

<b>REPORT DOCUMENTATION PAGE</b>		1. REPORT NO.	2.	3. PB88-248364
4. Title and Subtitle		Bibliography of Published Information on Heat Resistant Fabrics for Protective Clothing		5. Report Date
				6.
7. Author(s)		Brewster, E. P., and R. L. Barker		8. Performing Organization Rept. No.
9. Performing Organization Name and Address		Department of Textile Materials and Management, Raleigh, North Carolina, North Carolina State University		10. Project/Task/Work Unit No.
				11. Contract(C) or Grant(G) No.
				(C)
				(G) OH-01431-01
12. Sponsoring Organization Name and Address				13. Type of Report & Period Covered
				14.
15. Supplementary Notes				
16. Abstract (Limit: 200 words) A bibliography of information on heat resistant fabrics for protective clothing, or which might be considered asbestos substitutes was presented. Of particular importance in this bibliography were the papers dealing with the measurement of protective and comfort properties as well as the papers which deal with the means of measuring the garments themselves. The listing should benefit those working in the area of industrial safety apparel, as well as those concerned with developing, testing, or using clothing for protection against heat hazards. Specific papers deal with the question of flammability, fire retardance, product engineering, physical and chemical properties of various fabrics, asbestos substitutes, catalogues of available protective equipment, aramid fibers, convective heat hazards, resistance of wool, multipurpose finishes, zirpro wool, hazards of molten metals, problems of fire fighters, thermal injury resulting in irreversible epidermal injury, racing drivers, water cooled hoods, thermal stress, cutaneous burns, ventilation, psychological aspects of thermal comfort, flight suits, thermal radiation, and aluminized fabrics.				
17. Document Analysis a. Descriptors				
b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Grant, Grant-Number-OH-01431-01, Work-environment, Protective-clothing, Heat-stroke, Heat-exposure, Radiation-exposure, Personal-protective-equipment				
c. COSATI Field/Group				
18. Availability Statement		REPRODUCED BY NATIONAL TECHNICAL INFORMATION SERVICE U.S. DEPARTMENT OF COMMERCE SPRINGFIELD, VA. 22161		19. Security Class (This Report)
				21. No. of Pages 17
				20. Security Class (This Page)
				22. Price







1.

Elissa Pintauro Brewster<sup>1</sup> and Roger L. Barker<sup>2</sup>

Department of Design and Environmental Analysis

Cornell University

Ithaca, New York 14850

BIBLIOGRAPHY OF PUBLISHED INFORMATION ON  
HEAT RESISTANT FABRICS FOR PROTECTIVE CLOTHING

A considerable amount of information on heat resistant fabrics for protective clothing, or fabrics that might be considered asbestos substitutes in this application, has been published by various industrial and federal laboratories as well as by academic institutions and research institutes. Particularly valuable is work that scientifically measures the protective and comfort properties of fabrics or garments, or research that deals with the methods of

<sup>1</sup>Present address: Fiber Materials Incorporated, Biddeford, ME 04005

<sup>2</sup>Present address: Department of Textile Materials and Management  
North Carolina State University  
Raleigh, NC 27650



testing and performance requirements for these materials. Unfortunately, this information is scattered about in a variety of technical journals and government reports, and it is often not easily located by the researcher.

This bibliography was prepared to assist those working in the field of heat-resistant protective clothing. It will be of special interest to those working in the area of industrial safety apparel, but should also be useful to anyone whose concern is to develop, to test, or to use clothing for protection against heat hazards.

#### REFERENCES

1. Abbott, N. J., "The Flammability of Coated Apparel Fabrics," *Journal of Coated Fabrics*, Vol. 3, 135-141 (October 1973).
2. Abbott, N. J., Schulman, S., "Protection from Fire: Nonflammable Fabrics and Coatings," *Journal of Coated Fabrics*, Vol. 6, 48-64 (July 1976).
3. Abbott, N. J., Schulman, S., "Protection from Fire: Nonflammable Clothing - A Review," *Fire Technology*, Vol. 12, No. 3, 204-218 (August 1976).
4. Baitinger, W. F., "Fire Retardance Characteristics of Safety Apparel Fabrics," *Proceedings of the 1978 Symposium on Textile Flammability*, Le Blanc Corp., 5454 Post Rd., East Greenwich, RI 02818.



