies of fire casualty data were made locally through the cooperation of the Fire Marshal of the State of Maryland, and also nationally. We have outlined the development of computer based systems for managing and utilizing state-wide fire information at the request of Florida State Fire Officials. Exploratory studies have been made on several fire equipment devices suggested by staff members, including a cryostatic breather, a remote thermal sensor, and a flying tram. This latter device is an external system for fire suppression and evacuation of high rise buildings.

A portable command and control kit for on-scene Fire Operations has been developed and is being tested by a local fire department (Hillandale, Maryland). We are working closely with this group to improve operation. Interest has been expressed by other fire jurisdictions.

Physical and Chemical Studies of Fire and Flame Systems:

The objective is to relate basic chemical information to the fire problems. An elementary theory of flame inhibition has been developed using chemical kinetic rate data to calculate flame propagation rates and classify inhibitors. This should develop the understanding necessary to set absolute upper limits on the effectiveness of chemical inhibitors. Confirmatory experimental studies are being outlined. Studies have been made of the rate of toxic gas evolution during a building fire, in cooperation with the University of Maryland Fire Protection Curriculum. Exploratory studies were made of toxic gas evolution in the combustion of some common plastics and a survey of the literature was made. Studies of the kinetics of polymer attack by atoms and radicals have been undertaken to aid in the understanding of ignition and flame propagation in plastics. Studies of hydrogen atom inhibition reactions with halogenated compounds using a molecular flow reactor are in progress.

Medical and Biochemical Studies of Fire Deaths and Casualties:

The purpose of this study is to establish medical mechanisms of fire death and contributing circumstances. Information is gathered from local fire authorities; one of our scientists investigates the sites of fire fatalities; the State of Maryland Medical Examiner's Office provides us with careful standard autopsies on every fire victim in this area; and samples are studied at our own Laboratory for poisons not considered in the standard autopsy. Medical and toxicological authorities both from the Medical Examiner's Office and from our own University School of Hygiene and Public Health are aiding us in defining and interpreting the information. At the present time information from some forty cases is available and a preliminary report is being prepared.

Summary:

This report summarizes progress during the first two years of the Fire Problems Program and outlines current work. Publications in the fire field include: three books; six symposium articles; eight journal articles; twelve topical reports; and fourteen colloquium tapes. An annual report and list of available publications are available.

"Fire Safety in Urban Housing"—Principal investigator; R. B. Williamson; staff: R. Bender, B. Bresler, R. C. Cliff, W. C. Cooper, E. R. F. W. Drossman, P. K. Mehta, P. J. Pagni, R. F. Sawyer, B. D. Tebbins, J. F. Thomas, C. L. Tien (University of California at Berkeley, Berkeley, California)—NSF Grant No. GI 43

The danger of fire has always been one of the most important hazards in high density urban housing. There is a growing interest in improving the fire safety of buildings, particularly "high-rise" buildings, and there are new forces acting to change the current fire safety requirements. The basic reason for this is that building technology itself is changing. New materials, particularly polymers, are being introduced to replace the conventional materials, and new construction techniques are being employed. There is a great need to improve the general understanding of fire in buildings and to incorporate this understanding in the design of future buildings.

The primary objective of the fire research at the University of California is to provide a rational basis for the design of buildings safe from fire. This objective is extremely broad. It is the intent of the fire research group to seek additional support from the NSF to continue the project and to make the Berkeley Campus a center for rational fire safety design. Modern buildings are rationally designed in almost all respects, save for fire. For the safety of a building from fire, particularly the safety of the human occupants, the designer has no rational methodology to use. The final design will be checked to see that it conforms to the articles of the building code, and there is generally a measure of personal experience factored into the design, but, in the final analysis, the fire safety of buildings is not checked by any engineering methods. Even a dramatic change in the building codes would not change this situation since the designer would not have a rational basis to implement the change.

The fire research program at the University of California is organized around three major areas within the College of Engineering:

(1) System-oriented study of the overall building-fire process and human response
(2) Combustion processes and fire spread in relation to materials and micro-level physical factors
(3) Fire response of structures, selection of materials, and design for minimum damage.

In addition, a fourth area is being developed which is aimed at integrating a quantitative fire design process with the traditional methods of architects and planners.

The following applied goals are also being actively pursued:

(1) improvement of materials and structures from a fire safety viewpoint,

(2) provision of scientific and engineering inputs to the process of formulating safety codes, standards, and other fire-related legislation,
(3) creation and dissemination of improved techniques for fire prevention, detection, and control,
(4) identification of economically optimal fire avoidance and control policies, hence reducing the cost of fire both in economic and human terms, and
(5) improvement of the flow of fire safety information to the civil engineering, architectural, and fire-fighting communities.

A number of specific research projects and methodological approaches have been undertaken under the broad headings set out above, and a conceptual framework, supplied by a system model of the fire process, is being developed to integrate them into a meaningful whole.

System-oriented Study and Human Responses:

The human factors field of fire safety research may be defined as including all aspects of the fire process where human beings are involved as active agents. Pure research would focus on such topics as the following: human error as a factor in fire ignition and spread; the role of human senses in fire detection; the nature and acquisition of fire-fighting skills; popular beliefs and stereotypes relevant to fire safety; and so forth. Applied research might be directed towards formulation of building codes and other legislation; design and evaluation of potentially fire hazardous furniture and equipment; improved methods of fire detection, control, and reporting; design of fire-fighting equipment and systems; and fire department organization and training.

Available statistics reviewed point up the quantitative significance of the human component, and significant economic and social benefits could accrue from development of systematic human factor design and implementation procedures directed towards improvement of fire safety. An initial literature survey was followed by pilot trials of a novel "critical fire incident survey" technique and development of a qualitative fire process model emphasizing human factors aspects. In addition to providing much qualitative data, this pilot survey was devised to estimate the relative frequencies of significant causal sequences and to provide information on respondents' fire-fighting knowledge, beliefs, and skills, as functions of residential area and individual background.

Questionnaires were distributed to randomly selected members of the Berkeley staff, calling for reports on incidents which *could* have resulted in a major fire. Positive responses could be followed up, but as yet this has not been undertaken. It was hoped that this would permit quantitative estimates of (1) the fire hazard associated with various types of individual domestic situations, equipment, etc., and (2) fire-fighting and reporting methods. This has proved true from the analysis of the initial survey of 500 forms and the partially analyzed second survey of 1000 forms. There were 43 incidents reported in the first survey with 40 (93%) of these involving purposeful ignition of the initial fire [cooking (63%), smoking (5%), or lighting a fire in the fireplace (5%)], and the fire subsequently got out of control. The majority of the fires described were never reported to the fire department (only 9 out of 43 or 21%), but non-professional fire-fighting techniques were successful in controlling the fire. Considerable information was gained about these techniques, and a public information program might correct certain mistakes that came to light. More important was the realization that fire department statistics seriously underestimate the incidence of domestic fires (one in five is reported). In the same way the approximate 60% of the total fire incidents reported being in the kitchen is much higher than the 15% or so encountered in normal fire accident statistics gathered through fire department reports.

Following the initial survey, a qualitative and quantitative model of the fire process in domestic situations was formulated. The next survey contained special questions to test the model.

Most fires originate in a purposive human heat-using activity (the primary fire), which may run out of control (secondary fire). In the great majority of cases (around 80% according to our survey data) control is regained by the initiator or someone else in his immediate household and the secondary fire extinguished without professional help. Property damage and personal injury goes unreported and is repaired without external help.

In a few cases the initiator either does not attempt to control the secondary fire, or his attempts fail. He then reports the fire. This almost universally results in extinction of fires but is expensive both to the public authority and in terms of property damage.

Most of the apparent success attending professional fire-fighting efforts can be attributed to superior manpower and equipment. However, non-professional fire control has the major advantage of economy and rapid response and is also usually successful. There has been little previous research on domestic fire control.

The above qualitative description, based partly on survey responses, has been formalized in a branching state-transition model and this in turn has supported the development of a computable simulation model run first in Focal language on an inhouse PDP8 computer and later in Fortran IV on a CDC6400 computer. The existence of such a quantitative model structure makes it possible, to the extent that valid data are available for estimation of the various parameters, to predict the statistical outcome of various fire safety and fire-fighting policies applied at the domestic and local fire department level.

By simulating many fires, the model described above is a potentially powerful design tool for evaluation of the impact of changes in such factors as: available non-professional fire fighting equipment, fire fighting policies, fire department procedures, alarm systems, etc.

A Domestic Fire Incident Survey Methodology:

As pointed out above, available statistics all reflect the professional fire fighting viewpoint and do little more than identify major sources of fire hazard. Specifically lacking for domestic fires are data defining type and relative frequency of human error responsible for secondary (undesired) ignition and for failure of control both at the primary and secondary level, as functions of geographic area, socio-economic status, age, sex, and other parameters.

The results of the initial survey noted that the fire department was called in only 21% of the total incidents which suggested that the survey tapped a novel source of fire safety information. This encouraged us to proceed with a second distribution, this time including questions designed to estimate the hazard and error rates for various types of primary ignition (e.g., associated with smoking, gas cooking, and candles). The second survey included 1000 staff members on the San Francisco and Davis campuses of the University of California. Most returns are now in and results are awaiting analysis.

Combustion Processes and Fire Spread:

Inhibitor Investigations—The theoretical modeling of the role of gaseous halogen inhibitors in homogeneous flames was initiated at the Applied Physics Laboratory in collaboration with Dr. Robert Fristrom. Continued work on the theoretical model with Dr. Fristrom is in progress. Experimental investigations on the chemical kinetics of flame inhibition and extinction by halogen to be conducted at the University of California are planned. Objectives: Identification of the fundamental physics and chemistry of halogen flame inhibition.

Polymer Combustion—This study includes the analytical modeling and experimental observation of the burning of polymer rods in an opposed flow diffusion burner. Objectives: a) Development of a standard burning procedure for polymer samples based on the control of the burning environment; b) Study of the mechanism of polymer combustion; c) Comparison of the burning characteristics of different polymers; d) Collection and analysis of combustion products.

Model Flame Spread—Analytical and experimental analyses of flame spread rates and mechanics with application to all fuels and configurations. Objectives: a) Identify dominant heat transfer mechanisms in horizontal flame spread problems; b) Obtain appropriate non-dimensional parameters defining flame spread and conduct scaling experiments; c) Extend this rate of spread study to vertical, inverted, and inclined tests on practical building materials.

Radiation and Detection of Fires and Smokes—Analytical and experimental investigations on optical and thermal radiative characteristics of fires and smokes. Objectives: a) Develop a simple analytical understanding of the attenuation of optical (visible) radiation by carbon smokes; b) Establish a theoretical framework for calculating radiation energy emission by fires; c) Devise efficient optical detection schemes and techniques for detection of fires and smokes.

Fire Response of Structures, Selection of Materials, and Design for Minimum Damage:

Prediction of Structural Response to Fire—During 1971–72, the group concerned with the structural response phase of the fire research program at the University of California, Berkeley, focused its attention on the development of analytical methods for prediction of structural behavior of reinforced concrete frames. A two-dimensional mathematical model has been developed which is quite general, and the method has been applied to a study of behavior of reinforced concrete columns in different frames under different exposures to fire. One of the most encouraging features of this study is the realistic prediction of stress history in reinforcing steel and concrete under different fire conditions.

Analytical Studies—Progress Report:

In the method developed here, prediction of structural behavior with time is obtained, accounting for both time- and temperature-dependent properties.

Analytical evaluation of response of reinforced concrete structural elements exposed to fire must take into account the following:

(1) time-dependent variation of temperatures on the boundaries and within the element,
(2) non-linear and temperature-dependent thermal and mechanical properties of steel and concrete (including inelastic behavior, failure),
(3) thermal deformations in concrete and steel due to time-variable temperatures and thermal gradients,
(4) deformations in concrete due to drying under variable temperatures,
(5) deformations in concrete and steel due to stresses (instantaneous and creep deformations variable with time and temperature),
(6) compatibility of deformations (plane sections locally, and rotation and displacement of adjacent elements (globally), with consequent restraints of deformations, and
(7) stresses introduced by these restraints.

Numerical analysis for reinforced concrete frames taking into account the above factors has been developed using finite element technique. First, transient temperature distribution is determined using two-dimensional heat-flow equation with variable thermal properties and with a convection boundary condition. At specified time increments the temperature distributions at the end of each step are obtained. Then a displacement analysis at the end of each time step is performed which allows determination of stresses throughout the section, forces in the various elements, and the deformations. Using appropriate models for material behavior, this analysis indicates onset of cracking and crushing, their extent at any given time, yielding of reinforcing steel, recovery of capacity to carry compression by the previously cracked concrete elements, and the duration of a specified force which would lead to collapse.

Behavior of reinforced concrete columns in low-rise and high-rise frames and under varying fire exposures have been studied. Preliminary results give an indication of potential value of this method. Final conclusions must await additional analytical studies and experimental verification of the idealizations assumed in the analytical studies. Some of the preliminary conclusions are as follows:

(1) A column exposed to fire in the lower stories of a high-rise frame (restrained by the superstructure) is subjected to much more severe conditions than a similar column in the upper stories or a column in a low-rise building.
(2) A column exposed to a fire of high initial intensity but with short duration may be subject to less damage than one exposed to a lower initial intensity but longer duration fire (such as standard ASTM fire).

These preliminary conclusions suggest that in some cases the high rise buildings are not sufficiently conservative, while in other cases they may be too conservative.

A Heat Balance Analysis of the Standard Fire Endurance Test—Experimental determination of heat flux, fuel use, and other factors in the standard test for containment of elements (ASTM E 119). Theoretical analysis of the same tests on the basis of heat balance. Objectives: a) Perform experimental tests to determine the feasibility of heat flux and heat balance measurements; b) Analyze data and compare with theoretical studies previously published; c) Perform experimental tests on representative samples (including one-hour standard wood stud/gypsum board walls, metal stud/gypsum board, metal/cellular polymer/metal sand panel, and others).

Improving Water Retentiveness of Concrete—a) Measurement of weight loss of 6″×9″×2″ concrete slabs stored at 50% relative humidity: surfaces of some slabs were pre-treated with (i) a sodium carbonate solution, (ii) a magnesium sulfate solution. b) Drying characteristics of high viscosity solutions containing various percentages of water-soluble polymers such as sodium carboxymethylcellulose and Polyox were examined. Objectives: To improve the fire endurance of precast structural concrete units by increasing water retentiveness of concrete either by suitable surface treatments or by increasing viscosity of concrete mix water by addition of water-soluble polymers.

Quantitative Measures of Combustibility—The basic requirements for the fire safety of structures are to be reviewed and the role of a "combustibility" requirement established. The possible experimental procedures are surveyed, such as potential heat release, rate of heat release, and various GO/NO GO test procedures (i.e., ASTM E 136). Objectives: a) To formulate a logical basis for a combustibility performance standard; b) Determine the applicability of existent test procedures to measure the combustibility as defined in a); c) Develop new experimental techniques to measure combustibility as necessary.

Evaluation of Smoke, Characteristics of Polymers—A representative array of polymers is being burned or thermally destroyed under a variety of conditions corresponding to "real life" situations. The array of polymers under investigation consists of the four major types accounting for approximately 80% of the polymers in general use. Objectives: For each polymer and each condition: a) Measure the total mass of aerosol material produced per unit mass of sample; b) Determine the particle size array; c) Do a photographic analysis involving (i) a simple photograph of the typical emissions, (ii) light and transmission electron microscopic pictures of fumes and soot particles (A unique collection technique has been developed for sampling single particles.); d) Evaluate obscuration of visibility using both transmitted and reflected measurements from a single fixed source moving the light with respect to the source.

Evaluation of Canister-type Gas Mask for Fire Use—Objectives: To prepare a critique of all purpose canister-type equipment which is used in fighting structural fires. This paper attempts to present several major reasons for rejecting the use of canister-type masks in fighting structural fires.

"A Problem in Fire Safety: Flame Spreading Across Liquid Fuels"—Principal investigators: I. Glassman and W. A. Sirignano; staff: O. P. Sharma, F. L. Dryer, J. Fox, W. Meyer, C. Steinhagen (Guggenheim Laboratories, Princeton University, Princeton, New Jersey)—NSF Grant No. GK 2764

Earlier work at Princeton has shown that hydrodynamic convective effects in the liquid fuel play a dominant role in determining the propagation rate of a flame across the fuel and in determining the minimum film of fuel which would sustain propagation. To broaden the understanding of these findings theoretical analyses of the convective motions in the liquid have been performed for both the thin film (low Re number) and deep layer (high Re number) cases. It was postulated that the convection was induced by surface tension or buoyancy forces. Recent results in the high Re number analysis indicate that surface tension forces dominate except for very large fires. In the theoretical analyses the gas phase and heat transfer aspects of the overall flame spreading mechanism were decoupled from the problem for simplicity's sake. The gas phase part of this problem, which has never been treated, is presently being solved. For the interface conditions, results from the liquid phase analyses are being used and as the experimental results are obtained, they too will be used. Both phases are being considered simultaneously without incorporating the results of any prior analysis. It is believed that the results of the gas phase analysis will give greater insight and simplify the complexities in the numerical scheme necessary to solve the coupled problem. It is now essential to consider the complete coupled case in order to obtain the flame spreading rate as an eigenvalue of the problem and to understand the relative importance of the gas phase processes in the propagation problem.

The theoretical approach will be combined with an experimental effort that will measure exact flame propagation velocities and heat transfer rates in the liquid. A new, pulsed hydrolysis technique is now being used to measure liquid flow rates across a combustible (50% ethyl alcohol—50% water) fuel mixture. This mixture has been found ideal for study in the current program. A small thermocouple rig has been constructed to measure the temperatures. This experimental effort will permit quantitative evaluation of the theoretical model and analyses.

Theoretical Endeavors:

There is no theoretical analysis which deals with the combined gas phase and liquid phase phenomena and, more importantly, predicts the flame spreading rate in terms of the physical properties of the system. The present theoretical model will achieve both these objectives. The time-dependent conservation equations are being solved numerically by using a finite difference scheme developed by Harlov, *et al.*, at Los Alamos. We have written the computer program in PL 1, and it is in the debugging stage. The interface conditions include surface tension forces as well as vaporization. The interface matching will be achieved by an iteration cycle. At present, some arbitrarily constructed interface velocity and temperature profiles are being employed to obtain detailed flow fields. As soon as experimental results become available, we will also make use of them during the debugging stage. Since we are interested in the steady state solution, the flame position will remain fixed only if a correct choice of the speed for the moving coordinate system is made. Thus, the unknown flame propagation speed will be determined by varying the speed of the moving coordinate system as time progresses until the steady state is reached and the flame position remains fixed. The computer program is expected to be satisfactorily debugged by the month of August, and then hopefully the solution of the problem can be completed before the end of the year.

Experimental Endeavors:

By measuring the variation of flame spread across an alcohol-water mixture as a function of pan width and comparing these results to those obtained earlier on decane, it has been possible to obtain an estimate of the effect of flame radiation on flame spreading across liquid fuels. The decane results show an increase of spreading rate as the pan size is increased until a width of 15 cm. From 15–20 cm, the rate is independent of pan width, and above 20 cm rises at a rate of approximately 0.02 (cm/sec)/cm (width). It was postulated that the second rise was due to a radiation contribution from the very luminous decane flame. The alcohol-water flames are practically transparent. In these experiments, the propagation rate increased until a pan width of 20 cm and remained constant thereafter. These results appear to support the contention that, in pure hydrocarbon flames until one obtains very large flames, there is no radiative contribution to flame spreading. Even in large flames, the liquid convective heat transfer component appears to dominate.

Further modifications were required to be made in the hydrolysis-tank system and as yet no quantitative results of liquid flow patterns necessary for comparison with the theoretical analysis have been obtained. An all-glass tank to give greater flexibility in illumination and the removal of all metal parts to avoid contamination of the wire electrode have given what appears to be an ideal system.

"Flame Spreading Over Liquid Fuel"—Principal investigator: K. E. Torrance; staff: M. Remorenko (Department of Thermal Engineering, Cornell University, Ithaca, New York)—NSF Grant No. GI 31894X

The objective of the research is to determine quantitatively the range of parameters which will allow a flame to spread over the surface of a liquid fuel when the fuel is at a temperature below its flash point. This information will be useful for predicting the safe storage and handling ranges for liquid fuels. The aforementioned parameters will be formulated as appropriate groups of physical properties, all of which will be known in advance once the fuel and fuel geometry are prescribed. The effect of fuel depth and fuel stratification are among the factors that will be examined. This study will be a basic contribution to the general understanding of flame and fire processes, including the burning of oil spills, and could contribute to the ultimate reduction of losses due to unwanted fires.

Examination will be made of the subsurface fuel movements induced by surface tension and/or buoyancy forces. Numerical methods will be used, as these allow all coupling mechanisms and physical processes to be included. Gas phase effects will be approximated by suitable boundary conditions on the free surface of the fuel. The subsurface currents have been observed by several workers, but the detailed structure has not yet been determined. One important thesis is that the subsurface currents may limit the flame spread rate, and if so, the prediction of flame spread rates could be simplified considerably. The analysis will be extended to couple the liquid fuel to a simple model of gas-phase flow above it, with mass transfer included. Complementary experiments for testing the theory will be designed.

Suitable numerical methods have been developed for solving the time dependent, partial differential equations governing mass, momentum and energy conservation within a layer of liquid fuel. The layer is taken as two-dimensional with a hypothetical flame spreading over the surface. Subsurface flows are observed and have been examined for a range of buoyancy and surface tension parameters.

Present efforts are directed at formulating a compatible numerical simulation of gas-phase effects. The spreading diffusion flame is treated within the Schvab-Zeldovich framework. Time dependence, mass diffusion, heat conduction, and bulk convection effects are retained. The rate of vaporization at the fuel surface is prescribed.

Future work will combine the separate gas-phase and liquid-phase models using thermodynamic balances at the fuel surface (that is, heat and mass balances). The effects on the flame of finite reaction rates, flame quenching near the cold fuel, and natural convection remain to be considered.

"A More Extensive Study of the Behavior of Firebrands in a Turbulent Swirling Natural Convection Plume above a Fire Whirl and the Formation of Fire Whirls"—Principal investigator: R. S. L. Lee; staff: C. A. Garris, J. M. Hellman, S. Einav, W. K. Chan, A. Verdia, P. DiGiovanni, B. Otterman (Department of Mechanics, State University of New York at Stony Brook, Stony Brook, New York)—NSF Grant No. GK 10820

A combined theoretical and experimental study has been performed on the following:

a) Multiple firewhirls:

An analysis on the stability of the laminar free convection due to a line source of heat with ambient shear has been performed by numerical solution of a viscous stability equation. Results give rise to discretely spaced vortex columns, which agree closely, in functional form, with experimental results on the formation of multiple firewhirls from a line fire.

b) Firebrand trajectories:

Glowing-burning particles have been found to be capable of stabilizing themselves within the swirling core region owing to a delicate balance of two kinds of forces exerted on them, those proportional to their cross-sectional area (drag) and those proportional to their volume (gravity, centrifugal).

c) Glowing-burning of charred wood:

Preliminary results show great promise of the use of the two-phase suspension flow theoretical model in explaining the property of very slow but sustained glowing burning necessary for fire brands of charred wood to travel long and far.

d) Two-phase suspension flows:

Mathematical techniques have been developed for the solution of certain class of two-phase suspension flow problems. Results have been used to guide the development of experimental facilities, which are now comprised of a flow channel and a precision custom-built two-dimensional laser-doppler anemometer. Simultaneous measurements of instantaneous velocity components of both phases and the particulate phase density have been accomplished. These developments will help the expanded study on both the firebrand trajectories and the glowing burning flow in the ash layer.

Further study will include work involving a) formation of firewhirls under more realistic conditions; b) properties of Karman Street-like vortex columns shedding from behind a natural convection column exposed to transverse ambient flow and firebrand-like particle trajectories carried therein (hydraulic simulation will first be tried; individual columns in air will also be examined); c) glowing-burning of charred wood.

"Flame Radiation Distribution for Turbulent Free-Burning Fire Model"—Principal investigator: B. D. Wood; staff: M. Rugh (College of Engineering Sciences, Arizona State University, Tempe, Arizona)—NSF Grant No. GK 27779

The objective of this effort is to secure from empirical data a quantitative understanding concerning flame radiation heat transfer mechanisms for the purpose of developing a radiation-convection heat transfer fire model for turbulent free-burning fires. Of primary concern is the effect of the fuel vapor region interposed between the fuel surface and reaction zone. Quantitative experimental measurements include flame radiation spectral distribution from 0.2 to 10 μ, total radiant heat flux and total heat flux to the fuel surface. The analytical portion of this study will examine the extent to which current theory of combined radiation and convection heat transfer in optically thick gases is able to account for observed phenomena.

An ultra simple model of the free burning fire can be formulated by treating the fire plume as two regions—the unburned vapor region and the flaming combustion region. By prescribing the temperature and emissivity distribution for a fire plume modeled as a right cone, the relative effect of these two regions was estimated. This model shows that radiant heat flux to fuel surface is significantly effected by the emissivity (absorptivity) and thickness of vapor region ($\pm$100%) and a weak function of the flame emissivity ($\pm$20%). This suggests the flame emissivity is unimportant relative to the temperature distribution and radiative transport properties in the region immediately above the fuel surface.

"Infrared Remote Sensing of Air Pollutants and Forest Fires"—Principal investigator: S. H. Chan (Department of Mechanical Engineering); co-principal investigator: M. J. D. Low (Chemistry Department); staff: P. S. Jagannathan, D. A. Nelson, C. C. Lin, M. Osumi (New York University, Bronx, New York)—NSF Grant No. GK 24972

This project deals with analytical and experimental studies of forest fire detection and air pollution monitoring by infrared remote sensing. For forest fire detection, the feasibility of using an infrared dual sensor with two fields of view is studied and, for air pollution detection, the effective method of determining concentrations of stack gases by infrared emission measurement is investigated. Also, in connection with air pollution detection, infrared radiation properties of gaseous pollutants are measured.

1. Forest Fire detection: Using the harmonic-oscillator rigid-rotator model and the Curtis-Godson approximation, the mean spectral transmittance through inhomogeneous atmospheric path was formulated to compute the thermal radiance to be received by the dual sensor through two atmospheric window regions.

2. Air pollution detection: To avoid solving ill-conditioned integral equations, the total band absorptance is employed to convert the integral equation into an algebraic equation. The temperature of stack gases is remotely determined by derivative spectroscopic method.

3. Infrared radiation properties are measured by a high temperature, high pressure and long path (White) cell.

The detection of forest fires by the present dual sensing technique is feasible. Remote sensing of the temperature of stack gases (or plume) can be done simply by locating the position of the peak of a vibrational-rotational band. The use of total band absorptance will make remote sensing of the concentration of stack gases possible.

Experimental part of the project will be carried out to verify theoretical findings.

"Forest Fire Statistical Problems"—Principal investigator: F. N. David; staff: A. W. McMasters, C. A. Robertson, A. Dixit, R. Runnestrand (Statistics Department, University of California at Riverside, Riverside, California)—NSF Grant No. GI 31891X

The overall objective of this research is to analyze quantitatively various factors relevant to the development of forest fire control planning methods. The lines which we intend to pursue are as follows:

Distribution of Fire Starts Relative to Probable Cause and Terrain:

Most forest fires are caused either by lightning or by human agency. Empirical distributions of these two kinds of cause are available for past years. It will be necessary to get geographical and topographical descriptive data. We propose to try to build a simple model to enable us to predict the number of fire occurrences to be expected given the terrain, the weather conditions, and the time of year.

Forecasting the Occurrence of Large Fires Relative to Terrain and Weather Conditions:

The large fires are the small ones which get away, and we are here proposing to deal with what may be called an extreme-value problem. The large fires are reasonably well documented historically, but they have to be placed in the context of the general fire-occurrence problem before adequate forecasting can be done. Given the distribution of number of fires against area burned, some new methods of curve fitting will need to be devised to investigate the 5% of fires accounting for more than 90% of the total damage.

Production Rates of Fire Line Building and Holding Resources:

This problem will be treated from the operational research angle. The ultimate object is to achieve the most efficient allocation and use of available resources.

Modeling of Forest Fire Dispatching:

If we achieve some success with the first two items listed, the problems clearly call for a flexible decision process which will change as the numbers of fires and their extents change. We propose to begin by finding out as much as possible about the factors which guide dispatchers when they make decisions, and then to try to see if the decisions are optimum in the light of subsequent developments. Probably nothing can replace the expertise of an experienced fire fighter, but we may be able to come up with procedures to help the inexperienced.

Efficient Data Base Design:

Much information is scattered about the files of the Forest Service, and often remains uncoordinated unless a fire achieves notoriety by becoming large. It is very necessary for this project to arrange to store data on tape in a form suited to efficient retrieval. It is also, of course, necessary to define just what data should be so stored.

"Fourteenth Symposium on Combustion—August 20–25, 1972, The Pennsylvania State University"—Principal investigator: G. C. Williams (Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts)—NSF Grant No. GK 34613

Project support is in the form of domestic travel and publication of the proceedings of the symposium. Papers for the symposium are centered in a Colloquium on Fire and Explosion organized by Dr. R. Friedman. They are as follows:

P. H. Thomas
Invited Review Paper—"Behavior of Fires in Enclosures—Some Recent Progress"

G. Heskestad
"Modeling of Enclosure Fires"

J. deRis, A. Murty Kanury, M. C. Yuen
"Pressure Modeling of Fires"

J. S. Adams, D. W. Williams, J. Tregellas-Williams
"Air Velocity, Temperature, and Radiant Heat Measurements within and around a Large Free-Burning Fire"

C. P. Butler, S. B. Martin, S. J. Wiersma
"Measurements of the Dynamics of Structural Fires"

C. A. Garris and S. L. Lee
"A Theory for Multiple Fire Whirl Formation"

K. Akita
Invited Review Paper—"Some Problems of Flame Spread along a Liquid Surface"

G. H. Markstein and J. deRis
"Upward Fire Spread over Textiles"

P. J. Pagni and T. G. Peterson
"Flame Spread through Porous Fuels"

M. Gerstein and W. B. Stine
"Analytical Criteria for Flammability Limits"

G. E. Andrews and D. Bradley
"Limits of Flammability and Natural Convection for Methane–Air Mixtures"

A. Murty Kanury
"Rate of Charring Combustion in a Fire"

P. F. Nolan, D. J. Brown, E. Rothwell
"Gamma-Radiographic Study of Wood Combustion"

L. Krishnamurthy and F. A. Williams
"Laminar Combustion of Polymethylmethacrylate in O_2/N_2 Mixtures"

L. S. Bouck, A. D. Baer, N. W. Ryan
"Pyrolysis and Oxidation of Polymers at High Heating Rates"

W. S. Blazowski, R. B. Cole, R. F. McAlevy, III
"The Linear Pyrolysis of Various Polymers under Combustion Conditions"

R. A. Strehlow
Invited Review Paper—"Unconfined Vapor Cloud Explosions—An Overview"

A. L. Kuhl, M. M. Kamel, A. K. Oppenheim
"Pressure Waves Generated by Steady Flames"

P. Wolanski and S. Wojcicki
"Investigation into the Mechanism of the Diffusion Ignition of a Combustible Gas Flowing out into an Oxidizing Atmosphere"

D. Rae
"The Initiation of Weak Coal-Dust Explosions in Long Galleries and the Importance of the Time Dependence of the Explosion Pressure"

T. Kashiwagi and M. Summerfield
"Ignition and Flame Spreading over a Solid Fuel: Nonsimilar Theory for a Hot Oxidizing Boundary Layer"

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ABSTRACTS AND REVIEWS

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THE COMMITTEE ON FIRE RESEARCH functions within the Division of Engineering to stimulate and advise on research directed toward the development of new knowledge and new techniques that may aid in preventing or controlling wartime and peacetime fires. The Committee was established in December of 1955 at the request of the Federal Civil Defense Administration. It is supported by the Office of Civil Defense of the Department of the Army, the U.S. Department of Agriculture through the Forest Service, the National Science Foundation, and the National Bureau of Standards.

