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TEXTILE TECHNOLOGY FROM AEROSPACE RESEARCH

Prepared under NASA contract by
IIT Research Center
Technology Utilization Center

Miles A. Greenbaum
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INTRODUCTION

This paper presents a general review of government generated technology to illustrate their relevance to the textile and apparel industries. The applicable technology touched on a variety of areas concerned with fibers and fabrics; these include new products, thermal resistance, physical testing methods and manufacturing techniques. This paper will present selected topics from each of these areas. Many of these topics were not originally conceived as being applicable to commercial textile operations, but appear to have considerable potential for inter-industry transfer. An attempt has been made to select those items which may be of interest to textile management as well as to the technologist. These items should be viewed as samples of available relevant technology, not as an exhausted survey of the field.

In addition, a bibliography is included to give a more comprehensive list of pertinent articles which are available from government publications.

NEW MATERIALS DEVELOPMENT

High-tenacity synthetic fibers are generating increased interest in the textile community. The following discussion presents some of the problems related to the properties of these fibers and their use, and possible solutions to these problems. Also, an article will be presented on a coated fabric which can be heat-sealed, thus eliminating the need for sewed seams.

Advances in Polypropylene Fiber Technology: (44, 42)

Polypropylene fiber, a relatively new fiber made from gaseous polypropylene, is finding increased use in the textile industry. Predictions have been made that by 1970, annual consumption of this material will approach 200 million lbs.

Aside from its low cost, polypropylene fiber has many outstanding functional properties. It has a much lower density than other textile fibers, thereby giving a much greater yield in yards per pound for comparable geometric structures. Polypropylene has the greatest strength potential of the synthetic organic fibers, combining toughness, abrasion resistance and high rot resistance with ease of thermal shaping. The woven fiber has very promising "wash-and-wear" characteristics, and its low moisture absorption, dense structure, and little chemical affinity for contaminants make polypropylene probably the most stain resistant of present organic textile fibers.

Specific studies of polypropylene fibers for use in abrasion-resistant fabrics resulted in the development of a process for the production of high-tenacity fibers. The production of fibers which have tenacities of 13 grams per denier was achieved experimentally by a non-continuous method, by drawing bundles of filaments under constant load in a hot-air oven.

In order to produce a filament with high tenacity, a polypropylene resin having an isotacticity of 94% or greater must be used, but a completely isotactic material appears to be undesirable. Also, the polymer should have a molecular weight of 400,000 or over. The polypropylene fiber should also have a high molecular weight, but 500,000 appears to be the upper value for polymers that can be melt-spun satisfactorily.

In the continuous process developed, polypropylene pellets are fed into a screw extruder, with the hopper blanketed with nitrogen. The temperature in the metering zone of the extruder is 275° C. A spinning head and metering pump coupled to the extruder are held at a temperature of 295° to 300° C. A 10- or 12-mil, 8-hole spinneret backed with a sand pack is attached to the spinning head. The fiber is extruded vertically into a water-quench bath (0° to 3° C) positioned immediately below the spinneret. The quench bath should contain a wetting agent. The fiber passes under a roll in the quench bath and goes to a 2-roll take-up and then to a winder. The extrusion rate is approximately 5 grams of polymer or 160 yards of fiber per minute.

The spin-draw conditions are adjusted, mainly by adjusting the take-up rate, to produce a fiber having a molecular orientation as high as possible. The spun fiber is drawn by passing the fiber from a bobbin to a godet at room temperature and then to a godet at 135° C and out to a third godet maintained at 135° C, with further drawing to make the total draw ratio from the original bobbin approximately 5 times. The rate of drawing is 40 to 50 yards per minute.

The final product, with a tenacity of 13 grams per denier, is about 50% stronger than currently available commercial polypropylene filaments.

One of the major drawbacks in the commercial use of polypropylene fibers in textiles is the difficulty in dyeing the fiber. The present consumption of this fiber in industrial and consumer application has been mostly in the undyed or pigment-dyed form. To achieve its potential use in the broad textile market, polypropylene fiber must be readily dyeable under a range of processing conditions, by itself or in combination with other fibers, and must meet broad color and fastness requirements in a wide variety of end uses.

Toward this end, progress has been made to develop a dyeable type of polypropylene fiber. The fiber desired would be amenable to the disperse dyes, which are the staple of the synthetic fiber dyeing industry. The disperse dyes offer the greatest ease and flexibility of application uniformity and moderate fastness. Also desired was the use of the fiber with the neutral premetallized dyes, which are also easy to apply and give fairly good uniformity of shade. They can be used together with disperse dyes, and have a high level of light-, wash-, and dry-clean-fastness, particularly in the light to medium shades.

A new polypropylene fiber, PPX, has been extensively tested for dyeability. A commercially representative yarn (bulked 3500 denier/200 filaments) was used, and the evaluation included disperse, diazotized-developed, premetallized, and vat dyes. The dyeings were conducted at a 20:1 bath to yarn ratio.

In FadeOmeter light-fastness tests, a one-inch-width layer of yarns was exposed until a Grey Scale 4 rating color change occurred. Wash-fastness was tested at 160° F, and dry-clean fastness was determined using perchloroethylene at 115° F. After the wash and dry-clean tests, color change was rated against the International Gray Scale for Evaluating Change in Color. The range of light-fastness was from 4 to 7 for all four types of dyes, and is adequate to cover most textile applications. For the majority of vat dyes, polypropylene PPX fiber gave ratings of 7 to 7+, compared to 3 to 4 for cotton yarns.

Dyes (1%)	Light	Wash	Dry Clean
Disperse	4 to 7+	4 to 5	3 to 5
Diazotized-Developed	5 to 7	5	5
Premetallized	5 to 7+	5	5
Vat	6 to 7+	5	4 to 5

TABLE I - Fastness Rating Results

Because of difficulties with contaminants, present dyeable polypropylene fibers generally require thorough scouring and rinsing before dyeing. PPX has been engineered to have a minimum affinity for normal contaminants even under alkaline conditions. As a result, it appears quite feasible to eliminate the scouring as a separate step and to remove process finishes and soil during the dyeing operation. Anionic and nonionic detergents, salts, alkalies, and solvents can be used as necessary. With disperse and/or premetallized dyes, a 1% detergent and a 1 to 2% borax, tetrasodium pyrophosphate, or tri-sodium phosphate solution yielded excellent results. In vat dyeing, greige yarn was used, and the reducing bath alkalinity was satisfactory for simultaneous scouring during the dyeing process.

A substantial factor in the cost of most present dyeable polypropylene fibers is the need for incorporation of high levels of expensive ultra-violet stabilizers. These are used to a considerable extent in an effort to upgrade the light-fastness of the dyeings. In addition to cost, another important problem with ultra-violet as well as other stabilizers is the difficulty of stabilizer retention as the fiber goes through scouring, dyeing, washing and dry cleaning. An important part of the novelty of PPX fiber is the durable, high light-fastness achieved without the need for conventional, expensive ultra-violet stabilizers.

