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FEDERAL RESEARCH ON CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT :

A Summary of Federal Programs for Fiscal Year 1988

United States Fire Administration

National Institute for Occupational Safety and Health

Occupational Safety and Health Administration

United States Coast Guard

Environmental Protection Agency

August 1988

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16. Abstract A Federal Interagency Workgroup was established to coordinate federally-funded research, development, testing, and evaluation related to chemical protective clothing and equipment. One goal of this Work Group is to promote the transfer of information on this type of federal research both inside and outside the federal government. This report contains summaries of federal research programs on chemical protective clothing and equipment, by the participating agencies in the Work Group. These summaries provide a description, and other pertinent information for current or recently completed programs for Fiscal Year 88 (October 1987 through September 1988)			
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FOREWORD

A number of Federal agencies are engaged in the development or evaluation of chemical protective clothing and equipment, and procedures concerning their selection, use, and care. These efforts are aimed at improving the protection of their own employees or U.S. workers in general. The majority of this work is related directly to the pressing need for providing adequate protection to workers involved in hazardous waste responses or related chemical emergencies. Some of these programs are similar in nature and could result in the duplication of effort. Other work, if shared, could benefit the efforts of other agencies. In addition, much of the data and information generated by Federal agencies may be useful to non-Federal groups or individuals who use protective clothing and related equipment. A need, therefore, exists to coordinate Federally funded research and development of chemical protective clothing and equipment.

To address this need, a Federal Interagency Work Group was established to coordinate Federally funded research, development, testing, and evaluation of chemical protective clothing and equipment. Current participants of this Work Group include the U.S. Coast Guard, U.S. Environmental Protection Agency, U.S. Fire Administration, National Institute for Occupational Safety and Health, and Occupational Safety and Health Administration. The National Aeronautics and Space Administration has recently joined the Work Group, but project summaries have not been incorporated in this report. Two of the Work Group's objectives are:

1. To establish mechanisms for transmitting chemical protective clothing material/chemical compatibility data, selection information, research results, and relevant field experience to U.S. workers, those responsible for their protection, the research community, and any other interested persons.
2. To prepare periodic summaries of Federally funded research and development activities for chemical protective clothing and equipment for the National Response Team, the general research and user community, and any other interested persons.

To accomplish these objectives, the Work Group decided to prepare an annual summary of Federal research activity in the area of chemical protective clothing and equipment. The initial summary, which addressed Fiscal Year 1987, was completed in May 1987, (NTIS #AD A184 052). This document is the second summary and addresses Fiscal Year 1988 activities.

Each agency participating in the Work Group does its best to ensure that the information it provides in the summary is reliable, but none of this information represents endorsements of the products discussed. The Work Group advises that users be aware of the limitations of protective equipment and consult professionals if they have any questions regarding its use.

Some topics this summary addresses are:

1. Development of new equipment
2. Evaluation and improvement of existing equipment
3. Testing of clothing and equipment materials, and complete ensembles

FOREWORD (Continued)

4. Assessment of chemical protective clothing selection rationales
5. Evaluation of donning/doffing, decontamination, and storage practices
6. Development of predictive models

Some of the user problem areas which could be addressed by the summary include:

1. Guidelines for mitigating the effects of heat stress and other physiological hazards and discomforts
2. Reliability of chemical resistance testing
3. Problems of decontamination
4. The relationship between laboratory testing and field use
5. Dermal exposure limits and their relationship to chemical resistance test results
6. Chemical resistance of breathing apparatus and eyewear

The summary presents the projects by responsible agency in the following order:

- o United States Fire Administration
- o National Institute for Occupational Safety and Health
- o Occupational Safety and Health Administration
- o United States Coast Guard
- o Environmental Protection Agency

An index is located in the back of the report to assist you with finding information on specific subject areas.

This summary lists more detailed reports or papers (and where they may be obtained), and products associated with each project. Many of these reports can be obtained from the National Technical Information Service (NTIS) by calling (703) 487-4600 or (703) 487-4650, or by writing to:

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SECTION 1

UNITED STATES FIRE ADMINISTRATION

TITLE: FIREFIGHTER SHORT RANGE RADIO TESTING

AGENCY: United States Fire Administration

OBJECTIVE: To determine the utility of short range radios to fire departments during fire attack and hazardous materials incidents.

CONTRACTOR: Biotherm, Inc., Beavercreek, OH

TIMEFRAME: 1987-1988

DESCRIPTION: Field tests will be conducted under simulated conditions with the cooperation of two fire departments (in two cities). Information on communications system performance, including utility and human factors features, will be collected. The data will be analyzed to identify areas for improvement in radio utilization and design. Final report will detail field test results and recommendations.

STATUS/RESULTS: Work has been completed.

FUTURE WORK: Not identified.

REPORT:

1. J. Veghte, "Field Test Report on Short-Range Radios." June 1988. Available from agency contact.

AGENCY CONTACT: J. Tom Smith
United States Fire Administration
National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727

TITLE: BASE LINE FLOW TESTING OF SELF-CONTAINED BREATHING APPARATUS

AGENCY: United States Fire Administration
Department of Energy (Lawrence Livermore National Laboratory)

OBJECTIVE: To improve the standards under which firefighters' breathing apparatus is manufactured and tested.

FACILITY: Lawrence Livermore National Laboratory

TIMEFRAME: 1986-1988

BACKGROUND: In order to achieve the above objective, it is necessary: (1) to collect technical information on proposed test methods, and (2) to determine if these methods can be performed, and their results duplicated, in any well-equipped testing laboratory. Because other performance tests relate to base line flow, the results of the base line flow test had to be duplicated before other tests could be developed. Therefore, the purpose of this project was to duplicate the results of the base line flow test.

STATUS/RESULTS: Round robin results were submitted to the NFPA subcommittee in December 1986. These demonstrated that good agreement could be obtained between testing laboratories for base line measurement.

FUTURE WORK: Other tests are specified in the standard--all depend on no degradation from base line for passage.

REPORT:

1. J. Johnson, Final Report on Round Robin Test Results of Baseline Breathing Machines, Lawrence Livermore National Laboratories, Report No. 3265-33, August 1987.

AGENCY CONTACT: J. Tom Smith
United States Fire Administration
National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727

TITLE: LOW PROFILE, LONG DURATION BREATHING APPARATUS

AGENCY: United States Fire Administration
Bureau of Mines

OBJECTIVE: To determine if the two-hour, pure oxygen rebreather apparatus has utility for the fire service.

CONTRACTOR: Biotherm, Inc., Beavercreek, OH

TIMEFRAME: 1986-1987

BACKGROUND: In conjunction with the Bureau of Mines, the United States Fire Administration developed a two-hour pure oxygen rebreather. These units have been certified by the National Institute for Occupational Safety and Health (NIOSH), and subjected to field tests.

STATUS/RESULTS: Prototypes have been tested by NIOSH.

FUTURE WORK: None planned.

AGENCY CONTACT: J. Tom Smith
United States Fire Administration
National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727

TITLE: PROTECTIVE CLOTHING TOTAL GARMENT FIELD TESTS

AGENCY: United States Fire Administration
Federal Emergency Management Agency

OBJECTIVE: To conduct field tests of prototype and commercial chemical protective clothing ensembles.

CONTRACTOR: Biotherm, Inc., Beavercreek, OH

TIMEFRAME: 1986-1988

DESCRIPTION: The contractor is conducting field tests of commercial and prototype chemical protection clothing in four cities. Local fire department hazardous materials teams are participating. Limited investigation of the physiological response (e.g., of heart rate and core temperature) to the clothing is being conducted. Guidance for the evaluation protocol has been provided by a user requirements technical assistance committee comprising fire service hazardous materials experts and others with expert knowledge in the area.

STATUS/RESULTS: Field tests in four cities have been completed.

FUTURE WORK: A variation of the prototype under evaluation will be evaluated in 1988-1989.

REPORT:

1. J. Veghte, "Physiologic Evaluation of Hazardous Materials Protective Ensembles." Final report, Task 4, Contract No. FMW-85-C-2130, May 1988.

AGENCY CONTACT: Robert T. McCarthy
Project Manager
United States Fire Administration
National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727

TITLE: FIELD EVALUATIONS: HAZARDOUS CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT

AGENCY: United States Fire Administration
Federal Emergency Management Agency

OBJECTIVE: Evaluations (report) to be provided to users and developers of chemical protective clothing and equipment in furtherance of advancing an understanding to those groups of fire service requirements and their ability to use the equipment in the field.

CONTRACTOR: To be awarded in FY88.

TIMEFRAME: 1988-1989

DESCRIPTION: Field evaluations of chemical protective clothing and equipment will be conducted with a number of fire departments.

1. Hazardous Chemical Protective Clothing will be evaluated to determine the effect of different exhaust systems on the physiological responses of the wearer and the wearer's ability to operate efficiently while using the unit.
2. ASTM Standard F 1154-88 -- New Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function and Integrity of Chemical Protective Suit Ensembles, will be evaluated.
3. A hazardous chemical portable monitor (Chemical Parameter Spectrometer 100) will be evaluated.
4. Field testing and evaluation of a portable permeation/sorption field test kit will be evaluated.

STATUS/RESULTS: Field work to begin in 1988.

FUTURE WORK: Not identified.

AGENCY CONTACT: Robert T. McCarthy
Project Manager
United States Fire Administration
National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727

SECTION 2

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

TITLE: SAFETY IN HAZARDOUS MATERIALS INCIDENTS (803)

AGENCY: National Institute for Occupational Safety and Health (NIOSH)

OBJECTIVE: To develop safe work practices by (1) developing an on-line data base and criteria for selection and use of personal and equipment decontamination procedures for emergency response personnel, and by (2) determining the influence of major hazard prevention strategies on occupational safety and health in the chemical industry.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1986-1989

DESCRIPTION: This project involves conducting an extensive literature review, analyzing existing information, and developing a microcomputer data base, as well as conducting chemical industry site visits and consulting with industry, government and labor groups to assess the impact of major hazard control technologies. Finally, control strategies will be developed and disseminated.

STATUS/RESULTS: During FY86, NIOSH identified over 2,000 sources of information on personal and equipment decontamination agents and procedures for emergency response personnel, and compiled this information in a data base. NIOSH has learned that extensive information exists for some substances.

FUTURE WORK: From the acquired information, a contamination-decontamination model, which will be the basis for selection and use criteria for decontamination methods, is being developed. NIOSH intends to publish decontamination recommendations based on the information gained in this research in FY89.

AGENCY CONTACT: Richard Ronk
National Institute for Occupational Safety & Health
944 Chestnut Ridge Road
Morgantown, WV 26505-2888

TITLE: HAND TOOL DEXTERITY IN CHEMICAL PROTECTIVE CLOTHING - PHASE II (884)

AGENCY: National Institute for Occupational Safety and Health (NIOSH)

OBJECTIVE: To develop work practices for activities with and around hazardous materials.

FACILITY: Division of Safety Research (DSR), Morgantown, WV

TIMEFRAME: 1985-1989

DESCRIPTION: This project involves defining human factors issues related to the use of personnel protective equipment (PPE) in order to develop PPE, tool and task interface criteria.

STATUS/RESULTS: An initial study by DSR and the West Virginia University Industrial Engineering Department has shown that 15-37% more time is required to perform a simple standardized task with hand tools while wearing chemical protective gloves than to complete the same task without gloves. The number of errors, and dropped tools and parts also increased significantly. In FY86, the second phase of the study replicated Phase I using a different population of test subjects and adding new tests of dexterity which required the test subject to: (1) control a simulated chlorine leak by capping the valve of a 150-pound chlorine cylinder, and (2) control a simulated leak in an overturned gasoline tank truck by clamping the dome cover. Data collection was completed in the first quarter of FY87.

FUTURE WORK: This project will be extended to other types of chemical protective clothing. The collection of anthropometric data on a test panel for the extended study was begun in the first quarter of FY87.

AGENCY CONTACT: Richard Ronk
National Institute for Occupational Safety & Health
944 Chestnut Ridge Road
Morgantown, WV 26505-2888

TITLE: CHEMICAL PROTECTIVE CLOTHING INFORMATION COLLECTION/DISSEMINATION (774)

AGENCY: National Institute for Occupational Safety and Health (NIOSH)

OBJECTIVES: 1) To establish a computer data base of chemical protective clothing (CPC) permeation test results, and 2) to develop logic for proper clothing selection.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1984-1988

DESCRIPTION: To achieve objective (1), an IBM PC AT computer with dBase III software will be used. The bulk of the initial data entered will be obtained from the Environmental Protection Agency/Arthur D. Little, Inc., data compilation and the National Toxicology Program/Radian data generation. These data will be converted to the NIOSH format, which is derived from that being developed by the ASTM F23.40 Subcommittee. With regard to achieving objective (2), a logical approach to selecting the proper CPC was developed during the process of answering inquiries and contacting others working with CPC.

STATUS/RESULTS: Preparation of a publicly available permeation data base in the ASTM F23.40 (NIOSH) format was discontinued when two data bases became commercially available. Work will continue in developing the ASTM Standard Guide. The selection logic report is being revised after a second external technical review.

FUTURE WORK: Not identified.

AGENCY CONTACT: Michael R. Roder
National Institute for Occupational Safety & Health
944 Chestnut Ridge Road
Morgantown, WV 26505-2888

TITLE: SIMPLE BREAKTHROUGH TEST EVALUATION (813)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To develop a method to easily obtain the breakthrough time of chemicals through protective clothing without sophisticated analytical equipment and expertise.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1987-1989

DESCRIPTION: Existing field tests to determine the breakthrough time and steady state permeation rate of chemicals through chemical protective clothing samples require a knowledgeable person to use, maintain and calibrate sensitive analytical instruments. This project will evaluate alternative test methods and equipment which would require less skill to operate, maintain and calibrate. Included will be several chemical indicators which change color (a colorimetric system) in the presence of specific classes of chemicals. A permeation test cell will be modified for viewing. The breakthrough time determined with the colorimetric indicator system will be compared with that determined with the ASTM F739 permeation method. The feasibility of chemical detectors, based on changes in pH, fluorescence, electrical conductivity, thermal conductivity, etc., also will be investigated.

STATUS/RESULTS: For volatile hydrocarbons, a non-specific gas detector tube method of testing has shown potential. Investigation is continuing to define the method limitations. A detailed method description will be available in FY 88.

FUTURE WORK: Intralaboratory validation testing will be undertaken to compare potential test methods with the ASTM F739 method.