Volume 14 1972 Number 3

Fire Research Abstracts and Reviews

National Academy of Sciences

FIRE RESEARCH ABSTRACTS AND REVIEWS

Robert M. Fristrom, Editor

Geraldine A. Fristrom, Associate Editor

FIRE RESEARCH ABSTRACTS AND REVIEWS will abstract papers published in scientific journals, progress reports of sponsored research, patents, and research reports from technical laboratories. At intervals, reviews on subjects of particular importance will be published. The coverage will be limited to articles of significance in fire research, centered on the quantitative understanding of fire and its spread.

Editor: Robert M. Fristrom, Applied Physics Laboratory
The Johns Hopkins University, Silver Spring, Maryland

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Volume 14 Number 3

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Committee on Fire Research
Division of Engineering
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FOREWORD

This issue begins with a survey of the Soviet Fire Technology Information sources and ends with translations from the first issue of a new Soviet abstract reference journal, *RZh-Fire Protection* (*RZh-FP*).

This is an impressive work, both in coverage and in the rapidity with which the information reaches the public. It is a heartening sign that the Soviet technologic community now considers the fire field an important enough entity to warrant separate literature coverage. Taken together with its companion journals, one of which appears weekly, this represents a major effort by a dedicated staff. In terms of total pages it carries some five to ten times the material in *Fire Research Abstracts and Reviews*.

The coverage of *RZh-FP* appears to be principally engineering and technology; the scientific aspects of fire being abstracted under the heading of the parent science and not collected separately. This contrasts with the policy of FRAR which has been selectively to cover and interpret both the engineering and scientific aspects of the field. The abstracts appear to be completely written and the coverage apparently very thorough as compared with our evaluation of the field.

This new source of fire information is well worth evaluating and your editor is looking forward to the translations of the first six issues which have been undertaken by Messrs. Holtschlag and Kuvshinoff of the Applied Physics Laboratory of The Johns Hopkins University, supported in part by the Fire Problems Program grant from the RANN Program of the National Science Foundation.

Your editor would welcome comments on this new source of information since he feels that the position of *Fire Research Abstracts and Reviews* should be reevaluated and, if possible, strengthened by cooperation with our Soviet colleagues.

R. M. Fristom, *Editor*

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TRANSLATION

Soviet Fire Information Dissemination Media*

B. W. KUVSHINOFF

Applied Physics Laboratory, The Johns Hopkins University

Fire technology literature, in general, is marked by a high degree of scatter. Aside from the contents of a few fire service and fire technology periodicals, important fire and fire-related articles are found in an extraordinarily heterogeneous assortment of titles. One can find fire information in journals devoted to plastics, transportation, chemistry, physics, oceanography, mining, sanitation, textiles, air conditioning, plant management, occupational safety, building, materials, petroleum products, and many more fields.

Only two English-language secondary publications have attempted to draw this dispersed body of literature together: *References to Scientific Literature on Fire*, compiled annually by the Fire Research Station, Boreham Wood, England, and *Fire Research Abstracts and Reviews*, published by the National Academy of Sciences.

Consequently, the appearance in January 1972 of the Soviet abstracts journal *Fire Protection* was a welcomed addition to the field of fire science literature.

The Soviet *Referativnyy Zhurnal* [*Abstracts Journal*], abbreviated *RZh*, is outstanding in its scope of coverage of scientific and technical literature. It ranges all subjects from "avtomatika" [automation] at the top of the Russian alphabet to "yadernaya fizika" [nuclear physics] at the bottom.

For readers who are not acquainted with Russian technical literature, we will briefly review the chronological history of Soviet scientific and technical information dissemination programs.

VINITI and the Soviet System of Information Dissemination*

VINITI (Vsesoyuznyy Institute Nauchnoy i Tekhnicheskoy Informatsii), the All-Union Institute of Scientific and Technical Information, was founded in 1952 as the Institute of Scientific Information. The name was changed to the present one in 1956. The Institute has four primary functions in its mission: 1) systematic and exhaustive abstracting of the world literature on the natural sciences and technology; 2) publication of abstracts, reviews, bibliographies, and reference materials, as well as various series of *Ekspress Informatsiya* [*Engineering Digest*], discussed below; 3) research on and development of new methods and techniques in information science; and 4) translation of foreign technical literature on request. The institute is now governed by the National Committee on Science and Technology of the Council of Ministers USSR and is operated by the Academy of Sciences.

* The research for this review was supported by the National Science Foundation, RANN Program. This is an extension of a paper given at a seminar conducted by Dr. Isaac Welt at American University, Washington, D. C., fall semester, 1972.

The *Abstracts Journal*, *Digest*, and other reference publications of VINITI are available on subscription at modest prices.

Abstracts Journal Series

The main output of VINITI is, of course, the mammoth *Referativnyy Zhurnal* [*Abstracts Journal*], abbreviated *RZh*. The first of the "Chemistry," "Astronomy," "Mechanics," and "Mathematics" series appeared in 1953. By 1970 VINITI was regularly publishing 170 titles in the *RZh* series in the general subject fields of automation and radioelectronics, astronomy, biology, geography, geology, mining, geophysics, information science, mechanical engineering, metallurgy, mechanics, transportation, physics, chemistry, electrical engineering and power, and industrial economics. The medical literature is covered by a special abstracting journal, *Meditsinskiy Referativnyy Zhurnal* [*Medical Abstracts Journal*], published monthly in 16 subject fields by the Ministry of Public Health of the USSR.

RZh regularly covers the scientific and technical literature of 118 different countries in 64 languages. This coverage includes 14,000 periodical titles, over 6,000 serials, over 10,000 books, and over 160,000 patents. In all, more than a million items are cited in 1972. Distribution of the various titles in the *RZh* series has grown to 342,000 copies.

The various sections of *RZh* are published monthly, except chemistry, which appears semi-monthly. Author and subject indexes are published annually for all titles; for some, indexes are included in each issue. The average time between receipt of original source material and publication of its abstract is four months. It should be noted that this is almost an incredibly rapid through-put for a large information processing system. This high-speed processing appears to be meretricious, however, possibly because of delays in distribution and delivery. The September 1972 issue of the *Fire Protection* separate was received in Silver Spring, Maryland, during the last week of December.

"Fire Protection" Separate of RZh

Each of the major sections of *RZh* is divided into a number of subsections. Abstracts appearing in these subsections can be obtained as separates, without subscribing to the complete issue covering the entire field. One of these separates is *Pozharnaya Okhrana* [*Fire Protection*], inuagurated in January 1972. Annual author and subject indexes are provided automatically with the subscription.

The topics covered in this separate are grouped under the headings: general problems in fire protection, fire service and fire prevention training, fire prevention, fire technology, fire extinguishment, fire tactics, and fire service technology and equipment. Approximately 110 key articles, books, and patents are cited in each issue.

Owing to the dispersion of fire-related literature alluded to in the opening paragraph, many articles of interest are to be found in other sections of *RZh*. For example, the literature on combustion and explosions is cited in series 19ABV, *General Problems in Chemistry. Physical Chemistry. Inorganic Chemistry.* Articles on fire safety, fire resistance, and flammability are cited in series 19I, *General Problems in Fire Technology.* Literature pertinent to fire apparatus is cited in series 02A, *Automobile Construction.* Articles on fire fighting equipment and materials are covered also in series 33, *Communal, Domestic, and Commercial Appliances.*

Adjunct Secondary Publications

In addition to the abstracts journal, VINITI distributes catalog cards in 29 series in mechanical engineering and industrial economics, as well as 11 series in automation and radioelectronics and 23 series in metallurgy and welding.

Supplementing the *RZh* are two series, one called *Ekspress Informatsiya* [*Engineering Digest*] and the other, *Signal'naya Informatsiya* [*Literature Announcements*]. The *Digest* is published four times a month (48 issues per year) and the *Announcements* twice a month. Both have annual subject and author indexes.

Engineering Digest Series

VINITI launched the *Engineering Digest* series in 1955 to provide a medium for rapid distribution of key information appearing in the foreign technical literature. The time between receipt of source material and publication of a condensation or extract in the *Digest* is said to be 1.3 months–much more rapid than publication in the *RZh.* By 1972 the *Digest* was being published under 77 titles and reached a distribution of 117,000 copies. The fields covered include automation and radioelectronics, chemistry and chemical engineering, mechanical engineering, metallurgy, electrical engineering and power, geology, mining, transportation, and information science. Of special interest is the *Fire Protection* series of the *Digest.*

The *Digest* series entitled *Fire Protection* appears to have been started in 1970 by VNIIPO (Vsesoyuznyy Nauchno-Issledovatel'skiy Institute Protivopozharnoy Oborony), the All-Union Scientific Research Institute of Fire Protection, in two series: Series I, *Flammability of Materials Used in the Chemical Industry* (later changed to simply *Flammability of Materials*), and Series II, *Fire Technology.* No 1971 issues have been seen. The 1972 issues show VINITI as the publisher, and the single title *Fire Protection.*

This series cites approximately 170 key articles, books, and patents annually, and has a subject and author index. A hundred and fifty Soviet and foreign fire technology and industrial periodicals are scanned regularly for special articles on scientific, technical, and applied topics of importance to the fire service. VINITI plans to enlarge this separate substantially in 1974.

Literature Announcement Series

The other information dissemination medium, the *Literature Announcements* series, was introduced by VINITI in 1967 as an adjunct to *RZh,* after an initial trial period. The purpose of this series is rapid announcement of the availability of foreign and domestic technical literature—two and one-half to three months sooner than is possible through *RZh.* This series began with three titles in automation and radioelectronics and one each in physics and chemistry. A biology series was added in 1970. There are now 55 titles in this series, generally following the rubrics of the *RZh.* However, depending on the level of progress or urgency in given technologies, certain titles cover either broader or narrower subject fields. Since the literature is cited in the *Announcements* before it is translated, abstracted, or otherwise processed, interested readers can order copies of original articles from VINITI. There appears to be a lively interest in this service, since VINITI expects to distribute approximately 540,000 duplicated copies of requested articles in 1972.

Reviews Series

In 1957 VINITI introduced a new type of information service in the form of three reviews series entitled *Biological Sciences*, *Technical Sciences*, and *Chemical Sciences*. In 1964 the reviews series were grouped under two main titles: *Itogi Nauki* [*Reviews of Science*] and *Itogi Nauki i Tekhniki* [*Reviews of Science and Technology*]. In 1972 these were merged under the latter title. The purpose of this series is to generalize and systematize progress achieved in science and technology as reflected in the literature abstracted in the pages of *RZh.*

VINITI plans to issue a fire protection title in this series in 1974. Included will be analytical retrospective reviews of the state-of-the-art and information on the latest advances in and organization of fire protection, as well as assessments of relevant areas in materials and equipment technology that have been published during the two preceding years in *RZh.* These plans are being developed in the light of interviews and conferences with actual users of the abstracts service.

Book Literature

Production and distribution of all scientific and technical literature is at a high level in the Soviet Union. A number of books in fire technology are produced every year by native authors. In addition, outstanding books and monographs from other languages are translated into Russian and sold usually at a fraction of the cost of the original. Literature in general is produced cheaply and priced low. The author of this review has acquired an excellent collection of Russian classics and technical books on a churchmouse budget. As a typical example, a book in English priced at $18.00 was translated into Russian and sold at 1.74 rubles (less than $2.00).

Inasmuch as the Soviet Union does not subscribe to the Geneva Convention on Copyrights, it pays no royalties and, in turn, does not claim any for Russian works translated into other lauguages.

Primary Journal Literature

Only one Russian fire service journal has been obtained to date: *Pozharnoye Delo* [*Fire Practice*]. This monthly, founded in 1925, has the phenomenal circulation of over 112,000 copies. The closest second to this record is *Fire Command!* (US) with 50,000 copies.

Except for the fact it carries no advertising and is not quite as glossy, *Fire Practice* has a number of characteristics in common with such familiar periodicals as *Fire Chief* (US) and *Fire Protection Review* (Brit.). It stresses fire service news and events, letters to the editor, personalia, and a few technical fire-related articles. *Fire Practice* features a large number of pictures, many of them in color.

Another periodical that has been noted (but not seen) is *Na Boyevom Pozharnom Postu* [*On the Fire Fighting Front*]. This is assumed to be a popular fire service serial.

The most prominent technical journal in the fire field is *Fizika Goreniya i Vzryva* [*Physics of Combustion and Explosion*]. This is a quarterly, published in Novosibirsk since 1965 by the Siberian Division of the Academy of Sciences USSR. A cover-to-cover translation is produced in the US by the Consultants Bureau, N. Y., under the title *Combustion, Explosion, and Shock Waves.*

As elsewhere, fire articles appear in a wide assortment of Russian technical journals, such as *Bor'ba s Gazom, Pyl'yu, i Vybrosami v Ugol'nykh Shakhtakh* [*Combat with Gas, Dust, and Particulates in Coal Mines*]; *Bezopasnost' Truda v Promyshlennosti* [*Occupational Safety in Industry*]; *Avtomatika, Telemekhanika i Svyaz'* [*Automation, Remote Control and Communications*]; *Ugol'* [*Coal*]; *Khimiya Tverdogo Topliva* [*Chemistry of Solid Fuel*]; etc.

None of these periodicals has been reviewed in sufficient depth to identify what might be called "core" journals in fire technology. One of the by-products expected from the experimental translation of six issues of *RZh Fire Protection* is a better understanding of the fire technology literature not only in the USSR but in other parts of the world as well.

ABSTRACTS AND REVIEWS

A. Prevention of Fires and Fire Safety Measures

Baker, F. E. and Shepherd, R. E. (Goodyear Atomic Corporation, Piketon, Ohio) "Fire Testing of Electrical Cables and the Benefits of Fire-Retardant Paints," *Fire Technology* **7**, 285 (1971)

Section: A, G

Subjects: Testing of electric cables, Electric cable testing, Cable testing; Retardants; Fire retardant paints; Paints.

Authors' Abstract

The authors report the results of flammability tests of polyvinylchloride-sheathed instrument cables and chloroprene-sheathed power cables. Tests were conducted in both horizontal and vertical attitudes with markedly different results.

Chitty, T. B., Griffiths, D. J., Tucker, D. M., and Corrie, J. G. (Joint Fire Research Station, Boreham Wood, Herts, England) "Storage Properties for Four Foam Liquids," *Fire Research Note No. 933, Joint Fire Research Organization* (April 1972)

Sections: A, E

Subjects: Extinguishing agent; Tests; Foam; Protein; Storage; Fluoroprotein; Fluorochemical

Authors' Summary

At the request of the Defence Materials Standardisation Committee, various foam liquids have been placed in storage for an overall period of 2 years, at temperatures of −12°C, approx. +15°C and +38°C. At periodic intervals, samples are being withdrawn for test on the standard fire test of UK Defence Standard 42–3, Issue 1. In this interim report, the performances after storage for 1 year are discussed.

Holmes, C. A. (Forest Service Products, USDA, Madison, Wisconsin) "Methods of Evaluating Fire-Retardant Treatments for Wood Shingles," *Forest Products Journal* **32**, 45 (1972)

Sections: A, H

Subjects: Fire retardance; Shingles; Wood; Test methods; Weathering; Fire performance; Schlyter test; Burning brand test (Class C); Tunnel furnace test

Author's Abstract

Fire-retardant treatments for western redcedar shingles were evaluated for fire performance and leach resistance. The evaluation methods for fire performance included the use of the 8-foot tunnel furnace, the modified Schlyter test, and a modified Class C burning brand test. Leach resistance of the treatments were determined by accelerated outdoor exposure and by severe leaching and ultraviolet exposure in a weathering apparatus. The evaluation methods were shown to be adequately severe by comparing results obtained with Underwriters' Laboratories Class C-labeled shingles as a reference. Four impregnation treatment systems showed most promise of fire-retardant effectiveness and durability.

TABLE I

Results of fire tests on western redcedar shingles after 1,000 hours' accelerated weathering.

Code No.	Treating process	Results of burning brand tests				Results of Schlyter tests				
		Chemical retention (dry)	Coating		Burning brands (failures/applied)	Chemical retention (dry)	Coating		Type of test	Average flame spread
			Spread rate[1]	Dry weight[2]			Spread rate[1]	Dry weight[2]		
		P.c.f.				P.c.f.				In.
	Factory treated									
36	Factory treated, U. L. Class C. labeled	—[3]	0	0	0/8	—[3]	0	0	Mild	2
	do	—[3]	0	0	0/8	—[3]	0	0	Severe	13
	Untreated controls									
1	Untreated	0	0	0	7/7	0	0	0	Mild	38
	do	0	0	0	7/7	0	0	0	Severe	46
	Fire-retardant coatings									
13	Coating of F-R epoxy paint	0	90	36.3	0/8	0	133	24.8	Mild	4
	do	0	132	21.2	0/8	0	133	26.4	Severe	36
	Vacuum-pressure impregnations									
18	Impregnated, sodium tetraborate-monoammonium phosphate	6.4	0	0	4/8	6.4	0	0	Mild	16
	do	6.4	0	0	8/8	6.4	0	0	do	15
22	Impregnated, double-salt: sodium tetraborate and zinc chloride[4]	7.0	0	0	7/8	7.0	0	0	do	[5]3
	do	7.0	0	0	6/7	7.0	0	0	Severe	[6]15
	Vacuum-pressure impregnations with sealer coatings									
23	Impregnated, sodium tetraborate-monoammonium phosphate; coating of preservative sealer	5.9	31	15.0	7/8	5.9	34	13.7	Mild	[7]15
	do	5.9	32	14.5	8/8	5.9	33	14.4	do	[8]10

24	Impregnated, AWPA type D; coating of preservative sealer with tricresyl phosphate	6.3	42	25.0	0/7	6.3	41	25.9	do	3
	do	6.3	41	26.0	0/6	6.3	41	25.6	Severe	23
	Vacuum-pressure impregnations and additional reactions									
25	Impregnated, APO	6.3	0	0	0/6	6.3	0	0	Mild	3
	do	6.3	0	0	0/7	6.3	0	0	Severe	14
26	do	3.8	0	0	0/8	3.8	0	0	Mild	3
	do	3.8	0	0	0/8	3.8	0	0	Severe	20
28	Impregnated, THPC	2.7	0	0	1/8	2.7	0	0	Mild	27
	do	2.7	0	0	1/7	2.7	0	0	do	27
29	do	4.8	0	0	0 8	4.8	0	0	do	20
	do	4.8	0	0	0/8	4.8	0	0	do	15
31	Impregnated, dicyandiamide-phosphoric acid-formaldehyde	5.0	0	0	3/8	5.0	0	0	do	3
	do	5.0	0	0	3/8	5.0	0	0	Severe	26
32	do	8.3	0	0	2/8	8.3	0	0	Mild	3
	do	8.3	0	0	1/8	8.3	0	0	Severe	16
33	Impregnated, dicyandiamide-phosphoric acid	7.3	0	0	2/8	7.3	0	0	Mild	4
	do	7.3	0	0	0/8	7.3	0	0	Severe	25
34	do	9.3	0	0	1/8	9.3	0	0	Mild	4
	do	9.3	0	0	1/7	9.3	0	0	Severe	20
35	Impregnated, zinc sulfate-zinc silicofluoride-urea	12.9	0	0	5/6	12.9	0	0	Mild	7
	do	12.9	0	0	4/7	12.9	0	0	Severe	32

[1] In square feet per gallon of coating.
[2] Grams of dry coating per square foot of surface.
[3] Dry chemical retention not known.
[4] Dry chemical retentions are calculated as zinc borate.
[5] Panels had a light glow on butt edges for about 11 min.
[6] Heavy afterglowing. Extinguished with water after 10 min.
[7] Afterglow along several of the butt edges. Extinguished with water after 27 min. Glowing may have continued until the plywood backing ignited.
[8] Afterglow along butt edge at one place. Self-extinguished at 24.7 min.

Kordina, K. and Meyer-Ottens, C. (Institut für Baustoffkunds und Stahlbetonbau der Technichen Universität, Braunschweig, Federal Republic of Germany) "Relation between Fire Load and Temperature at Tests of Concrete and Wooden Partitions according to DIN 4102" (in German), *Materialprüf* **11**(8), 1 (1971)

Sections: A, G

Subjects: Concrete; Wood; Partitions; Fire resistance; Test methods; Fire load; Fire temperature; DIN 4102; Walls; Furnace tests; ISO-R 1060; Building fires

Authors' Summary

Two wooden partitions, as well as one reinforced concrete and one aerated concrete wall, were tested at fire loads which caused furnace temperatures following the standard time-temperature curve ("ETK") according to DIN 4102 (ISO-R 1060). Two other wooden partitions were tested each with a fire load of "100 q = 100% $q=q$ (reinforced concrete)" which was necessary to produce the standard time-temperature curve for the reinforced concrete wall. The corresponding furnace temperatures were measured.

The tests have shown that the fire load from the furnace according to the standard time-temperature curve "ETK" is 58 q only with wooden partitions, whereas 100 q represent the corresponding fire load from the furnace for reinforced concrete walls; the furnace temperatures determined at comparable wooden partitions are a fire load from the furnace of 100 $q=q$ (reinforced concrete) at any time exceed by about 28% the value required by "ETK" standard time-temperature curve; the wooden partitions tested according to the standard time-temperature curve "ETK" burnt down 100% more slowly than comparable walls under a fire load from the furnace 100 $q=q$ (reinforced concrete), i.e., their resistance to fire was half the time higher than with comparable wooden partitions.

Combustible structures thus have remarkable influence on the development of fire and should not be neglected. Due to these test results the question may arise whether this hitherto applied test procedure for structures according to DIN 4102(2) is correct. The test results will likely form a new basis for a rework of the standards of DIN 4102 (Behaviour of Building Materials and Structures in Fire) as well as of DIN 18 230 (Requirements for Structural Fire Protection of Industrial Buildings).

Law, M. (Joint Fire Research Organization, Boreham Wood, England) "Safe Distances from Wired-Glass Screening a Fire," *The Institution of Fire Protection Quarterly* **29** (73), 62 (1969)

Section: A

Subjects: Safe distances; Wired glass; Glass panels

Reviewed by J. Malcolm

In this paper the author addresses two problems. The first concerns the determination of the minimum distance from wire-reinforced glass panels forming fire barriers, at which combustibles such as wood and paper may prudently be stored. The second concerns the minimum distance during escape from fire at which personnel may approach wire-reinforced glass panels affording protection from open flame.

In both of these problems, the minimum distances are considered in terms of the area of exposure and fire intensity. In the second problem, the speed with which personnel can escape is also considered.

The stated purpose of the discussion is to give guidance in such general terms that each situation may be examined in light of its individual merit.

Reference is made to the existing U.K. building regulations and codes[1,3,4,8] and previously developed data on building fire performance characteristics such as fire radiation intensities anticipated from specified fire loadings. The fire performance characteristics accepted as basis for this discussion are as follows:

a. To preclude the ignition of combustibles such as wood and paper, by exposure to thermal radiation,[2] the radiation intensity must not exceed 0.8 calories cm^{-2} sec^{-1}.

b. A 6 mm thick wire-reinforced glass pane at equilibrium temperature with fire on one side transmits about 50 percent of the incident thermal radiation.

d. Fire loads of 45 and 170 kgm^{-2} area give fire severities equivalent to "one-half hour" and "one hour" fire resistance, respectively, and maximum thermal radiation intensities of 0.9 and 3.7 calories cm^{-2} sec^{-1}, respectively.[5]

e. For design, the U.K. Building Regulations[3] treat a thermal radiation value of 2.0 calories cm^{-2} sec^{-1} as a "normal intensity" fire.

Since the presence of a wired-glass screen would reduce transmitted radiation from a "one-half hour" fire or a "low intensity" fire to a value less than or very close to the critical radiation intensity for ignition (0.8 calories cm^{-2} sec^{-1}), the author dismisses the problems of shielding combustible storage areas at these fire intensities.

The "one hour" and "normal intensity" fires are considered as essentially identical, that is with a radiation intensity of 4.0 calories cm^{-2} sec^{-1}. The radiation intensity transmitted by a wire-reinforced glass screen is taken as 2.0 calories cm^{-2} sec^{-1}. The "space configuration factor" for the 4.0 calories cm^{-2} sec^{-1} intensity is then determined as the factor applied reducing the radiation intensity to the critical value of 0.8 calories cm^{-2} sec^{-1}, below which ignition by thermal radiation would not occur, i.e., 0.8/2.0 yields 0.4, the critical space configuration factor.

The parameters selected for correlation with the space configuration factor are

S, distance from screen to the combustible being shielded by the screen

D, height of the wired-glass screen

L, length of the wired-glass screen

$$N=L/D \text{ (length of screen/height of screen)}$$

Using these parameters, Fig. 1 shows the parametric relationships corresponding to a space configuration factor of 0.4 for three different positions of the combustible surface with respect to the screen.

The diagram of Fig. 2 shows minimum spacing of combustibles from a screen of length ND which shields the combustible from fire.

Criteria for safe egress of personnel, while being shielded from direct fire radiation by wire-reinforced screens, require consideration of additional data concerning the levels of thermal radiation tolerated by human subjects as a function of exposure duration.[6,7] Maximum levels based on tolerance to pair are given below.

Thermal radiation intensity	Time tolerated	Maximum path (meters) traversed at speed v		
		$v=0.2\text{m sec}^{-1}$ $v=40$ ft/min	0.5m sec^{-1} 100 ft/min	2.0m sec^{-1} 400 ft/min
Calories cm^{-2} sec^{-1}	sec.			
0.23	5	1	2.5	10
0.14	10	2	5	20
0.09	20	4	10	40
0.07	30	6	15	60
0.06	40	8	20	80

The author rationalizes that escape from a fire will most likely be effected during early stages of combustion before the maximum radiation intensity is developed. Hence, for the purpose of the discussion the author selects a value for the probable radiation intensity during escape equal to one-half the maximum intensity for the fire category. Since the wired-glass screen transmits only 50 percent of the incident radiation, the resultant intensities of transmitted radiation for the probable radiation exposure during escape for the "low intensity" and "normal intensity" fires are then 0.5 and 1.0 cal cm^{-2} sec^{-1}, respectively.

For the above radiation intensities and at selected walking speeds, Figures 3 and 4 show the required safe distances from wired-glass screens installed along the escape route at either one or two meters from the floor level. The dotted line on these figures shows distances from the British Standard Code of Practice[1] for glazing.

The author concludes that combustible materials located behind glazed panels should normally be located a distance approximately equal to the panel heights and that escape routes used by more than one or two people should not normally have glazing at heights less than 1 m above floor level.

Eight-references are cited, and an appendix showing two examples of "safe distances" calculations using the figures is presented.

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Malhotra, H. L. (Fire Research Station, Boreham Wood, Herts, England) "Expanded Polystyrene Linings for Domestic Buildings," *Fire Research Note No. 12, Joint Fire Research Organization* (1971)

Sections: A, D

Subjects: Polystyrene; Tiles, lining; Fire hazard; Building fires; Wall linings; Fire behavior

Author's Conclusions

An extensive investigation has been carried out to determine the fire hazard of expanded polystyrene ceiling tiles and wall linings. The experimental technique and the results obtained have been fully described. The main interest of the work was the use of materials in domestic-type buildings and therefore the thicknesses selected and the methods of fixing investigated were those commonly recommended for such occupancies. The results of this investigation may not be directly applicable to other situations particularly if thicker materials are used.

A number of *ad hoc* testing techniques were evolved to examine the influence of the size of the igniting source. Tests in full-size rooms were used to confirm the findings of the smaller tests. The 'Fire propagation' test of B.S. 476: Part 6 was used to see if its findings could be related to the behaviour pattern observed in the *ad hoc* tests.

(i) The fire behaviour of expanded polystyrene linings is influenced by the method of attachment to the substrate and the presence of a decorative finish.
(ii) Expanded polystyrene tiles, to a maximum thickness of 12.5 mm attached to a Class "O" substrate, with an overall application of adhesive and without a surface finish, do not ignite easily and are unlikely to assist a fire to spread.
(iii) 'Dab' application of adhesive is undesirable as the tiles become dislodged and are likely to become ignited and lead to fire spread.
(iv) The presence of a surface finish facilitates the ignition of expanded polystyrene. The use of flame-retardant paints does not lead to any significant deterioration in performance. Matt-finish emulsion paint results in some deterioration, but the resultant performance is acceptable for domestic-type buildings.

(v) The combination of gloss paint with expanded polystyrene presents an extremely hazardous lining capable of promoting rapid fire spread assisted by the fall of flaming material onto the floor.

(vi) When examined *in situ* no significant difference is observed between the performance of standard and self-extinguishing grade materials. The flammability tests conducted on the material by itself do not reflect the fire behaviour of the applied system.

(vii) The fire propagation test of B.S. 476: Part 6 is a reliable indicator of the behaviour of the lining under fire conditions. The performance index together with the sub-index for the first three minutes of a test (I/i_1) gives a measure of the overall hazard and the flammability of the lining system.

(viii) On existing linings with gloss-paint finish the reduction in hazard obtained by the use of flame-retardant paints is not adequate. For safety the tiles should be replaced with new undecorated material.

(ix) Expanded polystyrene has a tendency to produce flaming drops on ignition, but the quantity produced without a finish or with an emulsion-paint finish is negligible and restricted to the seat of fire. With gloss paint, burning strips of the material fall and continue to burn, thus promoting fire spread.

