United States Department of Agriculture

Forest Service

Technology & Development Program

6700 Safety & Health
Summer/Fall 1991
9167-2848-MTDC

Brian Sharkey

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The National Wildfire Coordinating Group (NWCG) coordinates wildland firefighting efforts among federal and state agencies. NWCG assigned the Missoula Technology and Development Center (MTDC) to coordinate the national effort and serve as the focal point for on-going and future studies on the effect of forest fire smoke on firefighters. This status report, the third in a series, provides an update on project activities.

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Fire Season Update

NIOSH Studies Montana Fire

As part of an integrated study of fireline exposure and health effects, a NIOSH study team gathered data at the Thompson Creek Fire in the Gallatin National Forest. Breathing-zone samples of carbon monoxide, organic vapors, and particulate were collected on the Boise and the Redmond Hot Shot crews during site protection and fireline construction both near and away from the fire. Smoke exposure during these operations was described by firefighters as low to moderate. A report summarizing the results should be available early in 1992. For more information contact John Kelly at NIOSH (513-841-4374).

Wildfire Studies Continue

Researchers from the California Occupational Health Program (COHP) are continuing their study of the health effects of smoke exposure among wildland firefighters. Eight hot shot crews received pre- and mid-season tests of pulmonary function and airway responsiveness. Data are being collected on smoke exposures throughout the season, to be followed by post-season pulmonary function tests. The study is under the direction of Robert Harrison, M.D., of COHP (415-540-2189).

Smoke Exposure At Prescribed Burns

The Pacific Northwest Research Station, in cooperation with the University of Washington Department of Environmental Health, and the Radian Corporation are making progress in their study of smoke exposure at prescribed burns. Study goals are to determine representative estimates of the peak, short-term exposures, and the time-weighted averages of carbon monoxide, acrolein, formaldehyde, respirable particulate and benzene and to examine how smoke exposures at prescribed fires are influenced by work

activity and environmental factors (e.g., windspeed, fuel moisture). For information contact Tim Reinhardt c/o the Radian Corporation (206-441-1106).

Initial Attack Study

Bill Weaver, CDF Project Coordinator, announces a cooperative project involving the Lawrence Livermore National Laboratory (LLNL), the CDF employees association (CDFEA), and CDF's Vina Helitack Crew. The project is designed to assess firefighter exposure during initial attack and to evaluate a prototype respirator designed by LLNL. This study will follow a helitack crew whose job is initial attack. The project includes pulmonary function testing and evaluation of the prototype respirator. For more information on this project contact Bill Weaver at 916-445-9418.

Figure 1—Tara Townsend, a graduate student in exercise science, conducts a test in the University of Montana Human Performance Laboratory.

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Health Hazards of Smoke Summer/Fall 1991

Respiratory Protection

Previous editions of this report have discussed the health hazards of smoke and the short, intermediate, and long-term effects of exposure. Forest fire smoke includes respirable particulates, organic vapors, and carbon monoxide. No currently available respiratory protective device, short of self contained breathing apparatus (SCBA), protects against all three hazards. And, it is not yet clear from available research if fireline exposures are sufficiently serious to warrant protection from all three. This section will review some available protection options.

Particulates are pieces of airborne soot. Larger particles are deposited in the airways and removed by cilliary action. Smaller or respirable particles find their way to the lung where they may deposit organic compounds. Particle filters protect against the inhalation of dusts, fumes and mists by trapping particles on a fibrous material. Lower efficiency filters are approved for protection against dusts, fumes and mists having an exposure limit not less than 0.05 milligrams per cubic meter. High efficiency particulate air filters (HEPA) are used on respirators certified (by NIOSH) for protection against dusts, fumes and mists having an exposure limit less than 0.05 milligrams per cubic meter. HEPA filters are recommended when the particle size is small and respirable, as in forest fire smoke. HEPA filters are 99.97% effective in the removal of respirable (0.3 micrometer) particles. Of course, the high efficiency filter offers more resistance to breathing. Low and high efficiency filters for dusts, fumes and mists are available in disposable, 1/2 face, full face and powered air purifying respirators (PAPR).