5. Baitinger, W. F., "Product Engineering of Safety Apparel Fabrics: Insulation Characteristics of Fire-Retardant Cottons," *Textile Research Journal*, Vol. 4, No. 4, 221-225 (April 1979).
6. Barker, R. H., "The Physical and Thermal Properties of Shell Fabrics for Firefighter's Turnout Coats," in *Proceedings of the International Conference on Fire Safety*, Vol. 6, 1981, Products Safety Corporation, SRI International, Menlo Park, CA 94025 (January 1981).
7. Barker, R. L., Yener, M. D., "Evaluating the Resistance of Some Protective Fabrics to Molten Iron," *Textile Research Journal*, Vol. 51, No. 8, 533-541 (August 1981).
8. Barker, R. L., Yener, M. D., "Protective Clothing: Evaluating the Performance of Some Asbestos Substitutes Against Molten Steel," (Abstract) in *Proceedings of the International Conference on Fire Safety*, Vol. 6, 1981, Products Safety Corporation, SRI International, Menlo Park, CA 94025 (January 1981).
9. Barnhart, W. L., Toney, C. R., Nicodemus, L. A., "Protective Clothing - Assessment of Need Vol. I," Final Report NIOSH-TR-75-01, PB-241 167, U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health (August 1974).
10. Barnhart, W. L., Toney, C. R., Nicodemus, L. A., "Protective Clothing - Assessment of Need Vol. II," Final Report NIOSH-TR-75-01, PB-241 168, U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health (August 1974).
11. Barnhart, W. L., Toney, C. R., Nicodemus, L. A., "Catalog of Available Protective Clothing Supplement to Final Report: 'Protective Clothing -



Assessment of Need', " Final Report NIOSH-HSM-99-73-75, PB-276 344  
National Institute for Occupational Safety and Health (August 1974).

12. Behnke, W. P., "Thermal Protective Performance Test for Clothing," *Fire Technology*, Vol. 13, No. 1, 6-13 (February 1977).
13. Behnke, W. P., "Aramid Fibres for Protective Clothing" in *Proceedings of the 1978 Symposium on Textile Flammability*, Le Blanc Corp. 5454, Post Rd., East Greenwich, RI 02818.
14. Behnke, W. P., Seaman, R. E., "Development of Clothing for Protection from Convective Heat," *Fire Technology*, Vol. 2, No. 3, 219-225 (August 1966).
15. Behnke, W. P., Seaman, R. E., "Laboratory Tests Which Predict End-Use Performance Under High Temperature Conditions," *Appl. Polym. Symp.*, No. 9, 49-62 (1969).
16. Behnke, W. P., Seaman, R. E., "Develop Novel Test Equipment in Fabric Heat Transfer Study," *Modern Textiles Mag.*, Vol. 50, No. 4, 19-24 (1969).
17. Benisek, L., "Improvement of the Natural Flame, Resistance of Wool Part I: Metal-Complex Applications." *Journal of the Textile Institute*, Vol. 65, No. 2, 102-108 (February 1974).
18. Benisek, L., "Improvement of the Natural Flame - Resistance of Wool Part II: Multi-Purpose Finishes," *Journal of the Textile Institute*, Vol. 65, No. 3, 140-145 (March 1974).
19. Benisek, L., "Zirpro Wool Textiles," in *Proceedings of the International Conference on Fire Safety*, Vol. 6, 1981, Products Safety Corporation, SRI International, Menlo Park, CA 94025 (January 1981).



20. Benisek, L., Edmondson, G. K., Phillips, W. A., "Protective Clothing - Evaluation of Wool and Other Fabrics," *Textile Research Journal*, Vol. 49, No. 4, 212-221 (April 1979).
21. Benisek, L., Phillips, W. A., "Evaluation of Flame Retardant Clothing Assemblies for Protection Against Convective Heat (Flames)," *Clothing Research Journal*, Vol. 7, No. 1, 2-20 (1979).
22. Benisek, L., Edmondson, G. K., "Protective Clothing Fabric Part I. Against Molten Metal Hazards," *Textile Research Journal*, Vol. 51, No. 3, 182-196 (March 1981).
23. Benisek, L., Phillips, W. A., "Protective Clothing Fabric Part II: Against Convective Heat (Open Flame) Hazards," *Textile Research Journal*, Vol. 51, No. 3, 191-196 (March 1981).
24. Berger, M. R., "Safety Clothing: A Matter of Personal Protection," *National Safety News*, Vol. 114, No. 3, 63-67 (September 1976).
25. Bingham, M. A., Hill, B. J., "A Study of the Thermal Behavior of Flame-Resistant Fibres and Fabrics," *Journal of Thermal Analysis*, Vol. 7, No. 2, 347-358 (April 1975).
26. British Standards Institution, "Specifications for Clothing for Protection Against Intense Heat for Short Periods," BS3791;1970, 2-28 (1970).
27. Brown, J. R., Ennis, B. C., "Thermal Analysis of Nomex and Kevlar Fibers," *Textile Research Journal*, Vol. 47, No. 1, 62-66 (January 1977).
28. Bruce, J. P., "Fire Retardant Textiles: Where Do We Stand," *Modern Textiles*, Vol. 59, No. 5, 51-51 (May 1978).