(x) Home decorators should, in the interests of safety, attach the ceiling and the wall linings with an overall application of the adhesive and preferably leave the surface undecorated. If surface finishes have to be applied, these in order of preference should be flame-retardant paints or matt-finish emulsion paints. The use of wallpaper on wall linings is unlikely to increase the hazard significantly.

Stark, G. W. V. (Department of the Environment, Fire Research Station, Boreham Wood, Herts, England), **White, R. W. and Moseley, G. E.** (Agricultural Research Council, Institute of Animal Physiology, Babraham, Cambridge, England) "Wooden Laboratory Cupboards for the Fire Protection of Solvents," *Chemistry and Industry*, 1193 (1971)

Sections: A, H

Subjects: Laboratory cupboards; Fire protection; Solvents; Flammable liquids

Authors' Summary

Most chemical and biological laboratories require the constant availability of relatively large quantities of flammable solvents stored in Winchester quart bottles. In the event of a fire these can contribute to its very rapid spread and intensity, and cause additional and immediate hazards to staff. Under these circumstances compartments or cupboards capable of protecting their contents for a short time would minimise the size of fire to be controlled and would assist staff to escape. It is doubtful if protection from a severe fire for more than ten minutes is required,

since after this time it is likely that the whole laboratory would be gutted. It is also desirable that any cupboard should be reasonable in cost and should fit in with normal laboratory furniture. Steere, examining chemical storage cabinets for fire protection, showed that heat transfer across cabinet walls constructed of 1-in.-thick wood was relatively very poor for short periods and recommended such cabinets for the storage of flammable liquids with the volumetric capacity limited to 50 ft.[3]

The Institute of Animal Physiology, Babraham, Cambridge, and the Fire Research Station, Boreham Wood, collaborated in the development of a suitable wooden cupboard. Two successive prototypes have been tested to destruction, and this note presents the results of an investigation to examine the performance of the second and final prototype in a spillage fire. It will, of course, be necessary to ensure that such furniture satisfies legal requirements and those of any controlling bodies.

Wilde, D. G. (Safety in Mines Research Establishment, Sheffield, England) "Fire-Retardant Treatments for Mine Timber," *The Mining Engineer* **132,** 281 (1972)

Section: A

Subjects: Fire retardants; Retardants; Mine timber; Timber; Wood; Roadways in mines; Testing of retardants; Pyrolysis; Testing methods; Coatings

Author's Synopsis and Conclusions

The manner and extent of use of timber as a lining for mine roadways has led to the adoption of some form of fire-retardant treatments in appropriate cases.

Impregnated fire-retardant treatments for timber cause increased evolution of the nonflammable proportion of the volatile products when wood is decomposed by heat. They also cause an increase in the proportion of charcoal that remains after the evolution of volatile products has ceased. Fire-retardant surface coatings for timber reduce the heat that is transferred to wood from flames near the surface of the solid, and inhibit the mixing of the flammable volatile products of decomposition with air.

Fire-retardant treatments can only be fully proved in full-scale fire trials; small-scale test are useful for "screening" new formulations for treatments and provide a convenient way of checking the quality of accepted treatments.

A treatment should prevent timber from contributing significantly to the heat and fumes of a fire with a total output, varying at times from 6 MW to 2 MW, in which temperatures in the fumes reach 800°C, and which last, in all, for about one hour.

The impregnated treatment, that has virtually exclusive use among treatments of this type in British mines, can achieve such a performance. There are a number of fire-retardant surface coatings that are similarly effective.

No treatment can indefinitely prevent the burning of timber; a typical impregnated treatment has been shown to lose its effectiveness after twenty-minutes' exposure to an exceptionally intense fire.

Conclusions

1. Timber linings of roadways are peculiarly susceptible to fire, because the wood is continuously distributed.
2. The flammability of wood depends largely on the type of pyrolysis induced by heating. Maximum flammability results when pyrolysis is rapid, and produces maximum evolution of tar vapour.
3. There is evidence that impregnated fire-retardant treatment for wood modifies the chemical processes during pyrolysis of wood, to produce a slow endothermic pyrolysis. This results in increased formation of char, which is retained within the wood, and in enhanced evolution of incombustible gases and vapours.
4. Fire-retardant surface coatings for mine timber are based on the principle of providing a practicable, stable barrier between wood and the atmosphere surrounding it.
5. As a basis for establishing testing methods, it is suggested that a fire-retardant treatment for mining timber should prevent, or greatly delay, the ignition of timber by moderate sized localized sources with radiation intensity of not less than 30 kW/m^2, and a total output of not less than 10 kW. A treatment should also halt, or control, spread of flame in timber exposed to a test fire with an average output of about 2 MW, intermittent outputs of up to 6 MW, and in which timber is exposed to radiation ranging in intensity up to 80 kW/m^2.
6. There is virtually only one impregnated fire-retardant treatment for use in Britain, the NCB product known as "Fyrprufe." The mixture is based on ammonium salts. Full-scale fire trials have shown that "Fyrprufe" is an effective fire-retardant treatment, capable of controlling the spread of a well-developed fire into a single layer of treated hardwood cover boards. The treatment was also effective in controlling the burning of wood in intense fires lasting 3 and 12 minutes, respectively. An experiment carried out in Germany indicated, however, that an impregnated treatment, having the same character as "Fyrprufe," failed to protect timber from an exceptionally intense fire after 20 minutes. After prolonged exposure to fire, impregnated timber burns freely through a charcoal/air reaction.
7. Fire-retardant surface coatings for mine timber have, until recently, been based on sodium silicate. Such coatings can be effective, but there are practical problems associated with their use in mines that make it difficult to apply them in a way that results in the desired performance.
8. Commercial development of other materials, capable of retarding the ignition and spread of fire, has eliminated many of the difficulties associated with sodium silicate coatings.
9. Fire-retardant surface coatings exist that are based on polymers and inert fillings, but they would probably not be admissible under the terms of NCB instructions governing the combustibility of surface coatings. Polymer materials may give rise to toxic fumes, in the event of their being exposed to a fire.

10. Full-scale trials have shown that a fire-retardant surface coating of sodium silicate/limestone, applied under ideal conditions, can be as effective as an impregnated treatment. Fire-retardant coatings, based on materials developed for use as roadway sealants, can seal off underlying timber from the effects of heat in a roadway and, consequently, can confer virtually complete protection on timber. For various practical and economic reasons, however, impregnated treatment seems likely to remain the main defense against the fire hazard of mining timber for some time to come.

Williams-Leir, G. (Division of Building Research, National Research Council of Canada, Ottawa, Canada) "Another Approximation for Spatial Separation," *Fire Technology* 6 (3), 189 (August 1970)

Sections: A, G, I

Subjects: Building separation; Spatial separation of buildings; Radiation; "Gray Radiator"; Building codes; Radiative spread of fire

Author's Summary

A simple, accurate, and fail-safe method is given for calculating the separations between buildings that would be sufficient to prevent spread of fire by radiation. The new method makes tables unnecessary for this purpose and avoids the errors of the "gray radiator" method, which are explained. The article is primarily intended to assist those who wish to simplify building codes, but the theoretical basis is also stated.

B. Ignition of Fires

Tolson, P. (Department of Trade and Industry, Safety in Mines Research Establishment, Sheffield, England) "The Ignition of Flammable Atmospheres by Small Amounts of Metal Vapor and Particles," *Combustion and Flame* **18,** 19 (1972)

Section: B

Subjects: Ignition of flammable atmospheres; Vapors and particles, metal; Exploding wires

Author's Abstract

The discharges between electrodes of certain low-boiling-point metals are known to be capable of igniting flammable gases at much lower levels of arc energy than with other metals, and it has been observed that during the course of the discharge these low-boiling-point metals emit relatively large amounts of metal vapor and metal particles. This current investigation was carried out in order to determine whether or not the small quantities of metal vapor or particles which are ejected into the surrounding gas during a discharge are capable of causing an ignition. In one group of experiments, metal wires were exploded by discharging a capacitor bank through them and some of the explosion products were allowed to pass through a small hole into a chamber containing a flammable mixture of methane and air. The results showed that all but the metals with the lower boiling points readily caused ignitions. Schlieren photographs of the development of the ignitions indicated that, whereas individual particles of aluminum readily caused ignitions, individual particles of the other metals examined (Cd, Cu, Fe, Pb, Sn, W, and Zn) did not. In another group of experiments, small quantities of vapor and particles were produced by focussing the output of a ruby laser onto the flat surface of samples of both metals and nonmetals. The amount of laser energy necessary to produce sufficient vapor to ignite a number of flammable atmospheres was determined for these materials, and it was found that this amount increased considerably as the boiling point of the material decreased. It was concluded that the ease with which arc discharges between low-boiling-point metals cause ignitions was not due to the ignition of the flammable atmosphere by the metal vapor and particles emitted during the discharge.

Weinberg, F. J. and Wilson, J. R. (Department of Chemical Engineering, Imperial College, London, England) "A Preliminary Investigation of the Use of Focused Laser Beams for Minimum Ignition Energy Studies," *Proc. Roy. Soc., Ser. A* **321,** 41 (1971)

Sections: B, I

Subjects: Lasers; Ignition; Minimum ignition energy; Plasma

Authors' Abstract

The plasma produced by focusing a passively Q-switched 30 J ruby laser beam is studied as regards its suitability for minimum ignition energy measurement. By comparison with electric spark discharges, it would appear to offer shorter times and smaller volumes of the initiating plasma, as well as freedom from energy losses to electrodes and elsewhere within the circuit. The growth of the initating plasma as well as that of the flame kernel are studied as a function of pressure and composition, the former using an optical delay line with a Schlieren system and the

latter by high-speed Schlieren streak photography. It is found that the difficulties of the method are associated with the finite duration of the laser pulse. In the time between the onset of breakdown and the end of the pulse, the plasma front facing the incident beam absorbs the incoming energy, leading to the production of an extended and unsymmetrical initiating source, an absorption threshold which may already be in excess of the minimum ignition energy, and the formation of a blast wave which may be powerful enough to initiate a detonation rather than a deflagration. For a pulse of approx. 20 nanosecond half-width, these effects become serious above about half an atmosphere for stoichiometric methane–air mixtures. For lower pressures, or near limit mixtures, the promise of the method is borne out and both ignition energies and quenching distances fall below those determined by the electric spark method. For higher pressures and faster reacting mixtures, it will be necessary to decrease the duration of the laser pulse and the size of the plasma.

C. Detection of Fires

D. Propagation of Fires

Vulvis, L. A. (Leningrad, USSR) "Turbulent Burning Rate," *The Physics of Combustion and Explosions* (*Fizika Goreniya i Vzryva*) **8,** 3 (1972) (in Russian)

Sections: D, G

Subjects: Burning velocity, Turbulent burning velocity; Temperature fluctuations

Author's summary translated by L. Holtschlag

Some results of a numerical computer calculation of the combined effect of fluctuating temperature and concentration on the turbulent burning rate of a gas jet under various conditions are given. The results were qualitatively uniform. The calculations confirm essentially the earlier results on the predominant effect of the temperature fluctuations and the relatively weak effect of fluctuating concentration. The appreciable acceleration of turbulent burning is particularly important in the ignition region, less so near the completion of combustion. In the limiting case of isothermal reaction, turbulent fluctuations in the concentration of reagents do not intensify, but smooth out the decelerating effect of dilution of a fresh mixture by inert reaction products.

Wiersma, S. J. (Stanford Research Institute, Menlo Park, California) "Measurements of the Dynamics of Structural Fires," *Annual Report, August 1971—August 1972, Defense Civil Preparedness Agency Contract DAHC-70-C-0219.*

Sections: D, G, I

Subjects: Dynamic behavior of structural fires; Pulse of radiant energy; Burning rate; Maximum energy release; Volumetric fire growth; Inflow winds; Air temperatures; Wood-frame structures; Carbon monoxide concentrations

Author's Abstract

The *dynamic behavior of structural fires* in the context of civil defense implications following nuclear attack is experimentally evaluated. During the third year of the program, some gross variations in the structures were made. Measurements from all three years of experiments are used to evaluate the nature and magnitude of behavioral changes that result from variations in both structural and environmental factors.

A simple empirical equation which fits reasonably well the *pulse of radiant energy* and the *burning rate* of a burning building is used to generalize the dynamic characteristics of structural fires. Qualitative observations are made of the dependence of two physically significant times, $t_{\max}$, the time of *maximum energy release*, and t_c, a time characteristic of the burning time, which can be related to the fitting parameters of the equation on the structural and environmental variations.

The *volumetric fire growth* is found to be exponential with time. The intrastructure fire spread, as measured by the volumetric doubling time (VDT) increases with wind and addition of fuel to the rooms and decreases when ceilings are made noncombustible.

Three replications of the basic test condition give mean values and variance expressed as standard deviation of $\bar{t}_{\max}=25.3\pm2.6$ min, $\bar{t}_c=19.7\pm2.1$ min, and $\overline{VDT}=2.73\pm0.22$ min.

Inflow winds induced by the fires are small. These results are consistent with estimates of air flow necessary for the measured burning rates.

Carbon monoxide and carbon dioxide levels and *air temperatures* all reach lethal levels within a short period of time after initiation of the fire in wood-frame structures, usually corresponding to a point just prior to flashover of the compartment. High temperature is usually the first lethal condition reached in well-ventilated rooms, whereas in rooms with windows intact and the door closed, *carbon monoxide concentrations* usually become lethal before lethal air temperatures are reached.

Ying, Shuh-Jing (College of Engineering, Wayne State University, Detroit, Michigan) "Flame Propagation of Burning Solid Material with Moisture," *Fire Technology* **7**(3), 243 (August 1971)

Sections: D, G, I

Subjects: Flame propagation theory; Burning solids; Moisture, effect on flame propagation; Evaporation and flame propagation; Theory of flame propagation

Author's Conclusions

Based on this simple physical model, reasonable temperature distributions in the solid are obtained for different evaporation rates. Maximum temperature occurs within the combustion region and the temperature decreases exponentially with the distance from the flame front.

Through this study, it is clear that the flame propagation of a burning solid with moisture is governed by three parameters—dimensionless propagation speed α, evaporation coefficient β, and combustion heat γ. An exact solution of α can be obtained by the numerical method shown. Approximate solutions of α show that the propagation speed increases with the temperature difference in the combustion region and with the reciprocal of the dimensionless coordinate of maximum temperature, $1/\bar{\xi}_f$. The evaporation process can always slow down the flame propagation speed. The flame will completely stop to propagate at

$$\beta=4[(\theta_f-\theta_i)/(\theta_i\bar{\xi}_f)]^{1/2}.$$

E. Suppression of Fires

Atallah, S., Kalelkar, A. S. and Hagopian, J. (A. D. Little, Inc., Cambridge, Massachusetts) "Evaluation of Auxiliary Agents and Systems for Aircraft Ground Fire Suppression—Phase I," *Final Technical Report ASD-TR-72-75 under Contract F 33-657-72-C-0422, Tri-Service System Program Officer for Aircraft Ground Fire Suppression, Wright-Patterson Air Force Base, Ohio* (1972)

Sections: E, N

Subjects: Fire extinguishment; Auxiliary fire fighting agents; Aircraft fires; Ground fire suppression; Auxiliary fire fighting systems

Authors' Abstract

This program was conducted with the ultimate objective of reducing the number and types of auxiliary extinguishing agents and systems used for aircraft ground fire suppression at military airports.

This phase was devoted to the definition of auxiliary agent/system requirements and to the review of existing knowledge on the performance of various agents and systems under particular fire and environmental conditions likely to be encountered at military airports. Where knowledge was lacking, a series of environmental and small-scale fire tests were conducted, the latter on three mockups simulating fires in an aircraft engine, fuel running along the incline of an aircraft wing, and in a ruptured fuel tank containing reticulated foam.

Candidate auxiliary agents and systems were recommended for the various requirements identified. A test program aimed at reducing the number of agents and systems to a minimum was planned and proposed for conduct in the second phase of the project. Two other areas were identified as requiring additional work and recommended for the second phase. These were the development of a more effective magnesium fire extinguishing agent and system and the optimization of the design of nozzles and delivery mechanisms used on portable and wheeled extinguishers.

Rogowski, Z. W. and Ames, S. A. (Fire Research Station, Boreham Wood, Herts, England) "Performance of Metal Foam as a Flame Arrester When Fitted to Gas-Explosion-Relief Vents," *Fire Research Note No. 931, Joint Fire Research Organization* (April 1972)

Sections: E, A

Subjects: Explosion; Flame arrester; Electrical equipment; Foam, metallic

Authors' Summary

A new metallic foam known commercially as 'Retimet' was examined for the purpose of protecting industrial equipment for use in flammable atmospheres. The metal foam functioned as a flame arrester when mounted on the casing of such equipment and relieved pressure resulting from ignition of flammable gas within the equipment but prevented the emergence of flames to the outer atmosphere.

Cubical enclosures up to 28 litres (1 ft^3) in volume have been tested with propane/air and ethylene/air mixtures using two different porosity grades of the metal foam. The pressure developed inside the enclosure was found to be dependent upon the vent area and the porosity of the metal foam. A limiting vent area was found below which damage to the arrester would occur and the outer atmosphere would be ignited. The mechanism of the explosion transmission through the arrester was established.

F. Fire Damage and Salvage

G. Combustion Engineering

Sadilov, P. V. and Baskakov, A. P. (Sverdlovsk, USSR) "Gas Burning Mechanism in a Fluidized Bed," *The Physics of Combustion and Explosions* (*Fizika Goreniya i Vzryva*) **8,** 252 (1972) (In Russian)

Section: G

Subjects: Fluidized-bed combustion; Combustion in fluidized beds

Authors' Conclusions translated by L. Holtschlag

An attempt is made to analyze the process of gaseous fuel combustion (methane–air mixture) in the continuous (emulsion) and discontinuous (bubble) phases of a fluidized bed theoretically and experimentally under the following assumptions: gas mixing in the bubble is so intense that the temperature over the volume is constant; the gas burns adiabatically in the bubble; the mean thermodynamic constants of the gas mixture are independent of time and temperature and are constant over the volume of the bubble. Visual and photographic observations yield the following patterns. At bed temperatures of 700–950 C, the emulsion gas burns with a continuous open flame, primarily on the surface of the bed. The gas of the discontinuous phase bubbling up through the bed also burns on the bed surface as the bubbles burst, accompanied by sound waves. They are ignited by the surface-burning emulsion gas. With bed temperatures of 1000-to-1100 C, most of the emulsion gas burns under isothermal bed conditions. The gas in the bubbles ignites within the bed farther and farther from the surface (thermal explosion of the bubbles). When the temperature is increased to 1150 C and above, the gas ignites at the instant bubbles are formed in the jets of the opening of the gas-distribution mesh. Visual observations indicate that this analysis is qualitatively valid for gas—air mixtures of differing composition.

Shetinkov, E. S., Shcherbina, Yu. A. and Spiridonov, V. A. (Moscow Physico-Technological Institute, USSR) "Turbulent Combustion of Gaseous Mixtures," *Astronautica Acta.* **15,** 597 (1970)

Sections: D, G

Subjects: Turbulent combustion; Flame propagation; Microscale of turbulence; Theory of turbulent combustion

Authors' Abstract

The theory of turbulent combustion waves lags appreciably behind that of laminar and detonation waves. Up to the present time, three general models of turbulent combustion have been formulated: wrinkled laminar model, stretched laminar flame model and micro-volume model. However, an experimental confirmation of these models cannot be taken as a sufficient one.

In this paper, a dimensional formula is proposed for a velocity of turbulent flame propagation u_{tf} in a homogeneous combustible mixture as applied to the microvolume model:

$$u_{tf} \sim \lambda_c / t_i$$

where λ_c-microscale of turbulence in a cold stream, t_i-ignition delay at burning temperature.

The justification of the denominator of this formula has been given in some papers by A. S. Sokolik, V. P. Karpov and E. S. Semjonov.

To justify the numerator, some measurements were conducted at the Moscow Physico-Technological Institute of a concentration microscale in a wake of a smoke source placed at the axis of a cylindrical tube 100 mm in dia. The microscale has been measured optically at the tube axis. Air speed and the distance from the measuring point to the source are varied.

The variation of the microscale against the velocity is shown to be linear. This fact confirms an agreement between the above formula and numerous experimental results which define the relation between the burning velocity and the flow speed.

H. Chemical Aspects of Fires

Homann, K. H. and MacLean, D. I. (Boston College, Chestnut Hill, Massachusetts) "Structure of Fluorine Supported Flames II—Concentration Profiles for Flames of the Systems: H_2–F_2, H_2–F_2–NH_3, NH_3–F_2, C_2H_2–F_2, and C_2H_4–F_2," *Report to the Office of Naval Research, Power Branch, under Contract N-00014-69A-0453* (*no date*)

Section: H

Subjects: Low-pressure flames; Fluorine-supported flames; Hydrogen–fluorine flames; Hydrogen–fluorine–ammonia flames; Acetylene–fluorine flames; Ammonia–fluorine flames; Ethylene–fluorine flames; Soot formation

Authors' Abstract

Concentration profiles of reactants, stable products and reactive intermediates have been measured in low-pressure flames of the following systems burning on a multi-diffusion burner.

H_2–F_2: Preliminary results for the H_2- and F-atom profiles are in good agreement with independent measurements of the elementary reaction $F + H_2 \rightarrow HF + H$.

H_2–F_2–NH_3: Ammonia acts as an inhibitor in H_2–F_2 flames. This is attributed to the formation of solid NH_4F.

C_2H_2–F_2: The main products of this flame are HF and CF_2. CF_2 recombines to C_2F_4 when the burnt gas is cooled. The nature of the intermediates indicates that addition reactions of F and F_2 to unsaturated hydrocarbons and their radicals, respectively, are important. The formation of soot in this flame is compared to that in an acetylene-oxygen flame.

C_2H_4–F_2: Since a large amount of C_2H_4 is decomposed to C_2H_2 in primary reactions, the concentration profiles in this flame are very similar to those in an C_2H_2–F_2 flames.

Lipska, A. E. (Stanford Research Institute, Menlo Park, California) "The Fire-Retardance Effectiveness of High-Molecular-Weight, High-Oxygen-Containing Inorganic Additives in Cellulosic and Synthetic Materials," *Annual Report to Defense Civil Preparedness Agency under Contract No. DAHC20-70-C-0219* (August 1972)

Sections: H, A

Subjects: High-molecular-weight inorganic additives; Permanent flame retardants; Cotton; Rayon; Roofing material; Nylon; Polyester; Cellulosic materials; Phosphomolybdic acid; Phosphotungstic acid; Ammonium phosphotungstate; Flaming ignition; Decomposition products; Char; Isothermal pyrolysis of cotton; Kinetics of decomposition

Author's abstract

A feasibility study was conducted to determine whether high-molecular-weight inorganic additives, particularly those with high oxygen content, can be used effectively as permanent flame retardants for cotton, rayon, roofing material, nylon, and polyester.

Results show that cellulosic materials treated with either phosphomolybdic acid, phosphotungstic acid, or ammonium phosphotungstate do not sustain flaming ignition when exposed to an irradiance of 6.2 cal cm^{-2} sec^{-1} from a CO_2 laser for 6.3 seconds. Furthermore, the retardant treatment caused a drastic change in the decomposition products of the materials and increased the yields of char.

Cedar shakes treated with either phosphotungstic acid or its insoluble ammonium salt required 65 seconds of exposure to a Fisher burner for ignition, whereas 4 seconds of exposure caused ignition in untreated shakes. Moreover, the treated specimens ceased flaming after they were removed from the Fisher flame and the untreated shakes continued to burn even when they were removed from the ignition source.

More extensive evaluation of the efficiency of these treatments and of our technique is needed to substantiate our present findings. For example, the procedure used to incorporate the phosphotungstic acid and its salt into nylon and polyester must be modified before the optimal loading and efficiency of the retardant can be achieved.

Comparison of the results of isothermal pyrolysis of cotton with those of α-cellulose suggests that there might be differences in the kinetics of decomposition of the two materials. The differences will have to be resolved by additional experimentation, namely, comparison of the rate of monomer loss and the rate of change in the degree of polymerization of the two materials using at least three different temperatures higher than 276°C.

MacArthur, D. A. and Packham, D. R. (CSIRO Division of Applied Chemistry, Melbourne, Australia) "Radiation from an Ethylene Diffusion Flame," *Combustion Science and Technology* **2**, 299 (1971)

Sections: H, G

Subjects: Ethylene–air flames; Flames and radiation; Radiation from flames; Diffusion flames.

Authors' Abstract

Radiation from a small ethylene flame burning in air has been measured at pressures between 40 and 95 cm of mercury.

The radiation between 0.4 μm and 5.5 μm was shown to be dependent on the pressure. At 40 cm Hg the radiation was 65% of that at 76 cm Hg, and at 90 cm Hg it was 120%. Radiation between 0.4 μm and 3.0 μm was more strongly dependent upon pressure, and at 40 cm Hg was 50% of that at 76 cm, and it was 140% at 90 cm.

An approximate calculation indicates that 45% of the total radiation at atmospheric pressure arises from carbon particles, the remainder coming from gaseous radiation.

Roberts, A. F. (Department of Trade and Industry, Safety in Mines Research Establishment, Sheffield, England) "The Heat of Reaction during the Pyrolysis of Wood," *Combustion and Flame* **17**, 79 (1971)

Section: H

Subjects: Pyrolysis; Wood; Heat of reaction

Author's Abstract

Published estimates of the overall heat of reaction during the pyrolysis of wood range from $q=370$ J/g (endothermic) to $q=-1700$ J/g (exothermic). Data from

differential thermal analyses show that the pyrolysis of lignin is more strongly exothermic than that of cellulose; this is consistent with the data from two sets of experiments with bulk samples of wood which suggest that $q=-800$ J/g for lignin and $q=-80$ J/g for cellulose, and that lignin contributes 65% of the exothermic heat of reaction of pyrolyzing wood. Data from other experiments in which bulk samples of wood are heated to temperatures greater than 320°C give reasonably consistent values of $q=-(160\text{–}240)$ J/g. Where the maximum temperature achieved is less than 320°C, the value obtained for the heat of reaction is highly dependent on conditions and may rise to -1700 J/g. The role of primary and secondary pyrolysis reactions in determining the overall heat of reaction and the influence of the physical structure of the wood are discussed.

Shafizadeh, F. (Department of Chemistry and School of Forestry, University of Montana, Missoula, Montana) "Thermal Behavior of Carbohydrates," *J. Polymer Sci.: Part C*, 21 (1971)

Section: H

Subjects: Carbohydrates; Thermal degradation; Thermal analysis; Wood; Pyrolysis; ESR; NMR; Kinetics of pyrolysis; Calorimetry

Author's Synopsis

Thermal analysis of a hardwood reflected the pyrolysis of its main components including xylan and cellulose. Thermal properties of these components were investigated with model compounds consisting of α-D-xylose, substituted phenyl β-D-xylopyranosides, β-D-glucopyranosides and α-D-*arabino*-hexopyranosides and 1,6-anhydro-β-D-glucopyranose.

At the lower temperatures these molecules displayed anomerization, loss of water and phase change, which were studied with a variety of physical methods. Calorimetric and wide-line NMR measurements showed that 1,6-anhydro-β-D-glucopyranose and related anhydro sugars undergo plastic crystalline transition, involving reorientation of the molecules about their centers of gravity, and self-diffusion before melting.

At more elevated temperatures the above compounds showed cleavage of the glycosidic group, polymerization of the sugar moiety, decomposition and evaporation of the pyrolysis products. This involved some heterolytic reactions, which could be catalyzed by acid or alkaline materials.

Kinetics of the pyrolysis process, including the rates and energies of activation were determined by thermal analysis and ESR spectroscopy. These data indicated that cleavage of the glycosidic bond is directly influenced by variation of its electron density and constitutes the rate determining step in pyrolysis of the carbohydrate compounds.

I. Physical Aspects of Fires

Weinberg, F. J. and Wilson, J. R. with appendix by J. Adler (Imperial College, London, England) "An Optical Study of Preignition Heat Release," *Proc. Roy. Soc., Ser. A* **314,** 175 (1970)

Section: I

Subjects: Ignition, heat release, preignition; Optical densities; Temperatures during ignition; Ethylene–air; Ignition temperatures; Velocity fields; Thermal ignition

Authors' Abstract

The distributions of temperature and velocity are measured by optical methods in an ethylene–air mixture flowing against a uniformly heated surface in order to determine the profile of heat release rate before ignition. The objective is to deduce the variation of heat-release rate with temperature (in a manner analogous to the thermal analysis of flame structure but in the absence of the large diffusive flux of active species associated with flames) so as to compare the rate laws with those applying in flames and to investigate their use for predicting ignition in other flow systems. Various practical igniter systems are investigated using cine-interferometry and particle tracking. The results manifest a constant activation energy of 8.8 kcal mol^{-1} (37 kJ mol^{-1}) and differ entirely from the heat release rate laws in equivalent premixed flat flames. The back-diffusion of radicals in the latter gives rise to much higher rates of heat release at low temperatures and no constant 'activation energy' based on concentrations of the primary reactants. The possibility of using such results to predict ignition, on the criterion that beyond this condition temperature would rise with time, without a steady state solution, is discussed. For unidimensional systems a simple analytical solution is proposed in an Appendix by Dr. J. Adler. This yields interesting and plausible predictions of ignition temperature as a function of flow velocity and initial temperature, using the present results. Computer solutions would be required for more complex systems.

J. Meteorological Aspects of Fires

K. Physiological and Psychological Problems from Fires

Kishitani, K. (Department of Architecture, University of Tokyo, Japan) "Study on Injurious Properties of Combustion Products of Building Materials at Initial Stage of Fire," *Journal of the Faculty of Engineering, University of Tokyo (B)*, **31**(1), 1 (1971)

Section: K

Subjects: Smoke inhalation; Building materials; Toxic gases; Carbon monoxide poisoning; Wood; Melamine; Polyvinyl chloride; Polyurethane; CO–Hb; Animal experiments

Author's Abstract and Selected Extracts

The study was made with the purpose of clarifying through experiments the harmful nature of a building material at the time of its combustion and is featured by comprehensive biological experiments. Such types of experiments have often been carried out in the field of building, but almost all of these have been confined to the relative harm dependent on survival or death of the animals used in the experiments. This study delves into the causes of deaths of the test animals from which it is attempted to ascertain the chief reasons for the harmful natures of building materials.

First of all, a scrutiny was made of literature. From the causes of deaths, it was anticipated that the greatest lethal factor would be carbon monoxide. The literature indicates that carbon monoxide is the most common gas in harmful gases produced from various building materials and, moreover, is generated in fairly large quantities. Also, the medical data shows that the toxicity of carbon monoxide is extremely strong in various harmful gases. Based on these, it was thought that if harmful gas could be fatal, this would mainly be due to the effects of carbon monoxide. As other injurious gases, judging by the chemical composition of synthetic resin materials, it was thought possible for hydrogen cyanide, chlorine, etc., to be generated and this is borne out by test results of the past. In other words, the relation between a certain material and a harmful gas peculiar to that material may be contemplated.

