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HEADQUARTERS

QUARTERMASTER RESEARCH & ENGINEERING COMMAND

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TECHNICAL REPORT

TS-121

PROCEEDINGS OF THE TEXTILE AND CLOTHING SEMINAR

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QUARTERMASTER RESEARCH & ENGINEERING CENTER

CLOTHING AND ORGANIC MATERIALS DIVISION

SEPTEMBER 1962 NATICK, MASSACHUSETTS

AD- Accession No.

Quartermaster Research & Engineering Center, Natick, Mass. PROCEEDINGS OF THE TEXTILE AND CLOTHING SEMINAR, QM R&E Center, 49 pp, illus. (Technical Report TS-121) Sept 1962

This report of a seminar held at the Quartermaster Research and Engineering Center on 17-18 May 1962 includes papers by representatives of the Air Force, Army and Navy on applications of textiles and clothing for space, for nuclear and limited warfare, and for surface ships and submarines. Problems faced by the military departments in these areas and approaches to the solution of difficult technical problems are discussed. Presentations by members of a panel from the textile industry cover the interrelationship of industrial and military research and the role of industry in making its resources available to the military in our present economy.

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2. Conferences
3. Textile industry
4. Supplies
5. Synthetic fibers
6. Body armor
7. Fire resistant textiles
8. Metallic textiles
I. Title
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QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

CLOTHING & ORGANIC MATERIALS DIVISION

Textile Series Report

No. 121

PROCEEDINGS OF THE TEXTILE AND CLOTHING SEMINAR

Held at the Quartermaster Research and Engineering Center

On Industry Day, 17 and 18 May 1962

Project Reference:
7-93-18-020

September 1962

FOREWORD

For the past several years the Quartermaster Research and Engineering Command jointly with the New England Chapter of The Quartermaster Association (now the Defense Supply Association) have sponsored "Industry Day" at the Quartermaster Research and Engineering Command at Natick, Massachusetts. This occasion has served as an "open house" to management and research people in the industries that support the national defense effort in the area of Quartermaster supplies, and has also provided an opportunity for special technical presentations to various industry groups.

This year a seminar on "Textiles and Clothing" was held for the benefit of people from these industries who were planning to attend "Industry Day". All of the papers presented during this seminar are included in this report, together with the address on "Army Research and Its Relationship to Industrial Research", by Major General William J. Ely, USA, Deputy Commanding General, U. S. Army Materiel Command, Department of the Army.

In view of the interest in interdepartmental standardization and collaboration, and the recent establishment of the Defense Supply Agency, it was felt appropriate that this seminar should present the activities in this area being carried on by all of the military departments. Through the cooperation of those agencies in the Air Force and the Navy which are also engaged in research and engineering in the field of textiles and clothing, reports were presented on the current work of all of these agencies. The interest in this seminar was evidenced by the fact that over four hundred people from industry attended.

For the effectiveness of this seminar we are particularly indebted to Mr. Donald Huxley and Mr. Jack Ross of the Wright Patterson Air Force Base and Mr. Thomas Seery of the Bureau of Supplies and Accounts, U. S. Navy. Also, appreciation is expressed to Mr. J. B. Goldberg who has served as a consultant to the textile industry for many years, and who consented to serve as chairman of this seminar.

We are also indebted to the members of the panel who participated. These were: Mr. David Clark, David Clark Company, Worcester, Massachusetts; Mr. James Love, Jr., Burlington Industries, Inc., New York; Mr. A. P. Anthony, J. P. Stevens & Company, Inc., New York; Mr. Ernest Chornyei, Bradford Dyeing Association, Rhode Island; and Mr. Arthur Spiro, Waumbec Mills, Inc., New York.

S. J. KENNEDY
Director
Clothing and Organic Materials Division

Approved:

DALE H. SIELING, Ph.D.
Scientific Director
QM Research & Engineering Command

MERRILL L. TRIBE
Brigadier General, USA
Commanding
QM Research & Engineering Command

TABLE OF CONTENTS

ABSTRACT

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ARMY RESEARCH AND ITS RELATIONSHIP TO INDUSTRIAL RESEARCH

MAJOR GENERAL WILLIAM J. ELY, USA

DEPUTY COMMANDING GENERAL

U. S. ARMY MATERIEL COMMAND, DEPARTMENT OF THE ARMY

It is a pleasure to be here today and to have this opportunity to participate in "Industry Day".

My remarks today, while accenting the Army's point of view, will illustrate the inter-relationship between research in the Army and in industry.

You are aware, I'm sure, that research has become all pervasive. News media are devoting increasing time and space to various aspects of research so that the average citizen cannot but realize that research plays an important part in his life today and his plans for the future. I believe firmly that research is the key to progress, not only in the Army, but in government, in industry, and in education.

Leonard Silk, in a recent book, while discussing this tremendous upsurge in research, asks:

"What will this new epoch be called? It's clearly an understatement to call it the atomic age, as people did at the end of the war. It's too narrow to call it the age of automation or cybernetics. And it's much more than the space age. Because of its tremendous breadth, we might simply call it the research age, however vague the term, however subject to misuse."

Today, in this research age, the Army's research efforts are focused on improving the ability of ground forces to win on any future battlefield—to move, shoot and communicate more effectively than any potential enemy. Our primary interest then, is in man—the soldier—and how to make him more effective in any environment, whether it be in the Arctic, the tropical jungle or the desert. And yet, we must realize that this research age we are discussing, this era of explosion in science and technology is creating changes overnight. Present weapon systems and equipment become obsolescent so rapidly that only through research can we keep ahead of these changes and provide the knowledge from which the weapons of ten years hence will evolve.

Modern science is less than 500 years old and technology perhaps half of that—but in the last century—only two percent of recorded time—man has achieved 90 percent of his technological progress. The future is even more challenging. Of all the men who have ever been trained in science and technology throughout the world—it is estimated that nine-tenths of them are alive today. So you can see that we have only just entered the research age. In relationship to time, a major percentage of scientific advancement has been compressed into a relatively short period. And speaking of time, how short can a period of time be? Research into methods for newer and better computers has forced scientists to express the time intervals required with a new word—the nanosecond—one billionth of a second. To provide for increments smaller than one billionth, the National Bureau of Standards has established the prefix "pico" to denote one trillionth—perhaps we will soon speak of picoseconds. It is in light of advances such as this that we must direct our efforts to meet the needs of the Army of tomorrow.

In Army research, we are constantly aware that, in order to do our job, we must increase and improve our planning and coordination with industry and with educational and scientific institutions.

Our research, in general, is conducted in two ways—the "in-house" approach on one hand, and contracts and grants with industry and with education and scientific institutions on the other.

"In-house" research concentrates on those projects which industry is not organized to accomplish or which are fundamentally incompatible with peaceful enterprise or interest. We need to maintain a small but highly competent scientific and technical capability of our own and to undertake research which demands continuous association with military organizations for successful and economical accomplishment. The bulk of all other research, however, is performed by contractual and grant arrangements with industry or non-profit institutions.

I consider that the Army is fortunate to have the research competence and capabilities of its in-house laboratories here at Natick. Here at the Quartermaster Research and Engineering Command Laboratories, we maintain our competence in research required to feed, clothe, and equip the soldier. Also here at Natick is the US Army Research Institute of Environmental Medicine, a research activity of the Army Medical Service. This institute is investigating the physiological effects of heat, cold and altitude on the combat soldier. At the next "Industry Day" you will be able to visit the new food radiation research facility which will be completed this summer. By then, the Food and Container Institute will have completed its move, and you will have an opportunity to visit its food research laboratories. Bearing in mind that this is only one of 25 such laboratories, you can understand our pride in our in-service research facilities.

Now I would like to discuss briefly some of our research efforts which are related to industry, either through contract effort or mutual interest in the problem or its solution.

A key requirement today is research to find new materials which will make the creation of military devices of the future possible. The unprecedented demand for new materials is staggering. For remember, today's materials research is looking for tomorrow's materials. Materials that withstand conditions of extreme heat and pressure, in the order of at least one-half million pounds per square inch and 2,000 degrees Centigrade are now almost commonplace. The demand for new properties and the properties demanded continue to spiral upward.

The Army's materials program covers a variety of fields—plastics, elastomers, ceramics, metals and textiles.

Right here at Natick, an important area of research is being pursued in the elastomer field. The Army has been working for several years to develop new types of rubber. Our scientists here at the Quartermaster Research and Engineering Command have recently produced an extremely promising new material known as nitrosomethane rubber, or, more commonly, nitroso rubber. Laboratory tests indicate that this new material possesses much better resistance to petroleum products, low temperature and burning than any other known experimental or commercial rubber. An analysis of production techniques indicates that this nitroso rubber will be competitive with other specialty rubbers.

In the field of clothing materials, our scientists are searching for multi-purpose materials which will simultaneously protect the soldier from the natural environment, thermal radiation, and noxious chemical agents.

Army materials research personnel watch carefully the fundamental work in solid state physics and basic chemistry. The knowledge gained in these fields has permitted the linking of chains of large molecules. Materials, expecially organic and inorganic non-metallics—with properties we can hardly imagine—are now being created to our order. Metallic materials shortly will follow suit. Instead of having to work with materials available, we can have the materials we want. We can determine the ideal characteristics we need, then tailor them out of atoms and molecules as required.

These and other research-sparked materials will rebound to the benefit of our civilian industry and commerce as well as to the military. There should be no question about it, the Army spends its research money primarily to improve its ability to fight and win a war. Still, the line of demarcation between research for war and research for peace is not sharp; in fact, it is quite obscure. The Army has found that knowledge gained for war usually has wide peaceful applications.

As you can readily imagine, one of our most important areas of research is the electronics field. This field has been characterized by great strides forward in the last ten years and can be expected to continue this explosive surge in the years ahead. Electronic parts have been reduced in size by modular and related concepts so that where previously we had 70,000 parts per cubic foot, we now pack 350,000 parts in the same space. Solid state research now gives promise of considerable improvement in this area. Where we used tp speak of miniaturization, we soon began to speak of micro-miniaturization. Advances now force us to speak of sub-micro-miniaturization. And, although just a gleam in the eye of scientists, we are investigating "molecular electronics" where we hope to coax molecules to behave like amplifiers, oscillators and the like.

We are also supporting research in the quest for new energy sources. We need new sources of energy which cost less, are smaller in size, and most importantly, have better performance characteristics under a variety of conditions. We are investigating every new avenue that shows promise in the power spectrum—from today's gas turbine to tomorrow's fuel cell—from the magnetohydrodynamic generator to the solar cell—and of course, improved nuclear power sources.

Of these, the fuel cell appears to offer the greatest promise for the 1970's. The fuel cell is an electro-chemical reaction. It has all the features of a battery except that the reactants—oxygen and a companion fuel such as hydrogen—are supplied continuously. The reaction products, carbon dioxide and water vapor, are removed continuously.

There are many reasons for military interest in this cell. Significant is its potentially high efficiency compared to that of a gasoline engine—about 60-80 percent compared to 25-30 percent. This means more utilization of fuel with a substantial reduction in the logistical load. The fuel cell has no internal moving parts, which means reduced maintenance. Of particular importance is the fact that fuel cells operate with an absence of noise or smoke, and generally without excessive heat. They then are harder to detect by an enemy on or above the battlefield.

Although the fuel cell promises some reduction in our supply requirements for fuels, in itself the fuel cell is not expected to be the complete solution to our age-old logistics problem. One possible solution, in the 1970's, lies in the integration of the fuel cell, or groups of cells, with the nuclear reactor.

We are considering a stationary nuclear-powered generation plant—to operate much like a filling station—furnishing hydrogen and oxygen as fuels. Viewed in this light, the problem of providing propulsion fuel is reduced to the task of converting the energy from a nuclear plant to a form which can be conveniently dispensed and utilized in a variety of vehicles.

The possibility of obtaining the optimum application, an integrated fuel-power system as an integral part of a vehicle, is speculative. Unfortunately, the extent to which nuclear plants can be reduced in size appears to be limited; and the cost of reactors is still very high. Yet, we can approach the optimum if we utilize a nuclear-powered, cross-country vehicle, such as an overland train, as a mobile supply point. As we visualize it, the several cars of the train could be equipped to manufacture certain chemicals, perhaps ammonia or hydrazine from air and water—and liquefy it for convenient storage and handling. The heat and power for the process equipment would be provided by the nuclear plant—which would also propel the train. The ammonia or hydrazine, in turn, would be furnished from this mobile service station to combat vehicles equipped with fuel cell propulsion engines, or to stationary fuel cells providing electrical power for other applications. Such nuclear-powered energy depots could manufacture versatile chemical fuel locally within a combat theater and transport it to the place of use. We can foresee such a unit that could develop, within itself, the equivalent of 500,000 gallons of gasoline a day. With POL constituting 40% of an Army's tonnage under combat conditions, the significance of this approach is apparent.

The Army research efforts in the field of physical sciences that I have just described are being pursued in our own laboratories and by contracts and grants with industrial research laboratories and educational institutions. The results of this research will have a significant impact not only on the Army of tomorrow but on the industry of tomorrow.