29. Chapman, A. C., Miller, G., "Fibres, Fabrics and Finishes for FR Workwear in Europe," *Journal of Coated Fabrics*, Vol. 10, 26-34 (July 1980).
30. Clark, J., "Fire-Resistant Clothing Supplement," Jim Clark Foundation, London, 1-20 (1972).
31. Claus, W. D., Jr., "Heat Conduction in a Two Layer System with Application to Heat Transfer to the Skin," *Journal of Fire and Flammability*, Vol. 4, No. 1, 52-55 (January 1973).
32. Coletta, G. C., Arons, I. J., Ashley, L. E., Drennan, A. P., "The Development of Criteria for Firefighters' Gloves Volume I: Glove Requirements," NIOSH Technical Information, U.S. Department of Health, Education and Welfare, NIOSH, Cincinnati, OH (1976).
33. Coletta, G. C., Arons, I. J., Ashley, L. E., Drennan, A. P., "The Development of Criteria for Firefighters' Gloves Volume II: Glove Criteria and Test Methods," NIOSH Technical Information, U.S. Department of Health, Education and Welfare, NIOSH, Cincinnati OH (1976).
34. Coskren, R. J., "Flame Resistant and Nonflammability Textile Fibers," The Society for the Advancement of Material and Process Engineering, Vol. 4, No. 4, 13-19 (July 1973).
35. Coskren, R. J., Kaswell, E. R., "Development of PBI Fabric for Flight Suit Wear Test," Technical Report AFML-TR-71-195 (September 1971).
36. Crapnell, S., "Hand and Body Protection: Vital to Safety Success," *Occupational Hazards*, Vol. 41, No. 2, 31-37 (February 1979).
37. Derksen, W. L., Monahan, T. I., De Lhery, G. P., "The Temperatures Associated with Radiant Energy Skin Burns," *Temperature - Its Measurement*



and Control in Science and Industry, Herzfeld, C. M. (Editor), Vol. 3, Part III, Reinhold, NY, 171-175 (1961).

38. Ernst, E. D., "Laboratory Test Techniques for Evaluating the Thermal Protection of Materials When Exposed to Various Heat Sources," AFML-TR-74-118 (March 1977).

39. Fonesca, G. F., "Heat-Transfer Properties of Ten Underwear-Outerwear Ensembles," Textile Research Journal, Vol. 40, No. 6, 553-558 (June 1970).

40. Freeston, W. D., Jr., "Flammability and Heat Transfer Characteristics of Cotton, Nomex and PBI Fabric," Journal of Fire and Flammability, Vol. 2, No. 1, 57-76 (January 1971).

41. Freeston, W. D., Jr., Coskren, R. J., Skelton, J., Sebring, R. E., "Flammability and Heat Transfer Characteristics of PBI Fabric," Air Force Materials Laboratory, Technical Report AFML-TR-70-267 (January 1971).

42. Gardella, J. W., Wohrer, L. C., "Textile and Flammability Properties of Kynol Blends," in Proceedings of the 1973 Symposium on Textile Flammability, Le Blanc Corp. 5454 Post Rd., East Greenwich, RI 02818.

43. Garrett, E. L., "Ceramic Fibre Materials for Fire Protection," Insulation, Vol. 22, No. 2, 6-9 (February 1978).

44. Givoni, B., Goldman, R. F., "Predicting Metabolic Energy Cost," Journal of Applied Physiology, Vol. 30, No. 3, 429-433 (March 1971).

45. Henriques, F. C., Jr., "Studies of Thermal Injury v. The Predictability and the Significance of Thermally Induced Rate Processes Leading to Irreversible Epidermal Injury," Archives of Pathology, Vol. 43, No 5, 489-502 (May 1947).