Further, the toxicity of carbon monoxide produced from organic materials was considered. In order to judge the cause of death due to combustion products of building materials to be carbon monoxide poisoning, or, in order to judge that there is considerable effect of carbon monoxide, it is necessary for behavior and lethal quantities to be determined. As a matter of course, this was ascertained on mice, the animals used for the experiments. Since there were no data in this regard, pure carbon monoxide was caused to be inhaled to obtain data necessary for research of the following stage. As a result it was concluded that the toxicity of carbon monoxide could be considered to be owed entirely to carbon monoxide hemoglobin concentration in blood, that the degree of poisoning from carbon monoxide could be clarified by its quantitative measurement, and it was found that the lethal quantity was in the neighborhood of 40%. From this it is thought the complimentary action with other harmful gases can be estimated to some extent.

Finally, building materials were actually burned in a furnace to observe their harmful natures. With lumber, plywood and woodwool-cement boards, carbon monoxide was clearly lethal, while with polyvinyl chloride, polyurethanes, etc., it was seen that harmful gases other than carbon monoxide had a considerable complimentary effect with carbon monoxide. Also, from analyses of electrocardiograms, it was found there was considerable effect before concentration of smoke was increased, and it was learned that harmful gases produced at time of combustion caused fairly great damage to human bodies at the early stages of fire.

Considerations

(a) Wood (cedar)

Of the test specimen of 30 g, it was considered that approximately two-thirds burned or was decomposed by heat. Flames could not be observed because of the large quantities of smoke. The portions burned were either turned to ashes or carbonized. The average time for the generation of carbon monoxide was 4 min 11 sec from the beginning of smoke emission. The heating temperature at this time was approximately 250°C, with thermal decomposition of the wood becoming severe and roughly matching the so-called critical ignition temperature. The average CO–Hb concentration in the mice at the time of death was 38.7%, within the range of lethal concentration (35–40%) established in the preliminary experiments; the cause of death was considered to be carbon monoxide poisoning. While there were no prominent external symptoms and no observed abnormalities in the various internal organs and the blood vessels presented a bright scarlet color, it may be concluded that the deaths were by carbon monoxide poisoning with no effects of other injurious gases. Some amount of soot was recognized in the tracheae, but it is not conceivable that death was caused by suffocation from this soot. The concentration of smoke suddenly increased at around 6 min 20 sec to 6 min 30 sec with carbon monoxide concentration also rising suddenly. About 30 seconds earlier than this, effects appeared in the heart with irregular pulses being recognized. Marked irregularities were roughly parallel to the rise in smoke concentration and the aspect was that of gas being harmful before smoke.

(b) Woodwool-Cement Board

It is noteworthy that CO–Hb concentrations in the mice were fairly high. Moreover, one of the mice died. As the CO–Hb concentration was fairly high (44.5%) and there were no other prominent symptoms, it may be said the cause of the death was carbon monoxide poisoning. Although only one mouse died, the others surviving recovered only after being on the verge of death. There was less weight loss and the time of emission of smoke was slower than in the case of cedar, but generation of carbon monoxide gas was quick, being detected at 3 min 30 sec, and harm due to carbon monoxide was recognized. The concentration of smoke was fairly low until around 8 min, but violently fluctuating changes were seen in some of the mice and the more dangerous nature of gas than smoke was evident. The electrocardiogram of the deceased mouse was similar to cases of pure carbon monoxide inhalation.

(c) Fire-Retardant Plywood

Initial smoking averaged 4 min 55 sec, which was considerably slower than cedar, while carbon monoxide gas increased abruptly from 5 min 30 sec. Therefore, the mice all died at a fairly early time. The CO–Hb concentrations at time of death were extremely high, averaging 48%, and since there were no other symptoms, the deaths were perfect cases of carbon monoxide poisoning. It may be said that treatment for fire retardation rather increased the danger of carbon monoxide poisoning. The concentration of smoke was also high, and after 7 min the interior of the chamber was hardly visible. Abnormalities in cardiac waveforms appeared slightly at 5 min and prominently after 7 min had elapsed. These were thought to be due to both smoke and gas. However, it may be said the lethal factor was still carbon monoxide.

(d) Melamine Finishing Board

The time of smoke emission was about 1 min 30 sec later than in the case of cedar. The CO-Hb concentrations at time of death were exceedingly high, averaging as much as 44.5%, and all of the mice died. The trend in generation and increase in carbon monoxide gas was similar to that of woodwool-cement board. According to electrocardiograms, there were marked abnormalities when concentration of smoke was suddenly increased. In other words, when the concentration of smoke became high, the effects had already appeared in the mice. At time of death there were no other prominent symptoms and, judging by the CO–Hb concentrations, the cause of the deaths was carbon monoxide poisoning.

(e) Polyvinyl Chloride

The injurious nature of polyvinyl chloride is most unique. All of the mice died, but CO–Hb concentrations were low and averaged 21.2%. This clearly indicates that the fatalities were not due directly to carbon monoxide poisoning. The mice tested all had injured mucous membranes of the eyes, which closed, while the eyeballs were decolored and became white. From the fact that there was a greenish-yellow gas inside the test chamber, it was thought to be the action of a chlorine gas. Therefore, the cause of death may be considered to have been the combined effect of carbon monoxide and some other harmful gas. Also, smoke was extremely thick, and the results of autopsy showed a considerable amount of soot in the tracheae.

Electrocardiograms showed the appearance of abnormalities prior to large-quantity generation of smoke. This indicates that a harmful gas produced at an early stage was causing an effect.

(f) Polyurethane

All mice died. There were no abnormalities in autopsy and other observations. Smoke was extremely thin. The average value of CO–Hb was 24.3% which was clearly below the lethal concentration of carbon monoxide. From these factors, it was conceivable that an injurious gas other than carbon monoxide existed. According to electrocardiograms, abnormalities became evident at 7 min 2 sec and suddenly around 8 min 30 sec pulses decreased to extremes. This was thought to be due to the effect of harmful gas generated rather than smoke.

(g) Polystyrene

From the fact that all five mice survived, it may be determined that there are less lethal properties in polystyrene than in other materials. However, the average of the CO–Hb concentrations was 23.9% while three of the five mice had injured mucous membranes. It is evident there was some variety of irritative gas other than carbon monoxide generated. According to electrocardiograms, irregular pulses appeared at 5 min, and since smoke was thin at this time it was thought this phenomenon was due to this irritative gas. Parenthetically, there was effect of a poisonous gas generated rather than of smoke.

(h) Acrylic Resin

Almost all of the mice died. The CO–Hb concentrations at the times of death averaged 43%, and the cause of death was carbon monoxide poisoning. Irregular pulses appeared in electrocardiograms from 5 to 7 min, which was sooner than the effects from smoke.

(i) Phenol Resin

The mice all survived but were in critical condition. The CO–Hb concentrations at that time averaged 29%. Irregular pulses appeared from 6 to 7 min while smoke was exceedingly thin. Although the mice did not die, they could not be said to have been safe from the standpoint of evacuation.

Conclusions

(a) The concentrations of CO–Hb in blood of mice average 20% or more for all specimens tested, and although there may be some differences of degree, carbon monoxide must in all cases be considered as the greatest factor for causing harm.
(b) The injurious properties of materials such as wood, woodwool-cement board, fire-retardant plywood, melamine finishing board, and acrylic resin are due to carbon monoxide. In particular, the cause of fatalities is carbon monoxide poisoning. The effects of harmful fumes become evident in electrocardiograms slightly prior to generation of smoke.
(c) In regard to the harmful properties of polyvinyl chloride, polyurethane, polystyrene, and phenol, the effects of gases rather than of smoke first appear strongly. Especially, the cause of death in the cases of the first two materials is thought to be the combined effects of carbon monoxide and some other noxious gas.
(d) With all materials generation of gas affects the electrocardiograms of mice before smoke does, and there is already a considerable amount of effect before smoke becomes thick or by the time smoke has become thick.

When discussing whether or not building materials are harmful at time of combustion, considerations must be given from the standpoint of early evacuation. It will be overhastiness to think of all matter generated at time of combustion to be smoke or to be represented by smoke. The possibility of early evacuation cannot be discussed merely with the amount of the visibility-obstructing matter called smoke. This paper reports on experiments using mice and it may not be possible to relate this directly to human beings, but at the least it may be said the effects of gas generated at time of combustion is an important matter for consideration more than simple smoke. In almost all cases, the effects of harmful gases begin to appear in human bodies when smoke has begun to drift only thinly and it can be presumed that movements become sluggish or sudden paralysis occurs.

Regarding examination of electrocardiograms, the researchers being laymen, detailed analyses could not be made, but discussions were attempted from the viewpoint of safety at time of fire.

Zikria, B. A., Weston, G. C., Chodoff, M., and Ferrer, J. M. (Department of Surgery, College of Physicians and Surgeons, Columbia University, New York, New York) "Smoke and Carbon Monoxide Poisoning in Fire Victims," *The Journal of Trauma* **12**(8), 641 (1972)

Section: K

Subjects: Smoke; Carbon monoxide; Fire victims; Casualties; Fire casualties; Deaths; Asphyxia; Carboxyhemoglobin; Poisoning by CO

Authors' Summary

Analysis of the causes of death of 534 fire victims with 311 autopsies indicates:

1. A majority (53%–60%) of these victims died in less than 12 hr following the accident.
2. Respiratory tract involvement was found in 70% of deaths under 12 hr and in 46% of victims who survived over 12 hr.
3. Considering respiratory tract pathology, 71% of the pneumonia/pneumonitis group lived beyond 12 hr and 77% of the pulmonary edema/congestion group lived less than 12 hr.
4. Considering respiratory tract involvement, smoke poisoning or asphyxia was the most common primary diagnosis (53.5%) in the deaths under 12 hr.
5. Seventy-nine per cent of those having primary diagnosis of smoke poisoning or asphyxia had CO poisoning.
6. Of 185 autopsied victims surviving less than 12 hr, 58.6% had CO poisoning, with 24.3% having had lethal levels of carboxy-hemoglobin.
7. Of 105 victims with less than 40% body surface burns, 77% should have survived; but the majority of deaths (76%) were related to respiratory involvement.
8. Analyses of data strongly suggest that, since there is a large early respiratory mortality among fire victims, significant reduction of mortality could be effected by making available respiratory resuscitative therapy for CO poisoning, smoke poisoning, and asphyxia at the scene of a fire, en route to a hospital, and in hospital emergency service.

Zikria, B. A., Ferrer, J. and Floch, H. F. (Department of Surgery, College of Physicians and Surgeons, Columbia University, New York, New York) "The Chemical Factors Contributing to Pulmonary Damage in Smoke Poisoning," *Surgery* **71**, 704 (1972)

Section: K

Subjects: Smoke poisoning; Pulmonary damage; Acrolein; Formaldehyde; Acetaldehyde; Butraldehyde; Wood smoke; Kerosene smoke

Authors' Summary

The syndrome of smoke poisoning is a problem which has been underestimated in magnitude and about which little has been known. To study the pathophysiology of this syndrome, an experiment was devised in which mongrel dogs were exposed to wood and kerosene smoke.

Kerosene smoke was found to produce neither death nor pulmonary edema. Wood smoke, however, produced a 50 percent mortality rate and pulmonary edema with increased sodium and water contents in the lung. Direct exposure of the canine tracheobronchial tree to wood or kerosene soot produced neither death nor pathologic changes.

The agents incriminated in the present study as one of the causes of acute pulmonary injury by smoke inhalation are the aldehyde gases, which are present in wood smoke in 15 to 20 times the concentration found in kerosene smoke. High concentrations of these aldehydes were also found in smokes of burning cotton clothing and household furniture. A mechanism is suggested whereby these gases may cause the above effects by protein and nucleic acid denaturation.

L. Operations Research, Mathematical Methods, and Statistics

Chandler, S. E. (Joint Fire Research Station, Boreham Wood, Herts, England) "Fires in Television Sets," *Fire Research Note No. 804, Joint Fire Research Organization* (March 1970)

Sections: L, B

Subjects: Casualties; Fire cause; Fire statistics; Television

Author's Summary

A recent fire in a hotel which occurred outside normal viewing hours but was attributed to a television set has prompted a study of the statistics of television fires. Fires in television sets more than doubled in frequency in the period 1960–1968. There were an estimated 1244 incidents in 1968 (based on a one-in-four sample of fire reports); only 56 of these occurred between 01.00 and 10.59.

Of those outside normal viewing hours, at least two-thirds occurred in sets that were said to have been left plugged in.

In the one-in-four sample of reports ten rescues and nine non-fatal casualties were noted.

M. Model Studies and Scaling Laws

Lee, B. T. (Stanford Research Institute, Menlo Park, California) "Modeling Individual and Multiple Building Fires," *Final Report to Defense Civil Preparedness Agency under Contract DAHC20-70-C-0219*

Sections: M, D

Subjects: Models; Structural fires; Predictability; Mass-fire dynamics; Single and multiple ignitions; Ceiling materials; Room contents; Blast effects; Array tests

Author's Abstract

Simple 1/16-scale structural fires, employing models fabricated from particle board, were used to assist in the predictability of mass-fire dynamics. Nine-unit array tests of simultaneously burning models were conducted as part of this program. The rates of fire development for the outer eight and for the center models in the array burns were evaluated separately. Models were also burned singly to evaluate the effects of the following parameters on the fire growth and spread in buildings: (1) single and multiple ignitions within the building, (2) combustible ceiling materials and room contents, and (3) structural damage from blast effects.

N. Instrumentation and Fire Equipment

Creeden, J. E., Fristrom, R. M., and Grunfelder, C. (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland) **and Weinberg, F. J.** (Department of Chemical Engineering, Imperial College, London, England) "A Large-Area Differential Laser Interferometer for Fire Research," *J. Phys. D: Appl. Phys.* **5**, 1063 (1972)

Section: N

Subjects: Interferometry; Laser interferometer; Fire research

Authors' Abstract

An interferometer is described which is based on two shadowgraphs minutely displaced with respect to each other. The apparatus, designed for fire research, allows the display of large test areas where the use of focusing optics becomes impractical. The present system, as confined by the dimensions of the laboratory, provides a field 3 ft in diameter with sufficient illumination for exposures shorter than 0.04 s for still or motion pictures, using commercially available cameras and films. A straightforward calculation suggests that a 1 W laser would allow coverage of a field 30 ft in diameter. The apparatus is simple and rugged enough to be potentially useful for field studies of fires, given a sufficiently large screen. Some illustrations of applications and a discussion of its theory are included.

Baev, V. K., Klimchik, G. V. and Yasakov, V. A. (Novosibirsk, USSR) "Optical Method of Measuring the Concentration in Axisymmetric Gas Jets," *The Physics of Combustion and Explosions* (*Fizika Goreniya i Vzryva*) **8**, 138 (1972) (in Russian)

Sections: N, G

Subjects: Schlieren techniques; Optical studies; Composition measurement

Abstract—L. Holtschlag

The aim of the authors was to develop the "knife-and-slit" variant of the Schlieren method to the point where the results from this method would not only yield the qualitative behavior of concentration in a flow, but would also correspond qualitatively to the experimental data obtained by other methods. An image of the inhomogeneity is obtained using a Toysler instrument; the jet is measured photometrically. The boundary and axis of the jet are obtained from the curve of film blackening. The angles of deflection are determined from a calibration curve, which gives the blackening as a function of the angle of deflection. Then the index of refraction is calibrated, and a formula is given for calculating the bulk concentration from the distribution of the refractive index. The method was used to measure the concentration in a jet of hydrogen issuing into static air.

Maxwell, F. D. (Pacific Southwest Forest and Range Environmental Station, Forest Service, U.S.D.A.) "A Portable IR System for Observing Fire Through Smoke," *Fire Technology* **7**, 321 (1971)

Section: N

Subjects: Fire detection, IR detectors; Smoke; Fire mapping

Author's Conclusions

The results to date suggest that the near-infrared system is a significant improvement over the unaided eye for the observation of fire and the fire environment. This fully portable system is convenient for use on most fires; no cooling of the sensor is required. It uses components that are commercially available and relatively low in cost. The television-type imaging and recording system is centered around a silicon vidicon. The background contrast is a function of the aspect angle of the sensor and angle of incidence of the incident radiation. The effects of aspect angle and polarization are controllable.

Satisfactory results were achieved in tests with a prototype, and further research is now underway. Areas of improvement and refinement include optimizing the spectral response of the receiver, including the silicon vidicon; and improving polarization techniques, refractive optics, zoom capability, scanning format, methods of use, and physical configuration. A suitable VHF transmitter can be included in the system design if the operation application of the system justifies the need. In addition, further measurements are needed to provide quantitative information on smoke attenuation of radiant energy in forest fires and the spectral characteristics of the emitted energy that can be attributed to the non-equilibrium electron excitation that occurs in the flames.

O. Miscellaneous

Lawson, D. I. (Joint Fire Research Station, Boreham Wood, Herts, England) "Fire Research in Europe," *Fire Research Note No. 924, Joint Fire Research Organization* (1971)

Section: O

Subjects: Fire research, European; Laboratory; Review

Author's Abstract

This is a summary of replies to a questionnaire sent out to fire research laboratories inquiring as to their distribution of interest and effort and facilities. The information has been catalogued.

PERIODICALS

BOOKS

MEETINGS

Proceedings of Conference on Hazard Evaluation and Risk Analysis—Houston, Texas (August 18–19, 1971).

These proceedings record papers on: (1) hazard evaluation and (2) risk analysis as they relate to hazardous materials in transport. Sponsored and conducted by the Committee on Hazardous Materials of the National Academy of Sciences, National Research Council with the support of the U.S. Coast Guard under Contract T.O.13 (DOT-OS-00035).

Contents

Benefit-Cost Studies in Socio-Technical Systems—Chauncey Starr, Dean, School of Engineering and Applied Science, University of California at Los Angeles
Technology and Safety—A Qualitative View—Roy Reider, Safety Director, Los Alamos Scientific Laboratory
Analytical Approaches to Risk Evaluation—Vernon Grose, Vice President, Tustin Institute of Technology
Decision Risk Analysis: Risk Theory—Jerome Selman, Member, Operations Research Group, U.S. Army Munitions Command
Decision Risk Analysis: Problems in Practice—John Mihalasky, Assistant Chairman, Graduate Courses, Newark College of Engineering
Pyrotechnic Hazard Evaluation and Risk Concepts—W. Paul Henderson, Chief, Engineering Test and Evaluation Section, Edgewood Arsenal, U.S. Army
The Environmental Risk Arising from the Bulk Storage of Dangerous Chemicals—E. H. Siccama, Directorat-General van de Arbeid, The Netherlands
The Geography and Ecology of the Houston Ship Channel-Galveston Bay System—Roy W. Hann, Jr., Head of the Environmental Engineering Division, Texas A. & M. University

The appendices include a statement by the Committee on Hazardous Materials and a list of conference participants. Proceedings are available from the National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C., 20418.

Proceedings of a Symposium on An Appraisal of Halogenated Fire Extinguishing Agents—National Academy of Sciences, Washington, D.C. (April 11–12, 1972)

For a listing of contents and a review of the articles, see *Fire Research Abstracts and Reviews* **14**(1), 99–104 (1972). Proceedings are available from the National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C., 20418

TRANSLATION

SOVIET ABSTRACT JOURNAL: Section 68. Fire Protection Series (Notes and translation of March 1972 issue)[1]

Translation by B. W. Kuvshinoff and L. J. Holtschlag

Among abstracting services the world over, the Soviet *Referativnyy Zhurnal* [Abstract Journal], abbreviated *RZh*, is outstanding in its scope of coverage of scientific and technical literature. It ranges over all subjects from "Avtomatika" (automation) at the top of the Russian alphabet to "Yadernaya Fizika" (nuclear physics) at the bottom.

RZh is published by VINITI [Vsesoyusnyy Institut Nauchnoy i Tekhnicheskoy Informatsii], the All-Union Institute of Scientific and Technical Literature, on a monthly cycle (semi-monthly for chemistry) in 25 major subject fields: e.g., automation, astronomy, physics, etc. (The medical literature is covered by a special abstracting journal, the Meditsinskiy Referativnyy Zhurnal [Medical Abstracts Journal], in 16 categories, each individually subscribable, published monthly by the Ministry of Public Health of the USSR.) Each field is divided into a number of subsections. Abstracts appearing in such subsections can be obtained as separates without subscribing to the complete issue covering the entire field. In addition, there are 39 different series in narrow or specific technical subject fields. One of these, available on subscription, is "Pozharnaya Okhrana" [Fire Protection]. This series can be obtained either with or without an annual subject index. No author index is available.

In order to assess the methodology and coverage of the "Fire Protection" separate of the Soviet abstracting journal system, five of the 12 monthly issues (Nos. 3 thru 7) for 1972 were surveyed statistically and reviewed. The entries are numbered successively in each issue, according to the following system: issue number (corresponding to month of year), abstract journal section number (Section 68 in this case), and sequential number of the abstract $(1, 2, \cdots, n)$; e.g., 3.68.1, meaning issue 3, section 68, abstract No. 1. The entries are further characterized by letters P, B, and S, meaning, respectively, patent, book, or standard, e.g., 3.68.128.P indicates that abstract No. 128 of issue No. 3 is a patent.

In information content, the entries range from a simple title listing to a full-fledged review. In all cases the entry begins with a Universal Decimal Classification number and a telegraphic Russian descriptive phrase, followed by the title in the original language, or, as in the case of Japanese, in Cyrillic transliteration. Almost always the abstract is the original work of the abstractor, often signed. In no case was a simple translation of an existing original-language abstract detected. Of the 803 entries reviewed in this survey, 144 were title listings only. Interestingly enough, half of these 144 title-only citations refer to Finnish, Japanese, and Russian

[1] This is a sample translation of the new Soviet abstracts journal "Fire Protection." The present plan is to translate 6 issues to determine its usefulness to the English-speaking fire community. Work was supported in part by the RANN Program of the National Science Foundation and in part by the APL Central Laboratory Library Translations Service. Complete translations available from: Fire Problems Program, APL, The Johns Hopkins University, 8621 Georgia Avenue, Silver Spring, Maryland 20910, Attention: B. Kuvshinoff.

articles; specifically, 5 of 27 Finnish, 4 of 18 Japanese, and 4 of 33 Russian. The few papers in these languages treated beyond title citation only, were sparingly abstracted.

From the scant information at hand at this time, no logical reason comes to mind why this should be so. From a selfish viewpoint, it is especially unfortunate that the Soviet literature is not covered in greater depth, for it is evident that a substantial amount of research is in progress in the fire sciences in that country and interest in the subject area is high. We can only speculate on this point, because it is possible that Soviet literature is expected to be known to readers in that country, or the neglected articles do not contain information considered sufficiently substantive for abstracting.

With regard to information value, most of the abstracts are quite informative. There seems to be a tendency toward enumeration of fire statistics, so that even a brief article, such as "USA Fire Deaths" in the March 1972 issue of *Fire Protection Reviews* is treated in fine detail. No article of a statistical nature seems to escape the attention of the selection board. News items, historical reminiscences, personality sketches, visits, editorial comments, letters to the editor, and the like are not cited, unless they contain some indication of present or future trends in fire protection service organization, or the introduction of new equipment, codes, or techniques. Wherever practical or necessary for clarity, tables and illustrations are provided. This is especially true of articles relating to patents and equipment.

To demonstrate the types of articles selected for abstracting, the tables of contents of several prominent fire journals with indication of cited articles are given in Exhibit I.

In proofreading the copy, one of the authors was startled by the value of 50 kg of fallout per m^2 in abstract No. 51, q.v. The original reads in part: "Firebrand densities were 50 per 100 sq ft although in one localized area a density of 500 per 100 sq ft was found." Also in the same abstract a house characterized as a split-level, namely: "one half of which was one floor, the other half two-storied" is in fact a two and one-half story farmhouse. Otherwise, this abstract is fair for the first half of the original. Several interesting results in the remainder of the original could have been mentioned to give a better representation of the entire paper.

This discovery led to a spot check of other abstracts to evaluate the general quality of abstracting. Three other articles of a statistical nature were checked, but no discrepancies were noted.

Worthy of appreciation is the diligence with which the selections board must scan the world literature to cull fire or fire-protection related articles from the mass available. The 803 entries found in this survey represented more than 200 journals, plus books, patents, and standards literature. Naturally, most of the obvious fire journals are regularly abstracted, as can be seen from Exhibit II, a list of fire technology journals from *Ulrich's International Periodicals Directory, 1971–72.* The regularly abstracted journals are denoted by an asterisk. Some of the fire journals not indicated as being abstracted regularly may have been, but outside the period reviewed (quarterlies, for example). Most of the journals not regularly abstracted are represented in the review period by only one or two issues, usually one. The scope of the technical and scientific journals scanned can be seen from the field-oriented list given in Exhibit III. Engineering in all its aspects (general, mechanical, civil, etc.) is most heavily covered, followed by transportation, chemistry, technology, safety, aviation, electronics, electricity, etc.

Close attention is paid to the patent literature, as illustrated in the Exhibit IV. No fewer than 114 of the entries related to patent literature, the U.S. alone being represented by 56 patents abstracts. Also listed in this exhibit are the standards and books reviewed. A listing of the number of journals represented by the various world languages in the review period is given in Exhibit V. The language breakdown is consistent with the percentages generally found in other fields, except for Russian, which is significantly less well represented in fire technology than it is, say, in the fields of physics, mechanics, or chemistry.

The time lag for the abstracts averages five to six months; some journals are abstracted in two months. Books, conferences, etc., are abstracted with lag times of one to two years. This does not ncessarily indicate inordinate procrastination, but rather that books and conferences are delayed in publication and distribution, to which we attribute most of the delay. Also, more time is needed to review a book than a short paper.

The average time lag of four months between receipt of source material and publication of the abstract is an extraordinarily rapid throughput for a large information processing system. Unfortunately, some of the gain appears to be diluted by slow distribution and delivery. Issue No. 9, for September 1972, for example, was received in Silver Spring, Maryland, during the last week of December.

Also notable is the fact that traffic- and transportation-related fire articles contained in many fire journals are not cited in Section 68 of the *Abstracts Journal*. They can be found in the semi-monthly *Signal'naya Informatsiya*, "Tekhnika Bezopastnosti" [Literature Announcements, Safety Technology], which contains a selective bibliography of occupational safety and health literature. One subject category in this bulletin is "Fire and Explosions." Nor are the purely scientific fire-related articles cited in Section 68. These are to be found in other sections of *Referativnyy Zhurnal*, as indicated in footnotes in the appropriate sections of "Fire Protection."

Exhibit I.

Tables of contents of selected journals cited in

Referativnyy Zhurnal, Sect. 68, No. 3, 1972.

Pozharnoye Delo [Fire Practice]. No. 2 (1972)

Article title *page*

* Indicates articles cited.

Fire. Vol. 64, No. 798, December (1971)

Fire Protection Review, Vol. 35, No. 377, March (1972)

Fire Engineering. Vol. 124, No. 11, November (1971)

Fire International. Vol. 3, No. 33 (1971)

Exhibit II.

Fire technology journals cited by Ulrich's

FIRE PREVENTION

* Indicates journal cited in *RZh*, "Fire Protection."

A D T TRANSMITTER. 1929. bi-m. Free. Ed. H. L. Reed. American District Telegraph Co., 155 Sixth Ave., New York, N.Y. 10013. illus.

AERIAL APPLICATOR; farm, forest and fire. see *AERONAUTICS AND SPACE FLIGHT*

* ANTINCENDIO E PROTEZIONE INDUSTRIALE. (Text in Italian; summaries in English and French) 1949. m. L. 10,000. Ed. Pier Roberto Pais. Edizioni di Protezione Cisile S. R. I., Via Piemonte 39A, 00187 Rome, Italy. bk. rev. abstr. adv. bib. 7000.

BOSAI. (Text in Japanese) 1947. bi-m. Yen 510 ($2.00). Ed. Shin-Ichi Asami. Tokyo Rengo Boka Kyokai, c-o Tokyo Shobocho 11-39, 1-chome, Nagatacho, Chiyoda-ku, Tokyo, Japan. circ. 12,000.

BRAND. (Koninklijke Nederlandse Brandweervereniging) 1950. m. f. 17.50 ($4.00) Ed. M. C. van Keule, Vermande Zonen N. V., Ijmuiden, Netherlands. bk. rev. adv. illus. circ. 8500.

BRAND AUS. 1892. m. S. 36 ($11.00) NOE. Landes-Feuerwehrverband, Bankgasse 2, A-1014 Vienna, Austria. bk. rev. bibl. charts. illus. stat. index. circ. 12,500.

* BRANDFORSVAR. 1946. m. Kr. 15 ($15.00). Ed. Ake Stalemo. Svenska Brandfors foreningen, Brunkebergstorg 15, Stockholm C, Sweden. adv. bibl. bk. rev. illus. index. circ. 16,000.

BRANDHILFE; Fachzeitschrift fuer die Feuerwehren des Landes Baden-Wuerttemberg und des Saarlandes. (Arbeitsgemeinschaft der Feuerwehrverbaende von Baden-Wuerttemberg) 1954. m. DM. 9.60 ($2.38). Ed. Werner Jauch. Neckar-Verlag, Klosterring 1, D773 Villingen, W. Germany. bk rev. illus. circ. 10,000.

BRANDSCHUTZ; Zeitschrift fuer das gesamte Feuerwehr- und Rettungswesen. 1946. m. DM. 16 ($3.30). Eds. Dipl.-Ing. Heinrich Schlaefer and Dipl.-Ing. Kurt Klingsohr. Verlag W. Kohlhammer GmbH, Urban Str. 14–16, 7000 Stuttgart, W. Germany. bk. rev. adv. bibl. charts. illus. stat. index. circ. 18,000. Indexed: *Chem. Abstr.*

BRANDVERHUETUNG; Mitteilungs-blatt der oesterreichischen Brandverhutungsstellen. 1956. bi-m. S. 20. ($1.00) Ed. Siegmund Ausobsky. Landesstelle fuer Brandverhuetung in Steiermark, Frauengasse 4, A 8010 Graz, Austria. circ. 9500.

* BRANDVERHUETUNG UND BRANDBEKAEMPFUNG. q. DM. 6.50. Feuersozietaet Berlin, Am Karlsbad 4–5, 1 Berlin 30, W. Germany.

BRANDWACHT; Fachschrift fuer Feuerschutz. 1946. m. DM. 9.60. Bayerisches Landesamt fuer Brand- und Katastrophenschutz, Puendterplatz 5, 8 Munich 23, W. Germany. adv. charts. illus. circ. 14,800.