Do not think that we in the Army are concentrating on research in the physical sciences at the expense of the other scientific disciplines. We recognize the need to exploit the life sciences, the earth sciences and the social sciences to keep pace with the rapid advances in the physical sciences.

The Army Medical Service is expanding its research program to insure that in any future conflict, our Army's most valuable resource—the soldier—is maintained as an effective force **wherever** he may have to fight. This expanded research effort is being carried on in the "in-house" facilities of the Army Medical Service, such as the Research Institute for Environmental Medicine here at Natick and by contract with industrial and non-profit laboratories.

This research is directed toward those areas of primary importance to military medicine—those areas that will remain relatively untouched if the Army doesn't do something about them.

For as long as there have been armies, infectious hepatitis has debilitated soldiers. The armies of Hannibal and Napoleon experienced the ravages of "camp jaundice" as it was called then. In Korea, 1.2 million man days were lost as a result of this disease. Even in this age of advanced science, we can only treat this disease **after** it is contracted. With the recent advances in the preparation of living attenuated vaccines against virus diseases, the Army is launching an effort to find a vaccine against hepatitis.

Some of the most urgent problems facing the Army in any type of warfare are in the field of preventive medicine. Diseases due to infectious agents may produce more casualties than actual combat. This is particularly applicable to specific parts of the world, especially in under-developed areas.

In response to the President's policy to direct our efforts toward increasing our capabilities to fight and to win limited wars, the Army medical research program is expanding in this area. A major effort is underway to provide means for the recognition, prevention and treatment of infectious diseases which are such a problem in the under-developed areas of the world.

Recognition of diseases in these areas presents a major problem. Many of these diseases are unknown in the United States today. Through research we must provide a means of rapid identification of these unusual and exotic infections. This will require advances in the field of medical laboratory methods and equipment. Our research effort, coupled with that of industry, is directed to this end.

Another problem which must be solved through research lies in the field of immunology. We must provide our soldiers with more effective immunizations against the diseases of military importance likely to be encountered anywhere in the world. We are investigating the principles of development of immunity to disease and other means by which the natural forces of the body combat disease. Our goal is to provide our soldiers with new vaccines against diseases for which there is presently no protection, to improve vaccines so that they are more effective over a longer period of time, have greater stability, and have negligible undesirable side reactions.

In other areas of the life sciences, we are actively pursuing new knowledge and application of that knowledge. In food research, a subject of vital importance to all, but of particular interest to many of you, the Army is searching for ways to reduce the logistic load and improve combat rations. In our research program, we are investigating unconventional means of food production, including algae and tissue culture.

Each individual has very definite reactions to particular foods. The taste and smell of a particular food influence its acceptability. We are trying to find what constituents of food cause it to have a given flavor or smell. Our ultimate goal is to determine how to enhance desirable flavors and odors and suppress those that are undesirable.

We are continuing our research in the preservation of food by ionizing radiation. Many of your laboratories are assisting us in this effort. The knowledge gained through this research effort has been tremendous. Determining what happens to food when it is irradiated has required a great deal of research into food itself with considerable benefits in areas other than radiation preservation. The industrial implication of irradiated food cannot be defined clearly until we have this method of preservation approved by the Food and Drug Administration for human consumption. Once this has been accomplished, irradiated food could well follow the lead of freezedehydrated foods in its benefits to the Army and to the civilian populace.

We are increasing our activity in human factors engineering to insure that our equipment and systems are compatible with man—the user of the equipment and operator of the systems.

The Army in its research program not only heavily utilizes the talents of industry but encourages industry to originate suggestions—or what we in the Army call unsolicited proposals. We try to make the

Army-Industry research relationship a true two-way street. To assist industry in determining where a proposal should be sent, we have a publication called Research and Development in the US Army—Contractors Guide. It lists the principal areas of interest to civilian contractors and the Army agency involved in each category of effort.

To bring to the attention of industry those Army problems that still are unsolved, current and wide open to research, we have published an eight-volume series entitled US Army Research and Development Problems Guide. These Problems Guides are made available to interested organizations as a clear and concise statement of the Army's needs. The solution of these problems, for which we are seeking industry's assistance, can substantially help this nation to maintain its strength and superiority on the battlefields of the future.

I have discussed a few of the Army's research efforts that are related to industrial research through either contract effort or mutual areas of interest. You probably wonder how the recently-announced reorganization of the Army will affect our research effort. Since I accepted the invitation to speak to you today, I have been named deputy to General Besson in the new Materiel, Development and Logistics Command. General Tribe and I are currently serving on the planning group to set up the organization for this command. I can state that research in the Army will continue to be dynamic and responsive to the needs of the nation. The titles of the "in-house" facilities will change, but the effort will continue and should be more effective under the functional alignment in the new organization.

For example, the Quartermaster Research and Engineering Command here at Natick will no longer be known by that name when the reorganization is completed. However, the research activities here will continue, and will probably grow in scope and importance. We are hopeful of continuing the development of this laboratory into the most important center of knowledge and research in the world, in regard to the soldier's needs for food, clothing, and individual equipment.

There is one other point that I would like to mention. This is the need for expanding basic research. Basic research is the well of knowledge from which we dip for our applied research and development. Today we are using knowledge gained in the years past and we have worked wonders in getting all we can out of the finds and discoveries of past centuries, decades and years. But we cannot continue drinking from this well without replenishing the supply.

It is doubtful that America today can claim a leadership in the field of basic research comparable to that which we hold in the field of technology. For the sake of continued material progress, as well as for the sake of our intellectual development—basic research being but the applied science of tomorrow—a supreme need right now is for the stimulation of more and better basic research in all facets of our economy. Happily, the President's Scientific Advisory Committee and others involved in determining policy in science and technology continue to stress the need to expand our national effort in basic research.

Let there be no mistake—at this point in history—basic research is crucial to the existence of our nation in the struggle of ideologies. But simply to increase government funds is not the answer to the problem; there is a real need for more, for dynamic and for realistic support by private enterprise—industry, educational institutions and scientific foundations.

I don't need to point out to you the progress of industries which have been nourished by and profited from, sound research programs. Indeed, in these postwar years, those who did not advance—did not make use of research as a key to modern progress—have fallen into oblivion.

I feel quite strongly that the foundation of technological progress is basic research. This foundation must be strengthened at every turn—by the Army and by industry.

Thank you very much.

<u>MODERN ASPECTS OF RESEARCH AND DEVELOPMENT</u>

DR. ROGER H. LUECK

AMERICAN CAN COMPANY

NEW YORK, NEW YORK

Here at Natick today we, with interests in the Defense Supply Association and the Research and Development Associates of the Food and Container Institute, are guests of the Quartermaster Research and Engineering Command. I dare say it is improbable that a successful meeting of this kind could have been held, or even considered, as late as two or three decades ago. At that time we lived in quite a different world than we enjoy today. Then, as aptly expressed by L. G. Cook of General Electric, "...the twin Damocles swords of uranium-powered weapons and rocket technology had cast no visible shadow on our lives. The Industrial Revolution, already nearly a hundred years in full development, had almost eliminated the horse, to be sure, but had not yet moved in on the 'marginal farmer' and the farm laborer. The miracle of hybrid corn had not yet created a 'farm problem'. The miracle of antibiotics had not yet come to extend life expectation and aggravate 'population pressures'. The miracle of D.D.T. had not yet reduced the death rate in poverty- and disease-ridden countries without any increase in available food supplies. The transistor had not yet made automation a household word. The development of high polymers had not yet influenced the growth in the use of the tin can. These two decades have spanned fantastic changes in the business of living.

"These revolutionary changes have had their origin in science, in laboratory research. Earlier phases of the Industrial Revolution appear to have been dominated by mechanical invention, by 'craft' invention while people interested in 'deeper understanding' worked away quietly and unmolested so long as they avoided colliding with theology. This long period of research in science seems now to have broken through into the area of practicality and begun to dominate the affairs of individuals, institutions, and nations. We appear, just in the last two decades, to have passed fully through the portals of a 'science-dominated' phase of the Industrial Revolution."

The situation just described is symtomatic of a new, loosely-cohesive group, a professional community, that has assumed a key role in the functioning of our industrial society. We are all aware of a community of business men and a governmental community, each with its unique way of looking at things. One of the most conspicuous changes in the post-war years has been the emergence of this new functional group, the community of technical men.

This community is really quite new, so new, in fact, that there is still no good word to encompass both the engineers and scientists which constitute it. This lack of a single word for the technical men reflects a time when engineers were likely to be relatively-junior hired hands in industry, and scientists were academic fellows quite remote from the workaday functioning of society.

The emergence of this new technical community is traceable to a basic change in our society, the one referred to by Mr. Cook as the "science-oriented" phase of the Industrial Revolution. We have institutionalized technical change; we organize our activities in the firm conviction that our knowledge and our techniques are changing fast, and will continue to do so; we are concerned less with exploiting what we know than with exploiting our ability to learn more.

It has become apparent that the destinies of nations as well as those of individuals are irrevocably associated with the growth and use of scientific knowledge. This change has brought the scientist, as the specialist in the pursuit of knowledge, into the main stream of society. It has changed the engineer from an expert in the use of known techniques to a discoverer of ways to apply new knowledge.

The two have come closer together. We see engineering schools throwing the handbooks out of their curricula and stressing science, while at the same time industrial employers are seeking the services of mathematicians and theoretical physicists.

Both corporate management and the federal agencies, particularly the Department of Defense, have recognized the potentials for growth and effectiveness inherent in the new community of technical men. This is apparent in the tremendous growth in the nation's annual R. & D. expenditures. These have grown from less than $500 million in the early 30's to 2.2 billion in 1950, to 8.2 billion in 1956, and to an estimated 16 billion in 1962. 75% of the cost is expended in the laboratories of industry. The federal government will finance almost 72% in 1962.

Such recognition, however, has brought its own problems, notably the techniques involved in the successful administration of R. & D. and the prompt and effective utilization of R. & D. results. Today wide-spread attention is directed to the functions, responsibilities, and relationships of the research administrator.

Some years ago, when R. & D. expenditures and efforts were relatively minor and when the facilities were relegated to some unused out-of-the-way location on the company's property, it was the purely technical objectives that were paramount. If these objectives were reached, usually with little or no attention from top management, only then was consideration given to whether the results could be made useful to the corporation. If the decision was negative, the results were discarded and the cost charged off as a loss.

Today the management trend is to know before the technical work is undertaken whether the technical objectives are compatible with corporate objectives. This new management philosophy stems from:

a. The emergence of research and development as a key corporate activity requiring major financing.

b. The accelerating rate of technological development which speeds the rate of obsolescence.

Management seeks nowadays to minimize those R. & D. efforts which are directed toward technical objectives which may later prove to be incompatible with sales, marketing, production or finance. This is manifest in the trend to work backwards from the market place and production to R. & D. in an effort to most effectively orient the R. & D. program in the company's interests. Research people can be just as creative within defined limits as they can all over the lot. I sense a similar trend in the various departments of the military where, of course, the market is the soldier in the field.

The conclusion is being reached that a successful R. & D. effort requires an input of information relative to the technological requirements of the company as visualized by sales, production, finance, and purchasing. R. & D. management needs to know basic corporate objectives, specifically defined. It must have forecasts of the effect of contemplated R. & D. action on the several phases of corporate activity. Major decisions are not made in production without consideration of the effect on sales, purchasing, and finance. Likewise, sales and marketing cannot set major goals without an analysis of production capability and the finances involved. R. & D. merits the same type of integrated approach, for eventually sales, production, finance, and purchasing must share the responsibility for implementing the results of a successful research.

Management is also showing an increasing interest in procedures which permit continuing review and evaluation of technical projects in order to determine if the research continues to hold reasonable promise of serving the previously-established objectives. Frequently circumstances force a change in objectives while the research is still in progress.

Top management is accepting the thesis that technical management needs corporate-wide cooperation if it is to fulfill its function properly. From this there has developed the concept of a small distinct group or department reporting directly to top management with specific functions in the area of planning and coordination at the corporate level. The acceptance of this concept has been marked since 1954. Omitting the details, the functions of such a group must include the following:

a. To establish and define with top executive personnel the company's fields of interest.

b. To study trends and to discover in the market-place needs, fulfillment of which falls within the company's fields of interest.

c. To solicit and collect new product ideas from any source within or without the company. Lightning can strike anywhere; many good ideas are conceived outside of the laboratory.

d. To screen ideas for technical feasibility, profitability, probable competition, profitable life, and capital investment required; in short, to develop the idea into a full business concept. In this process the assistance of appropriate operating departments is required.

e. To assure that all ideas which have survived the screening process are incorporated in the R. & D. program and appropriate priorities established.

f. To conduct market tests on the output of pilot lines and semi-works plants.

g. To coordinate the efforts of the operating departments involved in the commercialization of successful research results.