Dyeings with disperse and premetallized dyes are adequate, and the color yield, leveling, and ease of stripping and redyeing are fair to excellent. Diazotized-developed dyes are applied in a two-step process and yield bright colors with excellent fastness and are most useful to supplement the disperse and vat dyes. Vat dyes are applied by a one-step scour-reduce-dye process, and give good color yields and excellent color- and light-fastness.

Polypropylene PPX thus appears to offer considerable promise as a general purpose, low cost, easy to use fiber for broad textile applications.

<u>High-Tenacity Nylon Fibers</u>: (25)

Research was performed concerning high-strength, continuous filament, poly-epsilon-caprolactam (Nylon 6) fibers. The experimental work for producing high-tenacity Nylon 6 yarn samples involved the study of a number of factors such as choice of polymer, spinning conditions, quenching conditions, fiber orientation, annealing, molecular weight, and crystallization phenomena. Nylon 6 monofilaments were spun and oriented to yield a tenacity as high as 9.0 g/denier, while multifilament yarns showed considerable nonuniformity with a maximum yarn tenacity of 6.7 g/denier.

Four polymers were considered for the first experiments. These are the Plaskon series 8201, 8201 HS, 8205 and 8206. Type 8201 is a standard material used for film and fibers; type 8201 HS is a similar material containing an anti-oxidant. Type 8206 is like 8201 but contains a large amount of residual caprolactam which can act as a plasticizer and humectant. Type 8205 is a high molecular weight form of 8201, and has a very high melt viscosity.

Three types of laboratory spinning equipment were considered. These were a nylon rod-spinner, an extruder-spinner, and an extruder-pump spinner. The extruder-gear pump was chosen because it permits the spinning of Nylon 6 multifilament yarn with improved size uniformity.

Several major variations in spinning conditions were examined. Spinning temperatures of 450° to 550° F were used; 1-hole, 10-hole, and 28-hole spinnerets with hole diameters of .010", .020", .030", and .040" were examined; and yarns of 100, 50, and 25 denier per filament were made. The total polymer flow was in the range of 2 to 10 grams per minute. Combinations of these conditions provided filaments with varying degrees of spinning orientation.

Treatment of the spun nylon immediately after the spinneret involved quenching with still air in a fourteen-foot chimney, cooling with cross-flow air, the use of a short heated chimney followed by air cooling, and water bath quenching for monofilaments.

The drawing of the fibers was done between controlled speed trios through a four-foot air oven. Ordinary cold drawing, cold drawing of water-saturated fiber, cold drawing followed by hot drawing, single-step hot drawing, two-step hot drawing, and annealing were used.

Tests were performed on the undrawn spun fibers and on the drawn fibers and yarns. The tests on the undrawn fibers included draw limit, intrinsic viscosity, and per cent residual caprolactam monomer. The following are the tests used on the drawn fibers and yarns: tenacity (at 100%/min and 20%/min extrusion rates), modulus and elongation at break. Several tests were used on both the drawn and undrawn fibers. These include per cent linear shrinkage at a temperature near the nylon melting point, per cent crystallinity by X-ray, microphotographs to show yarn cross-section and the Uster tests for denier variability.

All of these variables were not used in every possible combination, and the tests were not applied indiscriminately. Only those combinations judged to be of the most importance were used.

The Plaskon Nylon 6 polymers are hygroscopic and can easily pick up a few per cent water by exposure to room air. Such moisture can cause bubbles and interrupt the smooth spinning of the fiber, or produce fiber which contains weak spots due to elongated bubbles. To avoid this, the polymer was dried for 3 hours before spinning by spreading in thin layers on large trays at 160° F. In addition, a spinning lubricant was used to reduce the effect of static in freshly-spun yarn.

Two types of drawing were used for monofilaments. The first type is a two-step procedure using room temperature for the first draw and elevated temperatures for the second. The second draw strongly increased the modulus and the tenacity, and decreased the breaking elongation. The range of 350° to 375° F was indicated as being the best. The second monofilament drawing procedure is a one-step hot draw at 350° to 375°F. The results of this procedure showed that it was at least as good as the two-step draw.

Both types of drawing procedures were used on multifilament yarns. These showed low tenacities, with higher tenacities for the single filaments. This is an indication that the polymer orientation in the drawn multifilament yarns is reasonably high, but that filament to filament non-uniformities are causing lower tenacity values in the yarns. In subsequent tests it could be seen that the yarns were breaking filament by filament rather than simultaneously.

Other results show that the percent crystallinity increased after hot drawing, but that the amount of crystallinity was not closely related to the tenacity obtained. The amount of polymer breakdown during spinning at 500° F was found to be small and relatively unaffected by changing the testing rate at room temperature from 100%/min to 20%/min.

Heat Sealable Coated Fabrics: (46)

Coated fabrics have been used for many years to protect equipment from the elements. However, the Army has experienced problems from moisture which penetrated the needle holes left in the coated fabric seams after the fabric has been sewed.

Several methods were tried in an effort to reduce the needle-hole problem; among these were the application of double-coated pressure sensitive tapes and the use of a variety of hole-sealing adhesives. These methods were costly and provided little assurance of water-tight seals.

A study was made to develop a coated fabric having excellent heat-sealing properties, a wide range of temperature flexibility, and better weathering characteristics than the waterproof coated nylon used at the time.

The first step in this development program was to look to industry to see if any new commercial coated fabrics had the desired properties. Twenty-eight commercial fabrics were found, several in conformance with the military specifications set down as the minimum criterion for acceptance. However, none of the thermoplastic type had sufficient low-temperature flexibility, and heat sealing of these was not acceptable because of the plasticizers in the coatings. The thermosetting group included several having adequate low-temperature flexibility, but, of course, were not heat sealable.

Since none of the commercially available coated fabrics had the desired properties, the program proceeded by delineating the determining factors in the development of a new fabric. These factors were 1) requirements needed, 2) method of coating, 3) substrate to use, 4) tie-coating, if needed, and 5) choice of polymer or resin coating.

After a careful survey of the various methods of coating available, "dip-coating" and the use of an inverted "L" calendar were chosen. The polymers were applied to the substrate from a toluene solution, heated to 200° to 225° F, containing 25% solids. The samples were air dried and oven-cured at 225° F.

Three substrates were tested, including fiber-glass cloth, Nylon cloth G-305 and open-mesh Nylon cloth A-2951/6. Eight tie-coatings and thirteen polymers were evaluated.