BRANDWEER. 1945. m. Ed. J. Keuzenkamp. Nederlandse Vereniging van Brandweercommandanten, Dutch Association of Chief Fire Officers, 244 Damlaan, Schiedam, Netherlands. bk. rev. adv. charts. illus. tr. lit. index. circ. 3000.

* CAHIERS DE NOTES DOCUMENTAIRES; securite et hygiene du travail. see *SAFETY EDUCATION.*

CHICAGO FIRE FIGHTER. 1951. q. $2.50. Ed. John Tebbens. Chicago Fireman's Assn. Local 2, 54 W. Randolph, Chicago, Ill. 60601. adv. charts. stat. tr. lit. circ. 6500.

CONDINCENDIE. see *ABSTRACTING AND INDEXING SERVICES*

* DANSK BRANDVAERN. (Formerly: *Brandvaesenet Paa Landet*). (Danish Fire Pretoction Assn.) 1970. m. Kr. 24. Eds. R. Serring and E. Lau-Nielsen. Dansk Brandvaerns-Komite, Nygaards Plads 9, 2610 Roedovre, Denmark.

F. P. A. JOURNAL. 1948. q. 42 s. Fire Protection Assn., Aldermary House, Queen St., London E. C. 4, Eng. charts. illus. stat. index every 2 yrs.

FACTORY MUTUAL RECORD. see *INSURANCE*

FEDERAL FIRE COUNCIL NEWSLETTER. 1959. 4/yr/ Free to federal personnel. Federal Fire Council, 19th and F. Sts., N. W., Washington, D.C. 20405. illus. circ. 3700.

* FIRE. (Incorporating *Industrial Hazards* and *Fire Prevention*) (British Fire Service) 1908. m. 50 s. ($8.00) Ed. Harry Klopper. UNISAF Publications Ltd. UNISAD House, Dudley Rd., Tunbridge Wells, Kent, Eng. adv. tr. lit. index. circ. 5295. Indexed: *Br. Tech. Ind.*

FIRE CHIEF. (Incorporating: *Volunteer Firefighter* and *Volunteer Fire Chief*) 1956. m. $7.50. Ed. William Randleman. H. Marvin Ginn Corp., 612 N. Michigan Ave., Chicago, Ill. 60611. bk. rev. adv. charts. illus.

* FIRE COMMAND (US) Vol. 37, 1970. m. $7.00. Ed. Warren Y. Kimball. National Fire Protection Assn., 60 Batterymarch St., Boston, Mass. 02110. adv. bibl. Charts. illus. tr. lit. circ. 50,000.

FIRE CONTROL NOTES; devoted to the techniques of forest fire control. (US Forest Service) 1936. q. $0.75 ($0.20 per No.) Supt. of Documents, Gov't Printing Office, Washington, D.C. 20402. charts. illus. index.

* FIRE ENGINEERING; the journal of the fire protection profession. 1877. m. Ed. James F. Casey. Reuben H. Donnelley, 466 Lexington Ave., New York, N.Y. 10017. adv. bk. rev. charts. illus. stat. tr. lit. index. circ. 23,920. Indexed: *Eng. Ind.*

FIRE FIGHTING IN CANADA. 1957. bi-m. $3.00. Ed. Jack Gubbins. Parkins Publishing Co. Ltd., 1215 Greene Ave., Montreal 215, Canada. adv. tr. lit. circ. 3898.

* FIRE INTERNATIONAL; the journal of the world's fire protection services. (Text, title and contents page in English, French and German; summaries in Spanish) 1964. q. 40 s. ($7.00) Ed. Harry Klopper. UNISAF Publications Ltd., UNISAF House, Dudley Rd., Tunbridge Wells, Kent, Eng. adv. bibl. charts. illus.

* FIRE JOURNAL. 1907. bi-m. Membership. Ed. Chester I. Babcock. National Fire Protection Assn., 60 Batterymarch St., Boston, Mass. 02110. adv. bk. rev. charts. film. rev. illus. index in each issue. circ. 24,406. Indexed: *Chem. Abstr., Eng. Ind.*

FIRE NEWS. 1916. m. $30.00. Ed. Deuel Richardson. National Fire Protection Assn., 60 Batterymarch St., Boston, Mass., 02110. bk. rev. illus. circ. 24,000.

FIRE PREVENTION BULLETIN. m. Membership. Ed. S. J. Murphy. New York State Hotel and Motel Assn., Inc., 141 W. 51st., New York, N.Y. 10019.

* FIRE PROTECTION REVIEW (Incorporating: *Accident Prevention*) (Directory) 1938. m. 45 s. ($6.00). Ed. J. L. Eades. Benn Brothers Ltd., Bouverie House, 154 Fleet Street, London E. C. 4, Eng. adv. bk. rev. illus. mkt stat. tr lit. circ. 4229.

* FIRE RESEARCH ABSTRACTS AND REVIEWS. see *ABSTRACTING AND INDEXING SERVICES*

FIRE SERVICE INFORMATION. 1970. bi-m. Ed. Keith Royer. Iowa State University of Science and Technology, Ames, Iowa 50010. bk. rev. stat.

FIRE STATION DIGEST. 1931. bi-m. $7.00 for 2 years., Ed. E. A. Hoefer. Fire Station Digest and North American Firemen's Assn., Box 25541, Seattle, Wash. 98125. adv. illus. circ. 10,500.

* FIRE TECHNOLOGY. (Society of Fire Protection Engineers) 1965. q. $5.00. Ed. George H. Tryon. National Fire Protection Assn., 60 Batterymarch St., Boston, Mass. 02110. abstr. bk. rev. charts. illus. index in each issue. Indexed: *Chem. Abstr., Eng. Ind.*

FOREST FIRE CONTROL ABSTRACTS/PRECIS DE REPRESSION DES FEUX DE FORETS. see *ABSTRACTING AND INDEXING SERVICES*

FROM THE STATE CAPITALS. FIRE ADMINISTRATION. 1946. 14/yr. (approx) $26.40. Ed. Ralph W. Ernst. Bethune Jones, 321 Sunset Ave., Asbury Park, N.J. 07712. (Processed). Covers developments relating to state and local fire prevention regulations and operations of fire departments throughout the nation.

I.M.S.A. SIGNAL MAGAZINE. (International Municipal Signal Association) see *TRANSPORTATION—TRAFFIC*

INSPECTIE VOOR HET BRANDWEERWEZEN MAANDELUKSE MEDEDELINGEN. 1948. m. f. 5. ($1.50). Inspectie voor Het Brandweerwezen, Spui 47–49. The Hague, Netherlands, bibl. stat. index. circ 1000.

* INSTITUTION OF FIRE ENGINEERS QUARTERLY. 1941. q. Ed. Peter Lush. Institution of Fire Engineers, Publications Dept., 61 Broadmeadow Rd., Wyke Regis. Eng. bk. rev. abstr. adv. bibl. charts. illus. cum. index. circ. 5600.

INTERNATIONAL ASSOCIATION OF FIRE CHIEFS. NEWS LETTER. Vol. 37, 1971. bi-m. International Assn. of Fire Chiefs, 232 Madison Ave., New York, N.Y. 10016. adv. charts. illus. stat.

INTERNATIONAL FIRE FIGHTER. see *LABOR AND INDUSTRIAL RELATIONS LABOR UNIONS*

* JOURNAL OF FIRE AND FLAMMABILITY. 1970. q. $45.00. Ed. Carlos Hilado. Technomic Publishing Co., Inc., 750 Summer St., Stamford, Conn. 06901. bk rev. charts. illus. cum. index. circ. 1000. (Processed) Indexed: *Eng. Ind.*, *RAPRA*.

KYOTO SHOBO/FIRE PREVENTION. (Text in Japanese) 1948. m. Yen 1140 ($3.25). Ed. Hideo Funjino. Kyoto-shi Shobo Gakko, Echigoyashiki-cho, Fukakusa, Fushimi-ku, Kyotoshi, Japan. bk. rev. adv. charts. illus. stat. index. (Processed).

MINNESOTA FIRE CHIEF. (Minnesota State Fire Chiefs' Assn.) 1964. bi-m Ed. Frank Oberg. Ramco Publishing, 287 E. Sixth St., St. Paul, Minn. 55101. adv. charts. illus. circ. 3800.

NATIONAL AUTOMATIC SPRINKLER AND FIRE CONTROL ASSOCIATION. NEWS BULLETIN. q. Free to qualified personnel. Ed. E. G. Reilly. National Automatic Sprinkler and Fire Control Assn., 2 Holland Ave., White Plains, N.Y. 10603. charts. illus.

OESTERREICHISCHE FEUERWEHR. (Oesterreichischer Bundesfeuervernamde fuer Brandebekaemfung. Brandverhuetung, Technischen Hilfdienst und Feuerwehrdienst im Zivilschutz) 1957. m. S. 84. Bohmann Verlag. Canovagasse 5, A1010 Vienna 1, Austria. adv. charts. illus. circ. 4500.

* PALONTORJUNTA—BRANDVARN; the trade journal of the fire safety field in Finland. (Text in Finnish and Swedish; summaries in English and Swedish) 1950. 10/yr. Fmk. 20 ($5.00). Ed. Lauri Santala. Suomen Palontorjuntaliitto r. y, Iso Roobertinkatu 7 A, Helsinki 12, Finland. adv. charts. illus.

* PALONTORJUNTATEKNIIKKA; the trade journal of structural fire safety. (Text in Finnish; summaries in English and Swedish) 1971. 3/yr. Fmk. 18 ($4.50). Ed. Lauri Santala. Suomen Palontorjuntaliitto r. y, Iso Roobertinkatu 7 A, Helsinki 12, Finland. adv. charts. illus. circ. 5000.

POZARNI OCHRANA. (Cesky Svaz Pozarni Ochrany) 1894. m. 42 Kcs. ($2.00). Ed. Milan Sedo. Borivoyova 21, Prague 3, Czechoslovakia.

POZARNI TECHNIKA. Vol. 13, 1965. m. 16.80 Kcs. Ed. Milan Sedo. Blanicka 13, Prague 2, Czechoslovakia.

PROTEZIONE CIVILE. see *CIVIL DEFENSE*

S. A. BRANDWEER INSTITUUT KWARTAALBLAD/S. A. FIRE SERVICES INSTITUTE QUARTERLY. (Text in Afrikaans and English) 1961. q. Membership. Ed. E. S. C. Barber. South African Fire Services Institute. Nigel, Transvaal, South Africa. circ. 1000.

* SAPEUR-POMPIER. 1889. 6/yr. 10 F. Federation Nationale des Sapeurs-Pompiers Francais, 27 rue de Dunkerque, Paris (10e), France. adv. bibl. charts. mkt. stat. index.

SENTINEL (US) 1945. bi-m. Free. Ed. F. C. Powers. Factory Insurance Assn., 85 Woodland St., Hartford, Conn. 16102. charts. illus. index cum. index: 1945-1965. circ. 38, 000 (controlled).

SIGURNOST U POGONU. see SAFETY EDUCATION

SOUTH AFRICAN FIRE SERVICES INSTITUTE QUARTERLY/SUID AFRIKAANSE BRANDWEERINSTITUT KWARTAALBLAD. (Text in Afrikaans and English) 1960. q. Membership. Ed. E. S. C. Barber. South African Fire Services Institute. Fire Dept., Nigel, South Africa. circ. 1200 (controlled). Tabloid format.

W.N.Y.F. (With New York Firemen) 1940. q. $2.00. Ed. Bernard Neer. New York Fire Dept., Welfare Island, N.Y. 10017. charts. illus. circ. 18,000. House organ.

* WESTERN FIRE JOURNAL. (Western Fire Chiefs' Assn.) 1950. m. $3.00. Ed. Warren Desimone. 9172 Greenback Lane, Orangeville, Calif. 95662. adv. illus. circ. 3747.

Exhibit III.

Technology fields covered by the journal literature scanned in *Referativnyy Zhurnal* sample reviewed

Fire Protection	24
Engineering (General, Mechanical, Civil, etc.)	30
Transportation (Automotive, Maritime, Rail, Air, etc.)	23
Chemistry (Research and Development)	24
Technology (Including Plant Management)	17
Safety	13
Electronics and Electricity	11
Aviation	10
Textiles	10
Construction (Including heating, cladding materials, air conditioning,etc.)	10
Fuel and Lubricants	8
Forestry	6
Mining	6
Physics	5
Metrology, Instruments, Automation	3

Exhibit IV.

Patents abstracted in *RZh*, by nation

U.S.	56
Great Britain	19
France	15
Soviet Union	10
Germany	3
Czechoslovakia	3
Switzerland	2
Sweden	2
Australia	1
Denmark	1
Japan	1
Norway	1

Standards abstracted in *RZh*, by nation

Soviet Union	6
Romania	2
Hungary	1
Great Britain	1

Books listed in *RZh*, by nation

Soviet Union	2
France	1

Exhibit V.

Number of items cited in *RZh*, by language

(Books, Journals, Patents, and Standards)

English (Includes U.S., Great Britain, New Zealand, South Africa, Canada, etc.)	119
German (Includes Austria and German Switzerland)	45
French (Includes French Belgium and French Switzerland)	21
Russian	14
Japanese	10
Danish	8
Swedish	8
Italian	6
Dutch	3
Polish	2

Spanish	2
Finnish	2
Czech	2
Bulgarian	2
Norwegian	1
Hungarian	1
Romanian	1

ABSTRACT JOURNAL

Section 68. FIRE PROTECTION

(First Year of Publication)

Publication editor: A. A. Novobytov

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Abstracts 3.68.1–3.68.113 No. 3 March 1972

Contents

FIRE PROTECTION

General Section

UDC 614.841.001.57

3.68.1. [Application of optimal control theory to the study of large-scale fires] Kato, Ken. THE APPLICATION OF CONTROL THEORY TO THE STUDY OF LARGE-SCALE FIRES. Doct. Diss. Univ. South. Calif., 1971, 101 pp. Ref. *Diss. Abstr. Int.*, 1971, **B32**, No. 1, 244–245 (English)

A mathematical model describing the process of controlling fire protection forces is studied. The mathematical tool is optimal control theory, using ordinary differential equations. The model permits consideration of a large number of different factors of practical importance (varying geometrical configurations of fires, urban and rural fires, natural obstructions preventing fire spread, e.g., rivers, highways, weather conditions—wind, humidity, temperature, topography). The model is capable of representing simultaneous fires. The study of actual fires in real time can be combined in the model with hypothetical predictions of their spread. The development of fires and the control of their extinction is described as a nonlinear dynamic system, discrete in space, and continuous in time. A numerical algorithm is worked out for the solution of this problem, using optimal control theory, especially Pontryagin's Maximum Principle. Use of these methods yields optimal allocations of fire-fighting equipment and personnel for the most effective fire protection, minimizing the overall cost of maintaining the service.

UDC 614.84:681.3

3.68.2. [The use of a computer in fire protection] Gaade, R. P. R. COMMENT L'ORDINATEUR PEUT AIDER LES SERVICES D'INCENDIE. *Rev. techn. feu*, 1970, **11**, No. 1, 102, 11–15 (French)

Some aspects of fire protection activity in which computers may be of substantial assistance are analyzed. Such aspects are the control of fire protection units (the dispatch of fire-protection "first aid", additional forces, the standby coverage of neighboring areas, etc.), the processing and storage of operational and administrative information (the location of fire brigades, the current status of fire fighting equipment, etc.). Various forms of interaction between the duty operator at a fire protection communications center and a computer in solving operational problems are examined.

UDC 614.8

3.68.3. [A new law on fire safety measures in England] Maxwell, J. C. A DIFFERENT APPROACH TO THE FIRE PROTECTION ACT. *Fire*, 1971, **64**, No. 797, 294, 297–298 (English)

The new fire protection act is the most comprehensive of English legislative documents. The chief inspector of the British fire protection service has announced that the provisions of the new act will become effective gradually, considering the fire hazard level of various occupancies and the practical capability of the fire protection service to make inspections. The fire protection service will carry out fire inspection and prevention work along with building code agencies. In fire protection agencies it is necessary to set up an inspectorate which should coordinate technical documentation (certification), perform preventive work, and verify compliance with fire safety codes and standards. Instead of the existing organization, a structure similar to that of the National Aeronautics and Space Administration in the U.S. is recommended. About 400 more people are needed to set up the fire inspection service (calculated on the basis of 150 surveys per officer for each of the nine years during which it is expected to complete the work of bringing all premises into compliance with the new requirements). Implementation of the act will make it possible to reduce the number of deaths in building fires, as well as material losses. In addition to enforcing fire safety codes in new construction, the act provides for inspection of how occupancies are used from the viewpoint of compatibility of the fire safety codes with the conditions of use. It is recommended that the work of day-to-day inspection and prevention be entrusted to junior officers and fireman ranks. The British center for training and retraining fire specialists at Moreton-on-Marsh can train the necessary personnel needed for the inspectorate. To date, the knowledge of the fire protection personnel in fire prevention in the construction industry and especially their knowledge of legislative measures in this field is highly deficient. The assistance of legal specialists is not often solicited. The extra cost of fire protection under the new fire act will amount to 0.25 million pounds in the first year, and will reach a maximum of one million pounds per annum. The financing will not be a burden on the fire service, but on municipal authorities. Note is made of the lack of information and publicity in the press with regard to the problems and needs of the fire service. It is assumed that it will take three to five years to strengthen the fire service to fulfill the tasks posed by the new law.

A. A. Rode

UDC 614.841.45.3

3.68.4. [Limiting the hazard of fire spread] Kimball, Warren Y. CONTROLLING EXPOSURE HAZARDS *Fire Command!*, 1971, **38,** No. 11, 16–17 (English)

The 1970 NFPA Standard 80A, "Protection from exposure fires," distinguishes between two types of exposure effects on new buildings: (1) the effect from the facade of a burning house as a result of intense burning of the outer facing or of substantial eruption of flames from window openings, and (2) the effect from the roof of a burning house in the presence of a column of flame of great height. The permissible safe distances between buildings, their mutual location, and various forms of fire stops are specified in the standards as a function of a number of factors, including the height and width of the erupting plume, the number, size, and location of window openings, the intensity of the fire as a function of the calorific power of the combustible insulation and its specific gravity per square meter of surface area. But the standard specifications presume that a preliminary estimate has been made of the fire hazard, which cannot always be established in advance due to the lack of sufficient and reliable data. This deficiency in the standard often leads to excessive development and spread of fire beyond the confines of a burning building, resulting in disastrous fires in cities, towns, and large adjacent wooded areas. In order to limit the danger of fire spread, it is proposed that preventive measures be taken, such as water cooling of outside surfaces of adjacent buildings within the range of dangerous thermal radiation and reduction of heat formation in fire centers by carefully directed streams of water. Also discussed are certain aspects of preplanning for fire fighting.

V. G. Olimpiyev

UDC 614.841:577.7

3.68.5. [Reducing the number of fire victims in Scotland] FEWER DEATHS FROM FIRE IN SCOTLAND. *Fire Prot. Rev.*, 1971, **34,** No. 373, 437 (English)

Comments are made on the report of an inspector who surveyed 11 fire brigades in Scotland in 1969 and 1970. In 1969, 127 persons died from fires (7 fewer than in the preceding year); in 1970, 119 people died (8 fewer). The principal reasons for fire deaths are defective heaters and electrical devices, the negligence of smokers, and children playing with matches. In 1969, losses from fires amounted to 12.2 million pounds, and 10.3 million in 1970.

UDC 331.94

3.68.6. [Industrial inspection section in the Ministry of Trade and Industry] Ollila, Olli. TARKASTUSTOIMISTO KAUPPAJA TEOLLISUUSMINISTERIOSSA. *Palontorjuntatekniikka,* 1971, No. 1, 19–21 (Finnish)

Fire Service and Fire Protection Training

UDC 614.84

3.68.7. [Specialization in the fire service] THE CASE FOR SPECIALIZATION. *Fire Prot. Rev.,* 1971, **34,** No. 373, 444 (English)

In addition to fighting fires, the British Fire Service is called on for ever-expanding activity in saving human and animal life in the most diverse situations. In 1970, for example, the fire service answered 2,335 calls to aid people trapped in elevators: 1,641 calls to help clean up after highway accidents; 690 calls to take part in rescue work in water-flooded buildings; 420 calls to participate in rescue work in collapsed buildings. Because of this broad scope of activity, the fire service works with a large variety of equipment. The greatest load rests on the shoulders of the fireman. Not only must he study and learn how to handle this equipment expertly, he must also know how elevator systems are built, buildings and highways are constructed, and about chemistry, underground communications, etc. It is proposed that the fire service be broken down into two specialized departments: an emergency rescue service and a fire fighting service proper. The two departments must be interrelated. The personnel of each must go through a course of study to learn the special equipment and modes of operation under specific conditions. In view of rapid technological progress, the training program must be continuously upgraded; it must provide for interchangeability of team and brigade members. Specialization in the fire service will further improve the emergency rescue system of the country.

I. I. Myagkov

UDC 752.19

3.68.8. [New fire brigade in Pori, its equipment and communications] Syrja, Lauri. PORIN UUSI SIVUPALOASEMA JA SEN PALOILMOITUS—JA HALYTYSLAITTEET. *Palontorjunta,* 1971, **22,** No. 1, 18–19 (Swedish)

A new fire brigade was formed 20 km west of Pori; it became operational in January 1970. The fire house is standard. The area is 533 m^2, 1980 m^3. The cost was 540,000 Finnish marks. The outer walls are of fire brick, the inner walls and partitions are of limestone sand brick. All of the walls are stuccoed. The roof is made of Siporex elements; the training tower, 15 m high, is made of concrete. The premises are all on one floor. They consist of a garage for 3 fire trucks and one ambulance, a drying area, laundry, toilet, hose area, spare equipment and workshop area, duty station, entrance hall, and three two-man rooms. There are also living quarters, kitchen, bath, cloak room, and dirty clothes hamper. The boiler is located in a basement. Notification of a fire in the Pori area is given by fire bell, fire communications telephones, and automatic fire alarm systems. The number of such systems and communications links has been increased. The handling of fire communications and calls is described. 2 figs.

V. G. Fukalov

UDC 658.386

3.68.9. [Training of firemen] Norvanne, Marti. KTV: n PALOHENKILOSTOJARJESTOJEN YHTEISTOYOSTA JA SEN KEHITTAMISMEHDOLLISUUKSISTA. *Palontorjunta,* 1971, **22,** No. 4, 200–204 (Finnish)

UDC 658.386

3.68.10. [Physical training of firemen] Jaakkola, Erkki. KUNTOURHEILUN MERKITYKSESTA. *Palontorjunta,* 1971, **22**, No. 4, 196–198 (Finnish)

UDC 658.386

3.68.11. [Requirements for physical training of firemen] Rikkonen, Pekka. PALOMIEHEN AMMATIN FYYSISELLE KUNOLLE ASETTAMAT VAATIMUKSET. *Palontorjunta,* 1971, **22**, No. 4, 198 (Finnish)

UDC 621.398:654.924(088.8)

3.68.12.P [System for determining the location of mobile emergency (and alert) radio communication units] MOBILE EMERGENCY UNIT LOCATING SYSTEM. (John Peter Chisholm). British pat. class H 4 D (G 01 s 5/06), No. 1248066, appl. 5 Dec 1968, granted 29 Sep 1971.

A system is proposed for the continuous identification and exact determination of the location of special vehicles equipped with radio sets in large urban areas. The system is designed for operational control of mobile police forces. Often police dispatchers do not have information on the exact location of police patrols in urban areas and on the nature of their activities at a given instant. For successful apprehension of criminals it is necessary to reduce as much as possible the time between receipt of an alert signal and the arrival of police at the scene or at possible points of capture of criminals in hiding. The proposed invention, which is a pulsed hyperbolic system in which fixed receivers pick up signals from mobile transmitters, ensures exact determination of the location of a large number of vehicles in an urban area with a fix error of less than one block, calculation of the coordinates of the vehicles relative to the system in brief time intervals during which police cars may travel extremely short distances, identification of each vehicle whose location has been determined from the time distribution of the sequence of signals broadcasted from the mobile transmitters, determination of the time the information is received from the vehicles along with subsequent transmission to the central computer, immunity from false pulse signals reflected from buildings, which ensures unambiguous and exact determination of the location of the vehicles, the reception of alarm signals from taxis, buses, etc., being attacked, with rapid determination of their location and the location of the nearest police car, which can be sent immediately to the point of reception of the alarm signal, etc. The important feature of the system is the use of only one frequency communication channel; e.g., in the range of 150 to 1500 MHz for about 1000 vehicles. The frequency of approx 450 MHz is considered optimal. The output from the police car transmitters is about 10 W per pulse. 6 figs.

Yu. N. Veideman

UDC 658.155:614.841

3.68.13. [Loss from fire (in Austria) in 1970] BRANDSCHADEN IM JAHR 1970. *Industrie* (Austria), 1971, No. 44, 32 (German)

According to Austrian statistical data there were 9,302 fires in 1970, with overall loss amounting to more than 500 million shillings. An annual increase in the average loss per fire is noted. In 1968, for example, the average loss from a fire amounted to 46,915 shillings, while in 1970 it reached 54,420 shillings. The tendency toward an increase in fire loss is particularly evident in industry. The total cost of fire loss amounted to 150 million shillings; 18.2% of all instances of fire occurred from electrical faults. The loss from these fires amounted to 13.5% of the total loss. Fire, light, and heat sources made up 25% of all fire incidents, with losses amounting to 13.9% of the total. Losses from fires caused by lightning amounted to 48 million shillings; that is, almost 10% of the total. It was found that most fires are due to violation of fire safety codes.

UDC 658.155:614.841

3.68.14. [Problems involved in reducing fire losses] Harris, William. PLAN NOW TO MINIMISE LOSSES IN THE EVENT OF FIRE. *Mot. Trade Exec.*, 1971, No. 143, 18–19 (English)

In 1970, 12 major garage and filling station fires in Great Britain resulted in about 10,000 pounds of direct loss. The cause of these fires was the failure to observe fire-safety codes (including smoking), faulty equipment (especially electrical equipment), efforts on the part of the entrepreneur to reduce expenditures in the design and construction of garages, filling stations, and auto paint shops. In addition to direct losses of equipment and buildings, indirect losses must also be noted (interruption of business and production, expenses for repairs, purchase of replacement equipment, etc.). The total losses for businessmen engaged in selling fuel and vehicle services amount to about 100 million pounds per year. To reduce the losses, the fire protection service of the Central Fire Liaison Panel plans to conduct a broad campaign among businessmen and firms to unite efforts toward improving industrial and fire fighting equipment and the planning of technical premises, introducing controls over the conditions of filling stations and garages, analyzing the causes and consequences of fires, accumulating statistical data for the development of recommendations aimed at reducing losses. The initiative of the fire protection service is supported by the Minister of Trade and Industry.

Yu. N. Veideman

UDC 634.043:368.1

3.68.15. [Insurance in the forest fire service of New Zealand] Shuttleworth, P. FOREST FIRE INSURANCE IN NEW ZEALAND. *N.Z.J. Forestry*, 1971, **16**, No. 1, 69–76 (English)

Fire Prevention

Fire Protection

(Publications on combustion and explosion problems can also be found in issue 19ABV "General Aspects of Chemistry, Physical Chemistry, and Inorganic Chemistry." Publications on fire safety, fire protection, and fire hazards of substances and materials can also be found in issue 19I, "General Aspects of Chemical Technology.")

UDC 699.81(088.8)

3.68.16. [Flame retardants] Touval, I. and Waddell, H. H. WHAT YOU SHOULD KNOW ABOUT FLAME RETARDANTS. *Plast. Tech.*, 1971, **17**, No. 7, 29–31 (English)

A study is made of the problem of increasing the fire resistance of a number of polymer materials by introducing fire-retardant additives. Various chemical substances can be used as additives. Suggested in particular are substances containing water of crystallization (hydrated aluminum oxide, borates, etc.). The fire-retardant effect of these substances is based on the principle of heat removal from the ignition source by the evaporation of the water contained in the retardant. Also considered are a number of substances whose decomposition products are capable of interacting chemically with the material being protected, with the formation (primarily) of relatively inert carbon and a small quantity of hot gases. Among such substances are antimony oxide, chlorinated products, and phosphates. The use of large quantities of antimony oxide in the composition of the material being protected has a negative effect on its mechanical properties and complicates its manufacture. Most interesting in this regard are phosphorous compounds, since they not only increase the fire resistance of a material, but also improve its physical and mechanical properties by polymerization. But in use, they exhibit a tendency to migrate, which has a negative effect on the fire retardant effectiveness of the polymer. Phosphates are somewhat cheaper than antimony oxide. A number of polymer materials of low combustibility have been obtained on the basis of these flame-retardant additives: polyethylene with a content of 8–16% by weight of antimony oxide and 8–16% weight of 70% chlorinated paraffin. Polypropylene of low combustibility can be obtained only by using fire-retardant additives in the form of a mixture of antimony oxide with a cycloaliphatic product containing chlorine. Chlorinated paraffin cannot be used for the given polymer because it is not stable in the temperature range (450°) of the industrial process used to manufacture polypropylene. Twenty-three parts by weight of chlorinated substance and 40 parts by weight of antimony oxide are required for 100 parts by weight of polypropylene. Polystyrene of low combustibility can be obtained by adding 10% tris-2,3-dibromopropylphosphate. In use, however, this substance tends to migrate, which affects its fire protection effectiveness. More reliable protective systems are compounds of chlorine with antimony oxide. The most effective fire retardant additives for rigid polyurethane foams are phosphorus (15%), chlorine (18%) and bromine (2 to 14%). The fire resistance of polyurethane foam can be enhanced by introducing halogens and phosphorous compounds. Antimony oxide is not effective for this material; it has a negative effect on the industrial process of foam formation.

M. N. Kolganova

UDC 666.765

3.68.17. [Fire protection methods for metal structures enclosing industrial equipment] Ermini, Luigi. METODI DI PROTEZIONE ANTINCENDIO DELLE STRUTTURE METALLICHE DI SOSTEGNO DI APPARECCHIATURE CHIMICHE. *Securitas*, 1971, **56**, No. 5, 357–373 (Italian; French, English, German, and Spanish summaries)

The safety codes in the design of metal structures (especially steel trusses) around industrial equipment are not consistent with the codes of the oil and chemical industries except for fire protection problems. In fact, special conditions (huge fires, etc.) prevail in chemical plants, and these make it necessary to use protective measures in steel frames; e.g., they must be covered with an insulating material (concrete, light-weight fillers, bricks, etc.) or they must be cooled using water spray or jets from nozzles. The various fire protection methods are analyzed and their operational qualities are compared. 9 figs., 4 tables, 13 refs.