Organic vapors, such as formaldehyde and acrolein, are strong irritants and possible carcinogens (formaldehyde). Prolonged exposure leads to bronchoconstriction and loss of cilliary action. Cartridges used for organic vapors and acid gases are designed to protect against specific contaminants. Activated charcoal is the most common material used to remove contaminants via retention of the molecule on the surface of the sorbent. Activated charcoal can be impregnated with other substances to make it more selective against specific gases and vapors.

Vapor and gas removing cartridges can be used alone or in combination with a dust, fume and mist filter (see Figure 2). The breathing resistance of a

typical HEPA cartridge (18 mm H20 at 42.5 liters airflow) can be doubled with the addition of an absorbent material.

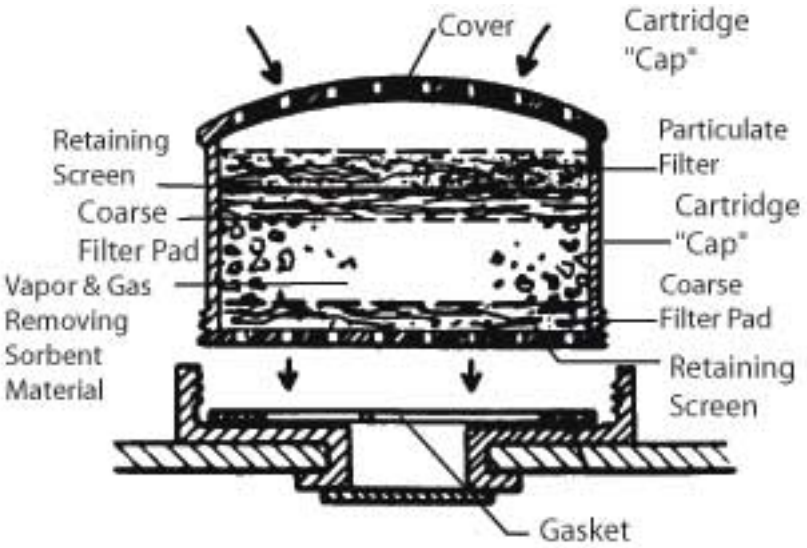

Figure 2—Typical combination particulate/gas/vapor-removing cartridge.

Carbon Monoxide is a colorless, odorless product of incomplete combustion that affects the nervous system by interfering with oxygen transport. It can be removed from inspired air via conversion to carbon dioxide by the catalyst hopcalite, in a reaction that generates considerable heat. Hopcalite is rendered useless by moisture, so the cartridge also includes a drying agent. The combination of respiratory resistance, heat and carbon dioxide all contribute to breathing difficulties during arduous work.

The Type “N” or Universal canister was commonly used by structural firefighters before SCBA became mandatory. The Universal canister included a high efficiency particulate filter, sorbents to protect against organic vapors, and hopcolite to remove carbon monoxide. Since the Universal canister did not offer protection in oxygen deficient atmospheres, it was deemed unsafe for structural firefighters. Moreover, since the sorbent bed of the Universal canister was less than that used for a single contaminant, its useful life was relatively short. For these reasons the Universal canister is no longer approved for firefighting.

Technical Panel

At the request of NWCG, a technical panel was convened to review existing research, identify research needs and recommend funding priorities. The third meeting of the panel was held in May in San Francisco. The meeting was hosted by Dr. Robert Harrison and Barbara Materna of the California

Department of Health Services. Panel members included John Kelly of NIOSH, Kim Muller representing CDFEA, Dave Blakeley of IFSL, Harrison, and Materna. Guests included Bill Weaver of CDF, Lyle Shook (FS/R5), and Dan Sullivan of the Park Service. Brian Sharkey, Ph.D., coordinator of MTDC's Health Hazards of Smoke project, chaired the meeting of the panel. The panel reviewed recent research and development activities and worked on research design and logistics for an integrated study of fireline emissions, exposures and health effects. The research project will be conducted during the 1991 fire season. The next meeting of the panel is scheduled for early in 1992.