After extensive sample testing, the open-mesh Nylon A-2951/6 was chosen as the

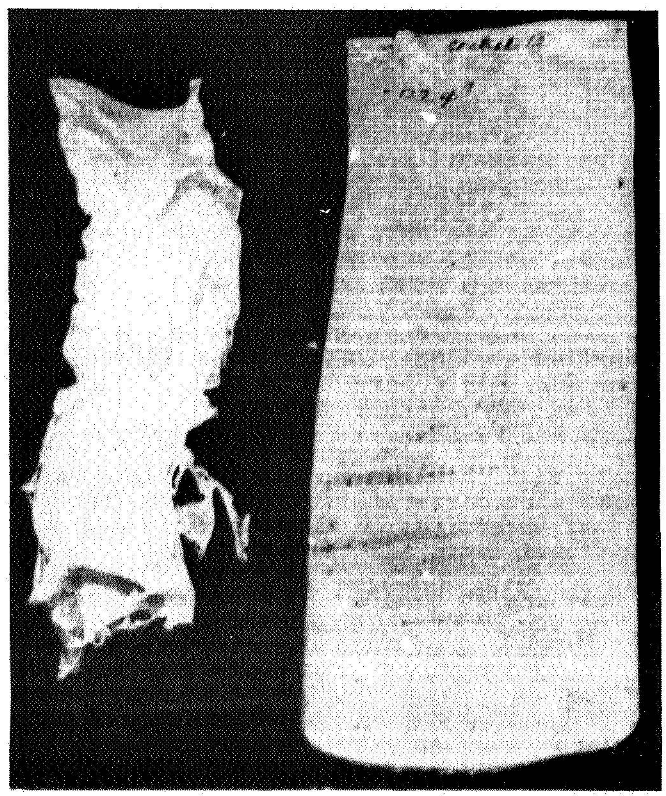

FIGURE 1 - Comparison in the reaction of a noncompatible tie-coating to that of one having an acceptable bond.

substrate for further testing. Of the tie-coatings, dimethyl sulfoxide (DMSO) was chosen. DMSO was not satisfactory as a tie-coating, but upon application to the substrate, it improved the low temperature flexibility of the finished coated fabric by approximately 20° F. The polymer selected for final evaluation was ethylene/ethyl acrylate.

The combination of the selected materials, dimethyl sulfoxide-treated open-mesh nylon coated within ethylene/ethyl acrylate, yielded a coated fabric exhibiting good processing, excellent heat sealability, and improved low-temperature flexibility.

MATERIALS TESTING

Heat- and flame-resistance of fibers and fabrics presents one of the more significant problems of the manned spacecraft experiments. For that reason, it would be expected that a significant amount of published material would be available in this field. Presented here will be examples of devices used to measure the thermal parameters of fabrics, and several studies pertinent to their heat- and flame-resistance.

Thermal Testing Devices: (21, 20)

Many studies have been proposed to investigate materials for thermal protection from both flame contact and radiation heating. We will be concerned with two devices developed to study heat from each of these sources.

Standard flame tests of fabrics are directed toward determination of characteristics such as glowing, flaming, and charring of the material. They do not, however, provide measurements of resistance to heat transfer through the fabric before destruction. An apparatus has been designed for simple and rapid flame-contact studies of heat transfer by a method especially developed for use with fabrics. It is applicable to direct determinations of destructive temperatures, heat-transfer resistance, and the insulation effect of air spaces between layers.

The apparatus, shown on the following page, consists of a Meker burner, equipped with a pilot light and attached to a propane-propylene gas source. The air-intake regulator cuff is removed so the air supply is maximal and constant. A flowmeter permits a fixed gas flow rate (325 cc/min), so the flame is reproducible. A movable carriage moves the specimen in and out of the flame, at times preset on an automatic timing device. A radiometer, protected by a front surface mirror and a flame shield, is mounted behind an automatically operated shutter, which opens as soon as the specimen is positioned in the flame. The radiometer provides measurements of the radiant temperature of the back surface of the specimen during the flame contact with the front surface. In addition, thermocouple terminals are provided so the thermocouples can be placed in any locations desired. The outputs from the thermocouples and the radiometer are fed into an oscillograph recorder.

Various holders may be mounted on the carriage for special purposes. For single layers of fabric, a flat plate is used; for double layers separated by air space, a series of curved plates are used. An iron-constantan thermocouple protrudes into the flame and monitors the temperature to assure reproducibility of the heat supply (1200° C) from one exposure to another. A backing for the test material, composed of a resinous compound of carefully determined thermal and optical properties, provides accurate temperature measurements within the compound at a depth of 0.5 mm from the surface of a section about 1 cm thick.

Observations were made on various fabrics; however, duPont's Nomex (a modified nylon) will serve

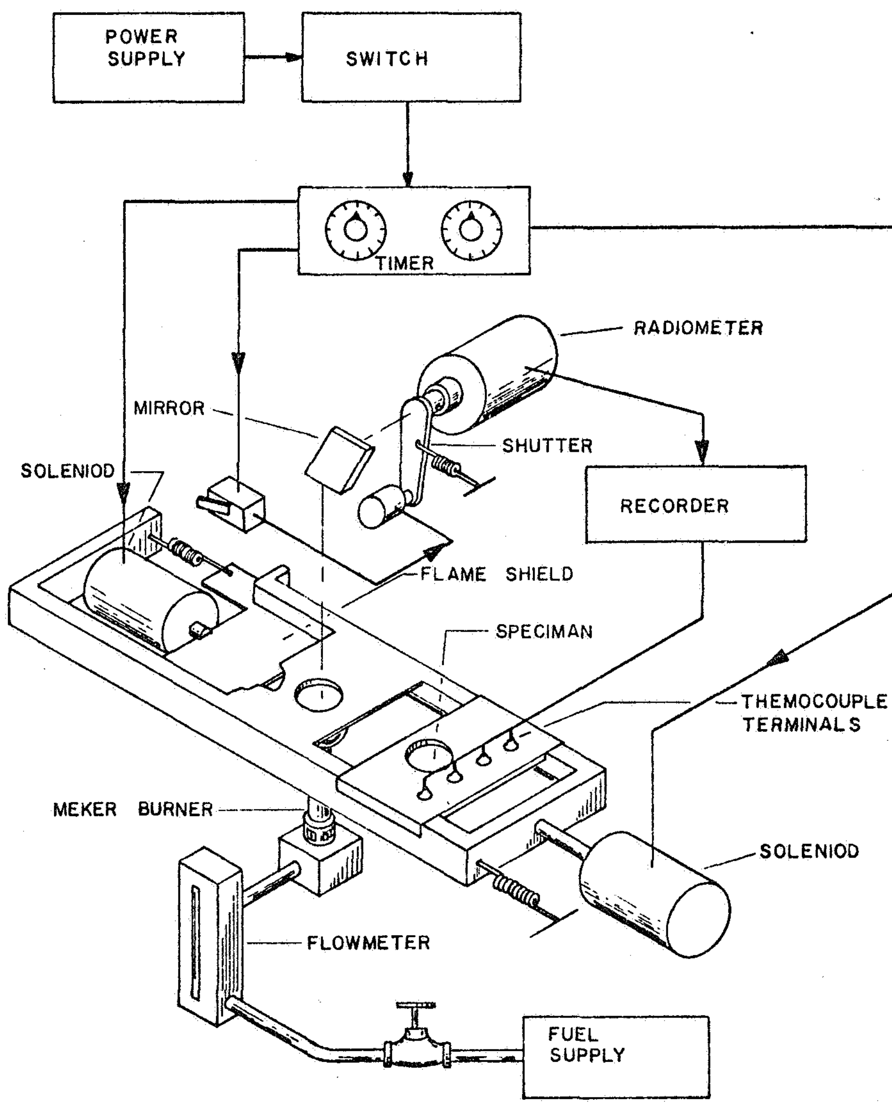

FIGURE 2 - FLAME CONTACT APPARATUS

as illustration. To determine the destruction temperature, measurements were made on the back of a single layer of fabric in contact with the flame, until the flame broke through the fabric. The average value for fabrics with a weight of 3, 4, 5, and 6 oz/sq yd was $427 \pm 3°$ C.