UDC 669.81:678.5

3.68.18. [Fire protection mechanisms for fluid (dripping) thermoplastic compounds] Gouinlock, E. V., Porter, J. F., and Hidersinn, R. R. THE MECHANISM OF THE FIRE RETARDANCE OF DRIPPING THERMOPLASTIC COMPOSITIONS. *J. Fire and Flammability*, 1971, **2**, July, 206–218 (English)

Tests are made of the fire retardancy of three compositions of self-extinguishing thermoplastics that drip during fire tests. Two methods are used: polypropylene containing phosphorus bromide compounds and chlorinated hydrocarbon; polystyrene containing brominated aliphatic hydrocarbons and peroxide; polystyrene and brominated salts of phosphoric acid. The specimens were analyzed according to the method in ASTM D653, in which the melted material flows through the burning spot. Comparison of the results leads to the conclusion that the drops have a substantial effect on the fire retardancy of materials. For each of the three melting compositions studied, it is concluded that a melted drop of material is an important component of the self-extinction mechanism. In the given case, the drop of melted material removes a part of the thermal energy from the burning zone of the composition being tested. This is well confirmed by the fact that when the compositions were ignited without the effect of dripping, i.e., in the melt, despite the additives, the fire-retardancy deteriorated. In the case of two systems based on polystyrene, the tests showed that the additives lead to a high degree of decomposition of the burning polymer. 6 tables.

V. L. Sushchinskiy

UDC 699.81:678.5

3.68.19. [Treatment of polyolefines with fire-retardants] Hofmann, Alfred. AUSRUSTEN VON POLYOLEFINEN MIT BRANDSCHUTZMITTELN. *Kunststoffe*, 1971, **61**, No. 11, 811–814, 1, 3, 2, 2 (German; English, French, and Spanish summaries)

There are a number of methods of protecting polymer materials from fire. Among them are chemical modification of polymers (graft polymerization), coating of plastic parts with various fire retardants, additives of various substances which increase the fire retardance of polymers. The last method is the most suitable for polyolefines. Formerly a large number of fire-resistant additives had been proposed. Thus, a combination of antimony oxide (Sl^2O^3) with chlorinated paraffin containing 70% by weight of chlorine had been recommended for polyethylene. Similar combinations are used for polyvinyl chloride and also for some polyesters. Instead of chlorinated paraffin, a large number of chlorinated or brominated alkyl or aryl esters, and halogenated amines have been recommended for polyethylene; they are applied in the form of films. Halogenated cycloalkanes and cycloalkenes are not bad fire-retardant additives to polyethylene. Hexabromocyclohexane, which is used as an additive to polypropylene and polystyrene, is preferred among this class of compounds.

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 7, review 42.

UDC 541.125

3.68.20. [The danger of acylating 3-ethyl-4-hydroxy-1,2,5-oxadiazole] Barker, M. D. THE DANGERS OF ACYLATING 3-ETHYL-4-HYDROXY-1,2,5-OXADIAZOLE. *Chem. and Ind.*, 1971, No. 43, 1234 (English)

It is reported that in the process of acylating 3-ethyl-4-hydroxy-1,2,5-oxadiazole an Na salt was obtained by mixing an alcohol solution of the heterocycle with a corresponding quantity of an aqueous solution of alkali (NaOH). The solvents were removed in a rotating evaporator at a temperature of 50°C. Before drying the residue by separation with benzene in Deane and Stark traps, an attempt was made to loosen the solid residue on the walls of the flask. Almost immediately after the scoop (spatula) touched the wall, the solid residue exploded. The protective glass and two protective glass shields 1.2 m away were shattered as a result of the explosion. The exact cause of the explosion was not established, but it is probable that the anion is thermodynamically unstable and regroups spontaneously to more stable products. It is noted that such compounds must be handled with care.

UDC 666.767
3.68.21. [Fire-resistant fluid] FIRE-RESISTANT FLUIDS. *Mining Mag.*, 1971, **125**, No. 4, 373 (English)

A fire-resistant water-glycol fluid has been developed for electric furnace control systems in the steel-casting industry. The fluid does not ignite even on direct contact with molten metal of up to 1630°C temperature.

UDC 66.097.7
3.68.22. [Composition inhibiting burning] CHEMICAL LOWERS ANTIMONY LEVEL FOR RETARDING FLAME. *Plast. World*, 1971, **29**, No. 8, 95 (English)

It is reported that the newly developed composition Oncor 75 RA, which is intended as a flame retardant for plastics, contains less antimony than the compositions stipulated for use by the ASTM standard. The new chemical product can be used effectively in polyester, nylon, and polyolefine resins, as well as in polyvinyl chloride.

UDC 667.767
3.68.23. [Intumescent fire-resistant coatings] INTUMESCENT COATINGS—FOAMING FIREFIGHTERS. *Plant Eng.* (USA), 1971, **25**, No. 16, 76 (English)

Data are presented on the composition and fire resistant effect of intumescent coatings. The coating begins to swell at a temperature of from 135 to 176°C. The deposited film, under the effect of the heat, increases its original thickness by a factor of 150 to 200.

UDC 614.841.3:666.765
3.68.24. [Behavior of interior finish materials during a fire] Christian, W. J. and Waterman, T. E. FIRE BEHAVIOR OF INTERIOR FINISH MATERIALS. *Fire Technol.*, 1970, **6**, No. 3, 165–178, 188 (English)

Research is being conducted at the IITRI research institute (U.S.A.) on the fire behavior of new structural materials used for interior finishing of occupancies in various buildings as well as on the determination of the level of their effect on the evolution of heat, smoke, and gas. A full-scale section of an experimental building 9.15 m long, 4.57 m wide, and 4.88 m high, included a room with an area of 4.57 by 3.05 m with a ceiling 2.44 m above the floor where the fires were simulated, and a corridor 15.25 m long, 1.83 m wide, and 2.44 m high, which communicated with the burn room through a double door. The test structure was made of steel and reinforced concrete blocks. All of the walls exposed to the fire were made of firebrick. The ceilings in the burn room and the corridor were faced with noninsulated asbestos cement panels and test samples of the seven finishing materials under study. The behavior of the finishes during the fire was monitored at four points distributed on the ceiling and the upper half of the burn room and corridor. In all, 88 natural fires were simulated, including 18 real fires originating in the bedroom, kitchen, study, anteroom, and pantry of an ordinary house; and 19 standard fires to determine the degree of influence of burn conditions on the finishes.

UDC 666.974.2

3.68.25. [Use of asbestos cement to increase the fire resistance of building structures] BRANDSCHUTZ IM HOCHBAU. DER WERKSTOFF ASBESTZEMENT IN SEINER ANWENDUNG FUER FEUERHEMMENDE UND FEUERBESTANDIGE KONSTRUKTIONEN. *Hock- und Tiefbau* (Fed. Rep. Germ.), 1971, **24**, No. 10, 30, 32, 34, 36, 38, 40 (German)

Modern building practice is characterized by less massive structures, higher density of housing, and taller buildings, which makes it impossible to predetermine the fire resistance of structures. Building materials such as steel, concrete, and wood are used primarily for bearing members. A description of their behavior to the effects of high temperatures is given. Steel structures heat up very fast and, beginning at 200°C, the strength properties of the steel drops, the modulus of elasticity decreases appreciably, and considerable deformation develops. In as little as 20 minutes, open metal structures heat up to critical temperatures. Reinforced-concrete structures heat up much more slowly than steel structures. The protective concrete layer of the reinforcement has a substantial fire-resistance limit. The percentage of reinforcement has an effect on the fire-resistance limit of reinforced-concrete structures. When the percentage of reinforcement exceeds 3%, the fire-resistance limit decreases. Concrete is different from steel in porosity. The concrete pores are filled with moisture. When concrete is heated above the temperature of boiling water, the moisture evaporates. If the heating occurs very rapidly, especially in structures with a thin cross section, the vapor pressure can exceed the tensile strength of the concrete and the structure will collapse. Tests of thin partitions have shown that at critical vapor pressures reinforced-concrete structural materials can be demolished explosively. Wood is a combustible building material, but the thermal conductivity of wood is considerably less $(0.6 \text{ to } 0.8)\times 10^{-3}$ m^2 per hr than that of steel and concrete, which are 42×10^{-3} m^2 per hr and $(1.8 \text{ to } 2.5)\times10^{-3}$ m^2 per hr, respectively. The complexity of the analytic solution of the differential Fourier equation makes it necessary to conduct fire tests of structures. The use of asbestos cement (Eternit) to increase the fire-resistance limit of structures is discussed. Asbestos cement in accordance with DIN 724 with a bulk weight of 1800–2000 kg per m^3 behaves like concrete at high temperatures. This deficiency is corrected by decreasing the bulk weight to 800 kg per m^3 and by increasing the porosity considerably. Comparative data on asbestos cement with bulk weights of 1800 and 800 kg per m^3 are given. The specifications of DIN 4102, technical solutions with regard to the facing of steel beams, columns, reinforced concrete coatings, partitions made from Eternit of varying thickness, and fire-resistance limits of these structures are presented. 12 figs. 4 tables.

I. L. Moskalov

UDC 623.454.76

3.68.26. [Protective fabrics] Fourniere, Nicole. LES TISSUS DE PROTECTION. *Rev. Secur.*, 1971, **7**, No. 73, 1–11 (French)

Various kinds of hazardous work require the use of various kinds of protective clothing. Special clothing is needed for protection against fire and high temperatures, low temperatures, corrosive chemicals, radioactive radiation, and mechanical damage. The characteristics are given of various materials that can perform one or more of the above-mentioned protective functions simultaneously. Several methods are described for determining the extent to which these materials fit the special purpose; their inadequacy is noted, and it is pointed out that a special committee of the International Standards Organization (ISO) is engaged in developing such methods. 6 figs.

UDC 623.454.76

3.68.27. [Fire-resistant treatment of fiber materials] Aenishanslin, Rudolf. BRENNBARE FASERSTOFFE UND FLAMMHEMMENDE AUSRUSTUNGEN. *Text. Ind.* (BRD), 1971, **73**, No. 11, 760–765 (German)

Almost all textiles, including materials made from different synthetic fibers, are combustible to some extent and are a major source of fire hazard. About 12,000 people perish in fires annually in the U.S.A. Of these, one-tenth die from textile fires. In Great Britain up to 10,000 textile material fires occur annually. Of these, about 300 involve deaths and about 1,000 result in serious aftereffects. In Switzerland about 50 people die annually from textile fires. In order to determine the degree of fire hazard of fiber materials, it is necessary to have reliable test methods. One of the methods which permits classifying various fiber materials by their degree of fire hazard is the "limit oxygen content" method, which is used in the Federal Republic of Germany. It consists in determining the oxygen concentration in an O^2-N^2 mixture necessary to maintain continuous burning of the specimen. The fiber specimen is stretched vertically and is ignited from the top; the flow rate of the O^2–N^2 mixture is held constant from top to bottom.

Limit oxygen concentration for some fiber materials and plastics

Name of fiber	Limit O^2 content
Rayon	15–19
Polyacrylic	18–18.6
Cotton	18.6–19
Polyamide	20
Polyester	20.6–22
Wool	23.8–26
Cotton impregnated with fire resistive Rovyl 55	37
Polybenzimidiazole	40.6

Plastics

Plastic	Limit O^2 content
Cellulose acetate	16.8
Propylene	17.4
Polyamide 6, 6	24.3
Polyamide	36.5
Polyvinylchloride	60.0
Teflon	95.0

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 7, summary 41.

UDC 536.46:677–48

3.68.28. [Burning of textile articles in homes] Potter, H. BRANDE VON TEXTILIEN IM HAUSHALT. *Textilveredlung*, 1971, **6**, No. 10, 671–674 (German; English summary)

Clothing, curtains, and bedding burn most frequently in homes. Particularly hazardous are light and thin textile fabrics and knitted articles made either of natural or artificial fibers and mixtures of them. The fire hazard depends in large measure on the density and thickness of the material and the way it is handled, rather than on the type of fiber. The larger the cut of the clothing, the greater its fire hazard. The ignition sources are usually burning matches, cigarettes, flame from gas burners, candles, etc. The ignition of clothing often leads to serious injuries, especially when synthetic fabrics burn, since they melt, causing intense pain and bring about poorly-healing injuries. In an insufficiency of air, a dangerous concentration of carbon monoxide may build up. More than 400 cases of burning clothing have been recorded in Switzerland in the last decade; more than 100 people were killed. This led to the introduction in 1964 of a ban on the manufacture of clothing made from readily igniting textile materials. Special types of fabric treatment must be used to reduce their fire hazard in the home. It is also suggested that the fire hazard of fabrics can be reduced by selecting appropriate compositions. Several generally known rules for safety and for first aid to the injured are given. The degree of fire hazard of fabrics is determined: if it burns even after the ignition source is removed, it is classified as "combustible", but if the fabric does not burn independently, but only smoulders or melts, it is considered to be "difficultly combustible"; if it flames up instantaneously, it is defined as "readily flammable."

A. V. Ivanov

UDC 541.125:661.92

3.68.29. [Compressed air and the risk of explosion] Munck, John. L'AIR COMPRIME ET LES RISQUES D'EXPLOSION. *Equip. mec. Carrieres et mater.*, 1971, **50**, No. 106, 69–71, 73 (French)

The occurrence of fires and explosions when using compressors is discussed. The fire source is a layer of soot generated by lubricant. Lubricants are usually a mixture of viscous oil (>0 centistokes at 50°C) and of low-viscosity oil (<10 centistokes). At 50°C the mixture has a viscosity of 38±4 centistokes. During the operation of a compressor, the low-viscosity component volatilizes, while the high-viscosity component oxidizes due to the effect of atmospheric air, forming soot. The effect of viscosity on the evaporation rate is determined experimentally. It was found that the viscosity of lubricating oil must be as low as possible, the oil must be homogeneous, and not a mixture of components of different viscosities; the oil must consist of naphthene hydrocarbons. If these recommendations are observed, the soot formation will be low and, consequently, the risk of spontaneous ignition and fire can be avoided.

UDC 541.125

3.68.30. [Reduction of explosion hazard] Lewis, D. J. REDUCING EXPLOSION HAZARDS. *Chem. Process.* (Gt. Brit.), 1971 **17**, No. 10, 65–67, 69 (English)

Imperial Chemical Industries Ltd. (Gt. Brit.) is implementing a number of measures to increase operational safety at chemical plants. These measures are based on a thorough study of fire and explosion hazard in production, along with the development of recommendations to reduce the hazard to a tolerable level. It is necessary to analyze not only new, but also old technological processes, since with the expansion of production they are subject to frequent and fundamental change. In some plants major disasters occurred after thirty years of normal operation, and it is practically impossible to set any definite period of operation beyond which safety would be fully guaranteed. In the recommended methods of estimating hazard, particular attention is devoted to a broad study of normal and emergency production conditions. After determining the hazardous situations, it is necessary to estimate the probability of occurrence and the possible consequences of each situation. The basic aim of prevention is elimination of hazards from working areas. The company is conducting systematic laboratory investigations of the fire-hazard indexes of flammable fluids, gases, dust, and condensed systems. The test methods being used are varied and not yet standardized. The reliability of a method is being established by testing a number of substances with well-known ignition limits. The ignition limits for a high initial pressure are determined in a closed vessel made of stainless steel. The vessel has an inner spherical cavity with a volume of 6 liters and is capable of withstanding pressures up to 350 kg/cm^2. In order to ensure safety in case of leaks through the joints, the vessel is placed in a ventilated chamber and is remotely controlled. An analogous apparatus is used to determine the self-ignition temperature and other hazard indexes. When it is necessary to determine the effectiveness of dilution of a flammable system by inert additives (nitrogen, carbon dioxide, steam), a diagram consisting of three components is drawn of the ignition limits of the mixture.

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 2, summary 11.

UDC 536.46

3.68.31. [Study of the fire hazard of aerosols] WEST GERMAN TESTS ON FIRE AND EXPLOSION HAZARDS OF AEROSOLS. *Fire Int.*, 1971, **3**, No. 33, 89–92 ii (English, French, German; Spanish summary).

Studies are being made in the Federal Republic of Germany of the fire and explosion hazard of aerosols in cylindrical containers having a capacity of 1000 cm^3. In some cases the aerosol components are fuels, e.g., butane or propane. Freon, a halogenated hydrocarbon, is frequently used as the propellant. The flame length from a bunsen burner was measured; the nature of its propagation with respect to the atomizer and the presence or absence of burning when this burner was removed were determined. Aerosols with an ignition temperature below 600°C were considered flammable. The flash point does not necessarily characterize the fire hazard of an aerosol. For instance, a jet of suntan oil with a flash point of 180°C is safe until it is finely atomized. Then an explosive gas-air mixture forms. More dangerous are aerosols which continue to burn after the ignition source is removed. Less dangerous are aerosols whose flame length does not exceed 20 cm. In order to determine the fire hazard of atomizing large quantities of aerosols in a confined space, a 200-liter vessel and an ignition source in the form of a hot plate were used. Aerosols were forced into the chamber through a narrow, valved opening. The aerosol was considered to be flammable if a combustible mixture formed in one minute. Aerosols with a flash point above 50°C exploded after various time intervals, depending on the plate temperature. Aerosols ignited from contact with the plates. The explosive power of the vessels was appreciable. Fragments penetrated concrete barricades of 10 to 15 cm thickness. Vessels exploding in a vertical position rose to heights of 50 m. In the horizontal position, fragments traveled up to 50 feet. Sometimes explosions were accompanied by the formation of a fire ball of several meters diameter. Fires do not occur when careful storage and use of aerosols are observed. The extinction of aerosol fires in plants is hindered by strong explosions.

I. I. Myagkov

UDC 536.46

3.68.32. [Temperature fields during the propagation of a fire in a mine] Kennedy, M. TEMPERATURE DISTRIBUTIONS DOWN-WIND OF MOVING MINE FIRES. *J. Phys. D: Appl. Phys.*, 1971, **4**, No. 10, 1493–1498 (English)

Results are presented of an experimental and analytical study of temperature fields during the propagation of a fire along the wooden planking of a ventilation duct 9.1 m long and with a cross section of 63.5 mm^2.

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 2, summary 8.

UDC 536.46

3.68.33. [Combustion of premixed laminar graphite powder flame at atmospheric pressure] Bryant, James T. THE COMBUSTION OF PREMIXED LAMINAR GRAPHITE DUST FLAMES AT ATMOSPHERIC PRESSURE. *Combust. Sci. and Technol.*, 1971, **2**, No. 5–6, 389–399 (English)

Considered is the combustion of fine solid particles of laminar graphite [sic] in an air and oxygen medium in pure form and in the presence of natural gas, as well as with additions (up to 2.5% per vol) of chlorine and (up to 4.75% per vol) of lead acetate. The study is a continuation of the previously published research (1–10) conducted in the U.S.A. from 1949 to 1969. The principal aim of the research is to find methods of increasing the operational properties of solid and liquid propellants for ramjet engines.

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 2, summary 7.

UDC 536.46

3.68.34. [Enthalpy of combustion and formation of cyclopropylamine] Good, W. D. and Moore, R. T. THE ENTHALPIES OF COMBUSTION AND FORMATION OF CYCLOPROPYLAMINE. THE C–N THERMOCHEMICAL BOND ENERGY. *J. Chem. Thermodyn.*, 1971, **3**, No. 5, 701–705 (English)

The value of the standard enthalpy of combustion, 532.20±0.10 kcal/mole, reduced to 25°C, gaseous CO^2 and N^2 and liquid H^2O is determined in a BMR II calorimeter with a rotating platinum bomb for a specimen of liquid cyclopropylamine (99.85±0.01% mol) of 808 kg/m^3 density and 0.616 cal/g·deg heat capacity. The standard enthalpies of formation of liquid cyclopropylamine, 10.95±0.12 kcal/mol; and of gaseous cyclopropylamine, 18.42±0.16 kcal/mol, and also the value of the thermochemical C–N bond energy [which does not differ from the value recommended by the All-Union Refractories Research Inst.] were calculated from this value, taking into account the enthalpy of evaporation at 25°C (calculated from the vapor pressure), equal to 7.47±0.10 kcal/mol. 19 refs.

UDC 620.1.05:536.46

3.68.35. [A heat-flux meter] Wraight, H. A. A ROBUST HEAT FLUX METER FOR EXPERIMENTAL BUILDING FIRES. *J. Phys. E: Sci. Instrum.*, 1971, **4**, No. 10, 786–788 (English)

At the fire Research Station in Boreham Wood (England) a heat flux meter has been designed which is widely used in the study of experimental fires in various buildings. With this meter it is possible to measure the rate of radiative and convective heat transfer in the 1 to 80 kw/m^2 range with an accuracy of up to 1 kw/m^2. The meter is reliably designed, making it possible to place it directly in burning or very smoky areas, which is very important in simulating large-scale fires. The meter is made in the following versions: to measure combined convective and radiative heat fluxes and to measure only a convective heat flux. Simultaneous use of two meters makes it possible to measure the two types of heat flux separately. In order to exclude the distortion of hot gas heat fluxes, the meter is mounted flush with the heated surface being studied, through which the heat transfer occurs. This method guarantees obtaining reliable results across an arc of 180°. The meter, which is designed to monitor convective heat fluxes, is practically insensitive to the ventilation conditions or to wind drafts. The response time to heat-flux effects does not exceed 10 sec. The meter can also work at relatively low temperatures (below 150°C) observed with weak convection during a fire. A description is given of the construction of the device and of methods of using it in practice. 2 figs. 1 table. 5 refs.

V. G. Olimpiyev

UDC 614.841.3

3.68.36. [Industrial standards work] Husson, Jean. LA PREVENTION DES RISQUES D'INCENDIE ET SES INCIDENCES SUR LES PROJETS DE CONSTRUCTION. *Allo 18*, 1971, No. 266, 18–24 (French)

Industrial standards work carried out by the Paris fire brigade is described. A list and brief contents of the basic standards documents used as a basis for this work are given. A statistical inquiry is made as to fires in a protected sector over various years.

UDC 614.841:351.824.1

3.68.37. [Fire protection measures in enterprises] Fernandez-Baldor Trueba, Jose Ramon. INCENDIOS: MEDIOS DE PROTECCION DE LA EMPRESA. *Econ. Ind.* (Spain), 1971, **8**, No. 92, 77–85 (Spanish)

Fire protection of industrial enterprises requires preventive measures and effective fire-extinguishing equipment. In Spain, the general occupational safety and health standards set up contradictory codes for the storage and transportation of highly flammable liquids and solid combustible materials; they specify safe distances between fire-hazardous production sites as well as the number of floors for industrial buildings and their height; they provide for the construction of earth embankments between dangerously explosive manufactured products. Various measures are aimed at fire prevention during the storage of flammable wastes, while operating heating devices, for pipes carrying flammable liquids, etc. The rules require compliance with certain building standards (the presence of emergency exits and ladders, the number and dimensions of door and window openings, the distance between them and the work area) to ensure the safe evacuation of people during a fire. Moreover, they require the installation of warning systems and fire-extinguishing equipment in areas where personnel are endangered in case of fire. Fires are classified by types of flammable materials, and the general principles of their extinction by modern equipment are considered. Attention is devoted to the physical-chemical features of extinction by concentrated water streams, spray and fog, snowy and gaseous CO^2, chemically and mechanically produced air foams, various dry powders and bromoethylene compositions.

E. D. Roev

UDC 614.841.3:351.824.1

3.68.38. [Fire prevention in industry] Kirschner, Ulrich. BRANDSCHUTZ IN INDUSTRIE UND VERWALTUNG. *Werkstatt und Betr.*, 1971, No. 10, 785–790, 5, 6, 7 (German; English, French, Spanish summaries)

UDC 614.84:351.824.1

3.68.39. [Fire protection in industrial plants] SECURITE. PROTECTION INCENDIE-DOCUMENTATION. *Chim. peint.*, 1971, **34,** No. 10, 399 (French)

UDC 614.841.3:533.2

3.68.40. [Fire protection of plants for the refining and storing of liquified natural gas] Walls, W. L. FIRE PROTECTION FOR LNG PLANTS. *Hydrocarbon Process.*, 1971, **50,** No. 9, 205–208 (English)

Basic trends in the fire protection of plants for the refining and storing of liquified natural gas reduce to the prevention of gas leakage from equipment and to the provision of effective protection in the case of spills. The requirements for LNG tanks and products are analogous to those specified for the tanks and manufactured products of liquid petroleum gas, but they can be less stringent. Damage occurs mostly to piping. Particularly dangerous is the piping between the inner cavity of the tank and the first valve regulating the flow of gas from the tank. If the pipes are laid horizontally, damage can drain the entire contents of the tank. The leakage rate can be reduced considerably by laying the pipes through the upper part of the tank or by inserting valves in the lines. Leakage is accompanied by LNG evaporation, with the formation of cold vapor or the accumulation of liquid gas. Contact of the cold vapors with the air causes atmospheric moisture to condense and form fog. When LNG contacts water, unstable solid compounds form, but their nature has not yet been adequately studied. Flammable gas–air mixtures form at the same time. When they are ignited, they very rapidly engulf near-by structures, buildings and communication lines. Protection from such events consists in preventing contact of the flammable mixture with an ignition source and in the insulation of structures from the thermal effect of the fire. Protection from gas leakage is achieved primarily by the correct design of industrial equipment and by installing the equipment in conformity with the design. Limitation of the size of the leak, the volume of flammable mixture formed, and the size of a fire can be achieved by using automatic or remote-controlled valves in the piping, by installing drainage channels and collectors for the detour of leaking LNG away from ignition sources and from structures sensitive to change (increase or decrease) in temperature. The size of a fire is also limited by establishing suitable barriers between structures. The means used to combat an accident on LNG spill is called secondary fire protection. Its systems and methods are essentially passive and should correspond to the particular conditions of an accident. The reliability of the secondary fire protection system depends on a correct evaluation of the circumstances attending the accident.

See also *Engineering Digest*, "Fire Protection" series, No. 2, summary 12.

UDC 614.841.3:665.66:553.982

3.68.41. [Fire protection of oil-well platforms and training of workers] Bleakley, W. B. PROTECT PLATFORM WORKERS WITH FIRE FIGHTING KNOW-HOW. *Oil and Gas J.*, 1971, **69**, No. 37, 97, 100–101 (English)

The Shell Oil Company has developed a fire-protection system for oil-rig platforms in Cooke Bay, Alaska. In view of the severe weather conditions, the machinery of the platforms is enclosed in shelters, raising the risk of filling them with smoke, making visibility poor, and inhibiting breathing when a fire occurs. The seawater in the bay is cold or is ice-covered, complicating evacuation and creating a high risk. To protect the platforms, therefore, a stationary system is used, providing for centralized supply of light-water solution to all sites having flammable liquids and gases. A light-water solution on a burning liquid forms a molecular layer which decreases evaporation and isolates the surface of the liquid from atmospheric oxygen. At the same time the light water cools the hot metal structures. The prepared solution is stored in a steam-heated container. The system is designed for the supply of the necessary amount of solution for 5 min. to the most highly protected site. In addition, powder-type fire extinguishers and hand-operated fire extinguishers are provided on the platforms. All the personnel working on the platforms go through a three-day training course in the fire school in California. Particular attention is devoted to acquiring practical skill in fire extinguishment in special training buildings and on the testing range. Typical actual situations are simulated in the exercises: burning of diesel fuel in a building, gasoline flow along a vertical wall, and burning of gasoline flowing through a leaky flange joint. 5 figs.

O. M. Volkov

UDC 614.841.3:621.64

3.68.42. [Demolition of a storage area] DEMOLITION OF PETROLEUM STORAGE TANKS. *Fire Prot. Rev.*, 1971, **34**, No. 373, 440–441 (English)

In 1971, 20 months after the inactivation of a petroleum storage area in Coventry, the tanks were removed. In order to ensure fire safety during the disassembly work, the following precautions were taken: before disassembly, the fuel pipes were washed out with a non-flammable, non-toxic fluid; the absence of a hazardous concentration of vapor was verified periodically; the absence of gas in the tanks was determined by chemists; if necessary, the tanks were streamed out; when gas cutting was used, the tanks were filled with foam; disassembly of the tanks started at the roof; a safety service specialist and firemen in fire-protection suits and protective respiration masks were on constant duty in the tank area. Preference was given to the dismantling of tank structures without cutting. Among the duty equipment were a pumper, a tanker, and a 141 m^3/min foam generator. Two grass fires occurred during the gas cutting process. A total of 10 tanks were disassembled, 6 for gas-oil, the rest for oil.

UDC 614.841.3

3.68.43. [Data on industrial fire load] Peukert, Joachim. ERMITTLUNG DER TECHNOLOGISCHEN BRANDBELASTUNG. *Dtsch. Textil-techn.*, 1971, **21**, No. 10, 633–638, 594, 596 (German; Russian and English summaries)

UDC 614.841.3

3.68.44. [Protective measures after polyvinylchloride fires] SCHUTZMASSNAHMEN NACH PVC-BRANDEN. *Kunststoffe*, 1971, **61**, No. 10, 774 (German)

UDC 614.841.3.629.12

3.68.45. [Organization of fire protection on a passenger ship] Thepot, J.-P. L'ORGANISATION DE LA SECURITE INCENDIE A BORD DU PAQUETBOT MERMOZ DE LA COMPAGNIE PAQUET. *Rev. techn. feu*, 1971, **12**, No. 111, 6–8, 10–11 (French)

The fire safety of a ship is ensured by means of a patrol service, warning equipment, and fire-fighting equipment. Among the measures taken to prevent fire are the choice of appropriate materials, their fire resistance, partitioning of the ship into compartments by fire-resistant partitions and firestop doors (the MERMOZ has about 120 doors). Sixty-three dampers have been installed in the ventilation shafts. All three fire-defense methods have been used in the ship. Places where specific fire load does not exceed 4 kg/m^2 are considered to be non-flammable. The patrol service is provided continuously in the daytime by a team; at night two shifts patrol, with a shift of two hours duration and clock-punching at 29 stations. A sprinkler system has been installed. A smoke warning system has been set up in difficultly accessible places (holds, between decks). The extinguishing system in these places is CO^2. The fire fighting equipment is handled by the survival team. Also provided for is a support team. The technical team is responsible for covering the ventilation ducts. In a difficult situation, the restaurant personnel are also mobilized to form a fighting team. The action team takes care of passenger safety all the way to placing them in the life-preserving equipment. The bow, midsection, and stern of the ship each contain one set of fire-fighting instruments. The main fire line makes it possible to supply water to any part of the ship. The first mate directs the fire fighting. The second mate, who is in charge of ship-safety problems, directs the individual fire-fighting sectors. He is responsible for training the personnel, for the status of the equipment, and for activation of fire-extinguishing equipment. Passenger exercises are held during the first few hours afloat. 3 figs.