Respirator Standard

The National Fire Protection Association (NFPA) brings together interested groups to participate in the development of fire protection and safety standards. NFPA has convened a subcommittee on Wildland Clothing and Equipment to recommend standards for wildland firefighters. A task group was created to study the need for respiratory protection. The task group consists of representatives from agencies, employee groups, equipment manufacturers, and technical specialists.

The committee, co-chaired by Bob Martin, Local 1014 of the International Association of Fire Fighters, and Brian Sharkey, Ph.D., FS/MTDC has met four times, and has completed the first draft of the proposed standard for respiratory protection. The document cycle for the proposed standard (#1977) includes:

Aug 9/91	*Request for Public Proposals*
Nov 3/91	*Close of Public Proposals*
Dec 15/91	*Subcommittee Report due to Technical Committee*
March 92	*Technical Committee Vote*
Spring/92	*Letter Ballot of Technical Committee Report*
Aug-Oct/92	*Public Comment on Technical Committee Report*
Nov-Dec/92	*Subcommittee Action on Public Comments*

Jan/93	*Committee Ballot for Technical Committee Document*
Spring/93	*Technical Committee Document Issued*
May/93	*Membership Vote at NFPA Annual Meeting*
July/93	*NFPA Standard Council Approval*
Aug/93	*Effective Dated NFPA Standard #1977*

Interested individuals will be encouraged to review the proposed standard and make comment during the public comment stage of development. Future editions of this report will provide information on the proposed standard and the mechanism for public comment.

WFCA Resolution

Since 1909 the members of the Western Forestry Conservation Association have worked to advance forest resources management, protection and utilization. The Association unites private and public forestry and conservation interests of the western United States and western Canada. Current membership includes 500 members as well as 40 companies or organizations. At their annual meeting on Dec. 4, 1990 in Cour d'Alene, Idaho, the Association adopted this resolution. Resolution 90-3: **URGES CONTINUATION AND COMPLETION OF STUDIES THAT WILL SCIENTIFICALLY QUANTIFY WILDLAND SMOKE EXPOSURE RISKS AND IDENTIFY APPROPRIATE AND ACCEPTABLE PROTECTIVE MEASURES.**

The resolution notes that wildland firefighters have expressed concern about short and long-term health impacts from exposure to smoke, and that exposure levels are increasing because of a continuing increase in the number and severity of wildland fires; that understanding and quantifying the detrimental effects of prolonged exposure to smoke from wildland fires is essential in enabling the fire agencies to protect the long-term health of firefighters; and if wildland fire smoke exposure is proven to have a detrimental effect on the health of firefighters, public agency workers compensation liabilities will continue to grow until effective protective measures are identified and implemented to limit exposure.

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Health Hazards of Smoke Summer/Fall 1991

Research

This section includes research abstracts and notes related to the health hazards of forest fire smoke.

Air Toxics and Fireline Exposure—D.E. Ward, in Proceedings of the 10th Conference on Fire and Forest Meterology, 1989

The 1987 and 1988 forest fire seasons generated concerns about the potential short-term and long-term health effects of firefighters exposed to smoke during suppression of wildfires and fire management activities associated with prescribed fires. This concern has prompted a new national initiative to characterize the exposure of fire personnel to open fires. The fire chemistry project is studying the fuel characteristics, both chemical and physical, affecting combustion leading to the production of air toxics and trace materials. The research approach includes burning modeled fuel arrays in a well instrumented, environmentally controlled combustion laboratory. These experiments will complement knowledge now available that was developed mostly from field experiments.

The combustion efficiency of open fires generally ranges from 60-95%. The predominant gases from the combustion of vegetative fuels are carbon monoxide, carbon dioxide, and water vapor. A small fraction of the carbon contained in the fuel is released into the atmosphere in the form of particles. The particles are of major concern, however, because of the high concentration of organic material with the particles, and also because a high percentage of the mass of this particulate matter consists of particles less than 2.5 micrometers in diameter. The small diameter particles can be carried deep into the lungs and contain about 50-95% organic carbon with the balance inorganic materials and graphitic carbon. The Polynuclear Organic Material (POM) fraction of the organic carbon content of the particles contains a class of compounds, polynuclear aromatic hydrocarbons (PAHs), some of which are known carcinogens. The levels of these materials that fireline personnel are exposed to are not well known. One of the PAH compounds, benzo[a]pyrene, has been studied in detail, and the concentration is known to increase for both the smoldering combustion

phase of fires and in fires burning in live vegetation. Other materials of concern include the high concentration of aldehydes, organic acids, carbon monoxide, and release of deposited materials (e.g., pesticides).