An indication of the heat-transfer resistance of a material is obtained by a comparison of the temperature rise of the backing material covered by a known thickness of fabric. When testing two layers of fabric in contact with each other, the layer in contact with the flame bulged out from the under layer, forming an air space and protecting the underlayer. Thus two layers of 3-oz/sq yd fabric, with no deliberate air space, remained physically intact after flame contact for over four minutes, whereas a single layer of 6-oz/sq yd material burned through in 7.5 seconds.

The insulation effect of deliberately-set air spaces can be attained by plotting the temperature rise, measured within the backing at a given exposure, against the thickness of the air space between two layers of 3-oz/sq yd fabric. This process discloses that there is an optimal thickness (4 mm) of air space which results in the greatest insulation effect. Beyond this thickness, heat transfer is enhanced because convection currents arise and contribute to the propagation of the flame front through the fabric causing it to perforate. At this point, of course, the flame reaches the second layer of fabric and the assembly behaves like a single layer.

This illustrates the increase in burn-protection offered by double-layer as compared with single-layer clothing. The efficiency of the double layer is due to its maintenance of an air barrier, however small and variable in thickness, between the two layers of fabric, so that heat transfer is significantly reduced as long as the outer layer remains intact.

The same apparatus can be used for determination of diffusivity and thermal conductivity of fabrics such as heat-resistant, synthetic Nomex.

In this determination, it was necessary only to measure the temperature rise at a fixed depth in the backing material, and in the backing material covered with single layers of fabric. The exposure time was 3 seconds. The fabric thicknesses ranged from 0.12 to 0.29 mm, corresponding to weights from 2 to 6 oz/sq yd. The fabrics were 2/2 or 3/3 twills, closely woven so that direct pathways for heat transfer from the source to the backing were obviated. The density of the Nomex fabric was 0.677 gm/cm^3 and the specific value used was 0.29 gal/°C. A thermal conductivity of 6.1×10^{-5} cal/cm °C sec was obtained for Nomex. The procedure for determining this thermal conductivity of the fabric consisted of matching the observed temperature rise of the simulated skin under the fabric layers with the theoretical temperature rise calculated for the various thermal conductivities associated with the density and specific heat of the fabric.

From known equations, charts can be constructed for finding the temperature rise and the corresponding diffusivity of layer 1. If the volume specific heat is known, then the thermal conductivity is quickly obtained as the product of the diffusivity and the volume specific heat.

Results show that Nomex is a good insulator because it provides a large temperature gradient over a thin layer of material, and thereby retards the temperature rise of the underlying surface.

The second apparatus is a high-intensity radiation source, which provides not only information on thermal protection application, but a means to predict from known physical properties the thermal protection capacity of any fabric.

The high-intensity source consists of a graphite element mounted in a clam-shell, paraboloidal mirror arrangement, such that radiation from the heated element is concentrated on the specimen mounted opposite the element as shown in Figure 3. The unique feature of the apparatus is the variable control of radiation intensity at the source, by adjustment of current

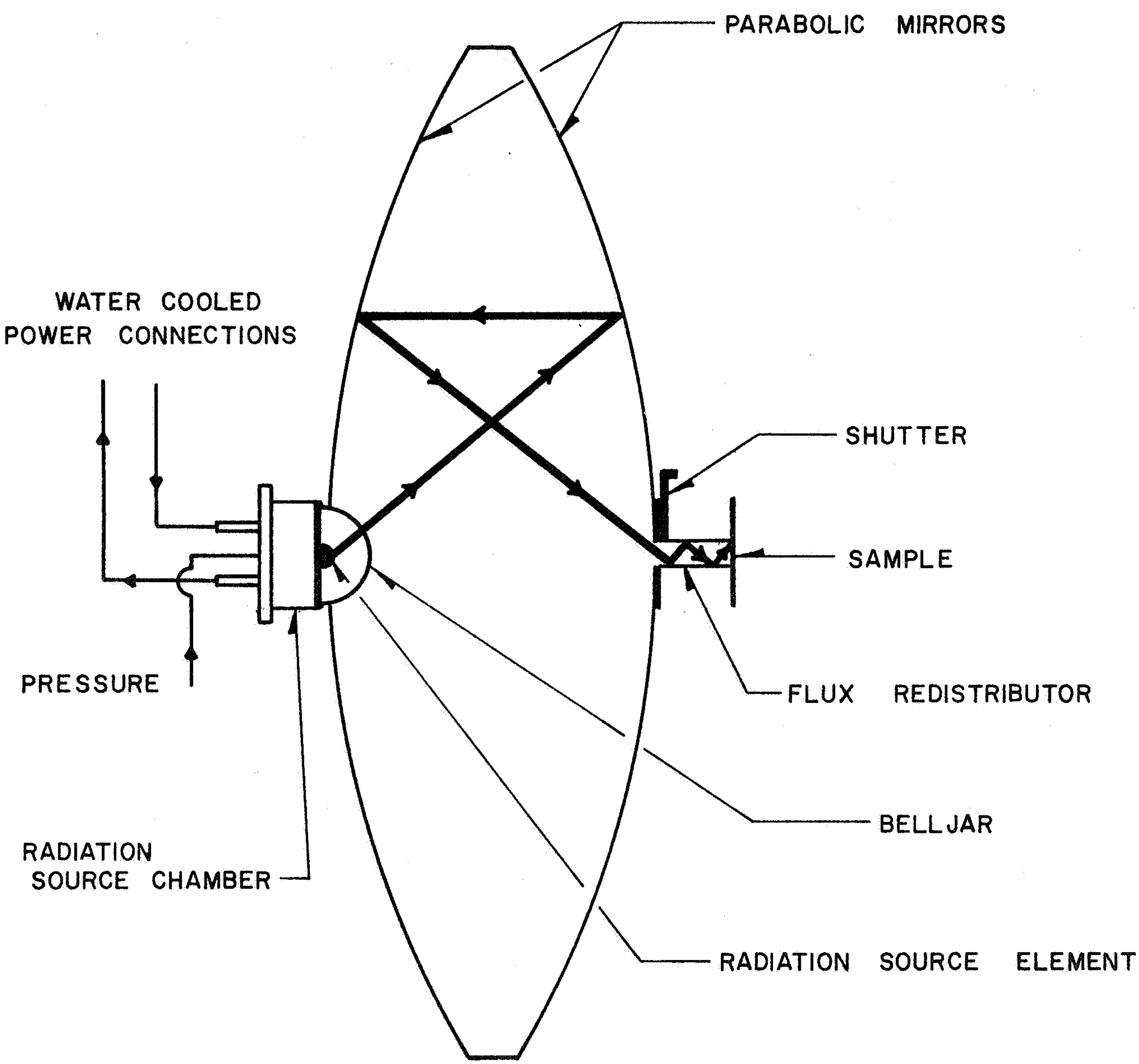

FIGURE 3- COMPOUND THERMAL RADIATION IMAGING SYSTEM AND SOURCE.

through the element to provide radiation distributed evenly within plus or minus 1 percent over the entire specimen exposure site. Thus, steadiness of flux and a constant rate of specimen heating, free from peak and edge effects, is assured throughout the intensity range of 0 to 15 cal/cm^{2}sec.