AGENCY CONTACT: Michael R. Roder
National Institute for Occupational Safety & Health
944 Chestnut Ridge Road
Morgantown, WV 26505-2888

TITLE: SEMI-AUTOMATIC VAPOR PERMEATION TEST SYSTEM (823)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To construct and conduct a preliminary evaluation of a semi-automated system to monitor and evaluate vapor permeation through chemical protective clothing (CPC).

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1987-1989

DESCRIPTION: Chemical vapor permeation data is an important factor in the selection of appropriate CPC against gases, but very little data is available. Therefore, a semi-automated system will be constructed to collect this type of information. A system used by Ernest Moyer, NIOSH, for vapor transmission and a system used by R.L. Mickelsen, NIOSH, for liquid chemical permeation will be incorporated, if feasible, into a new prototype test system. The initial test of the system will be with an acetone challenge of neoprene. Promising test methods may be proposed to ASTM for their proposed standard methodology.

STATUS/RESULTS: A prototype system was constructed and evaluated. Neoprene test material versus acetone liquid and vapor were tested. Results prove that the system does provide comparable results with the ASTM F739 method.

FUTURE WORK: In 1988 in-depth evaluations of the prototype test system will be conducted. In 1989 a report will be published in a peer reviewed journal detailing the construction and evaluation of the prototype system.

REPORTS:

1. S.P. Berardinelli, and E. Moyer, "Chemical Protective Clothing Breakthrough Times: Comparison of Open Versus Closed Loop Systems." Submitted to American Industrial Hygiene Association Journal.
2. E. Moyer, and S.P. Berardinelli, "Liquid and Vapor Permeation Through Protective Clothing." Presented at 1987 American Industrial Hygiene Conference, Montreal, Canada, June 1987.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
National Institute for Occupational Safety & Health
944 Chestnut Ridge Road
Morgantown, WV 26505-2888

TITLE: CHEMICAL PROTECTIVE CLOTHING INTERMANUFACTURER PERFORMANCE
VARIABILITY (775)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To determine the performance variability of chemical protective clothing (CPC) materials bearing the same generic name but produced by different manufacturers.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1985-1986

DESCRIPTION: Two generic materials, nitrile and neoprene, were subjected to a permeation test using three chemicals each. Nitrile and five neoprene glove products from different manufacturers were selected. Seven specimens (replicates) for each product/chemical combination were tested for breakthrough. The breakthrough times (both uncorrected and corrected for thickness variations) were compared to determine if any significant difference in performance existed.

STATUS/RESULTS: The project has been completed and significant intermanufacturer variability has been found. Materials with the same generic name from different manufacturers were found to perform quite differently.

FUTURE WORK: Not identified.

REPORT:

1. R.L. Mickelsen, and R.C. Hall, "A Breakthrough Time Comparison of Nitrile and Neoprene Glove Materials Produced by Different Manufacturers." American Industrial Hygienists Association Journal, Vol. 48(11):941-947, 1987.

AGENCY CONTACT: Leroy Mickelsen
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TITLE: DECONTAMINATION AND RE-USE OF CHEMICAL PROTECTIVE CLOTHING (788)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To evaluate the chemical permeation test method (i.e., breakthrough time as a measure of decontamination) and inter-relate it to the draft ASTM decontamination test method (i.e., Soxhlet extraction technique).

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1986-1987

DESCRIPTION: This project evaluated a draft ASTM method (which measures the decontamination efficiency of chemical protective clothing (CPC) by Soxhlet extraction of liquid chemical remaining in the CPC matrix) in conjunction with the ASTM Chemical Permeation Test Method. Three decontamination techniques were used: hand detergent washing, air drying, and automatic dishwashing. A glove-chemical combination exhibiting matrix release (slow permeation of chemical from a saturated glove matrix) and a glove-chemical combination not exhibiting matrix release were evaluated after two reuse/decontamination cycles.

STATUS/RESULTS: The laboratory experiments, analysis of data, and the final report were completed in FY86. The draft ASTM decontamination efficiency test method can be used to evaluate CPC, but the Soxhlet extraction technique for this method is time consuming and requires a high degree of chemical expertise. Change of breakthrough times (chemical permeation) is an easier test to evaluate decontamination efficiency. The glove-chemical without matrix release was decontaminated by air drying or automatic dishwashing. The glove-chemical combination with matrix release was decontaminated by automatic dishwashing only. Hand detergent washing was ineffective in all cases. Decontamination techniques must be experimentally evaluated to prove their efficiency; determination of breakthrough time changes (before and after application of decontamination techniques) is an effective test method to accomplish this.

FUTURE WORK: Not identified.

REPORT: Final report on the test methods. Presented at the 1987 2nd International ASTM Protective Clothing Conference. Due to be published in January 1989 in ASTM Special Technical Publications.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
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TITLE: CHEMICAL PROTECTIVE CLOTHING IN CHEMICAL WASTE DUMPS (786)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To develop and validate a chemical degradation and chemical penetration test method. Also, to develop and evaluate field test methods for degradation, penetration and permeation.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1984-1987

DESCRIPTION: A draft chemical degradation test method and a draft chemical penetration test method were evaluated by inter-laboratory testing via a NIOSH contract awarded in FY84. Field methods for degradation, penetration and permeation of chemical protective clothing (CPC) were tested in FY85; a final report was written in FY86. The relationship of these test methods to occupational dermatitis was a topic addressed by the NIOSH Dermatologic Conditions Working Group.

STATUS/RESULTS: This project is complete. The NIOSH Contract (200-84-2702) final report was sent to the ASTM F23 (Protective Clothing) Committee for consideration as a consensus standard. The penetration test is now an ASTM Standard Method. A Chemical Resistance Field Test Methods Manual has completed peer review and been published. A field test using methyl isocyanate was also conducted. The Project Officer was a member of the NIOSH Dermatologic Conditions Working Group and in that capacity was able to write a part of the final report to stress CPC testing. The degradation test is currently being refined.

FUTURE WORK: Not identified.

REPORTS:

1. S.Z. Mansdorf, "Chemical Protective Clothing Standard Test Method Development: Penetration Test Method Final Report." August 1985. Available from Agency Contact.
2. G. Coletta, and S.Z. Mansdorf, "Chemical Protective Clothing Standard Test Method Development: Degradation Test Method Final Report." August 1987. Available from Agency Contact.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
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TITLE: QUICK EMPIRICAL METHODS (787)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To develop and evaluate chemical permeation surrogate test methods. More specifically, to investigate the correlation between chemical permeation and chemical degradation to ascertain if the latter is an adequate surrogate for the former.

FACILITY: Division of Safety Research (DSR), Morgantown, WV

TIMEFRAME: 1985-1986

DESCRIPTION: Chemical degradation data (i.e., weight, volume and thickness data) were compared to chemical permeation data (i.e., breakthrough time and steady state permeation rate data). This computer study was conducted under an interagency agreement with Los Alamos National Laboratory using data generated by Los Alamos, Arthur D. Little, Inc., and Radian Corp.

STATUS/RESULTS: This project is complete. Solubility parameters were evaluated as chemical permeation surrogates and found to correlate poorly with chemical permeation data. (Solubility parameters, or "like dissolves like", are a measure of chemical degradation.) Correlation may be better if more precise solubility parameters become available. Correlation of weight or volume changes and thickness changes to breakthrough times and steady state permeation rates were poor when analyzed by regression analysis. Discriminant analysis was used to predict breakthrough times greater than either four or eight hours as a function of weight and volume changes.

FUTURE WORK: None planned.

REPORTS:

1. J.F. Stampfer, and R.J. Beckman, "A Screening Test for Selecting Chemical Protective Clothing." In Proceedings of the Second International Symposium on Protection Against Chemical Warfare Agents, National Defence Research Institute, Department 4, S-90182 UMEA, Sweden, 1986.
2. J.F. Stampfer, R.J. Beckman, and S.P. Berardinelli, "A Screening Test for Selecting Chemical Protective Clothing." Due to be published in September 1988 in the American Industrial Hygienists Association Journal.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
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TITLE: IN-USE EVALUATION OF CHEMICAL PROTECTIVE CLOTHING FEASIBILITY
STUDY (789)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To develop a chemical protective clothing (CPC) test method for effective evaluation of whole CPC garments while in use. Specifically, to determine the feasibility of using conventional sampling pumps and charcoal tubes to monitor the in-use performance of CPC.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1986

DESCRIPTION: Laboratory test methods have been developed to evaluate materials taken from CPC products, but this laboratory patch testing may not reflect the effectiveness of the whole garment. For example, a whole garment undergoes flexing and other physical stress while it is in use. This project was a feasibility study of an ensemble test method for detecting permeation. A prototype model was developed and evaluated through a literature search, peer communications, and preliminary laboratory testing.

STATUS/RESULTS: This project has been completed. A test system for monitoring the performance of whole gloves during use was developed. It consisted of five micro-bore Tygon tubes running down the hand to the tip of each finger under the glove. A traditional industrial hygiene sampling pump was used to draw sample through each of these five lines and through a charcoal tube. The efficiency of the charcoal tube collection system for very humid air was found to be adequate, but an unexpected bellows effect caused by flexing the glove was responsible for problems with data collection. Overall, however, the method seems sound and has the potential to be developed into a routine test for monitoring CPC performance.

FUTURE WORK: Follow-up studies may be undertaken in 1988

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TITLE: PHYSIOLOGICAL RESPONSES TO THE WEARING OF PROTECTIVE CLOTHING AND RESPIRATORS (792)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To evaluate work tolerance associated with the wearing of chemical protective clothing ensembles. More specifically, to develop a scientific basis for recommending safe work practices for individuals wearing self-contained breathing apparatus (SCBA), and chemical and firefighter protective ensembles over a range of work, temperature and humidity conditions.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: Continuing project

DESCRIPTION: The measurement of physiological response was conducted in two phases. In Phase I, nine healthy volunteers were studied to examine the effect of protective clothing ensembles and workrate on worker tolerance. Four ensembles were examined, including a light clothing ensemble with and without SCBA, chemical protective clothing with SCBA, and firefighters turnout gear with SCBA. In Phase II, the temperature effects (50, 72 and 93°F), all at 50% RH, were examined as a function of clothing ensembles (light clothing and chemical clothing, both with SCBA). Dependent variables included skin and core temperature, facepiece pressure and temperature, heart rate, sweat rate and various ventilatory and subjective parameters. Supplemental work has been conducted to examine neoprene and Gore-Tex™ liners in firefighters turnout gear.

STATUS/RESULTS: The results of Phase I indicated that wearing protective clothing and respirators causes significant stress to the cardiorespiratory and thermoregulatory systems, even at low work intensities in a neutral environment. When compared to lightweight clothing, the use of SCBA and impervious clothing resulted in decrements of as much as 95.6% in exercise tolerance time. At a low work intensity (with subjects wearing chemical clothing) three of nine tests had to be terminated because rectal temperatures exceeded 39.0°C, a signal of the onset of heat stress. The results of Phase II indicated that the response to wearing a totally-encapsulating chemical protective suit at cold temperatures is very similar to the response to wearing both an SCBA and lightweight clothing at cold or neutral temperatures. The physiological response to wearing chemical clothing at neutral temperatures was very similar to the response to wearing an SCBA in a hot environment. Wearing the chemical ensemble in the hot environment was extremely stressful, suggesting a need to closely monitor and adjust work/rest periods for the workers.

FUTURE WORK: An evaluation of disposable clothing used in the asbestos industry is planned. Also, studies of cooling garments used with fully encapsulating suits are planned.

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TITLE: PERCUTANEOUS ABSORPTION CHARACTERISTICS OF OCCUPATIONAL CHEMICALS (309)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVES: (1) To evaluate new approaches for studying percutaneous absorption of volatile occupational chemicals, (2) to evaluate work-related factors or situations which influence absorption, and (3) to develop a symposium to highlight risk assessment methods and approaches. Information generated from the various components of this project will help to focus the attention of the occupational safety and health community on the need to consider percutaneous absorption data during risk assessments of occupational situations.

FACILITY: Division of Biomedical and Behavioral Science, Cincinnati, Ohio

TIMEFRAME: 1984-1988

DESCRIPTION: A series of studies on the percutaneous absorption of toluene, ethylbenzene and aniline in hairless mice following single application of neat chemicals was completed. The intent of proposed symposium is to focus on topics related to: (1) methods of risk assessment, (2) the effectiveness of existing intervention strategies, and (3) the identification of chemicals and factors in the workplace that could lead to adverse health effects as a consequence of percutaneous absorption.

STATUS/RESULTS: When compared to uptake via inhalation at present standards, only the dermal absorption of aniline was potentially significant. These studies also showed an inverse relationship between the volatility of the compounds and their percutaneous absorption.

FUTURE WORK: Further studies of single application of N, N-diethyl-m-toluamide (M-DEET), and repeated applications of benzene were started in 1987. Plans are to convene the proposed symposium in Cincinnati during Spring or Summer 1988.

REPORTS:

1. A.S. Susten, B.L. Dames, and R.W. Niemeier, "In Vivo Percutaneous Absorption Studies of Volatile Solvents in Hairless Mice. I. Description of a Skin-Depot." *Journal of Applied Toxicology* 6:43-46 (1986).
2. A.S. Susten, B.L. Dames, J.R. Burg, and R.W. Niemeier, "Percutaneous Penetration of Benzene in Hairless Mice: An Estimate of Dermal Absorption during Tire-building Operations." *American Journal of Industrial Medicine* 7:323-335, 1985.
3. A.S. Susten, and R.W. Niemeier, "In Vivo Percutaneous Absorption Studies of Volatile Organic Solvents in Hairless Mice. II. Toluene, Ethylbenzene and Aniline." Submitted to *Toxicology and Applied Pharmacology*, December 1986.
4. A.S. Susten, "Percutaneous Absorption of Benzene-derivatives: Correlation to Physical Properties." In review.

AGENCY CONTACT: Allan S. Susten, Ph.D.
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TITLE: PESTICIDE PERMEATION (833)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To develop a pesticide permeation test method.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1988

DESCRIPTION: The ASTM F23 Committee has developed a chemical permeation test for pesticides. The ASTM F23 will conduct round robin testing to evaluate the test method. PES will be a participating laboratory.

STATUS/RESULTS: Work will begin in 1988.

FUTURE WORK: Other poorly water soluble, low vapor pressure chemical classes may be evaluated using this test method.

