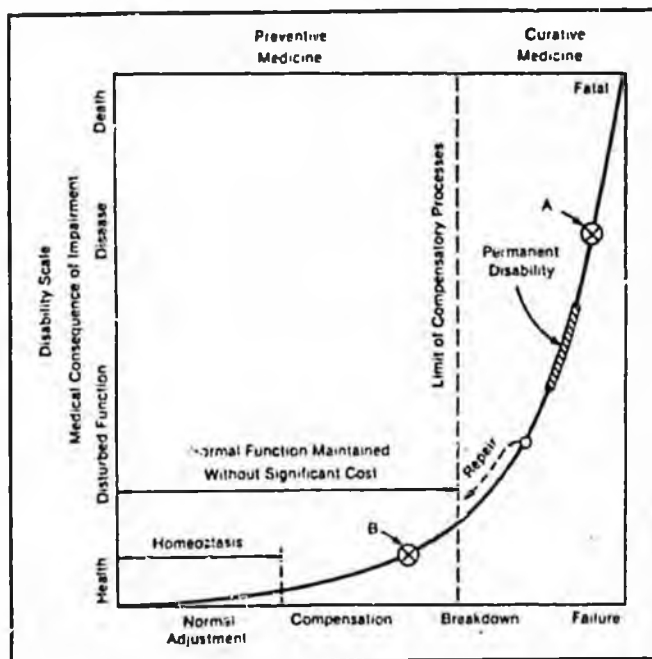


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DR. HOWARD A. ANDERSEN

THE EFFECTS OF SMOKE AND TOXIC GASES ON THE RESPIRATORY TRACT



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My first encounter with burns of any magnitude was in World War II when I was aboard a destroyer that was hit and was sunk by enemy action on D-Day at 6:30 a.m., the first day of the Allied landings at Normandy. We were hit amid-ship in the fire and engine rooms. Boilers exploded releasing hot steam and fuel tanks burst releasing oil that burned. Over half of our crew were burned, injured, dead or missing and I was a busy physician for the next two days aboard a rescue ship.

My next experience was a very personal one on Okinawa. I was attached to the Sixth Marine Division and was assigned to the latrine detail. Neither my corpsmen nor I had had experience with this, but according to the Navy Manual, a very acceptable way of cleaning latrines was by daily burning using diesel oil. After liberal splashing of presumed diesel oil in a 2-holer my first day, I dropped some burning paper in and inquisitively peered into the hole. Whoosh! It exploded in my face giving me an even higher forehead than I now have. This was not as bad, however, as a few weeks later when I had 12 men who were burned. Immediately after breakfast when a 12-holer was fully occupied, someone dropped a lighted cigarette into the latrine! It still hurts to think of it. At least it was only my face that was burned!

The respiratory tract from the nose to the pharynx, larynx, trachea, bronchi, and alveoli or air sacs is vulnerable to injury from inhaled smoke which may contain irritants and asphyx-

ants. Any or all of these respiratory structures can be injured. Smoke is not, of course, a single substance, but may be composed of hot steam and many irritant and toxic gases such as ammonia, chlorine, hydrochloric acid, nitrogen dioxide, phosgene, sulfur dioxide, and possibly many others. One must also remember that when anything burns, carbon monoxide is produced. Though this gas is not a local irritant it may be lethal. The amount of harm resulting from inhalation of these gases depends on several factors but particularly on the concentration of the toxic substance and the duration of exposure.

Tracheobronchial Effects

The respiratory tract from the nose to the larynx downward to the trachea, bronchi, and respiratory bronchioles (very small airways) is lined by ciliated epithelium and goblet cells attached to a basement membrane. This mucosa is composed of only one cellular layer in thickness. The cilia are tiny hairs which have a rhythmic beat in unison waving mucus and other material toward the larynx. Beneath the basement membrane is the submucosa with a network of connective tissue, bronchial vessels, nerve fibers, elastic tissue, and secretory glands. Muscle and cartilage comprise the other tissues in the trachea and bronchi. Goblet cells

in the mucous membrane and secretory glands in the submucosa both secrete mucus which keeps the membrane moist.

Smoke with irritant fumes and gases causes an acute tracheobronchitis with red and inflamed mucosa or lining which may swell and thicken. This causes hoarseness, cough and wheezing. In some instances the entire mucous membrane down to the cartilage may be damaged. The cilia are particularly susceptible to irritants and are the first structures to be affected. When healthy they beat approximately 25 times per second waving as a field of wheat waves in a breeze and washing secretions or particles toward the larynx at approximately the speed of 1.6 mm. per minute. Their action may be stopped for approximately 20 minutes by inhalation of smoke from one cigarette. With heavy cigarette smoking cilia may be destroyed permanently. The same sort of effect is one of the first results of inhalation of smoke from other types of fires.

When damage goes deeper ciliary and goblet cells may be destroyed and there is infiltration of the submucosa or connective tissue of the lining of the trachea and bronchi with inflammatory cells and fluid causing edema or swelling of the membrane. This may cause cough, shortness of breath, and wheezing because the air ways are narrowed. These symptoms occur at different times after injury probably depending on the dosage and the substance involved. When hot steam is inhaled, having 4000 times the heat carrying capacity of air, these symptoms may occur as early as 30 minutes later. In the Coconut Grove fire in Boston doctors noted they occurred about 3 hours after the burn, approximately the same amount of time that the swelling occurred in the external burns. Usually, however, it takes one or two days for these symptoms to appear.

Additional obstruction may occur with spasm of the bronchi which results from a reflex mechanism transmitted via nerve endings from the mucosa to the muscles surrounding the bronchi. This may aggravate the wheezing, especially on exhalation, similar to a person with asthma.

Pulmonary Effects

As bronchi extend further into the lung, they continue to branch and become smaller and smaller. Terminal airways are 0.5 mm. (1/50 of an inch) or less in diameter. It does not,

therefore, require much swelling of the mucosa to produce obstruction predisposing to collapse and airlessness of the lung (atelectasis) beyond the obstruction. "Micro-atelectasis" is a term that has been applied to this phenomenon when small bronchi and lung segments are involved. When airways of larger size are blocked by this swelling, bacteria may invade the lung beyond the effected bronchus causing pneumonia.

With continued branching the small airways become the respiratory bronchioles. The alveolar duct and the alveoli or air sacs branch off these. Within the alveoli are alveolar macrophages which normally provide one of the defense mechanisms of the lung against infection. They consume and inactivate bacteria and help avoid infection. It has been shown that after smoke inhalation alveolar macrophages have a reduced capacity for bacterial inactivation and that the bacteria within the macrophages are capable of multiplying. This phenomenon also predisposes to pneumonia.

Alveoli also may be the source of pulmonary edema or extravasation of fluid into them from actual damage to the alveolar lining cells or injury to the pulmonary capillaries. Reflex neurogenic factors affecting the tone of the pulmonary vessels have also been implicated as a cause of this transudation of fluid across the alveolo-capillary membrane into the alveolus. Accumulation of fluid may be so extensive as to cause marked respiratory embarrassment and even death.

When atelectasis, pneumonia or pulmonary edema occur, gas transport is disturbed so that oxygen is not absorbed properly and hypoxia is likely to result.

Detection of Respiratory Effects

One should suspect the presence of damage to the respiratory tract, even after minor burns, when there is a history of prolonged smoke inhalation in an enclosed area, when there are burns of the face, head, neck, or membranes of the nose and mouth, and when there are symptoms of cough, hoarseness, shortness of breath and wheezing.

One can detect the presence of tracheobronchial injuries by bronchoscopic examination. It is a simple procedure to slip a flexible bronchoscope into the trachea and bronchi and visibly assess the amount of damage. Lung scans using

Xenon 133 consist of injection of this radioactive substance into a vein of the arm or leg from which it is carried directly to the lungs. When the circulation through the vessels of the lungs is normal and when there is a normal amount of oxygen and other gas exchange in the lungs, the gas traverses the membrane between the alveolar air and the blood very readily. When alveoli are blocked off, however, or when the membrane is thickened, diffusion of the gas across the membrane is slowed. A normal scan demonstrates complete and equal clearing of Xenon 133 within 90 seconds. In inhalation injury there may be delayed clearing. In one series of 50 patients, 15 had delayed clearing and the mortality rate in these patients was considerably increased.

Examination of the lungs by x-ray may also be helpful and should be done. In the first day or two, however, it may be disappointingly normal even when there is moderately severe damage to the bronchi or to the lungs. Measurement of pulmonary volumes such as vital capacity, total capacity, residual volume, maximum

breathing capacity, and forced vital capacity is seldom helpful, however.

Measurement of arterial blood gases (oxygen and carbon dioxide) may be helpful, but one should not be lulled into a sense of false security if they are normal. Determination for carboxyhemoglobin in the blood should be performed to evaluate the amount of carbon monoxide absorbed.

In every study that has been done, the presence of an inhalation injury to the tracheobronchial tree or the lungs increases markedly the mortality rate. It is important, therefore, to remember to evaluate the respiratory tract in a burned person. The possibility of survival is definitely influenced by involvement of the tracheobronchial tree and the lungs, particularly if such involvement is ignored. It is particularly important that fire fighters do everything possible to protect their lungs whenever they enter smoke and whenever there is a possibility of inhalation of toxic gases.

DR. VICTOR H. ESCH

TOXICITY IN THE FIRE FIGHTER'S ENVIRONMENT

I wish to express my sincere thanks and appreciation to the trustees of the Redmond Fund, Dr. Atwood and the International Association of Fire Fighters for the opportunity to participate in the Fourth Symposium on the Health and Hazards of the Fire Service.

During the past 10 years there has been an explosive proliferation both in the manufacture and use of plastic and synthetic materials.



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Polyvinyl chloride production alone exceeded 44 billion pounds last year.

These products now flooding the marketplace are finding increased use in the manufacturing of household furniture, plastic pipe, buildings,

wall coverings, automobiles, buses, subway cars, aircraft and the covering of telephone and electrical conduit.

Accordingly there has been an increasing concern about the toxicity of the fumes and smoke produced by the pyrolysis or combustion of these materials . . . unfortunately, the toxicological aspect has lagged so far behind the knowledge of the physical properties (such as flame spread, melting point, etc.) that the toxic hazards cannot be described adequately except in generalities.

Environmental hazards, not long ago synonymous with DDT and "silent springs" are casting longer, darker shadows over the health of all people. An incredible series of disasters implementing new chemicals in the market place are sending growing numbers of patients exposed to these agents to physicians who are often unaware of either the magnitude or the precise nature of the chemical hazard.

Today there are almost too many potential hazards around for individual physicians to become familiar with: polycyclic aromatic hydrocarbons, inorganic microparticles, metals, halogenated ethers, aromatic amines and biphenyls, to name a few.

TRIS, KEPONE, VINYL CHLORIDE, BENZENE, PBB's and PCB's have now become household names due to recent disclosures by the American press.

The proliferation and sophistication of petrochemical products available to the building industry today far surpasses the ability of the scientific community to assess critically all of their toxic properties in a fire situation.

As experienced fire surgeons, we were shocked some six years ago by the untimely death of a 33 year old firefighter who died of acute pulmonary edema 24 hours after inhaling the fumes from a burning PVC-coated wire. Repeated inquiries at that time to the petrochemical and plastics industries as to the harmful effects of their products on humans were—in a word—unproductive. Few epidemiologic studies are mounted unless there is a suspicion, a guess or a hint that leads to these studies. Following a series of fires involving electrical insulation, our suspicions were confirmed and a five-year investigative study was launched. Our paper, published by the Journal of the American Medical Association was the

result of that five-year study. We found that firefighters exposed to the fumes from burning or thermally degrading polyvinyl chloride rapidly became incapacitated secondary to the development of chest pain, severe headaches, shortness of breath and in many instances became comatose or disoriented. To date over 200 firefighters have required treatment at the hospital following exposure to these fumes. Dr. Dyer has reported a number of cardiac arrhythmias developing after various periods of exposure.

In a fire situation PVC will soften and decompose on heating and produce hydrogen chloride, benzene and other decomposition products. Phosgene has also been listed by some investigators.

Hydrogen chloride vapors are more dehydrating and corrosive than aqueous hydrochloric acid and vapors. Hydrochloric acid mist will cause throat irritations when the concentration reaches 35 ppm. Further, concentrations above this level causes anosmia (loss of sense of smell) due to severe irritation of the olfactory or first cranial nerve. The firefighter is usually unaware of this sensory loss and is unable to detect the presence of the corrosive gas until considerable quantities have been inhaled and pulmonary symptoms begin to develop.

We feel that concentrations over 50 ppm are not tolerable for any length of time. At levels well below 1,500 ppm hydrochloric acid fumes can be fatal in a few minutes. The physiological effect of the corrosive action of hydrogen chloride inhalation is often delayed and in our experience may develop as late as 12 to 24 hours after exposure. Benzene inhalation will also result in either acute or chronic toxic symptomatology depending upon the concentration of the vapor and the length of exposure. Acute poisoning will develop following inhalation of vapors in the 3,000 ppm range after exposure to the fumes for several minutes.

Electricians are particularly vulnerable to death or severe injury if trapped in a confined area when a PVC electrical fire develops. We have observed a number of electricians either killed or injured in this manner since the onset of our investigation. Our findings have been confirmed by numerous other investigators and other PVC fatalities have since been recorded. There is now mounting evidence that perma-

nent lung damage will result from exposure to the corrosive fumes.

Recent studies at Yale University School of Medicine have confirmed an earlier impression (JAMA Medical News 234:1211 (Dec. 22, 1975) that pulmonary damage due to inhalation of toxic combustion products (corrosive gases in particular) is often not detected by standard X-ray studies. Ventilation perfusion scans utilized by the Yale group demonstrated airway or parenchymal lung damage that was undetected by the previous chest x-rays.

Since thermal degradation of some polyvinyl chloride formulation can result in at least 75 different chemical compounds—it is quite likely, in my opinion, that repeated exposures over a period of years could result in the development of lung cancer in the firefighter—only time will tell. Meanwhile, any exposure to this material should be avoided.

Industry, to date, has a bad track record for truthful disclosure. The Plastic Pipe Institute report 5474 lauds the physical properties of PVC plumbing assemblies during actual fire endurance tests—there is no mention of the toxic properties when the material is thermally degraded.

The National Electrical Manufacturers Association (NEMA) and the Society of Plastics Industry recently published a booklet—"Characteristics of Polyvinyl Chloride Conduct, Insulated Wire and Piping in Fire Situation." This report especially prepared for code groups, building inspectors, fire marshals and other officials states that "There are no documented cases of PVC conduit, insulated wire, or piping contributing unusual life hazards to a fire problem." Further, it states that the combustion products from plastics are "different"—but no more toxic than those from other organic material—(cotton, newspaper, douglas fir). We strongly disagree.

Finally on the last page is a thermometer showing a "flash ignition temperature" for PVC to be 735° F (well above the other organic materials listed). This is misleading since it is well known that thermal decomposition of PVC occurs at approximately 400° F or less with the quantitative release of HCL long before ignition occurs.

The 13th edition of the N.F.P.A. Handbook states that the "Toxicity of combustion and thermal decomposition products, possibly be-

cause of long chemical names of some plastics, have been cause for concern among fire fighters." This organization and the Society of Plastics Industry has recently released a "slide show" relating to plastics in fire situations.

Incredibly, the Society of Plastics Industry recently reported in a newsletter that they had not seen a single substantiated report of death, proven by autopsy related to PVC and HCL. Among other recent reports we would refer the ASPI to the February 1976, Fire Protection that lists 3 deaths from acute pulmonary edema from the inhalation of HCL. (proven by autopsy.).

Dr. Russell P. Sherwin, a University of California pathologist, stated that chronic low level exposure to smoke, chemicals, and other pollutants, can result in premature death. He calls the lung cells the "endangered species" and states that even low levels of pollutants can destroy lung tissue.

With the arrival of the Toxic Substances Control Act (TOSCA) there will be new emphasis on many of these problems and a new era of inter-agency cooperation within the Federal Government can be anticipated.

The engineering community is to be commended on the many technological advances in the art of combustion analysis and the physical properties of pyrolysis. In so doing, however, the technology of this phase of the problem has far out-paced our medical understanding of the patho-physiological relationship of humans actually exposed to fires and exotic toxic gases. At this time it is critical that the emphasis be re-directed to the biomedical aspects that will tell us what actually occurs with human exposure to the toxic combustion products.

Ralph Nader has stated that the FAA has dilly-dallied for years and still has not issued any standards in these crucial hazard areas. Synthetic materials used in aircraft seat cushions, carpets and the walls of aircraft interiors emit a deadly combination of cyanide and carbon monoxide fumes when subjected to intense heat or burning. These gases are so toxic that passengers are cut down in seconds before they can reach an emergency exit or other opening. A Boeing 707-300 series aircraft made a successful emergency landing near Paris in 1973 after a fire started near the rear lavatory in a plastic waste basket. The in-flight cabin interior fire did not involve the aircraft's fuel but was fed by the interior's material. One-hundred

and twenty four people died from inhaling the toxic fumes and smoke from burning materials. During the same year 144 French teenagers were trapped, trampled, and asphyxiated when plastic synthetic decorations caught fire in a night club.

The danger from fire exposed electrical wiring systems on escape potential from buildings is now widely recognized. A Factory Mutual Research Report (September, 1976) identified HCL as the major toxic compound in the pyrolysis and combustion of PVC. Laboratory tests showed that the rates of production of HCL are more than twice as great for PVC conduit and non-metallic sheathed cable as for wiring systems where steel raceways are used.

The analysis of data indicated that the PVC conduit exposed to fire could adversely affect the human escape potential from buildings. Based on the same analysis, steel raceways would NOT adversely affect escape potential. Data also indicated that smoke levels exceeded acceptable limits for a PVC conduit wiring system than for other systems tested.

We ask a question at this point as to why the fire community allows this problem to exist in the electrical building codes?

Recently the District of Columbia Fire Marshall learned that 1000 polyethylene mattresses had been purchased for the D.C. jail. He ordered them removed thus eliminating a definite hazard. Since these mattresses are commonly used throughout the United States, and since smoking materials are readily available to prisoners and patients, it is inevitable that sooner or later a tragedy will occur in a jail, prison, or hospital.

Plastic and synthetic materials should not be used in high rise buildings, night clubs or other places of public assembly because of the "flash over" potential and the rapid build-up of toxic gases in a fire situation. Again, it would appear that continued indiscriminate use of those materials in these situations will result ultimately in a tragic loss of life.

The building industry is primarily interested in keeping the costs of construction down and providing adequate equipment to reduce fire losses. Life safety is relegated to a poor third for the sake of a profit. Thus, the building industry has encouraged the use of plastic pipe to avoid the plumber's wages since the pipe can be assembled on the job by unskilled laborers. Similarly, the use of PVC covered cable is

cheaper than the safer metallic sheathed cable. There is a growing public awareness that the existing regulatory agencies are not using the limited power that they have, while industry is practicing "environmental blackmail" tactics threatening that stronger regulations would exacerbate unemployment in some industries. Douglas Castle, Administrator of the Environmental Protection Agency, stated that "We're a chemically oriented society . . . we know very little about those chemicals, and what they do, and about their passage through the environment, and what risks might be associated with them." He concluded that "the single most demanding problem ahead of us—getting a handle on the use of toxics and making judgments about what is acceptable".

It is time for the fire community to legislate tougher safety building codes for fire protection and life and not back away from industrial opposition.

Washington area fire chiefs have been successful in forcing the Metro system to modify the use of flammable plastic and synthetic materials in buses and subway cars and are attempting to limit the indiscriminate use of PVC pipe & cable in buildings.

A fire in an electrical control panel is apparently one of those disorders to which technology invariably is prey. While many of the PVC fires in the District of Columbia involved large electrical installations, our experience indicates that sometimes limited quantities of PVC can also be deadly. For example; electrical wiring insulation, telephone cable, vinyl wall covering, vinyl ceiling covering, and vinyl covered furniture. Special caution should be used in fires involving a heavy plastic fire loads such as drug stores, department stores, record shops, etc. In all cases, self contained breathing apparatus must be used, both during the extinguishment and overhaul phase. It is most difficult to determine when the atmosphere is safe enough to remove the mask. Repeated testing has demonstrated no pattern of consistency in the gas distribution. For example, there might be a high concentration in one part of a room while a "safe" concentration may be recorded some 10 feet away.

We are in the process of developing an acid detector badge to be worn on the turnout coat. The badges are being improved as to criticality and further evaluation under actual fire conditions will be forthcoming.

Currently the suspected PVC fire atmospheres are tested at intervals for HCL using the Drager detector. Any reading over 50 ppm should be considered dangerous and every effort to remove the gas by ventilating fans should be employed.

The use of a water spray is somewhat unreliable and should not preclude the use of fans. Every fire officer should preplan his response district and be aware of any PVC fire potential and/or heavy PVC fire load.

Suspected plastic materials should be collected for analysis and future evidence should later pulmonary problems develop. Likewise, photographic evidence may prove to be valuable at a later date.

Despite consistent and persistent assurances from the plastics and petrochemical industries indicting carbon monoxide as the major cause of firefighter mortality and morbidity in plastics fires, recent studies by numerous investigators have refuted this claim. The evidence clearly shows that irritant "off gases" are responsible for lung and pulmonary tree damage.

It should again be noted that carbon monoxide is odorless, colorless, and tasteless and has no irritating effect on the air passages or lungs. While carbon monoxide does kill, it is an oversimplification of the problem to conclude routinely that a death occurs from "carbon monoxide poisoning" or "smoke inhalation." The terms "smoke inhalation" and "carbon monoxide poisoning" should be abandoned by the fire community in most instances. We would suggest the use of the term "toxic gas inhalation" which would tend to focus attention on the toxic agent.

Some investigators have attempted to correlate a high level carbon monoxide in the blood with the degree of pulmonary injury, i.e., a high COhg level would indicate a serious insult to the lungs and pulmonary tree. This may be true in "ordinary" house fires, but this is not a valid assumption when evaluating exposure to plastic fumes. We have noted that in many of the most serious injuries, carboxyhemoglobin levels may range anywhere from 15% to the low or mid 20's. In almost all cases we observe the rapid development of a metabolic acidosis following exposure to PVC fumes.

While many large cities and communities are served by expert medical examiners who are trained forensic pathologists, much of the country still labors under the outdated coroner system. In many instances, the "Coroner" is not a physician—rather he is a political appointee, local businessman or undertaker.

In the excitement and confusion following major fires the victims are rapidly removed from the fire scene, embalmed and buried with the blessing of the local coroner as "smoke inhalation." In most instances, to the delight of the insurance adjustors, local officials and building owners, the deaths are attributed to "smoke inhalation" and no serious effort is made to determine the nature of the toxic chemical compound causing death and/or whether codes were violated by the use of certain building materials or furnishings.

This practice should be condemned and the fire community should seek the establishment of a medical examiner system by legislation and continue to insist on better building codes, emphasizing life safety. Every fire death should be investigated by autopsy and microscopic examination of lung tissue and other organs. In addition, blood samples in specially prepared containers should be submitted for analysis to regional centers that can perform sophisticated analytical chemical studies.

All exposed firefighters should seek immediate medical assistance, including chest x-rays, prior to the development of any serious symptomatology to establish a baseline for serial X-Ray follow-up.

In conclusion, it was felt that corrections to old premises were in order and that our experiences should be recorded and shared candidly with the medical and firefighting profession. Industry should place more emphasis on life safety. The inherent dangers posed by the unrestricted use (for example) of PVC insulated wire and cable in ceiling plenums used for air handling should be controlled by law. The solution is to hold technology in abeyance until building codes can be revised and test protocols can be developed to screen materials that produce highly toxic products of combustion. The fire community should exert every effort to see that this is done.

The fact that heart attacks have been killers of fire-fighters for a number of years is not new. But, it has been until only recently that major steps have been made to determine the nature of the problem — and how the life of the fire-fighter might be extended through careful exercise, good diet habits and a change in work patterns.

A University of California at Los Angeles professor, R. James Barnard, Ph.D., has undertaken a number of studies involving fire-fighters. His most recent involved the actual monitoring of selected fire-fighters while on duty for their full 24-hour shift, and recording of changes in heart rhythm during every phase of their activity.

The subjects were 35 men from Los Angeles City and County fire departments. They ranged in age from 23 to 42 and were all considered to be in good health without any overt symptoms of heart disease. Fire-fighting experience ranged from one-half year to 19 years.

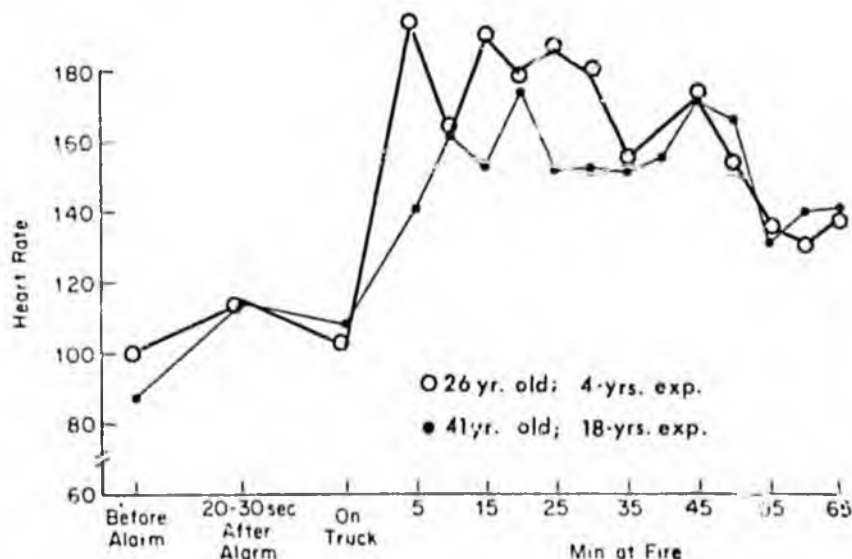
Prior to going on duty each shift, the men were connected to small Avionics Model 375 Mini Recorders. Electrodes were placed to provide a continuous ECG recording. The men kept a log book which included the exact time the recorder was started, time of all alarms and a description of their activities. The tapes were changed every four hours. Most of the men went to bed between 2300 and 2400 hours, with a new tape in the recorder.

TAPES ANALYZED

Tapes were transcribed to paper printouts and analyzed. The ECG was read before the alarm sounded, for 30 seconds after the alarm, and then every minute until the men returned to the station. To be included in the analysis, a man had to have responded to at least four alarms.

Data was obtained from 35 fire-fighters responding to a total of 189 alarms. Be-

Test on fire-fighters shows 'anxiety' increases heart rate; may lead to damage



Heart rate responses of two fire-fighters while involved in structural fire response.

cause of the wide range of heart rates recorded immediately before the alarm sounded, the data was expressed in beats per minute increase (beats/min.) and was measured from 6 second rhythm strips.

Fifteen to 30 seconds after the alarm, heart rate showed a mean increase of 47 beats/min. Range was 12 to 117 beats/min.

About one minute after the alarm, while on the truck, heart rate values were still 30 beats/min (range 1 to 80) above that before the alarm sounded.

While responding, no consistent increase

in heart rate was observed for any one individual. In particular, the responses obtained from one man while sleeping showed marked variation. After two alarms, his heart rate increased approximately 50 beats/min but while in response to a third alarm his heart rate increased 104 beats/min.

PUTTING ON TURN-OUTS

Seven men were tested in the laboratory to find out what effect the physical activity involved with getting onto the fire truck ready for response would have. Moving a similar distance to that required in a fire station and then putting on a coat increased heart rate an average 36 beats/min (range 10 to 49). One minute after the start of this activity, the heart rate was increased only 9 beats/min.

Additional data was obtained from five men while fighting major structure fires. Two men, arriving at the fire scene in approximately 3.5 minutes after the alarm sounded, had heart rates of 150 beats/min. Another was recorded after having finished at one fire and then responding directly to another upon receipt of a radio alarm. While on the truck going to the second fire he had a heart rate of 158 beats/min. For over 90 minutes in these two consecutive fires his heart rate was maintained above 160 beats/min. This included a 15 minute period of extremely high heart rate (average 188), during the initial stages of the second alarm when the roof on which he was working became surrounded by flames and there was danger of collapse.

HIGH ANXIETY SHOWN

The data obtained shows that for the most

Table 1. — Heart Rate and ECG Responses of a Less Experienced Fireman.*

Time	Before Alarm (beats/min)	15-30 sec After Alarm	On the Fire Truck
08:50	80	135†	140
09:45	80	120†	100
12:33	89	148†	128
13:46	120	155†	140
20:26	101	142	130

* Subject A, 24 yr old, fireman 1 yr

Table 2. — Heart Rate and ECG Responses of a More Experienced Fireman.*

Time	Before Alarm (beats/min)	15-30 sec After Alarm	On the Fire Truck
13:40	82	119†	106
15:11	73	142†	138
16:07	66	120†	126
17:41	81	132†	128
19:05	98	118	106
20:26	79	118	124
20:41	95	139	128

* Subject B, 43 yr old, fireman 15 yrs

Table 3. — Heart Rate and ECG Responses of a Fire Fighter While Sleeping.*

Time	Before Alarm (beats/min)	15-30 sec After Alarm	On the Fire Truck
23:30	52	100	86
07:24	45	149†	67
03:10	48	97	85

* Subject C, 38 yr old, fireman 11 yrs

part they were relatively inactive but at times are called upon to perform at or near their maximal heart rate for prolonged periods. The rate responses observed immediately after the alarm sounded as well as on the truck approaching a fire often indicated a state of high anxiety.

Why a man's heart rate might increase by only 15 to 20 beats/min in response to one alarm and then 70 to 80 in another could not be determined. The fire-fighters themselves recognized these different heart responses but could not explain them. Some men indicated they did not think they experienced anxiety when the alarm sounded, but their heart rate indicated otherwise. The data also showed that the rate of increase was about the same for the less experienced fire-fighter as the experienced men.

The method of receiving the alarm at the station also was analyzed.

One of the implications of the study was to show that mere receipt of the alarm, the ringing of a bell or sounding of a tone, produced anxiety and an increase in the

heart rhythm. He concluded that unnecessary alarms should be eliminated in cities which transmit to all stations, not just that called for on the response. He called for further study into the health and safety aspects of fire-fighting.

