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US ARMY
TEST & EVALUATION COMMAND



USATECOM PROJECT NO. 7-3-0903-01E

FINAL REPORT OF
SPECIAL STUDY OF
A METHOD FOR OBJECTIVELY DETECTING
THE INSTANT AND LOCATION OF RAINFALL
PENETRATION THROUGH FIELD CLOTHING

APRIL 1964

US ARMY
QUARTERMASTER RESEARCH AND ENGINEERING
FIELD EVALUATION AGENCY
FORT LEE, VIRGINIA

HEADQUARTERS
U. S. ARMY QUARTERMASTER RESEARCH AND ENGINEERING
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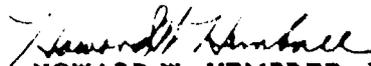
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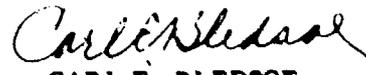

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TABLE OF CONTENTS

	PAGE
ABSTRACT	vii
SECTION 1. GENERAL	1
1.1 References	1
1.2 Authority	1
1.3 Objective	2
1.4 Responsibilities	2
1.5 Description	2
1.6 Background	7
1.7 Findings	9
1.8 Conclusions	9
1.9 Recommendations	9
1.10 Acknowledgment	9
SECTION 2. DETAILS OF TEST	11
2.0 Introduction	11
2.1 Design, Construction and Preliminary Evaluation of Prototype System	12
2.2 Modification of Prototype System and Final Evaluation	19
SECTION 3. APPENDICES	23
A. Study Authorization	24
B. Test Data	25
C. Illustrations	29
D. Distribution	37

**U. S. ARMY QUARTERMASTER RESEARCH AND ENGINEERING
FIELD EVALUATION AGENCY
FORT LEE, VIRGINIA**

USATECOM 7-3-0903-01E

**Final Report of
Special Study of
A Method for Objectively Detecting the Instant and
Location of Rainfall Penetration through Field Clothing**

Conducted at Fort Lee, Virginia

April 1964

Abstract

The present standard test method employed by the Field Evaluation Agency to compare and evaluate the water resistance characteristics of various types of field clothing consists essentially of periodic visual inspections by test observers to determine the incidence and location of water penetration. This special study was conducted by the Agency at Fort Lee, Virginia, to develop an objective method for detecting and locating, on a continuous basis, rainfall penetration through field clothing under dynamic field test conditions.

The experimental leak detection system consists of a wired, multi-circuit, sensing element designed to be worn under wet weather garments, and a portable moisture detecting and signaling device designated Aquatek, M60-1. Three different experimental sensing element vests--designated Type A, Type B and Type C--were constructed and evaluated during this study. The detection system, employing each of the three experimental sensing elements, was evaluated on the Agency's Rain Course facility.

Test results show that the experimental moisture detection system is a satisfactory method for objectively detecting and locating, on a continuous basis, rainfall penetration through field clothing. It is recommended that the system be used concomitantly with the standard system in future tests of wet weather garments to determine the comparative durability of the three experimental sensing elements under continued use.

SECTION 1 - GENERAL

1.1 REFERENCES

1. Harrison, Jennie S., An Engineering Test of Raincoat, Women's, Taupe, T60-5, Quartermaster Research and Engineering Field Evaluation Agency, Project No. AE, FEA 61015, March 1961.

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6. Perkins, James C. Jr., An Investigation of an Objective Method for Determining Moisture Penetration and Absorption Properties of End Items of Leather Footwear Under Dynamic Field Test Conditions, Quartermaster Research and Engineering Field Evaluation Agency, Project No. 7-98-05-001, FEA, MRS 59-7L, November 1960.

7. Quartermaster Research and Engineering Field Evaluation Agency, Test Methods Handbook, Test Method No. 1.9, Dynamic Rain Course Testing of Wet Weather Garments, November 1962, pp 191-195.

1.2 AUTHORITY

Letter, Headquarters, U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland. AMSTE-GE, 25 January 1963, subject: Test Methods Research Studies. See Appendix A.

1.3 OBJECTIVE

To develop an objective method for detecting and locating, on a continuing basis, rainfall penetration through field clothing under dynamic field test conditions.

1.4 RESPONSIBILITIES

The Quartermaster Research and Engineering Field Evaluation Agency was responsible for all portions of this project.

1.5 DESCRIPTION OF MATERIEL

The experimental leak detection system consists of a wired, multi-circuit, sensing element vest designed to be worn under wet weather garments, and a portable moisture detecting and signaling device designated Aquatek, M60-1. This device measures 4" x 4" x 2" and weighs only 18 ounces. Photographs of the components of the Aquatek detector are shown in Appendix C-1 and a diagram of the oscillator circuit is shown in Appendix C-2.