46. Henriques, F. C., Jr., Moritz, A. R., "Studies of Thermal Injury I. The Conduction of Heat to and Through Skin and the Temperatures Attained Therein, Department of Legal Medicine, Harvard Medical School Contract NDC rc-169 (December 24, 1946).
47. Hoschke, B. N., "Flame Resistant Pure Wool for Racing Drivers," Textile Journal of Australia, Vol. 48, No. 4, 20-23 (April 1973).
48. Hoschke, B. N., "Flame-Resistant Wool/Nomex Blends," Textile Research Journal, Vol. 44, No. 12, 956-958 (December 1974).
49. Hughes, J. C., "Personal Protective Equipment for Hot Work," Proceedings of the 1972 New South Wales Industrial Safety Convention, Sydney, Australia (1972).
50. Jackson, R. H., "PBI Fiber and Fabric Properties and Performance," Textile Research Journal, Vol. 48, No. 6, 314-319 (June 1977).
51. Jaynes, P. S., Jr., "Testing Fabrics with Molten Steel," Professional Safety, 15-20 (October 1980).
52. Kaswell, E. R., "Some Thoughts and Information on Nonflammable Products," Journal of the American Association of Textile Chemists and Colorists, Vol. 4, No. 1, 33-40 (January 1972).
53. Kenton, E., "Protective Clothing, Part 4. Industrial Environments," NTIS/PS-79/0439, National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 (May 1979).
54. Konz, S., Gupta, V. K., "Water Cooled Hood Affects Creative Productivity," ASHRAE Journal, Vol. 11, 40-43 (July 1969).
55. Konz, S., Duncan, Jr., "Evaluation of Two Water Cooled Hoods," ASHRAE Transactions 1971, Vol. 77, Part 1, No. 2190, 232-238 (1971).



56. Konz, S., Aurora, D., "An Evaluation of A Dynamic Cooling Shirt," ASHRAE Transactions 1973, Vol. 79, Part 1, No. 2262, 52-61 (1973).
57. Lands, S., "Protective Clothing for Industrial Use," U.S. Army Foreign Service and Technology Center, Report 78 11 15 120 (October 1977).
58. Locke, J. W., "Performance Standards and Safety," ASTM Standardization News, Vol. 6, No. 1, 23-24 (January 1978).
59. Martin, H. de V., Goldman, R. F., "Comparison of Physical, Biophysical and Physiological Methods of Evaluating the Thermal Stress Associated with Wearing Protective Clothing," Ergonomics, Vol. 15, No. 3, 337-342 (May 1972).
60. Mehta, P. N., "Engineered Wool Industrial Protective Clothing," Textile Research Journal, Vo. 50, No. 3, 185-193 (March 1980).
61. Mehta, P. N., Willerton, K., "Protective Clothing Evaluation of Clothing Materials for Protection Against Molten Metals," Textile Institute and Industry, Vol. 15, No. 10, 334-337 (October 1977)
62. Morales, V., Konz, S., "The Physiological Effect of a Water-Cooled Hood in a Heat Stress Environment," ASHRAE Transactions, Vol. 74, Part II, No. 2091, 236-249 (1968).
63. Morin, C. J., Hollies, N. R. S., Howard, M., Custer, A. G., "Comparison of the Wearing Comfort of Crease Resistant Cotton, Fire Retardant Cotton with THPOH-NH , and Nomex III Firemen's Shirts, Gillette Research Institute Harris Research Laboratories Department, Final Report, Contract No. 01-0331, 2-16 (December 28, 1977).



64. Moritz, A. R., "Studies of Thermal Injury III. The Pathology and Pathogenesis of Cutaneous Burns A Experimental Study," *The American Journal of Pathology*, Vol. 23, No. 6, 915-941 (November 1947).
65. Moritz, A. R., Henriques, F. C., Jr., "Studies of Thermal Injury II: The Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns," *The American Journal of Pathology*, Vol. 23, No. 5, 695-700 (September 6, 1947).
66. Morse, H. L., "Analysis of the Thermal Response of Protective Fabrics," *Air Force Materials Laboratories Technical Report AFML-TR-73-17* (January 1973). Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.
67. McCone, L. K., "Symposium on High-Temperature Fibers: HT-1 High Temperature Resistant Polyamide Fibers and Paper," *Textile Research Journal*, Vol. 32, No. 9, 762-767 (September 1962).
68. McNall, P. E., Jr., Gaax, G., Rohles, F. H., Nevins, R. G., Springer, W., "Thermal Comfort (Thermally Neutral) Conditions for Three Levels of Activity," *ASHRAE Transactions*, Vol. 73, Part II, No. 2065, RP-43, I. 31-I.3.14 (1967).
69. McNall, P. E., Ryan, P. W., Rohles, F. H., Nevins, R. G., Springer, W., "Metabolic Rates at Four Activity Levels and Their Relationship to Thermal Comfort," *ASHRAE Transactions*, Vol. 74, Part II, No. 2067, RP-43, IV.3.1-IV.3.14 (1968).
70. McQuade, A. J., Waldron, E. T., Farquhar, B. S., "Response of Fibers to Intense Thermal Radiation, *Annals New York Academy of Sciences*, Vol. 82, Art. 3, 762-773 (October 7, 1959).