Repeated exposure to states of high anxiety as well as inhaling pollutants such as carbon monoxide may be related to the high incidence of ischemic-stress tests previously observed in fire-fighters. He concluded, however, that his findings suggest that ischemic heart disease in fire-fighters may be job associated.

Muster 'finals' in Benecia on September 6-7

The first annual California Firemans Muster Assn. championships will be held in Benecia on September 6 and 7, hosted by the Benecia Volunteer Fire Dept.

Saturday's events start at 11 a.m. with gas pumping engines and hose wagons. Crowning of the fire queen will take place at 1:30 p.m. The bucket brigade finalists from other musters held this summer will complete for the state championship starting at 2 p.m. A dance will start at 9 p.m.

On Sunday, a parade will begin at 10 a.m., followed by hand pumping contests at noon, and hosecart races at 2 p.m.

Only fire equipment 1940 or prior is eligible to enter competition. All fire-fighters should register at the Benecia firehouse, 150 Military West, on arrival to obtain information on camping areas and guarded storage facilities.

CAFAA questions code change on door closers

The California State Fire Marshal has adopted the 1973 Uniform Building Code, but has proposed deleting the requirement for closing doors in fire rated corridors.

The California Automatic Fire Alarm Assn., has issued a bulletin calling this to attention. The bulletin stated: "Although integrity of fire rated walls is not within the scope of our Association's activities, we are calling this matter to your attention because codes should be progressive documents and this may be a step backwards."

The bulletin suggested interested parties "with convictions on Section 3304(b)" contact Fire Marshal Albert E. Hole in Sacramento.

(Information compiled from a report in "Journal of Occupational Medicine/ Vol. 17, No. 4/April 1975," by R. James Barnard, Ph.D., and Henry W. Duncan, B.S.)

'Half of fire-fighter's breathing apparatus fails in laboratory testing'

About half the respiratory devices worn by fire-fighters fail to work adequately when tested under conditions found in actual fires, according to a researcher from the Lawrence Livermore Laboratory (LL).

Bruce Held, a respiratory protection specialist at the laboratory, presented his findings at the Third Annual Fire Protection Technology Seminar at Stanford Research Institute in Menlo Park, Calif.

Held said that breathing protection equipment used by the nation's fire departments often fails the most basic stress tests. In an 18-month LLL research program, Held tested the breathing devices for resistance to heat, cold and temperature shock often found in real-life fire-fighting situations.

Testing the devices in a special chamber which can simulate fire conditions, Held found that in two out of six breathing units, the facepiece lens popped out at 200 degrees F. Fire-

fighters typically work in temperatures ranging from 200 to around 500 degrees F.

In another type of breathing protection device, Held found that at temperatures as low as 125 degrees, two out of four models failed. The facemask became loose, allowing outside air to flow in. In a fire-fighting situation, this would allow the fire-fighter to breathe smoke and other toxic gases.

STRAPS MELTED

In tests measuring the effect of radiant heat or the heat reflected from hot surfaces, Held found that in many models, the straps that hold the breathing devices on the fire-fighter's back melt and break. In one model, the straps melted when exposed to the amount of heat reflected from a fire in a metal wastebasket.

"When the harness that holds the breathing device breaks," said Held, "the weight of the air tank pulls the face mask off the fire-fighter, allowing the heated air of the fire to sear his lungs. The real danger arises when a fire-fighter is trapped by a 'Flare-up' of the fire. In that case there is a good probability that the harness straps would melt in all models we tested."

Because fire-fighters commonly store their breathing protection devices on fire trucks where, in many areas of the country, they are exposed to severe winter weather, Held tested the devices for cold resistance.

He stored eight devices at -25 degrees F. for 24 hours. In one brand, the facepiece shattered, the valves froze, and the air leaked out of the cylinder. In another brand, the tubes connecting the air supply to the face-mask became stiff and brittle.

In three other brands the air bottle leaked and the breathing tubes became rigid and difficult to use.

"Fire departments buy this protective equipment believing it will work under any conditions," Held said. "When the fire-fighters get to the scene of a fire and find their equipment doesn't work properly they may have to go without them.

"Fire-fighters have more job-related injuries and deaths than any other profession in the country. Many

investigation.

as Fred Gonzales,

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of those injuries could be prevented if firemen were using dependable respirators. Since we have already protected a man walking on the moon, we could certainly develop adequate protection for fire-fighters."

Held's findings will be submitted to the National Institute for Occupational Safety and Health (NIOSH), the agency that certifies respiratory equipment as safe for use. Working with Held in his research are Gail Cardenas and Charles Harder.

"Historically, it was the Bureau of Mines that certified respiratory equipment," Held said. "Now that the responsibility lies with NIOSH, certification requirements should be upgraded to assure that respirators are safe to use during fires."

Once respirators are upgraded, the attitude of fire-fighters toward their own safety will still have to improve, Held said.

NO MORE 'SMOKE EATERS'

"Among fire-fighters, it has always been considered manly to 'cut smoke' and go without breathing protection," Held said. "That may have been true in the days when fires burned mostly wood and paper. Now, with the development of synthetics, the situation is much more dangerous. Firemen have died from the gases produced by burning bean-bag chairs and plastic curtains.

"Industrial fires are likely to create phosgene and chlorine gas, deadly substances that have been used in chemical warfare. It is imperative that fire-fighters wear their respirators much more often than they do."

In future studies, the LLL researchers will test fire-fighters' respiratory equipment for its resistance to moisture and corrosion from combustion products. Their work is part of several fire safety and protection studies conducted at LLL for the Department of Energy.

The Lawrence Livermore Laboratory is operated by the University of California for the Department of Energy.

Funds for arson projects offered by factory mutual

A special fund of \$100,000 to assist groups wishing to conduct programs to combat the growing arson threat has been established by the Factory Mutual System: Allendale Insurance, Arkwright-Boston Insurance, Phila-

delphia Manufacturer's Insurance and Protection Mutual Insurance. This group is the nation's largest insurer of industrial properties.

Harry Merrow, chairman of the Factory Mutual Committee to Combat Arson, has announced that the first grant from the fund has been awarded to The International Association of Arson Investigators, Inc.

In announcing the grant Merrow commented:

"The fund is intended to assist such groups as state advisory committees on arson prevention, associations of arson investigators or private industry groups formed for the specific purpose of fighting arson.

"Because of this growing threat to lives and property, more programs of education and training to combat it are essential," he said. "Factory Mutual's assistance plan is a step in that direction and its progress and results will be carefully monitored."

Organizations wishing to apply for grants should write to: Harry Merrow, Factory Mutual System, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

Applications should indicate the scope of the organization activities and reasons for requesting funds.

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HOWE & OREN FIRE

The Case for Pressure-Demand Self-Contained Breathing Apparatus

by
Thomas O. Davis and Bruce J. Held

This article deals with the controversy occurring within the fire service over pressure-demand (also referred to as safety pressure) versus demand self-contained breathing apparatus (SCBA) and explains why the authors believe that only pressure-demand devices should be used by the fire service. It is an appropriate place to start, as many fire service personnel are confused about what each type is and what issues are.

The fire service has one of the highest inhalation injury and death rates of any occupation in the United States.¹ In addition to the direct effect of the inhalation of toxic decomposition products involved in a fire, there is also the very real, but unmeasurable, factor that the inhalation of decomposition products plays in the high heart disease rate among fire fighters. Obviously, no one factor can be singled out as the major cause of the high heart disease and inhalation injury and death statistics. It is a complex problem that must be analyzed piece by piece so deficiencies can be corrected.

Future articles will concern problems found with SCBAs and their effects on the fire fighters who use them. However, in the context of currently available apparatus, it is necessary for the fire service to understand the problem areas. Then, not only can an intelligent selection of equipment be made, but training programs can be developed to work around the equipment deficiencies. The first major decision regarding the purchase of SCBAs is whether to buy pressure-demand or demand apparatus. To make this decision, the fire chief making the selection must know the operations, advantages and limitations of each type of SCBA.

This work was sponsored by the Division of Operational and Environmental Safety, Department of Energy.

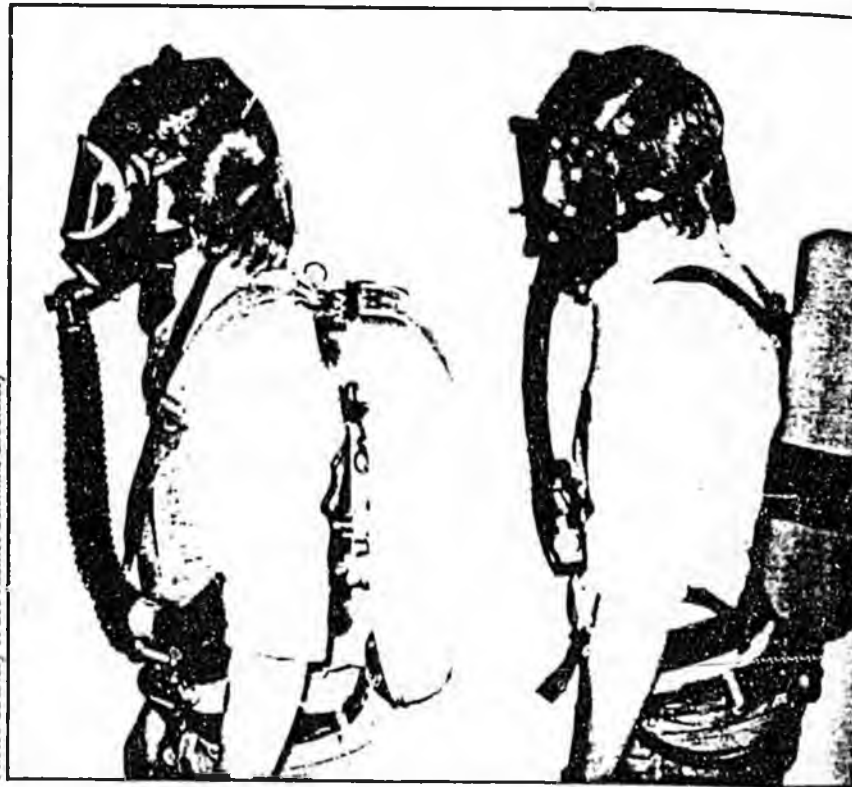


Fig. 1 A typical closed-circuit SCBA

Fig. 2 A typical open-circuit SCBA

Operational Characteristics

First, we must define the terms we will use. SCBA refers to both closed-circuit (Fig. 1) and open-circuit (Fig. 2) devices. In closed circuit devices the exhaled air from the facepiece is directed to the backpack (or front mounted pack), where carbon dioxide and water vapor are removed and oxygen added. Then the air returns to the facepiece. The airflow path is a complete loop, or a closed circuit, hence the classification of this type of device as a closed-circuit SCBA. By contrast, in open circuit devices, the airflow path is from a compressed air tank to the facepiece and then exhaled to the surrounding atmosphere. Therefore these units are referred to as open-circuit devices. The recommended type, and the most widely-used, for fire fighting is the open-circuit SCBA. In this section we will describe only open-circuit SCBAs.

Generally, in open-circuit both demand and pressure-demand, the air comes from a compressed air tank. The air pressure must be reduced from tank pressures (2000 to 4500 psig) to a suitable pressure for use in a facepiece (three to five inches of water or 0.1 to 0.2 psig), and then delivered to the facepiece when the user inhales. SCBA regulators perform two functions. The exact functions are different for each type. Usually a series of valves and expansion devices reduce air pressure. All use the same mechanism to deliver air when the diaphragm-operated valve, shown in Fig. 3, is large, about three inches in diameter, so that slight pressure fluctuations will move the valve open by the arrows.



Breathing Apparatus Part III

Operation of Self-Contained Breathing Apparatus Exposed to High Air Temperatures

by

Charles A. Harder, Bruce J. Held and Gail J. Cardenas

Introduction

Lawrence Livermore Laboratory (LLL) is operated by the University of California under a prime contract with the U.S. Department of Energy. Because of its size and the nature of its work, the Laboratory has a 40-member fire department that is sometimes called to fight fires that could involve highly toxic or radioactive materials. As the dangers of inhalation injury and death to LLL fire fighters are particularly acute, the Laboratory wants to provide them with the best possible protection. Thus, the Safety Science Group at LLL began a program to test various self-contained breathing apparatus (SCBA) under potential fire and emergency conditions.

We of the Safety Science Group knew the environment to which fire fighters and their equipment are exposed is the result of many variables such as high air temperatures, high humidity, water droplets in the air,

fire-decomposition products, fire-extinguishing agents and radiant heat. Therefore, we felt fire fighters' protective gear should not only help them fight routine fires in safety and comfort, but should give them the protection they need for hazardous rescues or for such unforeseen emergencies as flare-ups. Ideally, we believe fire fighters' protective gear should give them more protection than they need.

We centered our studies on evaluating existing equipment so SCBA could be selected from devices that offer the best protection against conditions that could exist during a fire at the Laboratory. As a literature search revealed very little information on such evaluations, we developed test parameters and criteria to evaluate various makes and models of SCBA.

In this article, we report the results of tests conducted on various SCBA operated at air temperatures ranging from room temperature to 200°F (93°C). Our future articles will cover results from other tests in the program.

Test Parameters and Equipment

Determining the air temperatures to which LLL fire fighters and their SCBA are exposed was complicated by conflicting reports from different investigators. Cempel and Burgess¹ monitored temperatures at 134 fires fought by the Boston Fire Department. For dry-bulb temperatures, they found the median maximum temperature to which fire fighters were exposed was about 92 to 125°F (33-37°C) and that maximum temperatures of more than 175°F (80°C) could be found in only one percent of all structural fires. Captain M.A. Myers reported that temperatures of 1100°F (594°C) were common six feet above the floor during fire tests in Los Angeles buildings.² When water was applied to the fire, fire fighters were exposed to temperatures in excess of 212°F (100°C) for short periods.

Another source, Dr. H. P. Utech, classifies the thermal conditions found in structural fire fighting into three categories:³

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory

*Routine conditions are those in which one or two objects in a room, such as a chair, sofa or wastebasket, are burning; air temperatures range from 68 to 140°F (20-60°C), and fire fighter exposure is less than 5 minutes;

*Ordinary conditions are found at more serious fires, such as one next to a flashed-over room, where air temperatures range from 140 to 300°F (60-300°C) and fire fighter exposure is from 10 to 20 minutes;

*Emergency conditions are severe and unusual, such as being caught in a flashed-over room. Under emergency conditions, air temperatures range from 575 to 1800°F (300-1000°C) and the fire fighter is exposed for about 15 to 20 seconds while trying to escape.

The SCBA must function properly under all three conditions because failure could result in injury or death from fire-decomposition products, oxygen deficiency or lung burns.

We chose a maximum temperature of 200°F (93°C) for two series of air temperature tests for long exposures because it was the highest temperature obtainable in the only available environmental chamber large enough to hold an entire operating SCBA unit. This temperature also seemed reasonable, being only higher than temperature reported by Gempel and Burgess and as high as Utech described for ordinary conditions with a 10-

20-minute exposure.

In the first series of hot-air temperature tests, we stored two units of each SCBA in the environmental chamber (Figure 1) for one-half hour at 150°F (65°C) and later at 200°F (93°C). Although the results of these tests were subjective, they identified problems that could be examined more thoroughly with instrumented tests. We also exposed five of each type of SCBA facepiece to the 200°F (93°C) air temperature in the chamber for 10 minutes and then hit the side of each facepiece lightly on the edge of the chamber to simulate a fire fighter accidentally bumping his facepiece while working.

In the second series of hot-air temperature tests, also using the environmental chamber, we dynamically tested two or three units (depending on availability) of each SCBA model. For these tests, we used mostly pressure-demand and some demand SCBA, conducting tests at 100, 125, 150, 175 and 200°F (38, 52, 65, 79 and 93°C) and at a relatively humidity of 85 to 95%. We mounted and sealed the facepiece for each SCBA on a dummy head and through this connected the entire SCBA to the LLL mechanical breathing machine⁴ located outside the chamber. The breathing machine was set at a moderate to heavy work rate of 52.2 liters of air per minute to simulate a fire fighter at work, and we humidified the exhaled air to

simulate human respiration. We measured facepiece pressure with a calibrated pressure transducer and monitored it on a strip-chart recorder. The air cylinder for the SCBA was turned on and off by means of a special clamp that attached to the valve with a handle that protruded through the chamber wall.

Each SCBA unit, including the facepiece, first was fully-inspected and tested for leaks. After setting up each unit in the environmental chamber and operating it for two minutes at room temperature (approximately 70°F (21°C) to ensure that it was operating properly and to measure its normal operating pressures, we turned the chamber on and set it at 100°F (38°C). We exposed the unit to that temperature for two hours and then operated the SCBA for two minutes. Next, we set the chamber at 125°F (52°C) and exposed the unit for 30 minutes before operating it for three minutes. We repeated this at 150°F (65°C). At 175°F (79°C), we operated the unit as soon as the chamber reached that temperature. We did not prolong exposure as a fire fighter wearing the unit would never be exposed long to temperatures that high. We followed the same procedure at 200°F (93°C). This time, however, we operated the unit until the cylinder ran out of air, noting the time it took. Also, we noted the time the low-pressure alarm on the unit sounded.

All the SCBA units tested were new, except for the Scott 6000- and 9000-series units.* The Scott units, although from existing supplies, first were fully-overhauled, inspected and tested by people certified by Scott for this work.

Test Results

Subjective Tests**

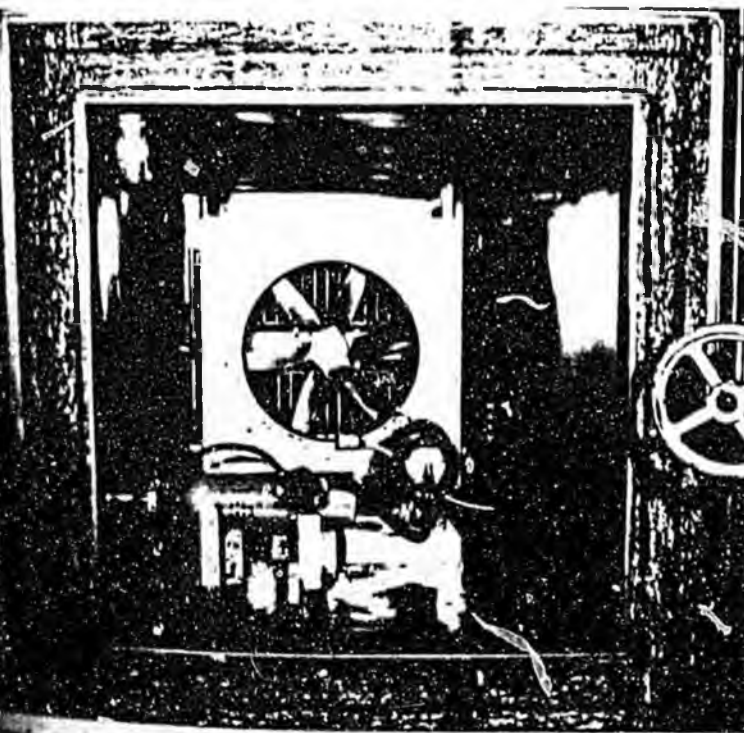
We conducted the subjective tests to determine obvious problems and what instrumented tests should be run.

Two units of each of these SCBA models were tested:

- Scott Air Pak (6000 series)

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

**This section on subjective test results has been abstracted from the full report.



Environmental chamber used for temperature studies of SCBA.

- Scott Air Pak (9000 series)
- Scott 4.5
- MSA Air Masks with Clearvue facepiece
 - MSA Air Mask 401 with Hycar rubber Ultravue facepiece
 - MSA Air Mask 401 with silicone Ultravue facepiece
 - Survivair with neoprene facepiece.
 - Survivair with silicone facepiece

The units were exposed to temperatures of 150°F (65°C) and 200°F (93°C) for 30 minutes and then were donned and operated by experienced SCBA users after each exposure. Any operating and visual problems were noted.

In general, the test subjects observed that black-colored facepieces, particularly those that had the greatest mass (and accordingly retained the most heat), were the most uncomfortable on contact with the face. Lighter weight and lighter colored (blue and yellow) silicone facepieces did not give this impression.

All the facepieces, except that on the Scott Air Pak (6000 series) were more flexible at these high temperatures and appeared to fit with less tension in the head harness. When exposed at 150°F (65°C) the Scott Air Pak (6000-series) facepiece lenses flattened out, causing the lens to separate from the facepiece.

At 150°F (65°C), the facepiece on the Survivair SCBA unit no longer fit firmly because the silicone headbands softened and slipped through the retaining buckles on the facepiece. The neoprene and Hycar rubber head harness materials did not exhibit any noticeable softening or slippage.

The breathing regulators on all the SCBA tested became increasingly noisy at higher temperatures and interfered with the user's ability to communicate. We believe this noise (a sort of honking) resulted from the softening and stretching of the breathing diaphragm housed in the regulator, the noisiest regulators being those with silicone breathing diaphragms.

The breathing tubes (most made of rubber compounds) of all devices tested softened and stretched considerably at 150 and 200°F (65 and 93°C), suggesting the airflow characteristics of the air-supply regulator could be reduced in volume. Such a reduction in airflow would increase

Table I

Effects of exposing SCBA facepieces to 200°F (93°C) air temperatures and then lightly bumping them.

Make and model of SCBA facepiece	No. of units tested	Effects of exposure and bumping
Scott 6000	5	Exposure alone caused all five lenses to flatten and separate from facepiece.
Scott 9000	5	No observable effects
Scott 4.5	5	One strap-retaining button broke on two of five units.
MSA Clearvue	5	No observable effects
MSA Ultravue with plastic ring and clips holding lens	5	Lens separated from facepiece on two of five units.
MSA Ultravue with plastic clamp ring holding lens	5	No observable effects
Survivair neoprene	5	No observable effects
Survivair silicone	5	No observable effects
Globe with Sierra facepiece	5	No observable effects
Biopak 45	1	No observable effects

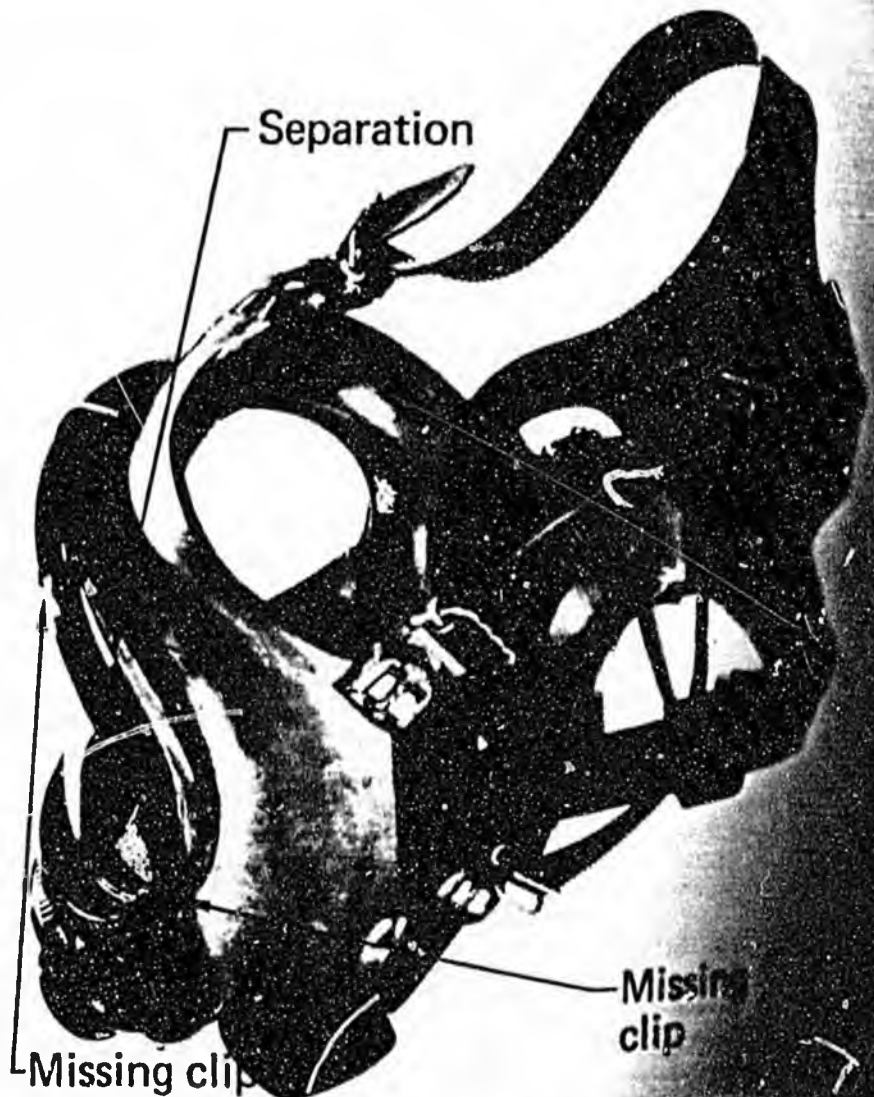


Figure 2. MSA Ultravue facepiece after heating and light bumping. Lens separated from body of facepiece. Though not directly shown, buttons holding the lens snapped off, allowing the lens to separate.

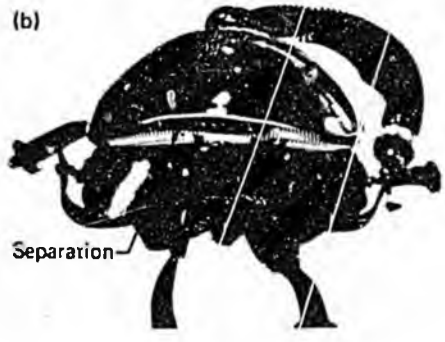
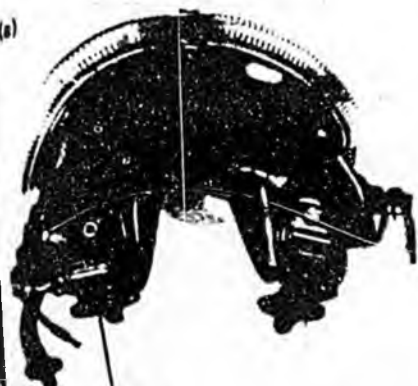


Figure 3. Old-style Scottoramic facepiece: (a) as purchased (note curvature of lens) and (b) after 10-min exposure to 200°F (lens has flattened).

them lightly on the edge of the chamber as they were being removed and then examined each for damage. Table I shows the makes, models and number of each of the facepieces tested and the test results.

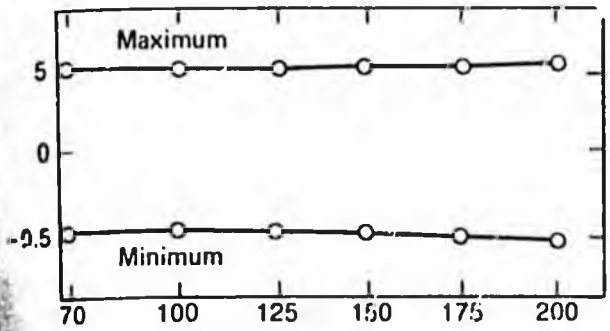
Two of the five MSA Ultravue facepieces, which have a lens held in place by plastic clips, failed when the lens separated from the facepiece after being lightly bumped (Figure 2). When the same facepiece was equipped with a plastic-ring lens holder, no problems were encountered.

The Scott 6000-series facepiece has a curved CR39 lens. At about 150°F (65°C), the curved lens tried to return to its original flat shape. Figure 3(a) shows the purchase condition of the facepiece and the curve of the lens, and Figure 3(b) shows the lens after it was exposed to 200°F

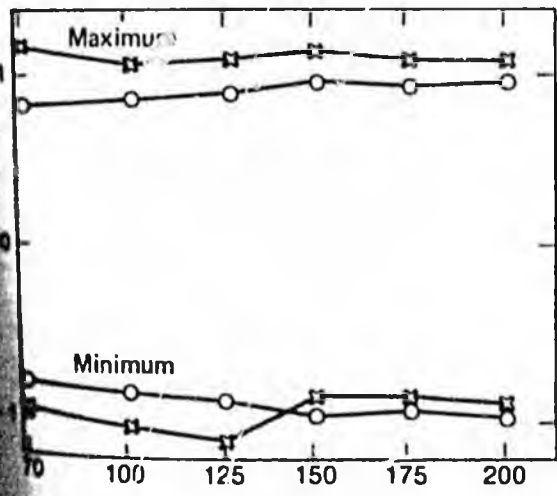
the user's inhalation resistance and possibly cause leaking around the facepiece.

We conducted the facepiece tests to simulate a fire fighter moving around near a fire and accidentally

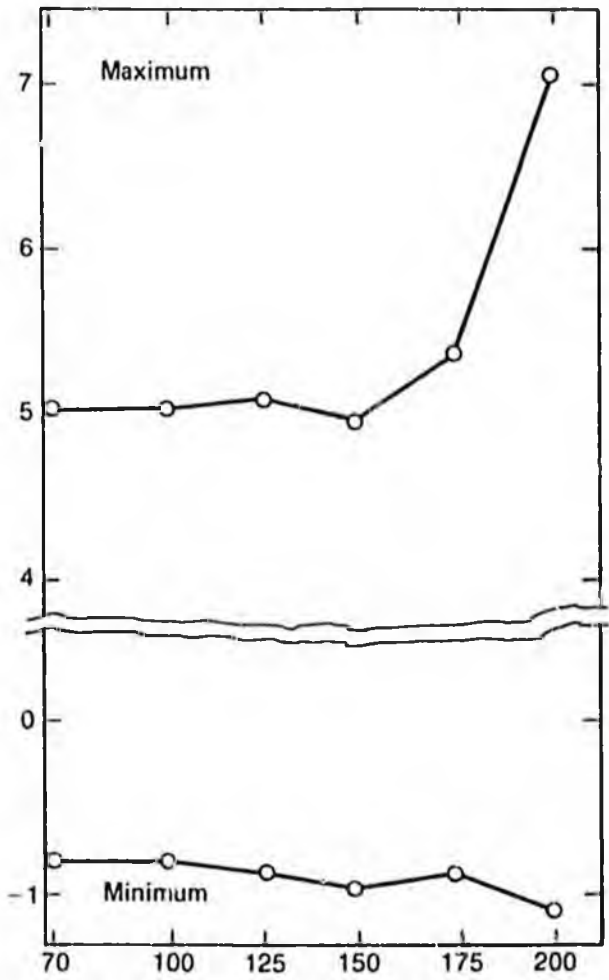
bumping his facepiece while it was exposed to hot air. For this test, we exposed the various makes and models of facepieces to the 200°F (93°C) air of the environmental chamber for 10 minutes, bumped



(a) Demand, Scott 4.5



(b) Demand, Globe Guardsman



(c) Closed circuit, Biopak 45

Air temperature in chamber - °F

Facepiece pressures for demand and closed-circuit models
 Inhalation pressures measured at the
 nose

93°C) for 10 minutes. The lens has flattened partially, distorting the shape of the facepiece, and has pulled free of the lens holder, allowing leakage. We did not bump the Scott 6000-series facepiece on the chamber edge because the heat exposure had already dislodged the lens from the facepiece. The lens is likely to heat up and flatten when the facepiece is in place on a person's head and cooler air from the cylinder is sweeping the inside of the facepiece. In this test series, the unit was not operating.