I am sure that most research administrators, at least those in large enterprises, have experienced the frustrations involved in translating a successful research result into the central stream of the company's operations. It is in this transition stage that the operating departments of the company become intimately associated with the project; the call on their manpower and budget money mounts rapidly. Questions of feasibility, profitability, competition, and return on invested capital arise. Obsolescence of an existing product and equipment is frequently a factor. At this point, non-R. & D. people tend to develop cold feet and, in turn, to pour cold water on the project. This has been a source of much lost motion in the industrial employment of R. & D., and it is here that the corporate planning or new products operation just described is proving its worth.

In the first place, the fact that the project was screened from the "business concept" approach and proved compatible with company objectives before any serious R. & D. monies were spent on it substantially limits the question that can be raised subsequently. Beyond that, the planning group charged with collecting and screening the idea can watch its progress through the R. & D. phases and thereby be in a position to alert all the functional departments of the company well in advance of the time when they must become intimately involved and appropriate the monies needed to produce the new product or process into the company's operations. The new product group's coordinating function is invaluable here.

I suspect that the transition stage has been the source of some concern to the Quartermaster Research and Engineering Command. Here the transition stage presents a special and very difficult situation in that the successful research result emanating from the agency's own facilities or those with which it has contracted must usually be translated into military supplies by private industry, over which the military has little control. It appears that this may be one good reason for the existence of the Defense Supply Association and the Quartermaster Research and Development Associates.

The problem should not prove too serious when the research result is a product or process possessing some civilian potential, perhaps with some modification. With civilian business in prospect, suppliers can be found ready to make the necessary capital investments even though the military requirement per se would not justify them. A case in point is a collapsible aluminum tube for perishable food that can be hermetically sealed and thermally sterilized. The Food and Container Institute was involved in this development, and most of you probably have seen it mentioned in connection with Colonel John Glenn's orbit of the earth. A minor modification of this has produced a unique and highly convenient package for baby food, which will be offered to the civilian market shortly.

An added incentive to the supplier in some cases is patent protection obtained through a patent arising in an R. & D. contract financed by the Quartermaster: that is, so long as the Department of Defense pursues its present policy and permits patent title to reside with the R. & D. contractor. Senators Long and McClellan are trying hard to upset this arrangement and force title policy on all federal agencies wherein patent titles must be assigned to the government. For many reasons, which I have elaborated elsewhere, success in their efforts will adversely affect the ability of military agencies to achieve their goals. Their efforts should be disputed at every turn. In this connection, the recent proposal of Senator Wiley, S. 2754, merits serious consideration.

Where the R. & D. result has military application only, the problems of the transition stage are much more complex. Here the prospective volume may be so low that the cost of necessary tooling cannot be justified as a business venture. I have no ready answer to this. In some cases government ownership of the facilities may be warranted, perhaps with provision for subsequent sale to the contractor in the event some civilian application is found or in case government requirements increase materially. Another arrangement could be for the federal agency to contract for a minimum annual quantity on a take-or-pay-basis.

Whatever the problems are in the transition stage, chances are that they can be met and loss of time avoided provided mechanisms are established to assure the proper planning that should precede applied research and development.

FIBROUS MATERIALS

JACK H. ROSS
DIRECTORATE OF MATERIALS AND PROCESSES
HQ, AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
U. S. AIR FORCE

During the last few years, radically new uses for textiles (or fibrous materials) have been advanced to a point where present commercially-available fibers are marginal at best for proper operation. In addition, some of the uses for textiles as we know them have become quite complicated with respect to the environmental conditions to which they will be exposed. Until recently we have been concerned with protecting man and his accouterments from environments encountered in an oxygen-rich atmosphere. Because commercially-available fibers were generally satisfactory, our research was limited to overcoming such unique requirements as abrasion, chemical deterioration, shock loading and flash thermal, to name a few. However, as we re-align our sights and become oriented to the needs of aerospace systems, it becomes very apparent that today's fibers will not fill the bill. The unique environments which our systems will have to endure, the totally new ultimate uses that fibers will be used in, have dictated a very definite switch toward research on high-temperature, high-strength, flexible materials. Let us review some of these potential uses for fibrous materials (Figure 1). From this we can see the

DECELERATORS
- Aero Space Vehicles
- Instrumentation Recovery
- Terminus Approach Control
- Reentry Of Space Vehicles
- Capsular Delivery

INFLATABLE STRUCTURES
- Energy Collectors } For Space Systems
- Reflectors And Communication } For Space Systems
- Dissipators
- Station Protection
- Satellites
- Re-entry Vehicles
- Targets

INSULATION MATERIALS
- Electro Magnetic Radiation Ranges
- Mechanical-Shock, Vibration
- Acoustical
- Thermal

PRESSURIZED CONTAINMENT
- Fluid Storage
- Pressure Suits
- Tires

RIGID STRUCTURES
- Composites
- Laminates
- Satellites

FIBER OPTICS
- Instrument Review
- Area Scanning
- Remote Photography

PROTECTIVE COVERING
- Hyper Environment
- Thermal Radiation
- Weathering

Fig. 1 Uses for Fibrous Materials

- **Compatibility With Associated Materials And Treatments**
- **Surface Characteristics**
- **Configuration Control**
- **Flexibility Or Rigidity**
- **Stability To Radiation**
- **Fatigue Resistance**
- **Energy Absorption**
- **Chemical Stability**
- **Heat Resistance**
- **Permeability**
- **High Strength**
- **Bulk**

Fig. 2 Properties of Interest

problem areas shaping up. In considering these uses it has been necessary to establish those properties in a fibrous woven form that would be of most interest (Figure 2).

In analyzing these uses and the properties of interest, it becomes necessary to arbitrarily decide which properties shall be given the highest priority. Since we are considering uses such as expandable structures, decelerators, tires and hose, three properties tend to predominate. These are strength, temperature resistance and flexibility. In our quest for fibers to fulfill these requirements, a number of classes of materials are being investigated (Figure 3). It would appear from these curves that we have materials which can withstand anticipated temperature environments. However, we must have flexible fibers which can be processed into woven forms. A key to flexibility, as has been shown previously in the theory, is diameter. As diameter decreases, flexibility increases. Further, considering the properties of the bulk material, we are able to theoretically calculate the diameter required to achieve flexibility, equivalent, say, to that of a single nylon fiber. This has been done (Figure 4) and it can be seen that we're looking for some very fine fibers.

Our research to achieve flexible fibrous materials is concentrated in the area of new fibers and fibrous materials. In the fibers area we have programs involving polymers, glass and metals. Even though we know that some of the materials involved are extremely brittle, we cannot overlook their potential and must therefore cover all areas. Today, I will briefly cover some of our work in the areas of polymeric and metallic materials.

In the field of polymeric fibers, HT-1, a duPont product, has shown excellent potential for such uses as decelerators, expandable structures, aircraft tires, and hoses. HT-1, which has good strength properties at up to 600°F, also has been found to have superior resistance to gamma radiation (Figure 5). Further studies of this fiber resulted in our being able to improve the strength at high temperatures through the use of a combined gamma-thermal pretreatment (Figure 6). Considering woven forms of HT-1, the Air Force has constructed three types of parachutes, namely personnel, aircraft deceleration and weapons delivery, the latter having been deployed at a speed in excess of Mach 1. Our inhouse studies have shown that HT-1 fabric covered with a ceramic-filled silicone elastomer will endure 1000°F up to one minute with no qualitative changes. Presently we are considering a material of this type in ribbon form for a decelerator for use in recovering missile boosters.

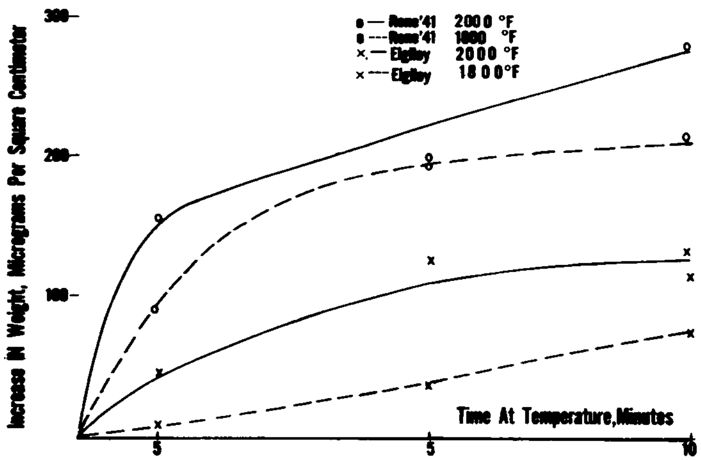


Fig. 3 Comparison of Oxidation Rate of 0.5 mil diameter alloys.

MATERIAL	MODULUS (p.s.i. x 10^{-6})	DIA. REQUIRED for SAME FLEXIBILITY 19μ NYLON (Microns)
NYLON	0.4	19.0
CARBON	0.7	16.8
FIBERGLAS	8.0	9.1
FUSED SILICA	10.0	8.6
COLUMBIUM	22.7	7.1
IRON, NICKEL	30.0	6.6
TUNGSTEN, MOLY.	50.0	5.8

Fig. 4 Filament Diameters Required to Give Flexibility Equivalent to Nylon

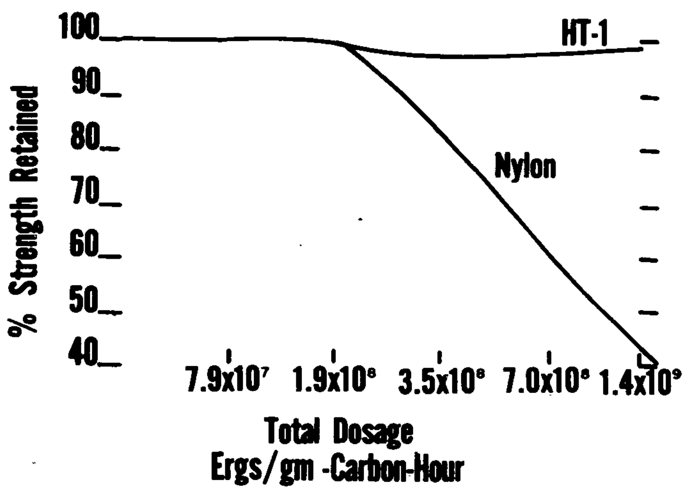


Fig. 5 Results of Gamma Radiation

Conditions

1. Subjected Simultaneously To Gamma Radiation Plus 400°F, or 500, or 600 (Tot.Dosage-1.4×10^9 Ergs/gm -Carbon-Hr)
2. Oven Aged At Indicated Temp. For 8 Hours.

	% Of Original Strength Retained 1	2
400°F	96.3	96.3
500°F	85.1	89.5
600°F	58.6	78.2

Fig. 6 Breaking Strength Data of HT-1

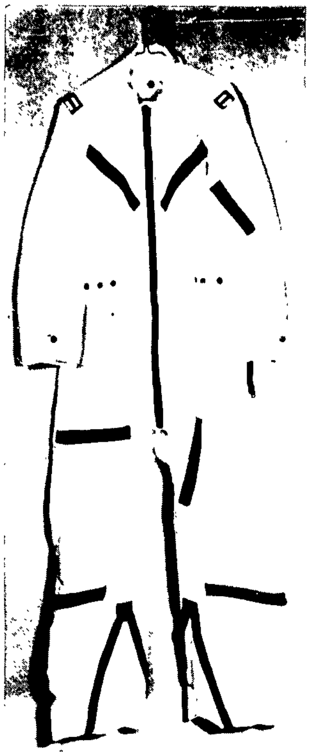


Fig. 7 Outer Clothing

Since HT-1 will not melt or fuse, its potential for personnel parachutes and outer clothing (Figure 7) is being thoroughly evaluated.

The need for flexibility and temperature resistance has necessitated further research in forming fibers from organic polymers. Such polymers as polybenzimidazole (Figure 8) Poly-1-2-3 oxydiazole, and triazoles are being studied for fiber-forming characteristics.

Realizing that the organic polymers won't carry the load above 1000°F, we have turned to the area of metals, and particularly super alloys. Many of these already are used in wire form as resistance heaters. However, to obtain the flexibility equivalent to nylon, much finer diameters are required. It has been found that these alloys, like most synthetic fibers, increase in strength as stretched and drawn to finer diameters. This is graphically shown in Figure 9. The low tenacity of the fibers is of course attributable to the high specific gravity of these alloys. One of the finest things we have done is to characterize these fine metal fibers for strength at various temperature levels (Figure 10). It has been determined that elongation is much more seriously degraded by elevated temperatures than strength at 1800°F; the fibers have zero elongation. To achieve a higher temperature capability we have begun investigating fibers formed from refractory metal alloys. Refractory metal-rhenium alloys have shown excellent strength properties at elevated temperatures (Figure 11). All of the data obtained have been on the single fibers. Recently studies of the behavior of yarns formed from 49 and 100 filaments of 1/2 mil metal fibers have been initiated. We are quite confident that the strength and elongation at elevated temperatures will be superior to those obtained on the individual 1/2 mil filaments. Studies of the flexibility and bending recovery are also being done on these yarns. At the same time we have initiated weaving studies, in which various yarn constructions will be woven, in order to assemble a series of fabrics which will be used for establishing optimum geometries.