71. Nemeć, M. M., "Hand and Body Injuries: Prime Targets in the War on Accidents," *Occupational Hazards*, Vol. 40, No. 3, 37-42 (March 1978).
72. Nevins, R. G., Rohles, F. H., Springer, W., Feyerherm, A. M., "A Temperature-Humidity Chart for Thermal Comfort of Seated Persons," *ASHRAE Journal*, Vol. 8, No. 4, 55-61 (April 1966).
73. Nivin, C. D., Babbitt, J. D., "On the Heat Transmission of Textile Fabrics," *The Journal of the Textile Institute*, Vo. 29, T161-T172 (August 1938).
74. Ordinanz, W., "Bibliography," in *Work in Hot Environments and Protection Against Heat*. The Iron and Steel Institute, London, 1970.
75. Ordinanz, W., "Operations in Hot Environments and Their Special Conditions," in *Work in Hot Environments" and Protection Against Heat*. The Iron and Steel Institute, London, 1970.
76. Ordinanz, W., "Personal Adaptation and Protective Measures," in *Work in Hot Environments and Protection Against Heat*. The Iron and Steel Institute, London, 1970.
77. Peirce, Rees, W. W., "The Transmission of Heat Through Textile Fabrics," *The Journal of the Textile Institute*, Vol. 37, T185-T186, T191-T196, T199-T204 (August 1946).
78. Perkins, R. M., "Insulative Values of Single-Layer Fabrics for Thermal Protective Clothing," *Textile Research Journal*, Vol. 49, No. 4, 202-212 (April 1979).
79. Pleasance, H. D., "Wool's Protective Safety Applications," *Textile Journal of Australia*, Vol. 5, No. 10, 20-21, 34-35 (October 1975).



80. Plitt, K. F., "Fabric Tests on Firemen's Coats," NBS Report 10 489, National Bureau of Standards, Washington, DC (February 1972).
81. Rees, W. H., "The Transmission of Heat Through Textile Fabrics," The Journal of the Textile Institute, Vol. 32, T149-T166 (August 1941).
82. Reischl, U., Stransky, A., "Assessment of Ventilation Characteristics of Standard and Prototype Firefighters Protective Clothing," Textile Research Journal, Vol. 5, No. 3, 193-201 (March 1980).
83. Rhodes, P. L., Graham, C. O., Jr., "Evaluation of Cotton/Kevlar Blends," Textile Research Journal, Vol. 49, No. 1, 28-33 (January 1979).
84. Rohles, F. H., Jr., "A Psychologist Looks at Air Movement," ASHRAE Journal, Vol. 7, No. 7, 48-49 (July 1965).
85. Rohles, F. H., Jr., "Preference for the Thermal Environment by the Elderly," Human Factors, Vol. 11, No. 1, 37-41 (February 1969).
86. Rohles, F. H., Jr., "Psychological Aspects of Thermal Comfort," ASHRAE Journal, Vol. 13, No. 1, 86-90 (January 1971).
87. Rohles, F. H., Jr., "The Ecosystem Complex A New Approach in Specifying the Man-Environment Relationship," Journal Environmental Systems, Vol. 1, No. 4, 321-328 (December 1971).
88. Rohles, F. H., "The Measurement and Prediction of Thermal Comfort," ASHRAE Transactions 1974, Vol. 8, Part 2, No. 2309, RP-118, 98-114 (1974).
89. Rohles, F. H., Jr., "The Modal Comfort Envelope and its Use in Current Standards," Human Factors, Vol. 16, No. 3, 314-322 (May-June 1974).