REPORT:

1. G.W. Mulholland, R. Bukowski, B.Y.H. Liu, and W. Zymanski, "Application of Smoke Detector Technology to Quantitative Respirator Fit Test Methodology." National Bureau of Standards, NBSIR86-3481, 1986, NTIS number not yet available.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
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TITLE: PERSONAL PROTECTIVE EQUIPMENT FOR PESTICIDE APPLICATORS (N20)

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To gain experience in selection and use of chemical protective clothing for pesticide applicators.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1988

DESCRIPTION: Literature review, review of injury and illness statistics, and site visits/field observations will provide background in current industry practice in the selection and use of personal protective equipment and techniques for agricultural pesticide handling and application. We will audit pesticide applicator certification training and evaluate existing training materials and safety guidelines. We also will review current pesticide labeling requirements regarding personal protective equipment. A final report will outline the current state of knowledge and practice in the use of personal protective clothing, equipment and techniques for pesticide handling, and application. It also will assess NIOSH/DSR's potential role in this area and make recommendations for further study.

STATUS/RESULTS: This is a one year project. Work will begin in 1988.

FUTURE WORK: A future effort may be warranted based on information obtained by this project.

REPORT:

1. R.A. daRoza, C.A. Cadena-Fix, and J.E. Kramer, "Powered Air-Purifying Respirator Study Final Report." Lawrence Livermore National Laboratory, UCRL-53757, 1986, NTIS number not yet available.

AGENCY CONTACT: Stephen P. Berardinelli, Ph.D.
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TITLE: TRANSPORT OF LIQUIDS THROUGH POLYMERS

AGENCY: National Institute for Occupational Safety and Health

OBJECTIVE: To investigate the critical polymer/penetrating parameters involved in transporting organic liquids through nitrile rubber; to correlate these measurements as a function of polymer composition (percent of monomer) and polymer fabrication process.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1988

DESCRIPTION: We will conduct experimental laboratory studies to identify physical parameters that are sensitive to variation as a result of the manufacturing process. We will study variations in manufacturing parameters and permeation properties to determine if a systematic relationship exists.

STATUS/RESULTS: Work will begin in 1988.

FUTURE WORK: A future effort may be developed based upon the results of this project.

REPORT:

1. The LANL report is not yet available.

AGENCY CONTACT: Ronald L. Mickelsen
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SECTION 3

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

TITLE: APPLICATION OF SMOKE DETECTOR TECHNOLOGY TO QUANTITATIVE FIT TEST METHODOLOGY

AGENCY: Occupational Safety and Health Administration

OBJECTIVE: To develop a low-cost respirator quantitative fit testing (QNFT) instrument using mass-produced components.

FACILITIES: National Bureau of Standards (NBS), Gaithersburg, MD
Particle Technology Laboratory, University of Minnesota,
Minneapolis, MN

TIMEFRAME: 1984-1986

DESCRIPTION: QNFT is the best available test method for the selection of appropriate respirators. However, the high cost of commercial QNFT equipment has limited its application to relatively large industrial facilities. The availability of a simple and relatively low cost system would enhance the appeal of a QNFT system and improve the effectiveness of respiratory protection programs in general. Therefore, a low cost QNFT system was developed by using mass-produced components such as a smoke detector, a clinical nebulizer and an air diluting device. Key design features of the apparatus include the generation of corn oil aerosol for fit testing, and light-emitting diode (LED) displays for fit factors of 25, 50, 125, and 450. The total cost of the apparatus is less than \$300.

STATUS/RESULTS: Three smoke detectors with analog output proportional to the intensity of the scattered light (rather than the commonly used audible alarm type) were selected for evaluation. A high sensitivity smoke detector with a special lens/light trap geometry was chosen for the QNFT system. Investigation was also carried out to select a commercial medical nebulizer which would produce a stable, high concentration of aerosol over a long period of time. The prototype QNFT instrument consists of these components, a diaphragm pump, and a ten light LED display. Operation and maintenance of the instrument are simple and require no special skill.

FUTURE WORK: Field tests of the prototype QNFT instrument are planned.

REPORT:

1. G.W. Mulholland, R. Bukowski, B.Y.H. Liu, and W. Zymanski, "Application of Smoke Detector Technology to Quantitative Respirator Fit Test Methodology." National Bureau of Standards, NBSIR86-3481, 1986, NTIS number not yet available.

AGENCY CONTACT: Mr. Ching-tsen Bien
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TITLE: POWERED AIR-PURIFYING RESPIRATOR STUDY

AGENCY: Occupational Safety and Health Administration

OBJECTIVE: To determine the performance of powered air-purifying respirators (PAPR) under a simulated heavy workrate and the effect of beard growth on the facepiece seals of these respirators.

FACILITY: Lawrence Livermore National Laboratory (LLNL), Livermore, CA

TIMEFRAME: 1985-1986

DESCRIPTION: Three brands of PAPR, including one tight-fitting half-mask and two loose-fitting helmet-type respirators, were subjected to a simulated workplace study. Six male test subjects participated in this study, working at up to 80% of their cardiac reserve on the treadmill in a test chamber with an aerosol challenge. The air flow into the respirators was varied from 86 to 170 lpm for the half-mask PAPR, and from 114 to 255 lpm for the helmet-type PAPRs. The approved minimum air flow rate is 114 and 170 lpm for the half-mask and helmet-type PAPRs, respectively. The effects of hair growth on the facepiece seal were determined for clean shaven faces, three day stubble, and two-to-three month full beards. Parameters measured for each respirator were: pressure inside the inlet covering of the respirator, and penetration of aerosol under varying conditions of hair growth, air flow, and workrates.

STATUS/RESULTS: Aerosol penetration into the two helmet-type PAPRs increased dramatically when the test subjects' workrates increased. In contrast, penetration into the half-mask PAPRs did not change with workrate. The penetration increased as the air flow was decreased for all subjects wearing the helmet-type PAPR and for non-clean shaven test subjects wearing the half-mask PAPR. However, for the half-mask on a clean shaven face, the average penetration stayed below 0.001 for all flow conditions. The helmet-type PAPRs could not maintain a positive pressure inside the facepiece. The half-mask PAPR is a positive pressure device at a flow rate of 170 lpm. At 115 lpm and 80% workrate, the half-mask PAPR does not maintain a positive pressure. The difference in performance between the tight-fitting half-mask and the loose-fitting helmet-type PAPRs is so great that they should be placed in separate categories when assigning respirator protection factors.

FUTURE WORK: Simulated workplace studies are planned for supplied air respirators and disposable air-purifying respirators.

REPORT:

1. R.A. DaRoza, C.A. Cadena-Fix, and J.E. Kramer, "Powered Air-Purifying Respirator Study Final Report." Lawrence Livermore National Laboratory, UCRL-53757, 1986, NTIS number not yet available.

AGENCY CONTACT: Mr. Ching-tsen Bien
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TITLE: THE EFFECTS OF TEMPERATURE AND HUMIDITY ON THE FIT OF RESPIRATORS
UNDER SIMULATED WORK CONDITIONS

AGENCY: Occupational Safety and Health Administration (funded jointly with
the U.S. Nuclear Regulatory Commission)

OBJECTIVE: To determine the protection provided by various types of respirators
under simulated work conditions (moderate to heavy workrate) and at extreme
temperature and humidity.

FACILITY: Los Alamos National Laboratory (LANL), Los Alamos, NM

TIMEFRAME: 1984-1986

DESCRIPTION: Recently published respirator field studies indicate that
protection factors (PF) obtained during actual use are much lower than the fit
factors (FF) obtained under laboratory conditions. Defective respirators or
improper wear of respirators are the two contributing factors for these low
results. However, it is difficult to determine which of the two is actually
responsible because there is little control of environmental conditions such as
temperature, humidity, and workload during field studies. This study determined
the performance of various types of respirators under simulated work conditions
in an environmental chamber. Seven respirators were selected, including one
half-mask and one full facepiece air-purifying respirator, one half-mask and two
helmet-type powered air-purifying respirators (PAPR), and one full facepiece
pressure-demand and one hood-type supplied air respirator (SAR). The test
subjects performed exercises such as stepping up and down a ladder, shoveling
gravel, pounding nails, and moving cinder blocks for 1 hr. The temperature and
relative humidity inside the environmental chamber varied from 0°C to 32°C and
from 15% to 85%, respectively. A total of 420 tests were performed by ten test
subjects for each type of respirator and set of environmental conditions.

STATUS/RESULTS: Respirators supplied with a continuous flow of air were found to
be more comfortable to wear and to offer more protection than negative-pressure
respirators. Humidity does not affect respirators that have a forced air flow,
such as the PAPRs or SARs. Slight temperature effects were found for the tight-
fitting, negative-pressure, air-purifying respirators. There were differences
between FFs and simulated work factors for helmet-type PAPRs. The helmet-type
PAPRs provided much lower levels of protection than the tight-fitting PAPRs.
Exercises used for the quantitative fit testing (QNFT) are not adequately
representative under simulated work conditions.

FUTURE WORK: Field tests are planned for the respirators used in this study.

REPORT:

1. The LANL report is not yet available.

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SECTION 4

UNITED STATES COAST GUARD

TITLE: EARLY DEVELOPMENT OF A HAZARDOUS CHEMICAL PROTECTIVE ENSEMBLE
(4155.4.1.1)

AGENCY: U.S. Coast Guard

OBJECTIVE: To develop a totally-encapsulating chemical protective suit that can provide a high level of protection against the majority of hazardous chemicals encountered by Coast Guard response personnel during emergency response activities.

CONTRACTORS: ILC Dover, Inc., Frederica, DE
Arthur D. Little, Inc., Cambridge, MA (Subcontractor)

TIMEFRAME: 1981-1985

DESCRIPTION: Since 1974, the U.S. Coast Guard has sought to identify or develop protective suits that would provide a high degree of protection against as many chemicals as possible. Early studies involved surveys and testing of commercial and military chemical protective suits. In 1981, ILC Dover, Inc., was awarded a contract to develop a hazardous chemical protective ensemble. Tasks in the contract included evaluating candidate suit and visor materials using physical properties, degradation and permeation testing; investigating clothing fabrication methods; designing prototype garments; and measuring prototype performance in manned testing in the laboratory.

STATUS/RESULTS: Through extensive physical property and chemical resistance testing, three suit materials were found to provide broad protection: butyl rubber, Viton[™]/chlorobutyl laminate, and chlorinated polyethylene. Teflon[™] (FEP)/Surlyn[™] laminate was used as a visor material for all three suit materials. A suit was designed with features that included one-piece construction with a hood and visor, positive pressure operation maintained by breathing system exhaust air and suit relief valves, a pressure sealing zipper, and a separate cooling system. The cooling system consisted of a full body garment through which cooled water was circulated via an externally filled ice pouch, heat exchanger, and pump. Laboratory evaluations included protection factor testing to measure ensemble integrity, and manned stress testing to assess ensemble function, fit, and comfort.

FUTURE WORK: Not identified.

REPORT AND PRODUCTS:

1. J.O. Stull, "Final Report-Early Development of a Hazardous Chemical Protective Ensemble." CG-D-24-86 (NTIS #AD A174 885).
2. Prototype of encapsulating suits and cooling garments, not available.

AGENCY CONTACT: Dr. Alan P. Bentz
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Avery Point
Groton, CT 06340

TITLE: DEVELOPMENT OF A COAST GUARD CHEMICAL RESPONSE SUIT (4155.4.1.1)

AGENCY: U.S. Coast Guard

OBJECTIVE: To develop a single, totally-encapsulating chemical protective suit that can provide a high level of protection against the majority of hazardous chemicals encountered by Coast Guard response personnel.

CONTRACTOR: Chemical Fabrics Corporation, Merrimack, NH

TIMEFRAME: 1985-1986

DESCRIPTION: Results from an earlier Coast Guard development recommended a suit system involving three materials for chemical spill response. While this provided a manageable approach for this application, it made suit selection for unknown chemicals and mixtures difficult. In 1985, the Coast Guard identified a new material, Teflon™ laminated Nomex Challenge 5100, manufactured by Chemical Fabrics Corp. This material demonstrated equal physical properties and greater chemical resistance than the original three selected materials. The Coast Guard is using this material, a 10 mil Teflon™ FEP visor material, and various commercial gloves in the production of new chemical emergency response suits. Minor changes in the original suit design were made to accommodate seam heat-sealing processes used with the new material.

STATUS/RESULTS: This project has been completed. The Coast Guard has taken delivery of several chemical response suits. A final report, suit operations manual, and training videotape have been prepared to document the use, capabilities, and limitations.

FUTURE WORK: The Coast Guard is investigating suit zipper, glove, and exhaust valve alternatives that have better chemical resistance and improved performance.

PRODUCTS:

1. J.O. Stull, "Final Report - Development of an U.S. Coast Guard Chemical Response Suit." CG-D-16-87 (NTIS #AD A186 402), June 1987.
2. Chemical Response Suit Operations and Maintenance Manual. U.S. Coast COMDT M16465.39 (Internal manual).
3. U.S. Coast Guard Response Suit Training Videotape (Internal Use).

AGENCY CONTACT: LTJG Bruce Herring
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TITLE: DEVELOPMENT OF TEFLON-BASED GLOVES FOR CHEMICAL RESPONSE SUIT
(4155.4.1.1)

AGENCY: U.S. Coast Guard

OBJECTIVE: To develop gloves for the Coast Guard Chemical Response Suit which provide similar chemical resistance as the Challenge 5100 material that is used as the base material in the suit and which possess adequate strength and dexterity.

CONTRACTOR: Chemical Fabrics Corporation, Merrimack, NH

TIMEFRAME: 1987-1988

DESCRIPTION: The original gloves developed with the Chemical Response Suit using Teflon™ (TFE) film demonstrated poor chemical resistance and durability in follow-up testing. If commercial gloves are used as replacements, six different types of gloves are needed to cover 2/3 of the 100+ chemicals that Challenge 5100 protects against. No glove material can be recommended for the remaining 1/3 of chemicals compatible with Challenge 5100. Chemical Fabrics Corporation has been awarded a contract to develop gloves using their propriety Challenge materials. They will devise fabrication methods which result in gloves that possess both structural integrity and adequate dexterity. Glove design acceptance will be contingent on integrity testing following simulated field use and the chemical resistance of the glove seam.

STATUS/RESULTS: Six pairs of prototype gloves were fabricated from Challenge 5200 (Teflon™/Fiberglass/Teflon™) using a three finger design and heat-sealed seams joining two hand silhouettes. These prototype gloves were evaluated in a test protocol to measure glove integrity and dexterity. Testing revealed a breakdown of glove integrity after use at particular seams and a large loss in dexterity when compared to conventional rubber gloves.