The general procedure followed in assessing the thermal properties of a typical thin-layered material is then as follows:

a. Determination of thermal diffusivity by means of the flame contact apparatus.

b. Measurement of reflectance and transmittance.

c. Determination of heat transfer on exposure to the high intensity radiation source.

d. Computation of the thermal absorption on the basis of source radiation wavelength distribution and measured properties of the material.

Procedures used in the flame contact apparatus have been previously described. Reflectance and transmittance are measured with a Beckman spectrometer and reflectance attachment. In the determination of heat transfer, the thermal flux is measured with a non-selective foil radiometer, and temperature rise within a simulated skin backing is recorded continuously during radiation.

The brightness temperature and the thermal flux are plotted against current flowing through the element. These data are specific for each element, although the differences from one element to another are very small. From these data and the known properties of the graphite, the wavelength distribution of the energy can be determined. Thus, from the brightness temperature and the emissivity of the gravity, the true temperature of the element is calculated.

Studies of the emissivity of graphite indicate that the spectral emissivity at wavelengths in the region of present interent increase with roughness of surface, and the spectral emissivity of graphite tends to decrease with increased temperature. This indicates that graphite is not truly a gray body radiator at long infrared wavelengths; however, it is in the visible range and at temperatures 1800° C, the area of present interest.

In general, data of this sort have shown that in radiant heating of partially transparent, thin layers transmittance is the property of greatest importance in heat transfer, with absorptance gradually surpassing it in importance as the thickness of the layer is increased to that of optical opacity. This process is in contrast to the mode of heat transfer in the same fabric in flame contact, where the optical properties are of no importance and heating beyond the contact surface proceeds entirely by conduction.

The situation in which air spaces are introduced between the layers is somewhat similar in the two types of heating. In both instances, the initial heat transfer between the two layers is primarily radiative. As the air space is increased, however, in the instance of flame contact heating, an optimal thickness is achieved. Increasing the air space beyond this thickness results in the generation of significant convection and acceleration of the temperature rise in the second layer. Upon perforation of the first layer, the entire heat transfer occurs by convection. In contrast, increasing the air space in the assembly exposed to the radiant source simply reduces the temperature rise behind the second layer in inverse linear proportion to the thickness of the space.

Such methods as these are essential to provide guidelines for the creation of fabric structures and the development of specialized, thermal-protection materials.

Thermal Resistant Fabrics: (56)

In an effort to develop a single-layer fabric to resist thermal radiation, the following concepts were investigated:

1) Air spacings incorporated in the fabrics by weaving.
2) Weaving into the fabric a metallic scrim to impede and spread laterally the heat passing through the fabric.

3) In corporating an insulating layer by lamination between two fabric layers.

In addition, in order to design a fabric which would be practical for wearing apparel, these factors were considered: 1) the design of spacer materials which would be effective, but which would result in the least possible weight added and resultant stiffness to a fabric; 2) the design of the fabric so that it would be comfortable to the wearer, if he should have to wear it next to the skin; 3) the selection of raw materials, which would have inherent thermal-resistant characteristics.

Prime consideration was given to the resistance to ignition upon exposure to high-intensity thermal radiation. Most of the fabrics submitted for evaluation contained some Nomex. The percentage of Nomex varied in these fabrics according to use. Some samples submitted were made with stuffer materials of nylon, asbestos, and modacrylic fiber. As many variables as possible were eliminated in manufacturing and preparing the yarns. For instance, a uniform twist in the Nomex was maintained with 8 turns/inch being used in the warp and zero twist being used in the filling.

These raw materials were investigated in terms of four fabricating concepts:

Warp Stuffer-- Various sizes and shapes of cord or core-like yarns were run as stuffers in the lengthwise or warpwise directions. Various experiments with weave, method of tieing the core to minimize thickness variations, and various methods of using the cores to achieve specified air spaces were studied.

Filling Stuffer-- A coarse core or cord-like material was used, running in the filling or lengthwise direction of the fabric, to establish a degree of air space between the two outer shells of fabric. Experiments were made to find the optimum arrangement of this cord-like spacer in the fabric.

Integrated Three-Layer Fabric-- An inner fabric scrim was woven as part of the overall fabric to improve the thermal resistance. This inner fabric, in effect, created and maintained a certain amount of air space, thus providing theoretical insulation against high-intensity thermal radiation. These fabrics demonstrated excellent thermal resistance without the undesirable roughness resulting from warp and filling stuffers.

Polyurethane Foam Laminating-- Polyurethane foam was selected as a means of bonding two shell fabrics together because of its relatively high resistance to melting (500° F). In addition, such a fabric, when exposed to flame, would separate into layers, thus increasing the amount of effective air-space insulation in the total structure.

Fabrics of good thermal resistance were obtained and certain principles regarding thermal protection were derived from this study, together with earlier flame contact studies. The most important principle was that air spacing is far more effective against heat transfer by flame contact than by radiation.

Another study (41) on the thermal resistance of fabrics was conducted to determine if the inclusion of color before fiber formation has any affect on the strength or temperature-resistance of yarns after high-temperature or radiation exposure. Natural and dyed 100-denier yarns of Nomex were exposed to temperatures up to 600° F and/or gamma radiation.

A variation in data was obtained between the dyed and natural yarns; however, this was believed to be due to yarn variations rather than the color process. The color-sealed yarns were furnished in very small experimental quantities with zero twist. The natural yarns were a contract item and had a producer's twist.

At higher temperatures, all the yarns tended to become somewhat brittle and fray out. The high temperature or radiation effected the elongation properties more readily than the strength properties.

All data obtained indicate that the color-sealing process does not adversely effect the strength or high-temperature-resistant characteristics of the Nomex yarns.

In this section of the paper, we are presenting several manufacturing techniques and devices which may be of interest. The range of topics covered is broad, extending from a sophisticated, servo-controlled web advance system to a simple modification of a soldering pencil for use as a synthetic fabric cutter, to an investigation of antistatic agents for synthetic fibers. It is hoped that some of these items may find a use in the day-to-day operations of the textile industry.