90. Rohles, F. H., Hayter, R. B., Milliken, G., "Effective Temperature [ET\*] As a Predictor of Thermal Comfort," ASHRAE Transactions 1975, Vol. 81, Part 2, No. 2368, RP-11, 148-156 (1975).
91. Rohles, F. H., Jr., Nevins, R. G., "Short Duration Adaptation Comfortable Temperatures," ASHRAE Transactions, Vol. 74, Part 1, No. 2065, RP-43, IV.1.1-IV.1.4 (1968).
92. Ross, J. H., "High-Temperature Fiber Research," Textile Research Journal, Vol. 32, No. 9, 768-777 (September 1962).
93. Ross, J. H., "Thermal Conductivity of Fabrics as Related to Skin Burn Damage," Journal of Applied Polymer Science: Applied Polymer Symposium No. 31, 293-312 (1977).
94. Ross, J. H., Stanton, R. M., "Relationship of Fabric Flammability to Fabric Structure," Applied Polymer Symposium No. 21, 109-119, (1973).
95. Ross, J. H., Schulman, S., Stanton, R. M., "Poly (1,3,4)-Benzimidazole A Nonflammable Fiber for Personnel Protection Systems," Textile Research Journal, Vol. 41, No. 2, 146-153 (February 1971).
96. Schoppee, M. M., Skelton, Jr., Abbott, N. J., "The Transient Thermomechanical Response of Protective Fabrics to Radiant Heat," Air Force Materials Laboratory, Technical Report AFML-TR-77-72 (May 1977).
97. Schulman, S., Stanton, R. M., "Nonflammable PBI Fabrics for Prototype Air Force Flight Suits," Air Force Materials Laboratory, Report AFL-TR-70-178 (May 1970).
98. Shealy, O. L., Lynch, J. A., Jr., Arnold, H. W., "New Flame Resistant Textile Fibers," Modern Textiles, Vol. 55, No. 10, 50-56 (October 1974).



99. Shivers, J. C., Hentschel, R. A. A., "A New High Temperature Fiber," *Textile Research Journal*, Vol. 44, No. 9, 665-669 (September 1974).
100. Simms, D. L., "The Design of Test Methods for Industrial Fabrics for Protection Against Fire," *Textile Institute and Industry*, Vol. 4, No. 2, 43-44 (February 1966).
101. Stanton, R. M., "Heat Transfer and Flammability of Fibrous Materials," *Air Force Materials Laboratory*, Technical Report AFML-TR-70-238 (February 1971).
102. Stanton, R. M., Schulman, S., Ross, J. H., "Evaluation of PBI and Nomex II for Air Force Flight Suits," *Air Force Materials Laboratory*, Technical Report AFML-TR-73-28 (January 1973).
103. Stoll, A. M., Chianta, M. A., "Method and Rating System for Evaluation of Thermal Protection," *Aerospace Medicine*, Vol. 40, No. 11, 1232-1238 (November 1969).
104. Stoll, A. M., Chianta, M. A., "Heat Transfer through Fabrics as Related to Thermal Injury," *Transactions New York Academy of Sciences Series II*, Vol. 33, 649-670 (1971).
105. Stoll, A. M. Chianta, M. A., Piergallini, J. R., "Heat Transfer Measurements of Safety Apparel Fabrics," *Naval Air Development Center*, Report No. NADC-78209-60 (January 25, 1978).
106. Stoll, A. M., Green, L. C., "Relationship Between Pain and Tissue Damage Due to Thermal Radiation," *Journal of Applied Physiology*, Vol. 14, 373-382 (1959).
107. Stoll, A. M., Munroe, L. R., Chianta, M. A., Piergallini, J. R., Zaccaria, D. E., "Facility and a Method for Evaluation of Thermal



Protection," Aviation, Space, and Environmental Medicine, Vol. 47, 1177-1181 (November 1976).

108. Sund, J. L., "Longitudinal Wear Study of Four Work Shirts--Three Fire-Resistant and One Non-Fire-Resistant--Worn in Ferrous Metal Operations, King County, Washington," Master of Science Thesis, 1980, University of Washington.

109. Wardle, M. W., "High Performance Coated Fabrics Kevlar Aramid Fiber," Journal of Coated Fabrics, Vol. 7, 3-23 (July 1977).

110. Wren, J. E., Scott, W. D., Bates, C. E., "Thermal and Mechanical Properties of Aluminized Fabrics for Use in Ferrous Metal Handling Operations," American Industrial Hygiene Association Journal, Vol. 38, No. 11, 603-612 (November 1977).

#### ACKNOWLEDGEMENTS

This work was supported by a grant awarded by the Department of Health and Human Services, National Institute of Occupational Safety and Health, Grant Number 5 RO1 OH00910.

The authors gratefully acknowledge the contributions of Cheryl Gomez who labored to insure the accuracy of the journal entries.

