ATTACKING and EXTINGUISHING INTERIOR FIRES

by
Lloyd Layman

NATIONAL FIRE PROTECTION ASSOCIATION
470 Atlantic Avenue - Boston, Massachusetts 02210

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FOREWORD

This book *Attacking and Extinguishing Interior Fires*, written by Lloyd Layman, was first published by the National Fire Protection Association in 1952. Since that time, the text has been reprinted several times and has become a standard reference on the application of water spray for control of interior fires.

The widespread adoption of the water spray technique for fire fighting led to changes and improvements in nozzles and other equipment. The illustrations in this text show the equipment used when Mr. Layman was chief of the fire department at Parkersburg, West Virginia.

Modern nozzles for fire fighting came in a wide range of discharge capacities, up to 2,500 gpm or more, with constant or variable flow features, varying or pre-set spray patterns, and other features.

In NFPA Standard No. 19 — *Specifications for Motor Fire Apparatus*, 1½- and 2½-inch nozzles, capable of spray and straight stream, are standard equipment on pumpers. Spray nozzles of at least 500 gpm rated capacity are among the standard tips which must be provided for aerial ladder pipes and elevating platform turrets.

Following the original publication of Mr. Layman's book, the National Fire Protection Association's Committee on Fire Department Equipment conducted three series of tests of available spray nozzles of various sizes. Since that time, Underwriters' Laboratories, Inc., has tested and listed numerous spray nozzles submitted by various manufacturers for hose stream service.

While *Attacking and Extinguishing Interior Fires* does not provide guidance for selection and use of particular makes and types of spray nozzles now available, it does present the fundamentals involved in using such nozzles from hand lines and heavy stream equipment. Without question, the use of improved types of nozzles facilitates this type of fire fighting, but the fundamentals set forth by Mr. Layman should be understood by all students of modern fire fighting. More than 15,000 copies of this text have been distributed to the fire service in the past fifteen years.

Warren Y. Kimball, *Manager*
Fire Service Department
National Fire Protection Association
November 8, 1967

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ACKNOWLEDGMENTS

The material for this text has been condensed from a vast store of professional knowledge accumulated during years of research, experimentation and experience. The author desires here to acknowledge the assistance which has been rendered by various organizations and individuals in developing a more scientific and practical method of attacking and extinguishing major interior fires:

Instructors, U. S. Coast Guard Fire Fighting School, Fort McHenry Training Station, Baltimore, Md., from August, 1943 to November, 1945.

Members of the staff, "Operation Phobos," San Francisco, April to October, 1946. This being a full-scale experimental project for the purpose of developing effective and practical methods of controlling and extinguishing fires involving baled cotton within the holds of cargo vessels. This project was conducted by a joint committee representing the Transportation Corps, Army Service Forces; Bureau of Ships, Navy Department; Research Division, Maritime Commission; and the U. S. Coast Guard.

Members of the Parkersburg Fire Department from June, 1947 to September, 1951.

Herman W. Muhlmann, Department Photographer, Parkersburg Fire Department.

J. W. Bradford, Department Instructor, and the late Kenneth C. Tomer, Chief Inspector, Fire Prevention Bureau, Parkersburg Fire Department. These two men were instructors at the Coast Guard Fire Fighting School and participated in conducting "Operation Phobos." Their assistance and suggestions are hereby accorded special recognition.

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LLOYD LAYMAN

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CHAPTER I

FUNDAMENTALS GOVERNING INTERIOR FIRES

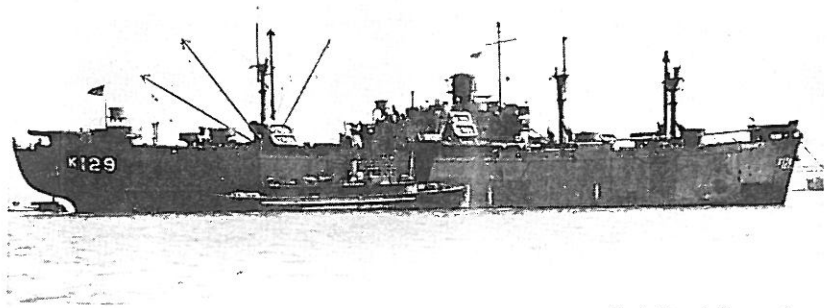
INTERIOR fires are usually more difficult to attack and extinguish than fires involving similar combustibles burning in the open atmosphere. Heat and smoke are the two major complicating factors in the problem of attacking and extinguishing fires within buildings or other confined spaces. Knowledge of the basic fundamentals and natural laws that govern combustion, generation and transfer of heat, and the production and movement of smoke, is necessary in order to comprehend and evaluate these factors.

Fire (combustion) is a chemical reaction in which oxygen combines with fuel at a rate sufficient to produce both heat and light. The essentials of this process are: (*a*) Fuel — any combustible gas, liquid, or solid; (*b*) Oxygen — sufficient in volume to support the process of combustion and usually supplied from surrounding air; (*c*) Heat — sufficient in volume and intensity to raise the temperature of the fuel to its ignition or kindling point. Normal air contains approximately 21 per cent oxygen by volume and this percentage is sufficient to support active flame production. A decrease of oxygen in the surrounding atmosphere results in a corresponding decrease in the rate of fuel consumption and flame production. Flame production ceases when the oxygen content of the surrounding atmosphere decreases to approximately 15 per cent. Fires involving gases and liquids are extinguished completely when flame production ceases but this is not true in the burning of solid combustibles. Decomposition begins once a solid fuel is heated sufficiently and the volatile products of the fuel are released in gaseous form. Flame results from the burning of the gases and vapors after they have obtained a proper air mixture. Although flame production ceases when the oxygen content of the surrounding atmosphere falls below 15 per cent, smouldering burning of the solid residue will continue in an atmosphere containing a much lower percentage of oxygen. Smouldering combustion is characterized by a slow rate of fuel consumption, limited heat generation, and production of smoke in considerable volume. Nature of the fuel, moisture content, surface exposure to the surrounding atmosphere, physical arrangement, air supply and draft conditions, volume and intensity of heat within the zone of combustion, and atmospheric conditions are contributing factors to the rate of fuel consumption and completeness of combustion. Flame production is necessary for rapid generation of heat and the development of high temperatures except in the burning of charcoal or other pure carbons. Pure carbons will burn without producing either flame or smoke and under favorable conditions of combustion will generate heat very rapidly.

Smoke released in the burning of ordinary combustibles consists of a mixture of vapors and gases in which minute particles of carbon, tar and ash are suspended. Smoke is a product of incomplete combustion. All smoke is toxic to some degree and is an irritant to the respiratory system and eyes. There is always some carbon monoxide present in smoke and the amount can vary from a small trace to a deadly percentage depending upon conditions of combustion. The carbon, tar and ash particles suspended in the vapor-gas mixture reflect light rays. Once these minute particles are removed the vapor-gas mixture becomes transparent. Smoke contains unburned fuel and when mixed with air in proper proportion becomes a flammable mixture. If a flammable mixture of smoke and air develops within a confined space, the mixture may ignite and burn with explosive force. This type of rapid combustion within a confined space is referred to as a smoke explosion or back draft.

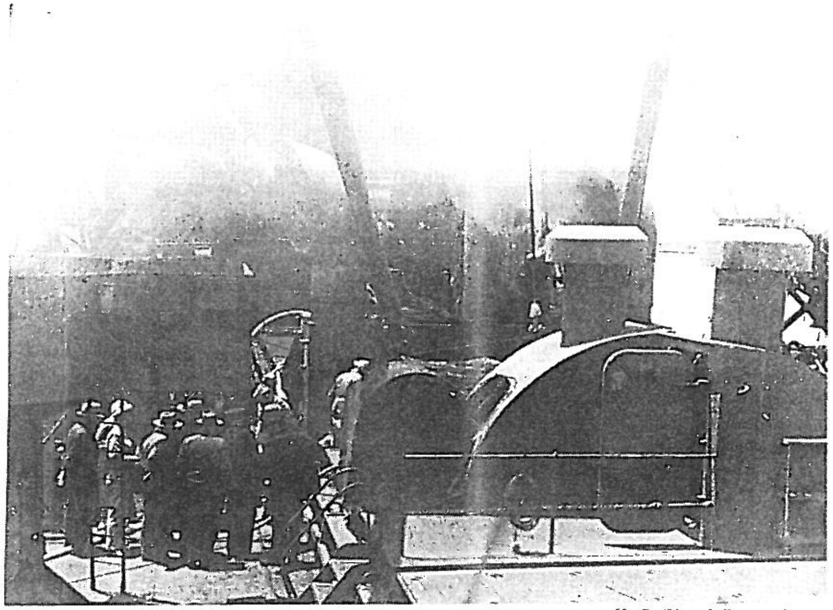
Heat is a form of energy generated by the transformation of some other form of energy. To comprehend the problem of heat in connection with the extinguishment of fire, it is necessary to consider both intensity and volume. The Fahrenheit (F.) system will be used in this text to indicate the intensity (temperature) and the British thermal unit (B.T.U.) to measure the volume. A B.T.U. is the volume of heat required to raise the temperature of one pound of pure water one degree Fahrenheit. A gallon of pure water weighs approximately 8.336 pounds, therefore, approximately 8.336 B.T.U. of heat are required to raise the temperature of one gallon of water one degree Fahrenheit. Fire extends its boundaries by transmitting heat to exposed combustibles and it is of utmost importance that those engaged in fire-fighting activities have a thorough understanding of the fundamentals that govern the transfer of heat. Heat is transferred by one or more of the following methods: (*a*) conduction, (*b*) convection, (*c*) radiation. A scientific explanation of these fundamentals may be found in any standard elementary physics manual or standard dictionary. The NFPA Handbook of Fire Protection provides a clear and concise explanation.

A gas is an elastic substance that expands or contracts upon an increase or decrease in temperature. Both air and smoke are a mixture of gases and the natural laws that govern the conduct of gases also govern the conduct of air and smoke. As a body of gas absorbs heat the heated portion expands and becomes lighter in weight per volume than the cooler portion, the heated portion moves to the upper atmospheric level and is replaced at the lower level by the cooler portion. This action creates an atmospheric circulation within a confined space, the heated smoke and air moving to the upper level of the space while the cooler air moves to the level of the fire. This results in the transmission of heat to the upper level while the fire is provided with additional oxygen contained in the cooler air. There has been some question regarding the development of pressure within a closed building during the progress of a fire. A study of the scientific data obtained from the experimental fires conducted aboard the cargo vessel *Phobos*, during the summer of 1946 at San Francisco, provides an answer to this question. It appears that once the volume of atmospheric expansion within a confined space exceeds the volume of smoke and air escaping from the space an increase of pressure occurs. This increase of pressure occurs during the period of intense flame production and usually amounts to only a fraction of a pound per square inch. The period of intense flame production within a confined atmosphere is of short duration, ranging from a few seconds to a few minutes, depending upon the net atmospheric volume of the space and the rate of oxygen consumption. Heat is gen-



U. S. Signal Corps photo

Cargo vessel *Phobos* with U. S. Coast Guard fireboat *Nellwood* alongside, San Francisco, June 1946.



U. S. Signal Corps photo

Test fire aboard *Phobos.* Baled cotton burning in cargo hold, smoke coming from exhaust ventilator.

erated very rapidly during this period and causes a rapid increase in atmospheric temperature and expansion.

Flame production decreases in proportion to the reduction in oxygen content of the interior atmosphere and this continues until the oxygen content is reduced to approximately 15 per cent, at this point flame production ceases. The rate of fuel consumption and heat generation decreases rapidly during this period. It appears that once flame production ceases, generation of heat from smouldering burning is insufficient to maintain the high atmospheric temperature attained during the intense period of flame production. This decrease in atmospheric temperature results from transfer of heat from the atmosphere to cooler solid materials within the space and also by convection and radiation to the outside. This loss of heat may be sufficient to cause the internal pressure to fall below that of the outside atmosphere. It appears that this negative pressure amounts to only a fraction of a pound per square inch and is equalized quickly by seepage of air from the outside atmosphere.

The term "atmospheric area" is used in this text to identify that part or section of building where the interior atmosphere can circulate freely. An atmospheric area may be confined to a single room or may include several rooms or the entire building depending on the openings between the various rooms or sections. An atmospheric area includes the floor or floors above the involved floor providing there are unobstructed vertical openings. This term does not include the floor or floors below the involved floor even though unobstructed openings exist. There is little, if any, exchange of atmosphere between the involved area and the floor below during a fire.

Interior fires involving ordinary combustibles may be of two general types. Buildings may be closed so that oxygen supply will be chiefly limited to that in the air in the structure and such fires may involve three distinct phases as described below. Other fires quite commonly involve structures which are not tightly closed so that the oxygen supply available to the fire is less limited. Such fires occur where windows and doors are open to the fire area or where a fire has already broken out to permit circulation between interior and exterior atmospheres as mentioned below under the "Second Phase" of confined interior fires.

It should be kept in mind that this text is devoted to the problem of attacking and extinguishing interior fires which makes up the bulk of the fire fighting operation in the average community. These are chiefly the so-called "Class A" fires involving combustibles which require cooling for extinguishment. Structural or interior fires go through phases from ignition, smouldering, flame production, build-up or extension, flash-over, and final burn out or extinguishment depending upon the types and availability of fuels and oxygen or the effect of extinguishing agents.

Fire fighters have a saying, "No two fires are alike." This is true insofar as arrangement and location of the structure, contents, time, place, and circumstances of ignition and discovery are concerned. Nevertheless fires do go through definite phases which must be understood if control and extinguishment is to be achieved in an intelligent manner. It is sometimes difficult for fire fighters to get a clear grasp of fire behavior because they arrive during various phases of development of fires in buildings of differing construction and occupancy. Thus an important consideration in the size up of any fire is to be able to recognize the approximate stage or phase of development of any particular fire as outlined in this chapter.

The development of a fire involving ordinary combustibles within a closed building may be divided into the following phases:

FIRST PHASE — Incipient or smouldering period. (Oxygen content of the interior atmosphere approximately normal, 21 per cent.)

A fire starting from a small source of heat may smoulder for a period ranging from a few minutes to several hours before flame production develops. This is a period of slow fuel consumption, limited heat generation, and the production of considerable smoke. The heated smoke moves to the upper level within the atmospheric space but loses much of its heat content through transfer to the cooler atmosphere and solid materials. Little, if any, increase in the average atmospheric temperature occurs during this period. A building is not air tight and there is some circulation between the interior and exterior atmospheres. This fact, together with limited oxygen consumption that occurs during this period, may prevent any appreciable decrease in the oxygen content of the interior atmosphere. Physical destruction is limited to the immediate fire area and the major damage is caused by smoke. The rate of heat production and fuel vaporization will continue to increase and it is only a matter of time until the fire enters its second phase.

SECOND PHASE — Flame-production period. (Oxygen content of interior atmosphere ranging from 21 to 15 per cent.)

Flame production is accompanied by an increased rate of fuel consumption and heat generation. As the fire extends its boundaries and the volume of flame production increases, strong convectional currents develop within the atmospheric area. Heat is transmitted to the upper atmospheric level by the updraft of heated smoke and air from the zone of combustion while flame production is accelerated by the indraft of cooler air and the fire is supplied with oxygen drawn from the entire atmospheric area. During the period of intense flame production the interior atmosphere is heated rapidly causing it to expand in volume. If this rate of expansion exceeds the rate of escape, the interior atmospheric pressure will become greater than that of the outside atmosphere. This differential in pressure may amount to only a fraction of a pound per square inch but when exerted against a window pane it may be sufficient to cause an outward rupture of the glass. Any sizable opening to the outside atmosphere would relieve the internal pressure and permit sufficient circulation between the interior and outside atmospheres to allow limited flame production to continue. Prompt extinguishing action is necessary to prevent destruction of the building.

This is the period of rapid extension and major destruction. If the involved area does not include the entire building, the fire may enlarge its atmospheric area by destroying doors, partitions, or other combustible boundaries. This provides an additional oxygen supply to support flame production. It is possible for upper floors to become involved through transmission of heat by convection. The downward extension of a fire within a building is slow but its extension on the same floor and to upper floors is rapid if not retarded by boundaries of fire resistant materials. If the fire fails to break through to the outside atmosphere the oxygen content of the interior atmosphere becomes inadequate to support intense flame production. As the oxygen content of the interior atmosphere decreases, the volume of flame production will decrease proportionally while smoke production will increase. When the oxygen content of the interior atmosphere falls below 15 per cent, flame production ceases and the fire enters its third phase.

THIRD PHASE — Smouldering period. (Oxygen content of interior atmosphere less than 15 per cent.)

The rate of heat production decreases rapidly during the latter part of the second phase and a further decrease occurs upon entering the third phase. It appears that the rate of heat production is no longer sufficient to maintain the high atmospheric temperature attained during the second phase. The interior surface and solid materials within the space absorb heat from the atmosphere and there is also some loss to the outside by convection and radiation. Loss of heat to the outside is restricted by the insulating qualities of the structure but this loss of atmospheric heat may be sufficient to cause the internal pressure to fall below that of the outside atmosphere. This temporary variation in pressure between the interior and outside atmospheres may be sufficient to cause an inward rupture of window panes. If this occurs limited flame production will be supported by indraft of air from the outside atmosphere. If window panes remain intact this negative pressure will be overcome by seepage of air from the outside atmosphere.

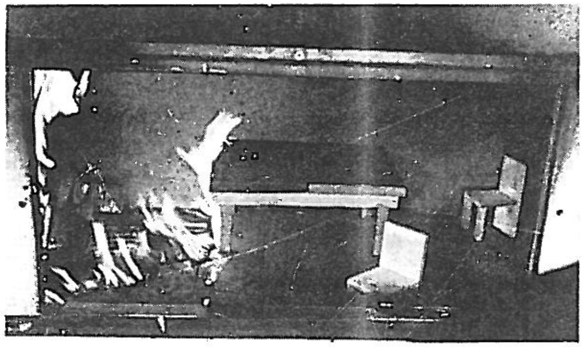
During this phase the interior atmosphere will stratify according to degree of temperature and become fairly static. There will be considerable variation in the degree of temperature between the upper and lower levels, the highest degree being at the upper level. The atmospheric temperature will become approximately the same degree at the same level throughout the atmospheric space. Solid materials will continue to absorb heat from the atmosphere until their temperatures equal that of the interior atmosphere at the same level. Transfer of heat from the atmosphere to exposed materials accounts for a major part of the heat loss and tends to prevent further loss of atmospheric heat once these temperatures are equalized.

Smoke is given off by the smouldering materials and there is a release of gases and vapors from other combustibles due to decomposition resulting from excessive heat. The interior atmosphere becomes heavily charged with smoke containing a hazardous percentage of carbon monoxide. Many of the combustibles within the space have reached a state of readiness and need only an adequate oxygen supply to support rapid flame production. The interior atmosphere may also contain sufficient fuel to form a flammable mixture with air. A fire in its third phase appears to have the basic factors of a potential smoke explosion. An attempt to ventilate a building at this time by allowing ventilating currents to develop through adequate and properly located openings would involve serious risks to both the involved building and fire-fighting personnel.

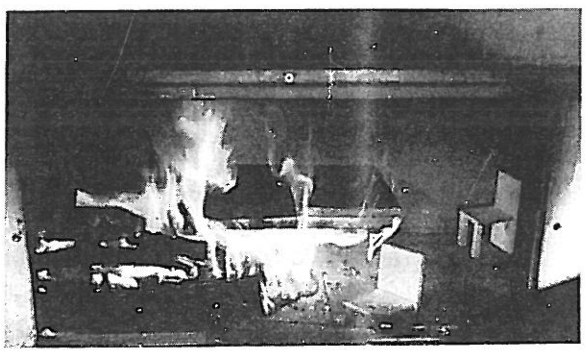
THE three phases of development of a fire within a closed building will be referred to many times and a clear conception of each is necessary to comprehend the theory of attack that will be explained in this text.

The stages in which a fire builds up or spreads so as to involve an atmospheric area are well illustrated by photographs from "Fire Research 1952" appearing on pages 16–17.

Data accumulated from full-scale experimental fires aboard the *Gaspar de Portola* and the *Phobos* indicate that within confined spaces the atmospheric temperatures at the upper level may vary from about 700 to 1,500° F. during the intense period of flame production. In the case history of the fire at 3605 Camden Avenue, included in this text, attention is directed to the fact that the atmospheric temperature near the ceiling of the dining room had reached approximately 1,300° F., yet there were combustibles located at and near the floor level that showed no evidence of char. During several of the experimental fires aboard the *Gaspar de Portola*, loose paper and other light

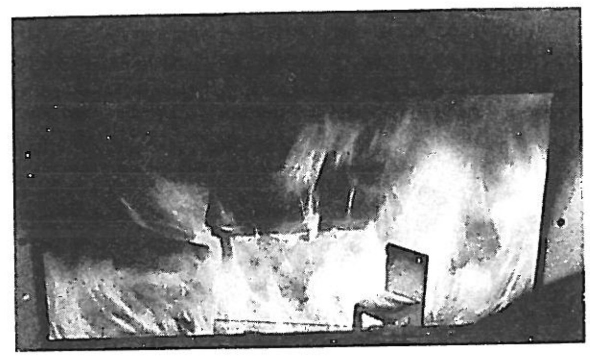


A series of pictures showing the stages in which fire spreads to involve the contents of a room. Room is one-fifth scale. Picture taken 12 minutes after a small fire has been started in a corner of the room.



Picture taken after 16 minutes. At this stage of the fire fire fighters could still enter the room as a dangerous over-all temperature has not yet been reached and there is still air to breathe and to feed the fire. This demonstrates about the latest stage of this particular fire at which direct attack with extinguishers or small hose lines would be possible.

Picture after 18 minutes. The steady progress of the fire up to this point has heated the contents so that all combustibles not yet burning are almost at the ignition temperature. At about this stage further development of the fire becomes very rapid as long as a reasonable supply of air can get in through doors, windows or cracks.



Last picture in a series taken after 19 minutes shows the whole room bursting into flames. This is known as the "flash-over" stage. Temperatures are high and remain high until the fire is extinguished, but the burning will adjust itself to the amount of air filtering in around windows and doors. In a tight room the fire could actually smother itself. If fog or water spray is applied at this stage, the turbulence due to rapid generation of steam carries the water particles to all parts of the room. At the same time these particles are turned to steam, a process that further increases the turbulence and promotes an efficient heat transfer from the burning material to the water.

Photos on pages 16-17 from "Fire Research 1952"; reproduced by permission of Her Brittanic Majesty's Stationery Office (Crown copyright reserved) combustibles located at the floor level of the machinery space were undamaged while the temperature at the upper level ranged from 900 to 1,200° F. There can be no doubt regarding the wide variation between the atmospheric temperature at the upper and lower levels within a confined space after flame production has developed sufficiently. Here is a fundamental that can be stated as follows: *Within a building or other confined space, the major concentration of heat is always located at the upper atmospheric level within the area of major involvement.* This is a very important fundamental that must receive due consideration in attacking major interior fires.

There are only a limited number of fires that ever enter the third phase and these are usually within basements or in buildings of fire-resistive construction. A large majority of fires within closed buildings are able to break through to the outside atmosphere during the second phase. If either an exhaust or an air-intake opening of sufficient size is effected between the involved area and the outside atmosphere, it is very unlikely that a fire will enter the third phase. An exhaust opening will provide an escape outlet for heated smoke thereby preventing an appreciable increase of atmospheric pressure within the involved area. This will allow seepage of air from the outside atmosphere to support limited flame production. A door or window opening will allow sufficient circulation between the interior and outside atmospheres to support flame production until the fire effects additional openings to the outside atmosphere.

Rapid involvement and destruction of a building depend to a major degree upon properly located exhaust and air-intake openings, adequate in size to allow the development of strong draft action within the involved building. A roof opening of adequate size with an unobstructed channel from the involved atmospheric area provides an ideal exhaust opening. Where no roof opening is present, open or burned-out windows can serve as both exhaust and air-intake openings. Heated smoke is exhausted from the upper section of the window while cool air from the outside atmosphere enters through the lower section. This action also occurs through an open doorway. A study of combustion as it progresses within an ordinary Burnside stove should remove any doubts regarding the importance of adequate exhaust and air-intake openings. The rate of fuel consumption and heat generated within the stove is controlled through adjustments of the air-intake opening and the exhaust damper. Once a fire within a closed building has entered its second phase and the volume of flame production has been sufficient to produce high atmospheric temperatures, any sizable opening to the outside atmosphere will enable the fire to increase and to continue its destructive action until adequate extinguishing action is taken. The most practical approach to this problem would be to leave the involved atmospheric area closed until the excessive heat has been removed. This cannot be accomplished by resorting to conventional methods of ventilation. "Conventional methods of ventilation" refers to the process of attempting to remove heated smoke and gases from an involved building by allowing ventilating currents to develop between the interior and outside atmospheres through adequate and properly located openings. Conventional methods of ventilation are practical only where a fire is in its first phase or has entered the second phase but has not developed sufficient volume of flame production to generate excessive atmospheric temperature within the involved area. Under these conditions, it is the lack of visibility due to the presence of smoke together with its toxic and irritating properties that retards the progress of fire-fighting personnel.

Extinguishment of fire can be accomplished by one or a combination of the following: (*a*) Removing the fuel from the zone of combustion; (*b*) excluding oxygen from the zone of combustion; (*c*) cooling the involved and exposed combustibles to a degree lower than their ignition temperatures. The principles *a* and *b* have their limited fields of application but are not applicable in the control and extinguishment of major fires involving ordinary combustibles. The most effective and practical method of extinguishing fires involving ordinary combustibles is by cooling the involved and exposed combustibles to a degree lower than their ignition temperatures. The ignition temperatures of all ordinary combustibles are above 300° F., therefore, if the involved and exposed combustibles are cooled to an approximate temperature of 300° F., the process of combustion ceases and extinguishment is accomplished.

Fire can occur and continue only where the following conditions are present: (*a*) fuel — any combustible gas, liquid or solid; (*b*) oxygen or other oxidizing agent — sufficient in volume to support the process of combustion and is usually supplied by the surrounding air; (*c*) heat — sufficient in intensity and volume to increase the heat content of the fuel to or above its ignition and burning temperatures. *It should be noted that there is but one abnormal condition present in a fire and that is excessive heat.* If excessive heat is removed from involved and exposed combustibles, normal conditions are restored and the fire will cease to burn. *The control and extinguishment of interior fires must be based upon the principle of removing excessive heat from the involved building.* The most effective and practical method of extinguishing a major interior fire is to transfer the excessive heat from within the space to the outside atmosphere. When the interior atmosphere, materials that form the structure, and contents have been cooled to an approximate temperature of 300° F, the fire has been extinguished.

There is a scientific and practical method of transferring excessive heat from the interior of an involved building to the open atmosphere. This method, if employed properly, will replace the heated and contaminated atmosphere with fresh air, extinguish surface burning, and reduce the interior temperature to a degree that will allow fire-fighting personnel to enter and complete the extinguishment of spot fires and smouldering burning. This method avoids the hazards inherent to conventional methods of ventilation and will reduce water damage to a very minimum.

When a fire department arrives at a fire in a building area that is not tightly closed, it must be remembered that the fire has more or less free access to the oxygen in the outside atmosphere and that more or less rapid burning may be expected depending upon the type of fuel and arrangement of building and contents with relation to possible extension of fire.

When a fire is relatively free burning a prompt attack with fog of sufficient volume to transfer heat and suppress flame as previously outlined is indicated. In such situations it may not be possible to obtain the very high relative efficiencies of heat transfer that may be experienced with tightly closed buildings,

but if fog jets are properly directed into the upper atmospheric area of the fire, flame suppression will be obtained much faster and with smaller volumes of water than would be possible with solid streams of water.

Experience with fog attack on unconfined fires indicates the importance of a prompt and aggressive mop-up and overhaul with direct application of water on any materials sufficiently hot to resume flame production when the steam and condensing steam has dissipated. In other words, flame suppression does not necessarily mean that destructive distillation of fuel, due to excessive heat, has ceased. Excessive heat and crackling noises frequently indicate that burning will continue after the water vapor has dissipated. Lines should be advanced as needed to take advantage of the flame suppression. At all times with free burning fires in structures which are not tightly closed, the flames should be approached as closely as good tactical operations will permit and attacked with adequate volumes of fog. Under draft and fuel conditions present at many unconfined fires there may not be enough heat to get a good "indirect" attack but in any event where properly applied as suggested in this text, fog will quickly absorb and transfer the bulk of the excessive heat, dilute gases of combustion and provide a humid atmosphere extremely unfavorable to flame production.

The above is true whether the fire is large or relatively small. Experience with master fog streams in major fires in large cities shows that the average time required to control such fires has been greatly reduced over that required for the solid stream method. The use of such master fog streams is discussed in the author's book "Fire Fighting Tactics" also published by the National Fire Protection Association.

Chapter II

WATER

PROGRESS in the art of controlling and extinguishing fire demands the recognition and application of certain scientific truths. The first and most basic of these scientific truths is that water is our primary fire-extinguishing agent. Water is nature's answer to the problem of controlling and extinguishing fire — it is the universal extinguishing agent. Man would be helpless against the destructive action of fire without the counteractive force of water. Adequate knowledge of the characteristics of this common liquid and understanding of the natural laws that govern its extinguishing action are essentials to those engaged in fire-fighting activities.

The most effective and practical method of fire extinguishment is by cooling the involved and exposed combustibles to a degree lower than their ignition temperatures. The ignition and burning temperatures of all ordinary combustibles are higher than 300° F., therefore, if the involved and exposed combustibles are cooled to an approximate temperature of 300° F., the process of combustion ceases and extinguishment is accomplished. It is a scientific truth that water is the most effective heat absorbing substance that can be employed to effect this cooling action. Water is not only the most effective heat absorbing substance but it is also the most economical and practical substance that can be used for this purpose. It is of utmost importance that individuals who are entrusted with the responsibility of controlling and extinguishing fire have adequate knowledge of the characteristics of water, the natural laws that govern its extinguishing action and its proper tactical employment in fire-fighting operations.

Water, in its normal state, is a liquid that can be solidified by the process of freezing or vaporized by the process of boiling. Heat is released by water in the process of freezing while heat is absorbed by water in the process of boiling. Under atmospheric pressure equal to that at sea level fresh water freezes at 32° F., and boils at 212° F. At higher elevations the atmospheric pressure is less and its boiling point is correspondingly lower. Steam is generated in the process of boiling. Steam is a transparent vapor and remains so until the process of condensation begins. Condensation results from loss of heat and as this process progresses what was formerly steam appears as visible mist. This visible mist will be referred to as "condensing steam."

Only a fraction of the heat absorbing capacity of water is utilized in the process of raising its temperature to the boiling point. It is in the process of vaporization that water exerts its maximum cooling action. These scientific truths can be recognized readily by comparison of the following data: One gallon of fresh water will absorb approximately 1,250 British thermal units (B.T.U.) in the process of raising its temperature from 62 to 212° F. This theoretical gallon of water has reached its boiling point (212° F.) and is ready to start changing from a liquid to a vapor. Absorption of additional heat will not increase the temperature of the liquid but will reduce the volume by converting liquid into vapor (steam) which will escape into the surrounding atmosphere. When the last drop has been converted into steam, this gallon of water has absorbed approximately 9,330 B.T.U.; 1,250 B.T.U. in the process of raising its temperature from 62 to 212° F. and 8,080 B.T.U. in the process of vaporization. It should be noted that in the process of vaporization this gallon of water absorbed more than six (6) times the volume of heat that is absorbed in the process of raising its temperature from 62 to 212° F. Based upon these scientific facts the following truism can be stated: *The maximum cooling action of a given volume of water is obtained only when the entire volume has been converted into steam.*

Vaporization of water results in the production of steam in ratio of 1 to over 1,600. Water in a volume of 1.05 cubic in., measured at its boiling point, will expand into 1,728 cubic in. or 1 cubic ft. of steam. A gallon of water, measured at 62° F., will produce approximately 223 cubic ft. of steam. This calculation takes into account the liquid expansion that results from increasing the temperature of the water from 62 to 212° F. If in fire-fighting operations only 90 per cent of a given volume of water is vaporized, approximately 200 cubic ft. of steam would be generated per gallon of water used. Based upon the techniques explained in this text, 90 per cent efficiency appears

to be a reasonable expectancy in the attack and extinguishment of major interior fires. Generation of steam is a factor that can be utilized to great advantage in attacking major fires within confined spaces. This factor provides a safe, practical and effective solution to the problem of ventilating a building or other confined space where the interior atmosphere is heated to a hazardous degree and is heavily charged with smoke.