Effects of Prescribed Fire on Air Quality and Human Health—D.V. Sandberg and F.N. Dost, in Proceedings of the 10th Conference on Fire and Forest Meterology, 1989.

Although it is known that a few hundred substances are formed, liberated or modified during combustion of vegetation, little information exists about the quantities of these substances. Ninety percent of the total mass emitted from wildland fires is water and carbon dioxide, neither of which is classified as a pollutant. The more efficient the combustion, the more carbon is converted to carbon dioxide. The portion of carbon not converted to carbon dioxide is converted to carbon monoxide, particulate matter, or to volatile organic compounds.

Particulate matter is the most important category of pollutants from prescribed fire; it is the major cause of reduced visibility, and serves as sorption surfaces for harmful gases. Particulate matter is the primary index for evaluating smoke movement. No specific health effects of these complex organic compounds have yet been identified. In urban environments, particulate loads have been related to health impacts, including mortality, but no methods exist for isolating particulate effects from other chemicals in the air. Certain volatile organic compounds (VOCs) may be important to human health. Polynuclear aromatic hydrocarbons (PAHs) are best known of these because some members of the class are carcinogenic. Risk associated with PAH emissions from prescribed fire appears trivial from early evidence, but more research is needed. The aldehydes may be important. Of these, formaldehyde has been extensively studied, is known to cause cancer in laboratory animals, and is regulated as a human carcinogen. It is an irritant and is allergenic at low concentrations. Estimating exposures to formaldehyde is tenuous but it is quite likely that formaldehyde may be responsible for some of the eye and upper respiratory irritation near fires.

Cross-Season Changes in Lung Function and Respiratory Symptoms During The 1990 Fire Season—D. Letts and S. Deichman, National Institute for Occupational Safety and Health, Interim report, 1991.

Pre- and post-season data were collected on 78 firefighters from six Park Service and Forest Service “hot shot” crews. Exposure estimation was

derived from questionnaire responses. Cross-season changes in lung function averaged -0.9% for FEV1, -3.7% for FEF 25-75, and -0.9% for FEV1/FVC. Cross-season changes in lung function by exposure category indicated that decreases in FEF 25-75 were associated with higher exposure (-1.3, -3.7, and -6.1% for low, medium and high exposure respectively). Dose-related decreases in FEV1 and FEV1/FVC were observed though the results were not statistically significant. Lung function changes were not associated with number of seasons of firefighting, days since last fire, or age.

The number of symptoms (nose and throat irritation, shortness of breath, chest tightness) declined over the season. The number of reports of cough, phlegm and wheezing remained about the same. Post-season respiratory symptoms were not associated with exposure category. Development of respiratory symptoms cross-seasonally was not associated with exposure category. The authors note that these results may not reflect the actual chronic effect on lung function among wildland firefighters, since crew members did not consider the 1990 season as a representative season for smoke exposure.

The Effect of Breathing Resistance on Pulmonary Function and Work Capacity—Z. Mead, B. Sharkey, and T. Townsend, University of Montana Human Performance Laboratory, and USDA/FS Missoula Technology and Development Center, 1991.