<u>Servo-Controlled Advance System</u>: (2)

A new method has been found of solving the old problem of tension changes in a cloth advance system. The cloth tension in such a system (see Figure 4) may vary due to mechanical

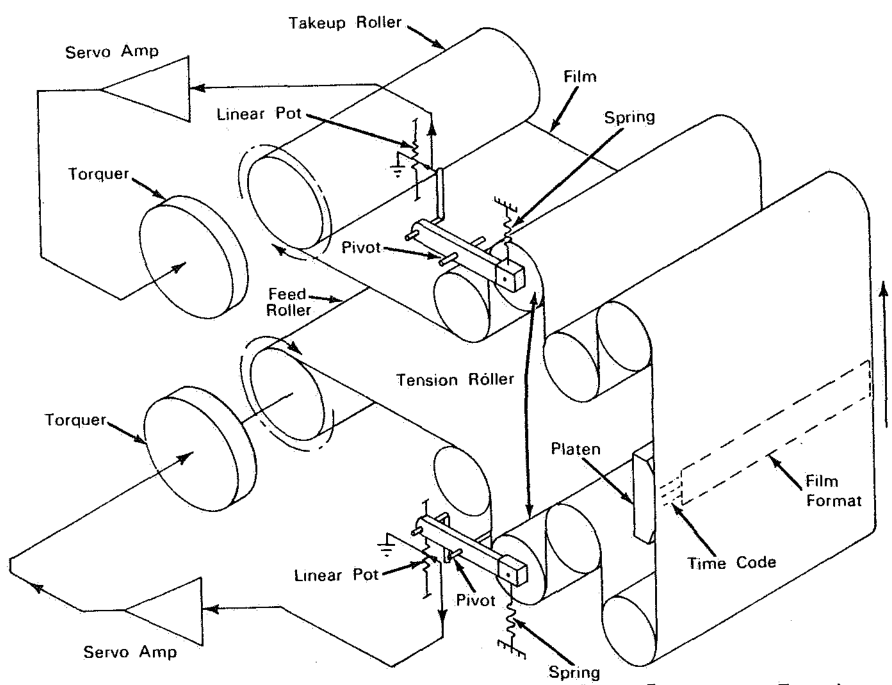

FIGURE 4 - Servo Controlled Web Advance System

disturbances, stopping and starting torques, and material irregularities. Tension changes beyond certain limits result in system degradation or complete stoppage.

The solution is a servo-controlled system in which cloth-tension changes are immediately sensed and corrective torque changes made to drive and/or take-up elements. A two-servo system incorporating two center-tapped, linear potentiometers is coupled through pivoting arms to two corresponding, spring-loaded tension rollers in the cloth advance system. The potentiometer center taps are grounded, and spring tension on the rollers is preset to provide a balanced cloth tension across the cloth loop.

In this mode, the potentiometer wipers are at ground potential and send no error signals to the servo amplifiers. If slack appears at the feed side of the cloth loop, the tension roller is pulled down by the spring, and a negative signal from the potentiometer is fed to the amplifier. This signal is amplified and drives the feed roller torque motor in reverse to take up the slack. As the slack is decreased, the roller moves upward to its normal position and the potentiometer correspondingly moves toward the null position, and the negative signal decreases and ceases.

Similarly, if too much tension appears on the feed side of the cloth loop, a positive error signal is generated in the potentiometer, and the feed roller is torqued in the forward direction to add more slack to the loop. The slack returns the potentiometer to a "no-signal" condition.

The take-up side has an identical arrangement, but is of reversed polarity. Slack provides a forward torque, and too much tension provides a reverse torque in the take-up roller.

Synthetic Fabric Cutting Tools: (47)

Several rather novel concepts in small-batch cutting tools for synthetic fabrics have been described. In general, these are hand-operated units capable of simultaneously cutting and sealing the fabric to a desired pattern. One of these is shown in Figure . This is a soldering pencil which has been modified by machining an axial slot in its tip. A stainless steel, rotary cutting disc is mounted on a pintle that rotates in a rapid heat transfer bushing through holes in the sides of the tip. With the power on, constant heat is supplied to the cutting wheel, and a heat-sealed cut is obtained.

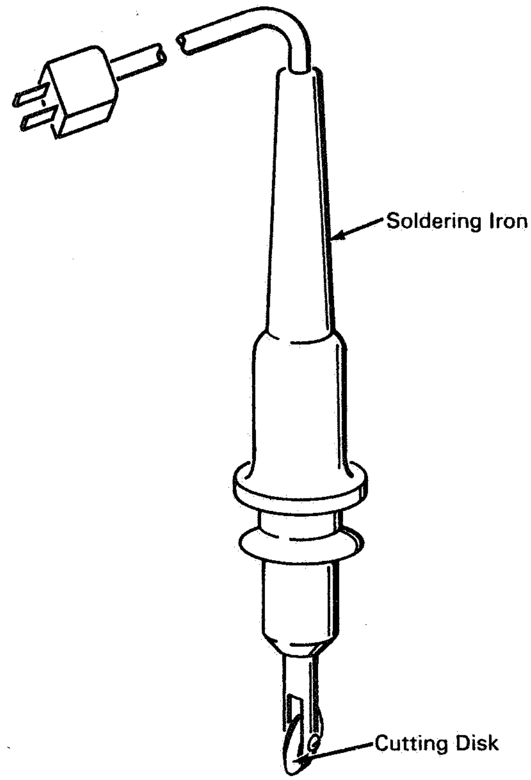

FIGURE 5 - Synthetic Materials Cutter

A similar hand tool has also been described which will cut and simultaneously edge-seal woven nylon and fiberglass cloth to a pinking-shears pattern. This tool consists of a $3\frac{1}{4}$-inch diameter ceramic wheel, on the edge of which is fastened a length of 1/32-inch diameter nichrome or other high temperature wire, laid in a sine-wave-like pattern. Each end of the wire is connected through the wheel to a large brass washer located on one side of the wheel. Each of the two washers makes continuous contact with a brass indented strip serving as an electric brush, which is connected to a wire passing through the handle to a 100-volt, variable transformer, which varies the power input to the tool, and therefore the wire temperature.

In practice, when the wire reaches the desired temperature (about 300° F for cutting the nylon cloth and 500° F for the fiberglass), the wheel is rolled over the cloth along the desired lines, either curved or straight. It neatly severs the cloth and at the same time effectively heat-seals the ends of the threads in the cloth to prevent subsequent raveling. Shock hazards are eliminated by the fiberglass-covered, wooden handle.

Adjustable Cutting Guide: (54)

A cutting guide was designed to provide a fixture which would accurately align and position stacks of material for cutting at various angles. This guide adapts its shape to stacks of any corner angle, adjusts to any cutting angle, and quickly aligns the stacks for repeated cutting.