Effective extinguishing action is dependent upon instantaneous transfer of heat from the involved and exposed materials to the water being applied and the volume of heat transferred should be sufficient to convert a large percentage of the water into steam. Perfection in the use of water as a fire-extinguishing agent would be achieved if water could be applied in a form and at a rate whereby the entire volume would be converted into steam. Perfection is difficult to achieve but it is possible to apply water in a form which will result in vaporization of a large percentage of the total volume. The rate of heat absorption can be increased by increasing the surface exposure of a heat absorbing substance in ratio to its volume. This is a natural law that the fire-fighting profession can no longer afford to ignore. The limited extinguishing action of water applied in the form of a solid stream is due primarily to the limited surface exposure of the water in ratio to its volume. The surface exposure of a given volume of water can be increased by breaking the water into finely divided particles. The surface area of a gallon of water broken into finely divided particles is increased many times over that of a gallon of water in the form of a solid stream. Water can be broken into finely divided particles by passing it through a properly designed nozzle under adequate pressure. The design of the nozzle and the nozzle pressure are the factors that determine the size of the particles or the degree of fineness. The degree of fineness that will produce effective results in fire-fighting operations may be defined as follows: (*a*) A large percentage of the particles should be of sufficient degree of fineness that they are light enough to be carried for some distance by air currents; (*b*) A large percentage of the particles should be of sufficient degree of fineness to vaporize instantaneously upon contact with materials having temperatures above the boiling point of water.

It appears that this degree of fineness together with sufficient reach for all practical fire-fighting purposes can be obtained with nozzle pressures ranging from 100 to 125 psi providing the nozzles are of proper design. Careful study of the data so far presented should convince any reasonable individual of the necessity and desirability of obtaining adequate surface exposure of water when used as a fire-extinguishing agent. Those who believe that the solid stream will continue to be accepted as the primary form of applying water in fire-fighting operations will find themselves occupying an untenable position.

The development of equipment that enables fire-fighting personnel to apply water in the form of finely divided particles was the most progressive advance in equipment since the advent of the power-driven pumping unit. This development has provided a basic weapon that is destined to revolutionize the art of fire fighting. Little, if any, progress can be made toward improving the tactical employment of water in fire-fighting operations until the fire service recognizes the gross ineffectiveness of the solid stream form of application. The development of the water particle or fog nozzle does not mean that the solid stream form of application will be eliminated. Small solid streams are very useful in extinguishing spot fires and to penetrate smouldering materials. Most of the high-velocity fog nozzles are designed to project either a cone of water particles or a solid stream. Situations are encountered from time to time in fire-fighting operations where the solid stream may be used to good advantage. The solid stream will continue to have a limited degree of usefulness in fire-fighting operations but it is destined to become the secondary form of application. Progress in the tactical employment of water in fire-fighting operations demands that water be applied in the form of finely divided particles. To exploit this development to its ultimate degree, the fire service must discard antiquated tactics and replace them with tactics based upon scientific facts and natural laws. Then and then only can the vast extinguishing action of water be released and utilized effectively in fire-fighting operations.

Extinguishing efficiency of a given volume of water depends upon the percentage converted into steam. Water that

fails to vaporize contributes little to actual extinguishment but is responsible for water damage to exposed materials. The most practical solution to the problem of reducing water damage is to increase the percentage of vaporization. An extinguishing efficiency of 90 per cent means that not less than 90 per cent of the total volume of water injected into an involved building is converted into steam. If this degree of efficiency is attained little, if any, water damage can occur. This efficiency figure is based upon an assumption that some unvaporized particles of water are exhausted from a building in the escaping steam, therefore, the "run-off" should be less than 10 per cent of the total volume of water injected into an involved building. It appears from a study of the case histories, included in this text, that an extinguishing efficiency of 90 per cent can be attained by the indirect method of attack further explained in Chapter III.

If water (temperature 62° F.) is injected into a building, a volume of heat amounting to about 41 B.T.U. is required to generate 1 cubic ft. of steam, therefore, each cubic ft. of steam exhausted from an involved building transfers approximately 41 B.T.U. of heat from the interior to the outside atmosphere. Based upon an efficiency of 90 per cent, 125 gallons of water would absorb a volume of heat amounting to approximately 1,000,000 B.T.U. and produce about 25,000 cubic ft. of steam. This explains why the progress of an attack on a major interior fire can be estimated and evaluated by observing the volume of smoke and condensing steam coming from the involved building. This should be emphasized in training of personnel and especially in training of tactical officers. Fire-fighting personnel should be acquainted thoroughly with the characteristics of condensing steam and be able to evaluate the information it conveys on the fireground.

Condensing steam can be observed and recognized instantly when projected against the sky. It is visible to the human eye in daylight or darkness. Observe a steam locomotive when it is exhausting steam, the live steam is invisible as it comes from the exhaust valve. As it expands and loses some of its heat, the process of condensation begins and the expanding cloud of condensing steam becomes visible. Condensing steam contains insufficient heat to cause physical injury. It is not toxic but it does restrict visibility. Fire-fighting personnel operating in the open atmosphere can be completely enveloped by a cloud of condensing steam, coming from an involved building during an attack, without experiencing any physical discomfort.

Under normal weather conditions the natural movement of heated smoke and steam is upward upon being exhausted from an involved building. Due to a combination of weather conditions an atmospheric inversion may exist only a few hundred feet above the earth's surface. This consists of a stratum of warm air and tends to place a lid on convection. This stratum of warm air prevents the upward movement of heated smoke and steam and they will linger near the ground. A low atmospheric inversion usually occurs at night or during very cold weather. While directing an indirect attack where a one-story building was involved, the author found it necessary to leave the immediate area and take position on higher ground to determine the progress of the attack. The involved building and the immediate surrounding area were blanketed completely in a cloud of condensing steam. Heated smoke coming through the blanket of condensing steam indicated the section of the building where extinguishment had not been completed. This fire occurred about 2:00 P.M. and the temperature was ten degrees above zero. Personnel operated without respiratory equipment and experienced no physical discomfort but were handicapped by limited visibility.

Water is a liquid that has a high surface tension. Its surface tension can be lowered by mixing a small percentage of a standard wetting agent with the water. The author has experimented with wetting agents since 1945 and has used treated water to extinguish various types of fires. Treated water can be used to good advantage in extinguishing deep-seated smouldering in bailed cotton, paper and similar materials. Considering the cost of a standard wetting agent and the practical results, it appears that the use of treated water can be readily justified in overhauling operations and to extinguish fires involving low-flash point liquids. The Fire Department, Miami, Florida, has a number of first alarm units equipped with a proportioner and storage tank for the wetting agent.

The operator can supply one or more 1½-in. lines with either plain or treated water. He can also provide either a one or two per cent mixture, one per cent for solid combustibles or two per cent for flammable liquids. The experience of the Miami Fire Department should assist materially in answering a number of questions regarding the feasibility of employing treated water in municipal fire-fighting operations.

Miami Fire Department photo

Three wet water "chemical" trucks of the Miami, Florida, Fire Department, consisting of 500-gallon-per-minute pumpers, 500-gallon water tanks and preconnected 1½-in. hose lines equipped with fog nozzles. These trucks have wet water proportioners.

An attempt has been made in this chapter to present and explain the simple fundamentals and natural laws that govern the extinguishing action of water. Future progress in the art of fire fighting depends to a major degree upon acceptance, comprehension and application of this knowledge. Without this knowledge it is impossible to appreciate and evaluate the vast controlling and extinguishing potential of water, our primary fire-extinguishing agent.

CHAPTER III

THE INDIRECT METHOD OF ATTACK

"THE indirect method of attack" is an evolutionary development resulting from an extensive study of fuel oil fires within confined spaces conducted by the instructors' staff, U. S. Coast Guard Fire Fighting School, Fort McHenry, Baltimore, Maryland, during World War II. The primary purpose of this study was to devise effective and practical methods of controlling and extinguishing major oil fires within the machinery spaces of commercial and naval vessels. The preliminary experimental work in connection with this project was conducted during the summer of 1943. As this study progressed, it was learned that extinguishment of a fuel oil fire within a confined space could be accomplished without applying water directly to the surface of the burning oil. A number of tests were conducted within a simulated boiler room in an effort to determine the factors that govern this phenomenon. A fairly definite technique was developed and this became known as "the indirect method of attack."

By the summer of 1944, the investigation had progressed as far as possible with the limited facilities available to the staff of the Fire Fighting School. It appeared that sufficient evidence had been accumulated to justify the expenditure of funds to undertake full-scale experiments under as near actual conditions as would exist aboard commercial and naval vessels. The Commandant, U. S. Coast Guard, procured from the War Shipping Administration a damaged and unseaworthy Liberty ship, *Gaspar de Portola.* This vessel provided the necessary facilities for continuation of this investigation and was berthed at the Fort McHenry Training Station.

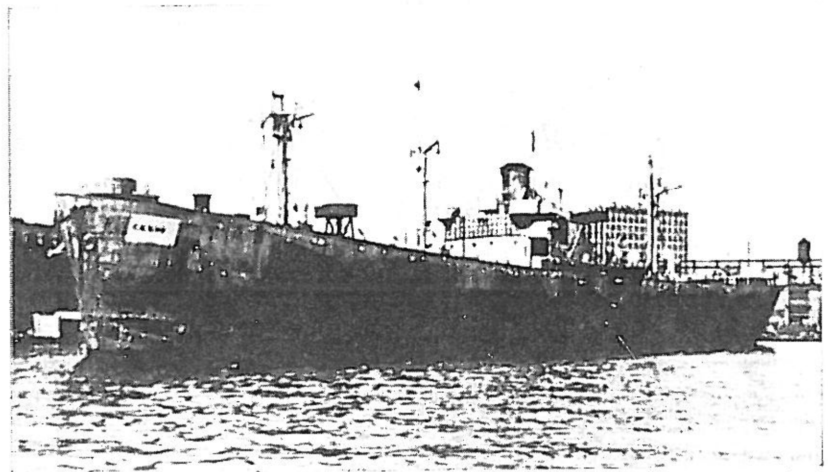
The machinery space of this vessel was approximately fifty ft. in length and fifty-six ft. wide at the floor level. The interior height varied from twenty-two to thirty-two ft. due to an offset created by the second deck. The total volume of this space was approximately 85,000 cubic ft. without deductions for machinery, piping, and other installations. This displacement amounted to about 20,000 cubic ft. leaving a net atmospheric volume of approximately 65,000 cubic ft.

The machinery space of this vessel was converted into a full-scale testing laboratory by minor modifications and installation of an electronic pyrometer together with thermocouple terminals located at strategic points within the space.

A series of full-scale experimental fires were undertaken and this phase of the investigation extended over a period of fifteen months. These full-scale tests were designed to create as severe a fire as would ever be experienced within the machinery space of a vessel with the possible exception of a fire resulting from a collision or under battle conditions. Fuel oil, in volumes ranging from five to seven thousand gallons, was released in the bilge of the machinery space. This provided a burning surface of approximately eighteen hundred square ft. The major part of this surface was located beneath steel-floor plates preventing any water from being applied directly to the surface of the burning oil. The freely-burning time of these tests ranged from thirty minutes to an hour before any action was taken to control and extinguish.

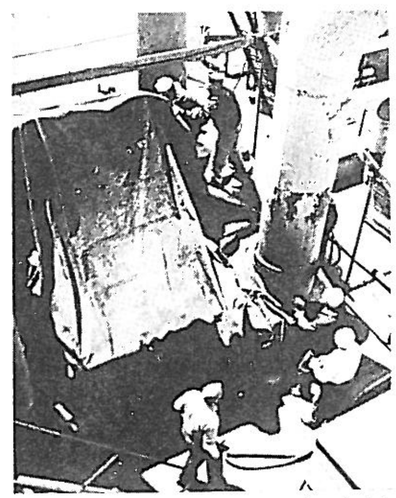
It was learned that the first and most important step in controlling this type of fire was to close all air-intake openings. This action restricted the oxygen available to support flame production to an extent that reduced the rate of fuel consumption and heat generation to a very minimum. Immediately following the closure of air-intake openings, the pyrometer would register a major decrease of atmospheric temperature at the upper level of the space. The opening between the smoke stack and stack casing extended upward from the forward section of the machinery space and terminated seventy-five ft. above the floor level. This opening could not be closed due to construction and height. It formed the exhaust outlet from the machinery space with an area of fifty-four square ft. and remained open during the entire operation.

Actual extinguishing operations were undertaken after all air-intake openings were closed. In the early tests, two 1½-in. hose lines fitted with low-velocity fog heads were lowered through skylight openings into an open space near aft bulkhead. This placed the fog heads in the heated atmosphere near the upper level of the machinery space where the fog cones would not strike bulkheads or other obstructions. Water, in



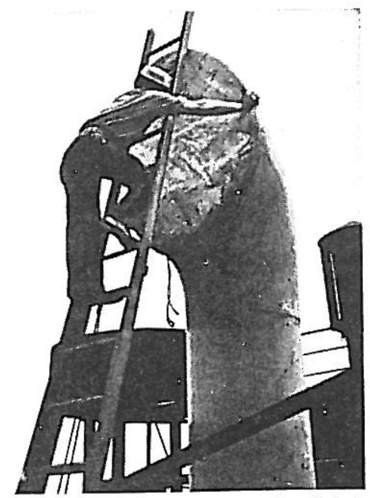
U. S. Coast Guard photo

The *Gaspar de Portola* at Fort McHenry.



U. S. Coast Guard photo

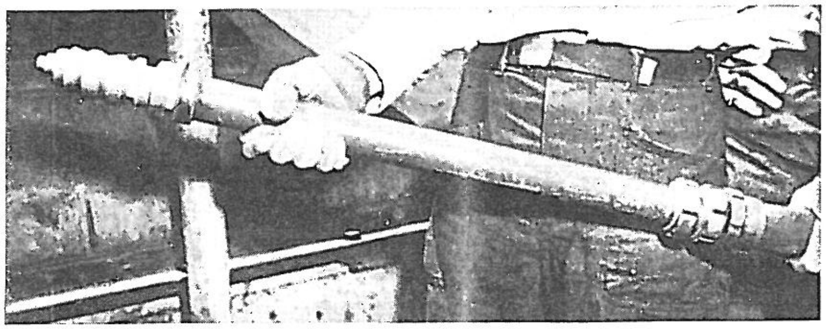
Skylight covered with hatch tarpaulin.



U. S. Coast Guard photo

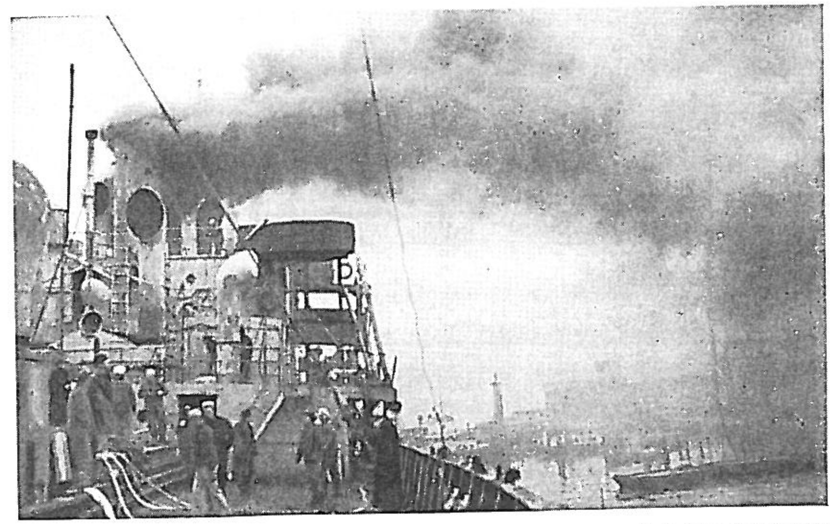
Covering aft main ventilator.

the form of finely divided particles, was applied through these fog heads using nozzle pressures of approximately 100 psi. The rate of application was about 168 gpm. In later tests, only one 1½-in. line fitted with a Navy type low-velocity fog head (L-10A) was used, approximately 114 gpm at 100 psi nozzle pressure. In one test, a specially designed low-velocity fog head with a capacity of only 60 gpm was used.



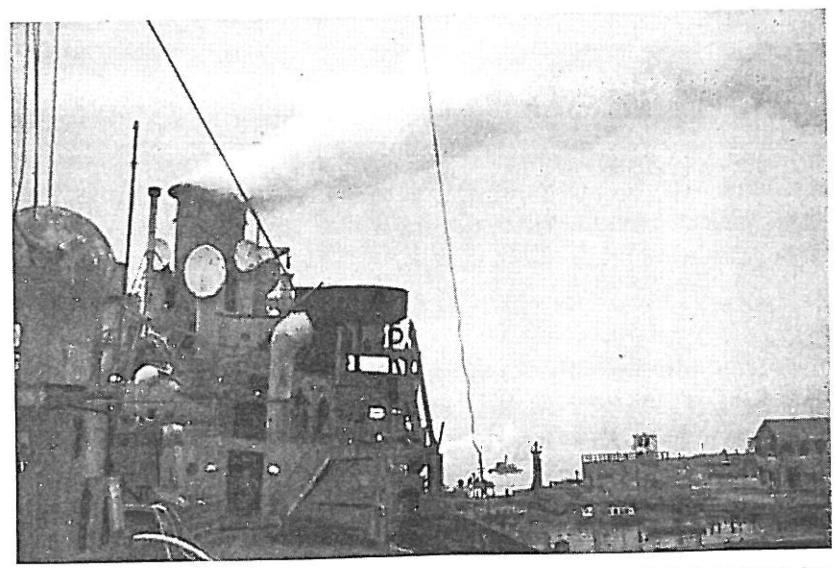
Low Velocity Head (L-10A) and Applicator Fitted to 1½-in. hose.

Immediately following the application of water, there was an outrush of smoke from the exhaust opening between the smoke stack and stack casing followed by a mixture of smoke and condensing steam. Usually this changed to condensing steam without any trace of smoke. Within a period of minutes, the volume of condensing steam would start to decrease and would continue to decrease until little, if any, could be observed coming from the exhaust opening. During this entire period the pyrometer would register decreases in atmospheric temperature throughout the machinery space. Application of water was continued until condensing steam ceased to come from the exhaust opening and the atmospheric temperature at all thermocouple terminals had been reduced to below 300° F. This usually required a period of twenty-five to forty minutes. This method of attack proved successful except when it was impossible to effect or maintain complete control of air flows from the outside atmosphere. The burning oil was not only extinguished but was cooled to below its flash point, 200° F. Light steel throughout the space was cooled to an approximate



U. S. Coast Guard photo

Test fire No. 7. Four minutes after ignition of fuel oil.



U. S. Coast Guard photo

Three minutes after start of application of water fog. Note condensing steam coming from stack.

temperature of 212° F. and the structural members of heavy steel to about 220° F.

An official report was published by the U. S. Coast Guard, June 1, 1945, under title — "Report of a Study of the Control and Extinguishment of Fuel Oil Fires in the Machinery Spaces of Vessels." This report contained a complete summary of scientific data accumulated from test fires conducted during 1944. Also an outline and explanation of the technique required in the indirect method of attack and recommendations regarding its practical application in the control and extinguishment of major oil fires aboard commercial and naval vessels. In this report, the author advanced a theory based upon convectional currents in an attempt to explain why extinguishment of the burning oil, cooling of the steel and cooling of the fuel oil below its flash point were accomplished without applying water directly to the surface of the heated materials. The author was never fully convinced that this theory was the correct explanation of this phenomenon. A further study of the scientific data resulted in two definite conclusions that can be stated as follows:

(*a*) Rapid generation of steam within a confined space creates a violent atmospheric disturbance within the space.

(*b*) Each cubic foot of steam generated within a confined space demands a cubic foot of that atmospheric space.

These two conclusions enabled the author to formulate a theory that explains what occurs when the indirect method of attack is employed. This may be termed "the theory of indirect application and atmospheric displacement." This theory assumed that —

the cooling action of water, applied in the form of finely divided particles at the upper atmospheric level within a highly heated confined space, is not limited to the immediate area. The injection of water into a highly heated atmosphere results in rapid generation of steam, thereby creating an atmospheric disturbance of sufficient force to distribute unvaporized particles throughout the space. Unvaporized particles are brought into contact with heated materials located beyond the immediate area, thereby exerting cooling action throughout the atmospheric area and at the same time contributing to the atmospheric disturbance by expanding into steam. It appears that this action continues until the surface temperature within the space is reduced to approximately 212° F., the boiling point of water.

Rapid generation of steam increases the atmospheric pressure within the space — each cubic foot of steam demanding a cubic foot of atmospheric space. A building is not air tight, therefore, the interior and outside pressures are equalized quickly by an escape of atmosphere from the higher to the lower pressure area. If the volume of steam generated within the space exceeds the net atmospheric volume of the space, most, if not all, of the original atmosphere will be displaced by steam. When the surface temperature within the space has been reduced to approximately 212° F., the boiling point of water, steam generation ceases.

At this time, steam within the space starts to condense and cool air from the outside enters filling the void created by the process of condensation. This indraft of cool air from the outside atmosphere tends to increase the rate of condensation and continues until the process of condensation ceases. At this time, a major part, if not all, of the atmosphere within the space consists of normal air.

IN JUNE 1947, the author completed his wartime service with the U. S. Coast Guard and returned to duty with the Parkersburg Fire Department. There were many questions regarding the practicability of employing water in the form of finely divided particles for general fire-fighting purposes. Answers to these questions could be obtained only through field experience. Within a period of two years, the personnel of the Parkersburg Fire Department had been trained and equipped for the purpose of determining the practicability of employing this system of fire fighting in municipal fire defense.

An intense and practical educational and training program provided the initial step in converting the personnel of the

Parkersburg Fire Department from the solid stream system of fire fighting to that of finely divided particles. The fundamentals and recommended technique of the indirect method of attack were emphasized. A tentative plan of operational procedure for employing this method in combating major interior fires was outlined for the personnel and strict supervision was exercised on the fireground to see that this plan was followed. Results were observed and recorded. After each fire photographs were made of the involved building and a careful study was made of the entire operation. Mistakes were recognized and necessary steps taken to prevent similar mistakes in future operations. The personnel of this department learned by the process of trial and error on the fireground. Gradually the mechanical difficulties were overcome and operational procedure improved. It took approximately two years to perfect this method of attack and for the personnel to develop the skill and confidence that enabled them to employ it successfully on the fireground.

The fundamentals of the indirect method of attack may be summarized as follows:

1. Degree of confinement and concentration of excessive heat are important factors in this method of attack. A high concentration of excessive heat within a closely confined space provides the most advantageous conditions.

2. The initial attack should be made within the area of major involvement. The cone or cones of water particles should be injected into the heated atmosphere at upper level of the space. The primary purpose of this attack is to transfer the excessive heat from the interior of the building to the outside atmosphere.

3. Indirect application and atmospheric displacement will occur only on and above the floor where the attack is made. The major movement of heated smoke and steam is upward and outward while the movement through openings to the floor below is minor in nature.

4. The progress of an indirect attack can be estimated readily by observing the volume of smoke and condensing steam coming from a building during the attack. Displacement of the interior atmosphere starts immediately following the injection

of water particles and continues in the following sequence: first — violent expulsion of smoke; second — a mixture of smoke and condensing steam; third and final phase — condensing steam with little, if any, smoke.

5. Injection of water particles should continue without interruption until the volume of condensing steam coming from the building has decreased to a major degree. A major decrease in the volume of condensing steam, providing there has been no interruption or reduction in the volume of water being injected, is a definite indication that a major part of the excessive heat has been transferred to the outside atmosphere. It also indicates that indirect application has practically ceased and the cooling action of the water is restricted to the area of direct application. At this time, injection of water particles should be stopped.

6. Providing an indirect attack has been executed in the proper manner, the following conditions can be anticipated:

(*a*) Residual heat will be insufficient to prevent personnel from entering and operating within the building. The interior atmosphere may cause some physical discomfort but this appears to be due to high humidity rather than to excessive heat. Conventional methods of ventilation may be employed to lower the humidity and to effect further reduction of atmospheric temperature.

(*b*) Some smoke and condensing steam may be present at the upper level of the space but usually of insufficient density to interfere with visibility.

(*c*) Oxygen percentage of interior atmosphere should be normal (21 per cent).

(*d*) Small spot fires and deep-seated smouldering may be found. Spot fires are usually located at or near the floor level.

Atmospheric displacement by indirect application is produced by rapid generation of steam within a confined space. The volume of excessive heat and degree of confinement are controlling factors in this chain reaction. These two factors have a direct influence on each other and must be evaluated jointly. An indirect attack can be employed successfully only when the atmospheric and surface temperatures at the upper level within a confined space are higher than the boiling point of water (212° F.). Degree of extinguishment that can be achieved is dependent upon the volume of excessive heat and the degree of confinement.

Fires in the first phase of development and in many instances after they have advanced into the early part of the second phase (limited flame production) have not generated sufficient volume of heat to require or justify an indirect attack. Accumulated smoke is the major problem. Smoke that has lost most of its heat content is not a serious problem for well trained and experienced firemen. Conventional methods of ventilation may be employed to increase the degree of visibility within the building while proper respiratory equipment can be used to protect against the toxic and irritating properties of smoke. A fire of this nature must be located and extinguished by direct attack. In making the initial size up of a building fire an experienced and capable officer should have little difficulty in determining if the situation demands a direct or indirect attack.

Under favorable conditions of confinement, it may be possible to transfer the excessive heat to the outside atmosphere by injecting fog at one point only. Under unfavorable conditions of confinement, it may be necessary to inject fog at several points. It is impossible to formulate any definite rule and the officer in charge must have sufficient knowledge of the fundamentals and be able to apply them to the individual situation. The primary purpose of an indirect attack is to eliminate the concentration of excessive heat within the involved building and if this cannot be accomplished by attacking from one position he must select additional points of attack. A study of the case histories should provide considerable information regarding this factor.

Where a sizable roof (exhaust) opening exists, water particles should be injected into the heated atmosphere at some distance from the opening. The machinery space of the *Gaspar de Portola* provided a clear example of the application of this principle. The exhaust opening (stack casing) consisted of fifty-four square ft. and was located near the forward bulkhead. The point of injection was located near the aft bulkhead.

The distance between these two points was about forty feet while the over-all length of the machinery space was only fifty feet. This principle was also applied in attacking the fire within the west section of Warehouse, Case History No. 3. The roof opening was located at a point of greatest distance from the opening through which high-velocity fog was injected into the upper stratum of the interior atmosphere.

Window and door openings (combined exhaust and air-intake openings) appear to exert only a limited influence on the degree of extinguishment. Considerable influence will be exerted by a sizable roof opening together with air-intake openings so located that strong drafts have developed within the space. Strong through drafts will reduce extinguishing action at the lower level but will not prevent the dissipation of excessive heat. Situations of this nature usually require injection of fog at more than one point. A study of Case History No. 3 is recommended.

Care must be exercised by the officer making the initial size up to locate the area of major involvement. This is not difficult if the fire has broken through to the outside. Flames coming from an opening or openings provide positive indication as to the area of major involvement. Considerable care should be exercised where there are indications that a fire has entered the third phase. Fires in this phase of development may be anticipated in basements or sub-basements and in buildings of fire-resistive or heavy timber construction. Metal frame windows fitted with wired glass may be a contributing factor in preventing a fire from breaking through to the outside. Fire-fighting personnel should realize that where a building or other confined space is heavily charged with smoke, together with indications of a hazardous concentration of excessive heat, it presents a situation that does not require immediate action, providing the fire has not effected an opening to the outside or human life is not involved. This is a situation that demands a complete survey, a careful size up, an intelligent decision and a definite plan of procedure. A situation of this nature offers ideal conditions for successful employment of the indirect method of attack.

It appears that the basic contributing factors of a potential smoke explosion may be present where a fire is in its third phase, therefore, considerable care should be exercised to see that no openings are made until the area of major involvement has been located. Then a small opening should be made followed immediately by injection of water particles into upper stratum of the interior atmosphere. Rapid displacement and dilution of accumulated smoke with steam, together with rapid absorption of excessive heat within the involved building, should eliminate any possibility of a smoke explosion.

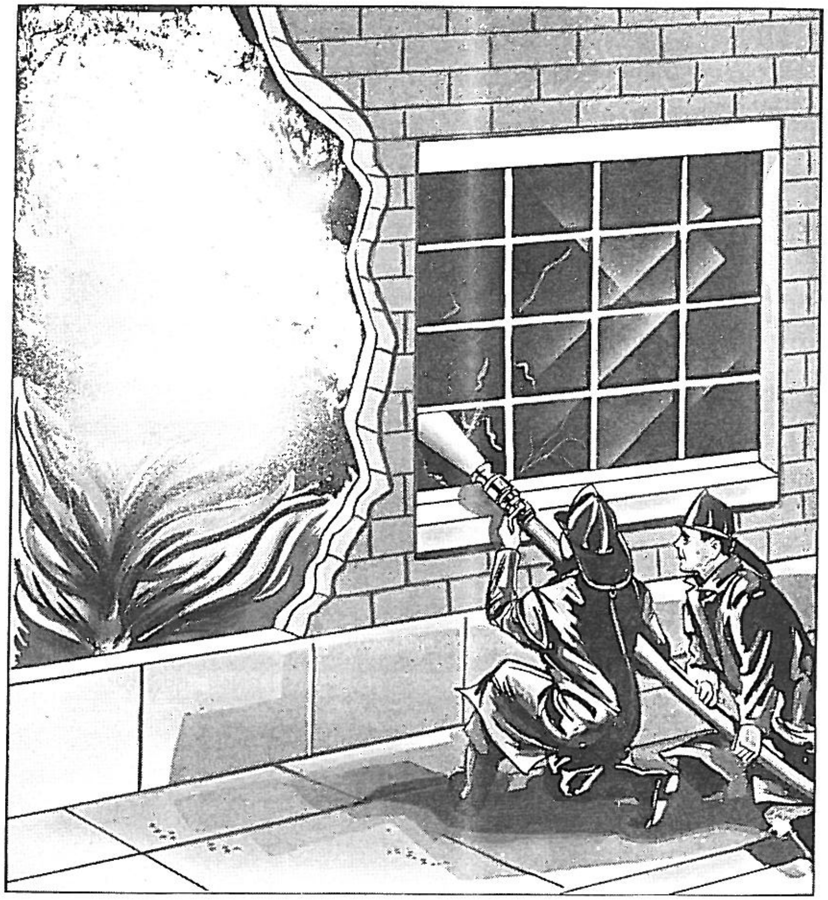
Rapid generation of steam within a confined space causes the original atmosphere (heated smoke and air) to be displaced by an atmosphere of steam. Where a sizable roof opening is present a major part of the original atmosphere escapes by way of this opening. Without the presence of a sizable roof opening, the original atmosphere will be forced out through cracks and other openings. The major movement of this displacement is always upward and outward. The downward movement through openings to the floor below is very limited. If the volume of steam generated within the space exceeds the net atmospheric volume of the space, the excessive steam will be forced out by way of the same channels and openings through which the original atmosphere was exhausted. It is believed that unvaporized particles of water are conveyed in the escaping steam. If these unvaporized particles come into contact with materials having surface temperatures above the boiling point of water they will exert a cooling action on the contacted materials. This appears to explain why cooling and extinguishment has been accomplished on upper floors and in attics without any water being injected directly into these spaces.