Respiratory protective devices have been shown to decrease work capacity via breathing resistance, increased dead space, heat stress, and respirator weight. This study explored the effects of respirator wear on pulmonary function and work capacity, and investigated several pulmonary function measures as possible predictors of work capacity while wearing a respirator. Fifteen male and fifteen female volunteer subjects performed pulmonary function tests (FVC, FEV1, FEF, PEF). Maximal voluntary ventilation (MVV) was performed with and without an air purifying respirator (half face with 2 HEPA/organic vapor/acid gas cartridges; cartridge airflow resistance = 36 mm H20 @ 42.5 L/min). Subjects also performed two treadmill tests of maximal oxygen intake, one with and one without the respirator. Results showed that the respirator significantly reduced ($P < .01$) maximal ventilation (-16.8 L/min; -15.1%), MVV (-41.6 L; -24.7%), VO2 max (-4.4 ml/kg-min; -9.4%), and ventilatory threshold (-2.2 ml/kg-min; -5.8%). Perception of dypsnea was increased while wearing the respirator. Claustrophobia forced one subject to end the respirator trial prematurely. Data on male subjects showed a nonsignificant correlation ($r = 0.36$) between MVV and VO2 max. Data on females yielded a nonsignificant correlation ($r = 0.39$) between PEF and VO2 max with the respirator. Combined male and female data yielded significant relationships between

MVV and VO2 max decrement (r = 0.44), and the FEV1 and the VO2 max with respirator (r = 0.55). In a related series of tests, five male and five female subjects participated in a sustained work test (50 min. treadmill walk at a heart rate of 150 bpm). The respirator caused a significant decline in sustained performance (-4.0 ml/kg-min, -16.3%; P<.01). These results indicate a significant reduction in pulmonary function and work capacity while wearing a respirator (see Figure 3). Multivariate analysis failed to yield a satisfactory predictor of the ability to perform while wearing a respirator.

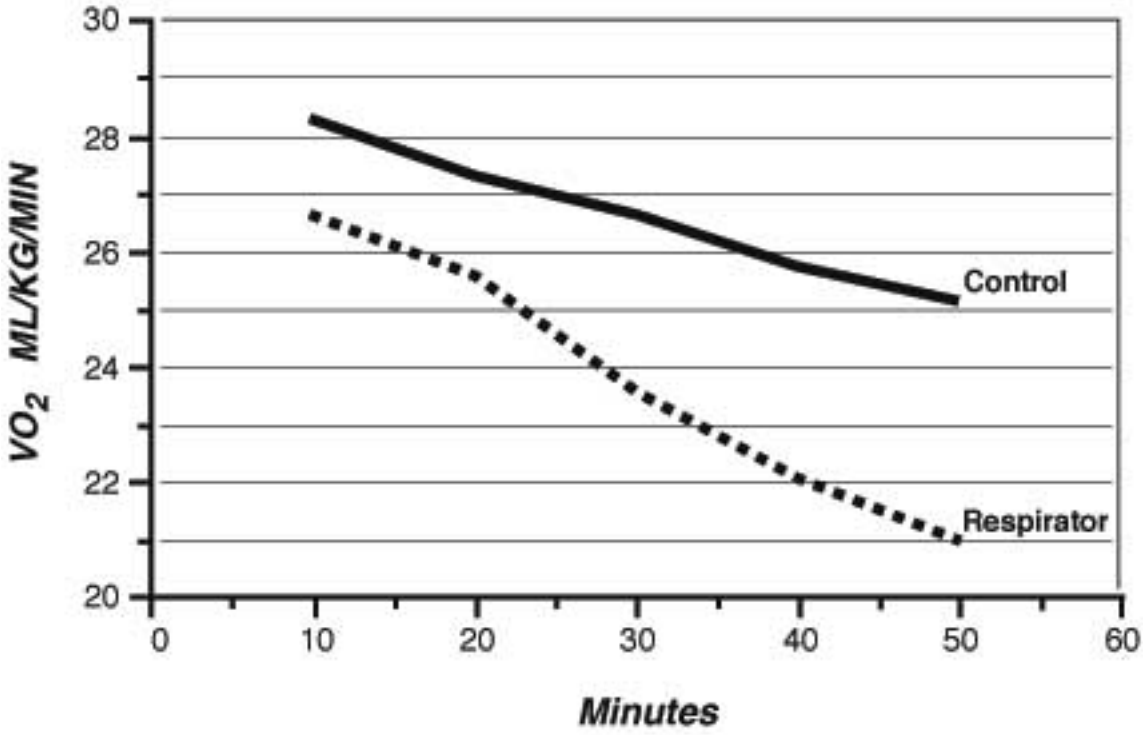

Figure 3—Energy expenditure (VO2) during prolonged work.