Regardless of whether the woven materials we specify for an application are of polymeric, metallic or glass fibers, we must consider the environments to which these fibrous forms will be exposed. Very briefly, two of these environments will be reviewed as to how they affect the behavior of fibrous material. When considering recovery devices, it has become essential that the fibrous materials must be

Fig. 8 PBI Strength, GPD

	ORIGINAL	AT °F FOR 15 MIN. 300°	450°	650°	750°	850°
FIBER	4.1	4.4	3.2	2.6	1.0	0.4
YARN	4.1	3.46	2.85	2.22		

	ORIGINAL	AFTER 24 HRS. AT °F 572°	662°	752°
FIBER	4.5	4.1	2.4	1.0

Fig. 9 Effect of Metal Fiber Diameter on Strength and Elongation

Diameter In Mils	Tenacity-GPD	Elongation-%
10	1.69	33
8	1.88	27
5	2.01	24
3	2.14	19
1.5	2.41	16
0.5	2.69	17

Fig. 10 Comparison of Strength of Two Alloys After Heating in Stagnant Air 1 Mil Fibers

TEMP. TO WHICH FIBERS WERE EXPOSED °F	HEATING TIME MINUTES 1 min. Elgiloy	1 min. Rene'41	5 min. Elgiloy	5 min. Rene'41	10 min. Elgiloy	10 min. Rene'41
ULTIMATE TENSILE STRENGTH p.s.i × 10						
NOT HEATED	200	169	200	169	200	169
1500	194	203	179	207	169	200
1800	155	146	118	114	85	66
2000	113	130	87	Too Brittle	77	Too Brittle
ELONGATION %						
NOT HEATED	28	23	28	23	28	23
1500	21	13	13	13	7	8
1800	6	6	3	1	< 2	1
2000	6	3	5	0	3	0

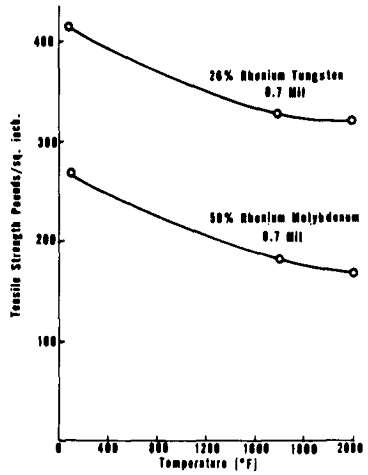


Fig. 11 Tensile Strength of Refractory Metal Alloy in Argon

compactable, yet retain their strength through single and multiple cycles of exposure to elevated temperatures. Further, we might have to use considerable pressure to fit a given shape to a specific container. This could be detrimental to some fiber types and might not affect others (Figure 12). In the case of some inflatable decelerators, extremely high shock loads will be put on the fibrous materials. As a beginning, the impact behavior of webbings is being determined (Figure 13). From this start, impact behavior of seams and joints of these webbings is a natural second step. Study of the impact behavior of promising new fibers in webbing and ribbon will be a must. Looking into the future, we will have to consider many problems. Some of these are permeability, emissivity, heat resistance, chemical stability, to name a few. For coated fibrous materials intended for expandable, re-entry devices, properties such as high strength, combined Vacuum U. V. radiation resistance, bulk, dimensional stability are necessary.

This brings us to some of the target requirements (Figure 14) that have been established that can be used as a guide in achieving first generation fibrous materials for aerospace systems. These targets are really only preliminary requirements, for as we progress through the coming years more sophisticated systems will require second generation fibrous materials. As we fulfill our present needs, the targets for these second generation materials will crystallize. In closing, I must say that the achievement of the Air Force materials research goals can only be accomplished through the continued cooperation of all phases of the textile industry.

Fig. 12 Pressure - High Temperatures

	CONDITIONS °F	Hr.	psi.	STRENGTH lbs.	% LOSS
HT -1	500	2	250	142	0
	600	2	250	118	16
	650	2	250	52	63
	700	2	250	43	69
GLASS, LIGHT	500	6	250	295	24
GLASS, HEAVY	500	6	250	454	32
METAL (316 STAINLESS)	1000	6	250	56	0
	1000	72	250	50	11

Fig. 13 High Speed Loading of Nylon

WEBBING DESIGNATION	INSTRON	@ 200 ft./Sec.	@ 500 ft./Sec.	@ 700 ft./Sec.
RUPTURE STRENGTH (lbs)				
WN 1505	4000	3600	4400	5300
WN 1512	6000	5100	8640	4900
WN 1509	9100	8000	8300	6400
TYPE XX	10400	7200	12000	7200
RUPTURE ENERGY (ft-lbs)				
WN 1505	1212	812	1835	1783
WN 1512	1490	1469	2258	1694
WN 1509	2920	2976	5335	5151
TYPE XX	3290	4397	6269	5267

Fig. 14 Target Requirements

Temperature	75%	2,000°F For Max. Of 10 Min. 1,500°F For 10-20 Min.
Vacuum And Solar Radiation	80% Strength Retention	Continous Or Intermittent Exposure Totaling 4×10 ^{7} Langleys At Orbital Altitude
Flexibility	No Failure	Crease Flexing And Compressive Creasing In Cycles For 24 Hours
Compaction	90% Strength Retention	Packing Pressure Up To 150-250 lbs/sq. in.
Vapor Permeability	Impermeable	Inflated With Air Or Helium In An Atmosphere Of Complete Vacuum At 1,200°F
Chemical Resistance	Inert Or Non-Corrosive	Ozone (11 P/M 100 M FT) Ionized Gases
Meteorites	No Penetration	Micro Meteorite Bombardment

"TEXTILES AND CLOTHING FOR SURFACE SHIPS AND SUBMARINES"

T. J. SEERY

BUREAU OF SUPPLIES AND ACCOUNTS, DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

ABSTRACT

Research and development of textiles and clothing are reviewed in relation to the environment of surface ships and submarines. Progress is reported on materials for insulation, buoyancy and protection from fragmentary ordnance. The use of mechanical devices is noted for ventilation of impermeable clothing. Synthetic blended fabrics are shown to reduce moisture vapor output in the operation of machine dryers in submarines. A basic Navy work-combat uniform is proposed to replace two separate types.

* * * * * *

It is interesting to speculate on the influence of clothing in the evolution of man. Having learned to attire himself against the elements, he remains essentially a delicate sub-tropical animal living at higher latitudes, and now probing for knowledge at higher altitudes. Meanwhile his progress creates new problems to be solved by devising all manner of protective shells. Were he to have advanced physiologically instead, we should be devoid of both clothing and problems and today share the apparent comfort of the aborigines of Australia or Tierra del Fuego. Since evolution or fate chose the former path we are obliged to continue, and design fabrics and clothing to conserve our pool of human and material resources. More specifically, our interest lies in the somewhat unpublicized area of clothing and textiles for the marine climate, and the occupational and combat environment of surface ships and submarines. Elaborate specifications have been prepared to guide manufacturers toward minimum acceptable standards for such applications. But these leave unsaid the reasons for the choice of fiber, fabric, finish and end item design. Anything that may be said to fill this void is beneficial in one of two ways. It should promote an improved product simply by better understanding of the purpose it serves or its purpose may suggest more effective or economic choices. This is also an occasion to note some unfulfilled needs and efforts to meet them. Finally, it is a rare opportunity to crack the public's image of the American sailor eternally clad only in summer "whites" or winter "blues".

The Topside Environment

The crew of a ship may be likened to the population of a small town transportable en masse and without notice from the tropics to the arctic. En route on deck one can expect windspeeds equal to the sum of prevailing wind and the speed of the ship. If a man is simply standing watch in an exposed position, a topside temperature of 32°F. is no real means for assessing his comfort or requirement for a specific type of clothing. For a two-hour watch under these conditions he might as well be driving an open sports car with the windshield down. This is a demonstration of windchill, or evaporative cooling, that should be taken into account, along with solar radiation, if we are ever to have a reliable measurement for determining man's comfort in the cold. A word should also be said here about the difference between the effects of sea water and natural precipitation on clothing. Most of us have observed that water repellent finishes "wear out" before the fabric. In some cases this is due to wet mechanical action in cleaning. More often the finish remains but is masked by wetting agents, in the form of excessive soil or residual solids due to improper dry cleaning or laundering. What bewilders the seaman, however, is his impression that the clothing has not been water repellent treated at all. Impinged water droplets or slightly wet water repellent fabrics, after exposure to natural rainfall, may be air dried with little or no effect on subsequent water repellency. When wetting is caused by salt water, often from sea spray in dry weather, air drying leaves a sea salt residue in the fabric. This residue, being hygroscopic, will take up water if the relative humidity is sufficiently high and will form an unsaturated solution. Thus, inboard the ship, clothing that has been dried after exposure to sea water may be rewetted by water vapor in the atmosphere. On the next exposure to rain or sea spray this clothing shows little evidence of water repellency. Thus the subtle differences between water repellent, water resistant and waterproof generally elude the seaman. His interest lies in knowing whether the clothing will keep him dry and confidence in anything but waterproofness will be established only by demonstration.

Buoyant Cold Weather Clothing

About ten years ago the Navy developed a new type of cold weather clothing for shipboard use. Employing a "picnic jug" construction, waterproof coating of the outer shell and linings protected the interlinings from external water or absorption of perspiration. With acetate batting enclosed in a waterproof nylon jacket liner, this clothing will also keep the wearer buoyant in the water for about twenty minutes. At this point slow leakage at the seams takes over and the clothing becomes negatively buoyant. Two important changes have been made recently in materials for this clothing. One is the use of a double, unbalanced chloroprene coating on a more open construction base fabric, employing producer's twist nylon yarns for high tear strength. Also, the acetate batting in the jacket liner has been replaced by a unicellular polyvinylchloride foam. The PVC foam is not intended as a substitute for a life preserver. It is nevertheless some insurance for the wearer in accidental immersion, since it provides sustained positive buoyancy in addition to serving as an insulation material. Other essential features incorporated in the original design were retained. These include a "three dimension" box-design for the jacket and built-in pouches at the trouser knees. This design reduces fatigue by transfer of jacket weight from the shoulders to the hips. It also reduces loss in thickness due to compression of insulation (See Figure 1). This is an example of clothing designed to supplement or upgrade material characteristics. In deciding on insulation, one might do well to take counsel from the heating engineer who determines the thickness of insulation in accordance with the diameter of steam pipes. It should be found consistent with the advice of the physiologist who prescribes the thickest insulation for the body trunk to protect the vital organs from excess heat loss. Particularly in sedentary occupations, this should reduce the borrowing of heat from the extremities and extend the man's tolerance to the cold.

Body Armor

Work is now underway on a new insulating material not only for buoyancy but also to provide ballistic protection from fragmentary ordnance. A promising material for this purpose is a compressed batting made of silicone-treated acrylic staple fiber, 1 denier 3" cut. Armor of this type behaves quite differently from laminated glass fiber plates or multilayer nylon armor cloth. The spinning, high velocity fragment simulator, upon entering the batting, builds up a fibrous "snowball". As the core of the enlarging "snowball", the fragment decelerates and is effectively entrapped within the batting or emerges at a markedly reduced velocity. The silicone acts as a lubricant to reduce friction between the compressed fibers and thereby permits formation of the fibrous wad around the metal fragment. It is also an effective hydrophobic treatment to impart buoyancy to the batting. In the future, such armored battings may be used as liners for winter clothing or as filler for life preservers.

Materials with multi-purpose characteristics of this nature will serve to protect the man with minimum impairment of his usefulness. Their merit may be appreciated by considering the alternative - - in this case men clothed in separate winter gear, body armor and life preservers manning amphibious craft and small boats putting troops ashore on a hostile beach. Unless we succeed in producing multi-purpose materials and end items we risk having an over abundance of protective equipment. We will then need a larger man to carry it and still have no place for stowage aboard ships where space and accessibility are already critical problems. (See Figure 2.)