The most effective rate of injection poses a difficult question for which there is no definite formula. A study of the data obtained from the experimental fires aboard the *Gaspar de Portola* tends to indicate that the rate of injection in attacking a major fire within a closely confined space can vary considerably without affecting the ultimate results. The machinery space of this vessel had a net atmospheric volume of approximately 65,000 cubic ft. with an exhaust opening (space between smoke stack and stack casing) consisting of 54 square

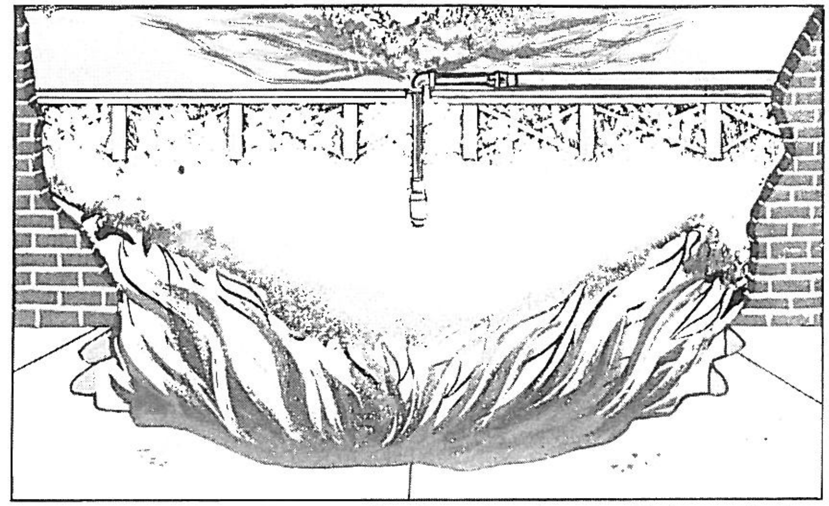
ft. Most of the experimental fires were extinguished by injecting water fog at a rate of 114 gpm. A maximum rate of 168 gpm and a minimum rate of 60 gpm accomplished complete extinguishment. In two experiments, only 36 gpm were used but complete extinguishment was not obtained although the atmospheric temperature at all thermocouple terminals was reduced to less than 300° F. In both these tests, a surface area of less than 50 square ft. continued to burn but the interior temperature had been reduced to a degree that allowed personnel to enter and extinguish the burning oil by direct attack.

A lower rate of injection may be employed successfully in attacking a major fire within a closely confined space than where there are sufficient openings to allow some flame production to continue during the attack. The rate of injection should exceed the rate of heat production by considerable margin. In dwelling fires where only two or three rooms were involved, 50 to 65 gpm of water fog injected in a proper manner have produced effective results. Where larger atmospheric areas are involved and especially if sufficient openings are present to allow some flame production to continue during the attack, the officer in charge should not hestitate to employ as much water as is readily available if it can be injected into the area of major involvement in the recommended manner. A rapid rate of injection appears to offer considerable advantage in obtaining a high degree of atmospheric displacement and extinguishing action.

The total volume of water required in this method of attack depends upon the volume of excessive heat contained within the building and the amount of heat generated during the attack. The officer directing the attack or a qualified observer should be in position to observe the volume of smoke and condensing steam coming from the building during the attack. An experienced observer can estimate readily and with considerable accuracy the progress of an indirect attack and determine when injection of water should be stopped. A noticeable decrease in the volume of condensing steam coming from the building indicates that the percentage of conversion is decreasing providing the rate of injection has remained constant. A



An indirect attack through window opening using high-velocity fog cone. Nozzleman should remain below opening to avoid outrush of heated smoke and live steam.



Showing proper placement of cellar pipe fitted with low-velocity fog head.

major decrease in the volume of condensing steam is positive evidence that indirect application has almost, if not entirely, ceased and most of the excessive heat has been transferred to the outside atmosphere. At this time, the injection of water fog should be stopped. Entry should be made promptly and any remaining remnants of fire extinguished by direct application. Conventional methods of ventilation may now be employed to effect further reduction of atmospheric temperature and to reduce the percentage of humidity within the building.

Additional fundamentals and suggestions that should be considered in order to obtain maximum results and to safeguard personnel when making an indirect attack:

(1) In making the initial size up care should be taken to locate the area of major involvement, also to determine where opening or openings are available or can be made for injection of water particles into upper stratum of interior atmosphere.

(2) *An indirect attack should always be made from positions that will enable personnel to avoid injuries from super-heated smoke and live steam.*

(*a*) If possible and practical an indirect attack should be made from positions outside the involved building.

(*b*) In a basement or other space where it is necessary to inject water through an opening from the floor above, personnel should be withdrawn from the building before water is applied. The valve control should be located outside the building.

(*c*) Where the area of major involvement is on upper floors, it may be possible and practical to attack from an interior stairway below the involved floor. The nozzleman may have to discontinue the attack temporarily to avoid the downward movement of heated smoke and steam.

(*d*) Burned-out windows provide ready-made openings if so located that the nozzleman can stay below the lower level of the opening to avoid the outrush of heated smoke and steam following the injection of water particles.

(3) When openings have to be made they should be small in size. *This is especially important if there are indications that the fire has entered its third phase.*

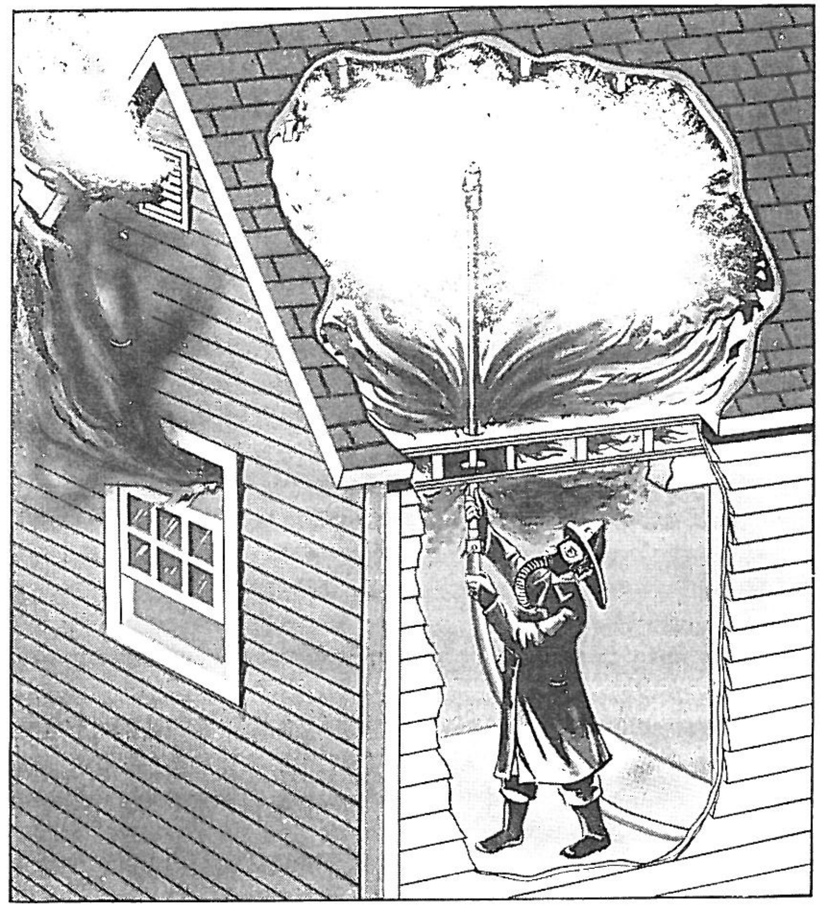
(*a*) Only the lower pane of a two-section window should be broken out. If window consists of several individual panes remove only a single pane. Any immediate obstruction that would prevent a cone of water particles from being projected into the upper stratum of interior atmosphere must be removed.

(*b*) A doorway is an undesirable type of opening due to size and usually the nozzleman will have to discontinue the attack and retreat to avoid envelopment by heated smoke and steam.

(4) If the attack is to be made through window or other low-level opening or from an interior stairway a high-velocity cone should be used.

(5) A fire in a cockloft or unfinished attic may be attacked by making a small opening in the ceiling below and inserting a straight applicator fitted with low-velocity fog head. The applicator must be of sufficient length to place the cone within the upper stratum of interior atmosphere. Nozzleman should wear gloves to protect hands from scalding water that may come through opening. This type of applicator can be used to good advantage to attack fires within other concealed spaces.

(6) Where an attack must be made from the floor above as may be necessary in basements or similar spaces a cellar pipe



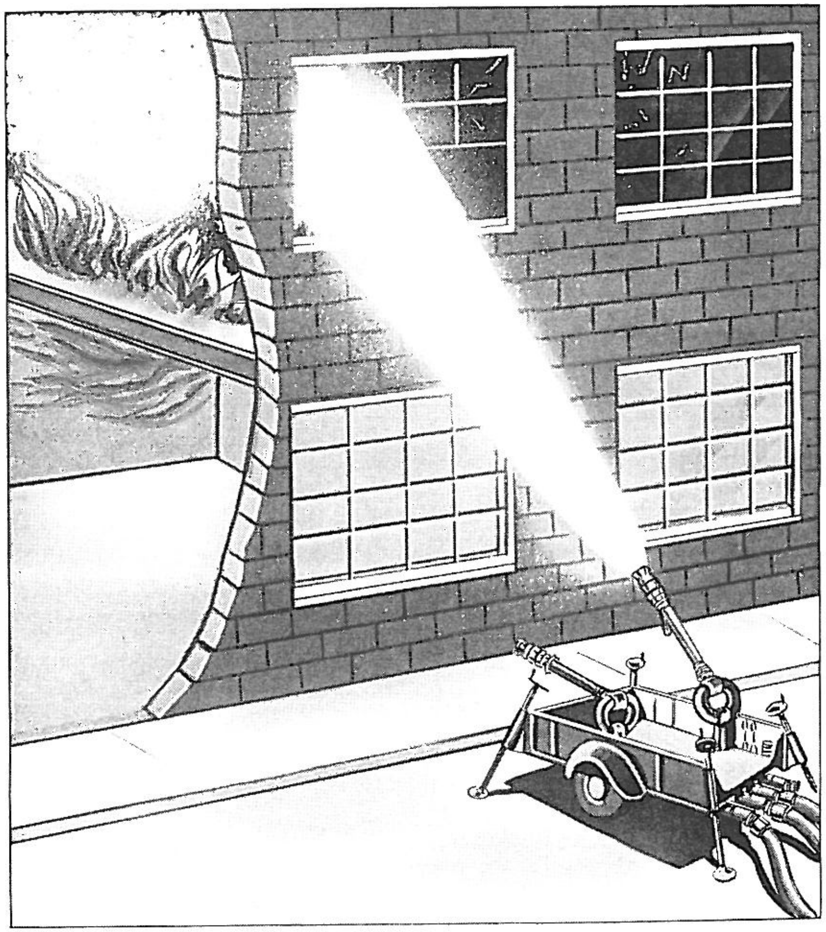
Straight applicator fitted with low-velocity fog head inserted through ceiling opening to attack fire in unfinished attic. Nozzleman should use gloves to protect hands from scalding water.

should be used. If the basement is a single atmospheric area with either an open stairway or elevator shaft that forms an exhaust opening, the point of injection should be located some distance from the exhaust opening. If the basement consists of individual sections, the point of injection must be within the involved section. The involved section may be determined by locating the "hot spot" on the floor above.

(7) A low-velocity fog head is designed to obtain maximum dispersion of water particles within a few feet of the head. A high-velocity nozzle is designed to project water for some distance before maximum dispersion occurs. A high degree of dispersion of water particles within the upper stratum of the interior atmosphere is an important factor in obtaining rapid heat absorption and a high percentage of conversion. If a high-velocity cone is directed toward a ceiling at a sharp angle the cone may pass through the upper stratum of atmosphere and strike the ceiling before sufficient dispersion of particles has developed. The degree of dispersion can be increased by slanting a high-velocity cone upward at a gradual angle. This allows the cone to expand and the water to separate into individual particles. Additional dispersion can be obtained by slight, brisk and continuous manipulation of the nozzle. Considerable skill and confidence are required to obtain a high degree of dispersion when using a high-velocity nozzle in an indirect attack.

(8) Should respiratory equipment be used by personnel entering a building upon completion of an indirect attack? This question must be answered by the officer directing operations. His decision should be based upon his estimate of the situation and in keeping with the policy of his organization.

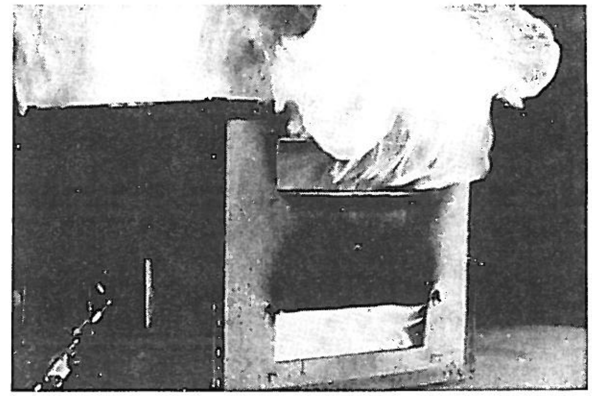
SUCCESSFUL employment of the indirect attack calls for courageous, intelligent, resourceful and competent leadership. Courage to employ this method of attack should be based upon knowledge and understanding of the natural laws and fundamentals presented in this text. Fire-fighting personnel should also have adequate knowledge and understanding of these natural laws and fundamentals together with the skill and confidence to perform the various operations in an



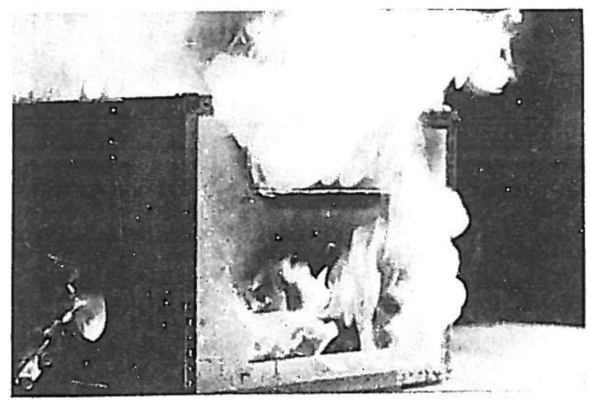
High-velocity fog cone from monitor unit projected through window opening of second floor. Large atmospheric areas may require greater volumes of water than can be projected by 1½-in. fog nozzles.

efficient manner. A certain degree of skill and confidence can be developed by practical and systematic training. Although adequate training is absolutely necessary, training alone will not provide these essentials; they are the natural product of trial and error on the fireground. Many mistakes will be made in early attempts but mistakes should be utilized as stepping stones to greater efficiency. Both skill and confidence will increase as successes are achieved on the fireground. This form of application and method of attack are so effective that mistakes can be made and yet the ultimate results are usually far better than can be achieved by the most skillful employment of solid streams.

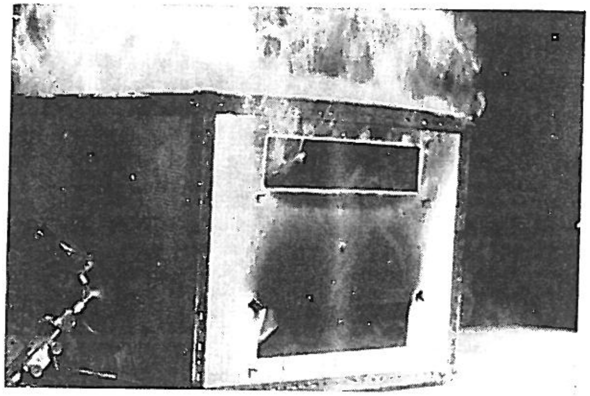
WHERE direct attack with fog nozzles is indicated, practice and experience will suggest the best attack technique for a given fire. In general, a 30-degree fog pattern is indicated for structural fires in order to provide effective reach of stream coupled with an effective water particle distribution pattern. Where the fire area is not deep, a wider fog pattern may be indicated in order to obtain greater coverage and prevent runoff of water striking opposing walls. Nozzles should be directed at an upward angle and the stream should be moved slowly enough through the heated area to permit effective heat absorption. Many cities are supplying 100 gpm fog streams with 1½-in. pumper lines at approximately 100 pounds nozzle pressure. In general, where possible fog should be applied at a rate sufficient to quickly remove abnormal heat. For example, other things being equal a 100 gpm fog nozzle operated for one minute would be more effective than a 50 gpm nozzle operated for two minutes because the generation of additional heat would be suppressed more quickly.



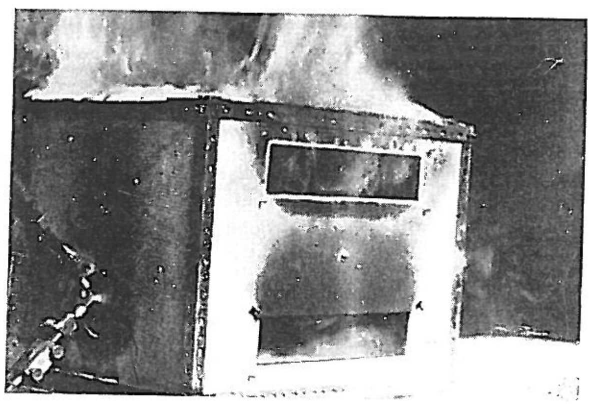
First of a series of six pictures demonstrating how a fog jet works to extinguish a fire in a confined room or space. This first view shows fuel burning briskly before the fog jet is applied.



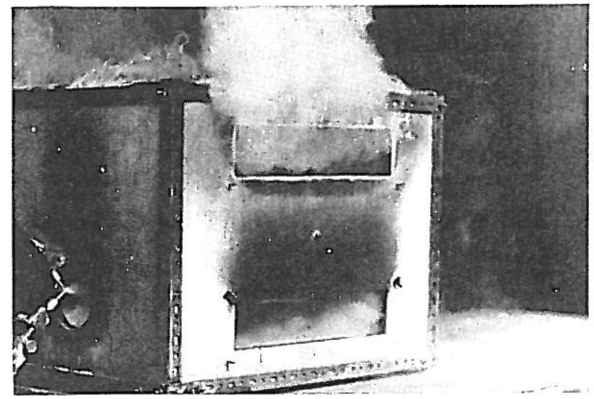
Second in a series of six pictures of fog (impinging jets at left) applied to a fire in a confined space. The experimental space is 4½ cubic feet, large enough to demonstrate what happens. First result is that smoke and combustible gases are driven out of the simulated windows where they mix with sufficient oxygen to burn freely.



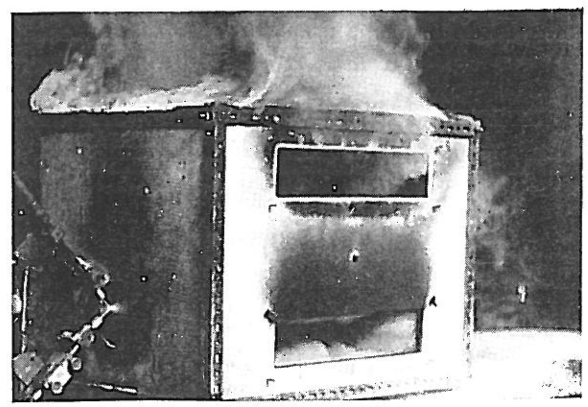
Third in a series of six pictures. The fog stream has caused flame in the space to collapse after one-half second.



Fourth in a series of six pictures taken after one second's application of a fog jet. Wisps of steam are beginning to appear from the windows of the simulated building.



Fifth in a series of six pictures taken 1¼ seconds after the first picture. Continued application of the fog jet shows increasing amount of steam coming from windows.



Sixth picture at 3 seconds. The flame has been extinguished and large clouds of steam (really condensing water vapor) have appeared on the outside of the building. The same sequence takes place when a fog jet is used on a building fire but this series of pictures shows the extinguishing effect clearly in its various stages.

Photos on pages 51-53 from "Fire Research 1952"; reproduced by permission of Her Britannic Majesty's Stationery Office (Crown copyright reserved)

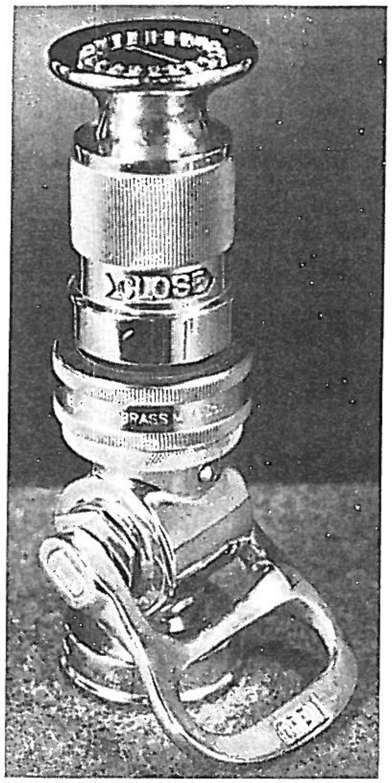
CHAPTER IV

EQUIPMENT

SINCE the introduction of the fog nozzle technique at Parkersburg and the publication of the first edition of Attacking and Extinguishing Interior Fires, considerable advance has been made in the development of fog nozzles for fire fighting. Nozzles are now on the market which combine features of stream pattern selection and shut-off or control valves. Nozzles are available in a large variety of volume classifications from 5 to 1000 gpm and from a number of manufacturers. Information regarding these nozzles is available in other publications of the National Fire Protection Association including *Fog Nozzle Studies* prepared by the NFPA Committee on Fire Department Equipment in cooperation with other agencies, and listings of nozzles are included in the NFPA Handbook of Fire Protection. Fire departments are urged to study the various products now available when making a selection directed to their own needs.

Many cities are making the 1½-in. line with fog nozzle their primary attack weapon on interior fires. Booster nozzles for 1-in. hose are used for small fires but even large cities are placing great reliance upon the 1½-in. fog nozzle for interior fires in structures having numerous rooms and partitions where it is difficult to maneuver 2½-in. lines. It has been found that the more mobile 100 gpm streams are effective even on advanced multiple alarm fires where it is desired to attack interior fires from numerous vantage points simultaneously.

Considerable experience has also been obtained with the operation of master fog streams. Where adjustable pattern fog nozzles are employed, the pattern may be adjusted toward straight stream as required to provide needed range and at the same time give a desired break-up of water particles. Where non-adjustable type large volume fog heads are employed, it is necessary to elevate or place the nozzle close enough to direct the fog into the heated area. Experiments have shown that adjustable fog streams have a range comparing favorably with large solid streams of the same volume when adjusted toward a straight stream. However, some difficulty has been experienced with loss of range of master spray streams from excessive break-up where nozzle pressures were considerably above that recommended by the manufacturer. One practice that should be guarded against is the tendency to adjust large fog nozzles to a straight stream pattern in order to gain a slight additional reach thereby losing the greater effectiveness of the recommended 30-degree fog. Company commanders should be instructed wherever possible to place the nozzles close enough to the fire area to bring them within effective range of 30-degree fog patterns. Use of fog nozzles on ladder pipes greatly facilitates the proper placement of fog streams. (See the Author's book: *Fire Fighting Tactics.*)



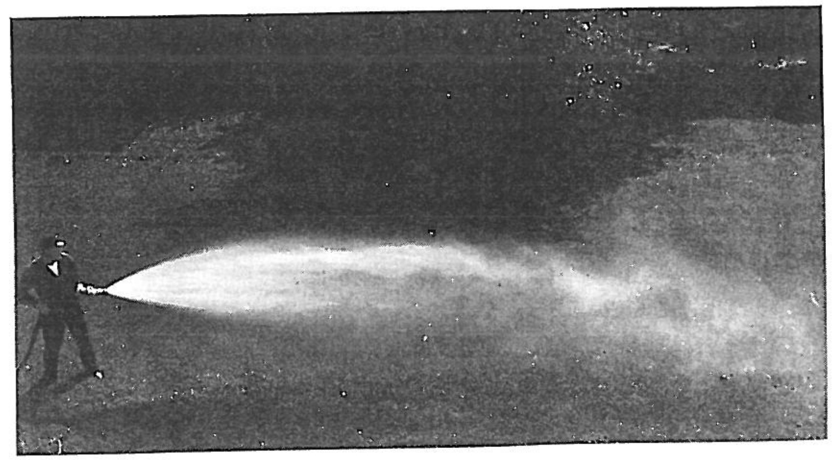
Elkhart Mystery Nozzle(205)

The equipment described in this Chapter has been used by the Parkersburg Fire Department while the author was chief. This equipment was not ideal but progress in the art of fire fighting can not await development of ideal equipment. This Department, by modification and improvision, provided its personnel with equipment which has enabled them to employ water, in the form of finely divided particles, effectively on the fireground.

The following nozzles are designed to project either a high-velocity cone of water particles or a solid stream:

This nozzle was used as an adjustable tip on 1½-in. standard shut-off nozzle valve (Wooster Brass), all threads are 1½-in. National Standard.

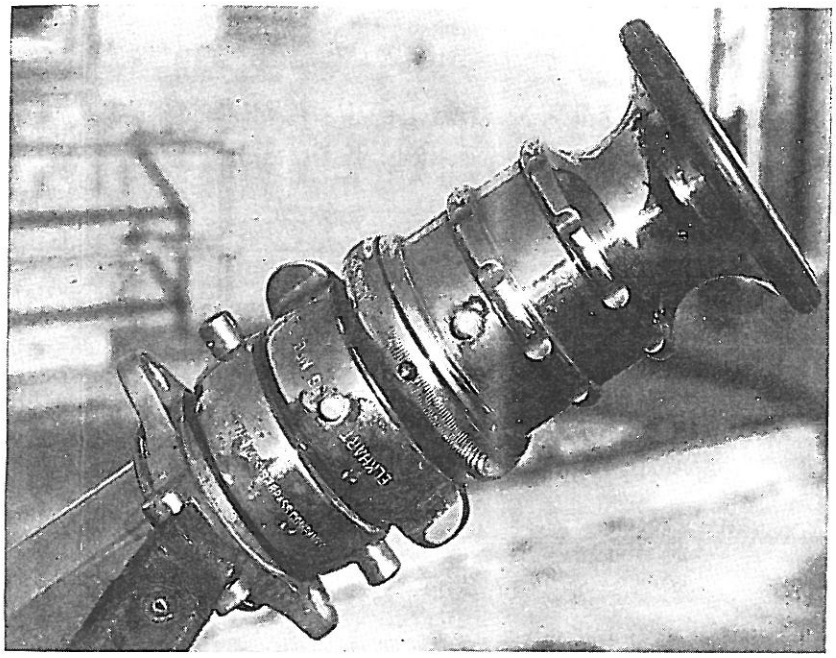
Shut-off nozzle enables nozzleman to project or discontinue fog cone without passing through solid stream or changing stream pattern. The Mystery nozzle was modified to prevent fog cone from being extended beyond 30° angle. When outer barrel is turned to open position this nozzle projects a 30° angle fog cone. This angle of discharge produces the maximum degree of fineness and reach. Nozzlemen are instructed to use only the 30° angle when projecting fog. Solid stream can be obtained by turning outer barrel toward closed position. Delivery volume at 100 psi nozzle pressure: fog cone — 65 gpm; solid stream — 60 gpm. Volume of solid stream can be reduced by turning



outer barrel toward closed position. Fog is produced by peripheral jet fitted with deflecting teeth.

Similar nozzles are now available having preset selected fog patterns and separate shut-off valves having full flow waterways. Such nozzles are capable of discharging 100 gpm or more through 1½-in. hose. It has been found that a standard nozzle valve from a 2½-in. hose nozzle equipped with 1½-in. threads on either side of the valve provides an excellent control valve for adjustable 1½-in. fog nozzles.

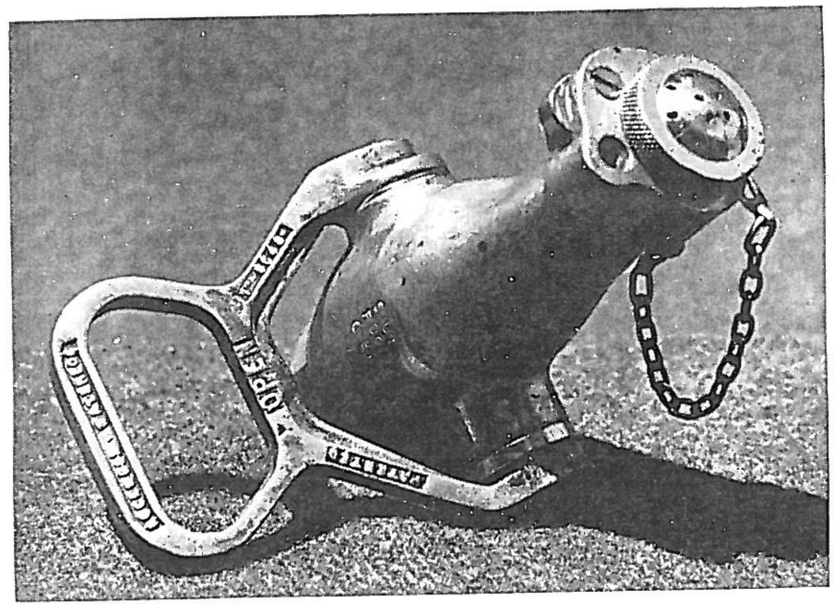
The Elkhart Mystery nozzle (L-200) is also used as an adjustable tip on 1½-in. standard shut-off nozzle. Modified to prevent fog cone from being extended beyond 30° angle. Delivery volume at 100 psi nozzle pressure: fog cone — 90 gpm; solid stream — 70 gpm. Volume of solid stream can be reduced by turning outer barrel toward closed position.



Elkhart Jumbo Mystery Nozzle (J-200)

The Jumbo nozzle is used as an adjustable tip on multiversal nozzles and ladder pipes. It can be modified to prevent fog cone from being extended beyond 30° angle or marked by spots brazed on base and outer barrel to indicate proper adjustment for projecting 30° angle cone. Raised spots shown on nozzle in photograph. Solid stream can be obtained by turning outer barrel toward closed position. Delivery volume at

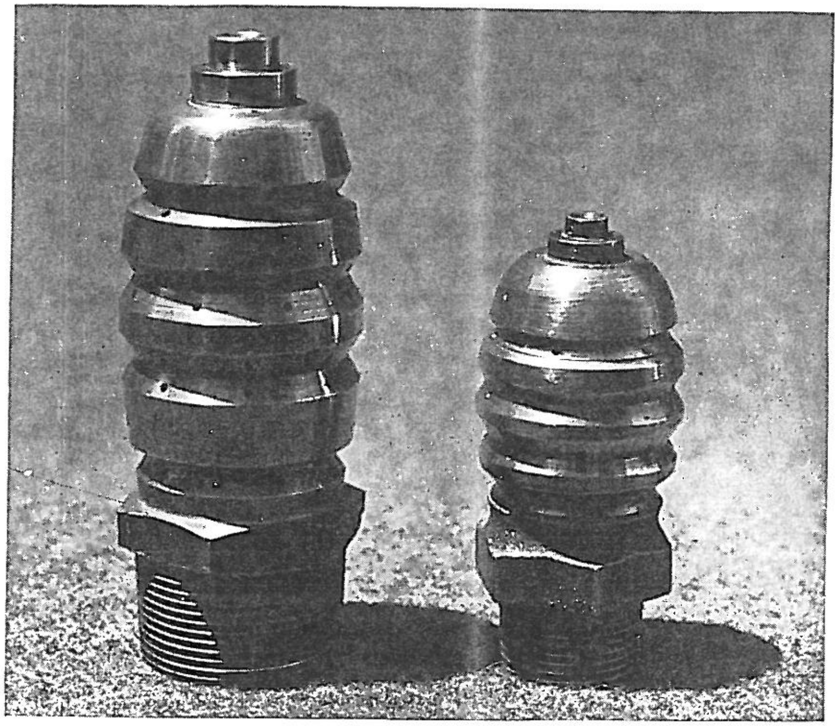
100 psi nozzle pressure: 30° angle fog cone — 425 gpm; solid stream — 350 gpm. At 125 psi nozzle pressure: 30° angle fog cone — 475 gpm; solid stream — 390 gpm. Volume of solid stream can be reduced by turning outer barrel toward closed position. Fog produced by peripheral jet fitted with deflecting teeth.



Rockwood All-purpose Booster Nozzle

Solid stream opening — ¼-in. Delivery volume at 100 psi nozzle pressure: fog cone — 18 gpm; solid stream — 18 gpm. Fog produced by impinging jets. An applicator may be attached to this nozzle to provide low velocity fog as shown on page 144. (See pages 62–63 for further discussion of applicators.)