Two guide arms adjust the corner angle of the material by pivoting one within the socket of the other. A threaded pin, extending through both arms at their joint, tightens to lock the two at the desired angle. These arms are attached to a circular

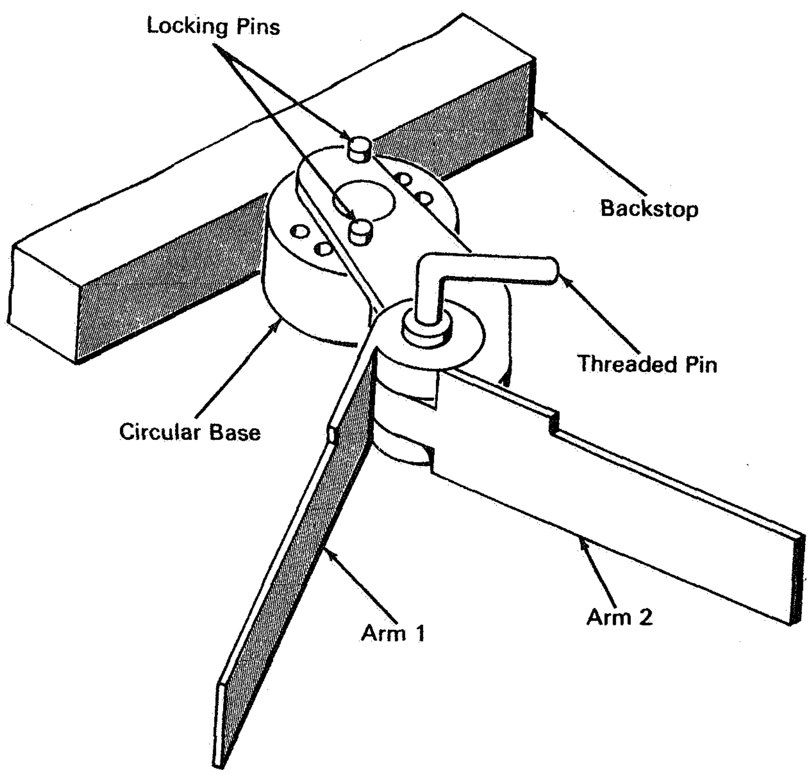

FIGURE 6 - Adjustable Cutting Guide

base by extensions of one of them, sandwiching the base. The arms can be rotated about a pin in the center of this base and pin-locked in place at various angles, the number of which is determined by the number of which is determined by the number of locking holes in the base. A backstop, which is positioned against a mating stop on the cutting machine, is fixed to the base, completing the alignment.

With this device, an operator need not put his hands under the cutting blade during alignment. Furthermore, previous guide tools were not always capable of both aligning and positioning materials, particularly those having corner angles other than 90°. In addition, while aligned cuts may have been made on individual stacks of material, the cutting angle was often lost when a series of stacks was cut.

Revised Simplex Fabric: (9, 11)

An improved dress glove fabric for general military use was desired which was to be fairly elastic, non-yellowing, was to provide a clean, snug-fitting, wrinkle-free appearance. The fabric was to have gripping characteristics equal to, or better than, standard cotton Simplex glove fabric.

With these characteristics in mind, commercially available yarn-types were screened for elasticity in the base fabric. Three types of fibers were chosen for further evaluation as the elastic component of the glove fabric; these were Type 55 Dacron Polyester, Type 680 Nylon, and Type 280 Nylon. The prime requisite of these stretch-yarn, raw materials was the coarse denier per filament required to achieve the high-powered stretch. Because large-diameter filaments react much like a coil spring in their power to recover from a deformation, the highest power was achieved with coarse denier/filament yarns. These yarns were made into a two-ply structure so that a zero-torque yarn would result after manufacturing.

A Whitin ARCT machine was used to produce the yarn. It presented the highest degree of uniformity of texture and dye affinity possible in false-twist-type stretch yarns as well as the greatest elasticity. The continuity of the ARCT process is excellent, and it can be varied to suit the end use desired. By using a high twist, a highly elastic yarn can be produced, or by using a low twist, the resultant yarn has low stretch and imparts a soft, nubby surface.

The yarn was knitted on a 30-guage, 2-needle bar, warp-knitting machine using a jersey stitch. Over thirty-five experimental fabrics were manufactured and evaluated in the first phase. Care was taken to run the synthetic and cotton in such a way that the synthetic would appear mostly on one side of the fabric. Warping of stretch nylon is a critical operation needing close control to insure the best product. Tension control is accentuated by the requirements of the stretch yarn, which, if allowed to run slack, provides an impossible situation for knitting. Every effort was made to produce uniform beams and warps.

On the basis of elasticity, hand, and appearance, ten of these fabrics were chosen for further evaluation. The results of this study indicated that the 30-denier nylon provided a much more supple and desirable fabric, both from the standpoint of hand and elasticity. The fabrics knitted from the 40-denier stretch yarn were heavy and boardy, lacked strength, and had a less desirable surface appearance.

The finished experimental gloves were subjected to wash tests. They showed very little shrinkage, indicating a very high degree of fabric stability. A slight degree of greying occurred after several washings, but the addition of small amounts of household bleach in the wash water maintained a satisfactory white.

The experimental fabrics were scoured, dyed white, and finished by heat setting while relaxed and also by sueding. The fabric is considerably loosened and loses some of its elastic characteristics when submitted to too severe a sueding operation. Table II indicates a typical finishing operating.

1. Scour (with detergent and caustic).
2. Bleach (with Textone).
3. Dry.
4. Suede cotton side.
5. Dye on Beck (including white).
6. Rinse (add finish if necessary).
7. Quench and dry.

TABLE II - Typical Cotton/Nylon Simplex Fabric Finishing

Two fabrics were selected from the ten chosen for advanced evaluation. One of these was chosen as the prototype for the production yardage. Table III gives the description of the yarns and fabric manufactured. The quality of the finished product was high, and the fabric produced is very desirable in its handling characteristics.

YARNS:	Raw Nylon -	30 denier - 10 filament .5 Z turns - Type 680 Nylon		
	Stretch Nylon -	ARCT crimping method - 2-ply zero torque final yarn		
	Cotton -	90/1 combed long staple cotton		
FABRIC:		A 635 S		
		30 guage Simplex		
		Weight - oz/sq. yd		7.25
		Texture:		
			Wales/inch	48
			Courses/inch	42
		Stretch:		
			Length (wales)	20.0%
			Width (courses)	66.6%

TABLE III - Description of Yarns and Fabrics

Anti-Static Agents for Synthetic Fibers: (22)

Protective garments made of synthetic-fiber fabric have certain advantages over those made from cotton. Some of these advantages are greater resistance to corrosive chemicals, higher strength-to-weight ratio, more abrasion resistance, and less shrinkage on laundering. A major disadvantage or such clothing is that it has a tendency to build up an electrostatic charge.

The charge built up can be dissipated gradually, without any alarm, but under certain circumstances it can be dangerous. It can mildly shock the wearer, or, in the presence of inflammable vapors, can cause an explosion. It is also likely that it causes greater particulate contamination.

Three synthetic fabrics were tested with three anti-static agents to try to alleviate the buildup of the electrostatic charge and thereby rid clothing made from these fabrics of the unpleasant effects of that static buildup.

The three fabrics tested were made from polyester, acrylic, and polypropylene fibers. The specifications for those fabrics are given in Table IV. The fibers used absorb smaller quantities

Polyester	Acrylic	Polypropylene
Warp 36^S	Warp 2/32 cc	Warp 48^S
Weft 36^S	Weft 1/16 cc	Weft 48^S
Ends 83/inch	Ends 80/inch	Ends 84/inch
Picks 58/inch	Picks 56/inch	Picks 59/inch
2/2 Twill weave	2/1 Twill weave	3/1 Twill weave
8 oz. sq. yd.	9/10 oz. sq. yd.	6 oz. sq. yd.