Impermeable Clothing and Heat Stress

There are any number of occupations in the military services, some peculiar to the Navy, that require impermeable protective clothing. Such clothing may be required by crews "at the ready", crash fire fighters in aluminized suits, damage-control parties or liquid propellent rocket handlers in suits of materials almost as exotic as the fuels and oxidizers. Below deck we have another problem in ships engine rooms and machinery spaces. Here the temperature will rise to

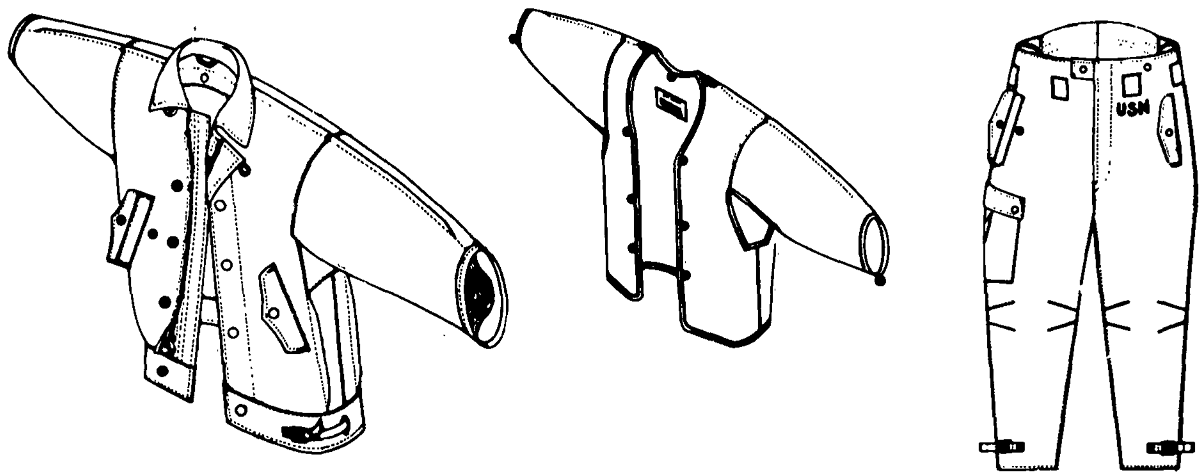


Fig. 1 Extreme Cold Weather Clothing

Fig. 2 A British Navy Jibe at Equipment Requirements

140°F when the ventilation system is closed down to exclude contamination under combat conditions. Many devices have been proposed or demonstrated to extend man's tolerance to heat stress in these situations. Perhaps the most sophisticated is the thermoelectrically-cooled suit. Based on the Peltier principle and Seaback effect, this cooling-heating package would have no moving parts except for a motor-blower to recirculate self-contained temperature-controlled air. Power would be supplied by an umbilical cord from a D. C. source or by a waist-belt of silver cell batteries. At the other end of the scale is a relatively simple exhaust fan. This might be used to ventilate impermeable clothing at ambient temperatures and humidities that man now tolerates in lightweight moisture vapor permeable clothing. The squirrel cage fan weighs about 18 ounces and is powered by a mercury battery with approximately 24 hours endurance. The fan is fitted to the upper back of the impermeable suit. Under test chamber conditions (see Figures 3 and 3a) with an ambient temperature of 84°F., R. H. 40%, the relative humidity between the skin and unventilated suit rises to 93% in 14 minutes. With the exhaust fan on, the R. H. within the suit falls rapidly, and in less than 2 minutes levels off at 45%. The result is a new technique advanced to reduce man's "down time" for relief from heat stress.

"Polaris" Clothing

The blue and gold crews that alternate in manning the Fleet Ballistic Missile (Polaris) submarines are outfitted in a smart-looking blue coverall. (See Figure 4.) Although it won a Caswell Massey International Award for Excellence in Design, this has little to do with the purpose it serves. The coverall, as well as socks and underwear, is made of blends to solve a unique and unanticipated problem in the submarine's closed environment. Water vapor can hardly be classed as an atmospheric contaminant but was a growing problem in nuclear submarines because of the continuous use of machine dryers on extended cruises. Not only did it raise the relative humidity in the immediate area but water condensed on bulkheads, lockers and other metal surfaces.

From laboratory trials it was estimated that machine drying of the standard cotton clothing for a 100-man crew would produce close to 19 gallons of water in the form of moisture vapor. On the other hand, 100 outfits made of the synthetic blends would produce somewhat less than 4.5 gallons. (See Figure 5.) In a typical 10-lb. load, moisture vapor is thus reduced about 65 percent. Moreover, exclusive of any reduction in drying time, the machine dryer would be more productive. The number of 10-lb. wash loads to outfit 100 men would be reduced from 22.2 to 14.5.

The standard clothing consisted of cotton T-shirt, 80-square print cloth shorts, cotton socks, chambray shirt and denim trousers. The blends were essentially off the shelf:

80% acrylic/20% cotton T-Shirts
65% polyester/35% cotton Boxer Shorts
50% stretch nylon/50% cotton Socks
50% polyester/50% cotton 2/2 twill 5-5.5 oz. Coveralls

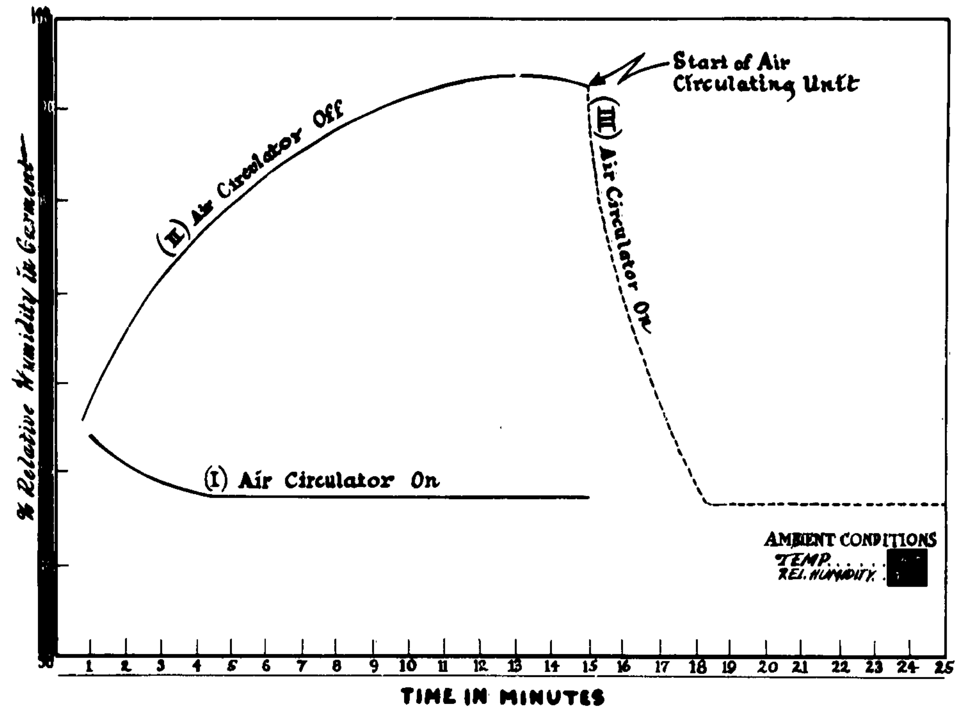
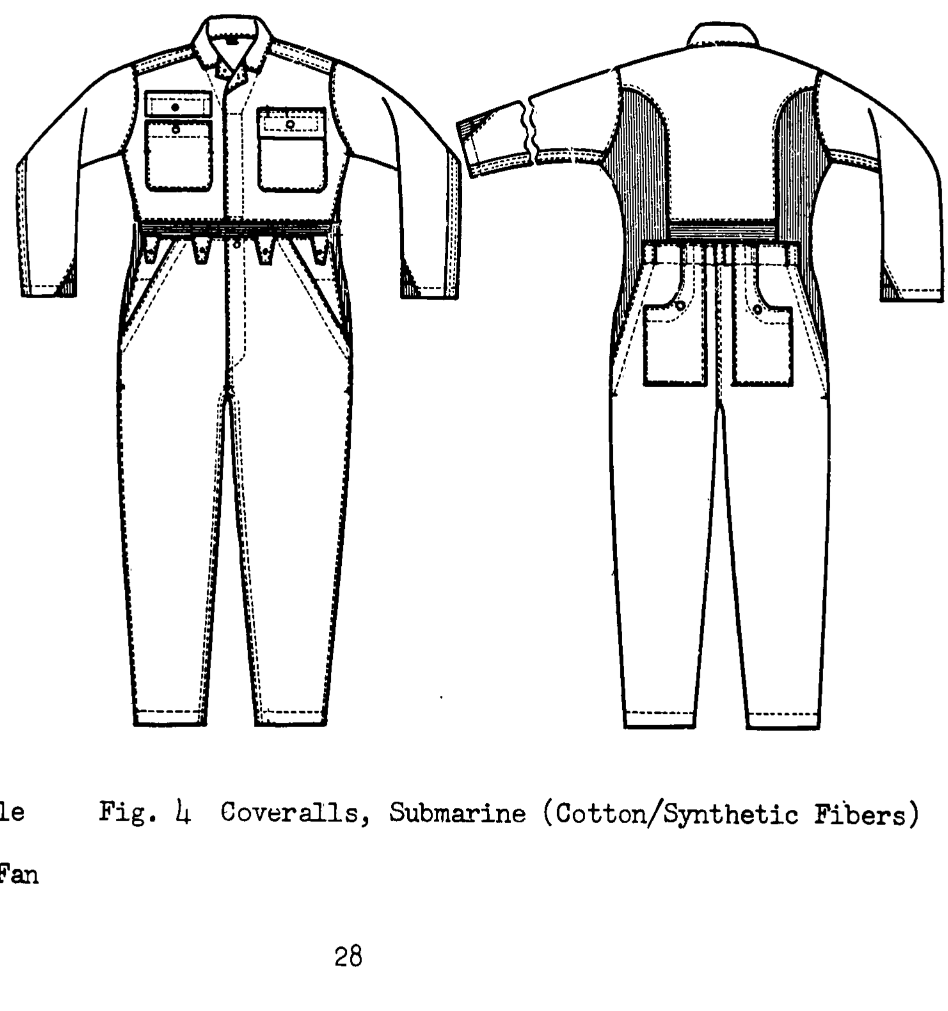


Fig. 3 Influence of Air Circulator on Relative Humidity



3a Impermeable Suit Equipped with Exhaust Fan

Fig. 4 Coveralls, Submarine (Cotton/Synthetic Fibers)

Following sea trials the shirt, or upper of the coveralls was changed to a lighter weight fabric: 55% polyester/45% viscose plain weave, 4.2 - 4.9 oz.

This is an example of blended fabrics in a very practical and useful application. If there is any aesthetic improvement it is purely coincidental.

A Work-Combat Uniform

Denim dungarees and chambray shirt still make up the Navy's basic work uniform. Considering cost alone, one could hardly find a better buy. But neither fabric has acquired a reputation for wear resistance. This uniform may not last even thirty days for the man working on the flight- or hangar-deck of an aircraft carrier. These decks are no longer wood over steel plate. To provide greater traction for aircraft, the steel decks are now coated with a highly abrasive compound containing large particles of aluminum oxide or silicon carbide (MIL-F-18176A (SHIPS) Flight Deck Compound; Nonslip; Lightweight, Abrasive Filled, Synthetic Binder Type). Every recruit receives three sets of dungarees and chambray shirts. Thereafter he buys replacements as necessary, making payment from his monetary clothing allowance. This arrangement may seem to favor the yeoman who might have his original three sets of work uniforms intact at the end of a four year enlistment. He would be quick to point out, however, that he must wear service whites or blues more often and their replacement cost is greater. So simply upgrading the quality of the work clothing fabrics is not a very discriminating or economic solution. From time to time the Navy therefore has rejected proposals that might result in nylon-reinforced cotton denim or cotton/polyester chambray. What has been sought instead is a much larger return for any extra investment, a combination work-combat uniform.

Now stowed away in the hold of every ship of the fleet is a quantity of so-called protective clothing, our defensive combat uniform. It consists principally of a parka and trousers, made of unbleached carded cotton twill, impregnated with XXCC3, a chloramide with a chlorinated paraffin binder and zinc oxide stabilizer. Originally this clothing was intended for chemical warfare protection. Worn with a mask, gloves and boots, it provides full body coverage and is now known as ABC (atomic, biological and chemical warfare) Protective Clothing. While it may serve these purposes fairly well, it nevertheless poses a number of logistic and operational problems. If stored in original unopened fiberboard containers it has a shelf life of several years. If broken out for training or in open storage, the impregnation may retain its protective characteristics for only a few months. Periodically, therefore, this clothing must be returned for replacement or reimpregnation ashore in order to maintain a proper state of readiness. Thus it is not worn for routine duty nor is its design likely to encourage continuous wear above or below deck. Finally, accessibility will depend upon location in storage, the speed with which it may be broken out and distributed to the crew in a reasonably proper fitting size, when and if needed in combat.