FUTURE WORK: The Coast Guard and Chemical Fabrics Corporation are attempting to identify glove construction methods which will yield seamless gloves with Challenge-type materials.

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TITLE: CHEMICAL RESISTANCE TESTING OF MATERIALS IN COAST GUARD CHEMICAL RESPONSE SUIT (4155.4.1.2)

AGENCY: U.S. Coast Guard

OBJECTIVE: To test the chemical resistance of candidate protective clothing materials for the Coast Guard's totally-encapsulating chemical protective suit; to use such data to support recommendations for use of the Coast Guard Chemical Response Suit.

FACILITY/CONTRACTORS: U.S. Coast Guard Research and Development Center
Texas Research Institute, Inc. (TRI), Austin, TX
Anderson Associates, Groton, CT

TIMEFRAME: 1984-1988

DESCRIPTION: The Coast Guard's selection of Teflon[™] materials for its Chemical Response Suit was based on data from testing against a selected group of chemicals. Subsequently, a comprehensive testing program has been established to test all major suit materials against priority chemicals for making suit use recommendations. The Coast Guard R&D Center has tested 115 priority chemicals identified on the basis of spill frequency, toxicity, and need for encapsulated protection. Only four chemicals have been found that permeate the garment material within one hour. Similarly, the visor and glove materials have been tested but against a smaller set of priority chemicals to determine differences in permeation performance. Other suit components such as the seams and zipper have been tested for permeation and penetration resistance against representative chemicals. Anderson Associates found no penetration of the various suit seam constructions and zipper.

STATUS/RESULTS: Results of this testing through July 1987 are contained in the final report (#3) listed below. TRI is continuing to test Chemical Response Suit materials against additional chemicals including gases and mixtures. Current experiments also involve testing of flexed materials against representative chemicals.

FUTURE WORK: New data will be provided in the Chemical Response Suit Operations Manual and used to augment suit use recommendations. New materials may be investigated for comparison with the Challenge 5100.

REPORTS:

1. A.P. Bentz et al, "Use of a Relational Database for Protective Clothing Research." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.
2. M.S. Hendrick, and C.B. Billing, Jr., "Final Report-Selection of Priority Chemicals." CG-D-22-86 (NTIS #AD A172 370), July 1986.
3. J.O. Stull, "Final Report-Development of an U.S. Coast Guard Chemical Response Suit." CG-D-16-87 (NTIS #AD A186 402), June 1987.

AGENCY CONTACT: Dr. Alan P. Bentz
U.S. Coast Guard R&D Center
Avery Point
Groton, CT 06340

TITLE: INVESTIGATION OF PARAMETERS AFFECTING THE PERMEATION RESISTANCE OF PROTECTIVE CLOTHING MATERIALS (4155.4.1.2)

AGENCY: U.S. Coast Guard

OBJECTIVE: To investigate the effects of various parameters which affect permeation resistance of candidate protective clothing materials; to use the collected data to model the permeation behavior of these materials.

FACILITY: U.S. Coast Guard Research and Development Center, Groton, CT

TIMEFRAME: 1984-1988

DESCRIPTION: Early studies involving the permeation testing of Viton™/chlorobutyl laminate and chlorinated polyethylene (CPE) demonstrated significant differences in the permeation breakthrough time for these materials under different environmental conditions. The Coast Guard R&D Center is studying the effects of contact time (chemical "splashes" versus constant contact), temperature, and internal suit pressure on the permeation behavior of candidate protective suit materials (Viton™/chlorobutyl, CPE, and Teflon™/Nomex™ laminate). Splash testing is conducted using a modified form of ASTM F739 now being considered for adoption by ASTM.

STATUS/RESULTS: Preliminary data show that the effect of contact time is variable, depending on the material/chemical pair. For some combinations, the expected behavior of increasing permeation breakthrough time with decreasing chemical contact is observed; however, other chemicals break through materials in nearly the same time with a single splash as with constant contact over three hours. Breakthrough times appear to decrease logarithmically with increasing temperature.

FUTURE WORK: Additional parameter studies will be performed on the Teflon™ laminate and extended to investigate the effect of internal suit pressure (3.8 mm Hg) on permeation breakthrough time. These results will be used to assess suit material performance and establish use recommendations. A final report will be prepared to document this study's findings.

REPORTS:

1. V. Man et al, "Permeation of Protective Clothing Materials: Comparison of Liquid, Liquid Splashes, and Vapor on Breakthrough Times." American Industrial Hygienists Association Journal, Vol. 48(6), 1987, pp. 551-5.
2. C.B. Billing, Jr., and A.P. Bentz, "Effects of Temperature, Sample Thickness, and Experimental Apparatus on Permeation Results." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.

AGENCY CONTACT: Dr. Alan P. Bentz
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Groton, CT 06340

TITLE: THREE-DIMENSIONAL SOLUBILITY PARAMETER MEASUREMENTS OF PROTECTIVE CLOTHING MATERIALS (4155.4.1.2)

AGENCY: U.S. Coast Guard

OBJECTIVE: To measure the solubility parameter of candidate materials used in selected chemical protective suits; to determine if these parameters or methods can be used to predict material-chemical permeation.

FACILITY: U.S. Coast Guard Research and Development Center, Groton, CT

TIMEFRAME: 1985-1988

DESCRIPTION: The three-dimensional solubility parameter has shown promise in past studies for predicting permeation of hazardous chemicals through protective clothing materials. The Coast Guard R&D Center measured these parameters for six materials--Teflon™ (Challenge 5100), butyl rubber, chlorobutyl rubber, Viton™ A (copolymer), Viton™ B (terpolymer), and chlorinated polyethylene. Fifty-five chemicals ranging in solubility parameter components (polarity, hydrogen bonding, and dispersion) and water were tested against each material. The degree of interaction between each chemical and material was determined using three methods: visual observations, weight gain, and dimensional changes. Yes or no criteria were established, and the results were plotted to show chemicals affecting the material in terms of the 3-D solubility parameter and to determine the solubility parameter of the tested material.

STATUS/RESULTS: Solubility parameters were measured for all materials with the exception of Teflon™ (Challenge 5100) which showed interaction for only a few chemicals and in no consistent pattern. Of the methods used to determine material-chemical interaction, weight gain measurements provided the most precision for defining a material's solubility parameter.

FUTURE WORK: The results of this effort will be made available in a NTIS Report. The Coast Guard R&D Center will attempt similar experiments at high temperatures to determine a solubility parameter for Challenge 5100 Teflon™ material.

REPORTS:

1. C.B. Billing, Jr., J.L. Derrickson, and A.P. Bentz, "Evaluation of Methods for Determining Solubility Parameter of Protective Clothing Materials." Presented at the 2nd Scandinavian Conference on Protective Clothing Against Chemicals and Other Health Risks, Solna, Sweden, November 1986.
2. A.P. Bentz, and C.B. Billing, Jr., "Determination of Solubility Parameters of New Suit Materials." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.

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TITLE: DEVELOPMENT OF A PREDICTIVE MODEL FOR DETERMINING MATERIAL CHEMICAL RESISTANCE (4155.4.1.2)

AGENCY: U.S. Coast Guard

OBJECTIVE: To develop a predictive model for determining chemical resistance of Challenge 5100 and other materials used in the Coast Guard Chemical Response Suit.

CONTRACTOR: Contract not yet awarded.

TIMEFRAME: 1988-1989

DESCRIPTION: The Coast Guard R&D Center will award a contract for developing a permeation model to predict chemical resistance for materials of interest, especially Challenge 5100 (Coast Guard Chemical Response Suit base material). The model will be based mainly on theoretical postulates and empirical data and is for chemicals similar to those which have been found to break through materials of interest (Chemical Response Suit garment, visor, and glove materials). The model will include the effects of solubility parameter, chemical class, molecule size, temperature, and other variables found to be significant in affecting the material's chemical permeation resistance.

STATUS/RESULTS: The Coast Guard R&D Center is currently preparing a work statement for the predictive model development contract.

FUTURE WORK: Not identified.

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TITLE: THE FEASIBILITY OF USING ISOTOPE-LABELLED CHEMICALS TO STUDY THE PERMEATION OF PROTECTIVE CLOTHING MATERIALS (4155.4.1.3)

AGENCY: U.S. Coast Guard

OBJECTIVE: To determine the feasibility of using radiochemistry methods for evaluating the permeation resistance of protective clothing materials and assessing the efficiency of recommended decontamination methods.

CONTRACTOR: Danish Isotope Centre (DIC), Copenhagen, Denmark

TIMEFRAME: 1986-1988

DESCRIPTION: Current Coast Guard practices require disposal of protective clothing after a significant chemical exposure. Decontamination methods are sought to extend the lifetime of protective garments and to ensure safe use. However, before decontamination methods can be investigated, techniques must be developed to determine the extent of contamination so that users can assess the effectiveness of the decon agent. In 1986, the R&D Center awarded a contract to DIC to use radiochemical-labelled compounds to determine the degree of chemical contamination before and after decontamination for specific material-chemical pairs. Use of Carbon-14 labelled compounds permits the investigator to "see" the chemicals inside the material matrix.

STATUS/RESULTS: The current work in the R&D Center contract involves four material-chemical pairs (Neoprene/Nitrobenzene, Viton™/Acetone, Teflon™/Vinyl Acetate, and Teflon™/Methylene Chloride) for investigating the feasibility of radiochemistry to characterize permeation and decontamination effectiveness. Decon methods include soap and water wash, Freon 113 rinsing, and heating in a hot-air oven. DIC has developed a detailed methodology for exposing samples to the labelled chemicals and examining the concentration profile across the thickness of the material.

FUTURE WORK: A final report on the feasibility study will be completed in late 1987. The R&D Center will use the results from the feasibility study and work done at other facilities to determine the effectiveness of various decontamination methods. A second contract has been awarded to continue the work. Recommendations for decontamination will be made to supplement the operation manual for the Coast Guard Chemical Response Suit.

REPORTS:

1. Danish Isotope Centre, "Interim Report-Feasibility of Radiochemistry Tracers to Elucidate Mechanisms of Chemical Permeation in Protective Clothing Materials." October 1986.
2. I. Drabaek, "Carbon-14 Tracers in Permeation Studies." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.

AGENCY CONTACT: Dr. Alan P. Bentz
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TITLE: FEASIBILITY OF USING THERMAL ANALYSIS TO CHARACTERIZE CHEMICAL EFFECTS ON
SELECTED PROTECTIVE CLOTHING MATERIALS (4155.4.1.4)

AGENCY: U.S. Coast Guard

OBJECTIVE: To evaluate the feasibility of using thermal analysis in determining the extent of protective clothing materials degradation following hazardous chemical exposure; the end-goal is to provide a quick and simple method of determining suit material viability after a chemical exposure, avoiding a full battery of chemical permeation or physical property tests.

FACILITIES: U.S. Coast Guard Academy Chemistry Department, New London, CT
Columbia University, New York, NY

TIMEFRAME: 1984-1986

DESCRIPTION: Thermal analysis may be useful for detecting changes in materials resulting from degradation by hazardous chemicals. Preliminary experiments conducted at the Coast Guard Academy have shown that differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) enable some detection of material degradation following controlled hazardous chemical exposure. This method may provide a rapid means for detecting contamination or evaluating decontamination methods.

STATUS/RESULTS: DSC and TGA were used to analyze contaminated samples of Viton™/chlorobutyl laminate against several chemical challenges. This study indicated that the method did indicate degradation of the material, but the sensitivity of the technique remains questionable. Similar analyses were performed on the Teflon™ laminate being used in the Coast Guard Chemical Response Suit. It appears that while the DSC and TGA can detect gross changes in an exposed protective material, sophisticated equipment and a high level of skill are necessary to determine even qualitative changes in a material. A final report is being prepared to complete the project.

FUTURE WORK: No additional method development work is planned. The Coast Guard may use these methods in its evaluation of decontamination methods.

REPORT:

1. S.W. Weidenbaum et al, "Thermal Analysis as a Means of Monitoring Protective Clothing." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.

AGENCY CONTACT: Dr. Alan P. Bentz
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TITLE: INVESTIGATION OF COAST GUARD CHEMICAL RESPONSE SUIT EXHAUST VALVE PERFORMANCE (4155.4.1.5)

AGENCY: U.S. Coast Guard

OBJECTIVE: To investigate the performance of Coast Guard Chemical Response Suit exhaust valves.

FACILITY: Lawrence Livermore National Laboratory, Livermore, CA

TIMEFRAME: 1986-1988

DESCRIPTION: Suit exhaust valves are constructed of relatively low-resistant materials and have uncertain performance. Little testing has been conducted to determine the performance characteristics of these valves. It is not known, for example, whether different types of valves are truly one-way, preventing negative pressures in the suits and the backflow of chemical through the valve(s), or how different operating pressures may affect this performance. Understanding the performance of these components requires that standard techniques be established. This program will provide the basis for both comparing and improving exhaust valves used in totally-encapsulating chemical protective suits.

STATUS/RESULTS: Lawrence Livermore National Lab is measuring the performance of suit exhaust valves. This effort involves developing a method and designing a test apparatus to measure individual valve performance, in particular, the pressures at which respective valves open and their resistance to backflow. Coast Guard Chemical Response Suit valves and other commercial valves have been tested using methane as a tracer gas. The test apparatus is divided into two chambers, with one side representing the interior of the suit (attached to a breathing machine) and the other side containing the challenge chemical. The apparatus also includes instrumentation to measure chemical concentration, pressure, and flowrate. By September 1987, leak rates and operating pressures had been measured for six different types of valves.

FUTURE WORK: Additional efforts are being considered in determining: (1) performance differences between valve types (flapper versus spring-loaded), (2) if valve leak rate is linear with concentration, and (3) the effect of splash covers and valve geometry.

REPORT:

1. P.M. Swearengen, J.S. Johnson, and J.O. Stull, "Evaluating the Performance of One-way Vent Valves Used in the Construction of Totally-Encapsulating Protective Suits." Presented at 2nd International ASTM Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.