The following fog heads are designed to project low-velocity cones of water particles and are used on cellar pipes and applicators:

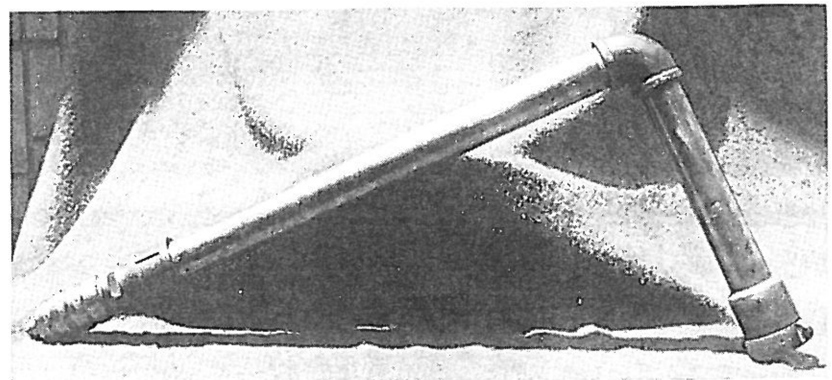


Navy Type Low-velocity Heads

LEFT: Navy type low-velocity head (Rockwood Sprinkler Company L-10A). Used on cellar pipes, projects only a low-velocity fog cone. Delivery volume at 100 psi nozzle pressure — 114 gpm. Fog produced by impinging jets.

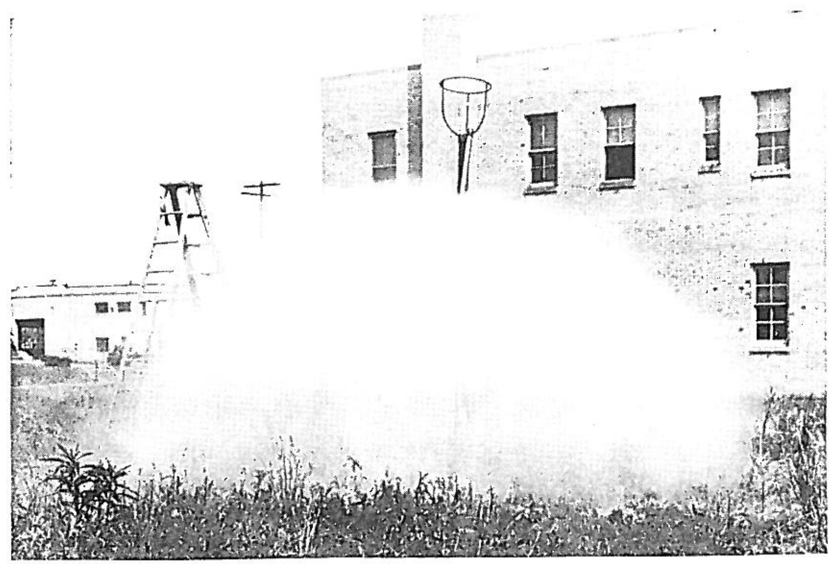
RIGHT: Navy type low-velocity head (Rockwood Sprinkler Company L-11A). Used on applicators and cellar pipes,

projects only a low-velocity fog cone. Delivery volume at 100 psi nozzle pressure — 54 gpm. Fog produced by impinging jets.

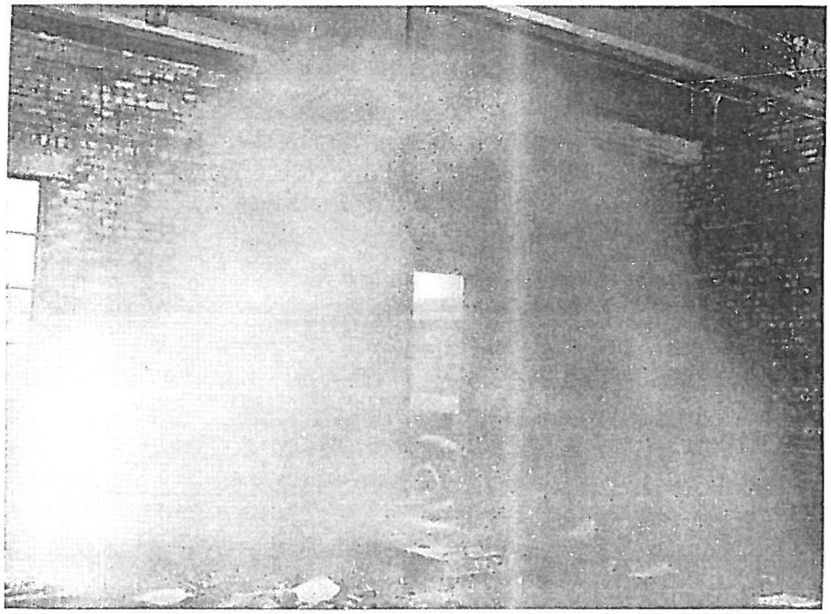


Cellar Pipe

This pipe is designed for use on 1½-in. hose. Consists of 1½-in. female coupling brazed to 1-ft. length of 1½-in. brass pipe, elbow, 2-ft. length of pipe, double female fitted with

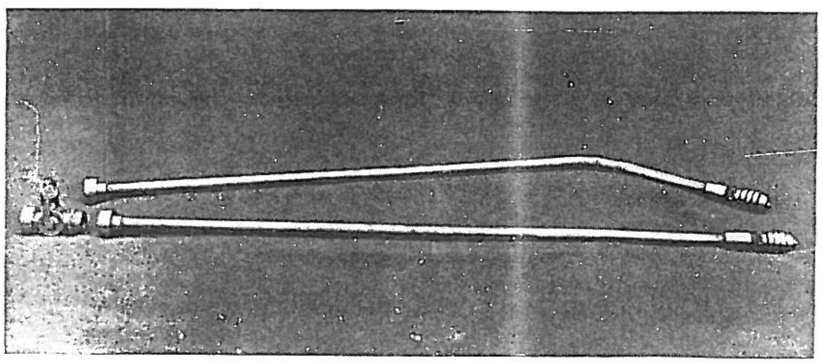


Showing Low-velocity Cone from Cellar Pipe Fitted with L-10A Fog Head.



Showing Low-velocity Cone from Cellar Pipe Fitted with L-11A Fog Head

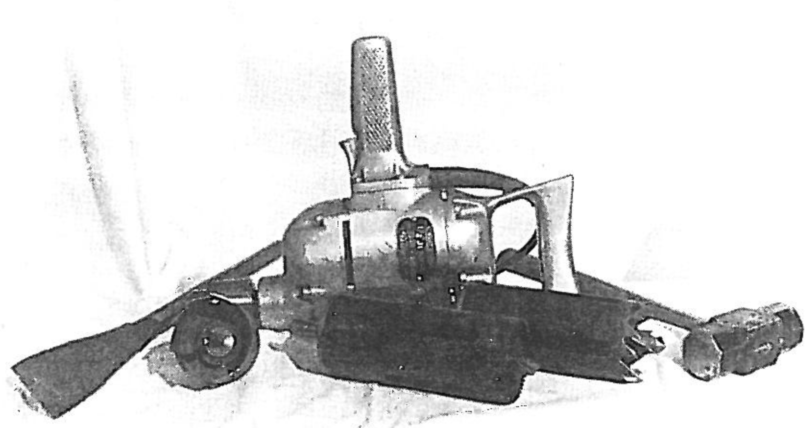
L-10A low-velocity head. Special strainer is fitted in pipe at intake opening. For smaller volume, this type of cellar pipe can be fitted with the L-11A low-velocity head. This pipe can be inserted through a 2½-in. diameter hole.



Applicators and Shut-off Nozzle

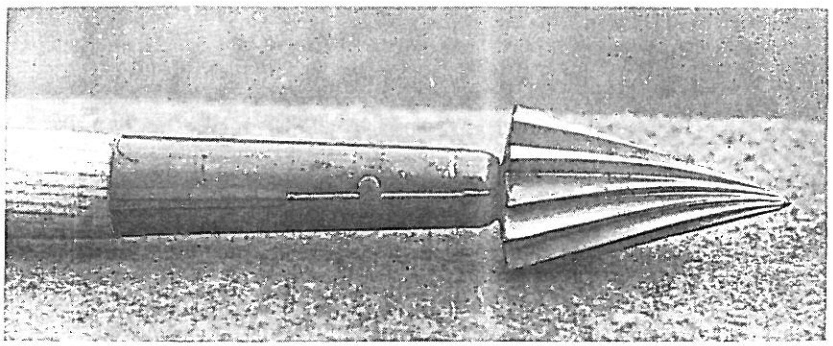
Applicator consists of 1½-in. NST female connection brazed to 5-ft. length of ¾-in. copper pipe, female connection for low-velocity head brazed to pipe, and a L-11A low-velocity head fitted with strainer. An applicator can be made in any convenient length and bent to desired angle. The 5-ft. straight applicator has proved very practical for attacking fires in unfinished attics and other concealed spaces. Applicator is always attached to shut-off nozzle. If line is equipped with a high-velocity nozzle and an applicator is needed, the high-velocity nozzle can be removed and applicator attached to shut-off nozzle.

The L-11 low-velocity head is also used on the conventional type of applicator, the 10-ft., 1-in. pipe, with head set at a 90° angle. These applicators are fitted with 1½-in. NST female connections.



Power-Driven Sawing Unit

Power-driven sawing unit used for sawing a 2½-in. diameter opening in wooden floor to insert cellar pipe. *Rear* — Black and Decker, ½-in., slow speed, power drill. *Extreme left* — chisel. *Extreme right* — hammer, these are used to remove floor covering to prevent clogging of saw teeth. *Left* — short saw bit made by Black and Decker, can be used to saw hole in light materials. *Center* — saw bit has teeth designed for cutting hole in light metals but has proved to be of little practical value. *Right* — saw bit has teeth designed for sawing hole through wooden floor and sub-flooring. This bit is made from 2½-in. oil well tubing; teeth were cut, set, and tempered for sawing wood, and is fitted with ⅜-in. mandrel. Drill can be operated from light circuit, power plant on apparatus, or portable unit. A 2½-in. diameter opening can be sawed through floor and sub-flooring in three to five minutes. Drill and attachments are carried on apparatus in special made canvas bag fitted with carrying straps.

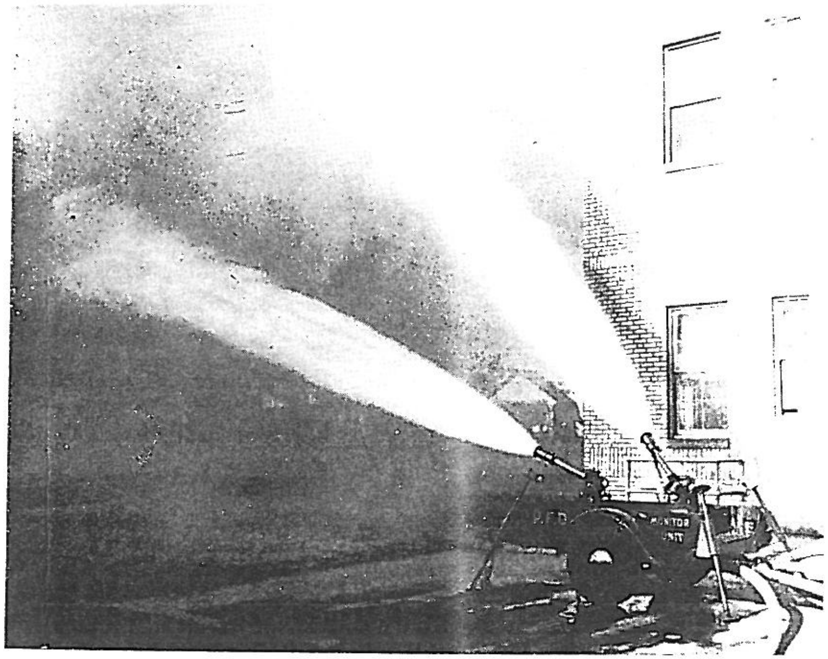


Plaster Reamer

The plaster reamer consists of 5-ft. wooden handle fitted with a 2-in. plumber's reamer. Used for cutting holes in plaster or similar materials. Makes a clean-cut opening of sufficient diameter for inserting applicator fitted with low-velocity head.

Monitor Unit

When the four stabilizing jacks on monitor unit are in place, the two Junior Multiversal (Akron Brass) nozzles can be operated at any angle. Elkhart Jumbo Mystery nozzles are used as adjustable tips. Each nozzle can be supplied by either two or three 2½-in. lines. Individual nozzles can be removed quickly from Unit and attached to window sill, parapet, or other location by using attachments carried on Unit.



Monitor Unit Projecting 30° Angle Cones

This photograph was taken the same afternoon as the previous photo. Lack of visibility is due to suspension of water particles in the atmosphere. Nozzle pressure is approximately 100 psi.

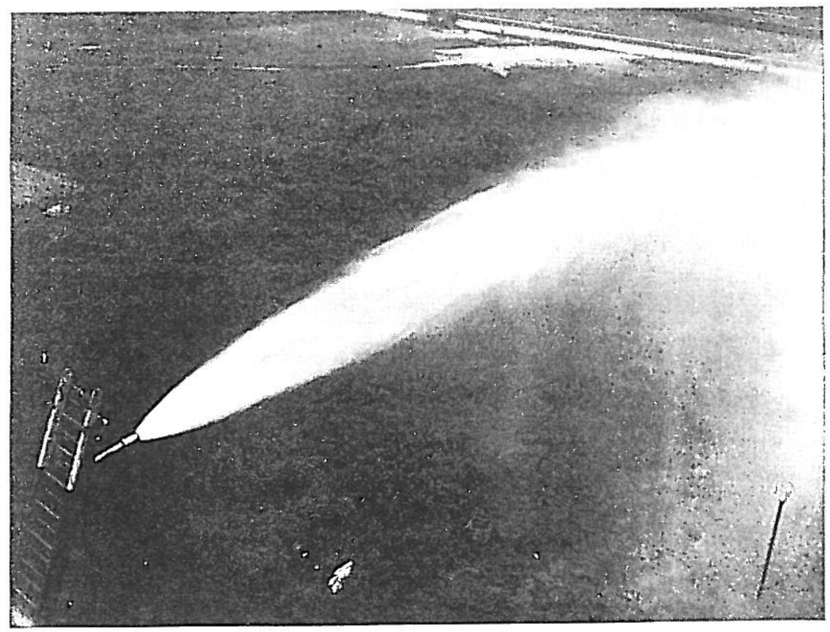
Showing Reach of Fog Cones

An effective cone is projected for a distance of over fifty ft. under still air conditions. These are 30° angle cones and the nozzle pressure is approximately 100 psi.

Monitor Unit Projecting Solid Streams

Nozzle pressure is approximately 100 psi. Each nozzle is delivering about 350 gpm.

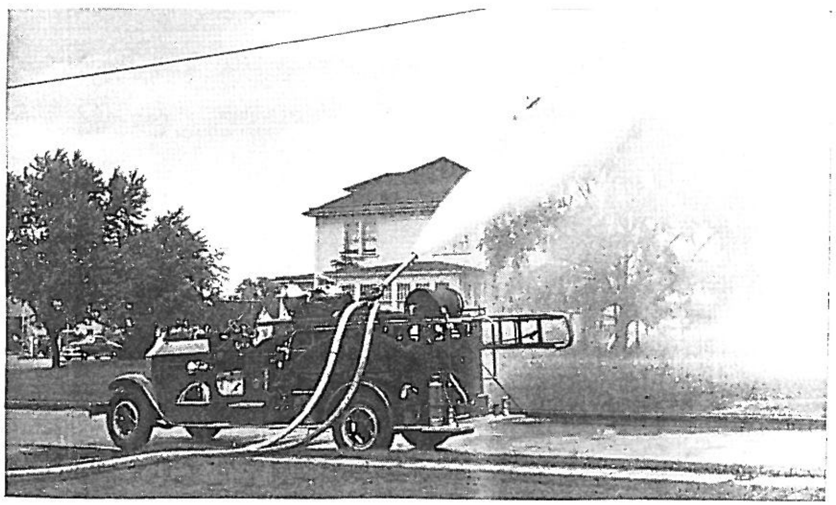
The use of 2½-in. hose for hand lines is unnecessary in this system of fire fighting. When larger volumes of water, than can be applied by 1½-in. nozzles, are required, multiversal nozzles and ladder pipes should be placed in service. The friction loss problem in using 1½-in. hand lines can be solved by limiting hand lines to a maximum of 200 ft. The use of 2½-in. hose can be limited to supply lines from hydrants to pumpers, from pumpers to 1½-in. hand lines, and from pumpers to multiversal nozzles and ladder pipes. Gradual replacement of 2½-in. hose with 3-in. hose fitted with 2½-in. couplings should be considered by any department that adopts this system of fire fighting.



Aerial Ladder Pipe 30° Angle Cone

Elkhart Jumbo Mystery Nozzle used as adjustable tip on ladder pipe. Supplied by 3-in. hose fitted with 3 2½-in. intakes.

The author wishes to emphasize that the equipment problem has not been solved. *This system of fire fighting offers a real challenge to inventors, designers and manufacturers of fire-fighting equipment.* They should approach this problem with a comprehensive understanding of the natural laws that govern the extinguishing action of water and its proper tactical employment on the fireground. Progress in the art of fire fighting demands practical equipment which will enable the fire service to utilize the vast extinguishing action of water more effectively in attacking and extinguishing fire.



Squad Truck

Grant Multiversal Nozzle (4 2½-in. intakes) mounted on Squad Truck projecting 30° angle cone at 100 psi nozzle pressure.

CHAPTER V

CASE HISTORIES

DURING the time the author was chief of the Parkersburg Fire Department detailed reports were compiled on all working fires including plans and sketches of the buildings involved as well as photographs taken by the Fire Department photographer. From these we have selected six "Case Histories" as examples of "indirect" fog application on interior fires in enclosed buildings. Examples of fog application on unconfined major fires are treated in the Author's book, "Fire Fighting Tactics." It is not claimed that in all fires an equally high degree of efficiency in heat transfer will be experienced, not only because fireground operations must be conducted in haste with the result that streams are not always applied in the most advantageous manner, but because in many cases the attack will be made before sufficiently excessive heat is present to obtain the full benefits of the indirect attack. Obviously where it is more feasible to make a direct attack upon the fire this should be done. Nevertheless, a thorough understanding of the principles of "indirect" application and heat transfer will make the fire officer alert to possibilities of obtaining maximum benefit from the water fog attack whether direct or indirect. The hotter the confined heat in the upper atmospheric area the more effective the conversion of water particles to steam.

CASE HISTORY NO. 1:

A building fire where plain water, in the form of finely divided particles, was used to attack and extinguish.

LOCATION OF FIRE: 2000 16th Street, Parkersburg, West Virginia.

TIME OF FIRE: May 31, 1949 — 8:50 P.M.

WEATHER CONDITIONS: Temperature — 71° F. Wind — calm. Humidity — 51 per cent.

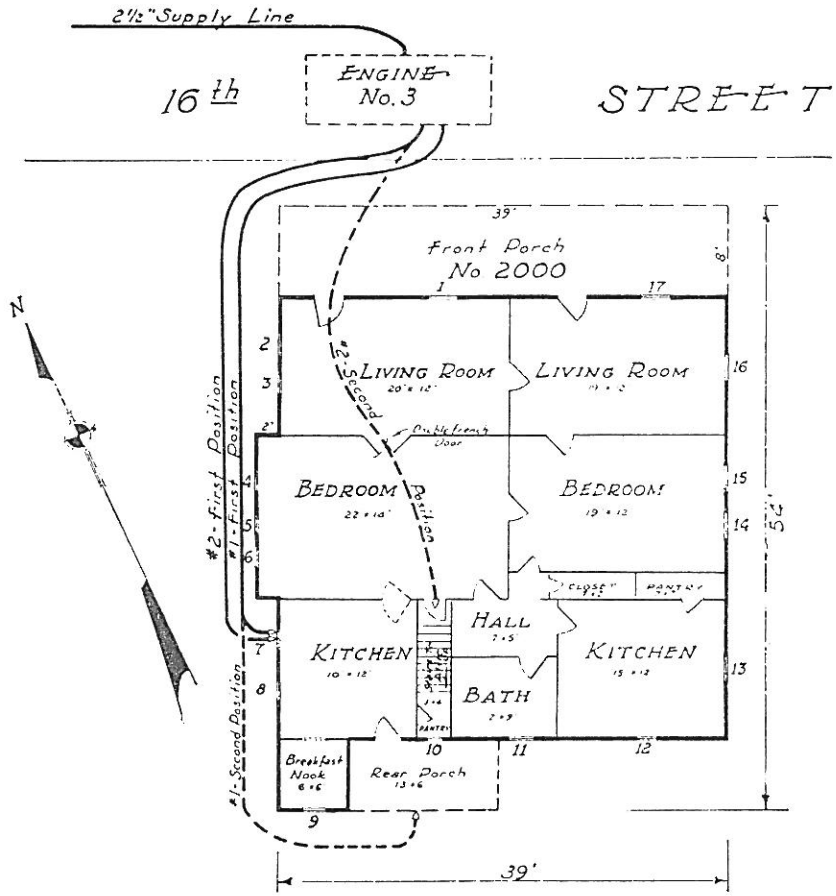
DESCRIPTION OF BUILDING: One-story frame dwelling (39 ft. x 38 ft.) with breakfast nook and enclosed rear porch (19 ft. x 6 ft.) extending beyond rear basement wall, concrete block foundation, gable type roof with ridge extending from front to

FRONT AND WEST SIDE OF DWELLING
2000 16th Street

rear, roof and sides of building covered with asphalt composition shingles. House constructed on sloping ground from front to rear with main floor front two ft. from ground and rear porch nine ft. from ground. Rear porch (13 ft. x 6 ft.) enclosed with wooden lattice work and without steps to ground level.

INTERIOR: Semi-finished basement (39 ft. x 38 ft.) without inside stairway. Two apartments on main floor consisting of three rooms each, small hallway and bathroom center rear. Semi-finished attic with stairway from rear of bedroom, west side apartment. Approximately two-thirds of attic area floored with tongued and grooved lumber. Open rafters except in front end of attic where the center section had been closed with corrugated cardboard on light wooden studding to provide a small bedroom. Doorway to bedroom was not fitted with door.

The ceiling height throughout the entire main floor was nine feet. All interior walls and ceilings were constructed of plasterboard nailed to wooden studding and joists.



EXPOSURES: East side — two-story frame dwelling located at a distance of 12 ft. West side — one-story frame garage consisting of four stalls located at a distance of 22 ft. There were no rear exposures.

INTERIOR LAYOUT: See diagram.

UNITS AND PERSONNEL RESPONDING:
- Engine company No. 3 — 2 firemen
- Squad company — 2 firemen
- Additional personnel — Chief of Department, 3 firemen

OCCUPANCY AND CONTENTS: West side apartment was occupied by owner and each room was completely furnished.

WEST SIDE OF DWELLING

Windows from left to right — three bedroom and two kitchen windows. Initial attack was made through fourth window opening from left.

Blinds and curtains were on all windows of main floor and attic except small window in pantry. The rear porch contained furniture and other combustibles. The walls and ceilings of kitchen and breakfast nook were painted. The living room and bedroom had been papered several times without removing old paper. East side apartment was furnished but was unoccupied at time of fire. Attic bedroom was furnished and the remainder of the attic space contained furniture, clothing and other combustibles.

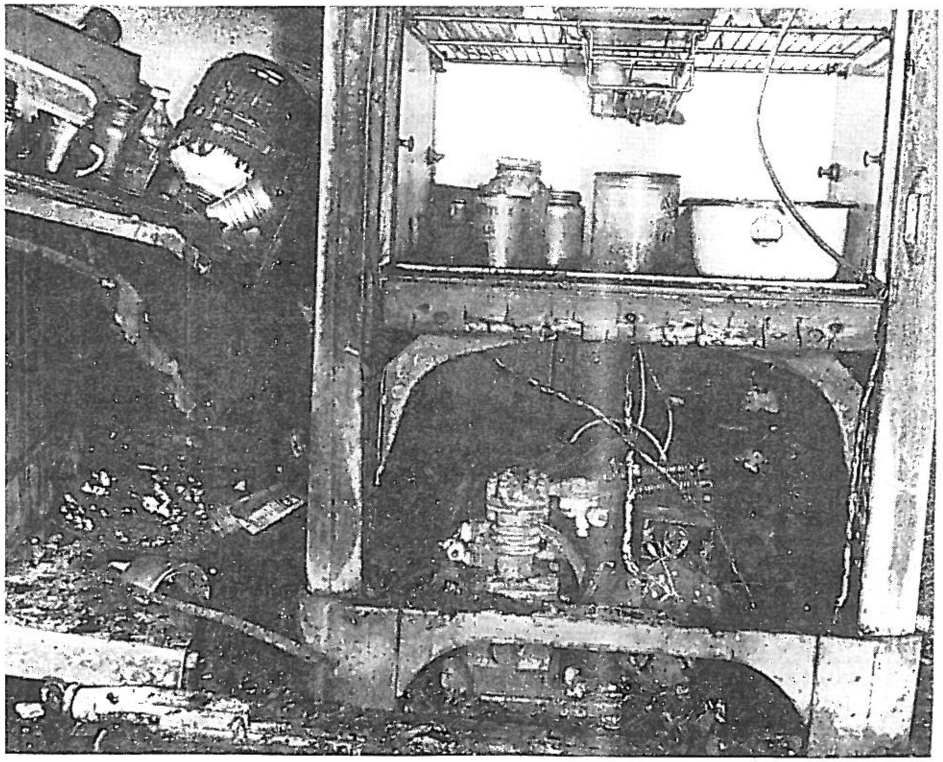
CAUSE OF FIRE: The refrigerator in kitchen of west side apartment was located against east wall next to doorway to pantry. The electric motor had been causing trouble but the owner

REAR VIEW OF DWELLING

had been unable to contact the service man. After the fire was extinguished a penny was found behind the burned-out fuse in the circuit which provided power to the kitchen. The fire was caused by refrigerator motor overheating and igniting combustibles.

CONDITIONS EXISTING AT TIME OF FIRE: The lady, who owned the house and occupied the west side apartment, had closed and locked the apartment at 7:00 P.M. and had gone to a club meeting. A neighbor discovered the fire and phoned the Fire Department, the alarm was received at 8:50 P.M.

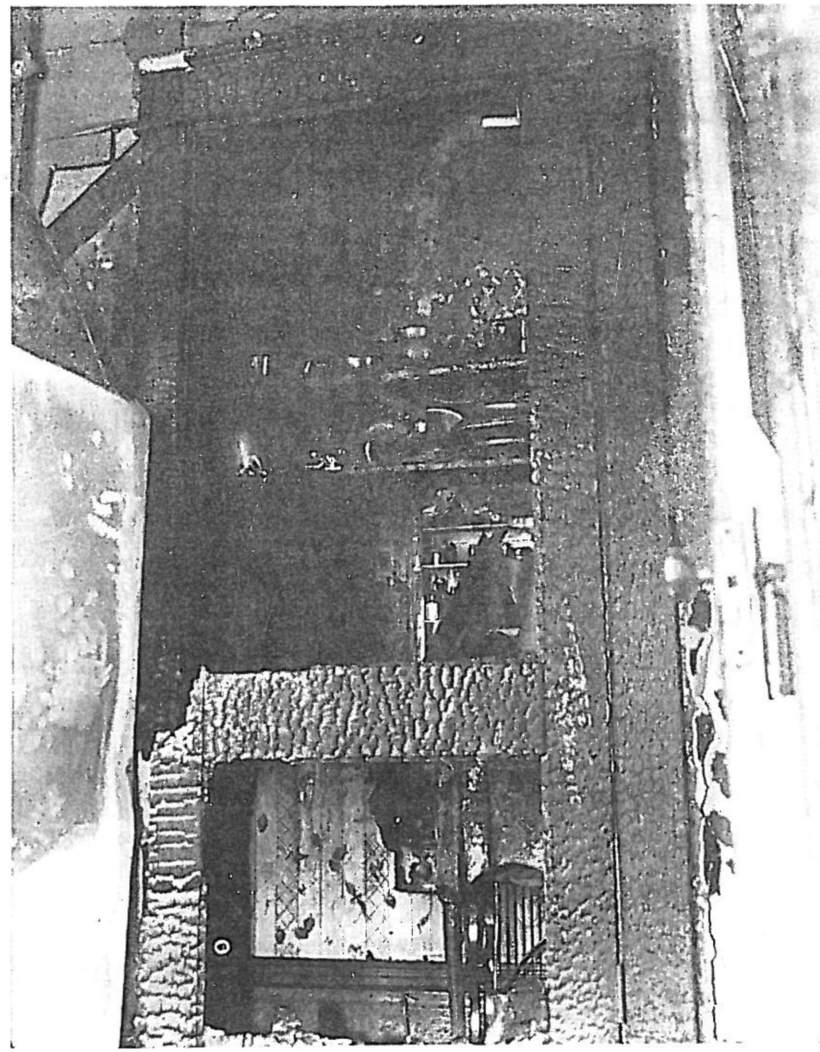
At the time the owner closed her apartment, it appears that all windows were closed except the two rear windows in attic. All exterior doors were closed. The single door between living



KITCHEN — WEST SIDE APARTMENT
Showing refrigerator and motor where fire started.

room of west side apartment and living room of east side apartment was locked and sealed with felt. The two center sections of French doors between the living room and bedroom, west side apartment, were open. The single door between bedroom of west side apartment and bedroom of east side apartment was locked and sealed with felt. The swinging door between bedroom and kitchen, west side apartment, was in a semi-open position due to the presence of a throw rug on floor. The door between kitchen and pantry, west side apartment, was closed. The remainder of the interior doors throughout the house were closed.

CONDITIONS UPON ARRIVAL OF ENGINE NO. 3: The entire kitchen, breakfast nook, pantry and rear porch of west side



PANTRY AND BURNED-OUT DOOR
Upper left within pantry shows under-section of stairway to attic.

apartment were involved in fire. The west side apartment and attic were heavily charged with smoke. The door between kitchen and pantry and the door from kitchen to rear porch were burned out. All windows were intact except the following: upper panes of rear window of breakfast nook, small

KITCHEN — INTERIOR VIEW

Showing door to bedroom which was in semi-opened position during fire.

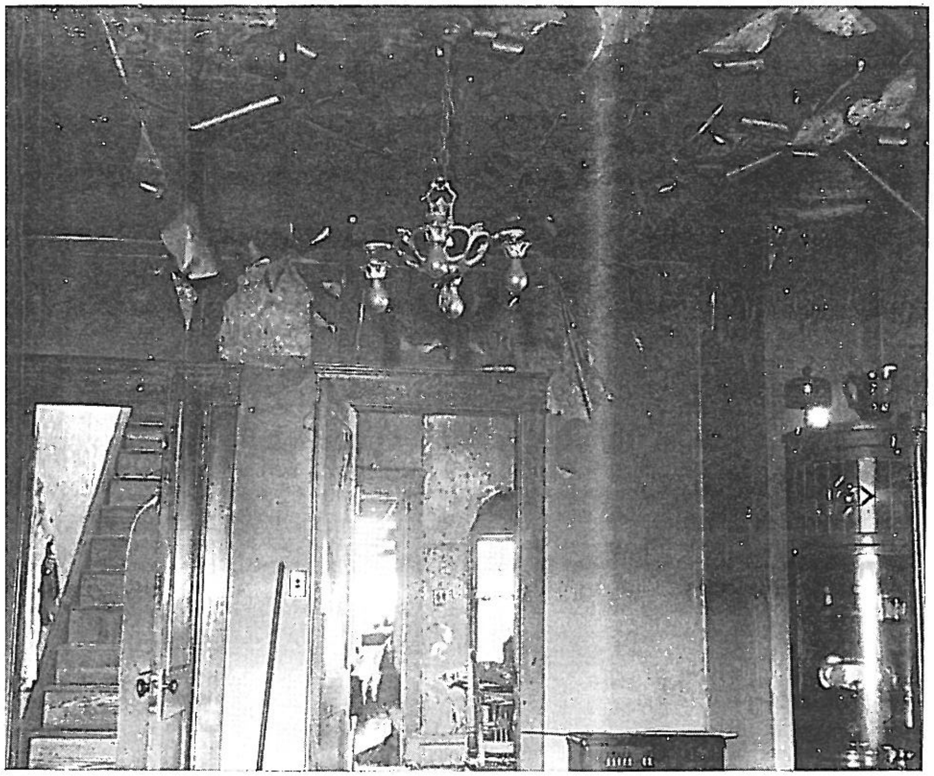
pantry window which opened onto rear porch and some of the panes in two rear windows of attic.