COMPOSITE CHARACTERISTICS IN MACHINE DRYING

ONE OUTFIT	STANDARD COTTONS	POLARIS BLENDS
Wt. after extraction (gms)	1700	816
Wt. after drying (gms)	996	654
Wt. of moisture vapor (gms)	704	162
10 lb. load		
Moisture vapor (liters)	3.17	1.12
Men outfitted	4.5	6.9
100 men outfitted		
Moisture vapor (liters)	70.4	16.2
" " (U.S. gals)	18.6	4.3
Number of 10 lb. loads	22.2	14.5

Fig. 5 Composite Characteristics in Machine Drying

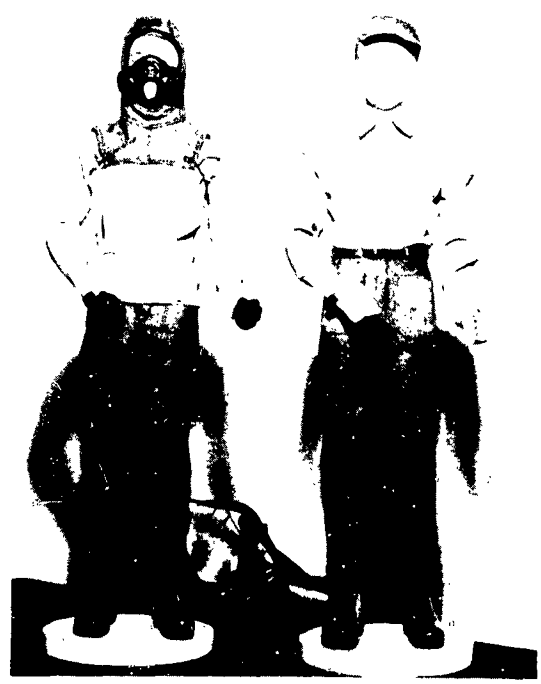


Fig. 6 Navy Experimental Combat/
Work Uniform

Critical examination of this situation shows that we have a work uniform readily accessible to all hands but unsuitable for defensive combat. On the other hand the combat clothing, reasonably good for defense, is relatively inaccessible and unsuitable as a work uniform. Our objective now is to meet the two requirements in a single uniform. For some time we have observed the work of the Army Quartermaster, in the development of 50-50 cotton/nylon blends. Carbon arc evaluations of such fabrics at the Naval Supply Research and Development Facility follow the same pattern as QM findings with respect to improved resistance to thermal radiation. Few will dispute an estimated two- or threefold increase in wear resistance of these fabrics over Navy denim and chambray. Sample dyeings of the blends show that a one-bath method should produce a reasonable approximation of the present standard blues. Concurrently, development of a prepackaged emulsion, and a method for its use for impregnation of clothing in the ship's laundry, promises to minimize the problem of converting uniforms from work to combat type. To do this properly, some changes are also required in the clothing design. Instead of a hooded parka to be fitted to a gas mask, each mask would be packed with a hood made of impregnated fabrics. The work shirt would be designed in a pullover style with standing collar and 2- or 3 button front closure. The hood would include a skirt sufficiently long to protect the neck and cover the front opening of the shirt. For combat protection the shirt would be worn preferably outside the trousers, which would also be designed with an improved closure. In this way 100 percent of the crew can be provided with a work-combat uniform, readily accessible, and with improved protective characteristics as well as use life. (See Figure 6.)

Research and Mobilization

At times the research scientist, rightly or wrongly, may be accused of preoccupation with matters of great academic interest to himself but to few others. It also may be said occasionally that the development engineer is designing obsolete equipment. There may be a measure of truth in both statements. The situation seems to be caused by the rapid advance of technology in general. It no longer waits for the slow learner and frequently abandons the problem of the present in favor of a more promising future. The reaction on the mobilization planner may be much more critical. If he makes the assumption that materials and equipment will be needed in the future simply because they are used now, he will indeed be prepared for the past. No panacea is proposed to avoid this pitfall. But improved communications among all concerned, from research through production, may be the first step in this direction. It is our earnest hope that what is said here today contributes to this aim.

TEXTILE AND CLOTHING FOR LIMITED AND NUCLEAR WARFARE

BY

DR. S. J. KENNEDY, DIRECTOR

CLOTHING AND ORGANIC MATERIALS DIVISION

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND

NATICK, MASS.

To those who participated in land fighting in World War II, particularly in the fighting in Europe, there could scarcely be a greater contrast between that type of military action and what we are now witnessing in Vietnam and Laos on the one hand, and that foreshadowed by the nuclear testing being carried on in the Pacific on the other. The spectrum of military action has been broadened far beyond what has generally been thought of as conventional warfare. The weaponry and the defensive measures needed today to enable our troops to fight successfully in these two disparate kinds of warfare must be both simpler and yet more sophisticated than those we have had in the past.

To interpret these needs we must first understand that limited and nuclear warfare - - these two opposite ends of the spectrum of military operations - - differ significantly from the characteristic type of combat of World War II, so far as the individual soldier is concerned. This statement is no less true for the soldier's clothing and equipment, which comprise a large part of his means for personal defense, than for any other items in the arsenal of our army. We need textiles for combat clothing today that will be significantly different from what we used in World War II.

Limited warfare, as indicated by President Kennedy in his special message on the defense budget on 28 March 1961 is of particular concern to the Army:

"Non-nuclear wars and limited or guerrilla warfare have, since 1945, constituted the most active and constant threat to world security. We must have strong, highly mobile forces trained in this type of warfare."

The significance of limited warfare in our present struggle with world communism, was stated by Mr. Khrushchev in an address on 6 January 1961 when he said:

"Recent examples of national-liberation wars include the armed struggle waged by the people of Vietnam. Such wars, which began as uprisings of colonial peoples against their oppressors, developed into guerrilla wars. The communists support just wars of this kind wholeheartedly and without reservations."

The kind of warfare which Mr. Khrushchev intends to sponsor and aid could occur anywhere in the world. However, since most of the former colonial and undeveloped areas of the world happen to be located in the tropics or sub-tropics, we are faced with the fact that such guerrilla fighting will to a large extent involve jungle operations.

Hence our problem of clothing and equipment for limited war is heavily oriented toward hot climates, areas having few transportation facilities, and where small forces must be able to operate effectively at considerable distances from their bases. These are areas where concealment, evasion, ambush, and sudden attack, followed by disappearance into the countryside, form the characteristic type of operation.

Under such conditions the individual soldier is the all-important factor in the campaign. His clothing and equipment may be the all-decisive factor of his success. It must have unique durability, and multi-functionality that will permit improvisation to meet unexpected needs.

Here, for example, is a lightweight net made of nylon which would be a useful item for many purposes. It could be used as a carrying device for irregularly shaped loads, or to move supplies quickly away from an air drop. Or it could be used as a device to evacuate wounded; or it could be used as a sleeping hammock; or as a fishing net to provide needed food. It could also be used to conceal a cache of supplies in the tree tops, or it could be used as an individual camouflage net. It could be used as a screen to cover a panji pit - full of sharp bamboo or metal spikes, the points of which would be covered with native poison. I am sure a resourceful guerrilla fighter could find other uses for it too, such as for concealing a sniper's roost among the branches and foliage of a tree.

What other textile equipment for such warfare is needed? We are fortunate that two living experts of guerrilla warfare, Mao Tse-Tung, leader of the Chinese Communists, and Che-Guevara, Castro's expert on guerrilla warfare, have been quite explicit about this. Let us quote from Che Guevara in his discussion of the essential equipment to be carried by the individual guerrilla fighter in the back country:

"Among the essential items for guerrilla warfare is a hammock. This provides adequate rest. In cases where one sleeps on the ground, it can serve as a mattress. Whenever it is raining or the ground is wet, a frequent occurrence in tropical mountain zones, the hammock is indispensible for sleeping. A piece of waterproof nylon cloth is its complement. The nylon should be large enough to cover the hammock when tied from its four corners, with a liner strung through the center to the same trees from which the hammock hangs, to make a kind of tent by raising a center ridge and causing it to shed water."

I think Che Guevara has designed us an Army hammock quite effectively as well as endorsing nylon as the basic fiber. As a matter of fact, he has described the hammock which Bob Woodbury of our group designed for the U. S. Army during World War II, and which became a part of our Army equipment at that time. We now have a new improved jungle hammock which is illustrated at the end of the report. It is less than half the weight of our World War II item, and takes only half as much space in the pack of the soldier.

The next indispensible item in Guevara's list is a blanket; because, as he says "it is cold in the mountains at night" (and it is, even in the tropics). Our concept of a blanket is a lightweight one. That developed in World War II was only 56" wide cut down ten inches in width to save weight. It weighed only 1-3/4 pounds instead of the standard 3-3/4 pounds when dry, and was made from a 75% wool and 25% cotton blend. Our present thinking is a polyester batting, stitched between two layers of one-ounce nylon parachute fabric.

It will dry quicker than the wool blanket and weigh much less when wet. It makes an excellent insulation also when one rolls up in a poncho to sleep on the ground.*

The next indispensable item of Che Guevara is "a jacket or coat which will enable one to bear the extreme changes in temperature." With this he advocates rough work trousers and shirt. We feel we can do this job more effectively by utilizing the results of our physiological and textile research to provide a wind breaker and trousers made from a thin lightweight, but very tightly woven fabric which will also be mosquito-resistant. We then give the man an insulating layer to wear underneath it, to protect against the damp chill of the jungle night. Our insulating layer at present is an all-wool sweater, but it increases excessively in weight when wet, so we are now considering an all-synthetic-fiber garment.

To us, the problem of protection against insect-borne disease vectors by providing clothing made from mosquito-resistant fabrics is far more important than it is to natives in such areas, most of whom have developed tolerances or immunities to the more common insect-borne diseases, such as malaria, sand fly fever, yellow fever, dengue, and other casualty producing diseases. Furthermore, we value life more highly than some of these other peoples and must do everything possible in guerrilla warfare to hold to the absolute minimum the amount of medical care required in the field.

Thus, mosquito protection is more than a matter of taking a pill of atabrine, or chloroquine, which has now replaced it. We want our clothing to be mosquito resistant so that the mosquitos cannot bite through it, both from the standpoint of disease prevention as well as to reduce the annoyance and discomfort of the swarms of mosquitos and sandflies in lowland areas. Hence, our concept of a fabric for tropical and jungle warfare is a tightly woven fabric but very light in weight - - as tight as our best wind resistant fabrics for cold weather. Such fabrics must also be snag-resistant for the tropics are full of thorny plants, such as the spring rattan, the black palm, and the wait-a-bit-bush, so called for its fish-hook like thorns from which you cannot pull yourself free if you once get caught by them, but must stop and disentangle yourself.

It is not surprising that Che Guevara is also concerned about footwear. Let us quote:

"Shoes should be of the best possible construction and also, since without good shoes marches are very difficult, they should be one of the first articles laid up in reserve."

We have developed a new jungle boot made with traction soles vulcanized to the bottom of the shoe. It utilizes a nylon/cotton blend duck for the uppers which is mildew resistant, will dry out quickly and allow water, once in the boot, to drain through and evaporate from the surface of the fabric. Drainage is also encouraged at the drain holes at the instep.

This boot, and in fact all of our combat boots in the future, will be provided with ventilating insoles made from vinylidene chloride mesh fabric. These insoles allow the skin on the sole of the foot to dry out, and thereby promote comfort and foot health.

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* Photographs of several new items of equipment are shown at the end of this report.

It is a quarter of a pound lighter in weight than our present tropical combat boot. When one considers that a half pound on the feet is equivalent to 3-1/2 pounds on the soldier's back, this means that he can carry more food, ammunition, or other supplies which will increase his ability to stay away from his supply line and be that much more effective as a guerrilla fighter.

As to the guerilla fighter's other equipment, the factors of lightness in weight, versatility, multi-functionality are all important. We have just recently produced experimentally a lightweight rucksack for guerrilla fighters which weighs less than three pounds, in contrast to seven pounds for the present rucksack in our system. We use a four-ounce highly calendered nylon fabric treated with a water repellent finish for the bag. The straps are all lightweight nylon tapes.

Best of all, the frame is convertible to a packboard and, in addition to the bag, which can be dropped down to a lower position for firing weapons, the wearer can place a case of ammunition, a can of water or gasoline, a pack radio, or any other necessary bulky items on the frame where they can be carried as on a packboard.

This means that the man, in addition to carrying his regular load, can carry special warfare mission equipment, such as radio,power pack,generator, or the medical bag which contains equipment and supplies for everything from an appendix operation to delivering a baby (all of which trained guerrilla fighters must be able to do as is evidenced in the writings of Che Guevara and our own experience in working with indigenous peoples).

Another item which obviously would be of great use in the jungle would be a strong ultra-lightweight rope which could be used for climbing lines, for scaling cliffs, for constructing rope bridges for crossing chasms hand over hand, or for use in triggering demolitions or for guide lines at night through swamps and difficult terrain. While we have been looking at nylon for this rope, we feel there is a place for polypropylene because of its lighter weight. However, if we are to use polypropylene we would have to have higher-tenacity fibers than are now available in ropes made from this fiber.

The right kind of headgear for the jungle may be expected to be different from that of past years. We need mosquito protection in this headgear since we cannot depend wholly upon available insect repellents due to their rapid absorption by the skin and their disappearance from the surface by rubbing off and abrasion. The hat should be something that could be folded up easily and be put into the man's pocket or pack.

We need also a textile-type flexible canteen, which will lose its bulk as the water is consumed and when empty can be folded up and stuck back in the pack as a low-bulk item.

We need also an all-purpose cloth which can be used as a neck cloth to keep ants and leeches from falling down one's neck, and will also be useable for a sweat cloth, a towel, dish dryer, and havelock.

We would also like to have a parachute which could be immediately and completely disposed of upon landing, without attracting any attention.

If the textile industry cannot produce this, then we would like a multi-purpose item which could be burned to provide a smokeless fuel for heating and cooking, or perhaps a combination of the two.

In addition to this, we want a new kind of dye for jungle equipment - - a chameleon-type dye which will appear to take the color, or at least the color value, of the surroundings of the soldier. Such dyes should, accordingly, be able to range over the greens, browns, and tans as needed.