AGENCY CONTACT: LTJG Bruce Herring
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TITLE: PHYSICAL PROPERTY TESTING OF CHEMICAL PROTECTIVE CLOTHING MATERIALS
(4155.4.1.6)

AGENCIES: U.S. Coast Guard
U.S. Environmental Protection Agency

OBJECTIVE: To measure the physical properties of the fabrics used in chemical protective clothing, especially totally-encapsulating chemical protective suits.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1987-1988

DESCRIPTION: Material physical properties rarely are considered in chemical protective clothing selection. Few manufacturers report physical properties for the materials used in their protective garment products. Yet, physical properties provide a good indication of material integrity and resistance to physical and environmental abuses. Common physical properties include thickness, weight, strength (tensile and bursting), and resistance to tears, cuts, punctures, and abrasions. A number of standard methods, including those of ASTM, exist for measuring these properties, but few criteria are available to assess a material's physical performance as related to probable exposure conditions.

STATUS/RESULTS: The EPA and the Coast Guard have prepared a work statement to quantify the physical properties of several representative protective clothing materials used in chemical spill response. The program contractor, Arthur D. Little, Inc., will select physical properties that provide the most meaningful results to end-users, i.e., those properties which best relate to actual use conditions. Part of this work will involve developing or modifying test methods to measure material performance in techniques that simulate actual use. After selecting a "battery" of physical properties, Arthur D. Little, Inc., will test several representative materials.

FUTURE WORK: A report, summarizing the physical property tests performed for each material, will be prepared. These results will be used to set performance levels for protective clothing materials used in emergency response applications. This work will support the development of standards by the ASTM and the NFPA.

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TITLE: THERMAL RESISTANCE TESTING OF CHEMICAL PROTECTIVE CLOTHING MATERIALS
(4155.4.1.7)

AGENCY: U.S. Coast Guard

OBJECTIVE: To measure the thermal resistance of protective clothing suit materials in terms of flammability, heat conduction, and heat degradation.

FACILITY: North Carolina State University, Raleigh, NC

TIMEFRAME: 1986-1987

DESCRIPTION: Several standard methods exist for measuring the flammability and heat-related properties of either textile or plastic/rubber materials. North Carolina State University is identifying or developing thermal resistance test methods for chemical protective clothing materials that are representative of the end-application. For example, materials should be classified in terms of ignition and self-extinguishing characteristics. They also are investigating how well materials retain certain key physical properties when exposed to low level heat for a long time as experienced in some storage conditions (heat degradation) and through contact with hot surfaces (heat conduction).

STATUS/RESULTS: The School of Textiles at North Carolina State University has devised appropriate methods to measure the flammability, heat conduction, and heat degradation of several representative materials used in chemical protective suits. Flame resistance tests provide ignition time, distance of burn, and the amount of time that samples continue to burn. Physical property testing (weight change, tensile strength, tear resistance, and stiffness) was conducted on samples exposed to both conductive and convective (oven) heat. Only small changes in material physical properties were observed, indicating little heat effect. However, permeation breakthrough time increased significantly for three of the four materials exposed to low convective heat.

FUTURE WORK: An interim report is available, containing most of the results for each material. North Carolina State University will investigate other material properties such as flame and heat resistance. A final report, with this information, is due in March 1988. The testing results will be used to set performance levels of protective clothing material used in emergency response applications. This work supports the development of comprehensive protective clothing standards by the ASTM and the NFPA.

REPORT:

1. R.L. Barker, and S.K. An, "Interim Report-Measurement of Flame Resistance, Conductive Heat Resistance, and Heat Degradation for Chemical Protective Suit Materials." North Carolina State University, August 1987.

AGENCY CONTACT: Dr. Alan P. Bentz
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TITLE: FIELD-RUGGED HAZARDOUS CHEMICAL PORTABLE PERSONAL MONITOR (4155.4.3.1)

AGENCY: U.S. Coast Guard

OBJECTIVE: To develop a field-portable instrument capable of detecting and identifying several priority hazardous chemicals with a simple, easy-to-use technology.

FACILITY: Argonne National Laboratory, Chicago, IL

TIMEFRAME: 1981-1987

DESCRIPTION: In 1981, Argonne National Laboratory was tasked with developing a new sensor technology which could be employed to monitor several chemicals in the field with a portable, low cost, low maintenance, easy-to-use device. They identified operational requirements and selected an appropriate analytical technique which could meet those requirements. They chose the combination of electrochemical cells and catalytic filaments configured in an array which provides universal detection of both inorganic and organic chemical vapors. This sensor package is coupled with a powerful microcomputer to monitor operations and process signal outputs. Four laboratory prototypes were constructed to demonstrate feasibility of the technology and to measure the accuracy, precision, sensitivity, and selectivity of the technique.

STATUS/RESULTS: Argonne National Laboratory has designed and fabricated prototypes that are field-rugged, incorporate changes identified in the laboratory prototype evaluation, and are flexible in design to accommodate future improvements. They delivered the four prototype chemical monitors with design drawings, specifications, and operating manuals. The portable instruments are approximately 12"(L)x8"(W)x10"(H), weigh 18 pounds, use a chemical library of 25 chemicals, and have information relayed via a 32 character liquid crystal display. The Coast Guard R&D Center and the Atlantic Strike Team evaluated these prototypes and found them to meet the majority of their requirements. Argonne National Laboratory also has investigated expanding the monitor chemical library to 100 chemicals.

FUTURE WORK: A final report on the development of the monitor is due in March 1988. While this technology is somewhat successful, the Coast Guard does not intend to do any additional development work. Commercialization efforts may be pursued if other parties are interested in sharing production engineering costs.

REPORTS AND PRODUCTS:

1. Internal Report-Laboratory Monitor Prototype Evaluation.
2. Five Field Monitor Prototypes and Specifications.

AGENCY CONTACT: C.B. Billing, Jr.
U.S. Coast Guard R&D Center
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TITLE: DEVELOPMENT OF A COMMUNICATIONS SYSTEM COMPATIBLE WITH CHEMICAL PROTECTIVE CLOTHING (4155.4.4.1)

AGENCIES: U.S. Coast Guard
U.S. Fire Administration

OBJECTIVE: To develop an effective "hands-free" communications system that is compatible with different types of chemical protective clothing (CPC).

CONTRACTOR: Remic Corporation, Elkhart, IN

TIMEFRAME: 1985-1986

DESCRIPTION: Under an interagency agreement, the Coast Guard, NASA, and FEMA jointly developed a communications system compatible with CPC using a commercial contractor, Remic Corporation. Remic Corporation had completed an earlier contract with the NASA Marshall Space Flight Center and FEMA to develop a firefighters' communication system, a system which showed promise for Coast Guard emergency response applications. Therefore, Remic Corporation was awarded another contract under which it (1) developed alternative configurations to package state-of-the-art communications technology in a device that met Coast Guard requirements, and was compatible with both totally-encapsulating chemical protective suits and splash suits, (2) developed a design for the Coast Guard-selected configuration of the chemical suit communications system, (3) constructed operational prototypes using the detailed design, (4) subjected the prototype transceivers and repeaters to field tests under actual conditions by the Pacific Strike Team, and (5) prepared a final report, specifications, and design drawings. Field input was sought at each of these phases.

STATUS/RESULTS: The development contract was completed in July 1986. Two commercial communications systems--the Earmark Model HLD-3M and the Communications Applied Technology C-AT QB-2 system--were evaluated by the Gulf and Pacific Strike Teams as alternatives to the Remic system. The merits of these systems, the prototype Remic system, and the current Strike Team communications devices were compared and the results are being summarized in an internal Coast Guard report.

FUTURE WORK: The Coast Guard will decide whether to produce the Remic System or use existing commercial devices for chemical spill response communications.

REPORT AND PRODUCTS:

1. Communications system prototypes and specifications.
2. B.D. Blood, and R.E. Radke, "Final Report-Development of a Communications System Compatible with Chemical Protective Clothing." CG-D-18-86 (NTIS #AD A170 683), June 1986.

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TITLE: EVALUATION OF COAST GUARD CHEMICAL RESPONSE SUIT COOLING SYSTEM AND
COMMERCIAL COOLING DEVICES (4155.4.4.2)

AGENCY: National Institute for Occupational Safety and Health (NIOSH)
U.S. Coast Guard

OBJECTIVE: To evaluate the differences in heat stress when wearing the Coast Guard Chemical Response Suit with and without cooling; to compare the cooling effects for selected cooling devices operating inside the Coast Guard Chemical Response Suit. The Chemical Response Suit is a totally-encapsulating chemical protective suit.

FACILITY: Division of Safety Research, Morgantown, WV

TIMEFRAME: 1987-1988

DESCRIPTION: The burden of cooling systems normally deployed with the Coast Guard Chemical Response Suit may actually negate the provided cooling effect, and contribute to heat stress. The Coast Guard and NIOSH have measured physiological responses of test subjects wearing the Chemical Response Suit with and without different cooling systems. These responses were compared against baseline tests for the subjects not wearing any protective clothing. All measurements were made during an exercise routine which was conducted inside an environmental chamber at 90°F and 50% relative humidity.

STATUS/RESULTS: All tests were conducted during June-July 1987. Physiological and subjective responses were measured/recorded for nine test subjects wearing the various ensembles. Cooling devices evaluated included the Coast Guard water-recirculating system (integrated into the suit), a Freon-based system, and "blue-ice" vests. Preliminary analysis has indicated slower increases in heart rate, skin temperature, and core temperature for wearing of the blue-ice based cooling systems as compared to the two other cooling systems. Test subjects also found the blue-ice based systems easier to don and more comfortable. These results are being analyzed and should be available by March 1988 in an American Industrial Hygiene Association Journal article.

FUTURE WORK: Not identified.

AGENCY CONTACT: LTJG Bruce Herring
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TITLE: OVERALL LABORATORY TESTING OF THE COAST GUARD CHEMICAL RESPONSE SUIT AND COMMERCIAL CHEMICAL PROTECTIVE SUITS (4155.5.1.1)

AGENCIES: Federal Emergency Management Agency
Occupational Safety and Health Administration
U.S. Coast Guard

OBJECTIVE: To test the integrity of the Coast Guard Chemical Response Suit and commercial chemical protective suits, using laboratory methods to measure the "protection factor" and internal suit pressure during simulated operations.

CONTRACTOR: Lawrence Livermore National Laboratory, Livermore, CA

TIMEFRAME: 1986-1988

DESCRIPTION: Lawrence Livermore National Laboratory has developed a test protocol to measure the "protection factor" of totally-encapsulating chemical protective suits using both Freon™ and aerosol challenge agents. This test protocol involves a subject, wearing the chemical protective suit and a self-contained breathing apparatus, undergoing a series of exercises in a closed chamber while the internal suit and chamber concentrations of the challenge agents are measured. The "protection factor" is determined by measuring the concentration of a challenge chemical agent both inside and outside the suit, the ratio of chamber to internal suit concentration measurements is the protection factor. Additionally, during the 30 minute exercise regimen, the pressure inside the suit is monitored and recorded. The integrity of all suits subjected to this testing was evaluated with ASTM F1052, "Practice for Pressure Testing of Gas-Tight, Totally-Encapsulating Chemical Protective Suits."

STATUS/RESULTS: Lawrence Livermore National Lab tested the integrity of several sample Coast Guard Chemical Response Suits. They measured protection factors of over 10,000 and observed internal suit pressures ranging from 0.1 to 7.0 inches water. This testing identified minor problems with the Chemical Response Suit which were corrected early in its production.

FUTURE WORK: A number of commercial chemical protective suits will be tested using this protocol, and the data will be used to compare the Coast Guard suit with commercial suits. Lawrence Livermore also will assess the differences in protection factors based on both challenge agents. These results will be published in another NTIS final report.

REPORT:

1. J.S. Johnson, "Final Report-Manned Integrity Testing of the Coast Guard Chemical Response Suit." Lawrence Livermore National Laboratory, CG-D-19-87 (NTIS #AD A185 736).

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TITLE: FIELD TESTING OF THE COAST GUARD CHEMICAL RESPONSE SUIT AGAINST HYDROGEN FLUORIDE VAPOR (4155.5.1.2)

AGENCY: U.S. Coast Guard

OBJECTIVE: To test the overall integrity of the Coast Guard Chemical Response Suit, focusing on its performance in controlled spill of hydrogen fluoride.

CONTRACTOR: Lawrence Livermore National Laboratory, Livermore, CA

TIMEFRAME: 1986-1987

DESCRIPTION: The Department of Energy and Lawrence Livermore National Laboratory have established a new facility for hazardous materials spills research at the Nevada Test Site. This facility provides data for public safety by studying the controlled spills of several hazardous substances. In the summer of 1986, AMOCO Oil Company sponsored a series of large scale hydrogen fluoride (HF) releases at the test site to develop and test atmospheric dispersion models. Lawrence Livermore used this opportunity to test sample Coast Guard Chemical Response Suits during two of the HF releases. Each totally-encapsulating chemical protective suit was placed on an instrumented mannequin 300 meters from the release nozzle and subjected to HF concentrations up to 30,000 ppm for ten minutes. Telemetry was used to control breathing air (to simulate exhaust from the breathing apparatus) and two of the four different chemical detection systems inside the suit.

STATUS/RESULTS: The results of the ensemble test showed no detectable hydrogen fluoride penetration into either of the suits tested. The most sensitive chemical detection system inside the suit had a lower limit of detection at 0.03 ppm. Also, there was no evidence of chemical degradation on the outside of the suit.

FUTURE WORK: Not identified.

REPORT AND PRODUCTS:

1. J.O. Stull, J.S. Johnson, and P.M. Swearengen, "Hydrogen Fluoride Exposure Testing of U.S. Coast Guard's Totally-Encapsulating Chemical Protective Suit." Presented at 2nd International Symposium on Performance of Protective Clothing, Tampa, FL, January 1987.
2. Videotape on Exposure of Coast Guard Chemical Response Suit to Hydrogen Fluoride.

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TITLE: HEAT STRESS TESTING OF THE COAST GUARD CHEMICAL RESPONSE SUIT
(4155.5.1.3)

AGENCY: U.S. Coast Guard

OBJECTIVE: To measure the heat stress from wearing the Coast Guard Chemical Response Suit and to provide preliminary guidelines for using the totally-encapsulating chemical protective suit under different environmental conditions.

FACILITY: University of North Carolina
U.S. Coast Guard Atlantic Strike Team, Elizabeth City, NC

TIMEFRAME: 1986-1987

DESCRIPTION: A Coast Guard graduate student at the University of North Carolina conducted a study in cooperation with the Coast Guard Atlantic Strike Force to measure heat stress in the new Chemical Response Suit. In July 1986, physiological responses (heart rate, core temperature, skin temperature in three locations, and weight loss) of six Atlantic Strike Team test subjects were measured while they were wearing Coast Guard Chemical Response Suits. These measurements were compared with responses of test subjects not wearing the suit under the same environmental conditions. Two sets of environmental conditions were used: indoors at 70°F and outdoors at 85°F with direct solar radiation.