On two of the five Scott 4.5-series units, one of the plastic buttons holding the head harness to the facepiece snapped off when the unit was bumped.

Instrumented Tests

In the instrumented tests, we subjected the various makes and models of SCBA to air temperatures between 70°F (21°C) and 200°F (93°C) in an environmental chamber while they were operating on the breathing machine. We ran these tests on the following makes and models of SCBA:

- Scott 6000—pressure demand Old-style Scottoramic facepiece

New-style Scottoramic facepiece

- Scott 9000—pressure demand Old-style Scottoramic facepiece New-style Scottoramic facepiece
- Scott 4.5—pressure demand
- Scott 4.5—demand
- Survivair—pressure demand Neoprene facepiece Silicone facepiece
- Globe Guardsman—demand
- Biopak 45—closed circuit

All units operated without failing in the 70°F (21°C) through 200°F (93°C) temperature range. However, the operating air pressure in the facepieces changed on some models. Figure 4 shows the facepiece pressures recorded in the pressure-demand units at the different test temperatures. The same information is shown in Figure 5 for a Scott 4.5 demand unit, two Globe demand units and the Biopak 45, a closed-circuit SCBA.

We tested the Scott 4.5 demand unit to see how it compared to the pressure-demand units. Our reasons for testing the Globe and Biopak units were because neither company made a pressure-demand unit at the time of the tests, and we

thought some information on their high-temperature operation would be desirable. We did not test the Scott, MSA and Survivair demand units because we felt, aside from facepiece pressures, that they would not differ enough from the pressure-demand units to warrant testing.

The bell alarms on all units operated well and at the proper time while the units were exposed to even the highest temperature. The whistle alarm on the Scott 4.5, however, was very weak and barely audible on the pressure-demand units and undetectable on the one demand unit tested. Although the walls of the environmental chamber did reduce the sound of the alarms somewhat, the openings in the chamber allowed the testers to periodically listen for the alarms at one of the openings and tended to negate the effects of the chamber walls. We feel, however, that all alarms should sound loudly under any condition so the user and those nearby can hear them and get out of a dangerous atmosphere before their air is used up.

Table II summarizes the facepiece pressures we found at different air temperatures. At higher air temperatures inhalation pressures in the

Table II
Summary of facepiece pressures at different air temperatures (note the numerous negative pressures).

Type and model of SCBA	Facepiece pressure at 70 F. in. water				Minimum inhalation pressure in facepiece, in. water			Temperature of minimum inhalation pressure, °F			Maximum exhalation pressure in facepiece, in. water			Temperature of maximum exhalation pressure, °F				
	Unit 1 Inh.	Unit 1 Exh.	Unit 2 Inh.	Unit 2 Exh.	Unit 3 Inh.	Unit 3 Exh.	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3			
Pressure-demand units																		
Scott 6000 facepiece	1.2	2.6	0.5	2.6	—	—	0.0	0.25	—	200	200	—	2.8	2.8	—	200	175	—
Scott 9000 facepiece	-0.55	2.8	-0.4	2.5	—	—	-0.6	-0.5	—	100	100, 125	—	2.8	2.5	—	70	70	—
Scott 4.5 facepiece	0.1	2.7	-0.46	2.3	—	—	-0.1	-0.5	—	200	150	—	2.7	2.3	—	175, 200	125	—
Scott 4.5 facepiece	-0.25	2.4	0.08	2.4	—	—	-0.5	-0.1	—	175, 200	175	—	2.4	2.5	—	70	200	—
Survivair facepiece	0.2	1.8	0.08	1.8	0.1	1.7	0.01	-0.06	0.05	200	200	200	1.9	1.8	2.1	200	70	200
Globe Guardsman facepiece	-0.1	2.6	-0.2	3.7	0.2	2.8	-0.15	-0.3	-0.06	200	200	200	2.8	4.6	2.9	100	200	200
Globe Guardsman facepiece	-0.04	1.7	0	1.8	-0.08	1.7	-0.2	-0.1	-0.27	200	200	200	1.7	1.6	1.6	150	200	—
Biopak 45 facepiece	0.27	1.1	0.1	1.7	0.3	1.6	0.3	0.1	0.3	70	70	70	1.7	1.7	1.6	70-200	70, 175	200
Biopak 45 facepiece	0.25	1.8	0.4	1.7	0.25	1.9	0.5	0.75	-0.1*	200	200	200	1.8	1.7	1.9	70	70, 100	70, 200
Biopak 45 facepiece	-0.45	0.45	—	—	—	—	-0.5	—	—	200	—	—	0.5	—	—	200	—	—
Biopak 45 facepiece	-0.92	1.1	-0.8	0.7	—	—	-1.08	-1.0	—	125	200	—	1.1	1.0	—	70	200	—
Biopak 45 facepiece	-0.75	5.02	—	—	—	—	-1.0	—	—	200	—	—	6.9*	—	—	200	—	—

*The silicone headbands loosened as the temperature increased, thus permitting a leak between the facepiece and the face.
*The wearer would normally relieve the high exhalation pressure by cracking the face piece.

facepiece are generally lower and exhalation pressures are higher. The only exceptions to this trend were the Survivair units, which maintained constant exhalation pressures regardless of temperature. Inhalation pressures also stayed constant with the neoprene Survivair facepiece but the inhalation pressures with two of three units having silicone facepieces increased with temperature. These increases probably resulted from the silicone becoming more flexible at higher temperatures and tending to seal to the face even better. The third silicone facepiece showed negative (subatmospheric) pressure on inhalation because the silicone head harness slipped (also noted in the subjective tests).

Besides Survivair, the only other pressure-demand units to maintain positive pressures in the facepiece on inhalation were Scott 6000-series units with the old-style facepiece and two of the three Scott 4.5-series units. The pressure in these two Scott 4.5 units approached zero (.008 and .048 inches of water) on inhalation and probably would go negative under a heavy breathing rate or with a leak between the facepiece and the face.

The negative pressures that showed up in the facepieces of pressure-demand units tested at a moderate to heavy work rate are disturbing because they indicate these units are not providing the protection they were assumed to provide. The facepiece leakage studies done at the Los Alamos Scientific Laboratory,⁶ which showed a 10,000-plus protection factor for pressure-demand units, were conducted on men who were standing still and moving their heads slightly (a low work rate). At a moderate to heavy work rate, which is much more realistic for a fire fighter, some pressure-demand units showed negative facepiece pressures at ambient temperatures. At higher air temperatures, many units showed more negative pressures or went from positive to negative. This would be the worst possible time for such an occurrence as the fire fighter would be breathing at a moderately heavy to heavy rate while fighting a fire and would most likely encounter the highest concentrations of toxic materials when closest to the fire. At the same time, the high heat would

cause increased negative pressure in the facepiece of a pressure-demand unit and increased leakage into the facepiece.

Results of the heat studies conducted and reported in this article will assist the LLL Fire Department in selection of SCBA. However, the results of other studies considering all parameters found in a fire environment will be necessary in order to select the most desirable unit for all conditions under which the fire department must operate. Perhaps even more important is the fact that, as these and other limitations become apparent and identifiable, the fire department training and use practices can make the necessary allowances to prevent the fire fighter from overtaxing himself beyond the capabilities of his equipment.

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Toxicity of Off-Gases From Furnishings

By CARLOS J. HILADO
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Abstract:

Relative toxicity data are presented for the off-gases from various materials used in furnishings.

Introduction

The toxic hazard potential of the off-gases evolved from materials exposed to overheating is an important aspect of safety. For occupants of residences and institutions, toxic gases can prevent or hinder escape from fires, and can have effects ranging from incapacitation to death.

A toxicity screening test method developed by the authors has been used to evaluate a wide variety of materials for toxicity of off-gases under specified test conditions (1-11). A large selection of test conditions can be used, but the test conditions used for evaluating over 300 materials, including many furnishing materials, were a rising temperature program, at 40°C/min from 200 to 800°C without forced air flow, an essentially closed system which provided for accumula-

tion of the toxic gases produced over this temperature range. These particular test conditions are intended to simulate the pre-ignition stage of a fire, as well as the nonflaming aspects of the pre-flashover stage of a fire. It should be remembered that no single set of test conditions can simulate all the possible conditions which a material could encounter in an actual fire, and that these particular test conditions represent an effort to simulate a range of conditions in the critical early stages of a fire.

Toxicity test data obtained by this method on the off-gases from various materials used in furnishings are presented in this article.

Method

The toxicity screening test method has been described in detail in earlier articles (1-11), and will be only briefly summarized here. Four Swiss Webster male mice, 25 to 40 g body weight, are placed in a 4.2 liter hemispherical chamber and the off-gases from 1.00 g of material are admitted into the chamber. The test animals are observed for responses such as staggering, convulsions, collapse and death;

and the times to the observation of each response in each animal are recorded. The test is terminated after 30 minutes.

The test conditions used to obtain the data in this paper were a rising temperature program at 40°C/min from 200 to 800°C without forced air flow.

Data and Discussion

Fabrics can be compared on the basis of generic type as shown in Table 1. The toxicity of the off-gases from blends of fibers was generally intermediate between that for the pure fibers and proportional to the content of the different fibers. In general, wool appeared to be more toxic than nylon; silk more than rayon; polyester more than cotton; cotton more than rayon; rayon more than polypropylene; and rayon more than nylon.

The toxicity test data on cushioning materials are presented in Table 2. There are differences between individual samples in each generic group, but the differences between generic types of foam plastics appeared

Continued on next page

Table 1. Relative Toxicity of Fibers and Fabrics by Generic Type

Material	Number of Samples	Time to Death min
Wool, 100%	4	7.65 ± 1.29
Wool, 85-90%/nylon	4	8.87 ± 1.01
Nylon, 100%	9	16.78 ± 3.49
Silk, 100%	2	9.18 ± 0.35
Silk, 70%/rayon, 30%	2	12.33 ± 0.58
Rayon, 100%	10	15.40 ± 2.41
Polyester, 100%	3	10.70 ± 2.25
Polyester, 65-87%/cotton	3	10.45 ± 0.26
Cotton, 59-70%/polyester	2	15.66 ± 1.17
Cotton, 100%	10	13.08 ± 2.14
Cotton, 82-86%/rayon	2	12.00 ± 0.16
Cotton, 52-75%/rayon	8	14.53 ± 2.06
Rayon, 54-75%/cotton	18	12.70 ± 2.49
Rayon, 100%	10	15.40 ± 2.41
Rayon, 100%	10	15.40 ± 2.41
Rayon, 56-73%/polypropylene	2	14.08 ± 2.16
Polypropylene, 100%	4	16.64 ± 2.76
Rayon, 100%	10	15.40 ± 2.41
Rayon, 52-72%/nylon	3	15.60 ± 3.86
Nylon, 57-62%/rayon	2	15.62 ± 0.15
Nylon, 100%	9	16.78 ± 3.49
Cotton, 100%	10	13.08 ± 2.14
Cotton, 100%, FR	6	14.19 ± 3.64

Table 2. Relative Toxicity of Off-Gases from Cushioning Materials

Material	Time to Death min
Flexible Foams	
polyether urethane, F1	20.86 ± 2.71
polyether urethane, F1	19.91 ± 1.41
polyether urethane, FJ	20.49 ± 0.83
polyether urethane, F4	19.41 ± 0.55
polyether urethane, F5	19.31 ± 0.80
polyether urethane, F6	20.10 ± 1.06
polyether urethane, F7	20.73 ± 1.12
polyether urethane, F8	22.38 ± 3.84
polyester urethane, 3000	18.91 ± 0.75
polyester urethane, 3003	18.54 ± 1.45
polyester urethane, 3013	16.17 ± 0.61
polyurethane, 1	18.55 ± 0.01
polyurethane, 2	21.99 ± 1.82
polyurethane, 3	22.73 ± 1.07
polyimide, 1	12.71 ± 0.02
polyimide, 2	14.76 ± 0.95
polyester, Pneumacel	18.97 ± 0.44
polyethylene, Microfoam	20.42 ± 0.26
polyethylene	20.93 ± 0.47
polychloroprene	24.51 ± 1.46
polychloroprene, ALS	26.84 ± 1.27
polychloroprene, LS	26.50 ± 2.52
polychloroprene, LS200	27.29 ± 0.42
polychloroprene, Vonar	25.83 ± 2.16
polychloroprene	24.29 ± 0.69
polyphosphazene, 1	23.98 ± 1.52
polyphosphazene, 2	24.11 ± 2.58
polysiloxane, 3-6548	25.00 ± 0.57
Fiber Battings	
cotton batting, untreated	9.66 ± 1.29
10% boric acid, padded on	14.58 ± 1.06
8% boric acid, vapor phase	11.20 ± 1.25
polyester batting	9.44 ± 0.76
13.3% acrylic resin	10.15 ± 0.64
20.6% acrylic resin	10.54 ± 1.28
Miscellaneous Materials	
feathers/down 75/25	7.25 ± 0.12
wool, washed	7.06 ± 1.18
rubberized hair	8.18 ± 0.50
rubberized hair, FR	7.62 ± 0.83
excelsior	15.82 ± 0.11
sisal	12.59 ± 3.41
kapok	16.15 ± 0.47

Table 3. Relative Toxicity of Plastics by Generic Type

Material	Number of Samples	Time to Death min
Polyether sulfone	3	12.30 ± 2.08
Polyphenylene sulfide	4	13.21 ± 3.80
Polyaryl sulfone	2	13.48 ± 3.17
Polyimide flexible foam	2	13.74 ± 1.45
Wood	12	14.03 ± 1.48
Polyamide (nylon)	3	14.36 ± 1.71
Polyphenyl sulfone	1	15.46
Polyurethane rigid foam	7	15.49 ± 4.06
polymethyl methacrylate (PMMA)	1	15.58
Polyvinylidene fluoride	1	15.86
Cellulosic board	8	16.57 ± 3.54
Polyvinyl chloride (PVC)	2	16.60 ± 0.33
Acrylonitrile/butadiene/styrene (ABS)	3	17.13 ± 2.45
Polyethylene, including foam	5	17.31 ± 3.73
Acrylonitrile rubber (NBR)	3	19.13 ± 2.89
Polyphenylene oxide, modified	1	19.96
Polyurethane flexible foam	14	20.01 ± 1.74
Bisphenol A polycarbonate	3	20.40 ± 3.77
Polyvinyl fluoride	1	20.50
Ethylene/propylene/diene (EPDM)	2	20.69 ± 0.04
Chlorosulfonated polyethylene	2	20.88 ± 2.07
Polyisocyanurate rigid foam	2	21.68 ± 1.38
Polyisoprene (natural rubber)	1	22.13
Chlorinated polyvinyl chloride (CPVC)	2	22.25 ± 0.69
Polystyrene	2	23.10 ± 4.33
Polyphosphazene flexible foam	2	24.05 ± 0.09
Styrene-butadiene rubber (SBR)	1	24.11
Polychloroprene flexible foam	6	25.88 ± 1.24
Chlorinated polyethylene	2	26.08 ± 1.80

Table 4. Effect of Fire Retardants on Toxicity of Off-Gases

Material	Time to Death min
cotton batting (California)	
untreated	10.16 ± 1.43
treated (believed to be boric acid based)	10.44 ± 0.95
cotton batting (Louisiana)	
untreated	9.66 ± 1.29
8% boric acid, vapor phase	11.20 ± 1.25
10% boric acid, padded on	14.58 ± 1.06
viscose fibers	
untreated	13.71 ± 0.37
12.3% Sandoflam 5060	14.39 ± 0.59
15.5% Sandoflam 5060	14.24 ± 0.31
17.5% Sandoflam 5060	14.58 ± 1.45
polypropylene fibers	
untreated	20.35 ± 0.18
3.1% Sandoflam 5070	17.87 ± 0.23
5.0% Sandoflam 5070	19.14 ± 1.22
vinyl fabric	
untreated	15.64 ± 0.95
FR to Boston code	17.49 ± 1.07
polyurethane flexible foam, A	
untreated	10.21 ± 1.57
FR (Sb, Cl) to California requirements	20.13 ± 1.06
polyurethane flexible foam, C	
untreated	18.28 ± 0.91
FR (P, Br) to California requirements	17.12 ± 1.72
polyurethane flexible foam, D	
untreated	10.16 ± 0.62
FR (P, Br) to California requirements	11.18 ± 0.74
polyurethane flexible foam, E/F	
untreated	9.69 ± 0.62
FR (P, Cl) to California requirements	12.68 ± 0.94
FR (P, Cl) to FAA requirements	13.18 ± 2.16
polyurethane rigid foam	
untreated	23.92 ± 2.14
10% RF-230	23.74 ± 2.11
7% Fyrol 6	25.69 ± 0.00

TOXIC GAS . . .

to be significant. Polyimide flexible foam exhibited the greatest toxicity under these particular test conditions — followed by polyurethane flexible foam, polyphosphazene flexible foam and polychloroprene flexible foam.

Plastics are compared on the basis of generic type in Table 3. The foam plastics are included in this comparison, and wood is included to provide a reference for comparison. The majority of the generic types of plastics appear to be less toxic than wood under these particular test conditions.

Fire retardants are widely used to increase the fire resistance of materials, and there has been interest in the effect of fire retardants on the toxicity of off-gases. Comparisons of various materials without and with fire retardants are presented in Table 4. In the majority of comparisons, the addition of fire retardants decreased relative toxicity under these particular test conditions.

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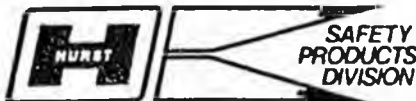


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Fire-Resistive Fabrics Tested For Toxicity

By CARLOS J. HILADO
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Five samples of flame-resistant fabrics were evaluated for toxicity of pyrolysis gases, using the USF-NASA toxicity screening test method. The samples were identified as wool, flame-retarded cotton, Nomex, unstabilized polybenzimidazole. Under these particular test conditions, time to death with wool was less than half



that of the other four fabrics.

Fabrics used in applications which require a certain degree of flame resistance are selected from materials which exhibit a natural flame resistance, which have been flame-retardant treated or which are inherently more thermally stable. The potential toxicity of the gases produced upon overheating or burning is one aspect which must be considered.

The USF-NASA toxicity screening test method has been used to evaluate a wide variety of materials for toxicity of pyrolysis gases under specified test conditions. We shall present the toxicity test data on five samples of flame-resistant fabrics.

Five samples of flame resistant fabrics were supplied in the course of the four-year NASA grant which supported the development of this

screening test method. These samples were wool, flame-retarded cotton, Nomex, unstabilized polybenzimidazole (PBI) and stabilized PBI.

The samples were conditioned at a room temperature of 21 degrees Celsius, plus or minus one degree Celsius, and at a relative humidity of 50 percent, plus or minus five percent.

There is need for a brief summary of the USF-NASA toxicity screening test. Four Swiss-Webster male mice of 25 to 40 grams of body weight are placed in a hemispherical chamber and the pyrolysis gases from a one gram of sample material are admitted into the chamber. The test animals are observed for responses such as staggering, convulsions, collapse and death. The times to the observation of each response in each animal is recorded.

A wide variety of test conditions can be used. The test conditions used for evaluating over 300 materials were at a rising temperature of 40 degrees Celsius per minute from 200 degrees to 800 degrees Celsius without forced air flow, in an essentially closed system which provided for accumulation of the toxic gases produced over this temperature range. These particular test conditions are intended to simulate the pre-ignition stage of a fire. It should be remembered that no single set of test conditions can simulate all the possible conditions which a material could encounter in an actual fire.

The toxicity test data obtained are presented in Table 1. Times to the various animal responses in individual tests, as indicated by a test reference, are reported as mean, plus or minus standard deviation within experiment (between animals).

Times to the various animal responses for each material are reported as mean plus or minus standard deviation between experiments.

The toxicity test data on the reference material (bisphenol A polycarbonate), evaluated at the same time, are comparable to historical data on this particular material. The data in this study can therefore be considered comparable to previously

Table 1. Toxicity of Pyrolysis Gases from Flame-Resistant Fabrics

Material	Test reference	weight charged g	weight pyrolyzed g	time to staggering min	time to convulsions min	time to collapse min	time to death min	CO conc. ppm	CO ₂ conc. ppm
wool	EM-114	1.00034	0.72706	4.03 ± 0.30	5.77 ± 0.94	5.91 ± 0.93	6.90 ± 0.64	60	
	EM-116	1.00012	0.75067		5.65 ± 0.46	5.83 ± 0.42	6.26 ± 0.62	230	
	mean			4.83	5.71 ± 0.08	5.87 ± 0.06	7.58 ± 0.98		
FR cotton	EM-115	1.00007	0.67329	7.28 ± 0.15	13.62 ± 0.26	14.05 ± 0.45	16.43 ± 2.45	10,400	1,060
	EM-120	1.00006	0.67865		15.64 ± 2.59	16.40 ± 2.32	19.44 ± 3.60	11,240	990
	mean			7.28	14.73 ± 1.57	15.27 ± 1.72	18.94 ± 0.71		
Nomex	EM-113	1.00000	0.45691	15.63	16.71 ± 0.33	16.94 ± 0.37	18.44 ± 0.83	6,720	920
	EM-119	1.00016	0.44054	14.00	16.03 ± 0.62	16.26 ± 0.56	17.87 ± 0.94	5,930	700
	mean			14.82 ± 1.15	16.37 ± 0.48	16.61 ± 0.47	18.16 ± 0.40		
unstabilized PBI	EM-111	1.00010	0.19814		16.75 ± 0.40	16.97 ± 0.41	18.24 ± 0.47	2,490	1,270
	EM-116	1.00046	0.19980	15.53 ± 0.07	16.10 ± 0.14	16.26 ± 0.13	17.52 ± 0.14	2,340	920
	mean			15.53	16.43 ± 0.46	16.62 ± 0.50	17.88 ± 0.51		
stabilized PBI	EM-112	0.99957	0.31287		17.37 ± 0.28	17.51 ± 0.14	19.74 ± 0.68	2,600	210
	EM-117	1.00040	0.34180	13.10	17.79 ± 0.08	18.00 ± 0.12	18.65 ± 0.42	2,540	210
	mean			13.10	17.58 ± 0.30	17.76 ± 0.35	19.70 ± 0.06		
reference (M-71)	EM-110	1.00014	0.84139	16.08 ± 0.86	17.23 ± 0.13	18.52 ± 1.10	21.80 ± 1.96	9,440	1,200

published data obtained under these particular test conditions.

Under these particular test conditions, time to death with wool was less than half that with the other four fabrics, about eight minutes compared to 18 to 20 minutes. Time to staggering, normally the first sign of incapacitation, was about five minutes with wool, seven minutes with Nomex, and 13 to 16 minutes with PBI.

Time to convulsions, an indication of effect on the central nervous system, was about six minutes with wool, 15 minutes with flame-retarded cotton, 16 minutes with Nomex, and 16 to 18 minutes with PBI.

Carbon monoxide appears to have been the principal toxicant in the gases from Nomex and cotton, and a significant toxicant in the gases from PBI. The toxicants in the gases from wool seemed to be gases other than carbon monoxide, and seemed to affect the animals more rapidly.

The stabilized PBI fabric appeared to exhibit slightly less toxicity than compared to the unstabilized PBI. The stabilized fabric exhibited a weight loss of 32.7 percent, compared to 19.9 percent for the unstabilized fabric.

This difference may be related to the respective times to death of 19.7 and 17.9 minutes, which means that the stabilized fabric sample was at a temperature of 800 degrees Celsius for 1.8 minutes longer before being removed.

One aspect of the potential toxic effects which cannot be readily quantified is the degree to which the gases found noxious by humans. The gases from wool were particularly noxious, making this material perhaps the most

unpopular among the laboratory personnel performing the test.

Under these particular test conditions, the wool sample appeared to be the least desirable from a toxic hazard viewpoint, and the Nomex sample may be the most desirable.

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Heart disease in fire fighters

Part 1

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Heart disease is a general term which includes many abnormalities of the heart. Two of these heart problems are listed in the right-hand portion of Figure 1. Valve disease, which includes stenosis of the aortic valve and regurgitation in the mitral valve, is unlikely to be a major heart problem in fire fighters since it is readily detected in a routine physical examination and should therefore prevent the individual from entering the fire service. Moreover, it is unlikely that fire fighters who pass an entrance exam would develop a significant number of valve disease problems.

Arrhythmia is a heart condition in which the various chambers of the heart do not beat in normal sequence. Generally, individuals with major types of arrhythmias (frequent ventricular arrhythmias) would not be allowed to enter the fire service because of the possibility of ventricular fibrillation and sudden death. However, fire fighters may develop arrhythmias as a result of exposure to toxic gases. That factor will be discussed later in this series.

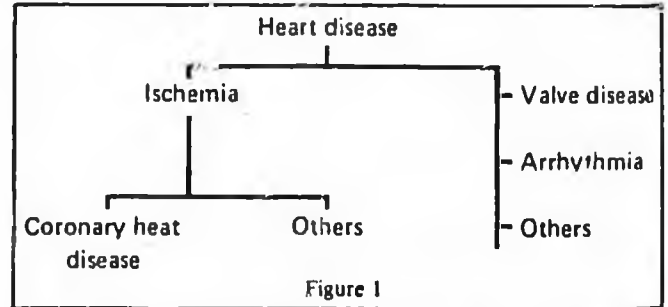
There are many other relatively common heart problems, but there is no evidence that their incidence is significant in fire fighters.

The term ischemia appears at left in Figure 1. Ischemic heart disease is a condition in which the supply of oxygen to the heart muscle is inadequate to meet the demand. If ischemia becomes severe, a myocardial infarction or heart attack occurs. Ischemic heart disease is common in the American population. It is due primarily to coronary heart disease (atherosclerotic heart disease), which is the accumulation of cholesterol and other substances within the coronary arteries. This accumulation decreases blood flow and oxygen delivery to the heart muscle. Ischemia may also be caused by other factors which reduce oxygen delivery, *i.e.*, carbon monoxide, or factors that greatly increase oxygen requirements, such as high levels of catecholamines (adrenalin). These causes of ischemia are uncommon in our general society, but may be an important aspect of the heart disease problem among fire fighters.

In 1976, the International Association of Fire Fighters published the results of a fire fighter mortality study¹ based on examination of the death certificates of 101 fire fighters who died in the line of duty during a 15-month period in 1975-76. Of the 101 deaths, 45 were caused by heart attacks. The results may seem alarming, but they might be obtained in any occupation since, in our society, more people die from heart attacks than from any other cause.

There are data, however, that show that the incidence of death from heart attack and ischemic heart disease is far higher among fire fighters than among the general population. (See Figures 1 and 2, which summarize statistics published by the Public Health Service.)^{2,3,4}

These data show that in the older age groups (55-64), where the highest percentage of the deaths occur, the death rate from cardiovascular diseases, including atherosclerotic heart disease, is highest in fire fighters. Personnel in this age group have 20 to 30 years' exposure to the stress of fire fighting. It is thought that the death rate from atherosclerotic heart



disease in fire fighters ages 55-59 and 60-64 is more than double the average death rate for the "All occupations" category. Furthermore, these data show that the death rate from atherosclerotic heart disease is higher in fire fighters than in any other occupation studied.

Exercise and electrocardiographic stress testing is a common clinical procedure used to test for the presence of ischemic heart disease.^{5,6} The Los Angeles City and Los Angeles County Fire Departments, California, use the procedure to eliminate fire fighter applicants who have ischemic heart disease. In a study conducted at the UCLA Medical Center on a random sample of 90 active Los Angeles City fire fighters, Barnard, *et al.*,⁶ found that ten percent of the group had electrocardiographic changes indicative of ischemic heart disease. These data were compared to data on a group of Los Angeles insurance executives, who had only eight percent ischemic responses.

Studies conducted on 529 Los Angeles County fire fighters revealed 10 percent ischemic responses.⁷ This was a higher percentage than that in other Los Angeles County safety personnel, including sheriffs, marshals, and lifeguards.

Other groups at "high risk" for atherosclerotic heart disease have been shown to have much lower incidence of ischemic electrocardiographic responses to exercise testing. Spangler, *et al.*,⁸ found only 4 percent ischemic responders in a group of 362 aircraft pilots and controllers, while McHenry⁹ reported 5 percent ischemic responders in a group of Indiana state policemen.

Risk factor analysis in Los Angeles City fire fighters

Data compiled by the city of Los Angeles, California, disclosed that fire fighters receive more disability pensions for heart disease than for any other illness. When compared with policemen, the fire fighters receive more disability pensions for heart disease despite the fact that they employ half the number of men. Since fire fighters are admitted to the department only after rigorous medical screening and reaching a high level of physical conditioning, the findings suggest some specific occupational hazard of fire fighting. The present study was undertaken to determine whether the apparent high incidence of heart disease in fire fighters is related to the usual risk factors associated with coronary heart disease or whether some unique phase of the fire fighters' lifestyle might be responsible.