V. G. Fukalov

UDC 614.84:629.12

3.68.46. [Fire protection of a gas tanker] Wetterich, W. FEUERSCHUTZ AUF GASTANKERN. *Hansa*, 1971, **108**, No. 20, 1971–1973 (German)

Special safety requirements are imposed for tankers transporting liquified natural gas, methane or petroleum gases, propane, butane, and also ammonia. The specific weight of methane in the gaseous state at a temperature of $-161°C$ is 0.7168 kg/nm^3, and in the liquid state 0.415 kg/dm^3. In the combustion of one nm^3 of methane, 9,500 kcal of heat are developed, and when one kg is burned, 13,000 kcal are given off. One m^3 of methane develops 5,400,000 kcal. These figures characterize the potential fire hazard of a tanker with a capacity of more than 120,000 m^3 of gas. Even with the small gas losses resulting from natural evaporation, gas escapes. The specific weight of gaseous methane is less than that of air. More dangerous are propane and butane, which are heavier than air. The requirements of the various safety codes on gas tankers are not identical. It is best to extinguish a gas fire, especially pressurized gas fires, with powders. The fire extinguishing effect of powders is due to the absorption of heat by the large surface area of the powder particles, to decomposition (this effect is not produced by all powders, e.g., sodium hydrocarbonate decomposes in flame to sodium carbonate, water vapor, and carbon monoxide), and to anti-catalysis, i.e., to deceleration of the combustion reaction. The latter effect plays a decisive role. To protect the deck of a tanker, it is possible to use a small self-contained powder device (PLO) with a capacity of 250 l of fire-extinguishing agent. Also one or several stations with 500 to 6000 kg of fire-extinguishing powder at each are described. Each powder container has two starter bottles of an inert gas (usually nitrogen) with a capacity of 50 l at a pressure of 200 atm. The length of the piping is up to 150 m, the pipe dia is 1.5 in. Certain points are set aside as powder tapping stations, consisting of a waterproof case, a hose, a pistol nozzle, and a starter flask with a pressure reducer. The number of pistols in a case depends on the number of tapping points. Each station has no fewer than two pistols. The output of a pistol is 3.5 kg/sec with a throw of 8 to 10 m. In the nitrogen devices, the duration of operation is 10 to 30 sec. The devices can also be actuated by compressed air and electric power. For large tankers the output of the pistols can be increased to 20 to 40 kg/sec. In ordinary powder extinguishers it takes 15 to 20 liters of gas to expel one kg of powder. In the tropics the properties must be constant at temperatures up to +350°C. The powder is siliconized and is thus suitable for extinguishing fires together with foam. 5 figs.

V. G. Fukalov

UDC 614.841.3:629.735.33(088.8)

3.68.47.P [Fire-safety ramp] FIRE PROTECTION SHIELD. (Brown Engineering Co. Inc.) U.S. Patent, Class 14–71 (B65g 11/00), No. 3581331, applied for 1 Oct 1968, granted 1 Jan 1971.

The device is intended for fire protection of airplane passengers leaving the cabin. An extensible ramp housing that fits tightly against the air-plane fuselage is used. The housing is a continuation of the ramp that leads to the main airport building. The device consists of a lift-and-rotation chamber with a telescopic passage having a transfer bridge with a sealing section, which fits up against the aircraft fuselage in the working position. An extensible housing is provided for the transfer bridge. In closed position the housing is supported by a cable system connected to a fusible insert. Springs are held in the compressed position. During a fire the fusible insert is destroyed, the housing moves forward by spring action to press the sealing section against the fuselage. The rate of motion of the housing is controlled by a hydraulic damper. The surface of the sealing section is coated with an intumescent paint to ensure tight contact in the case of a fire. The system ensures a fuselage inner-surface temperature of no more than 177°C for 5 min at an outer temperature of up to 982°C.

A. A. Rode

UDC 614.84:658.75

3.68.48. [Fire protection of warehouses] LA PROTECTION INCINDIE DANS LES ENTREPOTS PALETISES. *Rev. techn. feu*, 1971, **12**, No. 111, 35–36 (French)

At the present time almost every firm has large warehouses for palletized goods. There are huge warehouses of up to 30 m in height, thousands of m² of floor space, with automated warehousing. Vertical storage of goods creates conditions favoring fire development. Fires in automated warehouses result in losses not only from damage to goods, but also from damage to equipment, which, as a rule, must be completely replaced after a fire, since deformation of the frames make it impossible to use automatic load-handling equipment. It is considered necessary to construct a fire-warning and an automatic fire-extinguishing system; general rules for the construction of such systems are outlined. 3 figs.

UDC 614.841.3:814.3:537.2

3.68.49. [Reduction of the electrostatic hazard] Redding, R. J. ELECTROSTATIC HAZARD REDUCTION. *Chem. Process.*, (Gt. Brit.), 1971, **17**, No. 10, 59 (English)

The possibility of an electrostatic charge occurring during the operation of two materials with differing physical properties formerly in contact with each other is examined. It is noted that charge accumulation is promoted by the high electrical resistance of a material. Very hazardous systems occur when an electrical charge is observed accumulating in a volume with a flammable or explosive material. Attention is devoted to the fire hazard from static electricity in hospitals, where flammable anesthetics are used. It is proposed that, if possible, they be replaced by nonflammables, and also that the use of materials for flooring and piping for gases and liquids be studied. 1 fig.

UDC 614.841.3:621.316.36

3.68.50. [Fire safety of electrochemical apparatus] Frischmann, Pilz. BRANDSICHERHEIT IN ELEKTROTECHNISCHEN ANLAGEN. *Elek.-Prakt.*, 1971, **25**, No. 11, 378 (German)

The content of three reports by O. H. Blaum on the fire safety of electromechanical equipment is discussed. The first paper reports on methods of evaluating the combustibility of plastics used in insulation; the other two papers report on possible precautionary firefighting measures in such installations. (Fed. Rep. Germany)

UDC 536.46:614.841.41.001.57

3.68.51. [Field study of urban fires] Vodvarka, F. J. URBAN BURNS—FULL-SCALE FIELD STUDIES. *Fire Res. Abst. and Rev.*, 1970, **12**, No. 3, 209–212 (English)

The results of a study of urban fires artificially reproduced in full scale in the field are presented. The experiments were carried out on structures to be demolished for urban renewal. The fire was simulated in five- and two-story frame houses, one cement-block building, a brick diner, and a cement-block filling station. Important information was obtained as a result of the experiments: data on fire spread; on the radiation level; on the number of drifting deposits in the form of tiny unburned particles, soot, cinders, and smouldering brands; on the pressure in the fire center; on the composition of the gases evolved; on the wind speed during a fire; on the intensity of the convective fluxes formed, and on the temperatures in the various fire zones. The first experiment was carried out in an old stripped farm house, one half of which was one floor, the other half two storied. The fire was characterized by intense development 5 min after ignition. Because of holes in the walls and roof of the building and because it was open to ventilation, the height of the flame plume above the roof level was about 18 m. The fall-out of brands downwind was observed in a radius of 45–60 m; the mean density was about 5 kg/m², with a maximum of 50 kg/m² [sic]. The second test simulated a fire in the main hall of a one-floor diner 11 by 10 by 3 m, where mock-up wooden tables and various combustible furniture were used as fuel for the fire. In the case of closed wall apertures the fire spread over the whole volume in one hour. In the next 10 min the fire penetrated through the roof, fed by the asphalt, generating a large quantity of thick, black smoke. The maximum concentration of CO and CO_2, respectively, was 1.36 and 3.7%, the oxygen content was less than 17%; the gas pressure beneath the roof was approximately 3.5 mm H_2O. The third experiment in a service station showed that roof panels caved in considerably as a result of fire action and cement blocks exhibited numerous fractures, ruling out any further use of these structures. Interesting results of fire effects in barrier structures of urban-type buildings under study were also obtained in the rest of the tests, Nos. 4–8.

V. G. Olimpiyev

UDC 614.841.45.3

3.68.52. [Fundamental principles of fire protection] Witteveen, J. and Twilt, L. UITGANGSPUNTEN BIJ DE BRANDPREVENTIE. *Bouw.*, 1971, **26**, No. 38, 1348–1352 (Dutch)

Recently the possibilities have been enhanced for determining the elements of fire protection of structures by computation, similar to the way in which it is possible to determine their bearing capacity. But too-low fire-protection specifications can lead to the formation of an unavoidable hazard for persons in a building and/or to excessively high losses from a fire. Too-high fire-protection requirements make fire protection excessively expensive. Fire-protection requirements are divided into primary and secondary fire protection categories. Primary fire protection embraces all measures whose cost cannot be equated with material return. Primary fire-protection measures are aimed at protecting human life, humanitarian values, and social interests. Secondary measures take in expenditures comparable with the material benefit. The cost of secondary measures should not exceed the anticipated reduction in losses from fires. A fire hazard for people in the building arises when timely and safe evacuation of persons from the fire zone is impossible because of a deficiency or absence of satisfactory and reliable evacuation routes and exits, and also if the design of the building prevents people in the building from leaving it in time. Of the 4,000 fires occurring in residences annually in the Netherlands, in 400 cases it is probable that the hazard increased because of structural collapse.

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 2, summary 13.

UDC 614.841.3

3.68.53. [Designing for fire protection] Drews, Robert B. FIRE PROTECTION BY DESIGN. *Fire Eng.*, 1971, **124**, No. 8, 29–30 (English)

The particular features of ensuring structural fire protection of a residential complex for 8,000 people in the suburban belt west of Chicago are discussed. One of the features consists in supplying the sprinkler system with water from the pressurized water-supply pipes in the stairwells of 11- to 15-story residential buildings. Sprinkler nozzles are located not only on each floor, but also within each individual apartment, which is provided with a self-closing entrance door. The water main has a diameter of 25.4 cm, and the distribution pipe lines leading to the buildings are 20.3 cm in diameter. Electric fire pumps in each building deliver the pressure necessary for normal water supply and simultaneous operation of the garage sprinkler system over an area of about 12 m². At the end of the corridor leading to the landing in each floor there is a special recess containing the fire valve providing a fire-hose connection even if the stairwell door is closed. In steel-shell buildings the ceilings are equipped with suspended cement-plastic slabs, providing for a two-hour fire resistance limit in the complex. The cement-plaster-clad steel columns and walls separating the corridors and apartments have the same fire resistance. The reinforced-concrete beams, columns, and walls of the garage provide four-hour fire resistance, the walls of the stairwells and the elevator and smoke-ventilating shafts have a two-hour resistance, and the main doors along evacuation routes 1.5 hours. 1 fig.

V. G. Olimpiyev

UDC 614.841.3:69.032

3.68.54. [Fire safety in tall buildings] FIRE SAFETY IN BIG BUILDINGS. *News Eng.*, 1971, **43**, No. 4, 6–8, 14 (English)

It is noted that regardless of the capital invested in the construction of tall buildings, they cannot be made fully (100%) fire proof, since the expenditures for this purpose are based, as a rule, only on consideration of the most probable fire situations. The question is, do the fires that occur justify the probability of the anticipated hazard. As an analysis of the causes of fires occurring in two tall buildings in New York in 1970 shows, the real hazard in each of them exceeded the anticipated level. But this is not determined by imperfect building standards; rather, it is the consequence of low-quality design, unsatisfactory construction, and poor inspection. Of rather great importance are the observed cases of the death of people in elevators during the fire evacuation period. There is not a building standard which does not permit the use of elevators as evacuation routes during a fire. At the same time, instructions on elevator use permit their operation during fires, both manually and automatically. The New York building standard provides, as an exception, for the operation of one elevator during a fire. It is necessary to orient the residents and service personnel toward less expectation of using an elevator for evacuation to avoid fatalities. As before, the problem of smoke in tall buildings during a fire remains insoluble. Within a building smoke propagates primarily along shafts, stairwells, and the air ducts of the ventilation system. In order to prevent or limit the movement of smoke, it is necessary to keep closed all doors connecting adjacent floors or main hall areas on each floor. But this is not possible, since doors serve as passages for firemen, who have to lay fire hoses through them to extinguish a fire with water. The possibility of smoke spreading through the ventilation system has not yet been adequately studied, and greater attention must be devoted to it. It is emphasized that reliable fire protection of tall buildings cannot be achieved solely by constructing a complex ventilation system, by the installation of sprinklers, or by the presence of smoke-removing shafts. Much depends on reducing the combustible content of buildings, on reducing the fuel load, and on building standards conforming to the fire standards.

V. G. Olimpiyev

UDC 614.841.3

3.69.55. [Evacuation of people from buildings during fires] Spehler, Remo A. and Peissard, Werner G. L'EVACUATION D'IMMEUBLES EN CAS D'URGENCE. *Bull. techn. Suisse rom.*, 1971, **97**, No. 21, 499–502 (French)

Experimental data and the resultant conclusions are considered for obtaining theoretical principles of architectural planning expedients and the necessary devices to ensure rapid evacuation of people without panic. If it is required to evacuate certain numbers of people in a rigorously specified period of time, it is necessary to have an adequate number of evacuation routes and building exits, but it must be considered that even when rapid evacuation is necessary, a crowd of people does not move toward exits immediately, but only after the lapse of a certain response–time interval. During this period the evolution of smoke may lead to panic. Evacuation phases consist of the following stages: the establishment of an initial fire build-up level, e.g., by automatic pick-ups; the alarm needed to bring the fire-extinguishing equipment into action; preparation of evacuation measures without panic; evacuation proper. A calculation of the speed of evacuation is made, using a large store building as an example, on the basis of the following data: floor area of 1,000 m^2, people located on all three floors; on the first floor the exits are located at floor level; communication to the upper floors is via side stairs; the traffic capacity of the stairs is 45 people per min per unit width of 0.6 m; the traffic capacity of the first floor is 6.0 people per min for the same unit width at a speed of 60 m per sec; the length of the evacuation route in the stairwell for one floor is 10 m. The number of people to be evacuated from the various floors is determined from 0.2 to 1.0 person/m^2 of floor area, depending on the height of floor location. The total width of stairwells, evacuation routes, and building exits are determined as a function of the number of floors in the building (by a nomogram).

See also *Engineering Digest* "Fire Protection" series, 1972, No. 2, summary 18.

UDC 697.9

3.68.56. [Study of the propagation of gases from smoke flues along the ventilation system] Lindqvist, Bengt-Goran. TUTKIMUS SAVUKAASUJEN LEVIAMISESTA ILMONVAIKTOHORMEISSA. *Palontorjuntatekniïkka*, 1971, No. 1, 10–18 (Finnish)

UDC 614.841.3:614.844

3.68.57. [Inspection of private fire extinguishers and fire alarms] Schmalor, Guntram. PRUFUNGEN PRIVATER FEUERLOSCHUND MELDEEINRICHTUNGEN. *Brandverkut.-Brandbekampf.*, 1971, **21**, No. 3, 37–40 (German)

Considered are the requirements imposed by regulations on private fire extinguishers and fire alarms during periodic inspections. Schedules for performing inspections are given. According to the Berlin ordinance on public occupancies dated September 15, 1970, effective from January 1, 1971 (par. 124), the owners of public establishments must inspect smoke ejectors, fire extinguishers, and fire detectors, as well as fire alarms, fire screens, and lightning rods annually, but ventilation systems at least once every two years. The program for testing these devices includes tests of above- and below-ground hydrants; measuring the quantity of water delivered; wet and dry pressurized pipes with their hydrants, hoses, and nozzles; sprinkler systems in theaters, stores, and joinery shops, and sprinkler screens. Fire detection devices are tested in accordance with the specifications of Standard 14675 and the regulations of the Society of German Electricians, VDE-Vorschrift 0800. Firemen participate in the inspection of private fire-extinguishing and detection devices. (Fed. Rep. Germ.)

I. S. Taubkin

UDC 697.9 (088.8)

3.68.58.P. Maybury, John William. IMPROVEMENTS IN OR RELATIVE TO A DAMPER ARRANGEMENT FOR VENTILATING OR OTHER DUCTS [Amberley Engineering Co. Ltd.] British patent. Class A5A (A 62 c 3/14), No. 1246513, applied for 25 Jul 69, granted 15 Sep 71.

A damper arrangement capable of blocking the propagation of flame or smoke through ventilating or other ducts has been patented. In existing designs, the damper panel is mounted on a shaft that rotates freely on ball bearings mounted on the walls of air ducts. The panel is held in initial position (parallel to the longitudinal axis of the duct) by a fusible link, which melts when exposed to flame or hot gases. When the link parts, the panel rotates to a position perpendicular to the duct axis and blocks the passage of fire. This design is unreliable because the shaft hangs up in the bearings under high temperatures. The proposed design is free of this problem because it is based on an entirely different principle of operation. In this design the panel is held at one end, in open position by a flexible weight and a fusible link, and at the other by two sloping limit stops of different lengths that are mounted on the sides of the rectangular duct and press against the surface of the damper panel from above and below at a distance from each other. When the link melts, the damper drops under the force of gravity and, turning freely in the space between the asymmetrically positioned limit stops, tightly closes the cross section of the air duct due to the pressure of the moving hot gases. 3 figs.

V. G. Olimpiyev

UDC 614.841.001.4

3.68.59. Burgi, H. SWISS TESTS ON FIRE BEHAVIOR IN ENCLOSED AND UNDERGROUND PARKS. *Fire Int.*, 1971, **3**, No. 33, 64–77 (Eng., Fr., Ger.)

UDC 697.9 (088.8)

3.68.60.P Green, John Charles. IMPROVEMENTS IN FIRE DAMPERS FOR HEATING AND/OR VENTILATION SYSTEMS. [Andrews-Weatherfoil Ltd.] British patent. Class A5A(A 62 c 3/14), No. 1247798. Applied for 3 Mar 69, granted 2 Mar 70.

In order to reduce the size of the system, a blower with motor and directional sleeve are mounted on a damper at the outlet to a room. At normal temperature, the ventilator blows air through the sleeve into the room. When the air temperature increases, a fusible link that holds the damper in upright position melts and the assembly drops by force of gravity onto the flange, sealing the duct.

UDC 643.0.43

3.68.61. [Forest fires ignited by lightning] Torvinen, Johtaja V. J. AJATUKSIA METSAPALONTORJUNNAN TIEDOTTAMISESTA. *Palontorjunta*, **22**, No. 4, 194–195 (Finnish)

Fire Technology

(For publications on stability, maneuverability, reliability, loading, and safety of fire vehicles, see also issue 02A "Automobile Construction." For fire equipment and fire apparatus, see also separate issue No. 33, "Communal, domestic, and commercial appliances.")

UDC 614.844.1/.9

3.68.62. MODERN FIRE FIGHTING EQUIPMENT USELESS WITHOUT PROPER TRAINING. *Plant Admin. and Eng.*, 1971, **30**, No. 10, 36–38 (English)

Training of personnel in fire prevention and extinguishment is extremely important in plants using complex technological processes, especially those engaged in petroleum and chemical production. Experience obtained in theoretical and practical training of personnel in a petroleum refinery complex in Canada is described. The complex is equipped with powerful modern foam, water, and dry powder extinguishers. Water delivery volume can reach 350 to 500 l/sec. Foam generation rate reaches 700 m^3/min. Permanent deluge nozzles are mounted in hazardous locations. The necessity of applying engineering techniques to fire prevention problems is stressed. 6 figs.

UDC 614.844.4

3.68.63. [Carbon Dioxide Fire Extinguishers] CO_2-BRANDSCHUTZANLAGEN. *Textilveredlung*, 1971, **6**, No. 10, 682–684 (German)

Typical stationary, automatic carbon dioxide fire extinguishers used in various installations are examined. The parameters of applicability are given for such extinguishers, and their advantages over water are evaluated. Water is not a universal extinguishant because it can cause certain combustibles to explode and in many cases severely damages materials during extinguishment. From the mid-nineteenth century, carbon dioxide gas has been the fire extinguishant when water could not be used. Carbon dioxide is stored in liquid state under high pressure in sealed steel tanks, which are located adjacent to a given fire hazard. Discharge of the carbon dioxide absorbs approximately 3000 kcal of heat, which plays an important role in fire extinguishment. A typical system consists of a battery of interconnected tanks feeding into a conduit that carries the carbon dioxide to the fire hazard. The conduit has several branches at its end, each with a special nozzle that directs the flow of the gas. A special mechanism opens all of the tank valves simultaneously when triggered by a smoke or heat detector. Manual operation is also provided. Carbon dioxide systems are efficient and economical. Insurance companies offer up to 50% reduction in rates for plants equipped with such systems. Carbon dioxide is an effective extinguishant for flammable materials (ethyl alcohol, ethyl ether, ethylene, ethylene oxide, acetylene, carbon monoxide, carbon disulfide, hydrogen), for closed compartments, for transformers, textile machinery, drying ovens, etc. 2 figs. (FRG)

I. S. Taubkin

UDC 621.647.24

3.68.64. [Fire extinguishing sprinkler system] SPRINKLERBRANDSCHUTZANLAGEN. *Textilveredlung*, 1971, **6**, No. 10, 648–686 (German)

UDC 614.846.6

3.68.65. [U.S. fire and emergency vehicles] VEHICULES D'INCENDIE ET DE SECOURS AUX ETATS-UNIS. *Prot. air et secur. ind.*, 1977, No. 201, 67–70 (French)

Technical characteristics are outlined. 7 figs.

UDC 614.846.6

3.68.66. FOUR-WHEEL DRIVE HOSE-LAYER FORMS PART OF HEATHROW AIRPORT BACK-UP. *Fire*, 1971, **64**, No. 794, 128 (English)

UDC 614.846.6

3.68.67. CARMICHAEL INTRODUCE AN AIRFIELD TENDER FOR THE JUMBO JET AGE. *Fire*, 1971, **64**, No. 797, 309 (English)

The Tetrander 300 airfield tender manufactured by Carmichael and Sons (Gt. Brit.) satisfies the technical requirements of the International Civil Aviation Organization. The tender is equipped to use 6% foam solution. Models are available with a 635 bhp turbine engine. Engine performance is constant from sea level to 3000 meters. The six-speed hydraulic gear box is semiautomatic. With the 700 bhp engine, the power ratio is 20.8 bhp per unit weight. Water pumping capacity is 5500 to 6800 l/min, and foam for hand lines and hydraulic turret nozzles is generated at the rate of 22,700 to 61,300 l/min. Foam stream throw is 58 to 76 meters. The tender has four side outlets. The two forward ones can produce 7,560 l/min foam. Total foam generating rate is 26,400 to 58,600 l/min. Acceleration is 0 to 80 km/hr in 30 to 35 sec. Simplicity of operation guided the design of this vehicle. Most parts can be removed and replaced easily and quickly.

I. I. Myagkov

UDC 614.846.6:725.95

3.68.68. [Fire apparatus for work in tunnels] Achilles, Ernst. FEUERWEHRFAHRZEUGE FUER EINSATZE IN U-BAHNEN. *Int. Verkehrsw.*, 1971, **23**, No. 7, 81–82 (German)

A fire apparatus for fighting fires and performing rescue work in urban underground rail lines is described. For passability, the apparatus is mounted on a type 230 D16FA (Deutz) chassis and has a 230 hp engine. The apparatus weights 16 t. The unique feature of the apparatus is that it can travel on ordinary roads (85 km/hr) as well as on rails (30 km/hr). Upon arriving at a tunnel entrance, a special rail truck is lowered onto the tracks, the front axle is raised, while the rear traction wheels remain on the rails. The hydraulic lift for lowering and raising the rail truck can be operated from the drivers' cab or remotely. The apparatus has fire fighting and digging equipment, a crane, a welder, cutting torch, and a trailer hitch. A hydraulic lift is provided for loading and unloading heavy digging equipment. Three 1000-watt flood-lights are supplied by a 20 kw generator. All controls are located in an instrument compartment in the central part of the vehicle. Gangways 560 mm wide are provided on each side of the control compartment. Doors lead to the operations compartment, allowing personnel to move from one compartment to the other without alighting from the vehicle. It is noted that building the vehicle required extensive research on the appropriate engine, and the design and construction of the cab, chassis, and other features, specifically with respect to rail travel, effect of bank angles, traction, stability, cornering, etc. 1 fig.

L. M. Kuznetsov

UDC 614.846.6

3.68.69. [Apparatus] NEW APPLIANCE. *Fire Int.*, 1971, **3**, No. 33, 78 (English, French, and German; Spanish summary)

Albert Ziegler KG (FRG) has built an apparatus designed to fight large liquid fuel fires. The apparatus has a 24,000-liter tank, divided into four compartments and a separate tank of 1000 liters for foam solution. A Ziegler pump with an automatic priming system is used to deliver the extinguishing agents. The pump delivers 300 l/min at a pressure of 80 meters hydraulic head. The apparatus has a combination monitor, two hydraulically rewinding reels each with 30 m of foam sleeve and foam nozzles, and four underbumper outlets. The monitor, operated remotely with an electrohydraulic drive, produces an aqueous foam stream of 2000 l/min. With a nozzle pressure of 100 m hydraulic head, the throw of a water stream is 70 m and for a foam stream 45 m. The apparatus can be used to transport flammable liquids, which are loaded by a special pump that has a capacity of 800 l/min. 1 fig.

UDC 614.846.6

3.68.70. WATER TENDERS ARE BOTH VERSATILE AND VALUABLE FOR CITY BRIGADE WORK. *Fire*, 1971, **64**, No. 797, 273 (English)

UDC 629.113

3.68.71. MOBILE MEDICAL UNITS FOR LAND AND SEA. *Fire Prot. Rev.*, 1971, **34**, No. 373, 443 (English)

Information is given on the activities of Ibis 3H, a British firm that manufactures vehicles and medical units specially equipped to cope with epidemics in the wake of natural disasters. The firm is designing several types of vehicles, including a transporter for wheel-chair patients. This unit has a lifting device for the chairs. Another model is equipped for restoration of body functions. A list is given of countries interested in the firm's models, which range from small cars to large mobile vans. The firm is building x-ray units on Land-Rover chasses for Turkey and air-conditioned mobile units for Iran. The clinic units, having quarters for six persons, are mounted on Mercedes 6608 chasses. All of the models are designed for maximum utility and minimum need for maintenance specialists. The firm has medical and shipbuilding specialists on its staff. 1 fig.

UDC 614.84:629.118.6

3.68.72. MOTORCYCLES BEAT PARIS TRAFFIC JAMS. *Fire Int.*, 1971, **3**, No. 33, 46–47 (English, French, and German; Spanish summary)

Owing to the rapid increase in street traffic, the Paris fire service has established a new first-response motorcycle force. A tactical unit consists of four fire fighters and two BMW R50 493-cc motorcycles. The mission of these units is to get to fires as quickly as possible and begin first aid fire fighting operations before the arrival of large, less maneuverable fire apparatus. At the height of a traffic jam, a motorcycle unit arrived at a scene 2.5 km away in six minutes after receiving an alarm. A motorcycle, two fire fighters, and equipment weigh 417 kg. Equipment includes gas suits, flashlight, blanket, hydrant key, hose roll, 16 liters of liquid extinguishant, canvas pails, etc. 4 figs.

UDC 614.843.8

3.68.73. A FOAM ANSWER TO YOUR FIRE PROBLEM. *Fire Prot. Rev.*, 1971, **34,** No. 373, 431 (English)

The fire appliance company is offering new models of equipment. An aqueous foam monitor capable of throwing a stream 21.3 m vertically at the rate of 173 liters/sec, a water stream throw of 59.3 m or foam stream of 50 m. A medium (100 to 150:1) or low-expansion (8:1) foam generator using 4.53 liters/sec of water or 453 to 690 liters/sec foam. Stream throw for low-expansion foam is up to 24.3 m. A hand nozzle throws a flat low-expansion (7 to 8:1) foam stream 24.3 m at a pressure of 9.1 atm. A generator for feeding up to 66.5 liters/sec of foam through a sleeve to a distance of up to 122 m. A hand nozzle for 6:1 foam at 83 liters/sec and pressure of 10.5 atm.

UDC 621.647.24 (088.8)

3.68.74.P Juliano, Richard F. SPRINKLER ACCELERATOR SYSTEM WITH PRESSURE CHANGE DETECTOR. [The reliable automatic sprinkler] USA Patent Class 169–17 (A 62 c 35/00), No. 3589445, applied for 21 Apr 69, granted Jun 71.

The system consists of a pipe with a sprinkler filled with pressurized air. The pipe is connected to a chamber which has a normally closed valve shutting off a water pipe containing water under pressure and an annular cavity. This cavity is connected to the chamber by pipes through a valve.

The valve is connected by a pipe to an accelerator, which is also connected to pipes through a branch with a reverse valve. One valve is open and connects two pipes. In the event of a fire the sprinklers open, the pressure in one pipe falls, and the accelerator switches on to release compressed air through a pipe into a cavity. The drop in pressure in the chamber and the rising pressure in the cavity causes a valve to open. Compressed air in the pipe is also present in the upper chamber of the valve, closing it, shutting off water flow to the accelerator. Water in one pipe is fed to the open sprinklers. A branch serves to bleed air from the system during charging.

A. A. Rode

UDC 614.844:629.12

3.68.75. FOAM EXTINGUISHING SYSTEMS FOR TANKER SHIPS. Ackerman, Guenter. *Hansa*, 1971, **108,** No. 20, 1962–1968 (German)

The status of fire protection aboard ships is described, as well as methods of accident prevention and protection. The range of required fire equipment for various ships is given. A fire protection system for a 150-thousand-ton tanker is described. Measures are recommended for minimizing damage to the fire protection system in case of accident (explosion or collision). Conditions attending a deck fire are analyzed. The principles of use of various foams (20 to 1000:1) in fire protection systems are given for different combustibles (low-expansion foam is recommended where long throws are required). It is recommended that empty tanks be filled with inert gas to prevent explosions, and for optimum fire protection the most rational combination consists of foam, fog, hand lines, and carbon dioxide. Foam or fog systems are most practical for engine compartments. Large engine rooms should be protected by high-expansion foams. Likely places where fires can start are indicated, as are fire fighting problems resulting from smoke. It is asserted that cost is insignificant when compared with possible losses resulting from accidents.

UDC 629.735.45:614.842.6

3.68.76. [Helicopter fire equipment] AIRCRAFT, EQUIPMENT AND CHEMICALS. *Aqr. Aviat.*, 1971, **13**, No. 4, 123–124 (English)

A Bell-47G4 Model H-75 helicopter has been equipped in Canada to extinguish fires from the air. A 340-liter waterproof fabric container easily collapses and expands. This container is filled by two pumps that have a combined capacity of 4.5 l/sec. Water or chemicals are expelled through an elastic tube. The water intake and expulsion system are completely automatic. Manual operation is provided if the automatic system fails. Depending on flight speed, the water spray track is 1.5 to 9 m long.

UDC 614.847.7 (088.8)

3.68.77.P [Improvements in devices for saving lives in fires] IMPROVEMENTS IN OR RELATING TO FIRE ESCAPE MEANS OR APPARATUS. [Stephen Francis Flannagan] British Patent Class EIS (E 06 c 9/14), No. 1249153, applied for 6 Dec 69, granted 10 Jun 71.