ATTACK AND EXTINGUISHMENT: Engine Company No. 3 laid supply line from hydrant at Park Avenue and 16th Street and took position in front of involved house. The "ready line" (200 ft. 1½-in. hose equipped with all-purpose nozzle) was advanced along west side of house to position shown in diagram. It appeared that the area of major involvement consisted of the kitchen and breakfast nook of west side apartment and the decision was made to attack through kitchen window

next to bedroom. A ladder was placed and the nozzleman broke lower pane of window. He directed a cone of water particles through window opening slanting it upward toward ceiling of kitchen. Immediately there was a violent expulsion of smoke followed by a mixture of smoke and condensing steam. The entire house was enveloped in a cloud of smoke and condensing steam. Injection of water was continued for approximately one minute from this position. This line was then withdrawn and shifted to rear of house to attack the exterior fire involving rear porch and asphalt shingles. Number 2-line equipped with a 65-gpm nozzle was advanced to position at kitchen window and continued the attack until there was a noticeable decrease in the volume of condensing steam coming from the house. During this period, the exterior fire had been extinguished and a ladder had been placed to rear porch. Number 1-line was advanced to rear porch and completed the extinguishment of remaining fire on porch. Number 2-line was taken from position at kitchen window and moved to front porch. The front door of west side apartment was forced and this line was advanced through living room into bedroom. No fire or smouldering materials were found in either of these rooms.

The nozzleman was equipped with all-service mask but found the smoke and condensing steam in these rooms of insufficient density to interfere with visibility. Atmospheric temperature and humidity were sufficient to cause slight physical discomfort. The door to attic stairway was opened and line was advanced into attic. No fire or smouldering materials were found in attic although it was evident that surface burning had involved combustibles located in rear section of attic. The concentration of smoke and condensing steam was insufficient to interfere with visibility but the degree of atmospheric temperature appeared to be higher than it was on first floor.

The plasterboard on the ceiling of the kitchen and breakfast nook was damaged to an extent which necessitated its removal. Charred spots and smouldering embers were found on some of the joists. The insulation of the refrigerator was smouldering and producing smoke. It was necessary to open the top and sides to effect extinguishment of the insulation



BEDROOM — WEST SIDE APARTMENT

Left — stairway to attic showing undamaged coat hanging on door. Right — doorway to kitchen.

which consisted of sheets of corrugated paper. A jiffy hose unit, equipped with control nozzle and ⅛-in. tip, was attached to kitchen faucet and used in overhauling the kitchen, pantry, breakfast nook and rear porch. A few gallons of water were used to complete extinguishment of smouldering materials.

ADDITIONAL FACTS AND OBSERVATIONS: This fire was discovered about 8:40 P.M., at that time the fire had not broken through to the outside atmosphere. The fire was discovered as the result of neighbors smelling the odor of smoke and upon investigating discovered smoke seeping from the house. One of the neighbors observed a bright glow within the kitchen of west

side apartment. Between the time of discovery and the arrival of Engine No. 3 the fire burned through to the outside.

Upon discovery of the fire one of the neighbors, thinking the owner was trapped within the house, attempted to force the front door of the west side apartment. Upon being advised by another neighbor that there was no one at home, no further attempt was made to gain entry.

There was considerable evidence of surface burning having taken place at several points in the rear section of attic. Several small charred spots were found on roof sheathing above kitchen of west side apartment and over attic stairway. A large wooden clothes press located ten ft. from rear window of attic was scorched badly at the upper level. A light paper box located on top of press had burned together with its contents of loose paper, only the bottom of the box and ashes remained. Metal objects on top of a desk located about six feet from rear wall of attic had been heated to a degree that had melted the solder and allowed the pieces to separate. Sections of the curtains and blinds on rear windows of attic had been destroyed by burning. Clothing hanging in the rear section of attic appeared to have been involved in flame. Insulation of electric wiring throughout the attic had melted.

In the bedroom of west side apartment, paper on the wall and ceiling next to the kitchen had come loose and was hanging in strips. It appeared that some of this paper near the kitchen doorway had burned. Antique beer steins on top of a cabinet had been heated to a degree that caused the pewter lids and lead parts to melt. This cabinet was located in the northwest corner of the bedroom approximately fifteen ft. from kitchen doorway.

Shrubbery located in rear of the house was badly damaged by radiant heat. A limb of a cherry tree, which was located at a distance of 35 ft. from rear of house, was scorched.

No attempt was made to ventilate the house by conventional methods until after the line had been advanced into attic, then doors and windows were opened to facilitate the dissipation of remaining smoke and to reduce the atmospheric temperature. There was a light film of moisture on bed clothing and other materials which were located at the lower level in bedroom and living room of west side apartment. This is believed to have been caused by water particles being carried into these rooms through the doorway opening by strong atmospheric currents generated within the kitchen by rapid expansion of water into steam and also from condensation which occurred within these rooms.

There was no smoke discoloration to the ceiling and walls of the bathroom, hallway and the rooms of the east side apartment. There was a light concentration of smoke at the upper level of these rooms when entry was made.

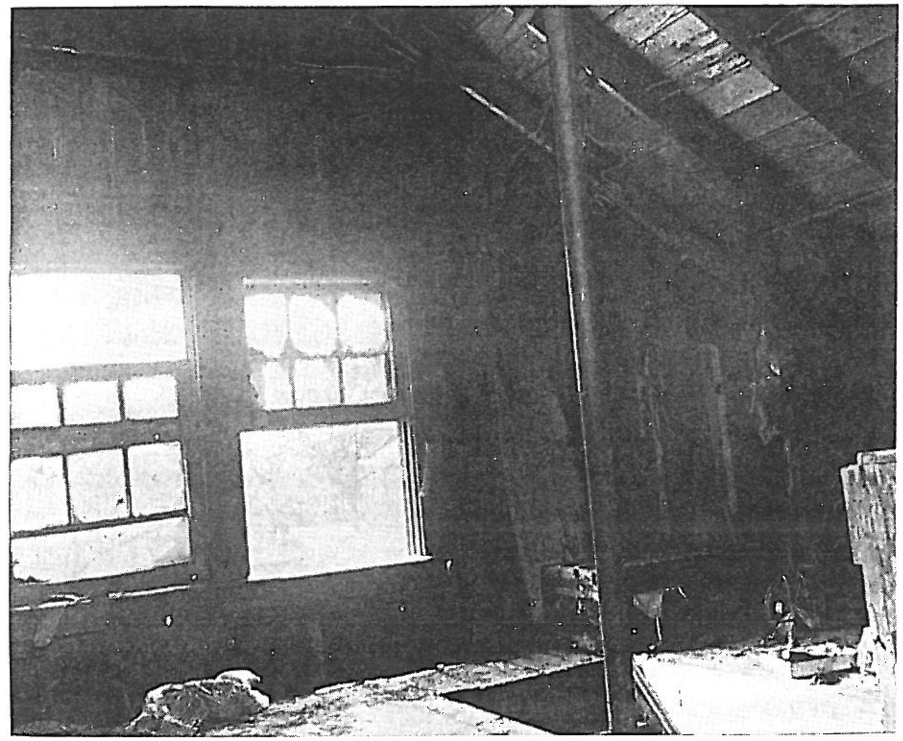
The pump operator maintained a pump pressure throughout the fire which was sufficient to provide a nozzle pressure of approximately 100 pounds per square in. The flow of water particles from the all-purpose nozzle used on the No. 1-line was approximately 54 gpm and from the nozzle used on the No. 2-line was approximately 65 gpm. Both of these nozzles were of the high-velocity type.

VOLUME OF WATER USED: Although it is impossible to determine the exact number of gallons of water used, all information and individual estimates indicate that the total volume was less than 200 gallons. Considering the nozzle flows and the time element this appears to be a very liberal estimate. The entire volume, except a few gallons used in overhauling, was applied in the form of water particles. The only water that remained in liquid form within the house was less than five gallons which was confined to the floor of kitchen and a few square feet of floor space in bedroom next to kitchen doorway. The damage to building and contents was caused by combustion, heat, smoke and forcing of the front door; there was no water damage

VALUES AND INSURANCE:

Adjuster's estimate as to value of building	$8,500.00
Adjuster's estimate as to value of contents	3,500.00
Insurance on building	3,000.00
Insurance on contents	1,200.00
Adjusted loss paid on building	2,285.16
Adjusted loss paid on contents	1,200.00
Uninsured loss on contents	800.00
Total Loss	$4,285.16

There was no loss to exposed buildings.



INTERIOR VIEW OF ATTIC
Showing two rear windows and stairway.

DISCUSSION: The atmospheric area from which this fire could draw oxygen consisted of the kitchen, breakfast nook, bedroom and living room of west side apartment. The gross atmospheric volume of these rooms amounted to approximately 6,300 cubic ft. When the fire burned through the pantry door approximately 100 cubic ft. were added to this area. Deducting 15 per cent as the estimated space occupied by contents there remained a net atmospheric volume amounting to approximately 5,400 cubic ft. This volume of air together with seepage from outside this area provided the necessary percentage of oxygen to support combustion until the fire effected an opening to the outside atmosphere.

It appears that this fire had been burning for a period of time previous to its discovery and the oxygen content within the bedroom and living room had been reduced to a percentage insufficient to support flame production. When the fire did effect an opening to the outside atmosphere, flame production within the kitchen, breakfast nook and pantry consumed the oxygen from the incoming air at such a rapid rate that the oxygen percentage within the bedroom and living room remained below the percentage necessary to support flame production. There was no exhaust outlet from these rooms and this also prevented air from entering these rooms by way of kitchen doorway. The indicated temperature at the upper level within both these rooms was far above the ignition temperatures of the available fuel. The fuel, due to its heated condition, was in a state of readiness to ignite and burn had the necessary percentage of oxygen become available. If the attempt by a neighbor to force the front door had been successful, there is every reason to believe that flame production would have involved both the living room and bedroom.

It is estimated that a total volume of approximately 125 gallons of water were used in the two attacks made through kitchen window and approximately 75 gallons used to extinguish exterior burning. Based upon 90 per cent vaporization, the 125 gallons applied within the kitchen would have produced approximately 25,000 cubic ft. of steam. The total net atmospheric volume of the west side apartment and the attic amounted to about 11,000 cubic ft. The volume of steam generated within the west side apartment was sufficient to have effected two complete changes of atmosphere within west side apartment and attic.

THERE are several salient features in connection with this fire which deserve careful consideration. They are as follows:

(1) Surface burning within the attic was extinguished without any water being applied directly to the involved materials.

(2) The firemen reported that the bedroom and living room of the west side apartment and also the attic were heavily charged with smoke at the time of their arrival. This condition is verified by the smoke discoloration which was found on the walls and ceilings. Yet when entry was made, the smoke was of insufficient density to prevent fair visibility.

(3) There was positive evidence that the degree of temperature at the upper level within the living room, bedroom and attic was far above the ignition and burning temperatures of the available fuel when the initial attack was made. Within a period of minutes the atmospheric temperature was reduced to a degree which permitted the firemen to enter and operate within these spaces. The temperature of the fuel had been lowered to a degree which was less than its ignition and burning temperatures. This cooling action was accomplished without any direct application of water within these spaces.

The following is a brief theoretical review of what occurred within this house from the time of the initial attack until entry was made by way of front door:

During the initial attack, water particles were converted into steam as rapidly as they came into contact with the heated materials. The rapid expansion of water into steam created an atmospheric turbulence throughout the west side apartment. This caused water particles to be carried through the open doorway into the bedroom and living room and to be distributed throughout these two rooms. These water particles contacted the surface of heated materials and were converted into steam, thereby cooling the heated materials. The steam generated within the west side apartment displaced a major part of the original atmosphere which consisted of heated smoke. During the second attack, this same action continued until the surface temperature of the materials was reduced to approximately 212° F., the boiling point of water. At this time, a major part of the atmosphere within the west side apartment and attic consisted of steam. Due to the reduction of interior temperature, steam started to condense and cool air from the outside atmosphere entered filling the void created by the process of condensation. This action continued until the process of condensation ceased. At this time, the atmosphere within the west side apartment and the attic consisted of normal air and a very limited amount of smoke. The oxygen content of the interior atmosphere was sufficient to support human life and flame production but flame production did not occur because the combustibles had been cooled to a degree lower than their ignition and burning temperatures.

In the burning of ordinary combustibles, flame production ceases when the oxygen content of the surrounding atmosphere is reduced to approximately 15 per cent. In an atmosphere consisting of a large percentage of steam, the oxygen content is less than 15 per cent and flame production cannot occur. The atmosphere within the bedroom, living room, and attic consisted of a high percentage of steam from the time of the initial attack until the combustibles were cooled to a degree lower than their ignition and burning temperatures. It is believed that unvaporized particles are carried by the steam and that steam follows the same channels through which heated smoke escapes from the building. This appears to account for the cooling and extinguishing action effected within the attic.

CONCLUSIONS:

1. The most practical and effective method of controlling and extinguishing this type of fire is by the proper application of the necessary volume of water in the form of finely divided particles.

2. The water particles should be projected upward into the overhead within the area of major involvement. The area of major involvement in this fire was within the area consisting of the kitchen, breakfast nook and pantry.

3. It is possible to displace a heated and contaminated atmosphere within a confined space by injecting a sufficient volume of water in the form of finely divided particles providing the degree of temperature and the volume of heat within the space is sufficient to convert the water into steam. This provides a safe, rapid and effective method of ventilating confined spaces which are heated to a high degree and are heavily charged with smoke.

4. Under the conditions set forth in the preceding conclusion, it appears that the following results are produced:

(*a*) That surface cooling of heated materials is effected throughout the area from which the atmosphere is displaced. This results from water particles being carried beyond the range of their original velocity in atmospheric currents which are generated by the rapid vaporization of water.

(*b*) That the surface temperature of the heated materials will be reduced to approximately 212° F., the boiling point of water.

(*c*) That surface burning will be extinguished but deep seated smouldering will continue.

This case history was prepared by Lloyd Layman while Chief of the Parkersburg Fire Department. The photographs were taken by H. W. Muhlmann, Department Photographer. The diagram was prepared by the City Engineer's Office. The adjustment of the loss and estimates of uninsured loss were made by Mr. Joe C Davis, Branch Manager, Insurance Adjusters, Parkersburg, West Virginia.

CASE HISTORY NO. 2:

A building where both plain and treated water, in the form of finely divided particles, were used to attack and extinguish.

LOCATION OF BUILDING: 645 Madison Avenue, Parkersburg. W. Va.

TIME OF FIRE: September 12, 1949 — 7:51 P.M.

WEATHER CONDITIONS: Temperature, 71° F. Wind, 6 mph from SE. Humidity, 70 per cent.

DESCRIPTION OF BUILDING: Two-story frame dwelling (36 ft. x 50 ft.); exterior walls — clapboard; roof — gable type with main ridge extending from front to rear and an auxiliary ridge extending from right to left side of house ten ft. from rear exterior wall, left front section of roof — cupola type, entire roof covered with two layers of asphalt composition shingles. This house was old and the roof and upper floor framing was constructed of light members (2 in. x 4 in.).

INTERIOR: FIRST FLOOR consisted of three rooms and hallway with open stairway from hallway to second floor and enclosed stairway from kitchen to second floor.

SECOND FLOOR consisted of four rooms, bath and hallway with stairway from hallway to attic room under cupola and stairway from hallway to main section of attic.

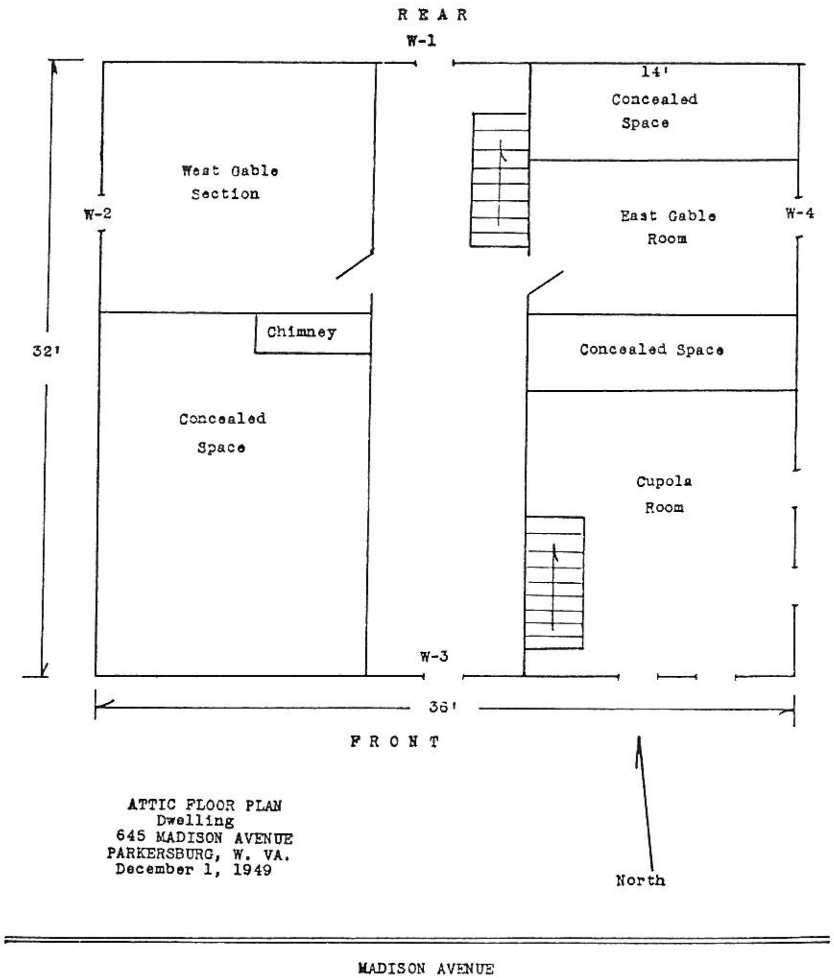
ATTIC: Single room (14 ft. x 15 ft.) located under cupola section of roof without opening to main section of attic. Main attic section consisted of center room (8 ft. x 32 ft.) extending from front to rear, stairway from second floor in east rear corner, single doorway to east room and single doorway to unfinished space, west gable section. Small room (8 ft. x 14 ft.) located in east gable section. The rooms were floored with tongued and grooved lumber, walls and ceiling were constructed of plaster on wooden lath and studding. Ceiling height was six ft. The west gable section was unfinished, a few boards had been laid on the joists to provide space for storage of discarded furniture and other combustibles. The main room had two small windows, one front and one rear, east side room had

REAR AND WEST SIDE OF DWELLING
645 Madison Avenue. Left to right — rear attic window, west gable window.

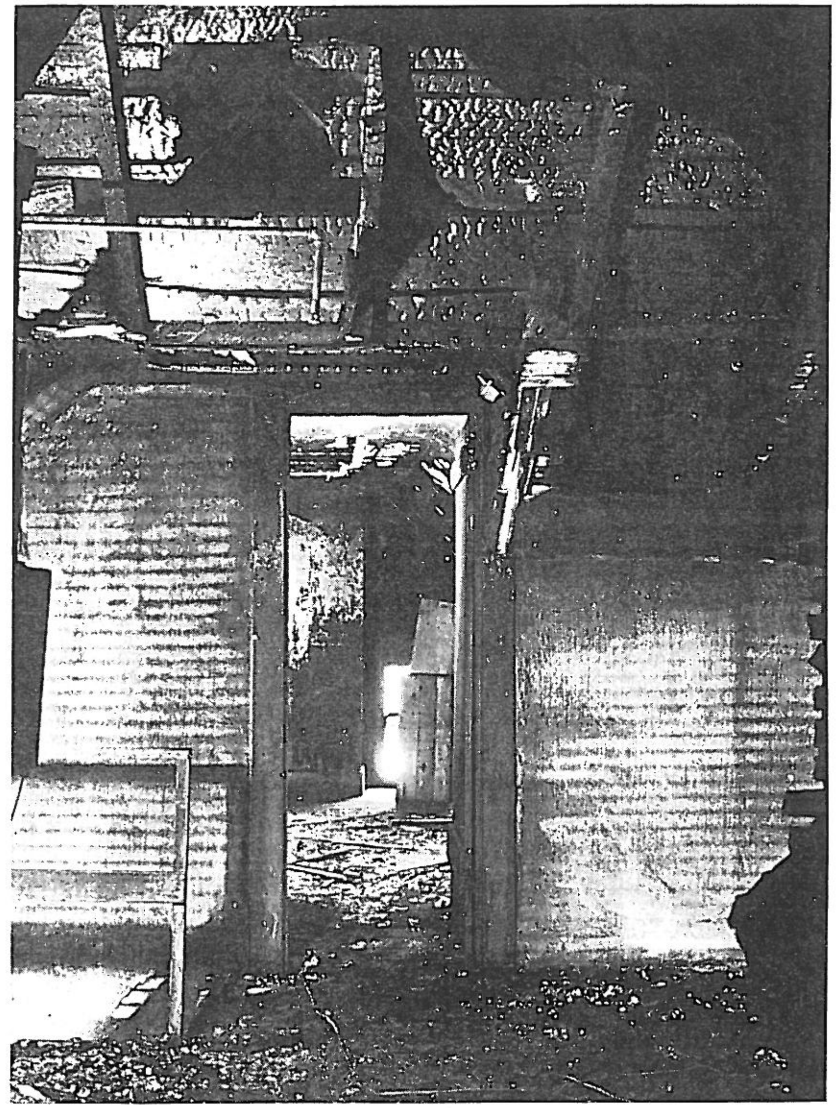
a small window at east end, and the unfinished west side space had small window in gable. The entire space between the roof and ceiling of the main room and the east side room opened into the unfinished west gable section.

EXPOSURES: Rear — two-story brick dwelling located at a distance of 12 ft. There were no other exposures.

OCCUPANCY AND CONTENTS: This house had not been occupied for a period of time and the only contents consisted of some discarded furniture and other combustibles located in the unfinished west gable section of attic.



CAUSE OF FIRE: During the period which this house had been unoccupied, the main electric switch had been disconnected. During the day on which the fire occurred, a crew of painters had started to work painting some of the rooms on the first and second floors. They closed the main electric switch in order to provide electric current for lights. When they quit work at 5:00 P.M. they disconnected the main switch. It appears that the fire started in the space between the roof and ceiling of the main attic room at a point about ten ft. from rear wall. The



EAST GABLE ROOM

Shows stairway opening, doorway to east gable room, charred rafters and sheathing.

only possible source of heat at this location would have been from defective wiring.

CONDITIONS EXISTING AT THE TIME OF FIRE: The painters quit work at 5:00 P.M. and left the kitchen door open to allow paint fumes to dissipate. Persons living in this neighborhood had observed the presence of smoke for an hour or more previous to the discovery of the fire. The alarm was transmitted by a neighbor who observed smoke seeping from the attic of the house. The alarm was received by the Fire Department at 7:51 P.M.

The kitchen door was open, other exterior doors were closed but were not locked. Most of the interior doors were open including the door to the stairway leading to center room of attic. All windows, including the four windows of main attic section, were closed.

UNITS AND PERSONNEL RESPONDING:

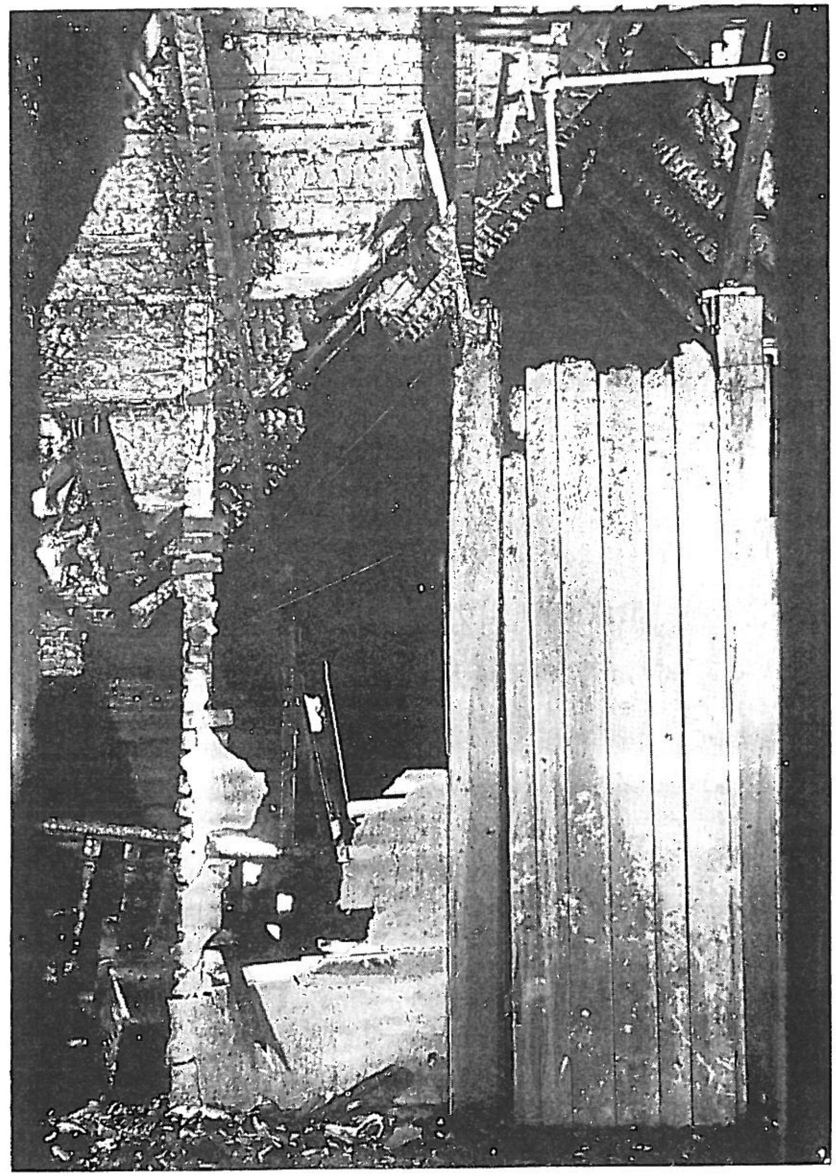
Engine Company No. 3: 750 gpm Triple combination pumper, 2 firemen.

Squad Company: Squad Truck — 500 gpm booster pump, 2 firemen.

Additional personnel: Chief of Department, 1 fireman.

CONDITIONS UPON ARRIVAL OF SQUAD COMPANY: A limited amount of smoke could be observed seeping from attic. All attic windows were intact. The initial survey was made by the fireman in charge of Squad Company. He proceeded by way of interior stairway to position on stairway of involved attic. From this position it appeared that the entire attic was a glowing furnace. There was very little smoke and the radiant heat was intense.

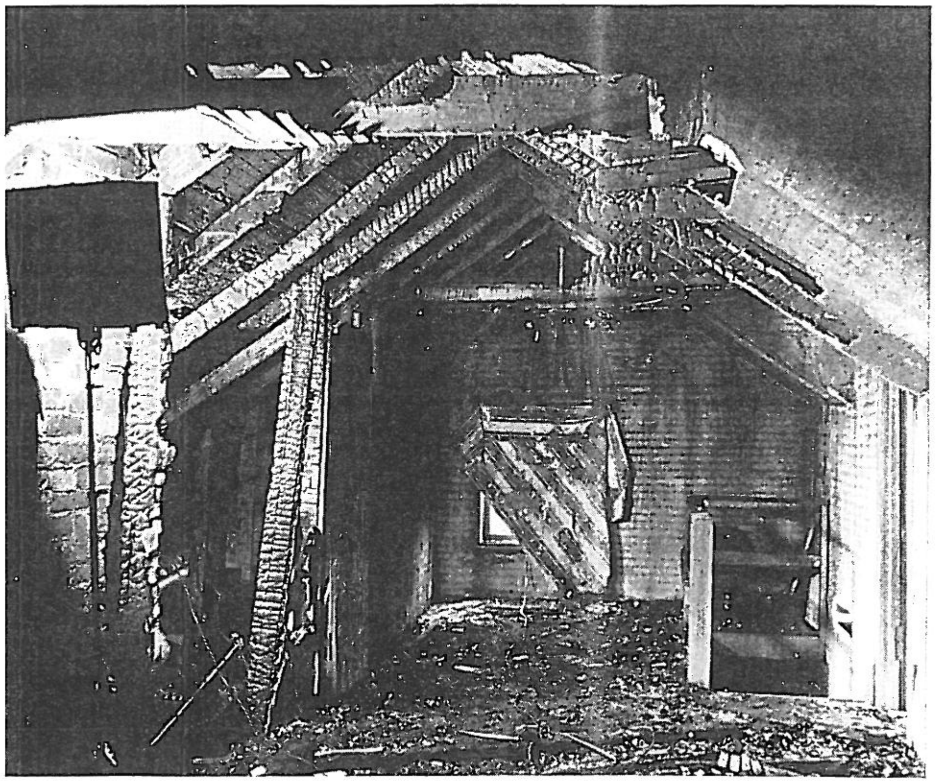
ATTACK AND EXTINGUISHMENT: Upon completion of the initial size up, the decision was made to attack from position on attic stairway. The "ready line" (200 ft. of 1½-in. hose carried connected to rear control valve and equipped with 65-gpm water particle nozzle) from Squad Truck was advanced to position near top of attic stairway. From this position a cone of water particles were directed upward into the attic space, the nozzleman moving the nozzle briskly to obtain maximum dispersion



WEST GABLE SECTION

Shows discarded furniture near chimney, doorway to west gable section, and roof char.

of the water particles. The fire was blackened almost immediately but the nozzleman was unable to hold his position due to the vast volume of steam being generated within the attic space. He closed his nozzle and took position on the landing of attic stairway which was half-way between the second floor and attic. The upper section of a rear window of second floor extended above the landing. He knocked out the pane of this window which provided an opening through which cool air from the outside atmosphere could enter. The nozzleman estimated that he applied water for less than one minute.



CENTER ROOM OF ATTIC

From left to right: Partial view of unfinished space, west gable section; rear attic window; stairway opening where nozzleman of No. 1-line made initial attack; doorway to east gable room.

Ladder had been placed and the "ready line" from Engine No. 3 had been advanced to position on rear porch roof. A ladder was placed to rear attic window and the window pane was removed. No flame or glowing materials could be observed from this position. Protected by air coming through the window opening at stairway landing and rear attic window, the nozzleman of No. 1-line was able to return to position near top of stairway. The heat was intense but no smoke, flame, or glowing materials could be observed from this position. The nozzleman of No. 1-line again directed a cone of water particles upward into the overhead moving the nozzle briskly to obtain maximum dispersion of water particles. The application was continued for a period of less than one minute. He was able to hold his position but the temperature above the floor level prevented him from advancing into the attic. No smoke could be observed but an atmosphere of condensing steam restricted visibility to within a few inches of the floor level. Small flames appeared outside under the eaves of rear gable. These were observed by the nozzleman of No. 2-line and were extinguished by a solid stream from position on rear porch roof.

Several minutes following the second application of water from No. 1-line, visibility near the floor level had improved and a feeble flame could be seen above the floor joists at a point near the chimney in the west gable section. A cone of water particles from No. 1-line was directed towards this point and within a few seconds the flame disappeared. The temperature above the floor level remained too high to allow the entry of personnel. The No. 2-line was ordered from position on rear porch roof to position at the west gable window. The nozzleman of No. 2-line was instructed to apply water particles from this position in order to reduce the temperature within the attic to a degree which would allow personnel to enter. A ladder was placed, the pane of the west gable window was removed, and short bursts of water particles were directed upward into the overhead intermittently over a period of several minutes. During these applications of water the nozzleman had to keep from in front of the opening to avoid the steam which came from the attic. The nozzleman of No. 1-line was able to remain near top of attic stairway during this period but steam and heat prevented him from advancing. A major part of the volume applied from No. 2-line was converted into steam. Water started to come through the ceiling of the room below the unfloored west gable section and a salvage cover was used to contain this "run-off." Approximately 30 gallons were accumulated and removed. When it appeared that the attic space had been cooled sufficiently to permit the entry of personnel, application of water from west gable window was stopped.