Table 1. Deaths per 1000 People — All Diseases of the Cardiovascular System

Occupation	Age			
	35-44	45-54	55-59	60-64
Firemen	.87	8.63	21.18	38.51
Policemen	1.99	8.71	18.94	28.98
Longshoremen	2.13	7.79	16.37	23.76
Lumbermen	1.40	5.23	11.89	20.66
Construction Workers	2.32	6.98	11.73	18.83
Smelter & Furnacemen	.74	3.27	7.91	9.43
All Occupations	1.49	5.42	11.26	17.20

Table 2. Deaths Per 1000 People — Atherosclerotic Heart Disease

Occupation	Age			
	35-44	45-54	55-59	60-64
Firemen	.67	5.97	13.95	20.40
Policemen	1.40	5.82	12.94	18.26
Longshoremen	1.04	4.10	7.73	11.88
Lumbermen	.64	2.55	7.05	10.77
Construction Workers	.99	3.19	5.81	9.62
Smelter & Furnacemen	.37	1.71	4.75	6.29
All Occupations	.79	3.25	6.75	9.90

The study consisted of investigating the electrocardiographic (ECG) response to near-maximal exercise of 90 randomly selected fire fighters between ages 40 and 59, along with documentation of their blood pressure, serum cholesterol, and smoking habits. The fire fighters were then compared to a similar age group of insurance underwriters previously studied in our laboratory.¹⁸

Methods

The subjects of this study were 90 men from the Los Angeles City Fire Department. They were selected using a random table and the employee numbers of all active fire fighters with 40 years of age and older. The age range was 40 to 59 years, with a mean of 46 years. All of the subjects were considered to be in good health without any overt symptoms of heart disease.

The testing was conducted in two phases. During the first phase the men reported to the hospital where they were given a history questionnaire. Height and weight were recorded and a standard 12-lead electrocardiogram was obtained. Blood pressure was also measured at this time. One week later the men reported to the stress testing laboratory in a fasting state for phase two. The history questionnaire, which contained information pertaining to health history as well as physical activity habits, was examined by the doctor and discussed with the subject.

Blood pressure was again measured and a blood sample obtained for cholesterol determination. Skinfold fat measurements were taken from the 10 sites described by Allen, *et al.*,¹⁹ using Best (USAMRN) calipers. The subjects were then given a continuous, near-maximal (> 90% of predicted max) multistage treadmill test as described previously.¹⁸ The ECG was continuously monitored from a single transthoracic lead with the positive electrode at the V₁ position and the negative electrode at the RV₁ position. An ischemic ECG change was defined as at least 1 mm of horizontal or down slanting depression of the S-T segment observed either during exercise or in the 5-minute post-exercise recovery period. All subjects with ischemic ECG responses were returned to the laboratory on another date for retest purposes. During the additional visit to the laboratory, the treadmill test was repeated and another blood sample obtained for cholesterol, triglyceride, and lipoprotein determinations.*

The data obtained from the fire fighters were compared to data previously obtained from a group (N = 232) of Los Angeles insurance underwriters 40 to 59 years of age (\bar{X} = 47 yrs.)¹⁸

Results

Risk factor analysis — Table 3 gives the data on coronary heart disease (CHD) risk factors. Cholesterol values ranged from 154 to 305 mg% with only 12 percent of the men having values greater than 260 mg%. None of the men had values

higher than normal ranges established by the National Heart and Lung Institute. Mean systolic and diastolic blood pressure values were well within the normal range. Only 2 percent of the fire fighters had values greater than 160/90 mm Hg. Thirty-two percent of the men were smokers. Only one man had elevated cholesterol, was a smoker, and was hypertensive at the time of testing. Only five men had two of the three risk factors elevated, and 47 had none of the three risk factors elevated. Total skinfold fat measurements in excess of 150 mm were considered to be approaching obesity, and 24 percent of the men fell into this category.

Near-maximal treadmill test — Figure 2 shows the workloads at which the fire fighters reached their near-maximal heart rates. The maximal oxygen uptake, estimated from the workload oxygen cost, was 49.9 ± 0.5 ml/min/kg. These data are compared to data previously obtained from the group of Los Angeles insurance executives. The estimated maximal oxygen uptake for the insurance executives was 41.9 ml/min/kg. Nine of the fire fighters had ischemic ECG responses indicating the presence of coronary heart disease. One subject in the random sample completed phase I of the testing having a normal resting ECG. Two days later he had a myocardial infarction at a fire and died in the hospital. One other subject (age 47) had a normal ECG during the stress test and then suffered a myocardial infarction while taking a shower in tepid water 20 minutes after exercise.

Fire fighters with ischemic ECGs — Of the nine fire fighters who had ischemic ECGs during the near-maximal stress test, only one had an abnormal resting ECG. Only one subject had a lipid abnormality (type IV hyperlipoproteinemia) and only one was hypertensive (165/100). Three of the men were smokers at the time of testing. All nine men had ischemic responses during exercise. One subject had previously experienced chest pains at a fire and was taken to a hospital where his ECG was reported to be within normal limits. This same subject experienced angina during the stress test. None of the other subjects admitted experiencing any chest pains or discomfort.

Discussion

The value of the exercise electrocardiogram as a predictor of subsequent coronary heart disease has been extensively

Table 3. CHD Risk Factor Data* for Los Angeles City Fire Fighters

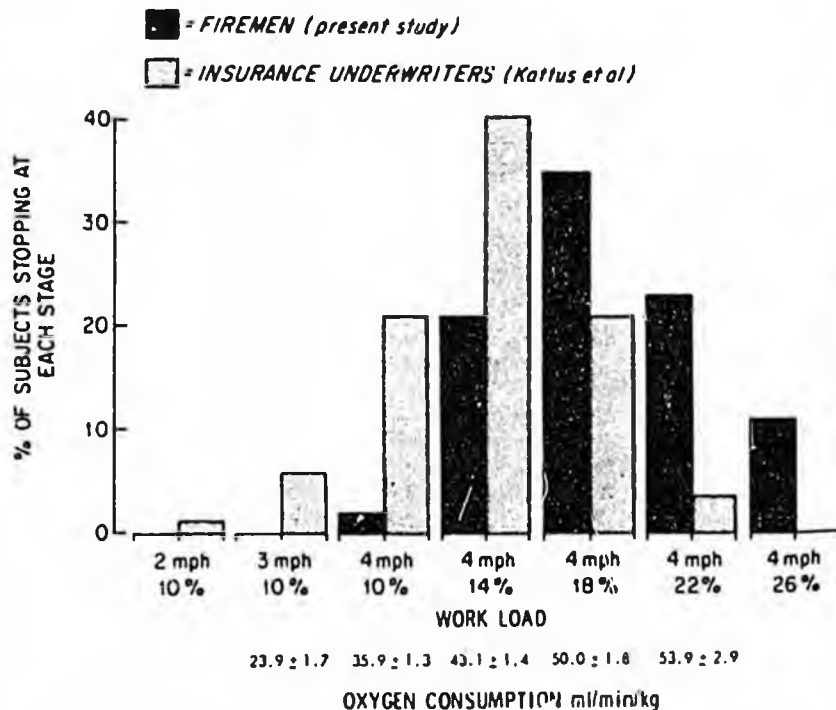
	Cholesterol (mg%)	Systolic B.P. (mm Hg)	Diastolic B.P. (mm Hg)	Skinfold Fat (mm)	Smoking (%)
40-50 yrs N = 68	221 ± 4	124 ± 2	77 ± 1	129 ± 4	40
51-59 yrs N = 22	226 ± 7	131 ± 3	82 ± 2	139 ± 6	5

*Values are means ± standard error

*All blood determinations were done by Laboratory Procedures Division, the Upjohn Co., Woodland Hills, CA 91364.



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Workloads at which the fire fighters (N=90) and insurance executives (N=232) reached their near-maximal heart rates. The oxygen consumption data were obtained from another group of subjects (N=9 for each workload) using the open circuit method.

Figure 2

studied. Kattus, *et al.*,¹⁸ reported that during a 2.5 year follow-up of their insurance group, 33 percent of those individuals with initial ischemic responses experienced a coronary event. In the study of insurance underwriters, Kattus, *et al.*,¹⁸ found that 8 percent of the 232 men (ages 40 to 59) had ischemic ECG responses during the near-maximal stress test. This value is compared to the 10 percent value observed for the fire fighters. Felton¹⁹ has reported a similar value for Los Angeles County fire fighters.

Comparison of our data obtained in Los Angeles with those reported for other areas is somewhat difficult because of different research designs, *i.e.*, different age ranges, stress tests, and criteria for ischemia. Lester, *et al.*,²¹ reported finding 5 percent ischemic responders in a group of 114 Birmingham businessmen (ages 40 to 75) performing a Master two-step test. Spangler, *et al.*,²² found only 4 percent ischemic responders in a group of 362 aircraft pilots, controllers, etc., performing a multistage treadmill test. McHenry, *et al.*,²³ reported 5 percent ischemic responses in a group of Indiana state policemen subjected to a maximal stress test. Doan, *et al.*,²⁴ observed 7.5 percent ischemic responses in a group of 433 Seattle volunteers also subjected to a maximal stress test. These reported incidences of ischemic responses are all lower than the incidence observed in our random sample of fire fighters; however, some investigators^{25,26} have reported a higher percentage of ischemic responses.

Our data as well as the data of Felton¹⁹ indicate that Los Angeles fire fighters have an unexpectedly high incidence of ischemic stress tests, which is difficult to explain since they are a medically-selected population and have relatively low risk factors for coronary heart disease. Only 12 percent of the fire

fighters had cholesterol values greater than 260 mg% while 18 percent of the insurance executives fell into this category. Only 2 percent of the fire fighters had blood pressure values above 160/90 mm Hg while 25 percent of the insurance executives were hypertensive. Thirty-two percent of the fire fighters were smokers at the time of testing as opposed to 26 percent for the insurance executives. The treadmill performances indicated that the fire fighters were in better physical condition than the insurance executives.

Of the nine fire fighters with ischemic ECG responses, only one was hypertensive. One had elevated triglycerides and a lipoprotein pattern indicating type IV hyperlipoproteinemia. All of the cholesterol values were within the normal ranges established by the Heart and Lung Institute. One subject experienced a myocardial infarction following a normal ECG response to near-maximal exercise (HR 180). He was transferred immediately to the Coronary Care Unit where he recovered from an uncomplicated anteroapical myocardial infarction. His blood pressure (125/80) and cholesterol (234 mg%) were within normal ranges. He was a little overweight and had skin-fold measurements for the 10 sites totalling 156 mm. He had previously never experienced chest pains or other symptoms.

Although the 10 percent ischemic responses observed in the fire fighters may not be statistically different from the 8 percent observed in the group of insurance executives, the finding is still unexpected since fire fighters are a medically-selected population with low risk factors for coronary heart disease.

The observations suggest that ischemic heart disease may be job-associated. Recent electrocardiographic recordings obtained from fire fighters while on the job show that for the most part they are relatively sedentary, however, they frequently must exert themselves maximally. Extremely high heart rates recorded immediately after the alarm, during the anticipation phase while riding on the truck, and for prolonged periods during actual fire fighting, indicate an emotional stress.²⁷ In addition, the men are exposed to thermal stress as well as inhalation pollution. All of these factors may be related

Note: Portions of this material first appeared in the *Journal of Occupational Medicine*, November 1975, Volume 17, No. 11. The material has previously appeared in *The California Fireman*, published by the California State Firemen's Association, Inc. Used with permission.

to the pathogenesis of ischemic heart disease and may be independent of atheromatous deposits in the coronary arteries.

Summary

Near-maximal ECG stress testing and coronary artery disease risk factor analysis, including blood pressure, serum cholesterol, and smoking habits, were conducted on a randomly selected group (N = 90) of Los Angeles City fire fighters ranging in age from 40 to 59 years. The data obtained from the fire fighters were compared to data previously reported for a group of Los Angeles insurance underwriters of the same age range.

Only 12 percent of the fire fighters had cholesterol values greater than 260 mg%, while 18 percent of the insurance executives fell into this category. Only 2 percent of the fire fighters had blood pressure values greater than 160/90 mm Hg, while 25 percent of the insurance executives were hypertensive. Thirty-two percent of the fire fighters were smokers at the time of testing as compared to 26 percent for the insurance executives. Only one fire fighter had all three risk factors elevated and only five had two risk factors elevated. Forty-seven of the fire fighters had no risk factors elevated. Ten percent of the fire fighters had ischemic stress tests as compared to 8 percent for the insurance executives. Of the nine fire fighters with ischemic stress tests, one was hypertensive, one had elevated serum triglycerides, and three were smokers at the time of testing.

Since the fire fighters are a medically-selected population with low risk factors for CHD, the observed incidence of ischemic stress tests is surprising and suggests that ischemic heart disease may be job-associated.

Editor's note: Next month, in Part 2 of "Heart Disease in Fire Fighters," Dr. Barnard will discuss a follow-up study conducted on Los Angeles City fire fighters, and analyze data obtained from the medical records of 1055 New York City fire fighters.



About the author

Dr. R. James Barnard is an Associate Professor in the Department of Kinesiology at UCLA and a widely published research cardiologist associated with the UCLA School of Medicine. He holds B.S. and M.A. degrees from Kent State University and earned his Ph.D. at the University of Iowa.

His research interests are in the general area of exercise physiology. "My major areas of interest at the present time," he says, "include biochemical adaptations in myocardial and smooth muscle, and the value of exercise as a preventive measure for vascular diseases." In recent years he has participated in and published papers on several research projects involving fire fighters.

Dr. Barnard's research has been supported by grants from the American Heart Association and the John P. Redmond Fund. Most of his work, however, is supported by contributions from fire fighter associations or individuals. Money is needed to continue this project, and donations may be made to: UCLA Foundation — Dr. R. J. Barnard, 405 Hiigard Avenue, Los Angeles, CA 90024.

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Heart disease in fire fighters

Part 2

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Ischemic heart disease in fire fighters with normal coronary arteries

Los Angeles City fire fighters, like fire fighters from most other cities, receive more disability pensions for heart disease than any other illness. Our initial study,¹ conducted on a random sample of Los Angeles City fire fighters, revealed that 10 percent had ischemic ECG responses to near-maximal stress testing. This section presents follow-up data obtained from the men who had ischemic ECG responses during the stress tests.

Methods

The subjects were nine men from a random sample of Los Angeles City fire fighters who had ischemic responses to near-maximal stress testing. An ischemic ECG change was defined as at least 1 mm of horizontal or down slanting depression of the ST segment observed either during exercise or in the five-minute post exercise recovery period.²

Following the initial testing when the nine men were identified, one additional visit to the laboratory was scheduled. During this visit, the treadmill stress test was repeated and an additional blood sample obtained for cholesterol, triglyceride, and lipoprotein determinations.*

All of the men were subsequently given the option to undergo cardiac catheterization and angiography. (Six of the men elected to do so.) The catheterizations were done at Cedars of Lebanon Hospital using the Seldinger or Judkin techniques. The study included right and left heart catheterization, selective coronary angiography, left ventricular angiography, coronary sinus catheterization, and atrial pacing.

Results

Table I gives the coronary heart disease (CHD) risk factor data obtained from the nine men. One subject (B.N.) was obese, as indicated by his skinfold fat measurements, and hypertensive. Another subject (D.L.) had elevated triglycerides and a lipoprotein pattern suggesting Type IV hyperlipoproteinemia. Two of the men were smokers at the time of testing. In general, these men with ischemic stress tests had low risk factors for CHD. One subject (S.J.) had ST abnormalities in his resting ECG.

The cardiac catheterization and angiographic studies revealed that only two of the six men had CHD. However, the four with "normal" coronaries had signs of abnormal myocardial function during the atrial pacing studies.

• • • •

Discussion

Our initial observation¹ that 10 percent of a random sample of active Los Angeles City fire fighters had ischemic responses

*Blood determinations were done by Laboratory Procedures Division of the Upjohn Co., Woodland Hills, California.

to near-maximal exercise was surprising. Los Angeles City fire fighters are a medically selected population, are generally in good physical condition, and have low risk factors for coronary heart disease. The observations suggest that some job associated stress(es) may be responsible for the relatively high incidence of ischemic stress tests.

The follow-up studies conducted on the nine fire fighters with ischemic stress tests are even more surprising. When the risk factors for coronary heart disease (lipids, hypertension, and smoking) were evaluated, five of the nine men had no abnormal risk factors, while only one subject had two abnormal risk factors.

Six of the nine men elected to undergo angiography and cardiac catheterization. Only two of the six men had significant ($\geq 50\%$ obstruction) coronary artery disease. The 66 percent "false positive" stress tests which were confirmed on two different tests is far higher than that reported by other groups. Several investigators have reported studies in which both stress testing and angiography were conducted on the subjects. Mason, *et al.*,³ compared the results of exercise stress testing on the ergometer with angiography in 84 patients. Only 12 percent of the individuals with ischemic stress tests had normal coronaries. In a similar study using maximal treadmill testing, Martin and McConahay⁴ studied 100 patients and found that only 11 percent of the ischemic responders had normal coronaries. McHenry, *et al.*,⁵ reported that treadmill stress testing in 80 patients showed only 5 percent false ischemic responses as evaluated by coronary cinearteriography. Roitman, *et al.*,⁶ using maximal treadmill stress testing in 46 patients, found a specificity of 87 percent for coronary artery disease, while Kaplan, *et al.*,⁷ studied 200 patients with ischemic stress tests and found that only 9.5 percent had less than 25 percent narrowing of any major branch of the coronary tree. Froelicher, *et al.*,⁸ studied 76 asymptomatic air crewmen with ischemic stress tests and found that 47 percent had insignificant coronary artery obstruction. However, some of their subjects had ECG changes due to vasoregulatory problems. No mention was made of abnormal left ventricle (LV) function in those individuals with normal coronaries.

Atrial pacing studies conducted on the four subjects with normal coronary angiograms provide further insight into the ischemic responses. Two individuals had abnormal lactate metabolism. Subject C.S. had -28 percent lactate extraction with moderate hypertrophy and hypokinesia of unknown etiology. Subject D.L. had 7 percent lactate extraction with a normal functioning ventricle. Moderate LV hypertrophy and hypokinesia was observed in another subject (J.E.), with normal lactate metabolism (24% extraction). Subject S.J. had a normal ventriculogram and normal lactate metabolism during atrial pacing. He did, however, experience angina and ST segment depression. Thus three of the four subjects with normal coronary angiograms had abnormal left ventricle function, which might explain the ischemic stress tests.

Although the abnormal LV function may explain the ischemic stress test, none of the data obtained can explain the

Table 1. Data from fire fighters with ischemic stress tests.

Subject	Age	Blood Pressure (mm Hg)	Skinfold Fat (mm)	Cholesterol (mg%)	Triglycerides (mg%)	Lipoprotein (Electrophoresis)	Smoking
L.S.	45	115/75	144	222	75	normal	No
C.S.	52	128/85	149	171	—	—	No
S.J.	45	110/75	91	210	49	normal	Yes
M.W.	53	110/70	105	174	168	normal	No
D.L.	53	145/90	147	278	200	possible type IV	No
J.E.	59	140/85	153	261	120	normal	Yes
B.J.	54	125/90	99	212	35	normal	No
R.R.	48	125/75	129	192	50	normal	No
B.N.	56	165/100	195	261	105	normal	No

abnormal LV function. All subjects had normal valve function and pressures which were within normal limits. The two subjects with moderate LV hypertrophy were avid handball players, which may explain the hypertrophy. However, hypertrophy resulting from athletic training is not associated with hypokinesia and abnormal LV function.*

We realize that angiography is not 100 percent accurate and that we have studied only a small number of subjects. However, the present data suggest that fire fighters have ischemic heart disease and/or abnormal LV function not due to coronary artery disease or any other known cause. The obvious conclusion is that stress(es) associated with the job of fire fighting is having a detrimental effect on the myocardium itself. Myocardial ischemia, necrosis, and even infarction in people with normal coronaries have previously been reported.^{10,11} Eliot and Bratt¹⁰ and Likoff, *et al.*,¹¹ reported myocardial ischemia and necrosis in patients with normal arteriograms but abnormal hemoglobin-oxygen dissociation. Although we did not check for this possibility in our subjects, it seems very unlikely that they were suffering from this abnormality since most of them had very good work capacities during the treadmill test.

Exposure to carbon monoxide, which reduces oxygen delivery to the heart, can cause ischemia and even myocardial infarction.^{12,13} This is a hazard to which fire fighters may be exposed.¹⁴ If exposure to carbon monoxide is frequent, it could produce myocardial necrosis and hypokinesia. High levels of catecholamines have also been shown to produce myocardial ischemia and necrosis.^{15,16} Our previous studies¹⁰ have reported rapid heart rate acceleration and electrocardiographic changes while responding to the alarm. Near maximal heart rates for prolonged periods and electrocardiographic changes have also been reported during actual fire fighting.^{17,18} These observations suggest high sympathetic nervous system activity which may result in the secretion of massive amounts of catecholamines.

Summary

Near maximal stress testing conducted on a group (N=90) of randomly selected Los Angeles City fire fighters (ages 40-59) revealed that 10 percent had ischemic ECG changes. These ischemic ECG responses were confirmed during a second test conducted two to four weeks after the initial test. Coronary heart disease (CHD) risk factor analysis revealed that in general the men were not at high risk for CHD.

Six of the nine men elected to undergo cardiac catheterization and angiography. One patient had severe triple vessel disease and subsequently underwent aorto-coronary bypass surgery. Another had 50 percent obstruction in the circumflex branch of the left coronary, while the other four men had no visible signs of coronary obstruction. The men with "normal" coronaries, however, did show signs of abnormal cardiac function during atrial pacing. One man had cardiac enlargement, hypokinesia, ischemic ECG, and abnormal lactate metabolism. Another had abnormal lactate metabolism and ischemic ECG. A third man had moderate cardiac enlargement

with anterior wall hypokinesia. The fourth had ischemic ECG changes with angina but otherwise normal cardiac function. All four of these men had pressures which were within normal limits.

These data show that some fire fighters have ischemic heart disease with patent coronary arteries. This disease may be due to job related factors (*i.e.*, carbon monoxide and other noxious fumes, catecholamines, etc.), which reduce myocardial oxygen supply or greatly increase myocardial oxygen demands.

Heart disease in New York City fire fighters

The data presented here were obtained from the medical records of 1055 fire officers from the New York City Fire Department. These fire fighters underwent a cardiopulmonary stress test administered by Cardiogramics Inc.

Methods

The fire fighters reported to the Cardiogramics Laboratory on an off-duty day and in a fasted condition. They completed a history questionnaire and then had a blood sample drawn for cholesterol analysis.* A standard 12-lead electrocardiogram (ECG) was obtained and resting blood pressure measured prior to the exercise ECG stress test.

A submaximal exercise test was performed on either a treadmill or bicycle ergometer, following the Bruce protocol and guidelines published by the American Heart Association.¹¹

Results

The results of the submaximal stress test are outlined in Figure 1. Of the 1055 men tested, 179 (17.0%) had signs of cardiovascular disease. Twenty (1.9%) had abnormal ECGs at rest and were not even given the stress test as recommended by

*Cholesterol analysis was done by Metpath, Hackensack, N.J., using an autoanalyzer.

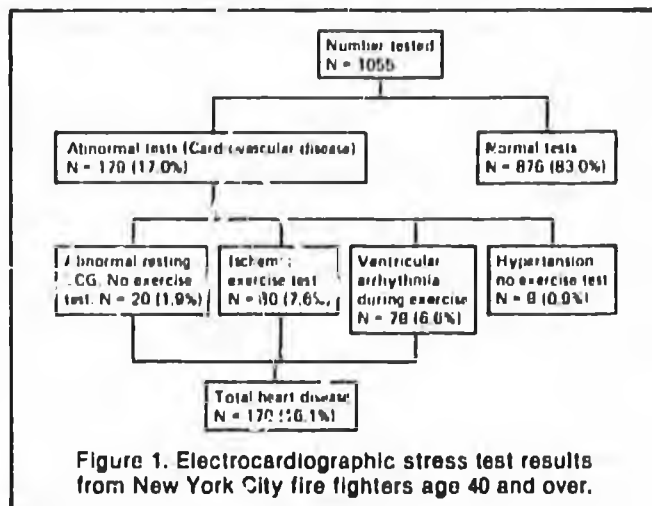


Figure 1. Electrocardiographic stress test results from New York City fire fighters age 40 and over.

Table 2. Coronary heart disease risk factors in New York City fire fighters.

Age Group	Total Men	Cholesterol > 260 mg%	Blood Pressure > 160/90mmHg	Smoker
40-49	542	86	52	150
50-59	479	86	69	107
≥60	34	3	4	6
Total	1055	175	125	263
%	(100)	(16.6%)	(11.8%)	(24.9%)

the American Heart Association. An additional nine (0.9%) were classified as hypertensive and also were not given the stress test. Of those who took the stress test, 150 (14.2%) had abnormal ECG responses; 80 (7.6%) had ischemic ST segment depression, and 70 (6.6%) had significant ventricular arrhythmias. A total of 170 (16.1%) had ECG signs of heart disease either at rest or during exercise.

Table 2 gives the coronary heart disease risk factor data for various age groups. Of the 1055 men, 175 (16.6%) had cholesterol values greater than 260 mg%, 125 (11.8%) had blood pressure greater than 160/90 mmHg, and 263 (24.9%) were smokers.

Two items on the history questionnaire provided some interesting information about the stress of fire fighting. A total of 442 (41.9%) fire fighters answered yes to the question: "Have you ever gone to the hospital for smoke inhalation?" Only 79 (7.5%) answered no to the question on smoke exposure and breathing problems: "Have you ever received a real shellacking or pasting?" To the question on the frequency, many answered numerous times, and two said 1000.

Discussion

New York City, like Los Angeles, admits fire fighters to the department only after they pass a preliminary medical screening and obtain a high level of physical conditioning. Therefore, one would anticipate finding an incidence of heart disease lower than that of the average population of adult men. Of the New York City fire fighters, 20 (1.9%) had abnormal resting ECGs, and 80 (7.6%) had ischemic ECG responses during the submaximal exercise test, for a total of 100 (9.5%) abnormal tests.

It must be emphasized that these results were obtained with a submaximal exercise test. Bellet and Roman²² have reported that maximal exercise testing increases the percentage of ischemic responses by 4 percent over that observed with a submaximal test. This would indicate that the true incidence of ischemic heart disease in New York City fire fighters is close to 14 percent. This value of 14 percent is even higher than that observed in Los Angeles City and County fire fighters. This difference may be due in part to the higher incidence of exposure to the actual stress of fire fighting.

In looking at the coronary heart disease risk factors, it can be seen that the New York City fire fighters had a lower rate of abnormal risk factors than the Los Angeles insurance executives, but slightly higher than the Los Angeles fire fighters. Of the New York City fire fighters, 25 percent were smokers, compared to 26 and 32 percent for Los Angeles insurance executives and fire fighters, respectively. Twelve percent of the New York City fire fighters had blood pressure values greater than 160/90, while 25 percent of the Los Angeles insurance executives, but only 2 percent of the Los Angeles fire fighters

Note. Portions of this material first appeared in the *Journal of Occupational Medicine*, December 1976, Volume 18, No. 12. The material also previously appeared in *The California Fireman*, published by the California State Firemen's Association, Inc. Used with permission.

were hypertensive. Seventeen percent of the New York City fire fighters had cholesterol values greater than 260 mg%, while only 12 percent of the Los Angeles fire fighters, but 18 percent of the Los Angeles insurance executives had values greater than 260 mg%.

These data on New York City fire fighters also support the hypothesis that stress associated with the job of fire fighting is involved in the high incidence of ischemic heart disease.

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Heart disease in fire fighters

Part 3

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We stated earlier in this series (see Part 1, *Fire Command*, August 1979) that the most common cause of ischemic heart disease is coronary artery disease, also known as coronary heart disease (CHD), or atherosclerotic heart disease. In this section, we will discuss the cause of coronary heart disease and see how the stress of fire fighting might be a major factor in the high incidence of this disease in fire fighters.

Coronary heart disease and the stress of fire fighting

The exact etiology of coronary heart disease is not known; however, the most widely accepted theory is that damage to the inner lining (endothelial cells) of the artery is the initial stage.^{1,2} Once the artery lining has been damaged, cholesterol and other fats enter the artery wall from the blood stream, and atherosclerosis develops. Factors which have been shown to

cause damage to the artery linings include high levels of cholesterol, hypertension, smoking, high levels of adrenalin, and high levels of carbon monoxide.³⁻⁵ Of these five factors, two, carbon monoxide and adrenalin, are a major concern to the fire fighter. In addition to causing damage to the artery lining, high levels of carbon monoxide and adrenalin have been shown to cause direct damage to the heart muscle.⁶⁻⁸ These observations may explain the heart muscle damage which Barnard, *et al.*, reported finding in Los Angeles City fire fighters.

In a recent study conducted in conjunction with the Los Angeles City Fire Department, Barnard and Weber⁹ observed carbon monoxide (CO) levels as high as 3000 parts per million (ppm). Examples of CO measurements are shown in Table 1. Higher values (4100 ppm) were reported by Kurt and Peters¹⁰ in a study conducted in Boston. The Boston fire fighters who were exposed to these high CO levels had carboxyhemoglobin (COHb) levels in the range of 18 percent.