Assessment of Respirators Among Agricultural Workers— J. Merchant, et al., University of Iowa College of Medicine, 1989.

The quantitative performance of half mask respirators used in agricultural settings by workers with mixed experience in wearing respirators was compared to that found in other field studies. The overall acceptability of the three classes of respirators varied considerably among the settings tested, with grain handlers preferring the half mask, poultry operators preferring the powered helmet (PAPR), and swine producers preferring the helped to disposable. Among all groups of workers, powered helmets were rated best for breathing ease, communication ease, skin comfort, and in-mask temperature and humidity, while disposables were rated best for weight and convenience. The use of pre- and post-shift lung function as a quantitative

physiological measurement of respiratory protection proved to be satisfactory in that it provided statistically significant differences over brief exposures and with modest changes in lung function.

Short-Term Effects of Carbon Monoxide Exposure on the Exercise Performance of Subjects With Coronary Artery Disease—E. Allred et al., New England Journal of Medicine, Nov. 23, 1989.

Results indicate that even low levels of CO exposure may have negative effects on individuals with coronary artery disease. Findings indicate a significant decrease in the time to ECG changes and chest pain (angina) during exercise at 2 and 4% carboxyhemoglobin (COHb) levels. Since exercise increases pulmonary ventilation and CO exposure, a level of 2% COHb is likely after one hour of exposure to 35 ppm CO during exercise.

Information

Jason Greenlee, Director of the Fire Research Institute, notes the availability of two documents that could be useful to researchers concerned with the health hazards of smoke. *The International Bibliography of Wildland Fire* lists over 30,000 articles on wildland fire. *The International Directory of Wildland Fire* lists researchers, institutions and vendors. Both sources are available in diskette and paperback, and both use smoke as a keyword for indexing. For Information, contact Dr. Greenlee c/o the Fire Research Institute, (509-649-2940).

Another excellent source of information is The *National Technical Information Service (NTIS) Government Reports*, published by the U.S. Department of Commerce. This twice monthly publication abstracts documents in a number of categories, including Biomedical Technology and Human Factors Engineering (Protective Equipment), Environmental Pollution and Control, and Medicine and Biology. For subscription information call 703-487-4630.

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Risk Management

Monitoring Exposure—A previous edition of this report discussed the use of inexpensive dosimeters by the Pacific Northwest Research Station to monitor exposure to carbon monoxide on prescribed burns. Some of the hazardous components of wood smoke, such as formaldehyde and respirable particulate, are correlated to carbon monoxide. Since carbon monoxide is relatively easy to monitor, it makes sense to use it as an index of exposure. However, dosimeters don't provide peak or current exposure information. Researchers and some field units have gained experience in the use of personal gas monitors that allow calculation and display of peak exposure, time weighted average (TWA), and the current level of carbon monoxide (in parts per million, ppm). Monitors are available with hardware and an enhanced graphics software package that interfaces with a PC, stores data and provides tabular and graphic summaries (see Figure 4).