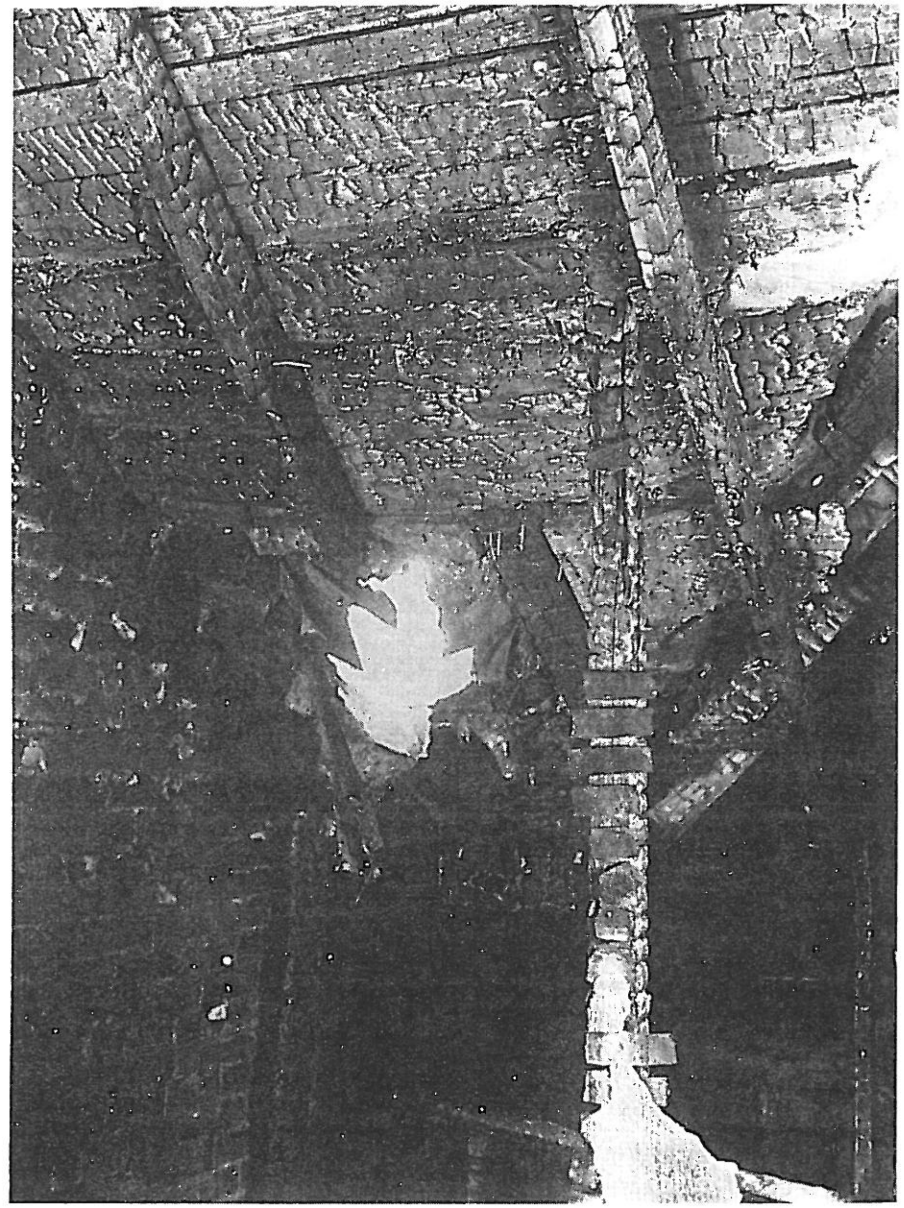
The appearance of small flames outside under eaves near top of rear gable indicated that complete extinguishment had not been effected within the cornice space. A straight applicator, equipped with low-velocity head, was attached to shut-off nozzle of No. 1-line. A section of the ceiling of center attic room next to rear wall was opened and water was applied near peak of gable for a few seconds. Condensed steam appeared in the overhead and came from under eaves of rear gable. This application effected complete extinguishment of the burning within the cornice space.

The only remaining fire was of a smouldering nature within the accumulation of combustibles located between and on the open joists next to chimney in west gable section. Less than a gallon of water was required to complete extinguishment. The rafters, sheathing, and joists over center attic room and over east gable room were badly charred but no fires or smouldering materials were found.

ADDITIONAL FACTS AND OBSERVATIONS: When the initial attack was made from position on attic stairway, the pump operator of Engine No. 3 was in position to view the exterior of the rear and west side of attic section. He stated that it was very obvious that the initial attack was effective because of the violent expulsion of smoke from the attic followed by a mixture of smoke and condensing steam. The volume was such that momentarily the entire attic section and roof were enveloped completely in a cloud of smoke and condensing steam.

An inspection of the attic disclosed the following conditions:

(*a*) A section of the ceiling and a section of the west



ROOF OPENING
Shows chimney, hole in roof, roof char.

wall of center room forward of the door opening to west gable section were burned out completely.

(*b*) A hole consisting of about two square ft. had burned through roof at a point near rear of chimney in west gable section.

(*c*) The joists and lath, in the area near the chimney in the unfloored west gable section, were badly charred. At one point the lath had been destroyed and the plaster on ceiling of the room had disintegrated forming a small opening.

(*d*) Considerable portion of the roof sheathing, rafters, joists and studdings in west gable section had been converted to perfect charcoal. A similar char condition was also present in the space between roof and ceiling of main and east gable rooms.

(*e*) At several points melted asphalt had come through between the sheathing.

VOLUME OF WATER USED: Estimate of the volume of water used:

Approximately 100 gallons of treated water from booster tank of squad truck.

Approximately 200 gallons of plain water from Engine No. 3.

Total volume, 300 gallons.

The treated water contained 1 per cent of "Unox," a standard wetting agent. The entire volume, except a few gallons used to extinguish flames under eaves of rear gable, was applied in the form of finely divided particles. The "run-off" within the house amounted to approximately 30 gallons.

The No. 1-line was equipped with a 65 gpm Elkhart Mystery nozzle (high-velocity type) with the maximum open position set to deliver a 30° angle discharge. This nozzle served as the tip for a standard 1½-in.-shut-off nozzle. No. 2-line was equipped with a Navy type all-purpose nozzle. Nozzle pressures of approximately 100 pound psi were maintained on these nozzles throughout the fire. The No. 1-line delivered approximately 65 gpm when equipped with high-velocity nozzle and 54 gpm when equipped with the applicator and low-velocity head. The No. 2-line delivered approximately 54 gpm.

VALUES AND INSURANCE:

Adjuster's estimate as to value of building	$8,000.00
Value of contents	none
Insurance on building	3,000.00
Insurance on contents	none
Adjusted loss paid on building	1,586.15
Loss on contents	none

There was no loss to exposed property.

DISCUSSION: About 50 gallons of treated water were used in the initial attack from position on attic stairway. The destructive action of this fire was halted by this limited volume of water projected into the heated atmosphere at the upper level of the space. Based upon an extinguishing efficiency of 90 per cent, a volume of steam amounting to about 10,000 cubic ft. was generated within the attic during the initial attack. The net atmospheric capacity of the attic amounted to less than 4,000 cubic ft. This volume of steam was sufficient to make over two complete changes of the interior atmosphere and accounts for the volume of smoke and condensing steam exhausted from the building during the initial attack.

Heat production within the attic practically ceased following the initial attack but the volume of water was insufficient to absorb the residual heat contained within the solid materials. The residual heat retarded the process of condensation and maintained an atmospheric temperature of sufficient degree that prevented personnel from entering the attic.

During the second attack from attic stairway approximately the same volume of treated water was projected into the heated atmosphere. An additional volume of 200 gallons of plain water was required to absorb the residual heat to an extent that allowed personnel to enter and operate within the attic.

Deep char in overhead of east gable and in parts of overhead above center room could not have been contacted by direct application from position on attic stairway or from west gable window. It should be noted that complete extinguishment was obtained in these sections. It has been observed in previous fires that regardless of the depth of char complete extinguishment can be effected by indirect application. Deep-seated smouldering in baled or loose masses of combustibles cannot be extinguished by indirect application. The rate that heat is conducted to the surface of charred timber appears to be rapid while in baled or loose masses of combustibles it is very slow. The conductivity of heated combustibles appears to be the determining factor in obtaining extinguishment by indirect application of water in the form of finely divided particles.

The roof covering of this house consisted of two layers of asphalt shingles. This prevented the fire from effecting an adequate exhaust opening and also insulated the attic against rapid loss of heat to the outside atmosphere. The fire had burned through the roof near chimney in west gable section but this opening was several feet below the ridge of roof and was too small to provide an adequate exhaust opening. These were contributing factors to the volume of heat that had accumulated within the attic.

CONCLUSIONS:

(1) The most practical and effective method of controlling and extinguishing this type of fire is by the proper application of the necessary volume of water in the form of finely divided particles.

(2) In attacking this type of fire, the water particles should be projected into the heated atmosphere at upper level within the area of major involvement.

(3) In attacking this type of fire, personnel should operate from positions where they can avoid being enveloped by heated smoke and live steam.

(4) Under similar heat and draft conditions, it appears that by proper employment of the necessary volume of water, in the form of finely divided particles, the following results can be anticipated:

(*a*) The heated and contaminated atmosphere will be displaced by an atmosphere of steam.

(*b*) Surface burning including deep char will be extinguished but deep-seated smouldering will require additional cooling to effect complete extinguishment.

(*c*) That the temperature of solid materials can be reduced to approximately 212° F., the boiling point of water. At this point steam generation ceases and condensation of steam within the space will cause the atmosphere of steam to be replaced by air from the outside atmosphere.

This case history was prepared by Lloyd Layman while Chief of the Parkersburg Fire Department. The photographs were taken by H. W. Muhlmann, Department Photographer. The diagram was prepared by the City Engineer's Office. The adjustment of loss was made by General Adjustment Bureau, Inc., Parkersburg, W. Va.

CASE HISTORY NO. 3:

A building fire where plain water, in the form of finely divided particles, was used to attack and extinguish.

LOCATION: Warehouse — Crotty and Co., 2nd Street and St. James Court Alley, Parkersburg, W. Va.

TIME OF ALARM: April 22, 1950 — 12:58 P.M.

WEATHER CONDITIONS: Temperature, 70° F. Wind, 7 mph from west. Humidity, 40 per cent.

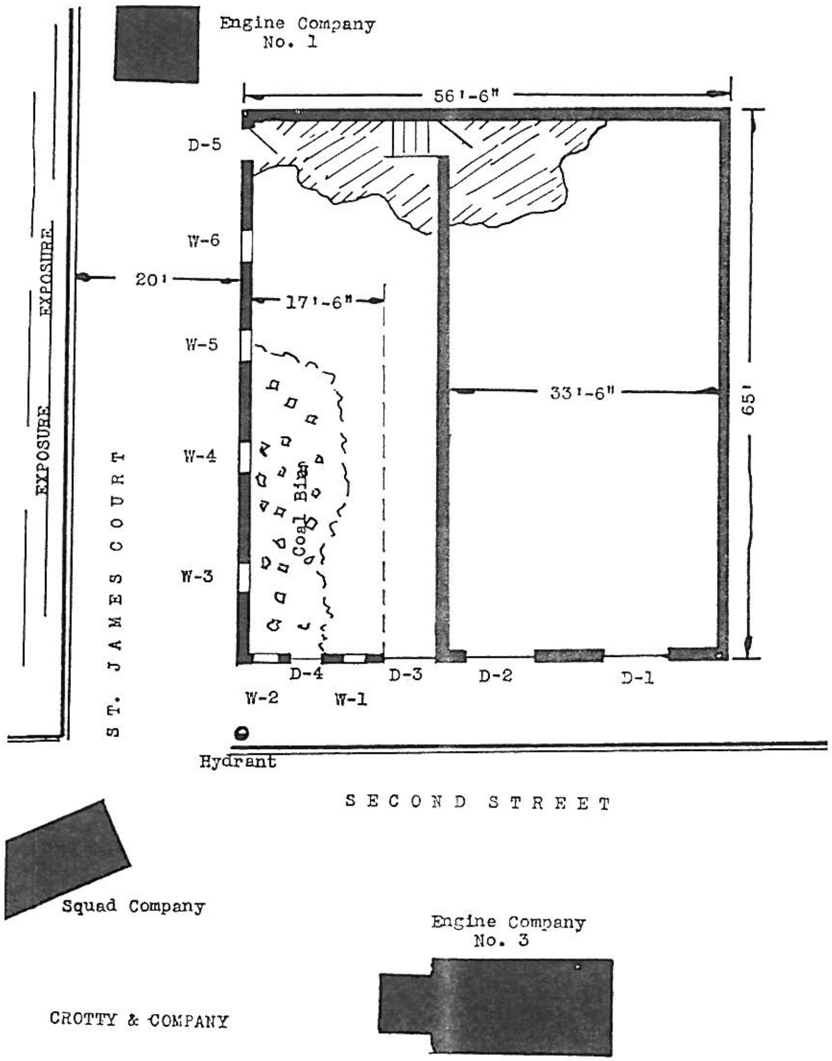
DESCRIPTION OF BUILDING: One-story frame warehouse; exterior walls — metal clad; flat type roof sloping from west to east, wood sheathing on wood rafters, covered with several layers of asphalt roll roofing; concrete foundation extending four ft. above ground level with floor of west section same level as top of foundation and floor of east section four ft. lower and the concrete foundation forming the exterior walls to a height of four ft.; West section — 33 ft. 6 in. x 65 ft.; East section — 22 ft. 9 in. x 65 ft.; overall dimensions — 56 ft. 6 in. x 65 ft. Doors and windows: EAST SECTION — single doorway from alley east side, double doorway to coal bin from 2nd Street (front), single doorway to passageway from 2nd Street (front), four window openings from alley east side, two window openings from 2nd Street (front); WEST SECTION — two double doorways from 2nd Street (front), transoms over doorways; entire west side and rear of building without doorways or window openings. See diagram and photographs.

INTERIOR: West section divided from east section by wood partition with single doorway next to rear wall; roof of west section supported by heavy wood beam on wooden columns extending from front to rear through center of section; roof of east section supported by heavy wood beam on wooden columns; located 5 ft. 3 in. from partition these columns also supported boards forming west side of coal bin; interior height — West section average approximately 16 ft., East section approximately 19 ft.; concrete floors. See diagram and photographs.

REAR VIEW OF WAREHOUSE
Shows where fire originated.

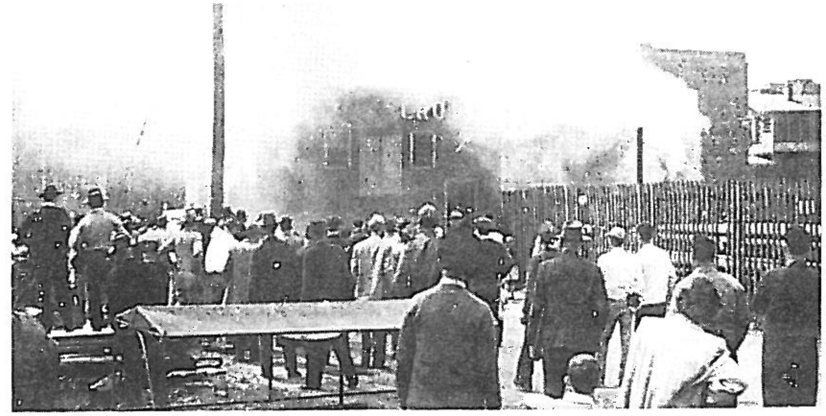
EXPOSURES: WEST SIDE — two-story brick warehouse; REAR — one-story frame, metal clad warehouse in the process of being torn down; EAST SIDE — two-story brick office building and one-story frame, metal clad, forge shop; width of alley 20 ft.; FRONT — no exposed buildings.

OCCUPANCY AND CONTENTS: Warehouse, Crotty and Company, coal bin located in east section contained approximately 50



tons of coal; west section contained engines for oil well drilling machines and spools of wire drilling cable.

CAUSE OF FIRE: The building located in rear of involved warehouse was being torn down, a trash fire ignited lumber and wood studding located against rear wall of warehouse. Sufficient heat was transmitted through metal siding to ignite combustibles within warehouse.

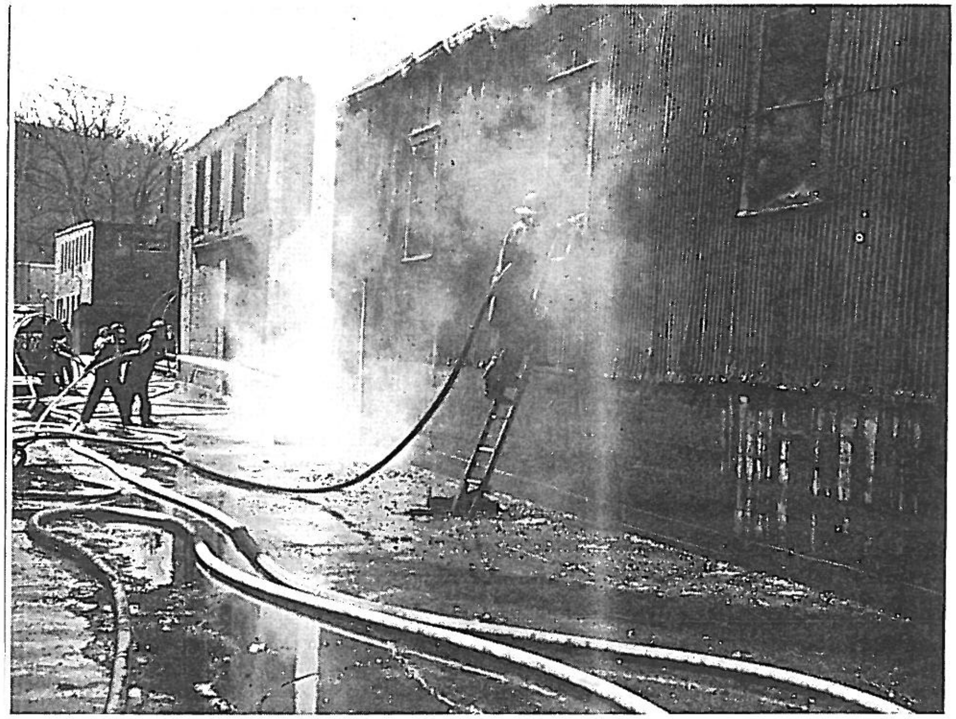


FRONT VIEW OF WAREHOUSE DURING FIRE
Engine Company No. 1 has two 1½-in. lines in service. A fog cone is being directed into east section through Window No. 6.

CONDITIONS EXISTING AT THE TIME OF FIRE: The alarm was transmitted by an employee of Crotty and Company from their office located on opposite side of St. James Court Alley from warehouse. The alarm was received at 12:58 P.M. An employee of Crotty and Company had opened the single door (No. 5) from alley to the east section, located at the rear east corner of warehouse, previous to the arrival of Engine Company No. 1. This door remained open during the entire fire. The single door (No. 3) from 2nd Street to passageway, east section, was open at the time of fire. All other exterior doors and windows were closed. The interior door between east and west sections was open.

UNITS AND PERSONNEL RESPONDING:
Engine Company No. 1 and Aerial Unit: 1 officer, 3 firemen.
Squad Company No. 2: 2 firemen.
Engine Company No. 3: 2 firemen.
Additional personnel: Chief of Department; Chief Inspector, Fire Prevention Bureau.

CONDITIONS UPON ARRIVAL OF ENGINE COMPANY NO. 1: As Engine Company No. 1 responded to the alarm, considerable volume of smoke was observed by the crew several blocks from the location of the fire. Flames were visible a block away. The



EAST VIEW OF WAREHOUSE DURING FIRE

No. 1-line attacking fire in east section through Window No. 5 while No. 2-line is attacking exterior fire at rear of warehouse.

combustible materials located outside along rear wall of this warehouse were fully involved in flame. Flames were lapping around the rear east corner of warehouse and were entering the open doorway (No. 5). The four east windows (Nos. 3–4–5–6) were burned out and flames were coming from these openings. A major part of the east section of warehouse was fully involved. Radiant heat had ignited combustible cornice of exposed building located on opposite side of St. James Court Alley. Some of the second floor windows of the brick office building were cracked and window frames were starting to ignite.

ATTACK AND EXTINGUISHMENT: Engine Company No. 1 was the first unit in and laid a 2½-in. supply line from hydrant at

corner of 2nd Street and St. James Court Alley. This unit took position in alley south of the involved warehouse. An additional 2½-in. supply line was provided from this hydrant for the Squad Truck which took position on 2nd Street east of involved warehouse. The following lines were placed in service:

From Engine No. 1:
- No. 1-line — 200 ft. 1½-in. hose equipped with 65-gpm Elkhart nozzle.
- No. 2-line — 200 ft. 1½-in. hose equipped with 90-gpm Elkhart nozzle.

From Squad Truck:
- No. 3-line — 200 ft. 1½-in. hose equipped with 65-gpm Elkhart nozzle.
- No. 4-line — 200 ft. 1½-in. hose equipped with 90-gpm Elkhart nozzle.

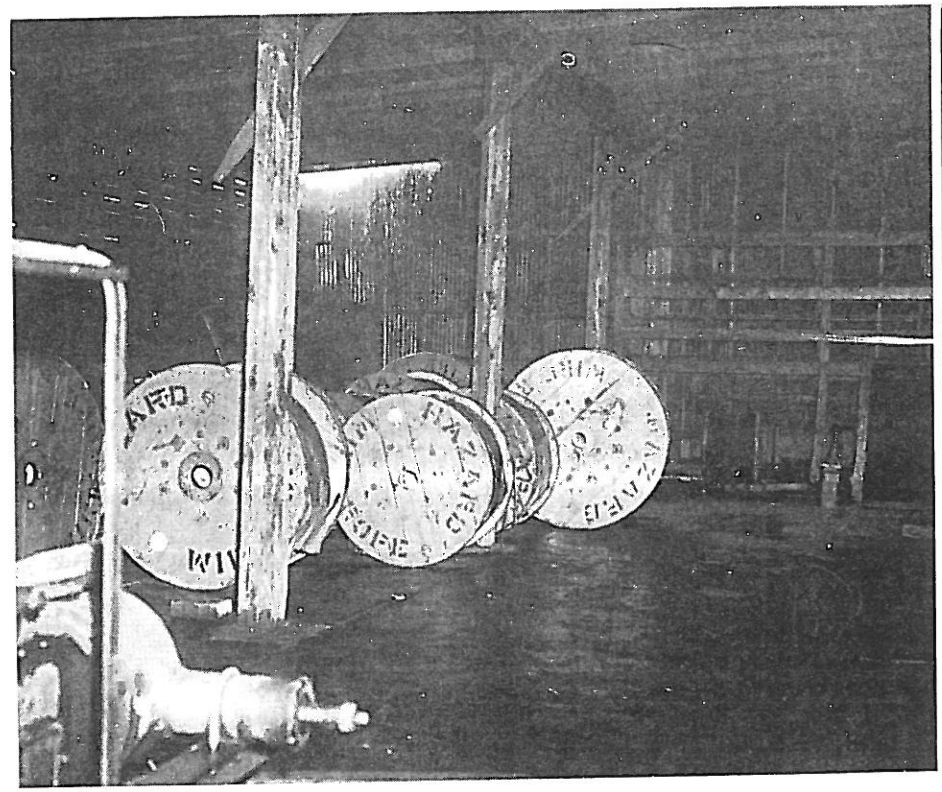
No. 1 and No. 2-lines were employed to attack the outside fire in rear of warehouse. A major part of this fire was knocked down quickly and No. 1-line was then employed to extinguish the fire and wet down the exposed buildings on east side of alley. A ladder was placed to window No. 5 and the nozzleman of No. 1-line took position on ladder and proceeded to attack the fire within the east section of warehouse. From this time on No. 2-line was employed to keep the exterior fire in rear of warehouse under control, to protect the exposed buildings on east side of alley, and to attack the interior fire by way of doorway No. 5.

A ladder was placed to window No. 3 and the nozzleman of No. 3-line took position on ladder and proceeded to attack the interior fire. At this time the Chief of Department arrived and took charge of operations. While making a survey of the situation, he closed door No. 3 which was open. He directed the nozzlemen operating at windows No. 3 and No. 5 to direct their cones of water into the overhead of the east section of the warehouse. The Chief of Department then ordered a ladder placed at door No. 1 and No. 4-line was taken to that point. The nozzleman took position on ladder and removed a glass section from transom over door and a cone of water was di-

NOZZLEMAN AT DOOR NO. 1

Shows nozzleman of No. 4-line preparing to make indirect attack in west section of warehouse. Chief of Department butting ladder.

rected through transom opening into the overhead of west section of warehouse. Application through this opening was continued for about two minutes. A section of glass was then removed from the upper section of the door and a cone of water



INTERIOR OF WEST SECTION

This photograph was taken a few minutes after completion of indirect attack. Note uniform distribution of moisture on concrete floor but there was no moisture on contents. Light coming through burned-out section of roof in rear east corner.

was directed upward into the overhead through this opening. During this period a considerable volume of smoke followed by condensing steam was observed coming from the roof opening at the southwest corner of this section. When the nozzleman reported that there was a marked drop in temperature in the overhead the application of water through this opening was stopped. The total period of time that water was applied through these two openings is estimated to be about three minutes.

The following conditions existed at this time:

(1) Engine Company No. 3 had laid a supply line from

hydrant at 2nd and Ann Streets and had taken position on 2nd Street in front of warehouse. Two 1½-in. working lines had been taken from Engine No. 3 each equipped with an all-purpose nozzle.

(2) It was evident that the fire within the warehouse was under control and the following overhauling operations were carried out:

(*a*) Door No. 1 was opened and No. 4-line was advanced into the west section. No fire or smouldering materials were found within this section of the warehouse.

(*b*) Door No. 3 was opened and a line from Engine No. 3 was advanced through passageway. Several small spot fires were found in rear area of east section.

(*c*) A line was advanced by way of window opening No. 3 and used to extinguish smouldering burning in coal bin section.

(*d*) A line was sent to roof and used to extinguish smouldering burning.

The fire within the warehouse had been extinguished and overhauling operations completed before the exterior fire in rear of warehouse had been extinguished. The entire operation within the warehouse had been completed within fifteen minutes following the arrival of Engine Company No. 1.

ADDITIONAL FACT AND OBSERVATIONS:

(*a*) The fire had burned through the roof in rear part of east section and southeast corner of west section.

(*b*) The interior door between east and west sections was in open position during the fire. The interior partitions above doorway had burned out.

(*c*) After overhauling operations had been completed, there was less than ten gallons of water on floor of west section and about fifteen gallons on floor of east section.

VOLUME OF WATER USED:

The following is an approximate estimate of volume of water used to control and extinguish fire within the warehouse. This estimate does not include water used to extinguish exterior fire in rear of warehouse and to protect exposed buildings.

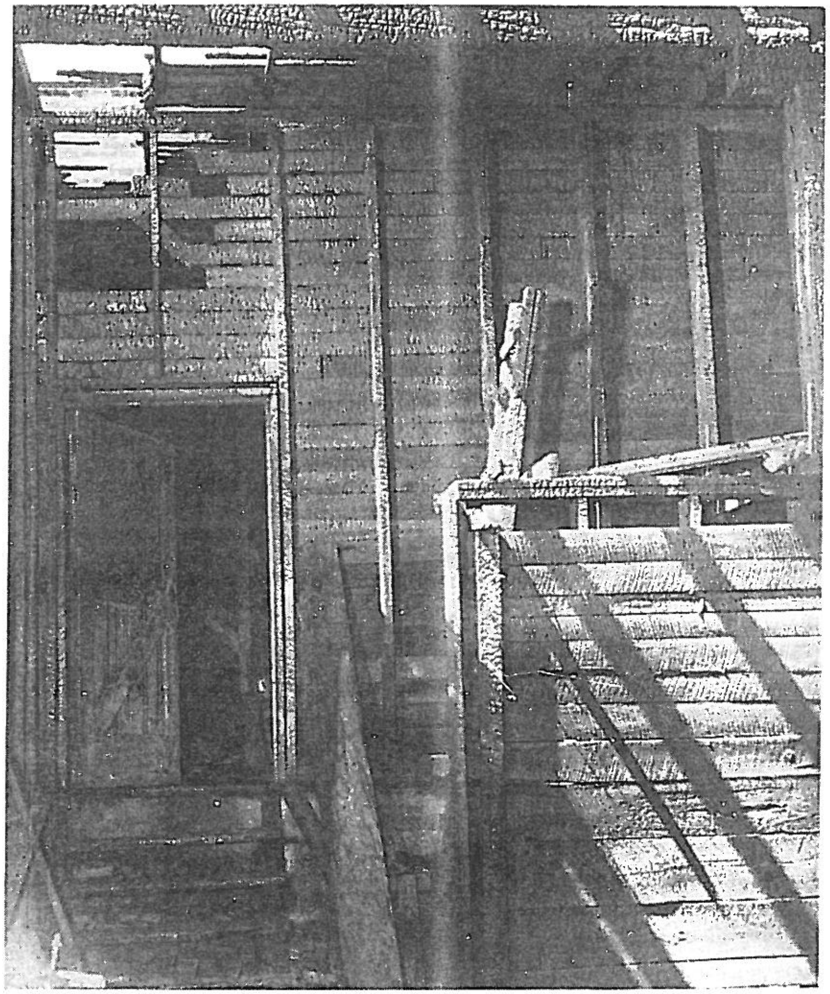
Line	*Number of Minutes*	*G.P.M.*	*Total Gallons*
No. 1	8	65	520
No. 2	4	90	360
No. 3	7	65	455
No. 4	3	90	270
Total volume of water used within warehouse			1,605

Pump pressures were set to provide nozzle pressures of not less than 100 psi. The Elkhart nozzles were operated at the 30° angle cone except when a solid stream was used in overhauling.

VALUES AND INSURANCE:

Adjuster's estimate as to value of building	$10,000.00
Owner's estimate as to value of contents	20,000.00
Insurance on building	500.00
Insurance on contents	None
Adjusted loss on building	500.00
Uninsured loss on building	4,500.00
Total loss to building	$5,000.00
Loss on contents	None
Adjusted loss on exposed buildings on East side of St. James Court Alley	111.45
Total loss	$5,111.45

DISCUSSION: Type of construction, age of building, presence of coal dust, and an adequate oxygen supply were contributing factors to the rapid progress of the fire within the east section of warehouse. An employee had opened door No. 5 previous to the arrival of Engine Company No. 1. This provided additional air that enabled the fire to burn through the roof, thereby providing an exhaust opening. Two doors were open and four windows were burned out, these six openings provided an air-intake area of approximately 115 square feet. Once the fire had burned through the roof and had extended its area of destruction sufficiently to provide an adequate exhaust opening, this

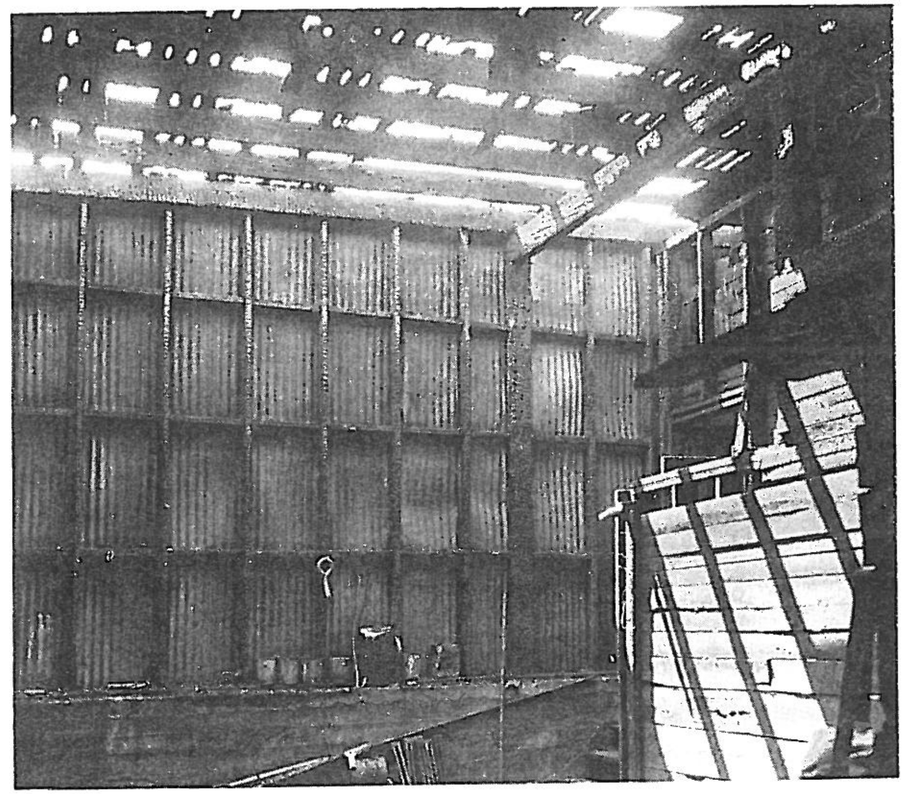


ROOF DESTRUCTION IN WEST SECTION

Shows interior doorway, partition, and roof destruction in west section.

fire was supported by all the essentials necessary for rapid progress.