In the normal environment, CO levels are generally very low (1-10 ppm) with carboxyhemoglobin levels of less than two percent for nonsmokers and 2-4 percent for smokers.¹¹

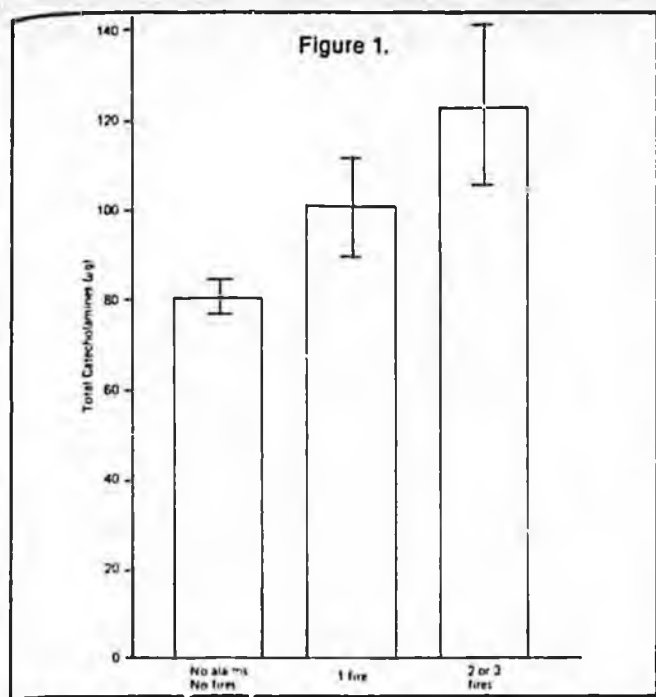
In a study conducted by Gordon and Rogers with the Denver Fire Department,¹² Colorado, it was reported that in nearly two-thirds of the instances of fire fighting a value of 10 percent COHb or higher was reached; in nearly one-fourth of the exposures a COHb value of 20 percent or greater was observed; one individual had a very high COHb level of 44 percent. Gordon and Rogers concluded, "By all criteria available, this exposure to carbon monoxide is both frequent and severe." These investigators also measured elevated levels of serum enzymes (LDH and CPK) and concluded "... that exercise alone does not elevate the blood enzymes in the manner, frequency, or degree seen in the exposure to fires." Other investigators^{13,14} have also reported elevated COHb levels in fire fighters. De Bias, *et al.*,¹⁵ reported that exposure to CO in levels sufficient to elevate COHb levels to 9 percent significantly increased susceptibility to ventricular fibrillation, which may account for some of the fire fighter deaths that occur on duty.¹¹

While the CO problem in fire fighting has been well documented, little is known about adrenalin levels in fire fighters. Kurt and Peters¹⁰ reported in a pilot study that urinary adrenalin levels in four Boston fire fighters were above normal ranges. Blimkie, *et al.*,¹⁷ reported an 81 percent increase in the heart rate of 15 fire fighters responding to an alarm and a 154 percent increase in plasma adrenalin levels. These investigators concluded, "In this study, the immediate response of fire fighters to an alarm was one of intense physical arousal which was accompanied by a substantial, but lesser, degree of emotional arousal." In a study that is presently being conducted with Los Angeles City Fire Fighters, Barnard and Duncan¹⁸ have found increases in 24-hour urinary catecholamines with increased fire activity (Fig. 1). To date, unfortunately, no data have been obtained with more than three fires and none during major fires lasting 45 minutes or longer.

Table 1. Carbon monoxide levels in the fire fighting environment

Incident Description	CO ppm	Comments
Foam rubber pillows burning in bathroom	150	front part of apartment, light smoke
	1600	closed bathroom, dense black black smoke
Greater alarm structure fire	200	1st floor
	600	mezzanine, light smoke
	2000 +	2nd floor, fire area
Two-story dwelling fire on first floor living room	900	immediately involved area, light smoke
	1600	2nd floor, uninvolved area heavy smoke
	2000 +	1st floor closet
Two-story dwelling fire on first floor and spread to second floor	300	1st floor involved area
	800	2nd floor uninvolved area
Dwelling area under house involved, rags soaked with flammable liquids	1000	inside house, no fire but heavy smoke
Dwelling service porch involved, carburetor cleaner fluid	1800	partially ventilated room
	3000	unventilated, uninvolved bedroom

- Summary:
1. In every instance where CO levels were significant, the smoke was quite heavy and noxious.
 2. In some instances where the smoke was heavy and noxious, the CO level was of minimal significance.
 3. In two-story structures, the higher concentrations of CO were found on the second levels along with heavy smoke.



Another factor which may be important in the heart disease problem of fire fighters is exposure to other toxic gases such as hydrogen chloride. Polyvinyl chloride (PVC) toxicity in fire fighters is becoming a major problem because numerous household items, electrical wiring, etc., are made of PVC. Dyer and Esch¹⁹ reported that between 1970-1975, 175 Washington, D.C., fire fighters experienced symptoms from PVC toxicity from one to four occasions; one died. Genovesi, *et al.*,²⁰ reported on 21 Los Angeles City fire fighters who were exposed to dense smoke containing PVC. Nineteen were found to have mild to moderately severe hypoxemia and 13 required hospitalization. All of the fire fighters were using self-contained breathing apparatus while fighting the fire.

Heart rate and ECG responses of fire fighters

A previous study from our laboratory revealed that fire fighters had a high incidence of ischemic responses to a standard near-maximal exercise test, even higher than that observed in a similar age group of insurance underwriters.¹² This observation was surprising because the fire fighters, a medically selected group, were in good physical condition with low blood pressure and cholesterol levels. These findings suggest that ischemic heart disease in fire fighters may be job associated.

Other studies from our laboratory^{13,14} showed that performing sudden exercise without the benefit of warm-up can produce an ischemic condition in the heart. Since fire fighters are required to perform sudden exercise without the benefit of warm-up and also are required to work under thermal stress as well as inhalation pollution, the present study was undertaken to observe electrocardiographic and heart rate responses during the fire fighters' normal 24-hour work day.

Methods

The subjects of this study were 35 fire fighters from the Los Angeles City and County Fire Departments. The men ranged in age from 23 to 42 and were all considered in good health without any overt symptoms of heart disease. Their service ranged from one-half to 19 years.

At approximately 0700 hours, the men were connected to Avionics Model 375 Mini Recorders. The electrodes were placed to record the ECG from the manubrium to the V₅ position with the ground at the RV₅ position. The men kept a log book which included the exact time the recorder was started, the time of all alarms, and a description of their activities. The tapes were changed every four hours. Most subjects retired between 2300 and 2400 hours with a new tape in the recorder.

The tapes were transcribed to paper printouts on an Avionics Model 650 Scanner. Analysis of the ECG was made before the alarm sounded, for 30 seconds after the alarm, and then every minute until the time the men returned to the station. Movement artifact prevented accurate analysis of the ECG in many cases; however, heart rate data could be obtained from the QRS complex. To be included in the analysis, a man had to have responded to at least four alarms.

Discussion

The data obtained from these 35 fire fighters show that for the most part they are relatively inactive, but at times are called upon to perform at or near their maximal heart rate for prolonged periods. The heart rate responses observed immediately after the alarm sounded, as well as on the truck approaching a fire, often indicated a state of high anxiety. Why a man's heart rate might increase by only 15 to 20 beats/minute in response to one alarm and then 70 to 80 beats/minute in response to another alarm could not be determined from our data. The fire fighters themselves recognize these different responses but cannot explain them. Some men indicated that they did not think that they experienced anxiety when the alarm sounded, but their heart rate indicated they were anxious on some occasions. From our preliminary data,¹³ we suggested that less experienced fire fighters showed a more excited response to the alarm than did more experienced men. However, the present, more complete data did not support this earlier suggestion. In addition, more experienced as well as less experienced fire fighters experienced similar periods of high heart rates during actual fire fighting. No consistent pattern of heart rate increase was observed for any one individual. Although fire fighters knew that a high percentage of box alarms turn out to be false, they still showed an excited response at times.

Summary

Data were obtained from 35 fire fighters responding to 189 alarms. Fifteen to 30 seconds after an alarm, heart rate showed a mean increase of 47 beats/minute (range: 12 to 117 beats/min.). Approximately one minute after the alarm, while on the truck, heart rate still showed a mean increase of 30 beats/minute (range: 1 to 80 beats/min.) above that recorded before the alarm. S-T segment changes were observed in the ECG shortly after the alarm sounded. Upon approaching a fire, heart rates as high as 150 beats/minute were observed before the men got off of the fire truck.

During actual fire fighting, extremely high heart rates were observed for prolonged periods of time. One fire fighter had a mean heart rate of 188 beats/minute for 15 minutes during the initial stages of a structure fire.

The heart rate responses observed immediately after the alarm as well as on the truck approaching a fire indicate that the men experience a state of high anxiety. The extremely high heart rates observed for prolonged periods during fire fighting may also indicate a state of high anxiety coupled with the heavy work performed in a hot environment.

Repeated exposure to states of high anxiety, as well as inhaling pollutants such as carbon monoxide, may be related to the high incidence of ischemic stress tests previously observed in fire fighters.

Note: The preceding section, "Heart rate and ECG responses of fire fighters," is excerpted from an article by the same title, published in the *Journal of Occupational Medicine*, Vol. 17, No. 4, April 1975. Reprints are available by request to: Department of Medicine, UCLA School of Medicine, Los Angeles, CA 90024. Attn.: Dr. Barnard.

Conclusion

The purpose of this report was to investigate the heart disease problem in fire fighters and to see if any of the information known about the stress of fire fighting could be related to heart disease in fire fighters.

Statistics published by the U.S. Department of Health,

Education, and Welfare show that the death rate for all cardiovascular diseases, and in particular atherosclerotic heart disease (coronary heart disease), is higher in fire fighters than in police officers, longshoremen, lumbermen, construction workers, smelters, and furnacemen. In fact, the death rates for the age groups 55-59 and 60-64 years were twice as high in fire fighters than the average for all of the other groups studied.

The second line of evidence which shows that fire fighters have an abnormally high incidence of heart disease comes from the electrocardiographic stress test studies. Published reports from both the Los Angeles City and County Fire Departments revealed a higher percentage of abnormal ECG responses than values reported for insurance executives, sheriffs, lifeguards, police officers, and airline pilots and controllers. The data presented in this report on the New York City Fire Department shows similar results. Since fire fighters are a medically selected group, the high percentage of abnormal ECG stress tests is indeed indicative of an abnormally high incidence of heart disease.

Although the exact etiology of coronary heart disease is not known, experimental studies have shown that damage to the endothelial lining of arteries can lead to the premature development of atherosclerosis. Several factors, including elevated cholesterol, hypertension, smoking, carbon monoxide, and high levels of adrenalin, have been shown to cause damage to the endothelial cells. Of these, carbon monoxide has been shown to be a major factor in fire fighting. Measurements made in both the fire environment and the fire fighters themselves strongly suggest that carbon monoxide may be a major factor in the abnormally high incidence of heart disease in fire fighters.

Although not extensive, the information on adrenalin suggests that an emotional response to fire fighting results in the elaboration of higher than normal amounts of adrenalin.

Heart rate and electrocardiographic data obtained from men during actual fire fighting show that their hearts are operating at near maximal to maximal limits, sometimes for prolonged periods. Any factors that would limit oxygen delivery, i.e., CO, PVC, or factors that would significantly increase oxygen demands, i.e., adrenalin, could cause direct damage to the heart muscle. Heart muscle damage has been reported in some Los Angeles City fire fighters.

In conclusion, the data overwhelmingly support the contention that fire fighters do indeed have an abnormally high incidence of heart disease. The information available on the stress associated with the job of fire fighting strongly suggests a causal relationship with this abnormally high incidence of heart disease.

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Note: Portions of this material appeared in the *Journal of Occupational Medicine*, Apr. 1975, Vol. 17, No. 4. The material has appeared previously in the *California Fireman*, published by the California State Firemen's Association, Inc. Used with permission.

The Lubbock fatalities

Information supplied by the
Fire Investigations Department
National Fire Protection Association

In Lubbock, Texas, on 25 March 1979, an early morning fire believed to be electrical in origin caused moderate damage to a restaurant undergoing renovation. The one-story building of ordinary construction was not equipped with automatic sprinklers, fire detectors, or an alarm system.

An employee of a nearby motel reported the fire at 4:30 a.m., and the Lubbock Fire Department's first unit responded at 4:32 a.m. Fire fighters found the kitchen area heavily involved and used 1 1/2-inch hose lines, controlling the fire within 20 minutes. During overhaul, three fire fighters wearing self-contained breathing apparatus (SCBA) entered a rear dining room to check for fire extension. They apparently became lost because of limited visibility and eventually succumbed to carbon monoxide (CO) intoxication.

Background

The one-story restaurant at 711 34th Street in Lubbock, Texas, was of ordinary construction with concrete block walls and a varied roof system consisting of both wood and steel bar joists supporting a wood deck and built-up roof. The irregularly shaped building measured approximately 144 feet long by 70 feet wide (see figure).

The interior had wood frame partitions, with interior finish consisting largely of 1/4-inch plywood veneer paneling in the dining areas and painted concrete block in the kitchen. The kitchen ceiling was of 24-by-48-inch fiberglass reinforced plastic panels suspended in metal "T" channels. Ceilings in the serving and dining areas were of sprayed noncombustible acoustical material on wire lath. Beneath this in the serving area was a suspended ceiling of

24-by-48-inch acoustical panels in steel "T" channels.

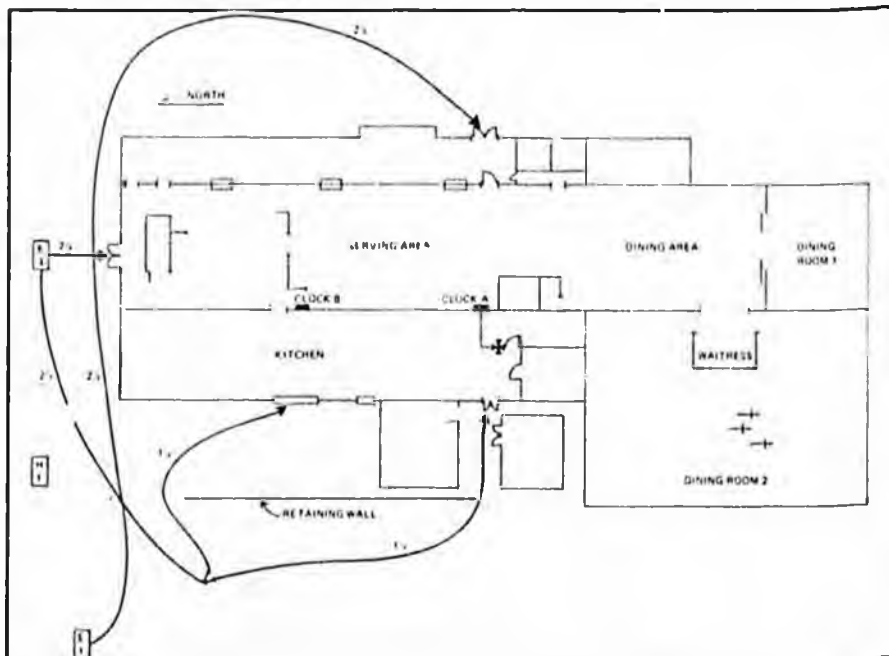
The building was not equipped with automatic sprinklers, fire detectors, or an alarm system. Because it was undergoing renovation at the time of the fire, the interior was cluttered with equipment and building materials. The south end of the building was windowless and had no exterior door.

Lubbock covers a 90-square-mile area with a population of about 180,000. The fully-paid Lubbock Fire Department has 255 career fire fighters who operate 12 engine companies, 3 truck (ladder) companies, 4 booster companies, and 1 manpower squad.

Departmental policy required the use of self-contained breathing apparatus (SCBA). Each fire fighter received breathing apparatus training in recruit school with additional training conducted at the company level. Companies were furnished with either demand or pressure demand SCBA. There was no policy

requiring operation of the pressure demand breathing apparatus in the pressure demand mode, but in training sessions fire fighters were urged to so operate the SCBA when they entered toxic atmosphere. Each shift checked the SCBA, and brief field inspections were made, but there was no general preventive maintenance check. At the time of the incident, field inspections consisted of checking air tank pressure, facepiece seal, and regulator function, by pressurizing and depressurizing the regulator. Fire department members trained by a breathing apparatus manufacturer's representative serviced malfunctioning units. A compressor and cascade system, with a recharging system configured with a mechanical filter, was used to refill air cylinders. In general, no periodic testing of air quality was conducted.

Weather conditions at the time of the incident were: temperature 42°F, barometric pressure 29.92, humidity 57 percent, wind 7 mph



from the south, and visibility 15 miles and clear.

The fire

An employee of a nearby motel saw smoke coming from the restaurant and notified the Lubbock Fire Department at 4:30 a.m. The response consisted of a chief and 14 fire fighters, assigned to Engine 1 (3 personnel), Hose 1 (1), Snorkel 1 (2), Engine 3 (4), and the Squad (4).¹ The first unit arrived at 4:32 a.m., and fire fighters found the kitchen area on the west side of the building heavily involved. In the initial attack, they advanced two 1½-inch hose lines from Engine 3 through the kitchen door and window. Engine 1 and Engine 3 also advanced two 2½-inch lines through the north and east doors, but these lines were not used. Cross ventilation was accomplished by opening doors and using smoke ejectors. The dining areas in the south end of the building had no windows or exterior doors and were not vented.

By 4:50 a.m., the fire was knocked down. Overhaul began about ten minutes later, and during it fire fighters discovered that the fire had extended to the ceiling above the serving area. They pulled portions of the ceiling and soon extinguished the fire. Both the suspended and acoustical ceilings above the serving area along the kitchen wall had to be pulled. Overhaul continued for over one hour as fire fighters completed various tasks and checked the building for additional fire extension.

It is believed that at approximately 5:15 a.m. three fire fighters entered the rear (south end) area of the building, presumably to check for fire extension. Apparently, they entered the area independently, without instructions from officers. They did not advance a hose line. The three were not seen for some time during overhaul and take-up operations. Fire fighter 1 was from Engine 1, fire fighter 2 was from the Squad, and fire fighter 3 was the driver of Hose 1 (see Table 1).

At about 6:40 a.m., the three fire fighters were found lying within five

¹Hose 1 runs with Engine 1 as a two-piece engine company or with the snorkel as a hose tender. Normally, Hose 1 lays lines from the fire to the water supply. The squad is a manpower unit which responds to all structural fires.

Table 1

	Fire Fighter 1	Fire Fighter 2	Fire Fighter 3
Age	25	30	34
Company	Engine 1	Squad	Hose 1
Type breathing apparatus	Pressure-demand	Pressure-demand	Demand
Condition of apparatus when found			
Facepiece on	yes	yes	yes
Facepiece hose attached to regulator	no	no	yes
Air supply remaining	0	0	Approx. 800 psig
Blood gases			
CO Hb	51.5%	43.3%	46.8%
O ₂ Hb	12.2%	13.8%	22.4%
NIOSH assigned number ^a	1	2	3
NIOSH leakage data ^b			
NaCl penetration	14% (d) ^c <0.002% (pd) ^d	0.0039% (d) <0.002% (pd)	7.77% (d)
Isoamyl acetate penetration	large leak	test not performed	very large leak (d)

^a See Page 2, "Test of Self-Contained Breathing Apparatus Received From Lubbock, Texas Fire Department, June 1979," NIOSH.

^b NIOSH, Page 9, Table 3.

^c Demand mode.

^d Pressure demand mode.

feet of one another in Dining Room 2 (see figure). They were removed from the building, and cardiopulmonary resuscitation was started immediately. At the hospitals to which they were transported, they were pronounced dead.

During the rescue effort, other smoke inhalation injuries occurred. Nine fire fighters were transported to hospitals for precautionary treatment, and two were held overnight.

Damage

The fire was confined to the kitchen area, which was heavily damaged, and to the area of extension in the combustible concealed space above the serving area. Heavy smoke permeated the entire building, and the rear dining rooms received smoke damage.

Analysis

The fire is believed to have originated in an electrical panel at the south end of the kitchen. Clock A (see figure), which was plugged into a circuit fed by this electrical panel, stopped at 11:58 p.m. The fire probably smoldered for a long time before becoming free-burning. Clock B, located at the north end of the kitchen, stopped at 4:23 a.m., a time which roughly coincides with the fire's discovery.

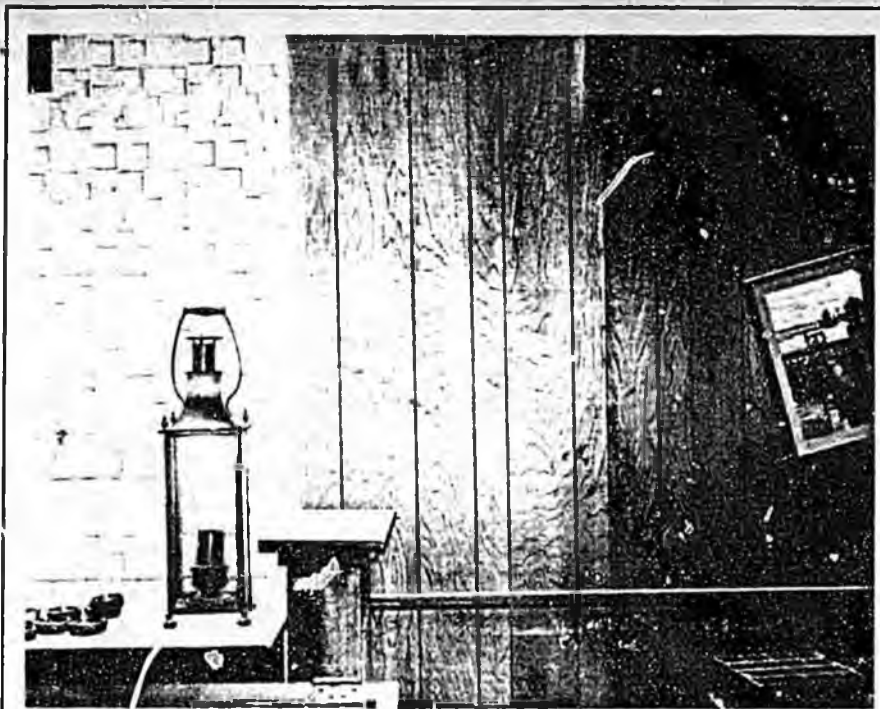
Physical evidence indicates that the fire developed in the area of the circuit breaker panel, which was

mounted on wood studs and recessed in the kitchen's wood panel wall. The fire spread within the combustible concealed space and exposed the wood joists above the suspended ceiling. In general, fire exposure to the kitchen was from the concealed space above the suspended ceiling.

The three fire fighters who are believed to have entered the dining room area at 5:15 a.m. to check for fire extension were isolated from the rest of the fire fighting forces. They were not missed until about 6:30 a.m. Reports indicate that even at 6:40 a.m., when the victims were found, a heavy smoke condition existed in Dining Room 2. As noted, Dining Room 2 was windowless and was not vented.

Fire fighters 1 and 2 were involved in fire fighting and overhaul. When they were found, their air supply had been depleted. Fire fighter 3 is believed to have been wearing breathing apparatus not used during initial operations. He reportedly donned breathing apparatus from Hose 1 and joined the others some time after the fire was knocked down (4:50 a.m.).

Examination of Dining Room 2 revealed handprints and scratches from breathing apparatus on the walls and footprints in the soot on the floor (see photo). By analyzing the footprints, handprints, and other items, it was possible to trace



These handprints of one of the victims were on the north wall of Dining Room 2. By examining footprints, handprints, and other marks, it was possible to trace some of the three fire fighters' movements in the room. (NFPA photo.)

some of the three fire fighters' movements. They were apparently checking for fire extension when they became lost in limited visibility caused by heavy smoke. Handprints and marks on the walls, as well as handprints on tables, indicated that at least one fire fighter attempted to follow the walls to find a way out. The prints further indicated that at least one fire fighter did find his way out of Dining Room 2, but re-entered it when he continued to follow the waitress station wall.

All three victims wore breathing apparatus: Fire fighters 1 and 2 wore pressure-demand breathing apparatus, while fire fighter 3 wore demand-type apparatus. Fire fighters 1 and 2 were found with their breathing apparatus hoses detached from the regulators and their air cylinders empty. Fire fighter 3, who had donned a fresh SCBA before entering the building, was found with breathing apparatus intact and about 800 psig of air remaining in the air cylinder.

Autopsy results indicate the cause of death for all three victims was "acute hypoxia due to acute smoke inhalation and carbon monoxide intoxication." Blood analyses indicated carboxyhemoglobin contents of 43.3 percent, 46.8 percent, and 51.5 percent (see Table 1). The reports do not indicate the presence of burns. In each case, the reports

note that "severe pulmonary edema is suggestive of irritation by smoke in addition to carbon monoxide intoxication."

The Lubbock Fire Department submitted the breathing apparatus to the National Institute for Occupational Safety and Health (NIOSH) for testing. The NIOSH report gives a complete description of the breathing apparatus, as well as results of physical examination and performance testing.¹ The NIOSH observations were limited to the condition of the self-contained breathing apparatus as received; the exact condition at the time of the fire could not be documented.

The NIOSH report identifies several significant performance problems and states that the assemblies received differed from the applicable Bureau of Mines (BOM) and NIOSH assemblies. The report also notes that each SCBA had missing, damaged, or defective parts when compared to BOM and NIOSH approval specifications. NIOSH concludes that the SCBA do not meet the application requirements of BOM and NIOSH specifications.

¹"Tests of Self-Contained Breathing Apparatus Received from Lubbock, Texas, Fire Department, June 1979," Division of Safety Research, National Institute for Occupational Safety and Health, Center for Disease Control, Dept. of Health, Education and Welfare.

The test results indicated significant performance problems. Of particular note were the holes in the diaphragms of SCBA worn by fire fighters 1 and 3 (labeled NIOSH No. 1 and NIOSH No. 3; see Table 1). Significant leakage occurred during tests, allowing outside air to penetrate the diaphragm and the facepiece. With SCBA in the demand mode, the NaCl penetration test method allowed leakage of 14 percent and 7.77 percent respectively in NIOSH No. 1 and NIOSH No. 3. The report contains these observations:

- NIOSH No. 1 — Diaphragm has 1/2-inch-by-1/4-inch hole.
- NIOSH No. 3 — Diaphragm has 3-inch-by-1/4-inch hole and is pulled away from retaining ring.

NIOSH made the following general observations about the SCBA:

1. Apparatus and regulator with damaged or displaced diaphragms, *i.e.*, NIOSH numbers 1, 3, and 4 (with diaphragm in envelope), showed excessive penetration when operated in the demand mode. (Ed. note: NIOSH No. 4 was an extra regulator not directly involved in the incident.)

2. All apparatus had airflow less than the 200 lpm required at full cylinder pressure.

3. Apparatus with dirt in facepiece, *i.e.* NIOSH numbers 1 and 2, showed excessive exhalation resistance.

4. Excessive inhalation resistance of NIOSH numbers 1 and 2 indicated possible regulator interior misadjustment, dirt, or damage.

5. Operation of remaining service time indicators was outside MSHA/NIOSH specifications on NIOSH numbers 1 and 4, indicating misadjusted, dirty, or damaged alarms.

In addition to NIOSH testing, air samples from fire fighter 3's air cylinder were tested at an independent laboratory to ensure the quality of the air in the cylinders. Initial testing was done with a threshold of 0.005 percent (5000 ppm) carbon monoxide. The results of these tests were inconclusive, *i.e.*, there was less than 0.005 percent (5000 ppm) carbon monoxide present, but this threshold test level was well above acceptable test levels for health and

safety purposes. ANSI Z88.5-1973, *Practices for Respiratory Protection for the Fire Service*, recommends a maximum level of carbon monoxide of 0.00002 percent (20 ppm).^{3,4} Consequently, the air was retested with a threshold of 0.00001 percent (10 ppm). Test results were negative; i.e., the air contained less than 0.00001 percent (10 ppm) carbon monoxide.

Fire fighters 1 and 2 appear to have exhausted their air supplies, and they were found with their facepieces on and their hoses detached from their regulators. This fatality scenario involving fire fighters trapped or disoriented in structures and exhausting their air supplies has been documented in other cases.^{5,6,7}

Fire fighter 3 was found with his facepiece on, the hose connected to the regulator, and 800 psig air supply remaining. In this case, the 7 percent leakage reported by NIOSH indicates that fire fighter 3 was probably affected by CO from the room environment while wearing the demand-type breathing apparatus. This is substantiated by both the results of air quality tests, indicating no CO present in fire fighter 3's air supply (to a threshold of 10 ppm), and the autopsy data. Operating in the demand mode, the leakage rate in fire fighter 1's pressure-demand SCBA was 14 percent. If fire fighter 1 used the demand mode, he too could have been affected by CO from the room environment while wearing the breathing apparatus; however, the data are inconclusive.

In this incident, several factors are related to the fatalities. Among them are the lack of ventilation of the room in which the fire fighters

³ "Practice for Respiratory Protection for the Fire Service," American National Standard Z88.5-1973, American National Standards Institute, Inc.

⁴ "Commodity Specification for Air," American National Standard Z86.1-1973, Compressed Gas Association, Inc., New York, New York.

⁵ Washburn, Arthur, and Harlow, David, "United States fire fighter deaths in the line of duty during 1978," *Fire Command*, May 1977.

⁶ Demers, David P., *Fire in Syracuse — Four Fire Fighters Die*, Boston: National Fire Protection Association, 1979.

⁷ Investigation Report — "Discotheque Fire, Edmonton, Alberta — August 15, 1976." Investigation conducted by NFPA under contract to the Department of Commerce, jointly funded by the U.S. Fire Administration, the National Bureau of Standards, and the National Fire Protection Association.

Acknowledgments

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The facts and conclusions in this report are the NFPA's and do not necessarily represent the views of the NBS or the USFA. The report is based on data gathered by John A. Sharry of Code Consultants, Inc., St. Louis, Missouri, under contract to the NFPA Fire Investigations Department. The cooperation and assistance of the Lubbock Fire Department's Chief Thomas Foster and Deputy Chief Horace Anglin are acknowledged and greatly appreciated. The technical review and assistance of A. Elwood Willey, Director, NFPA Fire Information and Systems Division, and David P. Demers, NFPA Fire Analysis Specialist, are also acknowledged.

died, the apparent limited supervision and control of fire fighters on the fireground (since the fire fighters were not missed for over one hour), and the condition of the self-contained breathing apparatus.

The lack of ventilation, either mechanical or natural draft, in the rear dining room allowed a condition of extremely poor visibility and probable high levels of toxic products of combustion to exist long into the fire incident. Dining Room 2 was a windowless area with no exterior doors, an arrangement which contributed to the nonvented condition. Additionally, the focus of fire fighting and overhaul operations was in the kitchen and serving areas, and ventilation measures were limited to those areas.

The lack of exterior doors and windows in Dining Room 2 eliminated any possible alternate escape routes for the three trapped fire fighters.

As stated, the fire fighters were not missed from the fireground for well over one hour. They apparently entered Dining Room 2 without specific instructions to do so. Unfortunately, officers on the fireground were unaware that the three fire fighters were in trouble in Dining Room 2.

The condition of the self-contained breathing apparatus, most notably the leakage through the diaphragms, in at least one case would have contributed to the effects of carbon monoxide intoxication. As previously discussed, this factor can be associated with fire fighter 3. Breathing apparatus leakage is a possible factor in the death of fire fighter 1, provided the apparatus was operated in the demand

mode. Protection factors of up to 50,000 (0.00002 percent leakage) are possible with properly designed, manufactured, maintained, and used positive pressure breathing apparatus.⁸ The 7 percent leakage of fire fighter 3's SCBA resulted in a protection factor of about 14 (100 percent leakage results in a protection factor of 1), and the 14 percent leakage of fire fighter 1's SCBA, assuming demand mode operation, could have resulted in a protection factor as low as 7.