While speaking of dyes, this is a good place to introduce our requirements for nuclear warfare. Here we need dyes for our uniform fabrics which will have the capability of immediately turning white, or at least to a highly reflectant shade, the moment the high-intensity radiation of the nuclear flash impinges upon them, but which will then return to their normal shade immediately afterward. This phototropic characteristic which actually is a nuisance to the dyestuff and the textile dyeing and finishing industry on most civilian-type dyeings, could be of great value from a military standpoint if it could be properly developed to serve our purposes.

Actually our requirement is for a shield fabric - - the outer fabric of the soldier's combat clothing - - which will have multi-functionality. In such a shield fabric the phototropic dye would contribute to the overall performance. Whatever the fabric is made of, i.e., the fiber itself, whatever we put on it in the form of a multi-functional finish, and the dye as well, should all make a positive contribution to the performance of the textile fabric system in providing specific types of protection to the soldier.

We need the dye, of course, for camouflage first of all. Camouflage in itself today is a very complex matter going far beyond simple observation by the naked eye, when one considers the various types of photographic film which can be used in battlefield surveillance, and the various types of detecting devices, such as those using infrared spectrum and radar.

From the standpoint of nuclear warfare itself, we have three basic protection requirements to be met in the soldier's clothing system: to protect against the thermal impace of the blast, against fallout, and against flash blindness. These are over and beyond the nuclear effects for which no clothing can be devised that will provide significant protection.

The extent of the area in which thermal burns may occur is illustrated in the Figure 1 which shows that area-wise, in 82% of the area subjected to the effects of a nuclear blast, thermal energy will be the main consideration from the standpoint of hazard. With such a large potential effect, it is therefore important that we utilize our textile materials system to the maximum extent to provide protection.

After a great deal of work in this area here in our Textile Materials Research laboratory, it is apparent that some of the principles involved are quite clearly defineable:

a. The mass of fibrous materials in the textile materials system of the soldier's clothing is important, simply from the standpoint of its ability to provide a wall or barrier to the thermal energy.

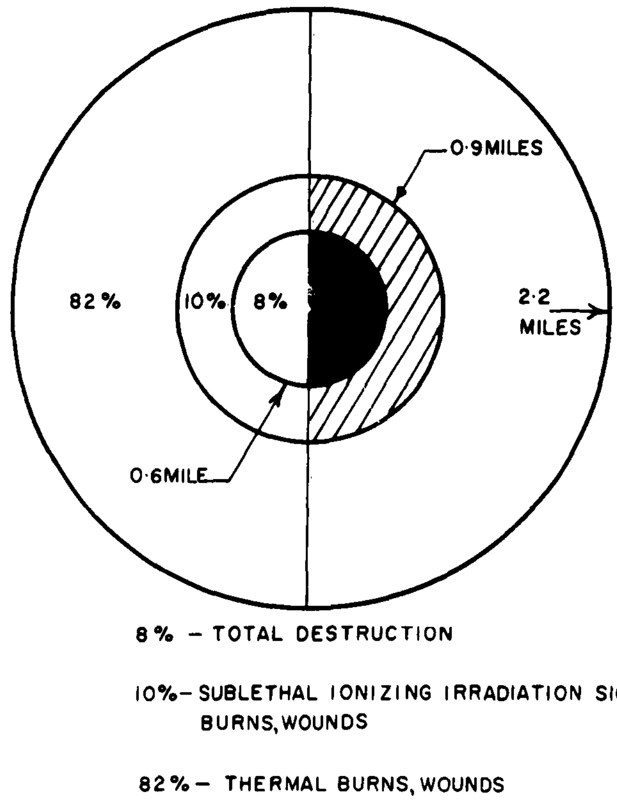


Fig. 1 Population at Risk From A-Bomb

This effect is shown in Figure 2 where the energy required for ignition of the fabrics is plotted against fabric weight (solid curve). Obviously the relationship is not linear and above 5 ounces per square yard, small increases in weight produce a much more than proportionate increase in ignition resistance. The dashed curve, which shows energy absorbed per unit weight at ignition, demonstrates that fabrics with minimum weight in the range 6 to 6-1/2 ounces per square yard are desirable.

b. The endothermic characteristics of some fibrous materials are important as means for providing a heat sink as the fibers become subjected to destruction. The behavior of the nylon in some cotton-nylon blends illustrates this. In the Figure 3 is shown the heat transfer data obtained when each of the two faces of an orthoblend of nylon and cotton was exposed to thermal radiation. With the nylon face exposed the endothermic reaction resulted in relatively low heat transfer, as shown by the curve labeled N. Conversely, with the cotton face exposed, the exothermic reaction from the same fabric produces a high degree of heat transfer (curve c).

c. Blends of fibers are generally better than single fibers, since in various ways disparate properties seem to contribute to the more efficient functioning of the total fibrous mask. That this factor varies with various combinations of fibers and is most effective with combinations of natural and synthetic fibers is shown in Figure 4. Here we have plotted the heat transferred from 50/50 blends of various materials of equal weight and optical properties, when they were exposed to increasing amounts of radiation. As shown, the least effective combinations are those consisting entirely of conventional synthetic fibers. In this instance the materials are rapidly destroyed with attendant high heat transfer. Thus, the combinations of Polyester/Acrylic, Nylon/Polyester, and Nylon/Acrylic are relatively ineffective. In comparison, the combination of cotton with Polyester or Nylon is considerably more effective with the cotton/Nylon blend being much the best.

d. The optical properties of the shield fabric play a major role both in the manner in which they reflect and transmit radiation, and the manner in which the absorbed radiation is utilized. This latter factor is demonstrated in Figure 5 where the energy required to ignite equal weights of cotton/Nylon blends is shown as a function of the ratio of the reflectivity of the Nylon fiber to the reflectivity of the cotton fiber for materials with varying Nylon concentrations. It is interesting to note that for the 40 and 50% Nylon blends, if the Nylon fiber is either very dark or very light compared to the cotton fiber, a low order of resistance to ignition results. However, at a ratio of 1.25 a 40% blend was raised to 16.5 calories and for the 50% blend ratios of approximately .8 to 1.25 would give good performance.

The significance of the manner in which the shield material reflects and transmits radiation is shown in Figure 6 where the ignition irradiance is listed in Part A for the same fabric dyed to two different conditions. These data show that even though two fabrics have equal reflectivity in the visible region of the spectrum, difference in the infrared region can have a marked effect upon their resistance to ignition.

Under essentially the same conditions, but using a different fiber and fabric, the role which may be played by transmittance is demonstrated by the data of Part B. Here is listed the protection provided by an outer layer which, although an OD shade, transmitted substantial amounts of energy. In this instance,

Figure 2
Ignition Characteristics of 40/60 Nylon/ Cotton Blends

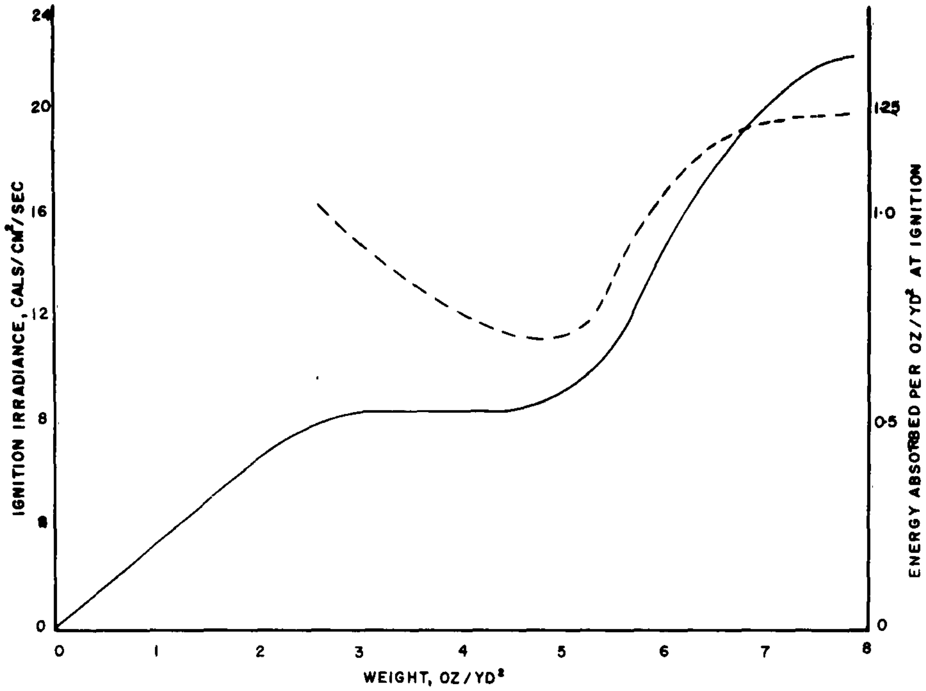
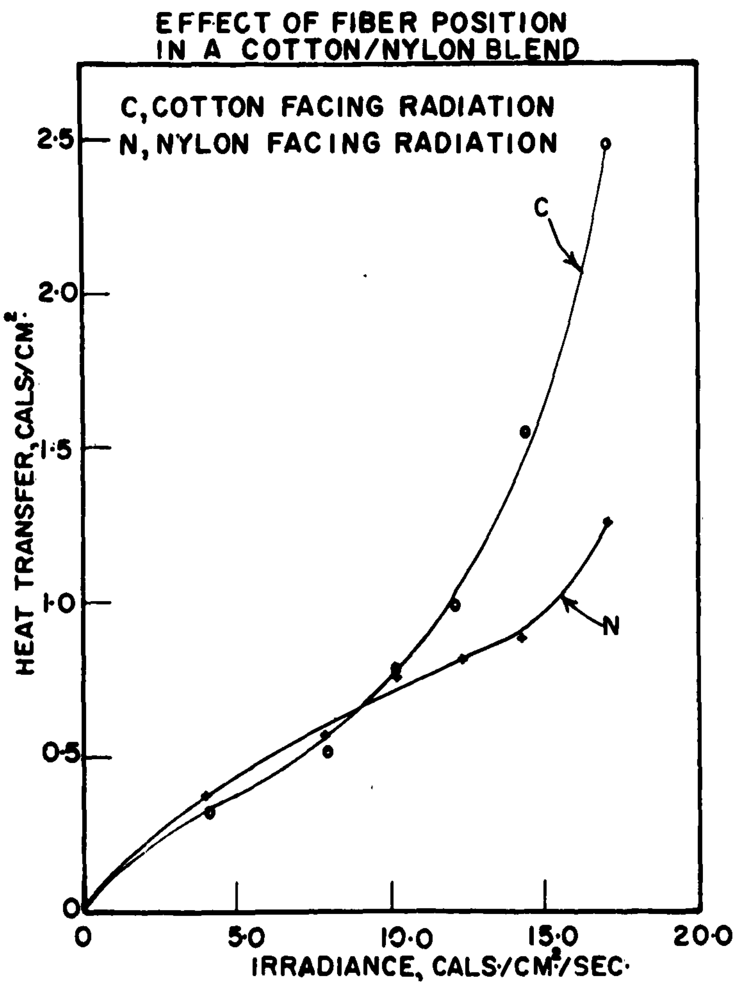