TABLE IV - Specifications of Synthetic Fabrics for Anti-Static Testing

of water than cotton, and therefore fabrics made from these fibers are correspondingly high in electrical resistivity. When atmospheric humidity is low, the fabrics develop considerable electrostatic charge by the surface separations that occur during handling and wear.

This charge may be eliminated most conveniently by treating the fabric with an anti-static agent which reduces the surface resistivity of the fabrics and allows the charge to dissipate rapidly. In general, anti-static agents are hygroscopic and can be either durable or non-durable on washing. Previous work has shown that the use of anti-static agents reduces soiling, but that an excess of the agents is worse than none at all. An excess causes the fabric to have a greasy or sticky finish, but the proper amount causes a greater reduction of electrostatic particulate pickup than the increase in contact soiling. The use of non-durable anti-static agents should increase the use of soil removal during laundering.

Anti-static agents can be grouped into two types--cationic and non-ionic. The cationic agent selected for testing is a paste containing 75% distearyl dimethyl ammonium chloride. This agent improves rot resistance of the cloth, and makes it feel soft and smooth to handle. The non-ionic agents chosen are a mixture of ethylene-oxide-modified, long-chain aliphatic alcohols, and polyglycol ester. All are water soluble.

The fabrics are treated by immersion in a water bath of the agent, centrifuge wringing, and drying in warm air. During the treating process, the anti-static agent is deposited both by adsorption onto the fabric and by evaporation after centrifuging. The temperature of the agent bath was found to have little effect in comparison with the concentration of the agent in the bath.

In the tests, the fabric strips were washed and dried to insure freedom from grease and other contamination. They were then immersed in the anti-static agent solution and stirred for 10 minutes at 20° C, after which they were centrifuged and dried overnight at 50° C. Their surface resistivity was then measured. Five agent-concentrations were used. Speed and spinning time of the centrifuge were kept constant. After the surface resistivity measurements, the treated fabrics were washed and dried, and the resistivity measured again. The fabric samples were 1" x 1" squares, and the surface resistivity was measured across opposite sides with a twenty-million megohmeter. Table V gives the results of the study. Of the three anti-static agents used, the cationic surfactant is the most efficient. The polyester fabric is easier to treat than the others, and the combination of the cationic agent and the polyester fabric easily attains the required resistivity.

The following Figures 7 and 8 demonstrate graphically the affect of anti-static agents when used in connection with synthetic fibers.

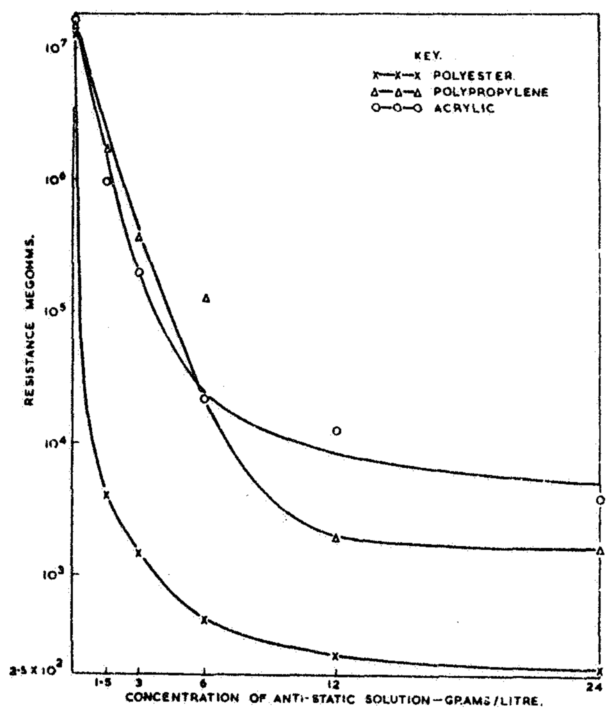

FIGURE 7 - Influence of Dimethyl Distearyl Ammonium Chloride on Synthetic Fabric

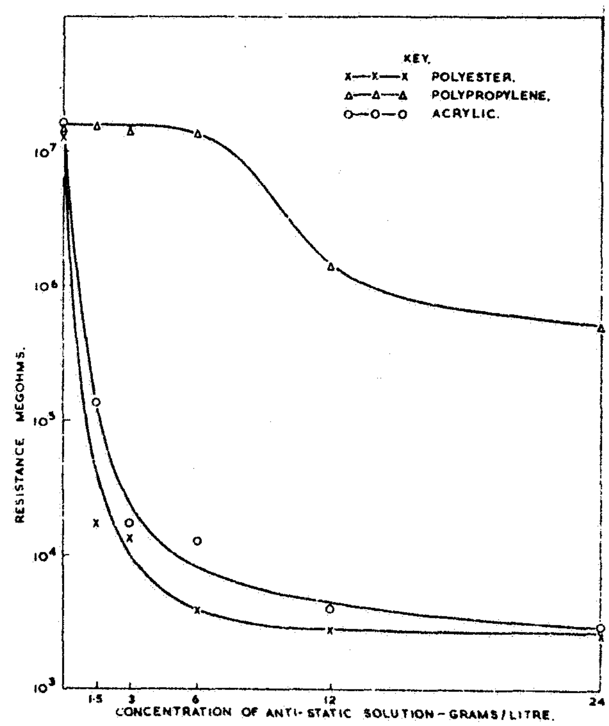

FIGURE 8 - Influence of Ethylene Oxide Modified Aliphatic Alcohol on Synthetic Fabric

Anti-Static Agent and Fabric	Strength of Anti-Static Agent				
	1.5 gm/litre	3 gm/litre	6 gm/litre	12 gm/litre	24 gm/litre
NON-IONIC I					
Polyester	2.3×10^4	1.3×10^4	5.9×10^3	4.4×10^3	4.2×10^3
Polypropylene	2.0×10^7	1.6×10^7	1.4×10^7	1.5×10^6	6.8×10^5
Acrylic	1.3×10^5	2.4×10^4	1.1×10^4	6.0×10^3	4.5×10^3
NON-IONIC II					
Polyester	2.9×10^4	1.1×10^4	6.8×10^3	3.5×10^3	1.9×10^3
Polypropylene	1.9×10^7	1.5×10^7	7.8×10^6	1.7×10^5	4.5×10^4
Acrylic	5.8×10^5	6.0×10^4	1.4×10^4	5.3×10^3	6.5×10^3
CATIONIC					
Polyester	6.0×10^3	1.7×10^3	6.7×10^2	4.0×10^2	3.0×10^2
Polypropylene	2.4×10^6	5.6×10^5	2.9×10^3	2.9×10^3	2.2×10^3
Acrylic	9.9×10^5	2.9×10^5	3.4×10^4	1.0×10^4	5.8×10^3

TABLE V - Surface Resistivity of Treated Fabric--Megohms/sq. in.

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