⁸ Hyatt, Edwin C., "Respirator Protection Factors," Los Alamos Scientific Laboratory report, LA-6084-MS, September 1975.





AMERICA BURNING

The Report of
The National Commission on
Fire Prevention and Control

9

THE HAZARDS CREATED THROUGH MATERIALS

The dazzling terminal buildings at New York's John F. Kennedy Airport are virtually a museum of contemporary architecture. But one of those buildings has demonstrated that man's monument, to his technological genius can turn on him with a vengeance, at the mere touch of a flame.

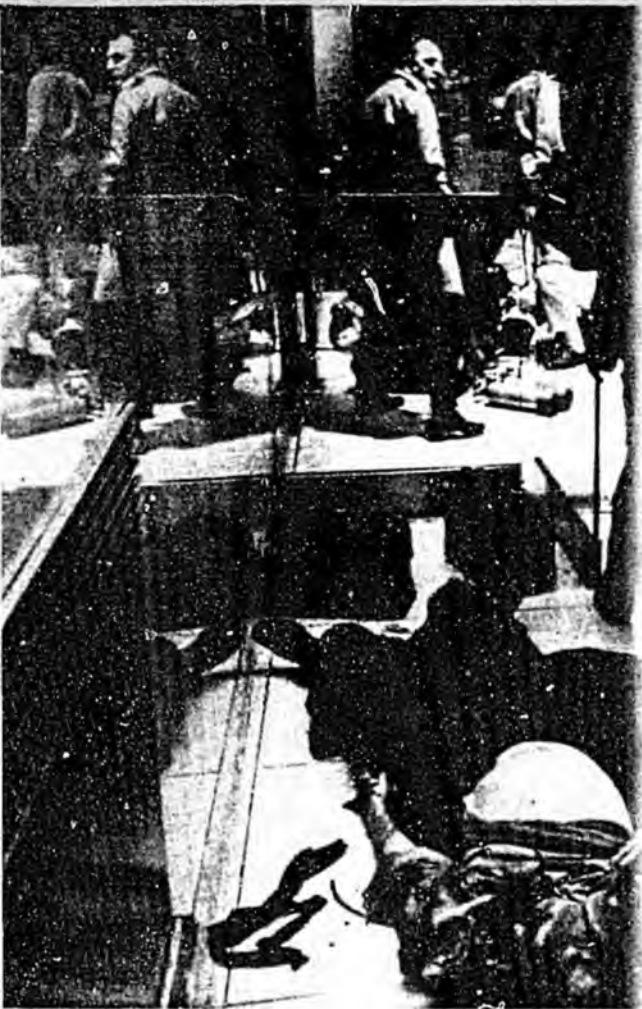
The new west wing of the British Overseas Airways Corporation building at Kennedy International had not yet been opened to the public when, on August 26, 1970, it caught fire—probably at the hands of an arsonist. Swiftly, flames moved from one seat to the next along the 330-foot length of the wing. Gases from the incomplete combustion of the seats gathered in clouds along the ceiling. When flames approached the clouds, the gases ignited explosively, spreading the fire and igniting other groups of seats. The explosions knocked out the terminal's huge glass windows. As the ceiling melted, combustible liquid dripped toward the floor, further spreading the fire. In the end, all 600 seats in the wing were consumed. Damages totaled \$2 million. The seats, which played the predominant role in spreading the fire, were like those in many airline terminals: layers of plastic and rubber foam covered by plastic upholstery material.

No lives were lost in the BOAC terminal fire.

But 3 months later, a synthetic material was implicated in a fire that killed 145 teenagers. It happened in a door-locked dance hall in St. Laurent-du-Pont, France, that had been lavishly sprayed with a plastic foam to give the appearance of a cave. The fire raged furiously within seconds after it began, leaping "like a red panther in a small cage," in the words of one survivor.

By no means do synthetics stand alone as hazardous materials. A frame house can be a tinderbox. Restaurants decorated with natural materials, basements full of old newspapers, and warehouses storing lumber or paper products provide the fuel for major fires. Inadequately protected structural elements of steel or concrete still collapse if a fire is intense enough. Burning silk and wool release deadly quantities of carbon monoxide and cyanide gas—and these and many other natural materials ignite at lower temperatures than many synthetics do. Plastics manufacturers contend that synthetics based on carbon, hydrogen, and oxygen exclusively are generally no more toxic, when burned, than natural materials. On the other hand, other synthetics containing sulfur and the halogens are not so innocuous.

Although plastic production has doubled in the



In the modern environment of synthetic material past 7 years, it is only about one-tenth that of wood, paper, and associated products. The contribution of plastics to the fuel load in buildings, especially older buildings where fires occur frequently, is therefore certainly well under one percent. But their use is increasing. Wool is giving way to synthetic fibers, wooden desks to plastics made to look like wood, glass light diffusers to clear plastic panels. There is hardly any use to which "classical" materials have been that has not been challenged by synthetic materials. Clearly, the advantages which plastics offer to consumers and manufacturers are many, and plastics will fill an increasingly large proportion of the built environment.

What makes plastics relevant to our discussion of materials is not only that many of them have introduced hazards previously uncommon, but also that they are sold and used without adequate



gases have become increasingly important hazards. In addition to the special fire hazards they present, a major investigation of the fire problem of plastics by the Federal Trade Commission highlighted a form of misleading representation of the combustion behavior of certain plastics.

How to Die in a Fire

Most people, when they think of fire as a killer, think of flames. Those who have not fire safety standards for materials have emphasized flame resistance. Yet, in a list of the five ways in which a person can die in a fire, flames rank last.¹

1. Asphyxiation. Fire consumes oxygen from the surrounding atmosphere, thus reducing its concentration. If the oxygen concentration falls below

¹This ranking and much of the following discussion is from a report by Irving N. Einhorn, director of the Flammability Research Center, University of Utah.

17 percent, thinking may be an effort and coordination difficult. Below 16 percent, attempts to escape the fire may be ineffective or irrational, wasting vital seconds. With further drops, a person loses his muscular coordination for skilled movements, and muscular effort leads rapidly to fatigue. His breathing ceases when the oxygen content falls below 6 percent. At normal temperatures, he would be dead in 6 to 8 minutes.

Attack by superheated air or gases. With temperatures above 300° F., loss of consciousness or death can occur within several minutes. In addition, hot smoke with a high moisture content is a special danger since it destroys tissues deep in the lungs by burning.

Smoke. Inhalation of smoke—or, more correctly, of the products of incomplete combustion—kills people who suffer no skin burns at all. In addition to carrying toxic products, such as carbon monoxide and hydrogen cyanide, thick smoke may be laden with organic irritants, such as acetic acid and formaldehyde. In the early stages of a fire, the irritants, which attack the mucous membranes of the respiratory tract, are often the more important danger. Smoke often blocks the visibility of exits.

Toxic products. Many toxic components of smoke are responsible for the damage done—including oxides of nitrogen, aldehydes, hydrogen cyanide, sulfur dioxide, and ammonia, to name only a few. There is ample evidence that the hazard of two or more toxic gases is greater than the sum of the hazards of each. Moreover, low oxygen and high temperatures increase the toxic effects. In addition to toxic gases that attack the lungs, there are irritants that attack the eyes with blinding effect, preventing escape. Some fire gases dull the senses of the victim or his awareness of injury.

Flames. Since the aforementioned factors can debilitate, confuse, blind, or kill without warning, the person who goes to sleep confident that advancing flames will provide sufficient warning for escape may be taking a fatal gamble.

Until such time as all five of these hazards have been well-studied and controlled by materials standards, too little will have been done to control the built environment and thus reduce the gamble Americans take in their daily lives.

Ironically, efforts to make materials fire-retardant—that is, with less tendency to ignite or

spread flames—may have increased the life hazard, since the incomplete combustion of many materials treated to increase fire retardancy results in heavy smoke and toxic gases. The technology of fire-retardance is often unsatisfactory in other respects: The additives are generally costly, can reduce the strength and weather resistance of the material to which they are applied, and often lose their effectiveness through washing or prolonged exposure to the elements.

Where There's Smoke, There's Damage

That concern about flames alone is insufficient is pointed up by the ample evidence that smoke and toxic gases are powerful forces of destruction. Smoke from restaurant fires renders uncontained food unusable; fabrics permeated by smoke can be altered beyond use even after cleaning. And a little smoke can go a long way: A department store recently lost \$100,000 of its merchandise and 3 days' business for cleanup—all because of smoke that seeped through walls from an adjoining building on fire.

Again, efforts to make materials flame-resistant have not always been beneficial. The sooty smoke given off by many of these materials leaves a thick, black coating on whatever it touches. Moreover, the chemical compounds added to reduce combustibility often contain halogens (bromine, chlorine, and fluorine) which are corrosive and toxic.

Why Be Half Safe?

According to the Society of Plastics Industry, Inc., manufacturers of plastics spend \$40 million annually on research to improve the fire safety of their products. That organization, along with other manufacturers, in 1964, a fire safety committee set flammability standards for cellulosic plastics. Fire resistance or fire classification standards for all sorts of construction materials are set by such organizations as the American Society for Testing and Materials and the National Fire Protection Association. Building codes incorporate many of these standards. Underwriters' Laboratories, Factory Mutual Research Corp., and other organizations test materials to see that they comply with such standards.

Yet, for all these efforts, the American public remains inadequately protected from combustion hazards in their midst.

Smoke and toxic gases have been underrated hazards. Recognition of these hazards has come belatedly, with the result that there is still little understanding, and hence little quantifiable knowledge, of the destructive effects of smoke and toxic gases.

As a result, *there are no nationally recognized test methods for measuring smoke production (both rate and amount)*. The American Society for Testing and Materials does have a tunnel test which measures the density of smoke produced. Development of more sophisticated tests—for example, ones which would measure toxic and corrosive products of combustion—is hampered by the complexity of the smoke problem. A single material can give off many different products of combustion under varying conditions of temperature, humidity, pressure, and other factors; burning cellulose, for example, can produce 96 different compounds.

Most tests do not simulate complexities of real fires. Nationally recognized test methods for evaluating the ignition and flame-spread hazards of conventional materials in conventional applications may not be appropriate for evaluating these materials when used in new ways or for evaluating new materials.

For example, the ASTM's tunnel test for building materials, devised long before the advent of plastics, would register a low rate of flame spread for a particular plastic, whereas, in a real fire environment, that same material will burn with an explosive intensity. As a result, architects, design engineers, building contractors, and ultimately the consuming public may grossly misinterpret or inappropriately extrapolate those test results as indicative of fire safety.

Existing large- and small-scale tests suffer from an inability to predict exact consequences of a real fire, particularly those involving foamed plastics. Improvement of test methods is dependent, to a large degree, on a better understanding of the basic processes of ignition and combustion and the mechanisms of fire retardancy and smoke generation and correlating these with actual fire experiences. The Commission recommends that research in the basic processes of ignition and combustion be strongly increased to provide a foundation for developing improved test methods.

The economic interests of manufacturers, installers, vendors, and others often run counter to stringent fire safety requirements. For example, in many West Coast communities, because of industry pressures and public preferences, building codes do not outlaw untreated wood shingle roofs, despite their potential for spreading fire.

Some important hazards are not covered by building codes. The fire safety requirements of building codes apply mostly to construction materials and interior materials used on walls and ceilings. Comparatively little attention has been paid to floors and floor coverings, since in the past their contribution to fire spread was minimal. The advent of synthetic rugs and tiles has made greater attention to floors imperative.

Building codes do not cover interior furnishings. While most political jurisdictions that have building codes also have fire prevention codes, designed to ensure fire safety after a building is constructed and occupied, the fire prevention codes, too, have little to say about interior furnishings. Moreover, seldom do fire prevention codes apply to private dwellings. Interior furnishings are not regulated partly because they are felt to be the province of the owner or tenant and partly because until recently there was no motivation to develop tests on which to base code provisions. They would, indeed, be difficult to regulate, since they are subject to continuing change.

While furnishings are likely to remain outside of code provisions, the fact that they contribute significantly to combustion hazards means that building codes only partly satisfy the demands of fire safety. The present practice can be compared to installing a burglar alarm at the front door and leaving the back door wide open. Only to a limited extent is this mitigated by Federal flammability standards for fabrics.

Consumers use materials with inadequate knowledge of their combustion hazards. Except for flammable liquids and the materials that are used in appliances and wiring, few of the materials that go into the home carry labels vouchsafing their fire resistance or warning of their hazards. The unlabeled hazards are found in draperies, rugs, storage cabinets, upholstered chairs, and other furniture. At present, the housewife working at the kitchen range has no way of knowing that her shiny new kitchen cabinets over-



Although considered "safe" by standard tests, this foamed plastic wallboard burns furiously in a "corner" test.



The plastic drawer fronts lack the fire resistance of the wood they simulate, and some synthetic garments burn furiously.

head are an invitation to a disastrous fire if their surface is a hot-dip polystyrene coating. A sudden flare-up from burning grease in a skillet might readily ignite the finish on the cabinets, and in no time at all fire could spread explosively throughout the kitchen.

Clearly, homeowners and building tenants need to know the relative hazards of furnishings as well as other materials so that they can minimize the risks. Fire inspectors, whether enforcing a fire prevention code or educating homeowners and tenants, need to know the hazards to carry out their tasks effectively.

New Efforts by Government and Industry

Federal initiative is needed to help close the gaps left by the voluntary action of industry and the loopholes in material standards and building codes.

In 1972 Congress created the Consumer Product Safety Commission, authorizing it to "conduct research, studies, and investigations on the safety of consumer products and on improving the safety of such products." The Commission can set standards of composition and design which

consumer products must meet; it can require labeling of hazards or instructions for safe use; it can ban products that present "an unreasonable risk of injury."

The materials that go into the built environment come under the purview of the Consumer Product Safety Commission. This Commission recommends that the new Consumer Product Safety Commission give a high priority to the combustion hazards of materials in their end use. Specific needs are refined understanding of the destructive effects of smoke and toxic gases, development of standards to minimize those effects, development of labeling requirements for materials, and outright ban of materials in uses that present unreasonable risks.

The development of a labeling system identifying combustion hazards is especially important. The purpose of such a system is not to regulate the lives of Americans, as an overly rigorous set of standards would do, but to enable consumers to evaluate the combustion hazards of the materials and products they bring into their homes. Further, in public buildings, nursing homes, and other occupancies subject to regulation, the labeling system would enable inspectors to verify adherence to fire load requirements. Though considerable research and testing would be needed, the eventual goal of the labeling program should be to identify fuel contribution, smoke production, and the production of toxic and corrosive gases, as well as such characteristics as ignition temperature and flame spread.

We feel we should be candid in expressing our concern that, because the Consumer Product Safety Commission is still in its formative stages, and because other hazards (many of them better publicized than combustion hazards) will be competing for attention, the problem of fire safety may become a delayed priority. The Consumer Product Safety Commission could, on the other hand, give early and deserved attention to the problem of fire safety by tapping the research capabilities of the National Bureau of Standards, universities, the national standards and testing organizations, and private industry, through contracts and cooperative arrangements.

Indeed, we do not see the Consumer Product Safety Commission supplanting the efforts in the private sector, but complementing them. For one

thing, the program we have recommended is extensive and long-range. Protection of the public cannot await completion of such a program; other steps must be taken. Material producers owe to various publics—building designers, code officials, fire service personnel, and consumers—an expanded and more candid effort to explain the fire characteristics of the materials they sell.

Further, the emergence of labeling requirements for materials will not eliminate the need for technical reports—that is, papers describing test data in detail. There will continue to be a body of technically oriented users who need detailed analyses.

Technically oriented users will, for example, have to have knowledge of fuel loads beyond that provided by the labeling system. In this connection, the Commission recommends that the present fuel load study sponsored by the General Services Administration and conducted by the National Bureau of Standards be expanded to update the technical study of occupancy fire loads. The information in the National Bureau of Standards' "Building Materials and Structures #149," a report on various fire loads found in different occupancies, published in 1957, is now largely out of date.

Flammable Fabrics

In 1971, the Department of Health, Education, and Welfare reported that, in recent years, more than 3,000 Americans die annually after their clothing catches on fire, and more than 150,000 are injured from this cause. One out of four whose clothing catches fire is a child under 10. Those 65 and over account for 15 percent of the clothing fires, even though they are less than 10 percent of the Nation's population. The very young and the old are also the persons least able to tolerate burns.

When clothing catches fire, the extent and depth of burns are more severe than skin burns on uncovered areas; from the standpoint of fire safety, the human species would be better off naked. A recent study by the National Burn Information Exchange showed that clothing burn victims were four times more likely to die than burn victims spared clothing fire. Their burns covered nearly twice as much body surface.

The power to set flammability standards for

fabrics now resides with the Consumer Product Safety Commission. During the 5 years that the flammable fabrics program was shared by the Department of Commerce, the Federal Trade Commission, and the Department of Health, Education, and Welfare, only a few standards were promulgated: those for young children's sleepwear (up to size 6X), rugs, small carpets, and mattresses.

These standards do nothing to protect the elderly smoker, the housewife whose sleeve passes over the kitchen burner, or the group of 8-year-olds playing with fire in a vacant lot. Notably they bypass most children between the ages of five and nine, who account for 13 percent of clothing fire accidents.

The Commission recommends that flammability standards for fabrics be given high priority by the Consumer Product Safety Commission. Specific needs are research to improve fire retardant processes, extension of flammability standards to further categories of fabric use, development of labeling requirements for other categories, and educational efforts to make consumers aware of fire hazards from clothing and other fabrics. The Commission does not favor unbridled extension of flammability standards to all categories of fabrics. Only grossly hazardous fabrics and fabrics implicated in a very large number of fire accidents should be banned from the marketplace. A preferable direction of emphasis is toward labeling requirements as to combustion hazards. This would honor the cherished principle of free choice, while at the same time informing consumers of potential risks and reminding them of the importance of fire. If reinforced by consumer education on fire safety, labeling requirements would have the effect of spurring manufacturers to improve the flame-resistance of fabrics.

Fireworks

One material hazard that has declined over the years, but not to the point of negligible concern, is fireworks. In recent years, fireworks have claimed an average of about 600 reported injuries and 10 deaths annually. Sixty years ago the annual toll from fireworks was more than 5,000 injuries and 200 deaths.

In 1938, the National Fire Protection Association published its "Model State Fireworks Law"

(NFPA 494L), which, where enacted, prohibits the use of all fireworks except those in supervised public displays. Today, a majority of Americans remain insufficiently protected from fireworks accidents, since only 18 States have laws as stringent as the NFPA's model law and an additional eight have laws similar to the model but with exceptions. The Commission recommends that all States adopt the Model State Fireworks Law of the National Fire Protection Association, thus prohibiting all fireworks except those for public displays.²

The Importance of Research

Adequate regulation of materials in the built environment depends upon adequate testing, and adequate testing, in turn, depends on adequate understanding of combustion and its hazards. That is not to say, however, that progress cannot be made at all three levels simultaneously.

Improved testing methods are being pursued. Scientists and engineers at the National Bureau of Standards, for example, are utilizing a smoke chamber which measures, in addition to the density and rate of smoke produced by a sample, the concentration of specific gases emitted. Experts there and elsewhere are improving devices for measuring heat release, ignitability, flame spread, and fire endurance. Other scientists are working on model testing techniques to simulate the conditions of full-scale fires.

The technology for more sophisticated testing and the technology for basic research on fire overlap, and the two activities go hand-in-hand. It is appropriate that the National Bureau of Standards continue to provide leadership in both these areas. The Consumer Product Safety Commission should champion the strengthening of NBS efforts in these areas. At the same time, ongoing efforts of university scientists, manufacturers, and industrial testing laboratories should be encouraged and expanded.

² The National Society for the Prevention of Blindness, Inc., lists the following groups as supporting the limitation of all fireworks to licensed public displays only: the American Academy of Pediatrics, the American Public Health Association, the California Fire Chiefs Association, the Fire Marshals Association of North America, the International Association of Fire Chiefs, the National Fire Protection Association, the National Safety Council, the National Society for the Prevention of Blindness, Optimist International.

One basic goal of research should be to improve understanding of the dynamics of fire—not of flames alone, but of smoke, heat, toxic gases, and oxygen depletion, which together cause more deaths than flames do. The Commission recommends that the Department of Commerce be funded to provide grants for studies of combustion dynamics and the means of its control.

Medical research is also pertinent. In Chapter 2 we recommended that the National Institutes of Health undertake a major program of research concerning smoke inhalation injuries. One outgrowth of that research should be new knowledge concerning human tolerances of various products of combustion. From this knowledge standards can be derived setting maximum allowable outputs of various products of combustion for materials. The Commission recommends that the National Bureau of Standards and the National Institutes of Health cooperatively devise and implement a set of research objectives designed to provide combustion standards for materials to protect human life. It would be appropriate for NIH to bring these objectives to the attention of the community of medical scientists, to in-

corporate appropriate objectives in its own research programs, and to transmit to the Consumer Product Safety Commission pertinent research results.

A Question of Priorities

The hazards of materials in the built environment will never be eliminated completely, and they cannot be significantly reduced overnight. Tinderbox houses will remain in the environment until economic circumstances favor their replacement or until wear and tear dictate their removal. In settings where we are forced to live with hazardous materials, we must turn to engineering means—automatic sprinklers, for example, or early-warning detection and alarm systems—to compensate for the dangers. But for the future, we as a Nation cannot rely on these systems alone to protect us; the materials themselves must be improved for fire safety. True, a building constructed of fire-safe materials and having an automatic extinguishing system as well offers a certain redundancy of protection. But one without the other leaves open possibilities of disaster.



FIREFIGHTER EXPOSURE TO ENVIRONMENTAL CARCINOGENS

by

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to be presented at

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Excess Cancer Incidence in Firefighters

Up to now, what little epidemiological study has been done on occupational exposure to carcinogenic chemicals has related to occupations in which employees are exposed to a single known or suspected carcinogen amenable to routine monitoring. The firefighter is exposed to a variety of known and unknown carcinogens under conditions not amenable to monitoring. Most monitoring systems available for airborne chemical carcinogens function only under conditions where a single carcinogen is the dominant chemical species present. The complex chemical mixtures characteristic of the fire scene require something of the sophistication of gas chromatography/mass spectrometric analysis.

Although little epidemiological work has been done on firefighters, the following reports of excess cancer incidence in firefighters are available: excess buccal and pharyngeal cancer (1959),¹ excess intestinal and rectal cancer (1963),² and excess colon and rectal cancer (1975).³ A 25-year study of cause of death in active firefighters⁴ found a steady increase in cancer in Toronto firefighters from 15.4% in 1945-49 to 38.4% in 1965-70 (see Figure 1). I believe this increase is due to the proliferation of synthetic organic chemicals resulting in firefighter exposure to increasing numbers and quantities of carcinogens and to the latent period between exposure and appearance of chemically induced cancer.

Some Workers Compensation boards recognize that cancer in firefighters is most likely employment related and have ruled accordingly.^{5, 6} In a recent (1977) report, occupational medicine specialist John Blair Webster, M.D., found excess total cancer and leukemia deaths among firefighters and concluded that leukemia in an Ohio firefighter was "the result of his exposure to carcinogens

as a firefighter and that 100% of his total and permanent disability is related to his occupation by direct cause."⁷

Benzene and Leukemia

Benzene is an accepted cause of aplastic anemia, it "...has been known for almost a century as a powerful bone-marrow poison, leading to aplastic or hypoplastic anemia."⁸ Aplastic anemia may be the fairly rapid consequence of exposure to a toxic substance or it may be virtually indistinguishable from early stages of leukemia or other myeloproliferative diseases.⁹

Vigliani and Saita have described benzene-induced leukemia preceded by an aplastic phase over 10 years ago: "...the leukemia was ... often preceded by a period of apparently aplastic anemia with leukopenia."¹⁰

The interval between initial benzene exposure and death from leukemia ranges from 2 to 21 years.¹¹ It is not known how much benzene is required to produce leukemia in humans; 0.001 milliliter of benzene per week in single doses has been reported to be enough to induce leukemia in mice.¹²

Benzene Exposure of Firefighters

A 1967 California case in which a retirement board found that leukemia could not be job-related in a firefighter because he would not have been exposed to benzene on the job led me to examine the question of firefighter exposure to benzene.

Over 3 million tons of benzene per year are obtained in the United States alone.¹³ Gasoline, degreasing agents, solvents, model airplane and other glues, paint strippers, etc., all contain benzene. The boiling point of benzene is 80°C or 176°F. This means that when benzene or benzene-containing products

are present at a fire site, benzene not in sealed containers evaporates at temperatures well below the boiling point of water and that the vapor pressure of benzene rises rapidly with temperature increases above ambient temperature.

Benzene is a product of combustion of polyvinyl chloride (PVC),^{14, 15} polystyrene,¹⁵ polyurethane,¹⁶ polyphenylene oxide,¹⁵ and polyester¹⁷ plastics; of bismaleimide,¹⁸ epoxy,¹⁷ phenolic,¹⁷ and silicone¹⁷ resins; and of douglas fir.¹⁸ The presence of some form of PVC plastic can be assumed at virtually every fire site in recent years because of the variety of PVC-containing products such as furniture, office equipment, electric wire insulation, car parts, water pipes, and kitchen gadgets. The ubiquitous nature of PVC and polystyrene plastics can be judged from the fact that in 1969 three billion pounds of PVC and two billion pounds of polystyrene plastics were manufactured in the United States.¹⁹

According to Victor Esch, M.D., Chief Surgeon of the District of Columbia Fire Department, the most dangerous period for exposure to toxic products of combustion of plastics is "the 'over-haul' or clean-up phase when firemen instinctively remove their masks for better visibility and comfort -- only to be zapped by the invisible, noxious gases that may linger for hours in confined spaces."²⁰

As firefighters fight fires at gasoline stations, where benzene is a component of the gasoline; at automobile repair shops, where benzene may be present in solvents, degreasers and glues and where benzene is probably a product of combustion of auto seats and upholstery; and at homes filled with all kinds of furnishings made of synthetic materials that are more flammable than wood, many of which produce benzene when they burn, they have multiple opportunities

for exposure to benzene. This exposure may well account for much of Blair's report of excess leukemia among firefighters.

Firefighter Exposure to Other Carcinogens

Asbestos. At the end of a structural fire, when the firefighter pulls down ceilings and breaks open walls looking for smoldering fires, he is exposed to asbestos from insulation (both thermal and acoustic); acoustical tile; decorating and fire-proofing surfacing materials; patching, spackling and jointing compounds; wallboard and floor tile. Asbestos-containing materials may be found on walls, ceilings, floors, exposed structural steel, air ducts, plenums and return air spaces. Bruckman²¹ has reported a 10-fold increase in mesothelioma, the specific type of cancer induced by asbestos, in the period 1935-1959, which appears to parallel cumulative asbestos consumption. Incidence of other types of cancer also rises among asbestos workers. Opportunities for firefighter exposure to asbestos rise with increasing asbestos use. Use of sprayed asbestos is now being controlled, however its presence in buildings built prior to recent institution of controls is widespread and generally unknown to building owners and occupants, much less firefighters.

Chlorinated Hydrocarbons. In fires at dry cleaning establishments firefighter exposure to the carcinogen carbon tetrachloride²² was replaced by exposure to perchloroethylene, which in turn proved to be a carcinogen.²³

Heating or burning PVC plastic, particularly in older products manufactured before the dangers of entrained, unpolymerized vinyl chloride monomer were understood, gives off varying amounts of carcinogenic vinyl chloride.^{14, 24} Fires in newer buildings will encounter not only a variety of interior objects made of PVC but also PUC insulation on wires. Some form of PVC is probably

now found at the site of most fires.

Acrylonitrile. The world demand for acrylonitrile approached 5 billion lb in 1976. About 80% of this went into acrylic and modacrylic fibers and into the thermoplastic resins acrylonitrile-butadiene-styrene (ABS) and styrene-acrylonitrile (SAN).²⁵ U. S. annual production of acrylonitrile is 1.5 billion lb. Workers exposed to acrylonitrile have an excess incidence of lung and colon cancer.²⁶ A major chemical tank farm fire involving acrylonitrile was reported at the 1976 Fall Meeting of the NFPA. Acrylonitrile is formed as a combustion product of durette (a polyvinyl fluoride treated with a chlorinating agent).²⁷

MOCA. The human carcinogen, MOCA (4,4- methylene bis (2-chloroaniline)) is used in the manufacture of isocyanate resins in the plastics, aircraft, resin, and synthetic rubber industries, in radio and television equipment, and in space and missile components. Cal-OSHA estimates that there are over 3,000 potential sites in California where MOCA is in use.²⁸ Firefighters at one of these sites would probably not know that MOCA was in use.

Benzidine. The human carcinogen benzidine is used in plastics, rubber and dyes. Cal-OSHA estimates that benzidine is in use at over 1,400 sites in California.²⁸ Workers routinely exposed to benzidine incur bladder tumors at a rate of 20% to over 50%.²⁹

Carcinogens from Wood and Fossil Fuels

A report by the National Institute for Occupational Safety and Health indicates an increase in myeloproliferative cancers in millwrights, millmen, cabinet workers, lumber and sawmill workers.³⁰ In the absence of knowledge as to what substance(s) produce this effect, it is possible that firefighters are

exposed to these substances at fires in wooden structures.

Polycyclic aromatic hydrocarbons (PAH), many of which are carcinogenic, are formed on combustion of fossil fuels and other organic substances. Anthropogenic combustion appears to be the main source of PAH. These carcinogens are presumably formed at every fire.

Pesticides

Pesticides known to be carcinogenic include: chlordane,³¹ heptachlor,³¹ aldrin,³² dieldrin,³² mirex,³³ chlordimeform,³⁴ endrin,³⁵ chlorobenzilate,³⁶ DDT,³⁷ benzene hexachloride,³⁸ dimethoate,³⁹ all ethylenebisdithiocarbamates,⁴⁰ etc. The carcinogen chloroform is found in at least six pesticide products, of which five are for the control of mites, screwworms, or mange on house pets and farm animals.⁴¹

Pesticides are now found in grocery stores, drug stores, hardware stores and garden shops, as well as in agricultural situations and homes. It should not be assumed that only agricultural situations pose a pesticide-exposure hazard. Pesticides with high immediate toxicity are generally found only in agricultural use, but many substances with long-term effects, such as carcinogenesis, are widely distributed and presently banned substances are found in many basements.