STATUS/RESULTS: Both weight loss and skin temperature varied greatly and were not easily related to heat stress. The results showed that pulse rate may be a good indicator of heat stress and its routine measurement in the field could be used to regulate a wearer's time inside the suit. The Coast Guard graduate student is preparing the report on this study as part of a master's thesis.

FUTURE WORK: This work will be extended to include a larger sampling of test subjects and to evaluate different commercial cooling devices.

REPORT:

1. W.D. Eley, "Final Report-Heat Stress Testing of the Coast Guard Chemical Response Suit." May 1987, NTIS number not yet available.

AGENCY CONTACT: LTJG Bruce Herring
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TITLE: AUGMENTATION OF CHEMICAL SUIT SELECTION GUIDELINES (4155.5.1.2)

AGENCIES: U.S. Coast Guard
U.S. Environmental Protection Agency

OBJECTIVE: To develop comprehensive guidelines for the selection of chemical protective clothing (CPC), particularly lower level protective clothing (splash suits).

CONTRACTORS: Los Alamos National Laboratory, Los Alamos, NM
Arthur D. Little, Inc., Cambridge, MA

DESCRIPTION: A variety of protective clothing is commercially available for emergency response. The Coast Guard needs clothing selection guidelines to optimize the items purchased to obtain the most efficient (in terms of chemical response) and cost-effective inventory. These guidelines should include the information/data on: (1) protective clothing materials from chemical and physical properties, (2) clothing fabrication processes, (3) clothing design features of commercial CPC, and (4) manufacturer quality control and assurance procedures. This work has taken the form of modifying the EPA's "Guidelines for the Selection of Chemical Protective Clothing," which already contains much of the existing material chemical resistance and vendor data. These guidelines were prepared by Los Alamos National Laboratory and Arthur D. Little, and published by the American Conference of Governmental Industrial Hygienists.

STATUS/RESULTS: By the end of 1986, Los Alamos National Laboratory and its subcontractor, Arthur D. Little, had completed a new draft edition of the "Guidelines". Concurrently, the EPA updated the material-chemical compatibility information for this publication. This product is available in two volumes (Volume I - Field Manual, Volume II - Technical and Reference Manual) through NTIS. It also will be made available through the American Conference of Governmental Hygienists (6500 Glenway Avenue, Bldg. D-5, Cincinnati, OH 45211, 513-661-7881).

FUTURE WORK: The Coast Guard will pursue a mechanism with other Federal agencies to update the information in the "Guidelines" as more data becomes available.

PRODUCT:

1. A.D. Schwope, P.P. Costas, J.O. Jackson, J.O. Stull, and D.J. Weitzman, "Guidelines for the Selection of Chemical Protective Clothing." Third Edition, February 1987. (Available through the American Conference of Governmental Industrial Hygienists (ACGIH), phone (513) 661-7881, NTIS #AD A179 516 and #AD A179 164).

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SECTION 5
ENVIRONMENTAL PROTECTION AGENCY

TITLE: CHEMICAL PROTECTIVE CLOTHING GUIDELINES ON-LINE DATA BASE

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To develop an automated data base containing information for selecting chemical protective clothing (CPC).

FACILITY: U.S. Environmental Protection Agency Headquarters, Washington, DC

TIMEFRAME: 1985-1988

DESCRIPTION: EPA is developing an on-line automated data base system for selecting CPC. The system is being developed using Battelle's Automated Search Information Systems (BASIS). BASIS, a software package which supports the searching and retrieval of full-text systems, is being run on an IBM 3090 with MVS/XA operating software. The data base includes recommendations for clothing selection, a chemical index, a product index, a vendor directory, product description codes, clothing classification codes, permeation data, weight change data, swelling data, diffusion coefficients, tensile strength, and text. The system will allow the user to enter the data base at any level and search. The CPC system can be accessed through menus or by using BASIS commands.

STATUS/RESULTS: The User's Manual for the on-line system is presently being written.

FUTURE WORK: The data base will be updated semi-annually as more CPC data becomes available. EPA will also periodically publish hard copy editions of "Guidelines for the Selection of Chemical Protective Clothing." The fourth edition of the "Guidelines" will be completed in late 1989 (see page 60).

REPORT:

1. A.D. Schwope, P.P. Costas, J.O. Jackson, J.O. Stull, and D.J. Weitzman, "Guidelines for the Selection of Chemical Protective Clothing." Third Edition, February 1987. (Available through the American Conference of Governmental Industrial Hygienists (ACGIH), phone (513) 661-7881, NTIS #AD A179 516 and #AD A179 164).

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TITLE: PREDICTING THE EFFECTIVENESS OF CHEMICAL PROTECTIVE CLOTHING: MODEL AND TEST METHOD DEVELOPMENT (Reference Nos.: DU No. L-104; Contract No. 68-03-3113, Work Assignment 1-2)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To evaluate and improve approaches by which the EPA's Office of Toxic Substances can estimate the permeation resistance of chemical protective clothing (CPC) as part of the Toxic Substances Control Act mandated Premanufacture Notification Review Program.

CONTRACTORS: JRB Associates (now SAIC), McLean, VA
Southern Research Institute, Birmingham, AL

TIMEFRAME: January-September 1986

DESCRIPTION: Several theoretical permeation models and test methods for estimating permeation related properties were identified and compared to the results of permeation tests. The models and test methods chosen were based on theories of the solution thermodynamics of polymer/solvent systems and the diffusion of solvents in polymers. These models and test methods were further developed to estimate the solubility (S) and the diffusion coefficient (D) for a solvent in a glove polymer. Given S and D, the permeation of a glove by a solvent can be predicted for various exposure conditions using analytical or numerical solutions to Fick's laws.

STATUS/RESULTS: This project has been completed. The model developed for estimating solubility is based on Universal Quasichemical Functional Group Activity Coefficients for Polymers (UNIFAP) theory, which is an extension of the Universal Quasichemical Functional Group Activity Coefficient (UNIFAC) method for predicting phase equilibria. The model recommended for estimating diffusion coefficients versus concentration is the Paul model, which is based on free-volume theory. The predictive test method developed is a liquid-immersion absorption/desorption method that provides estimates of S and D. The models and test methods chosen were incorporated into an algorithm for evaluating protective gloves recommended for use with new chemicals. Limited confirmation of the developed models and test methods was performed by comparing estimated values of S and D with reported experimental data, and by using the estimated values to predict instantaneous permeation rates, breakthrough times, and steady-state permeation rates for comparison with experimental permeation data.

FUTURE WORK: Follow-on work is being conducted under Contract 68-03-3293, Work Assignments 01, 08, and 80.

REPORT:

1. A.S. Bhowm, E.F. Philpot, D.P. Segers, G.D. Sides, and R.B. Spafford, "Predicting the Effectiveness of Chemical Protective Clothing: Model and Test Method Development." EPA-600/86/055, (NTIS #PB86-209-087/AS), September 1986.

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TITLE: DEVELOPMENT AND ASSESSMENT OF METHODS FOR ESTIMATING CHEMICAL PROTECTIVE CLOTHING (CPC) PERFORMANCE (Reference Nos.: Lab Work Plan No. TOX-003a and TOX-004; DU No. L-104; Objective E; PPA 15; Project No. 21; Contract No. 68-03-3293, WA 01, 08 and 80)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To evaluate and improve the procedures used by EPA's Office of Toxic Substances (OTS) to estimate the effectiveness of CPC in reducing chemical exposure as part of Premanufacture Notification (PMN) review.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1989

DESCRIPTION: The major components of a methodology for assessing clothing effectiveness have been developed which include a predictive model prototype for estimating CPC permeation resistance, and guidelines for specifying and interpreting results from chemical resistance tests. The permeation estimation model is based on Fick's law and was developed specifically to meet OTS needs for simplicity, accuracy, and broad applicability. Also, the contractor reviewed and is actively working (in conjunction with ASTM) to improve chemical resistance tests methods and data reporting requirements. During FY87, the effort focused upon working with OTS to integrate and implement the model and data interpretation guidelines into the standard PMN review process.

STATUS/RESULTS: The model predicts the diffusion coefficient and solubility and from them permeation. It is available on a personal computer at OTS and is under evaluation. Feedback has been positive. Existing test methods have been critically reviewed and a hierarchy for test method specification by OTS has been proposed. Also, major improvements to the ASTM F739 permeation method are being implemented and a splash permeation test method, believed to simulate a more realistic workplace exposure, is under development.

FUTURE WORK: The overall objective of FY88 is to integrate these existing components into an overall system that will expand and accelerate OTS's ability to estimate CPC effectiveness against PMN chemical exposure. The permeation model and test data interpretation guidelines will be further refined and validated. Development and validation of a splash test method, in cooperation with ASTM, will also be pursued.

REPORTS AND PRODUCTS:

1. R. Goydan, A.D. Schwope, and R.C. Reid, "Review of Models for Predicting Chemical Protective Clothing Effectiveness." EPA internal report, March 1986.
2. R. Goydan et al., "Development and Assessment of Methods for Estimating Protective Clothing Performance." Project report and project summary, EPA/600/2-87/104, October 1987.
3. Prototype of computer model (in Fortran) for use on an IBM PC, August 1986, revised September 1987.

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TITLE: SUPPORT FOR PREMANUFACTURE NOTIFICATION REVIEW - OCCUPATIONAL RESPIRATORY PROTECTION (Reference Nos.: Lab Work Plan No. TOX-006; DU No. L-104; Objective E; PPA 15; Project No. 21; Interagency Agreement DW 75931135)

AGENCY: U.S. Environmental Protection Agency (EPA) (joint with NIOSH)

OBJECTIVE: To provide EPA with information and research data on occupational respiratory protection to support EPA responsibilities under the Toxic Substances Control Act (TSCA). This support includes: (1) development of a decision logic concerning respirator selection recommendations, (2) recommendations on the degree of protection given by various respirators, and (3) research to determine actual respirator performance in the workplace.

FACILITY: National Institute for Occupational Safety and Health, Morgantown, WV

TIMEFRAME: May 1984-September 1989

DESCRIPTION: The initial phase of this work involved an assessment of quantitative fit test methods, which measure the effectiveness of a respirator by comparing the concentration of a test contaminant inside the respirator facepiece, to that outside the respirator. Laboratory evaluations demonstrated that measured protection factors are strongly biased by sampling probe location, face seal leakage, and breathing patterns.

STATUS/RESULTS: A Respirator Decision Logic was published by NIOSH (NIOSH publication No. 87-108), in fulfillment of objective No. 1. Evaluations were undertaken to determine the precision and bias associated with five alternative methods of in-facepiece sampling, using nine different facepieces. Of the five candidate procedures, one involving pulsed exhalation and deep probing demonstrated the best combination of bias and precision measurements and was selected as a recommended replacement for the conventional quantitative assessment of respirator fit and workplace protection.

FUTURE WORK: Having identified a candidate replacement procedure with significantly better precision and lower bias, a pilot scale evaluation of this procedure is planned for early FY88. Based on favorable results from pilot scale evaluations, full scale field evaluations shall commence later in FY88.

REPORTS:

1. W.R. Myers, "Interim Report on Laboratory Testing of Respirators: Biases Associated with In-Facepiece Sampling of Respirators." Completed September 1986, not yet published.
2. W.R. Myers, and R.W. Hornung, "Interim Report on Laboratory Testing of Full Facepiece Respirators--Evaluation of New In-Facepiece Sampling Procedures for Full Facepieces." Completed September 1987, currently being processed for entry into NTIS.
3. W.R. Myers, and J.R. Allender, "Causes of In-Facepiece Sampling Bias for Full Facepiece Respirators." Accepted for publication in the annals of the Occupational Hygiene, Pergamon Press Ltd., British Occupational Hygiene Society.
4. DHHS (NIOSH) Publication No. 87-108, "Respirator Decision Logic." Published May 1987.

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TITLE: PROTECTIVE CLOTHING TESTING AND TEST METHOD DEVELOPMENT FOR AGRICULTURAL PESTICIDE OPERATIONS (Reference Nos: Lab Work Plan No. PEST-07; DU E-104; Objective E: PPA 09: Project #90: Contract 68-03-3293, Work Assignment 100)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVES: (1) To produce, assemble and critically evaluate data of known precision and accuracy on the effectiveness of polymer gloves against pesticide; (2) To identify and verify correlations in the data collected in pursuit of objective #1 that will improve the ability of personnel to select or recommend appropriate chemical protective clothing for agricultural uses.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1989

DESCRIPTION: Prior to the conduct of this work, there was no suitable method for conducting permeation tests with many pesticides because of their low water solubility and low vapor pressure, which hindered their effective collection in these tests. In this study, several collection media were investigated and a silicone rubber sheeting was selected as the most effective. Using a modified ASTM F739-85 permeation test procedure with the silicone rubber sheeting, permeation tests have been conducted on 54 pesticide formulation/glove pairs (in triplicate). The permeation of both the active ingredient and the carrier solvent were measured. Degradation tests were conducted on 90 pesticide formulation/glove pairs (in duplicate). Seven generic types of protective glove materials were tested. The active ingredients studied to date are parathion, methyl parathion, ethion, endosulfan, methyl oxydemeton, monocrotophos, and dicrotophos. These formulations included a variety of carrier solvents such as xylenes, ketones, or alcohols.

STATUS/RESULTS: Statistical analysis of the 8-hour cumulative permeation data shows that 74% of the active ingredient permeation can be accounted for by measuring the carrier solvent permeation and adjusting for the percentage of active ingredient present in the formulation. Furthermore, very few gloves resist permeation of the carrier solvent and the active ingredient for an 8-hour period.

FUTURE WORK: In 1988, the development of a voluntary consensus standard involving the use of silicone rubber sheeting for the modified permeation test is ongoing. Permeation testing with additional pesticides and carrier solvents is underway. The results will be used to better define test method limitations and to refine and expand correlations for use in glove selection guidance and training. Oral presentations will be given to the ASTM and to the American Industrial Hygiene Conference.

REPORTS:

1. D.J. Ehntholt et al., "Laboratory Evaluation of the Degradation and Permeation Resistance of Polymer Gloves to Pesticide Formulations." Draft Internal Report, September 1987; Revised Draft, November 1987.