Figure 3
Effect of Fiber Position in a Cotton/Nylon Blend



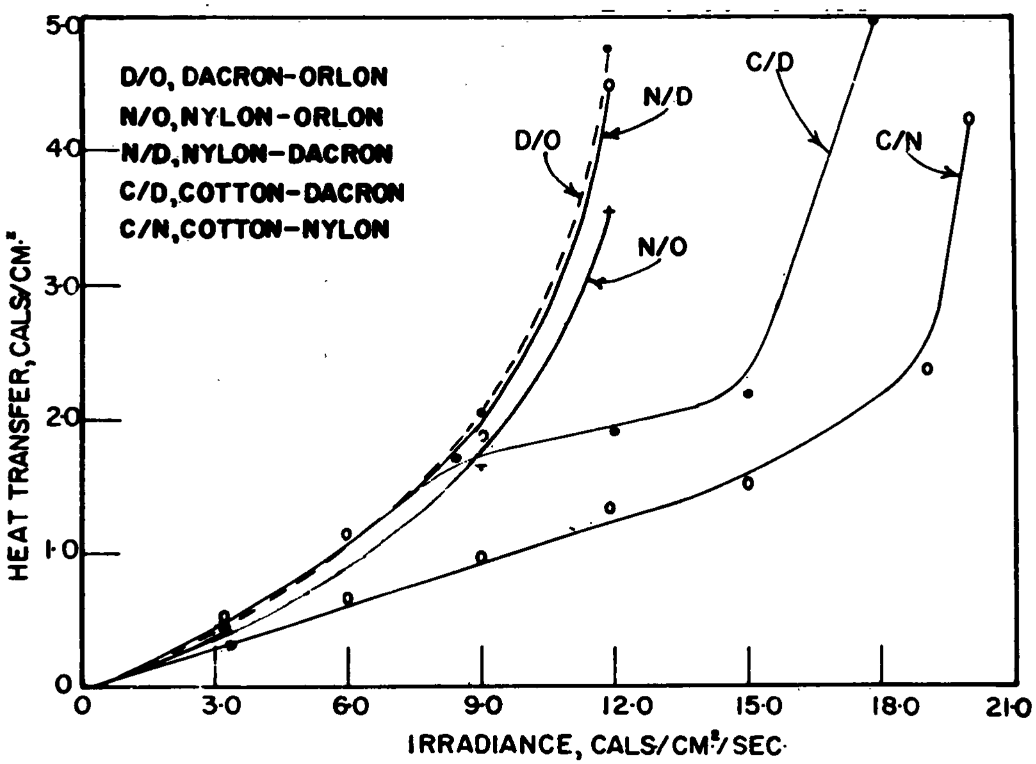


Fig. 4 Heat Flow From Typical 50/50 Blends

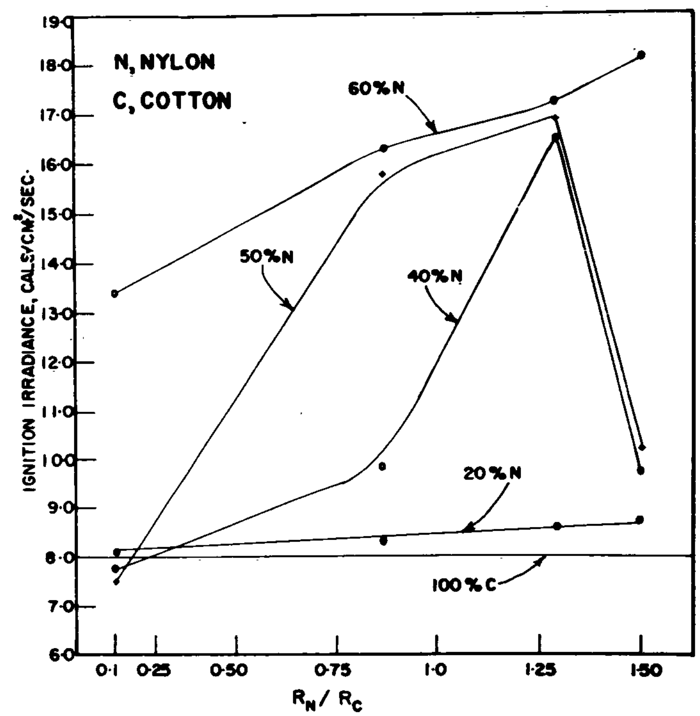


Fig. 5 Effect of Relative Color on the Ignition Characteristics of Cotton/Nylon Blends

by changing from a black to white T-shirt spaced 3/8" away from the outer layer fabric, the absolute protection provided was increased from 9.1 to 20.1 cals/cm^2, due to the increased reflection near the skin of the energy transmitted through the outer layer.

Figure 6

Part A - Effect of Reflectance

	Reflectance		Ignition
	.4 to .7 μ	.7 to 1.0 μ	Irradiance
Fabric A	6.9	46.9	26.5
Fabric B	6.1	16.0	18.0

Part B - Effect of Transmittance

	Protection (cals/cm^2)
White T shirt	20.1
Black T shirt	9.1

e. Insulation, where practicable, as in cold weather clothing, contributes positively and very usefully to protection as a barrier to heat flow through the clothing system. We have determined that our cold weather clothing gives sufficient insulation to provide thermal protection up to energy levels at which other weapon effects would become the limiting factor. Where such insulation is not practicable, as in hot weather clothing, other means must be found to dissipate the energy.

f. Resistance to flaming induced by radiation is definitely important from the standpoint of protection. It has been our experience, particularly with summer-weight uniforms, that the ignition of the outer layer defines the maximum protection that can be provided. If the fabric catches fire, the subject may be severely burned quite irrespective of the amount of energy received from the thermal blast.

To achieve resistance to the energy itself and thereby to provide minimal protection against the thermal energy of the blast, we have found that one of our most promising approaches at the present time is the blending of fibers. Recently we have developed an 8.8 ounce nylon/cotton blend in a tightly-woven wind resistant fabric which will be treated with our QUARPEL water repellent treatment. This fabric has excellent characteristics from the standpoint of resistance to thermal energy up to a point well above what we believe to be achievable in any cotton or nylon clothing fabrics by themselves.

This blended fabric which is 120 x 70, 5 harness sateen construction, all carded, is now being adopted by the Army as a replacement of the all combed cotton 9-ounce sateen which has been the basic fabric of our clothing since World War II. A final determination of the functional finish to be applied to this fabric has not been made but that it will be a multi-functional finish with characteristics of resistance to chemical warfare agents and for the suppression of flaming, is quite clear, in order to meet the multi-functional requirements of this clothing.

Over and beyond the thermal protection achieved in this fabric, there is of course, the added abrasion resistance to be expected from a fabric with a high nylon content in the blend. In all respects, adoption of this 50% cotton/50% nylon fabric represents a definite advance in the functional performance of the soldier's protective clothing system.

As one looks at the performance of the available textile fibers for this shield fabric, it is apparent that we are far from having an ideal fiber at this time. It is also apparent from observing the character of textile fiber development today and the revolution that is occurring in polymer chemistry and fiber technology, that a fiber of much better thermal characteristics should be obtainable.

For example, a new fiber having special thermal characteristics has already been described by the Air Force representative here today, HT-1. We have made an extensive study of this fiber from the standpoint of its possible application in the shield fabric of the soldier's clothing system but find it not suitable for our particular purpose of providing thermal protection.

While HT-1 performs admirably for the relatively low rates of thermal energy application encountered in a re-entry vehicle or a sustained fire, it lacks thermal stability against high intensity radiation energy in the short time of the nuclear flash.

The fact that such a fiber can be produced has encouraged us to believe that fibers can be made which will have the particular characteristics required for protection against high intensity thermal radiation.

In addition to nuclear and thermal effects there are problems with alpha and beta radiation resulting from the nuclear explosion, together with their related problems of cleaning up the uniform by dusting, by laundering, or by whatever techniques are available in the field. The principal hazard here is the danger of absorption of radioactive dust into the respiratory system of the body and the necessity of avoiding skin contact.

There is, however, a further problem and quite a critical one - - the hazard of flash blindness. There is a particularly serious hazard at night when the pupil of the eye is dilated, thereby admitting a much larger amount of light than would occur when the pupil is contracted on a bright sunny day. Retinal burns may also be a serious problem.

A phototropic dye in a suitable medium used as glasses or goggles may afford a solution. These would be transparent under normal lighting conditions and become opaque during the first pulse, then return to a clear state afterward. Here again the possibility of phototropism as a means of affording a positive contribution to the protection of the soldier indicates a potentially important area of research and development.

Another approach to protecting the face from skin burns would be to have a light-activated curtain dropped in front of the face during the first part of the blast, thereby protecting it from the full impact of the thermal energy.

You can see from the above that we are not trying to build a Maginot line type of defense for the soldier. The big question confronting us in research in this area is what price the soldier can afford to pay for protection and what kind of materials we will be able to work with in what one engineer has aptly called "the fourth dimension" of materials properties. In the past we have been limited to a few types of textile materials. Now with the revolution which is occurring in the fiber field in the development of new fibers and the combining of these fibers into textile structures, and in the development of chemical finishes which will react with the fibers and change their properties in the finish applied to the clothing, we have the possibility of a major step forward in the defense to continue the progress which has been made in offensive weapons.

Our objective is to utilize material properties of whatever kind to obtain multi-functional protection in the simplest possible system. We cannot furnish the man one set of clothing which will protect him against chemical warfare agents, another to protect him against biological and radiological agents, another against thermal effects of nuclear weapons, another to protect him against the cold environment, still another to wear in hot climates, something else to protect him against detection by all the various means now available, and still something else to ward off shell fragments. There must be integration of many forms of protection in the materials of his clothing-equipment system against the natural and enemy-imposed environments. In working toward such multi-functional system what we need is a material having total multi-functionality.

There is much more that could be said about the importance and the potentialities of this fourth dimension in design--the achievement of materials having significant functional properties which may affect the design itself. However, the most important thing to bear in mind is that the critical factor in anything worn or used by the soldier is the man himself and his response to it -- its physiological and psychological cost or advantage. It is in these terms that new developments in textile fibers, fabrics and finishes must be evaluated. Our success in this area may well be critical in determining the fighting efficiency of our combat forces in the era in which the spectrum of possible combat extends all the way from limited, through conventional warfare to possible nuclear warfare, in which man himself more than ever before has become the ultimate weapon.

Fig. 7 Special Forces Jungle Sleeping Gear

Fig. 8 Lightweight Rucksack

Fig. 9 Multi-Purpose Net as Seine

Fig. 10 Multi-Purpose Net as Carrying Device

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220 Wellington Street
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U. S. Army Standardization Group, UK
Box 65, USN 100, FPO
New York, N. Y.

1 Commandant
U. S. Army War College
Carlisle Barracks, Pennsylvania

1 Commanding Officer
QM R&E Field Evaluation Agency, US Army
Airborne Systems Test Div.
Yuma Test Station
Yuma, Arizona

1 CO, Chemical Corps
Protective Division
Chemical & Radiological Labs
Army Chemical Center, Maryland

1 CO, Chemical Corps
Army Chemical Center, Maryland
Attn: Tech. Library

NAVY

1 Director, Naval Research Lab.
4th & Chesapeake Street, SW
Washington 25, D. C.

1 Chief, Bureau of Supplies & Accounts
Department of the Navy
Washington 25, D. C.

1 Chief, Materials Laboratory
New York Naval Shipyard
Brooklyn, N. Y.

NAVY (Cont'd)

2 Navy Clothing & Textile Office
2800 S. 20th Street
Philadelphia 45, Pa.

2 Chief of Naval Research
Washington 25, D. C.
Attn: Code 402S

AIR FORCE

1. Commander, Wright Air Dev. Div.
Wright-Patterson AF Base, Ohio
Attn: Technical Library

1 Commander, Wright Air Dev. Div.
Wright-Patterson AF Base, Ohio
Attn: Materials Lab.

1 Commander, Wright Air Dev. Div.
Wright-Patterson AF Base, Ohio
Attn: Aero-Medical Lab.

2 Department of Air Force
Hqs., USAF, Wash 25, D. C.
(1 DC/S Material, 1 DC/S Dev)

1 Commander
Air Res & Dev Command
Attn: RDSBTL
Andrews AF Base, Washington 25, D. C.

1 Commander
Strategic Air Command
Offutt AF Base, Nebraska

1 Commander
AF Cambridge Research Center
Air Research & Dev Cmd
L. G. Hanscom Field
Bedford, Mass.
Attn: CRTOTT-2

MARINE CORPS

1 Commanding General
Marine Corps Clothing Depot
1100 South Broad Street
Philadelphia, Pa.

1 Commandant
US Marine Corps
Washington 25, D. C.

1 Marine Corps Equipment Board
Marine Development Center
Marine Corps School
Quantico, Va.

CONARC

1 C.G., U. S. Continental Army Command
Ft. Monroe, Va.

1 President
U. S. Army Artillery Bd.
Ft. Sill, Okla.
Attn: ATBA

1 President
U.S. Army Armor Board
Ft. Knox, Ky.
Attn: ATBB

1 President
U. S. Army Infantry Bd.
Ft. Benning, Ga.
Attn: ATBC

1 President
U.S. Army Air Defense Bd.
Ft. Bliss, Texas Attn: ATBD

CONARC (Cont'd)

1 President
U. S. Army Airborne and Electro[illegible]
Ft Bragg, N. C.
Attn: ATBF

1 President
U. S. Army Aviation Bd.
Ft. Rucker, Ala.
Attn: ATBG

1 President
U. S. Army Arctic Test Board
Ft. Greely, Alaska
Attn: ATBE

DEPT OF AGRICULTURE

1 Director
Southern Utilization Res & Dev D[illegible]
Agricultural Research Service
U. S. Dept of Agriculture
P.O. Box 7307
New Orleans 19, Louisiana

1 Office of the Administrator
Agricultural Research Service
U. S. Dept of Agriculture
Washington 25, D. C.

1 U.S. Dept of Agriculture Library
Washington 25, D. C.

MISCELLANEOUS

1 National Bureau of Standards
Textile Section
Connecticut Ave & Upton Sts, NW
Washington 8, D. C.

1 The Army Library
Pentagon Building
Washington 25, D. C.

1 Commandant
Command & General Staff School
Ft. Leavenworth, Kansas

1 Commandant
U. S. Military Academy
West Point, N. Y.

1 National Research Council
2101 Constitution Avenue
Washington, D. C.
Attn: Advisory Bd on QM R&D

2 Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

10 Commander
Armed Services Tech Info Agency
Arlington Hall Station
Arlington 12, Virginia
Attn: TIPDR

1 Prof. J. R. Brown, M. B.
U. of Toronto School of Hygiene
Toronto, Ontario, Canada

1 Director
Air Crew Equip Lab
Naval Air Material Ctr
Philadelphia 12, Pa.

2 Gift and Exchange Division
Library of Congress
Washington 25, D. C.