Plastics

The proliferation of plastic products in the last two decades has resulted in a qualitative change in the nature of the compounds to which firefighters are exposed at fires. According to Esch: "Literally hundreds of compounds are given off by flame retardants, fillers, plasticizers, ultraviolet light absorbers, antioxidants, lubricants, reinforcing fibers, peroxides, coupling agents,

halogen stabilizers, biological preservatives, 'anti-static' agents, flow controls, coloring agents and other exotic chemicals. These products create an extremely complex problem in plastics fires. It is mind-boggling, to say the least, when you consider that we are just seeing the tip of the iceberg and the tremendous amount of research needed to determine the specific hazard of burning plastics."¹⁹

It is not known how many carcinogens may be produced by burning plastics and portable instrumentation capable of monitoring for a variety of known carcinogens at the fire site is not yet on the drawing board, nor are there enough trained toxicologists in the country to run the requisite tests.

Multiple Exposures

It is important to realize that there is little experimental evidence on the effects of simultaneous exposures to low levels of two, much less many, carcinogens. It is known that smoking "greatly increases the risk of lung cancer associated with many cancer-causing chemicals,"²⁸ a suggestion that multiple carcinogen exposures may have synergistic effects. Firefighters may be the unwitting guinea pigs who will tell us what the consequences are of intermittent exposure to a variety of carcinogens at levels higher than those of the general population.

Conclusions

Given that a case can be made for exposure of firefighters to a variety of carcinogens on the job, what should be done? I would make the following recommendations:

1. Firefighter exposure to inhaled carcinogens should be decreased by

use of lightweight disposable face masks when self-contained breathing apparatus is not needed.

2. Overhaul procedures should be reevaluated in the light of the potential for avoidable firefighter exposure to carcinogens during overhaul.
3. Yearly physicals and lab tests should be provided for all firefighters.
4. Records of the nature of substances at fire sites should be improved. Present records rarely include information about substances on-site, even for spill clean-up incidents. These records should be kept long enough to allow analysis of occupational cancers with 20-30 year latent periods.
5. OSHA protection of workers exposed to carcinogens⁴² should be extended to firefighters.
6. Just as pneumonia in a firefighter is presumed to be occupationally related because of the effects of routine smoke inhalation, cancer in a firefighter should be assumed to be work related because of routine exposure to carcinogens.
7. Epidemiologic studies should be done to ascertain the actual level of cancer incidence in firefighters as compared to other occupations.

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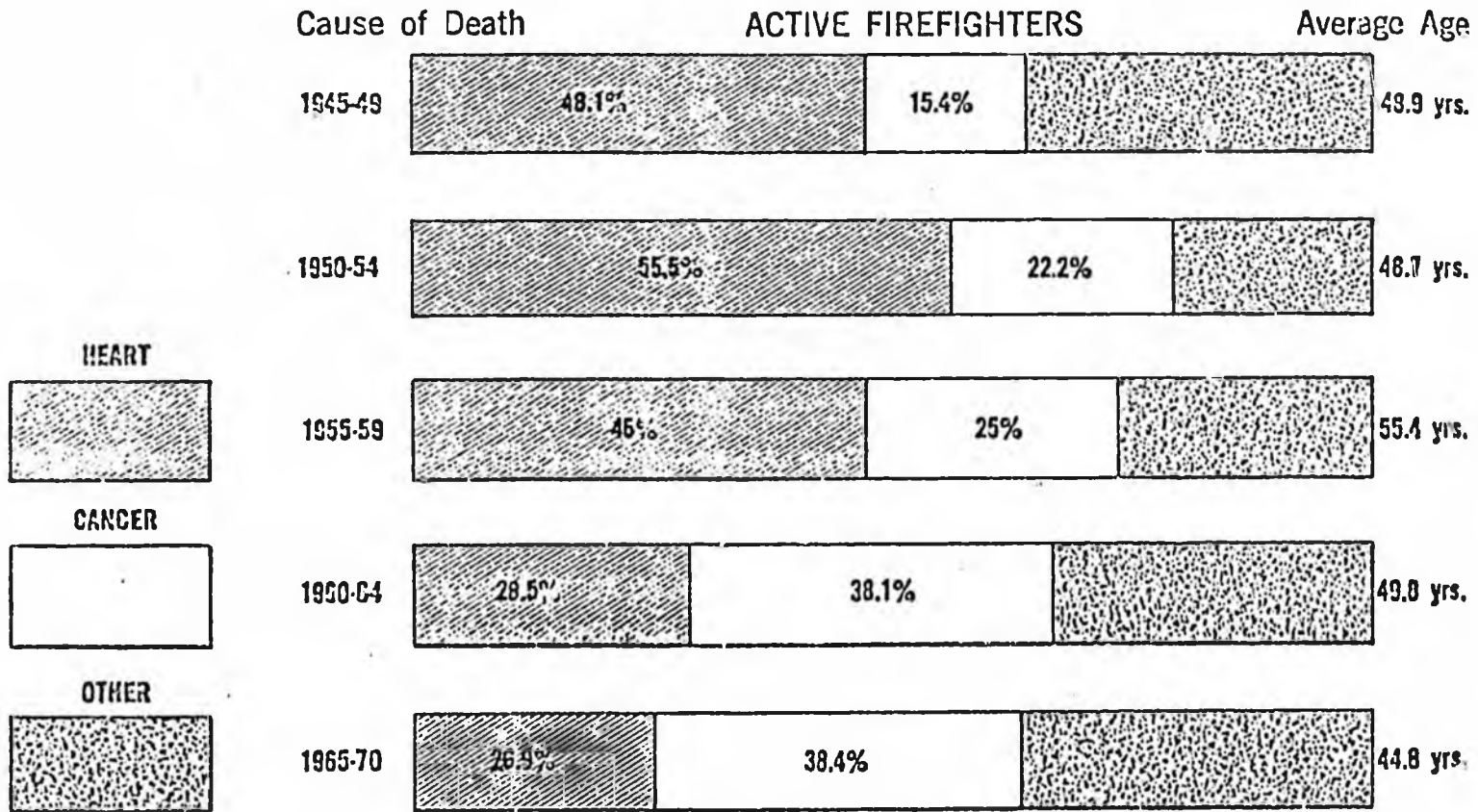
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Figure 1

From Reference 42. Cause of Death in Active Firefighters.



INHALATION INJURY: DIAGNOSIS AND PATHOPHYSIOLOGY

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Inhalation injury is damage to the mucosa of the larynx, trachea or bronchus from exposure to products of incomplete combustion. In addition, these particles resulting from incomplete combustion may cause bronchiolar and alveolar (small airway) damage as well. Since the nasopharynx has tremendous cooling capabilities and since laryngospasm will supervene if heat does reach the level of the larynx, seldom if ever is heat damage seen below the level of the larynx. However, heat may cause upper airway obstruction, followed by hypoxemia, cardiac arrhythmia and death. The chemical damage to the mucosa of the trachea, bronchi or bronchioles may result in copious secretions, bronchospasm, hypoxemia, pulmonary edema and pneumonia. The onset of the clinical inhalation injury syndrome may be delayed from hours to two or three days following exposure to smoke, during which there is a relatively asymptomatic period which may be followed by severe pulmonary complications. The essence of diagnosis of inhalation injury is a careful history, a thorough physical examination, laboratory blood gas determinations, chest roentgenogram, xenon¹³³ lung scan and bronchoscopy.

Since the patient may be asymptomatic, the important points in the history are burns occurring in a closed space or if in the open from a rapid combustion of petroleum products, or pre-existent depression of the level of consciousness so that the patient was exposed to smoke for a longer period of time. Burns about the nose and mouth should heighten the suspicion that an inhalation injury may have occurred, but absence of such burn injury does not eliminate the possibility of inhalation injury. The production of carbonaceous sputum during the asymptomatic period is evidence that an inhalation injury has occurred. The clinical inhalation injury picture is one of dyspnea, hoarseness or upper airway wheezing and a cough productive of fluid and carbon. The chest roentgenogram during the asymptomatic period is normal unless there is pre-existent pulmonary disease. Blood gas determinations in the asymptomatic period are also normal. However, with serial x-rays following the normal chest film on admission, one sees atelectasis and air trapping followed by patchy pulmonary infiltrates during progression of inhalation injury. In an attempt to accurately diagnose the presence of an inhalation injury during the asymptomatic period, two additional diagnostic techniques are utilized, that is, the xenon¹³³ lung scan and bronchoscopy.

The xenon¹³³ lung scan is performed by injecting xenon¹³³ intravenously, and since the xenon gas is cleared by the lungs, serial scintiphotos are obtained to document the pattern and rate of xenon clearance as the patient breathes. A normal scan will show complete and equal clearance of xenon¹³³ within 90 seconds. A delay of clearance beyond 90 seconds or segmental retention of xenon¹³³ is considered diagnostic of inhalation injury only if the patient had a normal chest x-ray prior to the performance of the test. A positive xenon lung scan in the asymptomatic period allows one to begin treatment to modify the severity of the inhalation injury syndrome before it occurs. Xenon¹³³ lung scans are most helpful to identify small airway and alveolar damage.

Bronchoscopy will identify laryngeal, tracheal and bronchial inhalation injury. Positive findings at the time of bronchoscopy include observation of carbonaceous material on mucosal surfaces, excessive secretion of endotracheal and endobronchial mucosa, swelling erythema, hemorrhage and ulceration of the mucosa.

If upper airway obstruction occurs, endotracheal intubation may be necessary to insure an open airway. However, racemic epinephrine and humidification may be sufficient for mild upper airway swelling. In addition, the treatment of inhalation injury includes bronchodilators for the treatment of bronchospasm, repeated bronchoscopy for the removal of debris, humidification of inspired air, antibiotics for pneumonia, monitoring with serial chest x-ray and arterial blood gas determinations, and if indicated use of a mechanical ventilator.

The accurate diagnosis of inhalation injury is extremely important, since the patient may have a significant asymptomatic period before a rather rapid onset of clinical symptoms and signs, and thus a positive diagnosis during the asymptomatic period mandates admission to the hospital and allows treatment to begin prior to the onset of clinical signs, so that the syndrome may be modified.

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AIR CONTAMINANTS ENCOUNTERED BY FIREFIGHTERS

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Our research group at the Harvard School of Public Health has recently completed the latest in a series of studies investigating the environmental conditions encountered by firefighters in the course of performing their duties. Because this project was based, to a large degree, on the experience and results from several earlier studies, a quick review is in order.

From 1970 to 1977, occupational health studies have provided physiological and epidemiological proof that excess respiratory disease is associated with firefighting. (1,2) A project completed in 1977 involved the development and implementation of a portable system for evaluating the thermal environment in structural fires. The main finding of this study was that the predominant source of heat encountered by the firefighter was radiative as opposed to conductive, and protective clothing should be designed to reflect this fact. (3)

Our efforts to characterize the chemical constituents of "smoke" began in the early 70's with the development of a portable carbon monoxide-oxygen sampling device which provided real-time data on the exposure profiles of these two gases. (4,5) The results from 72 residential fires showed that carbon monoxide presents a much greater hazard to the firefighter than does oxygen deficiency. For 29% of the time during these fires, the carbon monoxide concentrations exceeded 500 ppm, yet in only 6 fires did the oxygen concentration fall below 18%. The maximum CO concentration measured was 27,000 ppm, a level at which death would result immediately without respiratory protection. These results are interesting in that model fires consistently show depressed oxygen concentrations.

A study, completed in 1976, measured the levels of carbon monoxide, carbon dioxide, oxygen, hydrogen chloride, hydrogen cyanide and nitrogen dioxide encountered during firefighting using a prototype sampling system built into the firefighter's turnout coat. (6) This study, which included 45 fires with each of two companies, demonstrated that CO presented a potential acute hazard, hydrogen chloride was detected in only 5 of 90 samples, oxygen depression was not significant, and CO₂ and NO₂ concentrations did not approach significant toxic levels.

Using the experience gained from these studies, we developed an expanded air sampling program which would provide data on a wider spectrum of contaminants at a larger number of fires. The goal of this study was the characterization of air contaminants present during structural firefighting. The data obtained can be used for several purposes: (1) to provide further insight into the origin of observed disease in firefighter populations, (2) to improve the medical treatment of "smoke" inhalation victims, (3) to suggest modifications in firefighting procedures to reduce exposures, and (4) to provide real data to be used in the design and implementation of breathing apparatus.

As mentioned, the preliminary study was conducted with the air sampling system distributed throughout the storage pockets of the turnout coat. Because of its bulk, weight, difficulty in servicing, and lack of acceptance

by the firefighters, the expanded study required a redesigning of the sampling unit. After consultation with the firefighters, a new design for the sampler evolved. The unit which resulted was packaged in a vacuum-formed ABS plastic case, measuring 2½" x 8" x 10", weighing 4 to 5 pounds, designed to be worn over the neck.

Wherever possible, solid sorbents were used to collect the air contaminants. Some gases, unable to be trapped on these sorbents, were collected in a Tedlar plastic bag. The sampler was designed to pull air through a succession of filters and sorbent materials. The ascarite collected hydrogen cyanide, the triethanolamine treated sieve trapped nitrogen dioxide and hydrogen chloride, and the untreated activated molecular sieve collected aldehydes, specifically acrolein. Along the other circuit, the glass filter collected particulate matter, the charcoal tube absorbed aromatic hydrocarbons (benzene), and the Tedlar bag was used for the storage of carbon monoxide, oxygen and carbon dioxide.

Six units were constructed and placed in different fire houses throughout the city of Boston. Those firefighters who volunteered to participate in the project were instructed in the use of the samplers, the purpose of the study, and the results, as they became available. The reception of these units by the firefighters was positive.

On a limited number of fires, air samples were taken during active firefighting and at the overhaul operations. These data were used to evaluate the importance of the air contaminants encountered during overhaul, an issue of great concern to the fire service.

To evaluate the exposure of firefighters to air contaminants encountered during firefighting, three exposure guidelines were used. The American Conference of Governmental Industrial Hygienists publishes a list of Threshold Limit Values - Short-term Exposure Limits (STEL).⁽⁷⁾ These limits, expressed as airborne concentrations and based on exposures to single substances, not mixtures, were developed for unprotected industrial workers, and the appropriateness of their application to the fire environment is questionable, as they represent no-effect levels for 15 minute periods.

The second industrial exposure guide considered is the concentration at which the substance poses an Immediate Danger to Life or Health (IDLH).⁽⁸⁾ This index, which has been used in the NIOSH-OSHA Standards Completion Project in defining the application of respiratory protective devices, is defined as the concentration from which a worker might escape within 30 minutes without irreversible health effects or suffer any effects which may impede escape.

The third and probably most appropriate, standard is the Short Term Lethal Concentration (STLC), as used by Dr. J. B. Terrill⁽⁹⁾ Each of the contaminants considered in this study was evaluated by comparing the concentrations observed with each of these indices.

Nitrogen dioxide (NO₂) may be present in the fire environment as a result of the oxidation of the nitrogenous material or the fixation of atmospheric nitrogen. Although high concentrations of NO₂ have been noted in controlled burns,⁽¹⁰⁾ in our preliminary study of actual fires it was not present in concentrations greater than 1ppm. Acute exposure to NO₂ results in bronchial

irritation with subsequent dizziness, headache and weakness. Several hours later the individual may develop pulmonary edema with subsequent asphyxia and death.

A total of 212 samples were analyzed for NO_2 in this study. Four exceeded the ACGIH-STEL of 5 ppm; however, none exceeded 50 ppm, the concentration at which NO_2 is considered immediately dangerous to life or health (IDLH). The highest concentration noted over a five minute exposure period was 8.3 ppm. While it is possible that NO_2 may act in concert with other irritants to cause serious pulmonary irritation, it alone does not represent a critical exposure at the concentrations observed.

As mentioned, NO_2 may be generated from the degradation of nitrogen-containing materials or the fixation of atmospheric nitrogen. In the fires studied, the concentrations of nitrogen dioxide were low, indicating the absence of conditions conducive to the degradation of nitrogenous materials. The low concentrations also indicated that in residential fires, flame energies are not adequate to fix atmospheric nitrogen. Our conclusion is that the NO_2 concentrations observed in this series of structural fires do not constitute a respiratory hazard to the firefighter.

Hydrogen chloride gas is formed in a fire from the pyrolysis of a range of chlorinated polymers such as polyvinyl chloride, chlorinated acrylics, and flame-retardant materials.⁽⁹⁾ In concentrations greater than 100 ppm, HCl is corrosive to the eyes, skin and mucous membranes. This gas is an upper-respiratory irritant due to its solubility in water. When associated with high concentrations of respirable particulate, it may represent a lower airway hazard.⁽¹¹⁾ Due to its irritating effect, acute exposures to high concentrations are not willingly tolerated; however, if a person is incapable of terminating exposure or cannot escape, pulmonary edema and death may occur if concentrations exceed 500 ppm for several hours.

Of 216 samples analyzed, HCl was detected in 83, with a maximum concentration of 280 ppm encountered during one seven-minute sample. Seventy-three samples exceeded the ACGIH-STEL (5 ppm), and 5 exceeded the NIOSH-OSHA IDLH (100 ppm). None exceeded the short term lethal concentration (STLC) of 500 ppm.

Firefighters commonly complain of severe eye and respiratory irritation during and after fires and personnel without breathing apparatus may be forced from the fire scene. Responsibility for this acute irritation of the respiratory tract has, in some cases, been attributed by the fire service to HCl. In fact, this action may be caused by exposure to HCl, other respiratory irritants, or a combination of irritants. In our study, HCl was present in over one third of the fires sampled, and in a small number of fires, the concentrations were sufficient to impede the escape of a person not wearing respiratory protection. However, a concentration lethal to an unprotected person exposed over a short time was not observed during the study.

Hydrogen cyanide can be formed in the fire environment from natural products such as wool and silk, and a variety of nitrogen-containing polymers, including nitriles, polyamides, nylons, and polyurethane. Because of the widespread use of polyurethanes in furniture upholstery and building materials,

the significance of HCN in fire toxicity has received much attention.⁽¹²⁾ In our preliminary study, this contaminant was frequently found albeit at low concentrations. In the 6 fires from this earlier study in which HCN exceeded 1 ppm, 3 involved polyurethane foam mattresses, and one was a vehicle fire. Hydrogen cyanide, toxic by inhalation and skin absorption, interferes with metabolic oxidation and causes anoxia at the cellular level. Initial symptoms of acute exposure to levels above 20 ppm include weakness, headache, and confusion, then, ultimately, respiratory failure and death.

Hydrogen cyanide was detected in 27 of 253 samples. The maximum concentration noted for a minimum of 5 minutes in this series was 3.6 ppm. Neither the STEL (15 ppm), and IDLH (50 ppm), nor the STLC (350 ppm), were approached.

In a previous study, hydrogen cyanide was detected in low concentrations in approximately one half of the fires. The study included a predominance of room fires involving upholstered furniture. In the present study, HCN was detected in only about 10% of the fires; however, the fires involved a wider spectrum of building types and materials. On the basis of both data sets we conclude that the observed hydrogen cyanide concentrations do not present a health hazard to firefighters.

The formation of acrolein at the fire scene can result from pyrolysis or combustion of cellulosic materials such as wood, cotton, and papers, plastic materials such as styrene and polyolefins, and oils and fats containing glycerol.⁽¹³⁾ Inhalation of acrolein causes irritation of the nose and throat, nausea, shortness of breath, vesicant action with extensive lung damage, pulmonary edema, and ultimately death.

Of the 118 samples which were analyzed, acrolein was detected above the STEL (0.3 ppm) in 66 and above the IDLH (5ppm) in 5. In one fire, the concentration was at the upper end of the STLC range (30-100 ppm).

The distribution of concentration data indicates that one half of the analyzed samples showed concentrations which were greater than the STEL of 0.3 ppm and that 10% of the samples were in excess of 2.7 ppm, a concentration close to that immediately dangerous to life or health.

To our knowledge, this is the first time that acrolein has been identified in life-threatening concentrations at real fires. In over one half of the samples analyzed for acrolein, the concentration exceeded levels capable of causing significant eye and respiratory injury (0.3 ppm). Firefighters operating without respiratory protective devices in the most severe of these fires might well have suffered disabling injury. The frequency of detection of acrolein at fires suggests that a range of materials contributes to its formation. This study supports the belief by Zikria⁽¹⁴⁾ and Morikawa⁽¹³⁾ that aldehydes play an important role in respiratory injury to fire victims. As these authors suggest, medical management of fire victims should routinely consider possible exposure to this contaminant.

Structural fires are a source of particulates which include condensation products from volatilized materials, sub-micron carbonaceous material, large particles formed by agglomeration, and char released during fires. High concentrations of particulates cause irritation of the upper respiratory tract and massive concentrations produce respiratory spasm. Particulates also absorb many of the gases and vapors present in the fire environment and present this material to the non-ciliated portion of the lung.

Data are not available on the biological effects due to the inhalation of non-specific particulates; however, concentrations in the range of 20-50 mg/m³ will cause light obscuration, and 1000 mg/m³ causes immediate pulmonary distress.

The effects of exposure to particulates depend on their chemical composition, size distribution, and concentration. The sampling method used in this study did not permit an analysis of the size distribution and the scope of work did not include identification of the composition, a major analytical task. The concentration data obtained in the study are consistent with our earlier study and show concentrations which would cause simple irritation of the respiratory tract. The particulates may, of course, have a much more important role in disease production by providing adsorption sites for toxic gases and vapors.

Carbon monoxide occurs as the result of incomplete combustion of virtually all organic materials. The physiological effects of carbon monoxide are well known. As with most other toxicants, the two important parameters to consider are concentration and duration of exposure. Headache, fatigue, dizziness and sleepiness are classic symptoms of low level (150-500 ppm) exposures. Unconsciousness, collapse and death occur as the concentration and the duration of exposure increases. Visual vigilance or sensitivity is impaired at relatively low concentrations. Carbon monoxide combines with the blood's hemoglobin, thus interrupting the supply of oxygen to the tissues. Permanent tissue damage may result from asphyxia. The action is enhanced by heat, humidity and physical exertion.

Found in virtually all of the fire environments studied, the CO levels exceeded the STEL (400 ppm) on 16 occasions and the IDLH (1500 ppm) 4 times. One fire approached the short-term lethal concentration (STLC) of 5000 ppm.

The concentrations of carbon monoxide found in this study are in agreement with earlier studies by this laboratory and other investigators. This contaminant is without doubt the most routine and serious acute hazard to the unprotected firefighter. It is an extremely toxic gas with varied effects. Those exposed are given no warning of its presence and, although repeatedly shown to be the cause of most fire-related deaths, this gas continues to be underrated by the fire service. In addition, inadequate awareness of the problem by medical personnel continues to exist at many urban hospitals which routinely handle fire victims.

Carbon monoxide exerts a number of effects at low concentration, including impairment of judgment, visual acuity, and decision making--all faculties crucial to the safety of the firefighter. Therefore, even when it is not the principal cause of injury, CO may contribute to serious trauma. Furthermore, CO presents additional stress to the circulatory system, contributing to the development of cardiac disease. (15)

Carbon dioxide results from the complete combustion of organic materials and has been noted in high concentrations in engineered burns. At high concentrations, CO₂ causes stinging of the eyes, nose, and throat. At 50,000 ppm the respiratory center is stimulated, causing hyperventilation. Death has been reported at exposure concentrations in excess of 10%. At 30,000 ppm it is weakly narcotic.

Of 89 samples analyzed for CO₂, 3 exceeded the STEL (15,000 ppm) and 1 exceeded the IDLH of 50,000 ppm. In no fire did the concentration exceed the STLC (100,000 ppm).

Carbon dioxide is present in all fires but has a low order of toxicity, with mild and reversible physiological responses beginning to appear for exposures in the range of 1/2 to 1% (5,000-10,000 ppm). Therefore, at the concentrations observed in our study, it alone would not present a significant hazard to the firefighter. However, exposure may cause hyperventilation resulting in a potentiation of the effects of other air contaminants which might be present. Although high concentrations of CO₂ (100,000 ppm and above) have been identified in engineered burns, such levels have not been noted in our studies--further evidence that caution should be exercised in extrapolating results from the laboratory to real life situations.

The sources of benzene and other aromatics in structural fires are not precisely known, although likely sources include available petroleum products acting as fuel in the fire and the thermal degradation of certain plastics such as styrene. At high concentrations there is irritation of the eyes, drowsiness, nausea and headache, and finally unconsciousness and death from respiratory paralysis. Chronic exposures may cause blood changes and leukemia.

Of 197 samples analyzed, 181 contained measurable amounts of benzene. Thirty-three were over the STEL (5 ppm); none were over the IDLH (2,000 ppm). The IDLH index is based solely on acute effects, while the STEL was developed with consideration for long term hematopoietic problems. The maximum concentration determined was 165 ppm, well below the IDLH. Concentrations of benzene and other aromatic hydrocarbons in excess of 1,000 ppm would be acutely hazardous to the unprotected firefighter due to narcosis; however, the levels in our study were consistently below 200 ppm, so an acute danger was not present. In the observed concentration range, a chronic health hazard does not seem likely since the exposure is infrequent and of short duration. The identification by NIOSH of benzene as a human leukemogen presents a more subtle evaluation problem, and a definitive statement on this potential hazard to the firefighter cannot be made based on our present knowledge.

The personal monitoring of firefighter exposures to toxic air contaminants during structural fires in Boston has confirmed the complexity of the exposure. Carbon monoxide and acrolein are the most hazardous specific air contaminants in this series of fires, while combinations of respiratory irritants (e.g., acrolein, hydrogen chloride, and nitrogen dioxide) acting in a synergistic manner may be important in selected fires. The combined effects of mixtures of these and other irritants, especially in the presence of high particulate concentrations, often make effective work by the firefighter impossible without respiratory protection. The concentrations of hydrogen cyanide and

carbon dioxide, and the degree of oxygen deficiency were not found to be significant health hazards in this study. This study confirms earlier work by this laboratory which indicates that firefighters should wear respirators at all structural fires.

A limited number of fires were sampled both during active firefighting operations and the subsequent overhauling. This allowed us to compare the data so as to ascertain the relative severity of the exposure once the fire has been "knocked down."

A statistical analysis of these data showed that:

1. The concentrations of HCl and particulates are higher during firefighting than during overhauling;
2. There was no significant difference between the concentrations of NO₂, HCN, or benzene during firefighting versus overhauling; and
3. Insufficient data were available to reach conclusions regarding acrolein, CO, and CO₂.

There are several cautions which must be considered before extrapolating these data and conclusions to other situations.

All of the fires monitored were located in one city, Boston, and fought by the Boston Fire Department. Other cities may have a predominance of newer structures built with different materials and containing different furnishings. In addition, other fire departments may not employ the same firefighting techniques as those used in Boston. Due to the nature of the sampling protocol, it was impossible to measure gas concentrations during the initial stages of the fires. Another constraint was the limited number of contaminants identified to be sampled.

Furthermore, the fires sampled in the study were predominantly structural in nature. Other situations, such as fires involving chemicals, train tunnels, vehicles, and brush would probably present an entirely different contaminant profile.

These concentration data represent environmental conditions encountered by working firefighters, usually wearing self-contained breathing apparatus. These are not, nor should they be considered to be, exposure levels.

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substances, and sometimes in covering radiation diseases for the first time.

§ 41.72 Special statutes on heart and respiratory diseases of police and firefighters

An interesting recent phenomenon has been the burgeoning in all parts of the country of statutes granting special compensation coverage to firemen or policemen or both, for respiratory and heart³¹ diseases connected with the exertions of the employment.⁴ No two are quite identical. Most establish a

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³¹ California has a similar statute for hernias. See *Smith v. WCAB*, 45 Cal. App. 3d 162, 119 Cal. Rptr. 120 (1975), § 41.72(e) N. 11.6 *infra*.

⁴ The states having some kind of special statute in this category include: Alabama, California, Connecticut, Florida, Maine, Maryland, Michigan, Minnesota, Nevada, New Hampshire, New Jersey, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, Vermont and Wisconsin.

In several of these states, there may be some question whether the system is an intrinsic part of the workmen's compensation system, as distinguished from a separate pension program. Wisconsin, for example, was met with this question directly, and found the presumption to be part of workmen's compensation. See: *City of Manitowoc v. Iowa National Mutual Insurance Co.*, 68 Wis.2d 722, 229 N.W.2d 57 (1975). Iowa National refused to indemnify its insured, City of Manitowoc, for survivor's benefits paid under a statute allowing a fireman's widow compensation for any work-related disease causing the death of her husband. Iowa National's argument was that the special statute for firemen was a pension statute rather than a compensation one and therefore outside the policy coverage. The court ordered payment by the insurer, rejecting this argument.

As to the Alabama situation, see the following cases:

City of Tuscaloosa v. Howard, 55 Ala. App. 781, 318 So.2d 729 (1975). The claimant, a 27-year veteran of the fire department, experienced chest pains while performing housekeeping duties at the fire station. He left work at the end of the shift and reported to his second job. He later sought medical attention. After two weeks of hospitalization, the physician determined that during the preceding week the claimant had suffered a heart attack. He was hospitalized for a total of a month and was not permitted to return to his duties for two and one-half additional months. The claimant presented his claim under the Workmen's Compensation Act under three alternative theories: first, that as a city employee, he had suffered a compensable injury while in the scope of his employment; second, that he was entitled to compensation under occupational disease provisions (Title 26, Chapter 5,

Article 2C); third, that he was entitled to workmen's compensation under the Fireman's Heart and Lung Disability Act. The trial court found compensation due under each theory. The Court of Civil Appeals reversed and remanded, stating that, as a matter of law, the claimant could not recover workmen's compensation benefits under any of the theories. First, the Court held there was no accident within the definition of the Act, because there was no evidence that the strain and exertion of the claimant's work caused the injury. Second, the Court ruled, as a matter of first impression, that myocardial infarction resulting from progressive arteriosclerotic heart disease was not a hazard of employment of a fireman, was not particular to that occupation, and did not result from the nature of the employment. Finally, the Court held that benefits payable under the Fireman's Act are to come from separate pension funds, and are separate from and need not be identical in amount to workmen's compensation benefits.