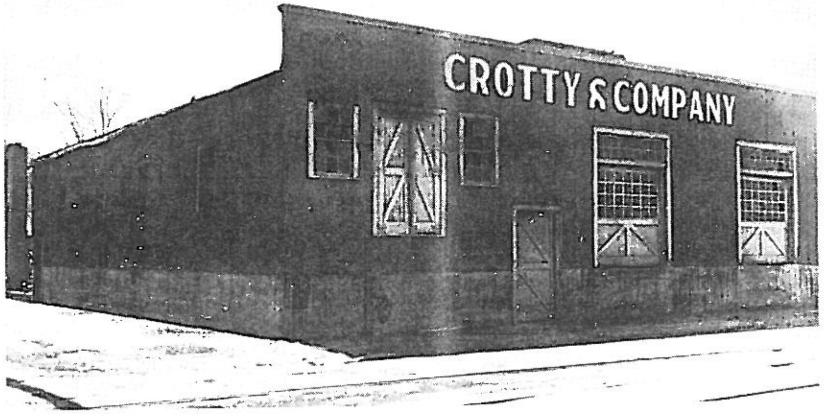
It appears that the major part of the fire within the east section was extinguished by direct application of water from Windows Nos. 3 and 5. The fire within the immediate area of



ROOF DESTRUCTION IN EAST SECTION

Door No. 5 was extinguished by direct application of water from line No. 2.

The fire within the west section was extinguished by indirect application of water from Door No. 1. The west section had a total atmospheric capacity of approximately 33,000 cubic ft. It is estimated that the contents displaced not more than 10 per cent of this volume, leaving a net atmospheric volume of approximately 30,000 cubic ft. About 270 gallons of water were injected into the upper atmospheric level of this section. Based upon an extinguishing efficiency of 90 per cent, this volume of water absorbed more than two million B.T.U. of heat and expanded into approximately 54,000 cubic ft. of steam. This volume of steam was sufficient to make almost two complete changes of atmosphere within the west section.



WAREHOUSE AFTER FIRE HAD BEEN EXTINGUISHED

The following results were obtained within the west section by the indirect method of attack:

(*a*) The fire within this section was beyond reach of direct application but complete extinguishment was effected.

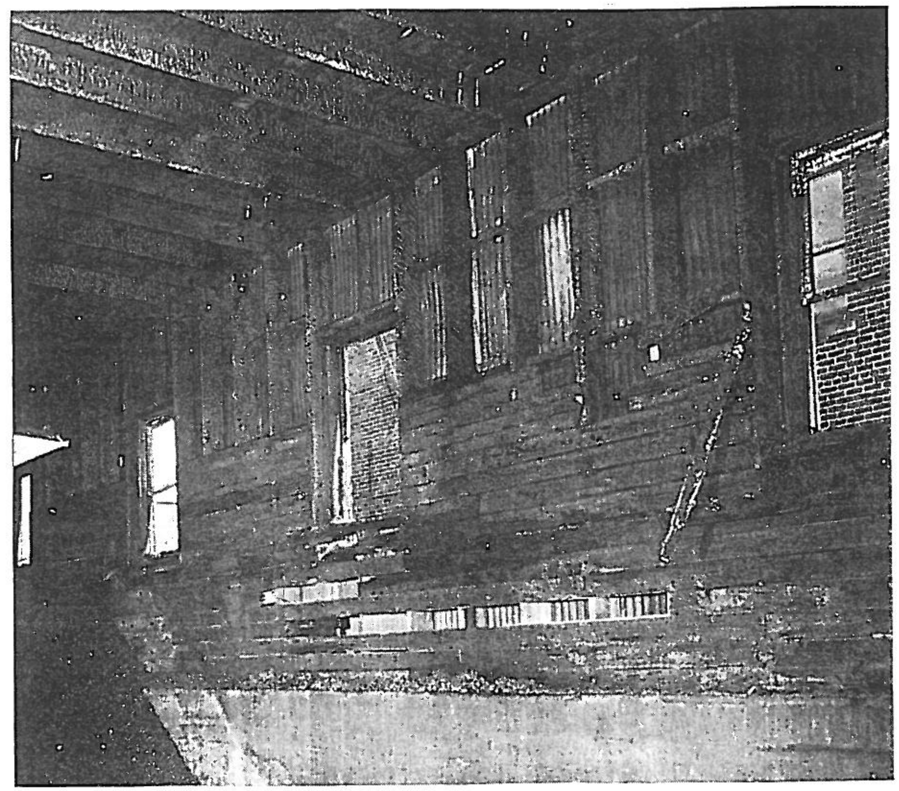
(*b*) The atmospheric temperature was reduced to a degree that allowed personnel to enter and operate within this section.

(*c*) A major part of the smoke was forced out by way of roof opening.

(*d*) The temperature of combustibles throughout this section were reduced to below their respective ignition points.

The roof covering consisted of several layers of asphalt roll roofing. After the fire within the warehouse had been extinguished a line was sent to roof. The roof covering was charred for some distance around the burned out section. Smouldering spots were extinguished with small solid stream. It is reasonable to believe that the charred area had been involved in flame but flame production ceased previous to the time the line was sent to roof. It appears that the cooling action of the water applied within the building had been sufficient to reduce the temperature of the roof covering to a degree insufficient to support flame production.

An inadequate oxygen supply was the only factor that had prevented involvement of the entire west section. Had either Door No. 1 or 2 been opened before the excessive heat had been



INTERIOR OF EAST SECTION
Shows the four burned-out windows.

transferred to the outside atmosphere, it was evident that flame production would have extended quickly throughout this section. If this had occurred, it would have been very difficult to have prevented the complete destruction of this building. The adjuster and other insurance representatives agreed that this building would have been a total loss if this fire had been fought with solid streams.

CONCLUSIONS:

(1) This building would have been destroyed if solid streams had been employed in an attempt to attack and extinguish.

(2) The most practical and effective method of controlling and extinguishing this type of fire is by proper application of

the necessary volume of water in the form of finely divided particles.

(3) Strong drafts within an involved building will decrease the effectiveness of indirect application. The location of air-intake and exhaust openings should be considered in determining the points at which water should be applied in order to obtain effective results.

This case history was prepared by Lloyd Layman while Chief of the Parkersburg Fire Department. The photographs at the time of fire were taken by the official photographer, Parkersburg Sentinel, other photographs were taken by H. W. Muhlmann, Department photographer. The Adjustment of loss was made by General Adjustment Bureau, Inc., Parkersburg, W. Va.

CASE HISTORY NO. 4:

A building fire where plain water, applied in the form of finely divided particles, was used to attack and extinguish.

LOCATION: 3605 Camden Avenue, Parkersburg, West Virginia.

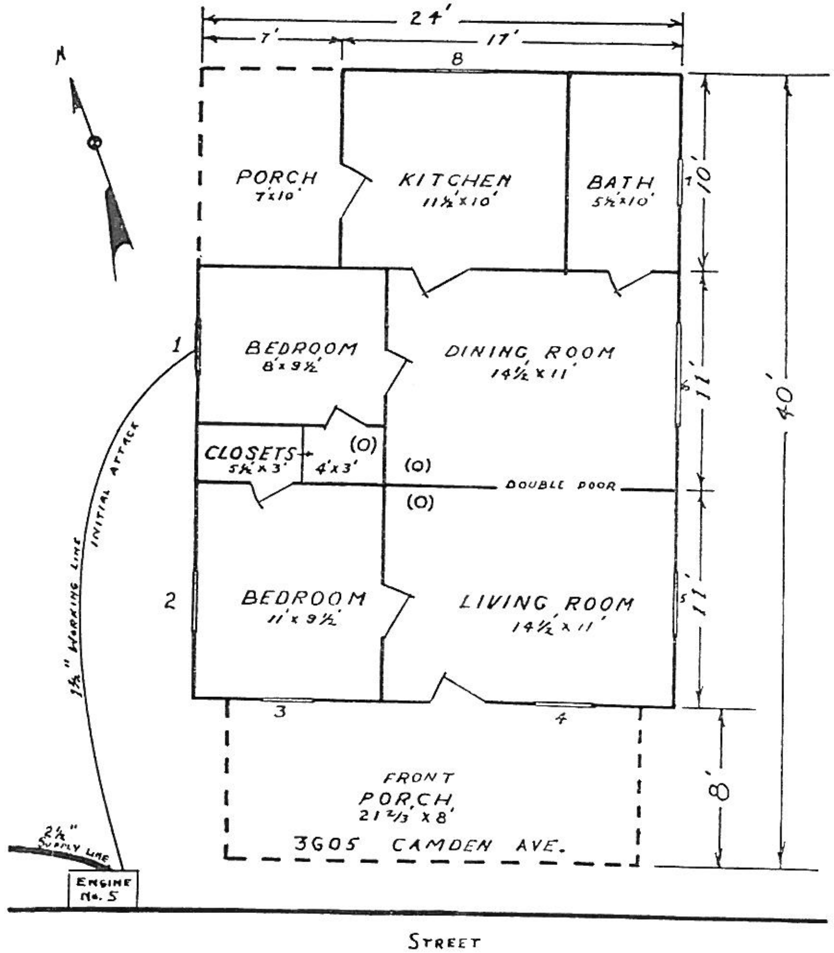
TIME OF FIRE: February 15, 1951 — 8:50 A.M.

WEATHER CONDITIONS: Temperature — 30° F. Wind — calm. Humidity — 90 per cent.

DESCRIPTION OF BUILDING: One-story frame dwelling 24 ft. x 34 ft.; exterior walls — clapboard; concrete block foundation; roof — hip type with dormer extension at front with two windows, asphalt composition shingles; front porch 21 ft. x 8 ft.; rear porch at north corner 7 ft. x 10 ft.

INTERIOR: Consisted of two bedrooms, living room, dining room, kitchen and bathroom; interior partitions — plaster board on wooden studding; ceiling — plaster board except in kitchen — celotex blocks; all rooms were papered; unfinished attic with two dormer windows at front, center height of attic 8 ft.; hole in ceiling of living room approximately 1 ft. x 1 ft.,

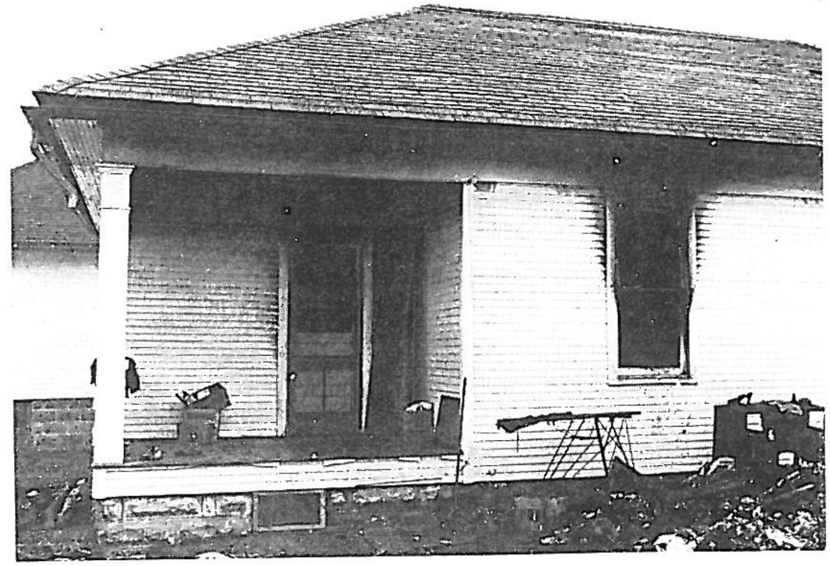
FRONT AND WEST SIDE OF DWELLING
3605 Camden Avenue



same size hole in ceiling of dining room where plaster board had been broken and had not been replaced at time of fire; open scuttle hole in closet of rear bedroom 3 ft. x 4 ft.; position of these openings to attic indicated on diagram by (0); ceiling height throughout the house 8 ft. 10 in.

EXPOSURE: East side only. One-story frame dwelling, distance 20 ft.

INTERIOR LAYOUT: See diagram.



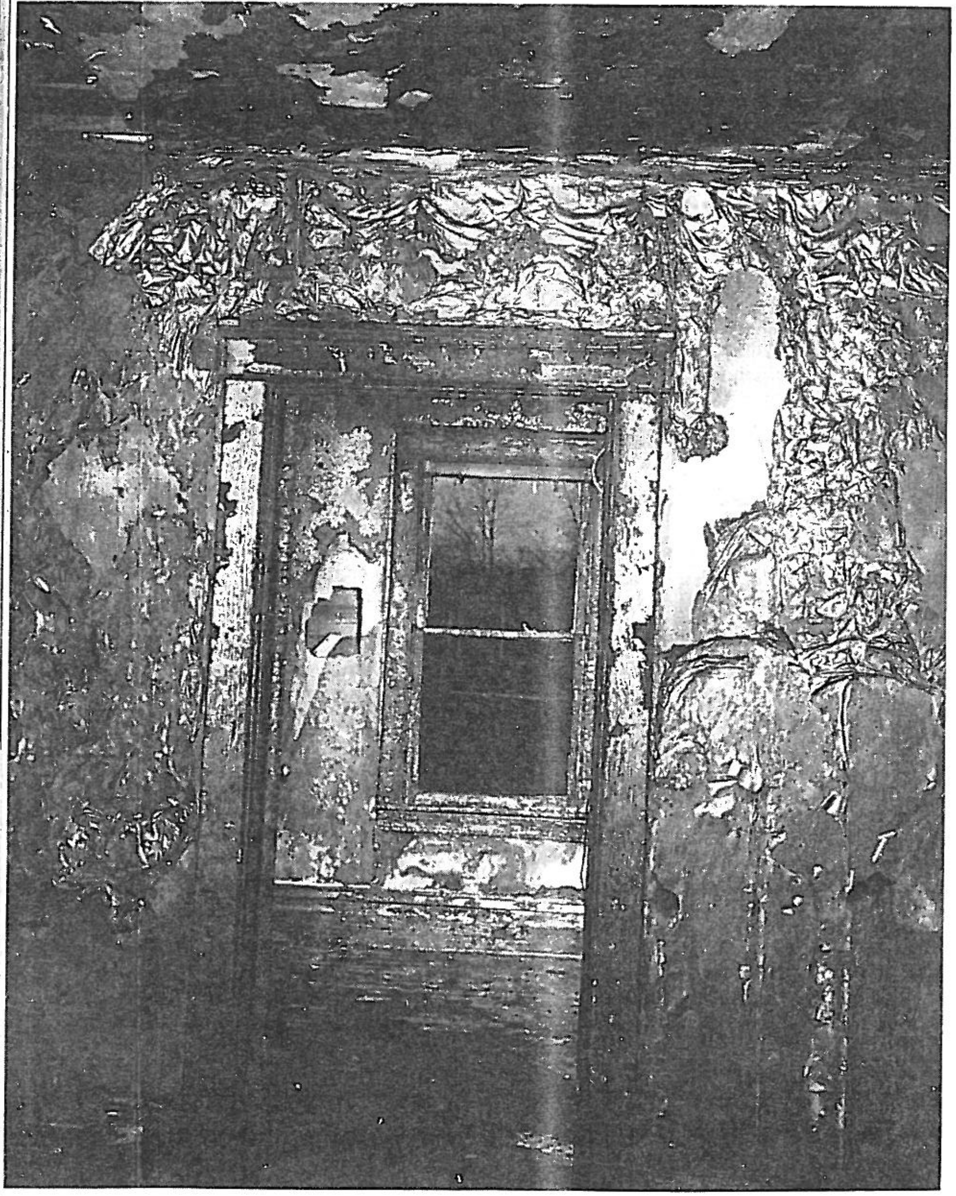
WEST REAR VIEW OF DWELLING
Showing rear porch, doorway to kitchen, window opening to rear bedroom through which initial attack was made.

OCCUPANCY AND CONTENTS: This dwelling was occupied at time of fire and a normal amount of furniture was contained in each room.

CAUSE OF FIRE: A child, three years of age, ignited a newspaper and used the burning paper to ignite combustibles in kitchen and dining room before fire was discovered by other members of family. A woman sleeping in rear bedroom was trapped and escaped through window after breaking pane. The two children were rescued by father who broke out lower pane of front window to front bedroom making entry through window.

CONDITIONS EXISTING AT TIME OF FIRE: All interior doors between rooms were in open position. The door to closet in rear bedroom was open and the scuttle hole to attic was uncovered.

UNIT AND PERSONNEL RESPONDING:
Engine Company No. 5 — 3 firemen.
Additional personnel: Chief of Department; Department Instructor; Chief Inspector, Fire Prevention Bureau; Assistant



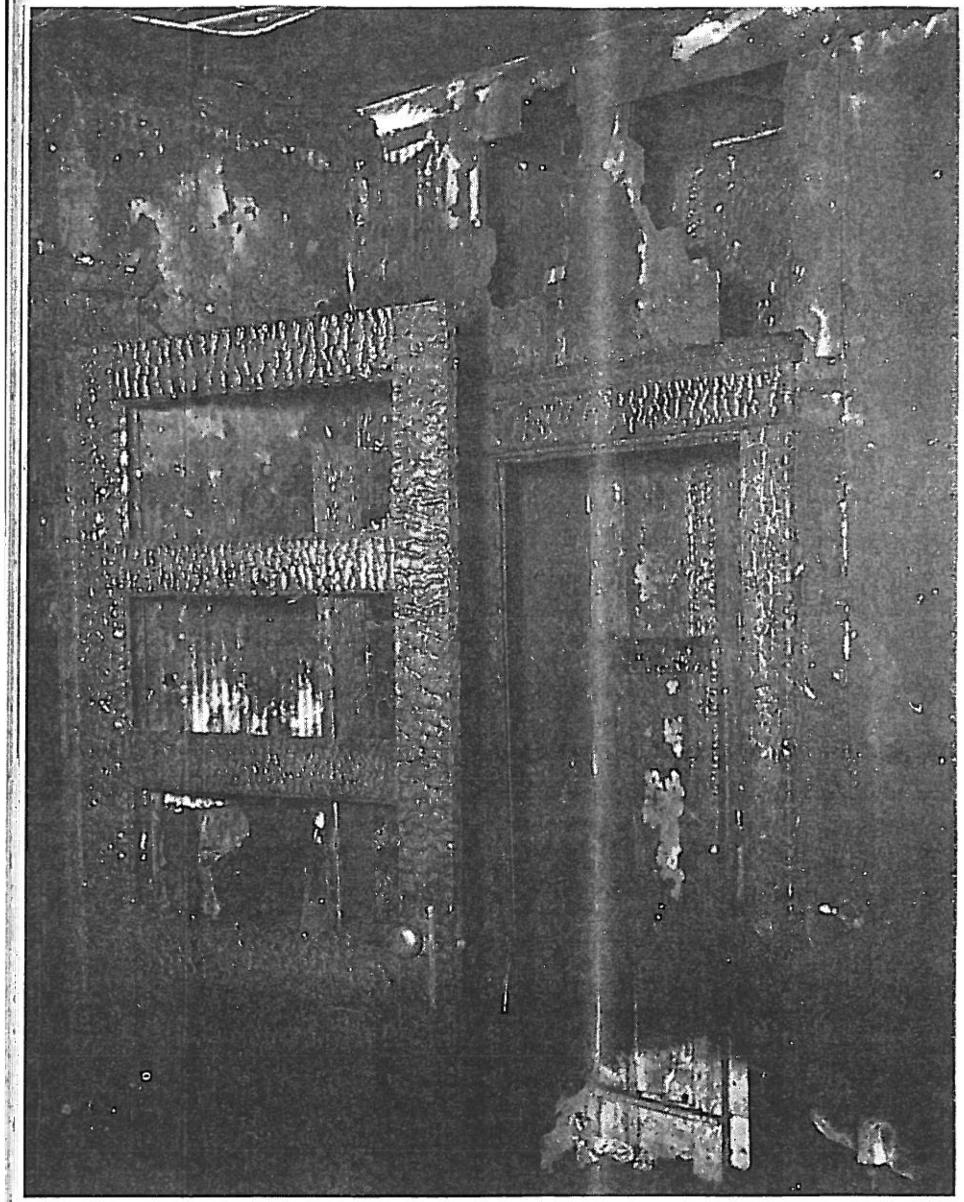
REAR BEDROOM

From dining room showing doorway to rear bedroom and burned-out window through which initial attack was made.

Inspector, Fire Prevention Bureau; Captain James V. Westling, Assistant Superintendent — Training, Minneapolis Fire Department, who was studying our fire-fighting methods.

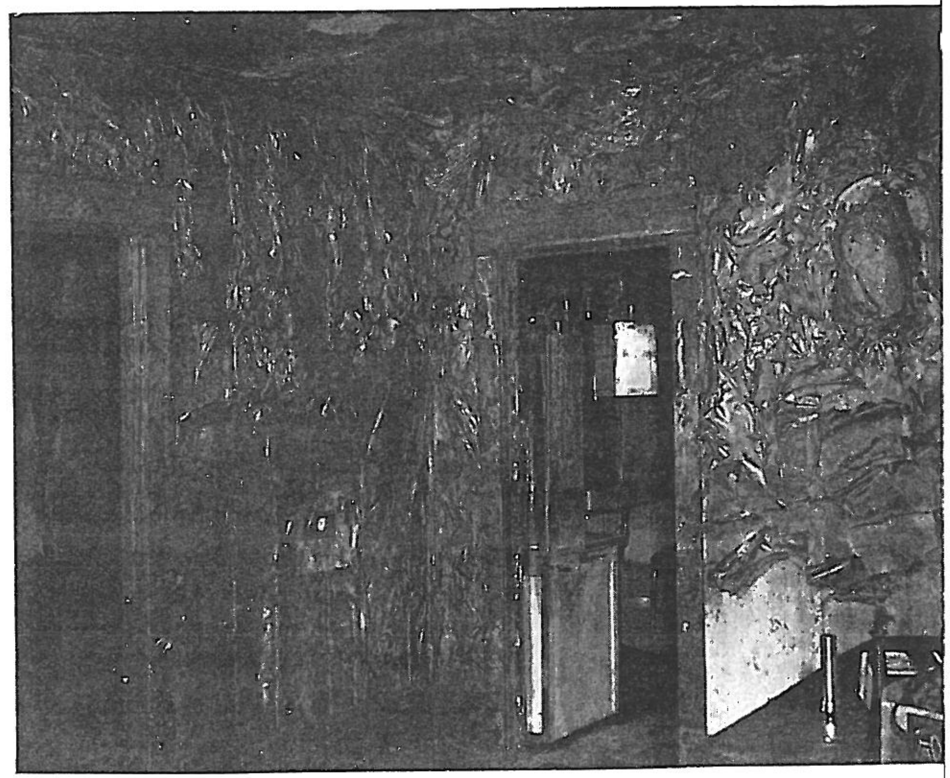
Conditions upon Arrival of Engine Company No. 5: The window of rear bedroom was completely burned out and flames were coming from this opening. The exterior door to kitchen was in open position and flames from opening were striking against ceiling of rear porch. The lower pane of front window of front bedroom was out. The front door was closed and remaining windows were intact. Rear bedroom, closet, dining room and kitchen were completely involved.

Attack and Extinguishment: Engine Company No. 5 dropped hydrant-man at corner of Camden Avenue and Laurel Street and proceeded to position near involved house laying a supply line of 200 ft. 2½-in. hose. The officer in charge made the size-up and decided to make the initial attack through the burned-out window of rear bedroom. The "ready line" (200 ft. of 1½-in. hose equipped with a 65-gpm Elkhart fog nozzle) was advanced to position near window. The nozzleman directed a cone of water particles through the window opening slanting it upward toward ceiling of bedroom. The pump operator stated that immediately following the application of water smoke and condensing steam came from all openings and from under eaves and shingles of roof. Condensing steam in considerable volume was observed in the sky above the house by the Chief of Department who was several blocks away. The nozzleman estimated that he continued the application of water from this position for a period of less than one minute. He then moved to position on rear porch where he directed a cone of water particles through door opening slanting it upward toward overhead of kitchen. He applied water from this position for a period of about thirty seconds. He then proceeded through kitchen into living room where he used a small amount of water to extinguish slowly burning spot fires and to wet down smouldering materials. The atmosphere within the house was hot and humid but of insufficient degree to cause serious physical discomfort. There was a slight trace of smoke in the atmosphere resulting from the smouldering burning.



CLOSET OF REAR BEDROOM

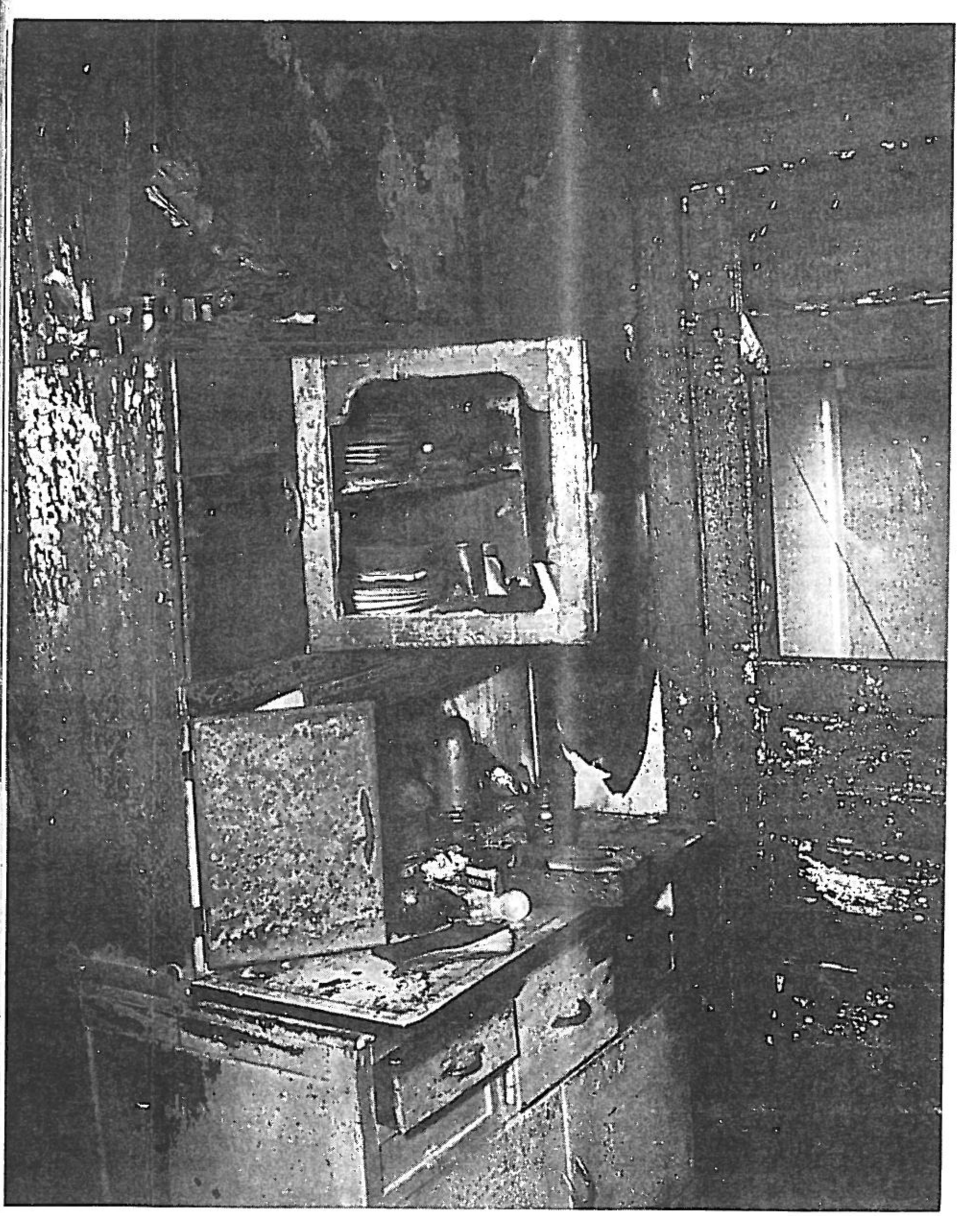
Showing doors to dining room and closet in same position as during fire.



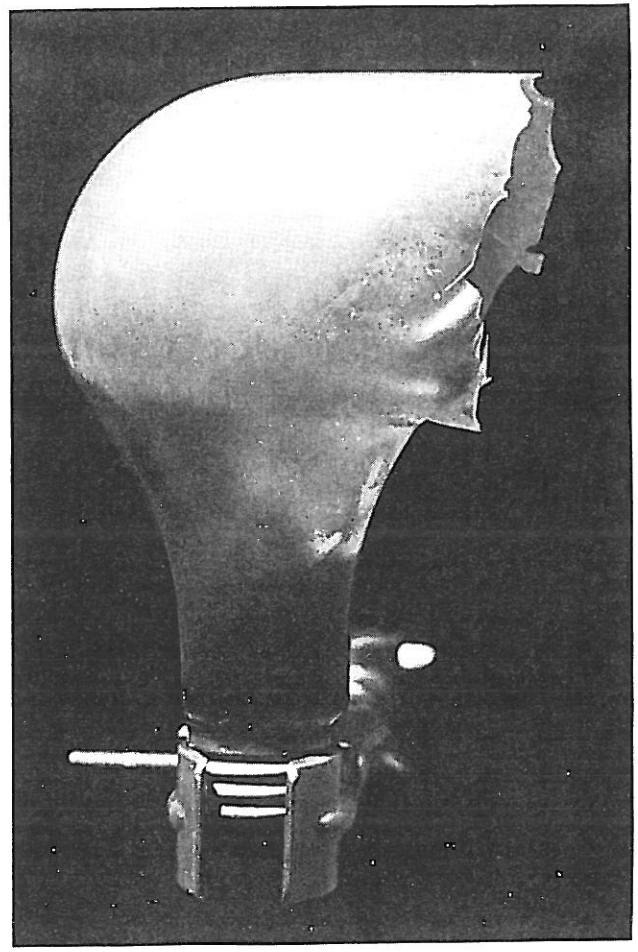
INTERIOR VIEW OF DINING ROOM

Showing doorway to rear bedroom and doorway to kitchen. Note charred paper on walls.

After the initial attack had been made a 1½-in. line was taken to the roof of front porch. The attic windows were opened in order to determine if the fire had extended into attic space. The atmosphere within the attic consisted of condensing steam and smoke and was too hot to permit entry of personnel. No flame could be observed and no water was used. It was found that the smoke was coming through the scuttle hole from smouldering materials located in closet of rear bedroom. This line was then moved to position in yard and used to wet down feather mattress and other smouldering materials that had been removed from bedroom, closet and kitchen.



INTERIOR VIEW OF KITCHEN
Showing exterior door.