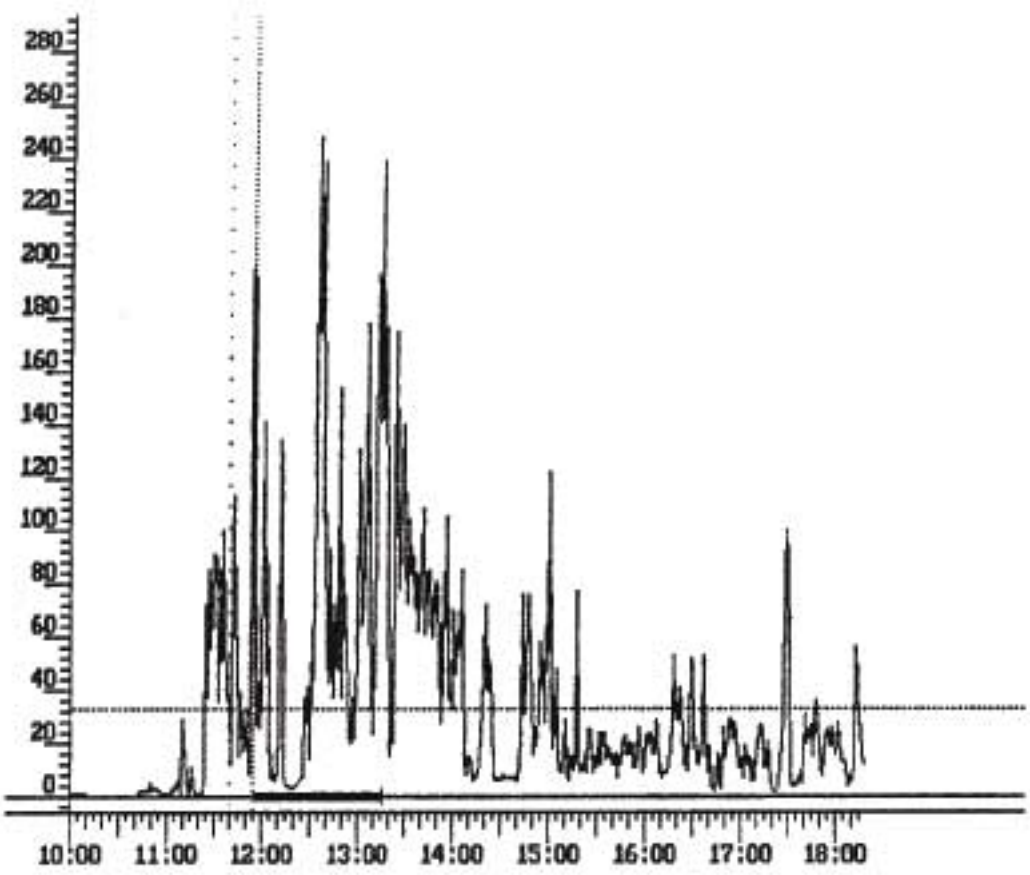

Figure 4—Monitoring carbon monoxide on a prescribed burn.

Tom Leuschen, Fuels Technician on the Twisp Ranger District of the Okanogan National Forest, reports on the District's experience with the Drager Model 190 Datalogger for Carbon Monoxide. The monitor fits in the shirt pocket or can be worn in a leather case. It includes an alarm that may be set to warn the user of high exposure levels. Tom reports that use of the device has make workers aware of acceptable levels of carbon monoxide. In general, employees begin to "feel uncomfortable with burning eyes and a runny nose" at 35 ppm. Symptoms increase at higher levels of exposure, and employees seek relief from the smoke at 200 ppm, the short term exposure limit (STEL). Of course, carbon monoxide is colorless and odorless, and symptoms may occur at different levels in different fuel types. But the monitor has helped to sensitize and educate employees concerning acceptable levels of exposure. For information on this instrument and how it has influenced the conduct of prescribed burns, contact Tom Leuschen (509-997-2131).

The Drager Model 190 Datalogger is being used by researchers at the Pacific Northwest Research Station in their study of firefighter exposure on prescribed burns, and by the California Department of Health Sciences in their study of wildfire exposures.

Health & Safety Plan

The Pacific Northwest Research Station, in cooperation with the University of Washington Department of Environmental Health and the Radian Corporation, are conducting a study of smoke exposure at prescribed burns. An important first step in the study was the development of a Health and Safety plan which addresses the safety procedures and personal protective equipment to be used during the project. The plan considers potential hazards in field data collection and laboratory analysis, and outlines safe work practices. A key feature of the plan is the use of a full-face powered air purifying respirator (PAPR) with combination organic vapor/HEPA cartridges for study personnel when exposed to smoke. The PAPR consists of a battery powered pump which draws air through filters for delivery to the facepiece. The airflow cools the worker and reduces fogging of the lens, and the full facepiece helps avoid eye irritation. For more information on this project contact Tim Reinhardt or the Pacific Northwest Research Station.