The patented device, an improved flexible fire-resistant ladder for saving people from fire, is stored compactly in a metallic container that is installed at the point of probable use. The ladder and container are mounted in a preselected safe place, for example, on the wall below a window of an upper-story room. In case of fire, the case lid is opened, the free end is tossed out the window, and the ladder is used to escape from the room. The container has side walls, a bottom, and a rear and a front wall that swing on hinges. In addition, the container has a removable lid with side flanges and handle. The lid retains the front wall in closed position. When the lid is removed, the front wall drops open automatically. The rear wall has bolt holes for attaching to the wall below window sill. The flexible ladder has two side chains, the top ends of which are bolted, welded, or otherwise reliably attached to the rear container wall. Each tread is an oval-shaped tube. Rods attached at each end to the chains, pass through the tubes, holding them in place. The lower ends of the side chains are attached by bolts to the side brackets of the stiffener, welded to the lid. To keep the ladder away from the building wall, one or more of the treads have spacers, which can be short metal bars bolted to the chains. For stowing convenience, the side walls have guide flanges. 5 figs.

O. M. Volkov

UDC 623.454.76

3.68.78. [Industrial fire protective clothing] PROTECTIVE CLOTHING—INDUSTRY'S FIRST LINE OF DEFENSE IN FIGHTING FIRE. *Chem. Process.* (Gt. Brit.), 1971, **17**, No. 10, 71 (English)

The first protective clothing was made of asbestos in 1926. During World War II protective clothing was used in fighting fire-bomb fires and flaming gas. Following the war, many new fire-resistant materials were found and extensive use was made of protective clothing in industry. Requirements of protective clothing and its use are given. If protective clothing has insufficient ventilation, heavy physical labor can be performed only briefly. Duration of use depends not only on the properties of the clothing but on external conditions and the characteristics of the user. Thus, the fire resistance of the clothing material is not a governing factor. Protective clothing is recommended as one means of fire protection in the chemical industry. At least two persons should work together when dressed in protective clothing to evacuate people in case of accident, turn off machinery, and turn on the fire extinguishing equipment.

UDC 614.843.8

3.68.79. [High-expansion HS-2000 generator foam] Hiltunen, Erkki. KEVYTVAAKTOTUISKO, HS-2000 PAKKASKAYTTOON SOVELTUVA SUURITEHOINEN VAAHTASAMMUTIN. *Palontorjunta,* 1971, **22**, No. 3, 146–147, 118 (Finnish; Swedish and English summaries)

A new foam generator, HS-2000, has been developed with the following characteristics: 2000 liters of water per min at 6 kg/cm^2 pressure, 1.20 l/min foam concentrate at water pressure of 1.5 to 6 kg/cm^2, and foam generation rate of 160 m^3/min. The generator, which can operate at extremely low temperatures, is recommended for use in the open as well as in compartments.

UDC 614.843.4 (088.8)

3.68.80.P [Deflector for fire nozzles] Fuller, Eric Robert Alfred. DEFLECTOR FOR FITTING TO NOZZLES FOR DIRECTING FIRE EXTINGUISHING FLUIDS. [The Sun Engineering (Richmond) Ltd.] British Patent Class B2F (B 05 b 3/08), No. 1248153, applied for 5 May 70, granted 29 Sep 71.

To provide a greater angle of spread on a fire, a deflector is attached to the nozzle. The deflector consists of a frame and clamp for attachment to a hand nozzle. The deflector, hinged to the frame, is a plate, bent to an angle of 105 deg, with an operating handle, spring, and limit stop for adjusting the maximum angle of the deflector during operation. Optimum bend radius of the plate is 0.1 to 1.0 d of the nozzle tip. The distance between the nozzle tip and the water stream impact point on the deflector is 0.5 to 0.75 d. During operation the deflector is held down by the nozzle man for delivering a solid stream. To deliver a flat stream, the nozzle man releases the handle and the deflector is raised by the spring to the position determined by the setting of the limit screw, producing a fan-shaped stream that reaches approximately the same distance as the solid stream because the deflector directs the stream forward and upward.

A. A. Rode

UDC 614.843.2 (088.8)

3.68.81.P [Improvement of fire hoses] PERFECTIONNEMENT AUX TUYAUX D'INCENDIE. [George Angus and Co. Ltd.] Belgian Patent Class A 621, No. 700701, applied for 29 Jun 67, granted 7 May 71.

A process is given for making fire hoses from a woven sleeve with a bonded water-impervious rubber liner or its substitute that does not twist under water pressure. Two methods are proposed for manufacturing the sleeves.

UDC 614.843.2

3.68.82. [A method of attaching couplings to hoses] A SWISS METHOD OF HOSE BINDING. *Fire Int.,* 1971, **3**, No. 33, 86–87 (English, French, German; Spanish summary)

A method developed by Oetiker Metallwarenfabrik (Switz.) is described for attaching couplings to hoses. The hose is inserted between the nipple and a zinc-coated steel bushing. A nylon ribbon passes through an opening in the bushing. The ribbon is pulled tight by a tension tool. Hermetic tests show absolute tightness for various types of hoses and prove the reliability of the method. 1 fig.

UDC 614.845.1.2

3.68.83. [Hand extinguishers] FIRE EXTINGUISHER RANGE. *Garage and Transp. Equip.*, 1971, **17**, No. 10, 58 (English)

Isabella International Co. (Denmark) manufactures hand extinguishers for Class A and B and electrical fires. The extinguishant does not stain clothing or corrode metals. Model 2, carrying a charge of 1800 g of powder extinguisher, is 33 cm tall, and costs £9.25. Model 12, carrying 10.8 kg of powder is 60 cm tall and costs £19.25. Model PIGE with 900 g of powder is 25 cm tall and costs £4.5. A one-time extinguisher, Model 600 VN, charged with 600 g of liquid is 22.8 cm tall and costs £1.3. Rechargeable Model 6, with 5.44 kg of powder is 40.6 cm tall, and costs £13.75. Rechargeable extinguishers are equipped with manometers. 1 fig.

UDC 614.845

3.68.84.P [Device for breaking the membrane of an extinguisher and dispensing an extinguishing agent] Bower, James C. SEAL RUPTURING AND DISPENSING FIXTURE FOR NORMALLY SEALED PRESSURIZED TANKS. USA Patent Class 169–31 (A 62 c 13/00), No. 3589446, applied for 4 Aug 69, granted 29 Jun 71.

The fixture consists of a fixture head with a self-seating type valve, handles for opening the valve, flexible hose for conducting the extinguishant. The handles have clips that clamp on the hose to prevent inadvertent operation of the valve. The head is attached to the extinguisher by a threaded adapter that has a cutter for breaking the seal. The assembly screws into a fitting of the extinguisher in which an opening is hermetically sealed by a membrane, a washer, and a threaded retainer that has a slot. The extinguisher is filled with extinguishing agent, after which it is pressurized and the seal is seated by tightening the retainer. To operate, the head assembly is screwed all the way in. On the last turn the blade on the adapter cuts the seal around its perimeter (an arc of 270°). The internal pressure bends the seal upward, creating a passage for the extinguishing agent. The discharge valve can be opened only after the hose is removed from the safety clips.

A. A. Rode

Fire Extinguishment. Fire Tactics

UDC 536.46

3.68.85. [Radiation of heat from laminar diffusion flames] Pfenning, Dwight B. RADIATIVE TRANSFER FROM LAMINAR DIFFUSION FLAMES. Doct. diss. Univ. Okla. 1970, 221 pp Ref. *Diss. Abstr. Int.*, 1971, **31**, No. 11, 6592 (English)

An annotated abstract is given of a doctoral dissertation on the investigation of natural gas and acetone flames at atmospheric pressure. Horizontal and vertical dimensions are established for the reaction and radiation zones, frequency characteristics, and maximum radiation. The latter are equal to 0.871 and 1.35 W/cm^2-ster., respectively, for natural gas and acetylene.

UDC 532.61

3.68.86. [Correlation of surface tension between various liquids] Papazlan, Harold A. CORRELATION OF SURFACE TENSION BETWEEN VARIOUS LIQUIDS. *J. Am. Chem. Soc.*, 1971, **93**, No. 22, 5634–5636 (English)

UDC 614.842.615 (088.8)

3.68.87.P [Additives to foaming agent] Rodriguez, Alan. FOAMING AGENTS. [George Angus and Co. Ltd.] British Patent Class A5A (A62 d 1/100), No. 1245124, applied for 5 Aug 69, granted 8 Sep 71.

Hydrolized protein is offered as an additive to foaming agent to increase the extinguishing effectiveness of the foam, perfluorohydrocarbon surface active substances (PSA). When 0.05 to 10% by weight of PSA is added to the foam agent, shear stress is decreased and thermal stability is increased. As a result, less foam is needed for extinguishing fires. The PSA should be soluble in water and be nonionic or anionic, since cationic PSA can produce a deposit in the agent. To provide solubility in water, special functional groups are introduced. In experiments testing the effectiveness of additives to foam agents containing 20% by weight of hydrolyzed protein, 0.1% by weight of ammonium perfluorocaprilate was added. By comparing the properties of foam from 4% aqueous solutions, foaming agents with and without additives using the same foam generating equipment, showed that shear is decreased by 25%, and 20% less foam is required. In another series of tests the properties of 0.5% by weight of PSA formula 5 were evaluated against a 1.7 m^2 petroleum fire. With the additive, foam effectiveness was doubled. Antifreeze can also be added without penalty, as can salts of iron or other metals for increasing the thermal stability of the foam. Salts lead to the formation of deposits in foaming agent.

A. N. Baratov

UDC 541.125.628.511

3.68.88. [Dust explosion following a fire] Hannunen, Kauno. VIIDELLE PALOMILHELLE PALOVAMMOJA TULIPALON JALKIT LANT EESSA TAPAHT UNEESSA POLYRAJAHDYKESSE A. *Palontorjunta*, 1971, **22**, No. 5, 226–228, 238, 222 (Finnish; Swedish and English summaries)

Small stones and sand grains embedded in wood surfaces produced sparks during cutting operations with multiple circular saws. This resulted in a large dust fire in a sawmill at Kotka. The flame spread through a scrap removal duct. Fire fighters extinguished the blaze and watered down the duct. When the air blower was turned on, 43 minutes after the alarm, an intense dust ignition occurred in the blower. The fire travelled along the duct to the bin under the blower and raised a cloud of sawdust. A strong explosion resulted from the second fire, and flames 10 m long erupted from the bin and burned five fire fighters.

UDC 614.84:550.34

3.68.89. [Work of fire fighters in coping with the results of an earthquake] Hill, Raymond M. HOW LOS ANGELES FIRE DEPARTMENT DEALT WITH THE 1971 EARTHQUAKE. *Fire Int.*, 1971, **3**, No. 33, 48–52 (English, French, German; Spanish summaries)

In February 1971, following the Los Angeles earthquake, the Fire Department handled 30,000 calls (compared to a normal daily 3,500 calls). Within 30 minutes following the quake, the Department dispatched 963 fire and rescue personnel, 110 pumpers, 42 trucks, 27 first aid units, as well as helicopters, emergency trucks, and fire boats. Primary tasks involved clearing rubble at two wrecked hospitals and evacuating residents living below a weakened dam. Fire fighting was hampered by lack of water due to broken mains. Water was supplied by tankers. Rubble was removed with the aid of construction tools. Earthquake casualties were evacuated by helicopters, which were also used as mobile command posts, to transport doctors and equipment, etc. City water tank trucks were widely used. The cost of Fire Department operations was $133,000, including salaries and overtime pay, amortization of apparatus and equipment, and replacement of damaged equipment. Repair of Fire Department buildings is estimated at $140,000.

UDC 614.841.45

3.69.90. [Lessons from a skyscraper fire] Powers, W. Robert. MANY LESSONS LEARNED IN SKYSCRAPER FIRE. *Fire Int.*, 1971, **3**, No. 33, 18–31 (English, French, German; Spanish abstr.)

UDC 614.841.725.4

3.68.91. [Large fire at the Halls Works plant] Jantti, Aulis and Wecksten, Erkki. SELOSTUS KYMIN OSAKYEHTION HALLAN TEHTAITTEN LAJITTELN JA RIMOITUSHUONEEN SUURTULIPALOSTA 24–1–1971. *Palontorjunta*, 1971, **22**, No. 4, 172–174, 179, 168 (Finnish: Swedish and English abstracts)

UDC 614.841(–21)

3.68.92. [Two converging fires in four hours] Lappe, Kenneth G. TWO MUTUAL AID FIRES IN 4 HOURS. *Fire Eng.*, 1971, **124**, No. 8, 26–27 (English)

In New Britain, U.S.A., a community of 80,000, a large night-time fire occurred. The fire grew to large proportions when two mutually dangerous fires merged. One started in a wood-products warehouse; the other, a few hours later, in a textile factory building located on the adjacent block. Arson is suspected in both fires. The first fire was brought under control in four hours by the joint efforts of paid and volunteer companies as well as by many private brigades. Many brick and small wooden homes approximately 90-years-old were destroyed. A layer of ash approximately 15 cm deep was found at a distance of 5 km from the seat of the fire. Half of the total personnel of the city fire department suffered from smoke inhalation and minor injuries. Water was used at the rate of 72 thousand l/min. for a total of 24.6 million liters. The fire fighting forces used 28 tankers, 2 aerial ladders, 4 elevating platforms, a rescue truck, and 4 first aid units.

V. G. Olimipyev

UDC 614.841.3:666.765

3.68.93. [Warehouse fire] 10 JUIN 1971. LES ENTREPOTS "NATALYS" DETRUITS PAR UN INCENDIE. *Allo 18*, 1971, aout-sept, 24–33 (French)

A fire in a warehouse complex consisting of five very old buildings of wood frame construction having four to five stories and 1900 m² area is described. The facade of one building was of red brick. The exterior walls of the other buildings were wood frame filled with brick. Roof rafters and sheathing were of wood, surfaced with zinc or plastic sheets. A large number of windows admitted natural light to all floors. Floor supports were also of wood. The large quantities of goods in storage were not separated by protective barriers. There were only a few lightweight partitions of wood or plasterboard. Access to all buildings was from one street only. Many floors could be reached only by unprotected wooden stairs. Two buildings were interconnected at the third and fourth floor levels by elevated wooden corridors. Goods on all floors were stored on wooden pallets in cardboard or plastic boxes. A large amount of this material consisted of children's toys, blankets, baby clothes, bedding, etc. Much of this was made of polyvinyl, polyurethane, and nylon. The loading platform with driveway was located inside the entrance. The basements of two buildings contained a dining room and kitchen, archival files, children's bicycles, chairs, tables, etc.

V. P. Smirnov

See also *Engineering Digest*, "Fire Protection" section, 1971, No. 2, abstract 17.

UDC 614.841:629.12

3.68.94. [Ship fire] Heinila, Viljo. PARI VIIKKOA KETANYT LAIVAPALO RAUMALLA. *Palontorjunta*, 1971, **22**, No. 4, 175–179, 168 (Finnish; Swedish and English summaries)

UDC 614.841:629.12

3.68.95. [Fire aboard the ship Anne Bewa] BRANDEN PA M. S. ANNE BEWA O. R. *Dan. skibsfart*, 1971, **62**, No. 8, 11 (Danish)

UDC 614.842.6:725.95

3.68.96. [Extinguishment of a complicated fire in a railroad tunnel] TUNNEL FIRE PRESENTS SERIOUS PROBLEMS FOR FRENCH FIRE-FIGHTERS. *Fire Int.*, 1971, **3**, No. 33, 37–45 (English, French, German; Spanish summary)

In the northern department of Loire, in France, on 20 March 1971, at 4:20, a fire started in a tunnel 226 m long when two freight trains collided. One freight had 17 petroleum tanks and 7 gasoline tanks. The other had 46 boxcars and flatcars. The fire quickly spread to major proportions. There were no means for ventilation in the tunnel, so the hot combustion products could not be vented. From the distortion of the tank cars, the temperature inside the tunnel was estimated to have reached 1500 to 2000°C. Flames erupted from both ends of the tunnel. Intense fire continued to burn for more than 24 hours, whereupon the tunnel collapsed in two places, and both ends of the tunnel were blocked. Since it was not possible to enter the tunnel to reach the seat of the fire, fire fighters were limited to cooling structures outside the tunnel. Inside the tunnel, petroleum product vapors exploded repeatedly. Because of the danger from explosion, nearby residents were evacuated. Approx 150 m^3 of petroleum products poured out of the ruptured tank cars. To limit the spread of the spill, numerous earthen dikes were thrown up and booms were floated on two nearby rivers. The spilled fuel trapped by the dikes was pumped out and removed or was burned on the spot.

See also *Engineering Digest*, "Fire Protection" series, 1972, summary 22.

UDC 634.043

3.68.97. [Fire in San Diego County] Wolley, Roy B. SAN DIEGO COUNTY'S WORST FIRE. *Fire Eng.*, 1971, **124**, No. 8, 36–37 (English)

See also *Engineering Digest*, "Fire Protection" series, 1972, No. 2, summary 23.

UDC 614.842.6:622.248.3

3.68.98. [Exinguishing fires at two gushing wells] FIRE FIGHTERS WIN BATTLE WITH TWO WILD WELLS. *Oil and Gas J.*, 1971, **69**, No. 38, 89 (English)

Fires started on 7 and 12 September 1971 in the states of Utah and Texas, U.S.A. The first began gushing from a depth of 4140 m. When the fire started, three workers were seriously burned. The wreckage of the rig was removed from the well site, and the fire was extinguished on 13 September by four high-pressure water streams. Gushing was stopped by increasing the hydrostatic pressure of the liquid. The preventer at the outlet was replaced after the gushing was stopped. The second wild well had a depth of 2220 m. Ignition occurred so suddenly that the drilling crew could not close the preventer. The fire and gushing were stopped by pumping a solution into the well through the drill hole. The cause of the fires was not determined. 1 fig.

UDC 614.841:678.5

3.6.99. [Two plastics fires] Friend, Dick. PLASTICS—TWO FIRE REPORTS. *Fire Command!*, 1971, **38**, No. 8, 33–34 (English)

On 5 May 1971 in a California factory producing plastic products using an ethylated benzene process, an explosion and fire occurred resulting in a loss of six million dollars. The explosion occurred when the cooling pumps of one reactor broke down. The operation, located outside the production building, which has a floor area of approx 22,500 m^2, consisted of three reactors, an evaporator, a storage tank of ethylated benzene, a free tank of benzene, a tank of pressurized oil, a tank of liquid nitrogen, and four 25-meter silo towers for storing granulated plastic. After the explosion, the fire spread to neighboring reactors and storage tanks to a radius of 30 m, penetrating into the main building through an open fire door. Six sprinkler heads opened directly above the fire in the building. Arriving fire fighters initially began cooling exterior equipment with solid streams, with little effect. Water depth in the area reached 30 cm. When they switched to foam with light water, the fire was extinguished in two minutes and only 28 liters of foam agent were used.

On 14 May 1971 a serious fire occurred at a plastic products manufacturing plant in Texas. The fire began in a new production section in the center of the building, where equipment was located for making children's toys, an ice-making machine, and chemical products. The portion of the building involved was a structure of unprotected steel and aluminum attached to the old brick building housing an ice-making factory. The metal structure failed early from the heat of the fire. Inside the building plastic materials burned in stacks 100 m long. The collapsed metal structures formed a shield that concentrated the heat in the stacks and prevented extinguishing agents from reaching the fire. Extreme heat and acrid smoke interfered with fire fighting operations.

See also *Engineering Digest* "Fire Protection" series, 1972, No. 2, summary 20.

UDC 614.841.45

3.68.100. [Fire at a rest camp] SIX HUNDRED EVACUATED AS FIRE STRIKES "VULNERABLE" THEATER AT BUTLIN'S MINEHEAD CAMP. *Fire*, 1971, **64**, No. 798, 360 (English)

At 2020 hours on 16 September 1971 a fire started at Butlin's Minehead Camp. The rest camp consists of a complex of recreational buildings, shops, and sports arenas. The fire started in the theater during the showing of a film. Within 1.5 hours 95% of the theater and its interior were destroyed. The fire originated in a storage room on stage. Its cause was undetermined. Measures taken by camp administrators succeeded in rapidly evacuating the audience of 600 without injury or panic. People in neighboring buildings were also evacuated. The alarm was received by the fire brigade house-man 16 minutes after discovery. Ten pumpers were used in fighting the fire. Water was taken from nearby open cisterns and hydrants. By 2400 the fire was completely under control. Fire fighting forces remained, however, until 1145 the following day.

UDC 634.043

3.68.101. [Discussion of forest fire fighting methods in the Ministry of Internal Affairs] SISAASIAINMINISTERIO JARJESTI NEUVOTTELNJAIVAN METSAPALONTORJUNNASTA. *Palontorjunta*, 1971, **22**, No. 4, 182–186, 191–192, 209 (Finnish)

UDC 634.0.43

3.68.102 [Extinguishment of a large forest fire] Alenius, Aarne. JAT-KOA KALAJOEN SUURMETSAPALON JALKIPALAVERIIN. *Palontorjunta*, 1971, **22**, No. 4, 193 (Finnish)

Technological Equipment for the Fire Protection Service

(For publications on fire alarms and warning signals, see also the separate issue No. 64, "Electrical Communications" and No. 01A, "Automation and Remote Control.")

UDC 625.748.56

3.68.103. [Automatic signalling systems] Hemardinquer, Pierre. LA PROTECTION AUTOMATIQUE CONTRE LE VOL ET L'INCENDIE. *Electricien*, 1971, **99**, No. 2132, 217–219 (French)

Automatic systems are required for early fire detection. Detectors react to physical or chemical changes in the environment. Each detector can monitor an area of 20 to 70 m^2. The devices are powered by house current. If they are connected in a protective system, a standby battery power source is provided. Several types of detection are distinguished: elevated temperature, smoke or products of combustion, and flame. Corresponding detectors are heat, smoke, ionization, and optical. Sensitive elements used in detectors are low-temperature fusible links (Wood or Dorset alloys), wax, lacquer, rubber; expanding liquids; bimetallic strips; expanding gas; change in electrical resistance in the presence of heat; change in electrical resistance of photocells when smoke interferes with a light beam; infrared radiation from flames; and change in conductivity and ionization of air. Detectors can switch on systems such as automatic carbon dioxide extinguishers.

V. G. Fukalov

UDC 614.842.4:621.357.862

3.68.104. [Laser fire detector] Edwards, Geoffrey. LASERS SPEARHEAD THE FIGHT AGAINST FIRE. *Design Eng.* (Gt. Brit.), 1971, Nov., 73 (English)

British fire losses between 1957 and 1968 have increased fourfold, and in 1971, according to the insurance industry, losses amounted to 120 million pounds sterling. Early detection is thought to be one of the most important factors in fire extinguishment. Early detection is possible with sensitive detectors. The solution to this problem in large warehouses, which are becoming even larger, involves large and expensive systems. As lasers become cheaper, laser detectors will soon be more economical than traditional detectors. A laser detector operates on the principle of interference. When the coefficient of refraction of air changes under heat, a laser beam is affected and a photocell detects the change and triggers an alarm. If a laser detector is installed below the ceiling of a large open building, the time between the start of a fire and its detection depends on the vertical distance between the fire and the level of the beam. If the laser and photocell are installed at opposite ends of a building, the system is more sensitive to a fire that occurs closer to the laser. Sensitivity is smoothed out if the laser and photoelement are mounted on the same wall, with a mirror reflector on the opposite wall. The mirror must be rigidly fixed to avoid false alarms. A corner reflector increases reliability and simplifies the installation and use of the system. Compared with traditional detectors, the laser system is more highly sensitive to smoke and heat and has a larger area of coverage. New fire resistant materials are discussed: (1) an agent combining carbon dioxide with bromochlorodifluoromethane and (2) honeycomb paper coated with intumescent paint that expands when exposed to heat, sealing the openings and releasing a gaseous extinguishant. The paper develops a hard surface. 1 fig.

Yu. N. Veydeman

UDC 625.748.56

3.68.105.–3.68.106. [Automatic fire alarm] Peissard, W. G. WIE MAN DAS FEUER ERKENNT BEVOR ES BRENNT. AUTOMATISCHE FEUERMELDER. *Textilveredlung*, 1971, 6, No. 10, 679–682 (German); Schrader, E. SELBSTTATIGE FEUERMELDER IN FEUERMELDE- UND FRUHWARNSYSTEMEN. *Hansa*, 1971, **108**, No. 20, 1977–1980 (German)

UDC 614.842.4:634.0.43

3.68.107. [System for detecting hidden forest fires] Maden, Forrest H. A NEW SYSTEM FOR DETECTING LATENT FOREST FIRES. *Conf. Rec.: Eng. Conserv. Mankind. IEEE 6th Req. Conf., Sacramento, Calif., 1971.* New York, N. Y., 1971, 6B.2/1–6B.2/8 (English)

Results are described of the experimental investigation of a double spectral instrument (DSI) of an infrared system for detecting latent forest fires and their cartography under conditions of various illumination and atmospheric haze. In contrast to monospectral ir systems (having one antimony-indium detector in the 1.5 to 5.5 mm range) the DSI has two double spectral transmitters: an In–SB transmitter in the 3.4 mm range (hot target detector) and a germanium-mercury detector in the 8.5 to 11 mm range (background detector). The target is detected by radiometric comparison of the ratio of the Ge-Hg and In–Sb signals with the aid of two heater elements adjusted in the range of 0 to 20°C and 40 to 55°C. A video signal from the elements contains information on the target and background. Noise in the electrical and navigational systems of an aircraft are screened out by a pulse length selector. The number of false alarms decreases by comparing pulses on two sequential linear representations of the target. The pulse from the representation appears on a recording strip and a video screen. This is recorded by a camera on positive film. 7 refs.

I. A. Trunov

UDC 625.748.56

3.68.108. [Miniature contact temperature detector] Grimminger, H. MESSUNGEN VON OBERFLACHENTEMPERATUREN MIT EINER ANSPRECHZEIT VON WENIGER ALS 1 MIKRO-SEKUNDE. *GIT*, 1971, **15**, No. 10, 1125–1126 (German)

To speed up the operation of heat detectors, their heat capacity is decreased. One way to do this is to use metal foils 0.5 to 1×10^{-3} mm. The heat detector is made of two metal foils which are thermally and electrically insulated from each other at one end. Their other ends are joined, forming a junction resting on a flat washer. The thermal conductivity of this washer is insignificant. Therefore the maximum value of a change in temperature is reached in less than 20 microsec. Thermal detectors of this type make it possible to read time-temperature characteristics of surfaces and all thermal calculations are made by using one-dimensional theory of thermal conductivity. Rhodium and platinum thermoelements can be used in a wide range of temperatures and have a long lifetime. 3 figs.

UDC 625.748.56

3.68.109. [Investigation of the effective distance of infrared radiation from flames for long-range fire detector systems] Matsui Matsunaga, Tsutsumi Suteo, and Takagi Toru. A STUDY ON THE OPERATING WAVELENGTH REGION OF INFRARED REMOTE FIRE SURVEILLANCE SYSTEM. *Bunko kenkuyu* (J. Spectroscopy Soc. Japan), 1971, **20**, No. 3, 149–155 (Japanese; English summary)

The optimum effective detection region of ir radiation for fire detector systems is investigated. It was found that 4.4 to 4.8 m waves, which are radiated by carbon dioxide in flames, are suitable for detecting fires because the atmosphere passes radiation especially well in this region and there is a low level of noise from earth radiation. The automatic system permits reliable detection of fires up to 5 km distance under moderate atmospheric conditions.

UDC 621.398:654:924(088.0)

3.68.110.P [Protective alarm system] RESEAU D'ALARME A PROGRAMMATION AUTOMATIQUE [Pauli, Georges]. French pat. class G08b 13/00, No. 2049507, applied for 10 Jun 1969, granted 26 Mar 1971

A patent was issued for a relay contact system which, according to a prepared program, performs a series of operations necessary to generate signals of various forms (light, sound, verbal, etc.). The sensitive elements of the system are several normally closed and normally open contacts. The change of state of these contacts releases the master relay, which switches on an array of signalling devices (signal lights, telephone, speaker) and opens a communication line to the police department. 1 fig.

UDC 621.398:654.924 (088.8)

3.68.111. [Alarm system for protecting safes] Kato Tomezo. ALARM DEVICE. U.S. pat. class 340–276 (G 08 b 13/06) No. 3550109, applied for 14 Jul 1966, granted 11 Dec 1970; priority 14 Jul 1965 (Japanese)

A patent was issued for the protection of safes and similar objects. The first device is a capacitance type that has a thin, flat, current-conducting plate mounted on a movable carrier with wheels made of insulation. The plate is placed directly adjacent to a safe or other protected object and is connected to an oscillator in the alarm. The oscillator is tuned to 150 kHz. When the plate is moved away from the protected object, the frequency changes and an alarm is sounded. The protected object is grounded, as is the oscillator. The oscillator frequency changes and an alarm is given when a hand reaches for the safe dial. The second device has three number accumulators with electrical contacts, vibration detectors mounted on the protected object, a control panel installed next to the protected object, and a remote unit. The operating principle is the same as that of ordinary digital code devices.

Yu. N. Veydeman

UDC 621.398:654.924(088.8)

3.68.112.P [Electromagnetic device for preventing car thefts] MECHANISME ELECTROMAGNETIQUE A INERTIE POUR CEINTURES DE SECURITE DES VEHICULES [Prostran, Luka]. French pat. class A62 b 35/00, B 60 r 21/00, No. 2050518, applied for 28 Mar 1969, granted 2 Apr 1971.

UDC 658.78.006.6:621.398:654.924

3.68.113. [Regulations for protecting storage warehouses] LES DEUX REGLES DE BASE POUR ASSURER LA SECURITE DANS UN CENTRE DE DISTRIBUTION. *Transp. Commerc.*, 1971, **19**, No. 9, 12–16 (French)

Problems are examined relating to thefts from warehouses: codes for windows, doors, locks, alarm systems, protection of yards and fences, and illumination. Also discussed are ideas on working with personnel: hiring, verification, training, personnel records, and accreditation. 2 figs.

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ABSTRACTS AND REVIEWS

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

THE NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

THE NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U.S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

THE DIVISION OF ENGINEERING is one of the eight major Divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

THE COMMITTEE ON FIRE RESEARCH functions within the Division of Engineering to stimulate and advise on research directed toward the development of new knowledge and new techniques that may aid in preventing or controlling wartime and peacetime fires. The Committee was established in December of 1955 at the request of the Federal Civil Defense Administration. It is supported by the Office of Civil Defense of the Department of the Army, the U.S. Department of Agriculture through the Forest Service, the National Science Foundation, and the National Bureau of Standards.