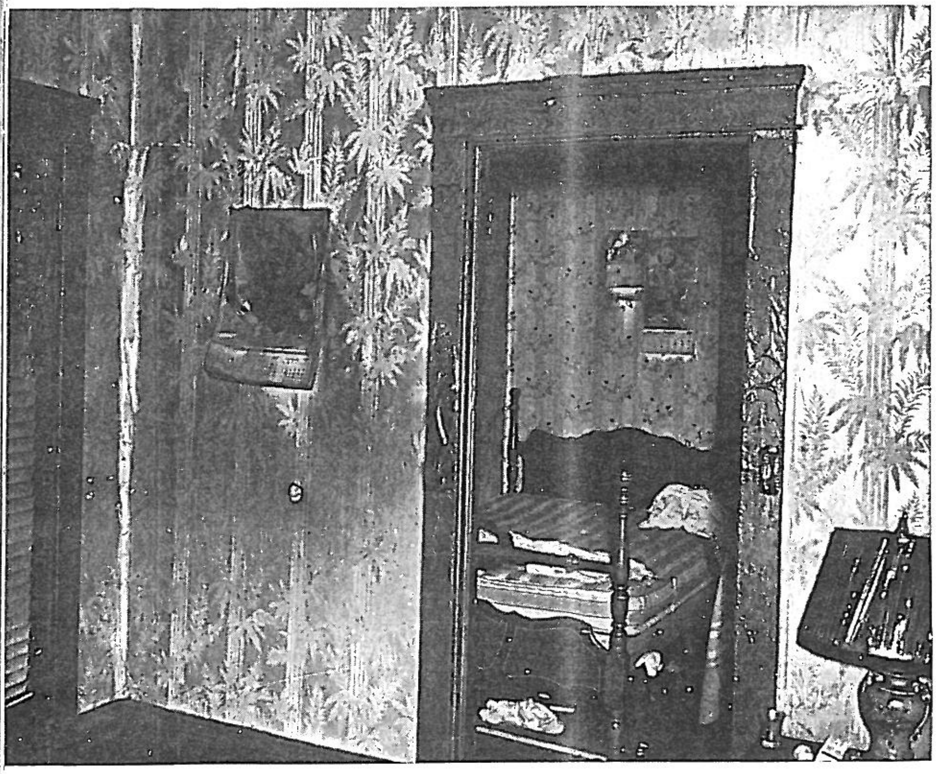
RUPTURED LIGHT BULB

tory and a photograph showing the position of the ceiling socket in dining room.

(*b*) The only water that remained in liquid form within the house was less than two gallons on the kitchen floor. There was no damage to either the building or contents caused by water.

(*c*) Plastic drapes in both living room and front bedroom had melted.

VOLUME OF WATER USED: Considering the time element and the volume of flow from the 1½-in. nozzle, it appears that not



INTERIOR OF FRONT BEDROOM FROM LIVING ROOM

more than 100 gallons of water were used to attack and extinguish the fire. This estimate includes the water used to complete the extinguishment of smouldering burning within the house but does not include the water used to complete extinguishment of feather mattress and other smouldering materials that were removed to yard.

Pump pressure was set to provide nozzle pressure of not less than 100 psi. The Elkhart nozzle had a stop insert that prevented it from being opened beyond a 30° angle cone and was equipped with a 1½-in. shut-off nozzle in order to avoid passing through the solid stream position when opening and closing. This nozzle delivers approximately 65 gpm of water, in the form of finely divided particles, at 100 psi nozzle pressure.

VALUE AND INSURANCE:

Adjuster's estimate as to value of building	$7,500.00
Adjuster's estimate as to value of contents	2,600.00
Insurance on building	5,000.00
Insurance on contents	2,000.00
Adjusted loss on building	2,298.00
Adjusted loss on contents	2,000.00
Uninsured loss on contents	None
Amount of actual loss to building and contents	$4,298.00

There was no loss to exposed property.

DISCUSSION: The gross atmospheric volume of the house including attic amounted to approximately 9,300 cubic ft. Deducting 10 per cent as displacement of furniture, there remained a net atmospheric volume of approximately 8,400 cubic ft. Based upon a vaporization efficiency of 90 per cent, each gallon of water used in the initial attack would have produced approximately 200 cubic ft. of steam. Approximately 42 gallons of water would have been sufficient to have displaced the original atmosphere. It appears that approximately 85 gallons of water were used in the initial attack by way of bedroom window and kitchen doorway. This volume of water was sufficient to have made two complete atmospheric changes within this house.

A study of the photographs of dining room is recommended. Note the condition of the charred paper on ceiling and walls. The slightest contact with this charred material would have caused it to break and fall. If water had been applied directly to this material it would not have remained on the ceiling and walls. A study of the heat level within this room is very interesting. The temperature at the upper level was sufficient to soften the light bulb (minimum 1300° F.) while combustibles at and near the floor level were not charred. It should also be noted that the interior temperature of this room was reduced within a period of minutes to a degree that allowed personnel to enter and extinguish spot fires and smouldering materials.

CONCLUSIONS:

(1) The most practical and effective method of controlling and extinguishing this type of fire is by the proper application of the necessary volume of water in the form of finely divided particles.

(2) In attacking this type of fire, the water particles should be projected into the upper atmospheric stratum within the area of major involvement. The area of major involvement consisted of the bedroom, dining room and kitchen.

(3) In attacking this type of fire, personnel should operate from positions that will enable them to avoid envelopment by heated smoke and live steam.

(4) Under similar heat and draft conditions which were present in this fire, it appears that through the proper employment of the necessary volume of water, in the form of finely divided particles, the following results can be accomplished:

(*a*) The heated and contaminated atmosphere will be displaced by an atmosphere of steam.

(*b*) The surface temperature within the building can be reduced to approximately the boiling point of water (212° F.). At this point steam production will cease and condensation within the building will cause the atmosphere of steam to be replaced with the air from the outside atmosphere.

(*c*) That surface burning will be extinguished but deep seated smouldering and small spot fires at or near the floor level will require direct application of water to effect complete extinguishment.

This case history was prepared by Lloyd Layman while Chief of the Parkersburg Fire Department. The photographs were taken by H. W. Muhlmann, Department Photographer. The diagram by M. J. Warner, member of Department. The adjustment of loss was made by General Adjustment Bureau, Inc., Parkersburg, W. Va.

CASE HISTORY NO. 5:

A building fire where plain water, in the form of finely divided particles, was used to attack and extinguish.

LOCATION OF FIRE: 1612 Race Street, Parkersburg, W. Va.

TIME OF FIRE: June 25, 1950 — 10:40 A.M.

DESCRIPTION OF BUILDING: One-story frame dwelling with basement, size 23 ft. x 24 ft.

INTERIOR: Basement — concrete floor; open joist ceiling; stairway to kitchen; six windows, size 33 in. x 24 in., located above ground level and fitted with removable screens; ceiling height seven feet.

OCCUPANCY AND CONTENTS: This dwelling was occupied at time of fire. Rooms on first floor contained normal amount of furniture. Basement contained gas heating furnace, hot water heater, washing machine and normal amount of storage.

CAUSE OF FIRE: The owner's wife was in basement using gasoline contained in glass jug to remove spots from clothing. She dropped the jug on concrete floor and almost a gallon of gasoline was released. She escaped from basement before the vapor-air mixture ignited from pilot light of hot water heater.

CONDITIONS EXISTING AT TIME OF FIRE: The five basement windows were open. Door from basement stairway to kitchen was open. Door from kitchen to rear porch was open.

CONDITIONS UPON ARRIVAL OF ENGINE COMPANY: Smoke was coming from some of the basement windows and from doorway from kitchen to basement stairway. The occupants were too excited to provide information regarding fire.

ATTACK AND EXTINGUISHMENT: The officer in charge attempted to enter basement by way of stairway but the heat was too intense. He then closed the stairway door and returned to the outside. He decided to attack the fire through a basement window located on opposite side from stairway. The screen was removed from window and a high-velocity fog cone was slanted upward toward ceiling, the nozzleman whipping nozzle briskly to obtain maximum dispersion of particles. Smoke and condensing steam came from the window openings. Within a period of seconds the volume of condensing steam coming from the window openings started to decrease in volume. It was estimated that water was applied for a period of about twenty seconds when the volume of condensing steam had decreased sufficiently to indicate that a major part of the accumulated heat had been transferred to the outside.

Entry was made by way of stairway, there was no smoke within the basement and the fire had been extinguished. At this time the Chief of Department arrived and was able to enter and remain within the basement without respiratory protection. The interior atmosphere was warm but of insufficient degree to cause physical discomfort. Neither spot fires or smouldering burning were found. It appeared that gasoline had been almost, if not completely, consumed.

ADDITIONAL FACTS AND OBSERVATIONS:

(*a*) Small spots of water were scattered on the uninvolved surface of the concrete floor. This appeared to have resulted from condensation of steam on the cold concrete. It was estimated that this volume amounted to less than a gallon.

(*b*) An ironing board was located in line with window opening through which the attack was made. A piece of wearing apparel hanging from the ironing board had been partly destroyed but the ironing board and the undestroyed portion of cloth showed no evidence of moisture.

(*c*) Paper boxes containing fruit jars were stacked along basement wall in a position that was unexposed to any direct application of water. These boxes were partly destroyed but there was no evidence of moisture on the remaining portions.

VOLUME OF WATER USED: A single 1½-in. line equipped with a 65-gpm Elkhart high-velocity nozzle was used. Pump pressure sufficient to provide a minimum nozzle pressure of 100 psi was maintained. The water was taken from booster tank and measurement showed that a volume of approximately twenty gallons was used to extinguish this fire.

VALUES AND INSURANCE:

Adjuster's estimate of value of building	$8,000.00
Adjuster's estimate of value of contents	4,000.00
Insurance on building	8,000.00
Insurance on contents	4,000.00
Adjusted loss paid on building	368.18
Adjusted loss paid on contents	171.63
Total loss	$539.81

DISCUSSION: The total volume of the basement amounted to about 3,864 cubic ft. Allowing ten per cent as displacement of furniture, fixtures, and contents the net atmospheric volume amounted to approximately 3,500 cubic ft. Vaporization of twenty gallons of water, based upon 90 per cent efficiency, would have produced about 4,000 cubic ft. of steam. Approximately 175,000 B.T.U. would have been required to vaporize this volume of water. It is estimated that a gallon of gasoline should generate about 125,000 B.T.U. if complete combustion was obtained. Considering this data it is not difficult to realize why the original atmosphere was displaced and complete extinguishment was obtained.

CONCLUSIONS:

1. An indirect attack is the most effective and practical method of attacking this type of fire.

2. Extinguishing action within the basement was increased by closing the stairway door.

This case history was prepared by Lloyd Layman while Chief of the Parkersburg Fire Department. Adjustment of loss was made by General Adjustment Bureau, Inc., Parkersburg, W. Va.

CASE HISTORY NO. 6:

A building fire where solid streams were used to attack and extinguish.

LOCATION OF FIRE: 315–317 Juliana Street, Parkersburg, W. Va.

TIME OF FIRE: June 24, 1939 — 3:40 A.M.

DESCRIPTION OF BUILDING: Consisted of three-story section and one-story section. Three-story section faced Juliana Street, width 40 ft., and extended west to depth of 80 ft. One-story section, width 40 ft., extended west from rear of three-story section to depth of 60 ft. Basement under three-story section only. THREE STORY SECTION: exterior walls — brick; interior wall — brick, from front center to rear with open archways on each floor, this wall provided support for all floors. Windows: Front — all floors; south side, rear, and north side — second and third floors only. Floors: wood supported by interior wall. Roof: frame, flat with cockloft, metal covered. ONE-STORY SECTION: exterior walls — tile; concrete floor; roof — frame supported by unprotected steel, flat with built-up covering.

INTERIOR: Frame enclosed stairway from alley near south rear to second floor. Open stairway from first floor to basement located near front center of first floor. Open elevator shaft from basement to metal-covered penthouse on roof located against north wall 20 ft. from rear wall, two sides enclosed with tongue-and-grooved boards. Office and rest rooms, second floor, located in south rear section and occupied floor space of 20 x 40 ft., plaster on wood studding and lath. Remainder of second floor formed a single atmospheric area. Ceiling all floors — plaster on wood lath, height 12 ft.

EXPOSURES: No direct exposures front or rear. South side — three-story brick building located on opposite side of 12-ft. alley. North side — three-story brick building extending entire length of building.

OCCUPANCY AND CONTENTS: First floor and basement occupied by Royal Furniture Company, retail furniture store. Second floor occupied by Case Mfg. Company, shirt and overalls factory. Third floor occupied by Royal Furniture Company, storage and furniture. Large amounts of combustibles on all floors and basement. One-story section used as garage and storage space by Royal Furniture Company.

CONDITIONS EXISTING AT TIME OF FIRE: The furniture store and clothing factory were closed between 5:00 and 6:00 P.M. the previous day. Alarm was transmitted by pedestrian who observed smoke seeping from building. The elevator was located at first floor level. Doors to office and rest rooms, second floor, were closed. All exterior doors and windows were closed.

CONDITIONS UPON ARRIVAL OF FIRST ALARM UNITS: Gases escaping from penthouse on roof were burning. Rear window next to north wall, second floor, had burned out and flames were coming from opening. All other windows were intact. Second and third floors were heavily charged with smoke. Some smoke at upper level on first floor. Interior of elevator shaft was involved from first floor to penthouse. Burning pieces of tongue-and-groove boards, used to enclose two sides of elevator shaft, had accumulated on elevator at first floor level and had ignited combustibles near shaft. It was evident that the area of major involvement was on second floor in north rear section.

ATTACK AND EXTINGUISHMENT: A 2½-in. line equipped with shut-off nozzle was advanced through front door and a solid stream used to extinguish fire on elevator and around shaft. Another 2½-in. line was laid to rear of building and raised to roof of one-story section. This line was equipped with shut-off nozzle and one-in. tip. The burned-out window opening was fitted with steel bars to prevent breaking and entering. The lower part of opening was about four ft. above the roof of one-story section. The solid stream had to be slanted upward through the window opening and in attempting to obtain maximum coverage the stream was moved from side to side across the entire opening. The stream was broken by striking the steel bars and then striking the ceiling. When the attack was made through this opening the entire rear area to and beyond the elevator shaft was a mass of flames. Within a few minutes the fire was blacked out and application of water was discontinued. Within a few seconds a swirling mass of flame appeared and water was again directed through window opening in the same manner as in previous application. A few seconds later the fire was again blacked out but application was continued for a few minutes. Re-ignition did not occur after the second attack.

Entry was then made to both the second and third floors. The interior atmosphere was hot and humid but it was possible for ventilating parties equipped with all-service masks to open windows on both floors. There was some smoke but of insufficient density to prevent fair visibility. Two 1½-in. lines equipped with shut-off nozzles and ⅜-in. tips were used to extinguish spot fires and smouldering burning on second and third floors and in cockloft.

ADDITIONAL FACTS AND OBSERVATIONS:

(1) The heat level on second floor had come within about four ft. of the floor.

(2) Sewing machines located in south section of second floor were undamaged by either heat or water.

(3) Furniture located in north rear section of first floor below the fire area was damaged by water. Personnel attempting to cover the furniture located in this section could not complete the job due to the temperature of water coming from second floor, it was almost to the boiling point.

(4) While line was being placed on roof of one-story section, entry was made to second floor by way of one of the front windows but the dense smoke and intense heat forced personnel to withdraw.

(5) No attempt was made to ventilate this building until after the attack through second floor window had been completed.

(6) It was evident that the fire had extended to third floor and had involved combustibles in area near elevator shaft. It was also evident that a considerable area within cockloft had been involved.

VOLUME OF WATER USED: Only a few seconds of application was required from nozzle on first floor to extinguish the fire on and

near the elevator. Although it is difficult to estimate the time water was applied through window opening to second floor, it is believed that the total application period did not exceed seven minutes. Considering the hydrant pressure in this district, friction loss in hose line, and elevation loss the nozzle pressure should have been about 55 psi. This would have provided about 220 gpm making a total volume of about 1,500 gallons.

VALUES AND INSURANCE:

Estimated value of building	$30,000.00
Estimated value of contents — Royal Furniture Company	25,000.00
Estimated value of contents — Case Mfg. Co.	10,000.00
Insurance on building	8,000.00
Insurance on contents — Royal Furniture Co.	12,500.00
Insurance on contents — Case Mfg. Co.	3,000.00
Adjusted loss paid on building	4,121.53
Adjusted loss paid on contents — Royal Furniture Company	6,581.78
Adjusted loss paid on contents — Case Mfg. Co.	2,616.61
Total Loss	$13,319.92

DISCUSSION: The author was in command at this fire and directed the attack that was made through rear window of second floor. This operation was reviewed and discussed many times but no logical explanation was found for the extinguishing action obtained on third floor and in cockloft. In the light of our present knowledge regarding the indirect method of attack, it is not difficult to provide logical explanations for the results obtained.

The concentration of excessive heat within the area of major involvement and degree of confinement offered ideal conditions for successful employment of an indirect attack. The burned-out window provided a ready-made opening at the most advantageous point for injection of water into the upper stratum of the interior atmosphere within the area of major involvement. The only additional requirement for successful employment of an indirect attack was skillful injection of water, in the form of finely divided particles, at a rate and in sufficient volume to absorb the excessive heat contained within the building. Although finely divided particles were not used, a break-up of the solid stream was achieved by force of circumstances. The contributing factors in producing this break-up were adequate nozzle pressure, stream striking the steel bars and being deflected from ceiling. This break-up did not produce finely divided particles but did increase the surface exposure of the water sufficiently to increase the percentage of vaporization to an extent that produced effective results.

It is interesting and instructive to consider the net atmospheric volume of this atmospheric area and the percentage of vaporization required to displace the original atmosphere. Deducting the space occupied by office and rest rooms on 2nd floor and allowing 15 per cent for displacement of contents, the net atmospheric volume of second floor consisted of less than 25,000 cubic ft. Vaporization of 125 gallons of water, based upon 90 per cent efficiency, would have provided this amount of steam. Allowing 15 per cent for displacement of contents on third floor, the net atmospheric volume of this floor amounted to less than 33,000 cubic ft. Vaporization of 165 gallons of water would have produced sufficient volume of steam to displace the original atmosphere of third floor. Vaporization of less than 300 gallons of water would have provided a volume of steam in excess of the net atmospheric volume of second and third floors and cockloft. Vaporization of from 300 to 500 gallons of water out of a total of 1,500 injected through window opening of second floor appears to be a reasonable estimate. The results obtained tend to confirm the reasonableness of this estimate.

CONCLUSIONS:

(1) A single 1½-in. line equipped with a 65-gpm high-velocity fog nozzle should have provided sufficient rate of application to have effected extinguishment of fire on first floor.

(2) A single 1½-in. line equipped with a 90-gpm high-velocity fog nozzle should have provided sufficient rate of application to have displaced the original atmosphere and extinguished surface burning on second and third floors and in cockloft, providing the cone of water particles had been directed into the upper stratum of interior atmosphere through the burned-out window.

(3) If an indirect attack had been made through the burned-out window using a 90-gpm high-velocity fog cone, equal or better results would have been obtained with one-third to one-fifth the volume of water that was applied with the solid stream.

This case history was prepared by Lloyd Layman. Adjustment of loss made by General Adjustment Bureau, Huntington, W. Va.

Chapter VI

PRACTICABLE SUGGESTIONS

THE change-over from the solid stream system of fire fighting to that of finely divided particles is by necessity an evolutionary process within the individual department. Successful completion of this evolution requires time, perseverance and patience. Personnel can not be converted by directives or orders. Wholehearted and sincere acceptance comes only as the individual officer and member comprehends that this system of fire fighting is based upon scientific principles and if employed properly will produce far better results than can be achieved by the use of solid streams. The first and most important convert in any department is its chief. Under guidance of capable, intelligent and aggressive leadership, a fire department can convert from the solid stream system of fire fighting to that of finely divided particles without incurring any unnecessary loss during the transitory period.

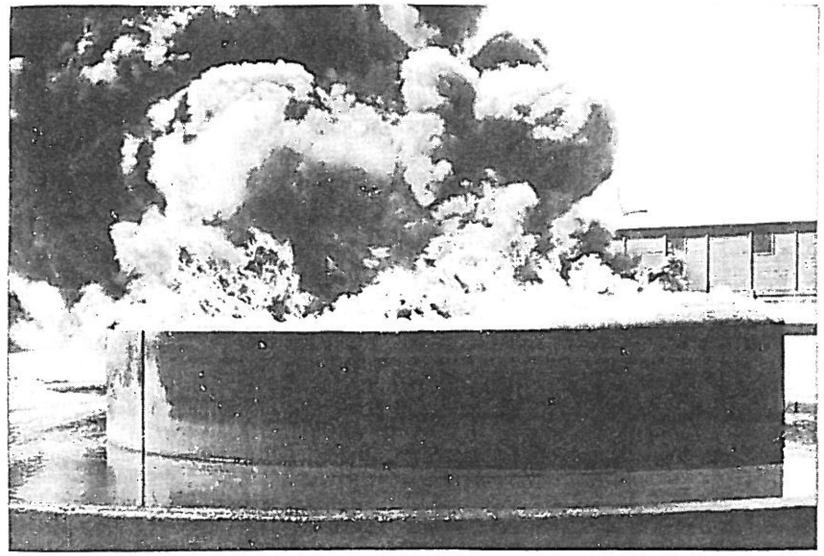
The foundation for this change-over must be provided through the medium of a carefully planned and thorough training program. This program should be designed to give each officer and member ample opportunity to comprehend the natural laws and fundamentals which are presented in this text. Successful execution of this program depends to a major degree upon the ability and resourcefulness of the department instructor and members of his staff. A competent instructor can conduct organized classes in an interesting and inspiring manner. He should be resourceful in the use of simple demonstrations to illustrate and clarify. This is basically a job of salesmanship and the instructor must know his subject and know it well. A qualified and resourceful instructor can sell this system of fire fighting on its merits alone without resorting to any misrepresentation or falsification. The motion picture "Chemistry of Fire" can be used to good advantage. This picture presents many of the fundamentals of combustion and extinguishment in a clear and concise manner. It presents such a vast amount of useful knowledge that it must be seen several times to comprehend the information it attempts to convey.

This was one of the official fire-fighting training films used by the U. S. Navy and Coast Guard during World War II. Distribution is handled by Castle Films, Inc., and reprints can be obtained through any local film distributor.

The oil tank fire has proved its usefulness in teaching this system of fire fighting. This provides the most inexpensive form of practical training. A tank should have a depth of from three to four ft. with a diameter of from ten to fifteen ft. It should be fitted with drain pipe and control valve for removal of excess water. This phase of training provides the individual with an opportunity to use the various types of nozzles to extinguish a definite volume of fire. The trainee learns the technique of direct attack under practical conditions. It is the type of training that instills confidence and enables the trainee to develop skill in the use of both high and low-velocity fog.

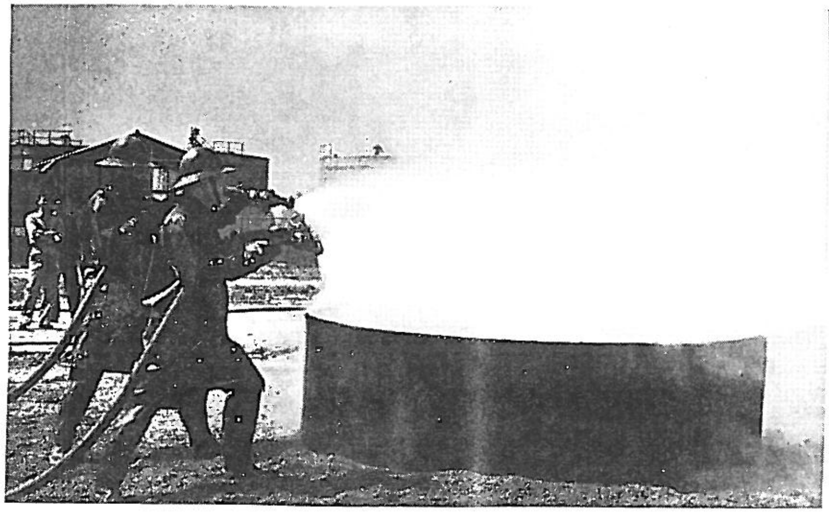
A BUILDING of fire-resistive construction, designed especially for experimental and training fires, would simplify the problem of teaching the indirect method of attack. Few departments have this type of training building but a number of departments and state fire schools are planning to overcome this deficiency in their training facilities. The limited resources of the Parkersburg Department prevented construction of a suitable training building. The personnel of this department had to learn the proper technique of the indirect attack by trial and error on the fireground. Although a suitable building is most desirable for training of personnel in the technique of the indirect attack, this deficiency should not deter a progressive department from adopting the fog system of fire fighting.

While yet in the early phase of the training program, units of the Parkersburg Department were equipped with all-purpose booster nozzles. This proved to be a very constructive step in converting the personnel to the fog system of fire fighting. It enabled a nozzleman to project either a solid stream or a high-velocity fog cone of approximately the same volume. Many were amazed with the results they were able to obtain with about 18 gpm of water in the form of finely divided particles. A booster nozzle was used in the first attempt to employ the



No. 2 fuel oil burning in 15-ft. diameter training tank.

Single 1½-in. all-purpose nozzle projecting high-velocity fog cone, delivery volume approximately 54 gpm, used to extinguish No. 2 fuel oil in 10-ft. diameter tank.



Two 1½-in. all-purpose nozzles projecting high-velocity fog cones, used to extinguish No. 2 fuel oil in 10-ft. diameter tank.

Ten-ft. applicator fitted with L-11A low-velocity head, 10-ft. diameter tank, No. 2 fuel oil, note volume of condensing steam.

indirect method of attack. Two rooms of a four-room bungalow were fully involved. A burned-out window provided a ready-made opening to the area of major involvement. Conditions of confinement and excessive heat were ideal and the attack was very successful. Less than a gallon of water remained in liquid form after the fire had been extinguished. This fire provided the first case history for use in the training program. Although this attack was very successful, it is advisable to discourage the use of booster nozzles in making an indirect attack except where a single stall garage or other small building is involved. The volume of water per minute is too small to produce satisfactory results in larger spaces except under the most favorable conditions.

Case histories furnished an unlimited source of instructional material. By using a blackboard and slides made from photographs and a diagram of the building, the instructor was able to use the case history of a particular fire to review and discuss the entire operation in the classroom. The effectiveness of the case history system of teaching was verified by increased efficiency on the fireground.

Conversion of the Parkersburg Department was accelerated by a major increase in personnel. Probationary firemen received three weeks of intensive training before being assigned to fire duty. This basic course included thorough training in the fog system of fire fighting. The indoctrination of probationary firemen in this system can be accomplished readily during the basic training period.

A period of approximately two years was required to design, improvise and procure suitable equipment and for the personnel to develop sufficient skill, judgment and confidence to employ this system of fire fighting effectively on the fireground. As each unit was supplied with sufficient amount of 1½-in. hose to provide an adequate number of hand lines, the 2½-in. solid stream nozzles were replaced with 1½-in. fog nozzles. Two and one-half in. hose was used only as supply lines from hydrant to pumpers, from pumpers to 1½-in. hand lines, and from pumpers to multiversal nozzles and ladder pipe. Hand lines were limited to maximum lengths of 200 ft. to overcome the friction loss problem in 1½-in. hose. Pump operators were required to provide sufficient pressure to insure a minimum nozzle pressure of 100 psi but not to exceed 125 psi. This was a period of gradual but progressive change in both equipment and operational procedure.

Two questions frequently asked regarding this form of attack are: "Should fire fighters wear gas masks or protective breathing apparatus when making an indirect attack?" and "What will be the effect of steam or fog on persons who may be trapped in the structure?" In answer to the first question it is suggested that the individual fire department follow its normal policy with regard to use of respiratory protection. However, it has been observed that the use of masks will protect fire fighters from the discomfort occasioned by the condensing steam and products of combustion expelled by the indirect fog application. Also use of masks will permit fire fighters to follow up the advantage of flame suppression for the direct application and overhauling by advancement of lines more quickly than is possible where it is necessary to wait for the condensing steam to dissipate.

In answer to the question regarding the effect on occupants of steam from fog application, we can only state that we have never heard of any adverse effects. Contrariwise, the much more rapid flame suppression with indirect application makes it possible to reach endangered persons more quickly so as to be able to remove them to safety and render aid as necessary. In addition, a fog jet provides a much more effective water curtain for protection of personnel engaged in rescue operations than does a solid stream. The fog stream also has the advantage that fire fighters are not in danger of being injured by impact from a fog stream or from objects struck or displaced by a hose stream.

Very few incidents have been reported where a small backdraft or smoke type explosion has occurred after fog has been introduced into a highly charged area and before adequate heat transfer could be effected to purge the area of hot combustible gases. However, there is no indication in any of these cases that the smoke explosion would not have occurred had solid stream attack been employed in the same situation. It is true that a fog jet may introduce some entrained air just as will a

solid stream of water. If conditions favorable to an explosion are present, this may conceivably take place during the extremely small interval of time before heat has been sufficiently transferred.

Where there are indications of an oxygen deficiency within an involved building (Third Phase), care should be exercised in making the size up. The area of major involvement should be determined and the smallest possible opening made followed immediately by injection of an adequate volume of water fog. Rapid steam generation will increase the interior atmospheric pressure and thereby prevent an inrush of air from the outside atmosphere. At the same time combustible smoke will be displaced and diluted by steam.

Where fires occur in basements and other confined areas, standard procedures should be followed for covering vertical extension of fire while making an attack with fog cellar pipes and distributors as suggested in this text. Where advancement of fires into the basement is indicated, men should be wearing self-contained respiratory protective equipment. Opening up of openings to the outside at the opposite side of the fire area from where attack is made will help permit expulsion of steam and products of combustion away from the openings or area from which the fog attack is being made. Usual procedures for covering exposures should be followed in such instances. One mistake that should be avoided in such cellar fires is a direct attack with fog or any other streams from opposing directions. This invariably results in needless punishment of both crews by driving heat and smoke back inside the structure with the frequent result that the seat of the fire cannot be reached until the fire has extended through the first floor.

Where an intense large area cellar fire is encountered, it may be necessary to operate master fog streams into the first floor area while ventilation is being effected above the fire in order to remove excessive heat to allow fire companies to operate in the building so as to place distributors or cellar nozzles in service and to check vertical openings and partitions against the upward spread of fire. It must be recognized that frequently cellar fires are in cut-off areas and it may be very difficult to determine just where to introduce the fog attack. In such situations proper application of adequate fog streams on the first floor has been found effective against upward extension of the main body of fire.

Where fires involve cocklofts and other concealed spaces, the use of low velocity fog heads, sometimes employed with bayonet type heads to facilitate forcible entry, has proved highly successful. Also the use of cellar type fog distributors through roof openings has been effective in a number of instances.

The fire service now has available an array of fog nozzles and applicators from which the fire officer may choose his attack weapons to achieve the effective transfer and elimination of excessive heat in accordance with the fundamental principles stated in this text. In general, attack must be in sufficient volume for a rapid reduction of heat, and lines should be placed in accordance with sound tactical procedures calling for covering all normal fire fighting positions including the front and rear of the structure, possible upward extension of fire through vertical openings, internal and external exposures, as well as an adequate attack upon the main body of the fire. (See the book "Fire Fighting Tactics.") It should be remembered that water conservation and reduction in smoke and water damage is enhanced by heat reduction and transfer achieved by adequate rate of fog application.

Effective nozzle pressures are important so officers and pump operators should know the volume discharged by the various fog nozzles used in the department at various fog pattern settings in order to calculate the pressure requirements. As shown in other publications of the National Fire Protection Association, 1½-in. fog nozzles are available with discharge ratings at 100 pounds nozzle pressure, all the way from 40 to 125 gpm or more. The various 2½-in. fogs nozzle discharge from 90 to 1000 gallons per minute. Thus each individual nozzle presents a different water supply and pump pressure problem if best results are to be obtained. Incidentally, for most effective use of fog nozzles, use of fire department pumpers is generally indicated because very few communities have water systems that will supply the recommended 100 pounds nozzle pressure in addition to pressure losses in the hose.

During the past two years, the Parkersburg Department

has had to combat several major exterior fires. These operations provided ample proof that major exterior fires can be controlled and under favorable conditions extinguished providing a sufficient volume of water in the form of finely divided particles is employed in a proper tactical manner. In one of these fires, the aerial ladder pipe, delivering 425 gpm of high-velocity fog, prevented involvement of a railroad bridge located 12 ft. from the burning building. It would have been impossible to concentrate sufficient number of solid streams to have prevented involvement of this bridge. The only effective and practical solution to the problem of controlling major exterior fires is to provide adequate and suitable equipment which will enable fire-fighting personnel to produce, control and project large volumes of water in the form of finely divided particles.