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TITLE: PROTECTIVE APPAREL FOR DERMAL EXPOSURE REDUCTION IN PESTICIDE APPLICATION
(Reference Nos.: Lab Work Plan No. PEST-03; DU No. E-104; Objective E;
PPA 09; Project No. 90; Cooperative Agreement CR812486)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: (1) To measure and compare the pesticide penetration resistance of selected clothing fabrics; (2) to identify correlations between penetration resistance and the physical properties of the fabrics; and (3) to assess the thermal comfort of fabrics.

CONTRACTOR: University of Tennessee, Knoxville, TN

TIMEFRAME: 1985-1988

DESCRIPTION: To isolate the effect of fabric characteristics on pesticide penetration, eight woven fabrics were screened for weight and thickness and evaluated for penetration properties. The fabrics were evaluated with and without a fluorocarbon finish using four pesticides: Chlorobenzilate, Dicofol, Ethion, and Terrazole. In addition, eight nonwoven fabrics were evaluated for penetration protection. All fabrics were evaluated for thermal properties by a battery of three thermal tests.

STATUS/RESULTS: A total of 600 fabric samples were tested and the data analyses and statistic evaluations have been completed. The findings indicate that in woven fabrics, weight is the most influential fabric characteristic in predicting pesticide penetration. Caution is recommended for agricultural workers wearing clothing below 250 g/m². Alternative nonwoven fabrics were found to provide a penetration barrier equal to Tyvek™. In thermal comfort laboratory testing, weight and thickness of woven fabrics were found to influence thermal performance; in nonwoven fabrics, the addition of a natural fiber appears to be the only factor in increasing thermal comfort performance. Based on the results, fabrics with superior combinations of thermal comfort and penetration protection have been identified in the laboratory.

FUTURE WORK: The fabrics have been constructed into coveralls and are being subjected to field tests with citrus and greenhouse workers under Cooperative Agreement CR810743 with the University of Florida.

REPORTS:

1. C.B. Hassenboehler, Jr., H.N. Nigg, and J.O. DeJonge, "Comparison of a Thermal Test Battery Analysis and Field Assessments of Thermal Comfort of Protective Apparel for Pesticide Application." International ASTM Symposium on the Performance of Protective Clothing, Proceedings, January 1987.
2. J.O. DeJonge, E. Easter, "Protective Apparel for Dermal Exposure Reduction in Pesticide Application." Draft Project Report (1988).

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TITLE: FLORIDA PESTICIDE HAZARD ASSESSMENT PROJECT (Reference Nos.: Lab Work Plan No. PEST-04; DU No. E-104; Objective E; PPA 09; Project No. 90; Cooperative Agreement CR810743)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To investigate (1) the pesticide exposure received by workers in various agricultural pesticide operations, and (2) the penetration of the pesticide through various protective coveralls, and (3) the thermal comfort of these coveralls while doing actual field activities. This work is conducted in support of regulatory and educational activities of the EPA's Office of Pesticide Programs mandated by the Federal Insecticide, Fungicide, and Rodenticide Act.

FACILITY: University of Florida, Lake Alfred, FL

TIMEFRAME: 1985-1988

DESCRIPTION: Efforts have been directed toward field tests of (1) pesticide exposure received by workers in greenhouses and in citrus groves in Central Florida, (2) the penetration resistance of pesticides through various protective clothing materials, and (3) the workers' thermal comfort while wearing these protective suits using physiological data. These studies provide data for future regulatory decisions for protecting greenhouse and citrus grove applicators, who tend to spray frequently in hot and humid conditions and tend to stay for long periods in the treated areas. Raw data are generated by having the sprayers wear collection patches on the inside and outside of the protective suit. The patches are worn for measured periods of work, then removed and subjected to extraction and chemical analysis to quantify the presence of pesticides. A standard procedure is followed to extrapolate the pesticide concentration in the patches to an estimate of whole body exposure. By calculating the accumulated body exposure inside the suit and dividing by the accumulated body exposure outside the suit, a ratio of penetration through the suit can be deduced. Physiological data on the subject includes measuring skin temperatures on the shin, forearm, and chest, and heart rate at designated times throughout the work exposure period.

STATUS/RESULTS: Approximately 3000 pesticide samples generated in the first phase of the greenhouse applicator study identified a number of promising fabrics which could be used for coveralls in Florida citrus operations and in greenhouses. Almost 2000 pesticide samples have been generated during the second phase of the project which deals with penetration through four different experimental protective suits. Almost 200 exposures in Florida citrus groves have been completed to assess worker's thermal comfort in these suits. Pesticide data is still being generated in greenhouse environments. Work is scheduled to be completed by March 1988.

FUTURE WORK: As clothing material recommendations are developed based on laboratory evaluations under Cooperative Agreement No. 81248 (University of Tennessee).

REPORT:

1. H.N. Nigg, J.H. Stampfer, and W.D. Mahon, "Pesticide Applicator Exposure to Florida Greenhouse Applicators." EPA/600/2-88/033 (NTIS #PB88-219331), June 1988.

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TITLE: INTERIM GUIDANCE MANUAL (IGM) FOR SELECTING PROTECTIVE CLOTHING FOR AGRICULTURAL PESTICIDE OPERATIONS (Reference Nos.: Lab Work Plan No. PEST-01; DU No. E-104; Objective E; PPA 09; Project No. 90; Contract 68-03-3293, Work Assignment 09)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To provide EPA's Office of Pesticide Programs (OPP) with a concise and up-to-date reference document on (1) assessing the probable effectiveness of polymer gloves for preventing dermal exposures to pesticides, and (2) assessing the limitations, imposed by thermal comfort and the risk of heat illness, on the use of protective garments for agricultural pesticide operations.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1987

DESCRIPTION: An IGM was produced to (1) characterize the operational requirements for protective clothing of mixers, loaders, and applicators of pesticides; (2) provide concise discussion of clothing fabrication methods for glove, designs, material types, and test methods; and (3) review available data on the resistance of glove materials to the chemicals present in pesticide formulations. The IGM proposes a clothing selection rationale for gloves to match and optimize the physical properties, human factors, and chemical resistance properties of a glove to the operational requirements of representative tasks performed by mixers, loaders, and applicators. Also, the issues of heat stress (a heat stress model is presented to guide the selection of full coverage clothing), and the development and regulation of safe work practices for field workers are addressed.

STATUS/RESULTS: The IGM was completed and delivered to the OPP.

FUTURE WORK: Further development of the IGM is planned (See Contract 68-03-3293, Work Assignment 130).

REPORT:

1. J.D. Sakura, A.D. Schwope, P.P. Costas, and R.F. Goldman, "Interim Guidance Manual for Selecting Protective Clothing for Agricultural Pesticide Operations -- Protective Gloves and Heat Stress Effects of Protective Garments." EPA Internal Report, September 1986.
2. J.D. Sakura, and A.D. Schwope, "External Review of the Interim Guidance Manual for Selecting Protective Clothing for Agricultural Pesticide Applications." EPA Internal Report, April 1987.

AGENCY CONTACT: Michael D. Royer
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TITLE: GUIDANCE MANUAL FOR THE SELECTION OF PROTECTIVE CLOTHING FOR AGRICULTURAL PESTICIDE OPERATIONS (Reference Nos. Lab Work Plan Nos. PEST-07; DU E-104; Objective E; PPA 09; Project No. 90; Contract 68-03-3293, Work Assignment 130)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To develop a guidance manual for the EPA's Office of Pesticide Programs (OPP) that will provide more detailed coverage of agricultural protective clothing topics than the Interim Guidance Manual (IGM) and that will serve as a basis for guidance documents for specific segments of the pesticides user community.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1987-1989

DESCRIPTION: The Guidance Manual will build upon the IGM, EPA research (e.g., Cooperative Agreements CR810743 and CR812486) and other efforts that are generating, collecting, and analyzing data on the performance of protective clothing for pesticide operations. Potential topics include: work task functional requirements for protective gloves; glove manufacturing methods and materials; performance data on gloves and other protective clothing; human factors data on gloves; field tests of glove performance; a summary of current research to evaluate and improve glove performance; guidance on the use of permeation and physical property test data in the selection process; glove and protective clothing product lists; penetration resistance of garment materials to pesticide sprays; thermal comfort and heat stress effects of protective clothing materials; effects of protective finishes; foot, eye, head, forearm/arm and respiratory protection; decontamination of pesticide-contaminated clothing; a list of available pesticide protective clothing documents and training materials; a list of reference documents; and selected case histories that identify unresolved problems.

STATUS/RESULTS: Information on the IGM has been produced. Data collection is underway. The IGM has been circulated among the research and user community; final topics selection will be based on their comments and recommendations, and on those of the OPP.

FUTURE WORK: Completion of the draft Guidance Manual is scheduled for April 1989.

REPORTS:

1. J.D. Sakura, A.D. Schwope, P.P. Costas, and R.F. Goldman, "Interim Guidance Manual for Selecting Protective Clothing for Agricultural Pesticide Operations-Protective Gloves and Heat Stress Effects of Protective Garments." EPA Internal Report, September 1986. (See also contract 68-03-3293, WA09).
2. Guidance Manual for Selecting Protective Clothing for Agricultural Pesticide Operations. Draft scheduled April 1989.
3. Intermediate products tailored to specific segments of the target audience; delivery dates to be determined.

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TITLE: DEVELOPMENT, PRODUCTION, AND TESTING OF A 2-1/2 HOUR, SELF-CONTAINED, FULLY ENCAPSULATING, CHEMICAL PROTECTIVE ENSEMBLE FOR WORKERS IN HIGHLY TOXIC ATMOSPHERES (Reference Nos.: Lab Work Plan #85277, DU No. Y-105; Objective D; PPA 02; Project No. 80; Interagency Agreement DW 21930850)

AGENCIES: Interagency Agreement between the Chemical Research and Development Center (U.S. Army) and U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To enhance worker safety during emergency response and uncontrolled hazardous waste site cleanup and to improve worker efficiency in atmospheres that are known or suspected to be immediately dangerous to life or health.

FACILITY: Chemical Research and Development Center, U.S. Army, Aberdeen Proving Ground, MD

CONTRACTOR: USD Corporation, Santa Ana, CA

TIMEFRAME: 1982-1987

DESCRIPTION: Project involved completing the development of a prototype long-term, self-contained, chemical protective ensemble (LSCPE). The major tasks were technical modifications of the LSCPE oxygen rebreather and totally-encapsulating chemical protective suit, National Institute of Safety and Health (NIOSH) certification of the breathing apparatus, and production of five complete LSCPE's.

STATUS/RESULTS: Modifications and NIOSH-required in-house testing were completed. In 1984, two breathing apparatuses sent to NIOSH for certification testing failed due to cracks in the breathing bag manifold. The parts were refabricated from a different material and the breathing apparatuses were resubmitted to NIOSH in late 1985. Shortly thereafter, another breathing apparatus failed NIOSH certification due to the failure of component parts very similar to those of the LSCPE breathing apparatus. No further attempts will be made to obtain NIOSH certification of the breathing apparatus.

FUTURE WORK: Alternate approaches to the objective will be pursued.

REPORTS:

1. M.D. Royer, D.D. Druyor, R.D. Turpin, and M. Kranz, "A Long-term, Self-contained, Chemical Protective Ensemble." Presented at the 1984 Hazardous Material Spills Conference, Nashville, TN, April 1984.

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TITLE: EVALUATION OF THE RESISTANCE OF A CHLORINATED POLYETHYLENE (CPE) PROTECTIVE GARMENT MATERIAL TO PERMEATION AND DEGRADATION BY LIQUID CHEMICALS (Reference Nos.: DU No. Y-105, Contract 68-03-3113, Work Assignment 1-1)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To evaluate the permeation and degradation resistance to a 20 mil chlorinated polyethylene chemical protective outer garment material when contacted by hazardous and toxic substances to which chemical spill and uncontrolled hazardous waste site response personnel may be exposed.

CONTRACTOR: JRB Associates (now SAIC), McLean, VA

TIMEFRAME: 1984-1985

DESCRIPTION: Ten liquid chemicals (acetic acid, acetic anhydride, acetone, bis (2-chloroethyl)ether, carbon tetrachloride, ethylene diamine, isopropyl alcohol, nitrosodimethylamine, phenol, and xylene) were placed in contact with 20 mil thick CPE in order to determine permeation rates, breakthrough times, and swelling of the CPE.

STATUS/RESULTS: This project has been completed. Mean permeation breakthrough times ranged from 15 minutes to over 8 hours. Steady-state permeation rates ranged from 0 to $170 \text{ mg.m}^{-2}.\text{s}^{-1}$. Swelling and solubility data also showed wide variation, depending upon the chemical. Soaking the CPE in one chemical resulted in a loss of weight, while contact with four other compounds resulted in weight gains of over 100% by the CPE test swatch. Chemical contact was also shown in eight of ten cases to reduce the capacity of the CPE to resist tearing due to deformation.

FUTURE WORK: Not identified.

REPORT:

1. J.M. Meade, W. Ellis, and J. Ludington, "Evaluation of the Resistance of a Chlorinated Polyethylene Protective Garment Material to Permeation and Degradation by Liquid Chemicals." EPA 600/85/084, (NTIS #PB85-242337), December 1985.

AGENCY CONTACT: Michael D. Royer
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TITLE: EVALUATION AND IMPROVEMENT OF CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT FOR HAZARDOUS SUBSTANCE RESPONSE OPERATIONS (Reference Nos.: Lab Work Plan No. 86022Y; DU No. Y-105; Objective D; PPA 02; Project No. 80; Contract 68-03-3293, Work Assignment 60)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To identify, evaluate, and promote technological improvements to commercially available or prototypical chemical protective clothing and associated equipment that have the potential for significantly enhancing the safety, efficiency, cost-effectiveness, and range of EPA and EPA contractor operations in emergency response and uncontrolled hazardous waste sites.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1989

DESCRIPTION: Protective clothing and equipment will be subjected to desktop, laboratory, and field evaluations, and the results provided to EPA personnel engaged in the selection, acquisition, and use of such clothing and equipment.

STATUS/RESULTS: Several tasks have been completed: (1) a draft evaluation of the high pressure oxygen compatibility of the materials of construction of a novel 2.5-hr. oxygen rebreather for the long-term, totally-encapsulating chemical protective suit (October 1986) (see IAG DW21930850); (2) a draft assessment of the state-of-knowledge of the physiological response of routinely breathing high concentrations of oxygen (October 1986); (3) an evaluation of the stiffness and strength at low temperatures of TeflonTM/NomexTM laminate; (4) a preliminary investigation of critical design features of back-mounted equipment (to minimize risk of back injuries); (5) a limited field evaluation of three vital signs monitors to assess ease of use, suitability for field use, and accuracy; (6) laboratory and field (Region 7, Dioxin site) evaluations of personal coolers; (7) survey of personal communications needs and problems; and (8) assessment of the life-cycle costs and quality of construction of protective clothing.