Norris v. Seihels, 353 So.2d 1165 (Ala. 1977), 353 So.2d 1169 (Ala. App. 1978). Under the provisions of Title 37, section 450(4), all municipal firemen within the state were eligible for benefits for heart disease and hypertension as if injured in the course of their employment. The law including this section was applicable only to firemen. Subsequently, an amendment to the municipal pension laws excluded municipal firemen in cities with over 250,000 inhabitants (i.e. Birmingham) from the coverage of § 450(4). The Court of Civil Appeals held that the amendment did not violate the equal protection clause of the United States Constitution. On appeal, the judgment was reversed. The court held that there was no reasonable relationship between the classification and purpose of the pension law, to provide protection from disability to firemen disabled by occupational disease.

See also: *Mitchell v. Public Employees' Retirement Board*, 28 Or. App. 339, 559 P.2d 1325 (1977). The court held that the refusal to apply a Workmen's Compensation Act presumption—that a heart attack is related to a fireman's employment—to the Public Employees' Retirement system was proper.

See also, as to the Pennsylvania coordination problem:

Commonwealth v. Oil City, 15 Pa. Cmwlth. 544, 328 A.2d 170 (1974). The claimant had been employed as a fireman with the City Fire Department for approximately twenty years. In November, 1970, while fighting an especially tragic fire, the claimant had suffered a heart attack and incurred right lobar pneumonia. The incident resulted in temporary, total disability from that time until May, 1971, when the claimant returned to duty. The claimant's heart disease came within the provisions of the Pennsylvania Occupational Disease Act. He was also entitled to compensation payments during the period of temporary disability to be paid by the city. The city continued to pay the claimant his full rate of salary. The city was only required to pay \$60 per week, which is the amount payable under the Occu-

presumption of work connection when these diseases result from performance of active service.

The commonest controversy generated by these statutes has centered around the strength of that presumption. The best way to measure this strength is by the negative test of how much it takes to rebut or overcome the presumption.

§ 41.72(a) Rebutting the presumption of work-connection under police and firefighter statutes.

The possible grounds for rebutting the presumption vary so widely that the end product varies from a virtually irrebuttable to a virtually worthless presumption.

In California (by statute), Michigan, and Tennessee, the presumption cannot be rebutted merely by evidence of preexisting heart disease.⁵ Michigan and Wisconsin even hold that

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Occupational Disease Act. The city did not pay the claimant's hospital, doctor, and drug bills. The claimant filed a claim seeking compensation under the Occupational Disease Act. The referee held that compensation under the Act should be suspended until a loss of earnings was shown by the claimant. It also held that the Commonwealth was liable for all hospital, medical, and drug bills. On appeal, the Board held that the Commonwealth was liable not only for medical expenses, but also for occupational disease compensation at the rate of \$60 per week. It held that the city was subrogated to receive all said payments. The Commonwealth Court affirmed. It held that, pursuant to a 1965 amendment to the Occupational Disease Act, the Commonwealth was primarily liable for compensation to firemen who suffer from heart and lung diseases. When a city has made payments to a fireman under the Heart & Lung Act for a disability also compensable under the Occupational Disease Act, that city is entitled to be reimbursed to the extent the fireman is entitled to compensation under the Occupational Disease Act.

⁵ "Such heart trouble or pneumonia so developing or manifesting itself in such cases shall in no case be attributed to any disease existing prior to such development or manifestation." Cal. Labor Code § 3212.5. This passage was added by amendment in 1959.

Turner v. Workmen's Compensation Appeals Bd., 258 Cal. App. 2d 442, 65 Cal. Rptr. 825 (1968). California provides that for policemen with five years' service, heart trouble developing or manifesting itself while the officer is in the service of the police department is presumed to arise out of and in the course of the employment, and that such heart trouble can not be

attributed to preexisting disease. Claimant, a police officer, suffered a heart attack while on duty, and the only medical evidence presented indicated that the attack was due to preexisting heart disease, and not in any way connected with his work. *Held*: Presumption of compensability could not be rebutted by showing of preexisting heart disease. Denial of compensation reversed.

Bussa v. Workmen's Compensation Appeals Bd., 259 Cal. App. 2d 261, 66 Cal. Rptr. 204 (1968). Decedent, a fireman, suffered a fatal heart attack working at a second job. The attack was found to have been caused by preexisting atherosclerosis, and benefits were denied. The denial was reversed, on the ground that since claimant was a fireman, a heart attack occurring during his period of service was presumed to be compensable, and this presumption could not be rebutted by attributing the attack to any preexisting disease.

City and County of San Francisco v. Workmen's Comp. App. Bd., 49 Cal. App.3d 659, 122 Cal. Rptr. 599 (1975), *aff'd*, 583 P.2d 151 (1978). The claimant's decedent was employed as a San Francisco police officer from 1943 to 1968. When he suffered a fatal heart failure in 1972, his widow and minor daughter claimed benefits from the city. The city challenged a state statutory presumption that a policeman's heart trouble arose out of and in the course of his employment. Medical testimony was introduced to the effect that the decedent's condition was progressive and not conclusively related to his employment. The court held that the statutory presumption was not a "denial of due process" nor "an unconstitutional invasion of the municipality's domain" by the state. The court also gave effect to an amendment providing that the statutory presumption "cannot be rebutted by a pre-existing heart disease." Benefits were awarded. *Treatise* cited in majority opinion and dissent. See further reference to the constitutional issue, which focused entirely on the passage quoted at the beginning of this note, at § 41.72 (e) *infra*.

Michigan: Schave v. Department of State Police, 58 Mich. App. 179, 227 N.W.2d 278 (1975). The claimant was a policeman who alleged his heart condition was a result of his employment. The court ruled that the statutory words "in the absence of evidence to the contrary" did not allow the presumption in the plaintiff's favor to be rebutted by evidence of preexisting heart disease or medical opinion that the occupation had no effect. In order to avoid the presumption, the defendant must introduce evidence of non-work related causation. *Treatise* quoted.

Tennessee: City of Oak Ridge v. Campbell, 511 S.W.2d 686 (Tenn. 1974). The employee, a city policeman, suffered a myocardial infarction while performing his duties. He sought a 100% disability classification, which was challenged by employee's employer and employer's insurance carrier on the ground that the injury producing the disability was not an " . . . injury by

the presumption cannot be rebutted by medical opinion that the occupation had no effect on the weakened heart.⁶ How then can the employer rebut the presumption? Michigan, in the case^{6.1} holding that neither of these two^{6.2} showings are sufficient, provided the answer: by affirmative proof of non-occupational causation. It is interesting to note that Michigan achieved this result under a statute that creates the presump-

accident arising out of and in the course of employment . . . " The Court held that the employee was entitled to the 100% disability classification because the employee satisfied the statutory criteria which provided a presumption that the disability occurred " . . . due to accidental injury suffered in the course of employment." The statutory criteria which employee satisfied which gave the employee the presumption were: (1) the disabled employee was employed by a regular law enforcement department manned by full-time employees; (2) the employee suffered a disability resulting from hypertension or heart disease; and (3) prior to such claimed disability, the individual had had a physical examination which did not reveal heart disease or hypertension. The Court also held that the presumption was not rebutted by the fact that a doctor's testimony established that employee was suffering from arteriosclerotic heart disease in the day in question, and that the medical doctor would not have recommended that the employee pursue his regular nighttime duties, at which time the infarction occurred.

⁶ *Michigan: Schave v. Dept. of State Police, N. 5* immediately *supra* under *Michigan*. Treatise quoted.

Wisconsin: Sperbeck v. Department of Indus., Labor & Human Relations, 46 Wis. 2d 282, 174 N.W.2d 546 (1970). Wisconsin provides a rebuttable presumption that a fireman who sustains a heart attack under certain circumstances has had a compensable heart attack. The employer sought to rebut the presumption through the testimony of a doctor who was of the opinion that the occupation of a fireman had no effect on the arteriosclerotic heart disease that resulted in decedent's heart attack. The court held that this was not the type of testimony that could rebut the presumption, since in enacting the legislation that created the presumption, the legislature had rejected the school of medical opinion espoused by this doctor.

^{6.1} *Schave v. Dept. of State Police, N.5 supra* this subsection under *Michigan*. Treatise quoted.

^{6.2} When only one of the two showings is ruled out by statute, as the first is in California, the Supreme Court of California has held that this limited trimming of the scope of rebuttal does not create a constitutionally questionable "irrebuttable presumption." *City and County of San Francisco v. WCAB, N.5 supra* this subsection under *California*. See further discussion of the constitutional point *infra* at § 41.72(e).

tion "in the absence of evidence to the contrary." This "contrary" evidence, then, can not be merely negative; it must be positive proof of a cause independent of the employment.

The intermediate position is represented by the rule in Louisiana^{6.3} and New Hampshire.^{6.4} In those states the presump-

^{6.3} *Vincent v. City of New Orleans*, 326 So.2d 401 (La. App. 1975), writ denied, no error, 329 So.2d 760 (1976). Act 337 of 1965 provides that: "Any disease or infirmity of the heart or lungs which develops during a period of employment in the classified fire service of Louisiana shall be classified as a disease or infirmity connected with the employment . . . Such disease or infirmity shall be presumed, prima facie, to have developed during the employment whenever same is manifested at any time after the first five years of employment." In a suit to recover permanent and total disability, a 14-year veteran fireman alleged that his duties caused or accelerated the cardiovascular disease and angina pectoris which resulted in his retirement. The employer offered no proof to rebut the testimony of the claimant's expert witness, who stated that there was a direct correlation between the physical and emotional stress of the claimant's job and his disease. The Court of Appeal affirmed an award of benefits, stating that the statute shifts the burden of proof to the employer, who must prove the lack of causation between the disease and the employment. The Court concluded that the City had failed to prove the negative. Act 30 of 1975, passed after this decision, specifically provides that manifestation of heart or lung disease after five years employment is presumed not only to have developed during the employment, but also is presumed to have been caused by or to have resulted from the nature of the employment.

See also: *Buse v. City of New Orleans*, 349 So.2d 397 (La. App. 1977). The plaintiff was employed as a fireman. In 1965 he sustained a knee injury, which required him to miss over one year of work. He brought suit for compensation in 1968, alleging that the injury was work-related but had not manifested itself until 1967. In 1973 he amended his complaint, alleging total permanent disability from obstructive lung disease resulting from the inhalation of smoke at a marsh fire. The plaintiff had a pre-existing bronchitis condition. The plaintiff's treating physician testified that he thought the marsh fire had at least aggravated the plaintiff's condition. The trial court awarded permanent total disability benefits. On appeal, the defendant contended that the amendment to the old complaint should have not been allowed, because it stated a cause of action arising after the date the complaint was filed, and that the evidence was not sufficient for a finding that the plaintiff's lung condition was related to his work. The judgment was affirmed. The court held that the defendant was not prejudiced by the amendment, even though its contention was technically correct. The plain-

tion shifts the burden of proof as to employment causation, and it is possible for the employer to rebut the prima facie case based on the presumption by proving a negative: that the employment did not contribute to the injury.

At the other extreme is the rule in Oregon, which is accounted for to some degree by the particular choice of words in the statute, which speaks of a "disputable" presumption. Oregon has taken the position that if the employer presents any evidence challenging the work-connection of the injury, the presumption has been "disputed";^{6.5} apparently this puts

tiff was not entitled to the statutory presumption that his lung condition developed during his firefighting performance, because it developed prior to rather than after his first five years of firefighting work. Nevertheless, the court held that the plaintiff had proved his case by a preponderance of the evidence.

^{6.4} *New Hampshire Insurance Co. v. Duvall*, 337 A.2d 533 (N.H. 1975). A New Hampshire statute established a prima facie presumption that heart or lung disease in a firefighter is occupationally related. Pursuant to the statute, a labor commission regulation required insurance carriers to pay compensation within ten days after a fireman proved that he had such a disease, unless the carrier offered rebutting medical evidence (defined as evidence that the "disease is not work related") within that time. The court construed the statute to permit, rather than to require, the commissioner to order such payments within ten days. It held that the regulation, insofar as it provided insufficient time for an insurance carrier to obtain rebuttal evidence and allowed no extensions of time, unconstitutionally deprived carriers of their property without due process of law.

^{6.5} *Norris v. State Accident Insurance Fund*, 27 Or.App. 623, 557 P.2d 61 (1976). The claimant, a fireman, suffered a myocardial infarction at home after experiencing chest pains at work that day. In Oregon, claimant-firemen are aided by a disputable presumption that a heart attack is work-related. In this case, there was opposing medical testimony that the attack was not work-related. The court held that this testimony disputed the presumption, and that the claimant had failed to meet his burden of proving work-relation. Therefore benefits were denied.

Pflughaupt v. State Accident Insurance Fund, 26 Or.App. 77, 552 P.2d 284 (1976). The claimant, a fire chief, suffered a myocardial infarction at home. He filed a claim for benefits based on a statutory "disputable presumption" of work-connection for certain occupational diseases occurring in firemen with a certain tenure. The court held that the testimony of two cardiologists that there was no causal relation between the attack and his

matters right back where they would have been without the presumption, and the claimant must proceed to prove his case in the usual way. The only usefulness the presumption would have for the claimant, then, would be to support an award if no opposing evidence whatever was offered by the employer. Since it would be a rare case in which the employer could not find some testimony to "dispute" the presumption in this sense, the characterization of this kind of presumption at the outset of this subsection as "virtually worthless" does not seem exaggerated.

Expressions can also be found in Minnesota cases suggesting that a roughly similar rule has been accepted there. Thus, in *Scrabek v. Teleprompter Corp.*,⁷ the court stressed that the presumption was only a "rule of law dictating decision on unopposed facts."

employment was sufficient to dispute the presumption. Affirmative proof of what did cause the attack was not required to dispute. Thus, with the presumption gone, the claimant had no case and benefits were denied.

⁷ 255 N.W.2d 377 (Minn. 1977). The claimant, a 25-year veteran of the City of Rochester fire department and part time employee of Teleprompter, experienced severe chest pains while working for Teleprompter. He had experienced less severe pain the previous day while at the firehouse. At the hearing, two doctors testified. They agreed that the employee had suffered one myocardial infarction, but disagreed as to any relation between the infarction and the claimant's job as a firefighter. The compensation judge found that the claimant's personal injury arose out of and in the course of both employments equally, and held each employer liable for a percentage of benefits equal to the percentage which each had contributed to the total pre injury earnings. On appeal, the Worker's Compensation Court of Appeals found that the claimant had performed "arduous duties" in participating in firefighting activities which led to two myocardial infarctions. Consequently, it assessed all disability payments against the city. The Supreme Court reversed, citing a lack of evidence that there were two infarctions. The court noted that there was substantial evidence to rebut the statutory presumption, embodied in Minn. St. 176.011, subd. 15, that a fireman's heart failure was occupational. "We have frequently characterized this statutory presumption as a *rule* of evidence. It is not evidence. It is, rather, a rule of law dictating decision on unopposed facts. . . ." 255 N.W. at 380.

§ 41.72(b) What persons are covered

The typical statute covers police or firefighters or both. Inevitably there has been pressure on legislatures to extend the statutes to categories of employees similar or related to these. Thus, Minnesota started with members of organized fire departments in 1955;⁸ in 1957 added members of organized police departments;⁹ then in 1959 the highway patrol;¹⁰ and in 1963, members of the game warden service and State Crime Bureau.¹¹

The courts, however, have displayed no disposition to enlarge the protected circle by stretching the statutory language beyond its normal meaning. Thus, when California extended its police coverage to embrace campus policemen in the University of California system, the court declined to interpret it as covering California State University policemen.^{11.1} Similarly, it refused to stretch coverage of full-time salaried deputy sheriffs to include a deputy coroner who was also a deputy sheriff.^{11.2}

⁸ Minn. Laws 1955, Ch. 206.

⁹ Minn. Laws 1957, Ch. 854. See also Minn. Laws 1955, Ch. 34, with special compensability of tuberculosis of policemen due to contact with the disease. *Gray v. City of St. Paul*, 250 Minn. 220, 84 N.W.2d 606 (1957), awarded compensation to policeman who had intermittently ridden in a police car with a fellow officer who had tuberculosis.

¹⁰ Minn. Laws 1959, Ch. 20.

¹¹ Minn. Laws 1963, Ch. 497.

^{11.1} *Saal v. Workmen's Comp. Appeals Bd.*, 50 Cal. App.3d 291, 123 Cal. Rptr. 506 (1975). The claimant was a campus police officer employed by the California State University. After suffering a heart attack, he claimed benefits based upon statutory provisions that the heart trouble of certain classes of policemen was presumed to have arisen out of and in the course of their employment. The special provisions had been extended to cover campus policemen in the University of California system, but not California State University. The court held that the presumption did not apply to the claimant. Noting the "wide discretion" of the legislature to make classifications, the court found that the legislature "has proceeded step-by-step in conferring additional benefits upon certain peace officers with respect to certain employment hazards."

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A question may arise, when statutes speak of "firefighters" or of "active firefighters," whether clerical or sedentary workers connected with the fire department are meant to be included. Pennsylvania has answered this question in the negative, in the case of a dispatcher, on the ground that his work did not expose him to the kind of special hazard contemplated by the statute.^{11.2} California faced the same problem as to a maintenance employee, who, however, was required to attend fires, and held that coverage at least could not be summarily ruled out.^{11.4}

§ 41.72(c) Effect of leave or retirement

Once the firefighter or police officer is within the coverage of the special presumption statute, he does not, according to the reported cases that have addressed the issue, lose the bene-

^{11.2} *State Compensation Ins. Fund v. Workmen's Compensation Appeals Bd.*, 251 Cal. App. 2d 772, 59 Cal. Rptr. 760 (1967). Claimant worked as deputy coroner out of the coroner's office, and was also sworn in as a deputy sheriff, but was issued a sheriff's identification card marked "non-salaried." He then developed heart disease, which in the case of a "deputy sheriff employed upon a regular full-time salary" is compensable. The court denied coverage, stating that even if it was found that claimant was a salaried deputy, he could not be considered full-time in view of his primary duty as deputy coroner, and therefore was not one of those the legislature intended to benefit by this provision.

^{11.3} *Andes v. City of Lancaster*, 23 Pa. Cmwith 56, 350 A.2d 457 (1976). The claimant, a dispatcher for the last four years and eight months of his employment with the fire department, sought occupational disease benefits after suffering a heart attack. The Section 108(o) of the Occupational Disease Act provided benefits for "diseases of the heart and lungs resulting in . . . disability or death, after four years or more of service in fire fighting." The court held that the claimant was ineligible for benefits because his employment did not involve exposure to the hazards of occupational disease.

^{11.4} *Buescher v. Workmen's Compensation Appeals Bd.*, 265 Cal. App. 2d 520, 71 Cal. Rptr. 405 (1968). California applies a presumption of compensability to heart trouble which develops or manifests itself during a period of service as an active fire fighter within the Division of Forestry. Decedent was employed by the Division to maintain equipment, and was required to be present at all fires in his district. Claimant held entitled to determination whether decedent was an "active fire fighter."

fit of that presumption when he is on vacation,^{11.5} on disability leave, or in retirement.

California has held that, even under a statute requiring that a hernia, to be within the presumption, must manifest itself while the fireman is "in the service" of the department, the presumption applies to a fireman who sustained a hernia while on disability leave, who had intended to retire at the expiration of the leave, and who had actually moved away from the city.^{11.6}

California has also applied its heart statute to an already-retired policeman who suffered a heart attack two months after the statute creating the presumption was passed.^{11.7}

^{11.5} *Schwartz v. City of Duluth*, 264 Minn. 514, 119 N.W.2d 822 (1963). Fireman's fatal coronary thrombosis while on vacation held compensable as causally related to coronary sclerosis, an occupational disease developed during the course of his employment as a fireman.

^{11.6} *Smith v. Workmen's Comp. App. Bd.*, 45 Cal. App. 3d 162, 119 Cal. Rptr. 120 (1975). A city fireman sustained a back injury during the course of his employment. On the basis of his back disability, he received full-pay disability status for one year. He spent a full year in this status and retired at the year's end after 28 years of service. He physically moved from the city at the beginning of the one-year disability period. During the eleventh month of the disability period, he sustained a hernia. He applied for workmen's compensation benefits for expenses related to this condition. His application was granted by the referee. On reconsideration, the board denied his application on the grounds that the injury was not work-related. At the referee's hearing, the city offered no medical evidence that the hernia did *not* arise in the course of his employment. The court of appeals reversed the Board's decision, finding that the fireman was "in the service" of the city fire department within a statute raising a presumption that a hernia, which manifests itself while fireman is "in the service" arose out of and in course of employment. The fact that the fireman had physically moved from the city, that he intended to retire permanently at the end of the disability period, and that the hernia manifested itself when the disability period had almost expired were not sufficient to rebut the statutory presumption.

^{11.7} *Kniser/Permanente v. Workers' Comp. Appeals Bd.*, 61 Cal. App.2d 408, 132 Cal. Rptr. 96 (1976). A state police officer retired in 1972 after 23 years of service. In 1973, the legislature created a statutory presumption that a policeman's heart trouble arose out of and in the course of his em-

§ 41.72(d) What injuries are covered

California has encountered some difficulty in construing the broad term "heart trouble" in its statute. In its most expansive holding, *Muznik v. WCAB*,^{11.8} it concluded that the term should include a fireman's hypertension. Two years later, however, in *Coyne v. WCAB*,^{11.9} it stopped short of extending the term to cerebral vascular stroke. The court had to distinguish both *Muznik* and the earlier case of *Stephens v. WCAB*,^{11.10} which had reversed and remanded a refusal to apply the presumption to acute and chronic arteriosclerotic disease. The key to the distinction was that in *Coyne* the disability, although traceable to the arteriosclerotic disease, manifested itself as the result of the independent process of that disease in a part of the body removed from the heart.

ployment. Two months later, the retired policeman suffered a heart attack. Finding sufficient evidence to establish that the heart trouble developed while he was a policeman, the court held that the officer was entitled to the benefit of the presumption. The court stated that its holding "does not result in retroactive application of the statute" under the circumstances.

^{11.8} 51 Cal. App. 2d 622, 124 Cal. Rptr. 407 (1975). The claimant was a fireman for 33 years. California law provided that a fireman's "heart trouble" was compensable because it was presumed to arise out of and in the course of his employment. The court held that "the phrase heart trouble assumes a rather expansive meaning," and included the claimant's hypertension within its scope. In reversing the appeals board's denial of coverage based upon "an unduly restrictive definition" the court found that an expansive definition of the phrase was needed to effect the legislative intent.

^{11.9} 69 Cal. App. 3d 770, 133 Cal. Rptr. 373 (1977). The petitioner, a city-employed fireman, sustained a cerebral vascular stroke while at home, which resulted in total permanent disability. The medical evidence indicated that he had previously suffered from arteriosclerotic occlusive disease attributable to such non-industrial factors as inheritance and the aging process, and that the stroke would have occurred when it did irrespective of any prior activities. The court held that the statutory presumption of "heart trouble" arising out of and in the course of employment as a fireman was inapplicable, since the petitioner's disability manifested itself from the independent process of his arteriosclerotic disease in a part of the body removed from his heart. The Board's denial of compensation benefits was affirmed.

^{11.10} 20 Cal. App. 3d 461, 97 Cal. Rptr. 715 (1971).

California had also held, in the earlier case of *Baker v. WCAB*,^{11,11} that cardiac neurosis caused by the stresses of a fireman's work was not a true heart attack and did not involve heart disease. The impact of the decision was softened, however, by the conclusion that a case for compensable injury had been made independently of the presumption.^{11,12}

^{11,11} 18 Cal. App. 3d 852, 96 Cal. Rptv. 279 (1971). The claimant had been a full-time fireman for 26 years. In 1953, he had one particularly severe exposure to acrid fumes, and suffered severe chest pains, and expectoration of blood and mucus. The symptoms recurred with progressive intensity and frequency thereafter. By 1968, he complained that his condition had become so disabling that he could no longer work. The referee found that the claimant had developed heart disease in the course of his employment and awarded benefits accordingly. The Board on reconsideration found that claimant did not have heart trouble and reversed the award. The court of appeals agreed with the Board that there was ample evidence for a finding that the claimant had not suffered a true heart attack. However, the court found that claimant was in fact disabled from what appeared to be "cardiac neurosis" caused by the stresses and anxieties of his employment experience, and that an award on this basis was in order. Since the claimant was a fireman, there was injected into the case the argument that, by Labor Code § 3212, a fireman's heart attack is presumed to arise out of his employment. This presumption obviously was out of place here, since no heart disease was involved. The presumption relates to causation of heart disease, once it is established that heart disease is the injury involved. The presumption does not serve to aid in proving that the disability itself was in fact produced by heart trouble. Treatise cited.

^{11,12} The claimant can, of course, if he prefers, prove his case without the aid of the statute.

Beckham v. City of New Orleans, 327 So.2d 460 (La. App. 1976), writ denied, no error, 332 So.2d 278 (1976). A fireman, who was suffering from coronary artery disease and angina pectoris, became dizzy and experienced chest pains while fighting a fire. A medical expert testified that the claimant's activities prior to fire-fighting played a major part in causing the heart condition. The court held that the disability was compensable under the workmen's compensation statute, even though occasioned by usual and customary activities connected with the employment. Since the claimant proved his case under the workmen's compensation statute, the court held that he need not rely on the Firefight's Heart and Lung Bill.

See also *New Hampshire Ins. Co. v. Duvall*, 337 A.2d 533 (N.H. 1975) § 41.72 N.4 *supra*, holding that a regulation issued under the New Hampshire statute was unconstitutional insofar as it required carriers to begin

§ 41.72(e) Constitutionality of special police-firefighters statutes

The first state to consider the constitutionality of a special police-firefighter type of statute, North Carolina, found it unconstitutional as class legislation.¹²

Since then, three states—California,¹²¹ Connecticut,¹²² and Maryland¹²³—have held such provisions constitutional, and Alabama has also upheld its more separate Firemen's Heart and Lung Disability Act, although its coverage was constricted by an amendment excluding, in effect, firemen in Birmingham.¹²⁴

payment in these cases within ten days unless within that time they offered evidence that the disease was not work related.

¹² *Duncan v. City of Charlotte*, 234 N.C. 86, 66 S.E.2d 22 (1951). Commission had awarded benefits for death of a fireman which occurred on his vacation.

¹²¹ *City and County of San Francisco v. W.C.A.B.*, 583 P.2d 151 (Cal. 1978), § 41.72(a) *supra*. Treatise cited in majority opinion and dissent. The opinion contains an excellent analysis of the background and justification for this type of statute, and of the various constitutional issues — including the constitutionality of alleged "irrebuttable presumptions."

¹²² *Grover v. Town of Manchester*, 357 A.2d 922 (Conn. 1975), *app. dismissed* 44 L.W. 3182 (1975). The court held that a special statute on heart and hypertension cases of police was not unconstitutional.

¹²³ *C. Colgan v. Board of County Comm'rs for Prince George's County*, 21 Md. App. 331, 320 A.2d 82 (1974), *aff'd*, 274 Md. 193, 334 A.2d 89 (1975). The appellant, a fire fighter, claimed workmen's compensation benefits under a statute which provided that any impairment of health of a fire fighter caused by lung and heart disease could be presumed to have been suffered as a result of employment. The Workmen's Compensation Commission dismissed the claim. The circuit court affirmed, finding that the statute was in violation of the Constitution of Maryland. The Court of Special Appeals reversed, holding that the statute did not violate the state constitution. It held that the statute did not violate due process or equal protection clauses of the federal constitution.

¹²⁴ *Norris v. Seibels*, 353 So.2d 1165 (Ala. App. 1977), 353 So.2d 1169 (Ala. App. 1978), § 41.72 N.3 *supra*.



Official Business

Alaska State Legislature

Senate

Pouch V
State Capitol
Juneau, Alaska 99811

TO: Senator Richard Eliason
FROM: Senator Joe Josephson
DATE: February 27, 1984

A handwritten signature in dark ink, appearing to be "JJ", written over the "FROM" line of the letterhead.

RE: SB 262, Presumptions/Alaska Worker's Compensation

SB 262 relating to Presumptions in Alaska Worker's Compensation law relating to firefighters, police and emergency medical personnel, has been assigned to the Senate Labor and Commerce Committee.

This bill is very important and I would like to see it moved as soon as possible. I will be happy to meet with you at any time to discuss concerns you may have.

SB262

456-8354

Barry Haight

3/22/84

Glenn C. Smith
P.O. Box 874421
Wasilla, Alaska 99687

Senator Eliason
Pouch V
Juneau, Alaska 99811

Re: Sponsor Substitute for Senate Bill 262 in the Legislature of the State
of Alaska Thirteenth Legislature - Second Session

Dear Senator Eliason:

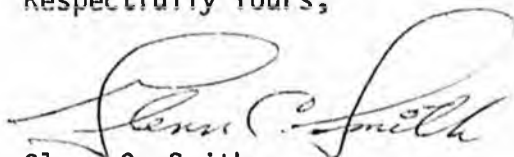
I would like to express my personal opinion on Senate Bill 262 proposed by Senator Josephson and Rodey.

As you know, this relates to "an act relating to presumption under the Alaska Workers' Compensation Act", Section AS 23.30.120. I would assume that there is a statistical base to support a bill that there is a rebuttable presumption that firefighters and policemen have a greater frequency of heart or lung disease, to include hypertension. I would at this time, submit a request for that statistical base to support Bill 262.

Judging from a laymen's observation of the physical condition of long term firefighters and policemen, I have some doubt that heart or lung disease, to include hypertension, is job related but rather self-inflicted due to neglect by the individuals, when in fact, they are called upon to be not only mentally alert but physically capable of performing their duties. Beyond that, as stated, I know of no statistical base to support the fact that heart or lung disease, to include hypertension, is more prevalent in firefighters or policemen than in general labor, trucking industry, warehousemen, or for that fact, senators.

To impose this type of presumption in addition to including, "time immediately following the termination of employment", means a period of time, not to exceed 60 months would, I believe, cause undue litigation expense in addition to liability expense to municipalities throughout the State not to mention volunteer departments in small communities. This expense would ultimately be levied back against each and every individual within the State of Alaska. I look forward to hearing from you regarding this proposed bill.

Respectfully Yours,



Glenn C. Smith

GCS/fm