Disposable Respirators

An article in the 1991 edition of Bests Safety Directory indicates that low-maintenance, disposable, chemical cartridge half-mask respirators are coming of age in the 1990's. Recent versions are extolled for employee acceptance and comfort, fit and protection, compatibility with other equipment, easy maintenance, availability, and reasonable cost. In general, reusable respirators become cost effective when cartridges are changed more often. However, cleaning, maintenance and storage add to the cost of reusable respirators. And when cleaning and maintenance are difficult, as in fire camp, the disposable respirator may be a reliable alternative to the reusable.

NIOSH Notes

The National Institute of Occupational Safety and Health has endorsed a proposed time-weighted average (TWA) of 35 ppm for carbon monoxide exposure. This 8 hour TWA is down from the previous level of 50 ppm. The standard attempts to limit carboxyhemo-globin levels below 5%.

NIOSH condemns workplace smoking: NIOSH has concluded that cigarette smoke causes cancer and possibly heart disease in non-smokers. It said all available preventive measures should be used to limit occupational exposure. Those measures include banning smoking outright or restricting it to enclosed, separately ventilated areas.

Smoking and Health

Since wood smoke is often compared to cigarette smoke, a brief summary of smoking risks seems appropriate. The U.S. Surgeon General's Report for 1990 attributes 390,000 deaths annually from diseases caused by smoking. When a long-time smoker quits, the risk begins to decline. The heart disease and stroke risks begin to decline within a few months, while it takes longer to outlive the effects of smoking on lung cancer. In 10-15 years, the one-time smoker can approach the risk of those who never smoked.

Cigarette smokers are exposed to toxic substances 16 or more hours a day, every day of the year. Health effects of smoking are dose-related, the more one smokes the higher the risk. Firefighters experience intermittent exposure over a 3 to 5 month period. Unless the firefighter spends the rest of the year in a polluted atmosphere (e.g., urban pollution, wood burning), some recovery is likely during the off season. Of course, if the firefighter is a

smoker, all bets are off.

A California study of long-term exposure to air pollution and incidence of respiratory symptoms and chronic diseases in a non-smoking population, indicated statistically significant relationships between total suspended particulate (TSP) and symptoms of obstructive airway disease, chronic bronchitis and asthma. Elevated risks for malignant neoplasms in females but not males were associated with TSP. There was a trend toward increasing risk of respiratory cancers with ozone exposure. Incidence of heart disease and natural causes of mortality were not related to any of the pollutants studied. (Incidence of Respiratory Symptoms and Chronic Diseases in a Non-smoking Population as a Function of Long-term Cumulative Exposure to Ambient Air Pollutants, D. Abbey, California Air Resources Board, 1990).

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Coming Up

Meetings

The NFPA Task Group on Respiratory Protection for Wildland Firefighters will meet in December in Sarasota, Florida, to put finishing touches on a draft of a proposed standard for respiratory protection. The group will join the Wildland Fire Service Protective Clothing Equipment Sub-committee to present the proposed standard to the NFPA Technical Committee (see related item in this report).

The NWCG Technical Panel on the Health Hazards of Smoke will hold their next meeting early in 1992. Panel members will meet with Park Service, CDF, Pacific Northwest Research Station, and other workers interested in the project. The panel will review 1991 study results, plan 1992 projects, and recommend research priorities for 1993.

Research

This report has summarized work being conducted by NIOSH, California Department of Health Sciences, Pacific Northwest Research Station, CDF and Lawrence Livermore National Lab. Results from these studies will be reported as soon as they are available. The Missoula Technology and Development Center is analyzing results of a questionnaire study of respirator use by firefighters. Results of that analysis will be reported in the next issue of this report. MTDC is continuing to search for a test or battery of tests that will predict a firefighter's ability to work while wearing a respirator. And MTDC is planning field trials of respirators and monitoring devices for the 1992 fire season.

Next Issue

The next issue of this report will be available in late winter, 1992. For

information on this project contact Brian Sharkey, Ph.D., at the Forest Service Missoula Technology and Development Center, 5785 Hwy 10 W, Missoula, MT 59808 (406-329-3989).

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