FUTURE WORK: In 1988, additional efforts in respirator performance, heat stress, and disposable clothing will be performed.

REPORTS:

1. W.S. Augerson, and C.C. O'Leary, "Technical Review of the Long-term, Self-contained Chemical Protective Ensemble Rebreather." October 1986 (Draft).
2. C.M. Snyder, "State-of-the-Art Study of Back Injuries Related to Back-mounted Equipment (Design Review and Literature Search)." November 1987 (Draft).
3. P.P. Costas, and A.D. Schwope, "Low Temperature Characteristics of Protective Clothing Materials." November 1987.
4. Heat Stress Field Study Report (In progress).

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TITLE: EVALUATION AND IMPROVEMENT OF PERSONNEL PROTECTIVE PROCEDURES FOR HAZARDOUS SUBSTANCE RESPONSE OPERATIONS (Reference Nos.: Lab Work Plan No. 86021Y; DU No. Y-105; Objective D; PPA 02; Project No. 80; Contract 68-03-3293, Work Assignment 50)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To evaluate, improve, and, if required, develop work practices to improve safety, efficiency, and cost-effectiveness of hazardous substance response operations.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1988-1989

DESCRIPTION: CERCLA/SARA mandates programs that require EPA personnel and EPA contractors to participate in investigation, mitigation, removal, and remedial operations that involve hazardous substances. The safety, efficiency, and cost of these operations are influenced by the availability, appropriateness, and reliability of a wide range of personnel health and safety procedures. Three efforts are underway: (1) development and evaluation of a field test kit for protective clothing, (2) evaluation of the technical and economic aspects of decontaminating protective clothing, and (3) application of robotics to waste site cleanup.

STATUS/RESULTS: A field test kit for chemical protective clothing has been developed and laboratory tested, and three kits have been supplied for field trials by EPA response groups. Liquid/waste is placed in a shallow cup, the cup is covered by a swatch of clothing material and inverted, and the rate of permeation is monitored gravimetrically by a two place, battery-powered balance. The permeation cup approach is the subject of interlaboratory testing by ASTM Committee F23. Approaches to removal of contamination from the surface and from matrix of clothing were critically reviewed. Among the conclusions were that the surface contamination could be removed (although no method has been optimized), but uncertainty would always exist relative to absorbed contamination. Also, a cost analysis of EPA FSOP #7 for decontamination was completed. Possible levels of absorbed contamination were estimated and used in an assessment of the proper disposal category for clothing: hazardous waste versus municipal land fill. Several high hazard or tedious hazardous waste site tasks were identified and possible applications of robotics/automation to those tasks were recommended.

FUTURE WORK: Several efforts will be performed in FY88: (1) further field testing of the test kit; (2) measure contamination in boots taken from field; (3) assess the feasibility of automating a soil bagging procedure used at dioxin clean-up sites; (4) update the Guidelines; and (5) produce a video tape on heat stress.

REPORTS:

1. D.J. Ehntholt, and D.L. Cerundolo, "Evaluation of Decontamination Agents and Methods for Removing Contaminants from Protective Clothing." Phase I Internal Report, September 1986.
2. T.R. Carroll, and A.D. Schwope, "Evaluation, Development, and Verification of Field Methods for Rapid, On-Site Determination of Appropriate Chemical Protective Clothing," (Draft), June 1988.

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TITLE: EVALUATION AND IMPROVEMENT OF PERSONAL HAZARD DETECTORS FOR HAZARDOUS SUBSTANCE RESPONSE OPERATIONS (Reference Nos.: Lab Work Plan No. 86121Y, DU No. Y-105; Objective D; PPA 02; Project No. 80; Contract 68-03-3293; Work Assignment 120)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To identify and evaluate commercially available or prototypical personal hazard detectors that have the potential for significantly enhancing the safety, increasing the range, improving the efficiency, or decreasing the cost of EPA or EPA contractor operations at uncontrolled hazardous waste sites or emergency response.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1989

DESCRIPTION: Desktop, laboratory, and field evaluations will be conducted on personal toxic gas, combustible gas, and oxygen deficiency detectors with the potential described in the objective statement. Evaluation criteria will include: reliability, ease of use, sensitivity, portability, cost, and safety. Results will be made available to EPA personnel who select, buy, and use personal hazard detectors. Detectors to be evaluated will be selected based on the detector needs and experience of EPA and EPA contractor personnel.

STATUS/RESULTS: Initial information gathering has been completed and an interim draft report has been produced. The report concludes that: (1) available information on the reliability of currently used and alternative chemical detectors is limited; (2) few experimental evaluations of detectors have been conducted under conditions similar to those in hazardous material incident responses; and (3) little information is available on the failure mechanisms for personal hazard detectors. Under field conditions, currently used and other available detectors exhibit some generic failure modes: (1) failure below 0°C; (2) lack of portability; (3) failure in precipitation; (4) selectivity (or lack thereof); and (5) lack of sensitivity.

Three organic vapor monitors, i.e., HNU 101, Photovac TIP and Foxboro OVA, are undergoing evaluation of operability and instrumental drift at -10°C, 25°C and 35°C and relative humidities of 15% and 95% RH. Preliminary results suggest that there is a greater effect of temperature and humidity on instruments using photoionization detectors than on instruments using flame ionization detectors.

FUTURE WORK: In 1988 information gathering will continue, and detectors will be evaluated under environmental extremes. Results will be documented and disseminated to users.

REPORTS:

1. K.T. Menzies et al., "Interim Evaluation of Hazard Detectors for Hazardous Substance Response Operations." Draft Internal Report, September 1986.
2. R.P. O'Neil et al., "Evaluation of Portable Organic Vapor Analyzers for Hazardous Substance Response Operations." Draft Interim Report, July 1988.

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TITLE: COORDINATION ACTIVITIES WITH EPA AND OTHER USER, MANUFACTURER, AND RESEARCH GROUPS PERFORMING RELATED PERSONNEL PROTECTION WORK (Reference Nos.: Lab Work Plan No. 86024Y; DU No. Y-105; Objective D; PPA 02; Project No. 80; Contract 68-03-3293, Work Assignment 70)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: To promote the transfer of information on personnel protection research needs, activities, plans, and outputs; to analyze and quantify EPA personnel protection technology research needs and potential benefits of meeting those needs; to conduct short-term, limited scope investigations of the state-of-the-art (SOA) of protective clothing and equipment in areas required to support EPA's missions.

CONTRACTOR: Arthur D. Little, Inc., Cambridge, MA

TIMEFRAME: 1986-1989

DESCRIPTION: This project includes: (1) conducting intra-EPA workshops to identify, quantify, and prioritize EPA research needs and advise attendees of current and planned (by EPA and other organizations) personnel protection research pertinent to their needs; (2) identifying, classifying, and tracking current personnel protection research of importance to EPA CERCLA/SARA programs; (3) performing SOA studies on topics related to EPA's personnel protection requirements, specifically to the safe and efficient performance of hazardous tasks at uncontrolled waste sites and chemical emergency responses; (4) producing a Personnel Protection Technology (PPT) Profile that will include EPA PPT research needs and ongoing research, an inventory of protective clothing and equipment, and a mailing list for agency members who require up-to-date information on the capabilities and limitations of PPT.

STATUS/RESULTS: Intra-EPA workshops on personnel protection technology research and research needs were conducted in 1986 and 1987. Work has been initiated in the other areas described above. A dBASE III+ mailing list has been produced and used.

FUTURE WORK: Activities planned for 1988 include: (1) continued participation in ASTM Committee F-23 on Protective Clothing; (2) oral presentations on research progress at the May AIHC; (3) participation in the Interagency Memorandum of Understanding Work Group; (4) conducting a third intra-EPA workshop on PPT; and (5) conducting an external peer review of all contract assignments in February.

REPORTS:

1. A.D. Schwope, J.B. Ketchum, and T.H. Murray, "Proceedings of Intra-EPA Workshop on Personnel Protection Technology." Internal Report, April 1987.
2. A.D. Schwope, J.B. Ketchum, T. Carroll, R. Murphy, and C. Mond, "Proceedings of Intra-EPA Workshop on Personnel Protection Technology." Day 1 and Day 2. November 1987 (Draft).

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TITLE: FLUORESCENT TRACER EVALUATION OF PROTECTIVE CLOTHING PERFORMANCE DURING OCCUPATIONAL EXPOSURE TO PESTICIDES (Reference Nos.: Lab Work Plan No. PEST-09; DU No. E-104; Objective E; PPA 09; Project No. 90; Cooperative Agreement CR814919-010)

AGENCY: U.S. Environmental Protection Agency (EPA)

OBJECTIVE: 1) To evaluate the effectiveness of agricultural protective clothing ensembles for reducing pesticide exposure; 2) to compare the fluorescent tracer/video imaging technique for pesticide dermal exposure measurement vs. existing techniques.

CONTRACTOR: Rutgers University, New Brunswick, New Jersey

TIMEFRAME: 1988-1990

DESCRIPTION: In order to evaluate the effectiveness of various types of protective clothing performance in field situations, most current methods employ gauze patches, placed under the clothing, to collect pesticide residues reaching the skin. This approach is known to produce highly variable measurements, since the placement of patches can only sample a small fraction of the dermal surface beneath the clothing. This project will employ fluorescent tracers and video imaging techniques to evaluate the performance of four types of protective clothing under realistic field conditions. Dermal exposure beneath the clothing will be measured, providing calculation of relative protection afforded by the garments. Design features of the garments will also be evaluated through study of tracer deposit patterns. This approach will allow direct evaluation and comparison of different protective clothing options.

STATUS/RESULTS: This Cooperative Agreement is currently in the processing stage, with a tentative start-up date of April 1, 1988.

FUTURE WORK: Initial tests will be conducted to determine appropriate tracer compound, mixing procedures, and concentrations to be employed in the field. Pilot field studies will be conducted, followed by full-scale tests of the procedure at various locations involving different types of clothing and agricultural pesticide operations. Data will also be collected via the commonly used patch method, a photographic record will be maintained, as well as a record of visual observations. Comparisons between the methods will be made based on the data collected, and the relative protection afforded by the test garments will be calculated. In addition, the role of garment design in reducing exposure will be determined.

REPORTS: Final report on evaluation of protective clothing via fluorescent tracers due in September 1990.

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SECTION 6
LIST OF MAJOR PRODUCTS

1. Personal Protective Equipment for Hazardous Materials Incidents: A Selection Guide, DHHS (NIOSH) Publication 84-114, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV 26505, October 1984.

Provides step-by-step guides (algorithms) for selecting chemical protective clothing and equipment to protect employees engaged in the control of hazardous materials incidents. The algorithms are based on environmental, physiological, chemical, and chemical interaction of numerous factors which influence protective equipment performance.

2. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, DHHS (NIOSH) Publication 85-115, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV 26505, October 1985.

Provides general guidance for developing health and safety programs aimed at workers engaged in hazardous waste site clean-up activities. Topics include chemical hazards, planning site clean-up, training programs, medical monitoring, site characterization, air monitoring, personnel protective equipment, site control, decontamination, handling drums and other containers, and site emergencies.

3. Guidelines for the Selection of Chemical Protective Clothing, 3rd Edition, Volumes I and II (NTIS #AD A179 516 and AD A179 164 respectively), February 1987.

Provides recommendations to end users and purchasers for selecting chemical protective clothing. Recommendations are based on extensive material chemical resistance data provided in Volume II. Volume I describes chemical protective clothing design and performance features and contains specific vendor information on available products.

4. Bhowan, A.S., E.F. Philpot, D.P. Segers, G.D. Sides, and R.B. Spafford, "Predicting the Effectiveness of Chemical Protective Clothing: Model and Test Method Development." EPA-600/86/055, (NTIS #PB86-209-087/AS), September 1986.
5. Goydan R., et al., "Development and Assessment of Methods for Estimating Protective Clothing Performance." Project report and project summary, EPA/600/2-87/104, October 1987.

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2. Berardinelli, S.P., "Chemical Resistance Field Test Methods." Presented at the 1986 American Industrial Hygiene Conference, Dallas, TX, May 1986.
3. Blood, B.D., and R.E. Radke, Development of a Communications System Compatible with Chemical Protective Clothing, CG-D-18-86 (NTIS #AD A170 683).
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5. Ehntholt, D.J., et al., "Test Method Development and Evaluation of Protective Clothing Items Used in Agricultural Pesticide Operations." November 1987; ASTM STP Publication Paper (Submitted).
6. Eley, W.D., An Evaluation of Heat Strain Monitoring Methods for Workers in Encapsulating, Impermeable Protective Clothing, Final Report CG-D-12-87 (NTIS #AD A180 155).
7. Mansdorf, S.Z., and S.P. Berardinelli, "Chemical Protective Clothing Standard Test Method Development: Penetration Test Method." American Industrial Hygiene Association Journal, 49(1):21-25, 1988.
8. Myers, W.R., "Interim Report on Laboratory Testing of Respirators: Biases Associated with In-Facepiece Sampling of Respirators." Completed September 1986, not yet published.
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10. Stull, J.O., "Considerations for Design and Selection of Chemical Protective Clothing." Journal of Hazardous Materials, Vol. 14, p. 165-189, 1987.
11. Stull, J.O., "The U.S. Coast Guard's Research and Development Program for Hazardous Chemical Personnel Protection." Chemical Engineering Progress, Vol. 83 (11) p. 34-39, 1987.
12. Stull, J.O., S.S. Weidenbaum, C.C. Gryte, and C.J. Durning, "Applying Differential Scanning Calorimetry to Characterize Chemical Protective Clothing Materials." Proceedings for the Hazardous Materials Spills Conference, Government Institutes, Inc., Rockville, Maryland, May 1986.
13. Stull, J.O., J.S. Johnson, and P.M. Swearngen, "Hydrogen Fluoride Exposure Testing of the U.S. Coast Guard's Totally-Encapsulating Chemical Protective Suit." In Performance of Protective Clothing: Second Symposium, ASTM STP 989, S.Z. Mansdorf, R.G. Sager, and A.P. Nielson, Eds., American Society for Testing and Materials, Philadelphia, 1988.

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