Three different experimental sensing element vests--designated Type A, Type B and Type C--were constructed and evaluated during this study. The Type A vest incorporated 4 separate sensing circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding sewn onto an 8.0 oz. cotton sateen base fabric. The Type B vest incorporated 8 separate sensing circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding sewn onto an 8.5 cotton sateen base fabric. The Type C vest incorporated 4 separate sensing circuits of No. 41 Nichrome¹ wire, 26 T.P.L. on a 270 denier Fortisan Core, sewn into a 6.0 oz. cotton broadcloth base fabric. A photograph of these three sensing element vests is shown in Appendix C-3. A view of a test participant wearing a complete experimental leak detection system comprised of a sensing element vest (Type C) and the Aquatek leak detector is shown in Figure 1.

¹Corrosive resistant alloy.



Figure 1. Test participant wearing experimental sensing element vest and Aquatex M60-1, Detector under standard Army posture.

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Figure 2. Test participant traversing
Clear Track of Rain Course.

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1.6 BACKGROUND

The present standard field test method (7) employed by the Field Evaluation Agency to compare and evaluate the water resistance characteristics of various types of field clothing consists essentially of periodic visual inspections by test observers to determine the incidence and location of water penetration. Measurements of the size of wetted areas are made and recorded in square inches as a quantitative measure of the degree of penetration. The garments are also weighed both before and after exposure to rainfall and any increase in the weight of the outer garment is taken as a measure of moisture pickup, whereas any increase in weight of the undergarment is taken as a measure of penetration. This technique may be applied under both controlled and normal wear conditions, and under dynamic or static exposure conditions, but is used more frequently in conjunction with controlled exposure of field clothing to simulated rainfall on the Agency's Dynamic Rain Course facility. A view of a test participant traversing the Clear Track Section of the Agency's Rain Course is shown in Figure 2.

The standard technique is based on a periodic rather than a continuous detection process. Use of the standard detection method requires periodic controlled withdrawal of the test participants and garments from exposure--normally at 10 to 30 minute intervals--for visual inspection of undergarments for the detection of wet spots indicating penetration. This inspection method necessitates the removal of the experimental overgarment being tested. The operations performed during the inspection interval, including inspection, measuring wet spots, charting the location and size of leaks and weighing, require approximately 6 minutes per test participant. Following each inspection operation each participant, in turn, re-dons the experimental overgarment and re-enters the Rain Course to continue exposure. The exposure and inspection cycles are continued for a pre-determined period of time, usually two hours, or until the garments become saturated, or until the test criteria are met.

The primary disadvantages of this standard method are (1) detection is periodic rather than continuous, i.e., any penetration which occurs at the beginning or during an exposure period will not be detected until the end of the period. (2) the removal of the wet outer garment for inspection of the undergarment greatly increases the chance for error in detection, i.e., it is extremely difficult, even with great

care and assistance, to raise or remove the wet outer garment without dripping excess surface water onto the undergarment and thereby introducing an error factor in the detection method; (3) the number of participants and the length of exposure periods are limited by the facilities and number of personnel available to complete the inspections within the allotted inspection time-interval; (4) since the quantitative measure of the size of the wetted area is affected by the rate of spread of moisture on the fabric of the undergarment, it is essential that the exposure periods be equal for all test participants. The participants, therefore, must enter exposure at time intervals equivalent to the time allotted for withdrawal, inspection and re-entry into the exposure phase. The order of entry, withdrawal, and re-entry must also be maintained to assure equal exposure time for all participants. It is also noted that, since time as well as quantity of moisture contributes to the size of a wet spot, the size of the wet area may increase even after withdrawal from exposure. It is imperative, therefore, that the garments be inspected immediately upon withdrawal and at equal time intervals. Since the participants' entry into exposure must be staggered at equal time intervals, it would require 27 minutes to begin exposure of 10 participants at 3-minute intervals; 54 minutes for 20 participants, etc. In the first instance, with a 20-minute exposure period, the first three participants would complete the first exposure before the last man begins.

Although the standard method of comparing and evaluating the water resistance characteristic of field clothing has some disadvantages, it has been proven adequate for evaluating experimental garments where rather gross differences exist between garments of different finishes and materials. With more recent and continuing development of improved water repellent treatments for fabrics, and the use of newly developed synthetic materials for the fabrication of rain garments and field clothing, the need for a more refined and reliable method of evaluating the water resistance characteristics of these items has become increasingly important. The aim of this research effort, therefore, was to develop an objective method of automatically detecting and locating moisture penetration through field clothing, including rain garments, on a continuous basis under dynamic field test conditions.

1.7 FINDINGS

See Section 2.

1.8 CONCLUSIONS

Based on the results of this study, it is concluded that:

a. The experimental moisture detection method, incorporating the Aquatek, M60-1, Leak Detector, and a wired, multi-circuit, vest-type, sensing element is a satisfactory method for objectively detecting and locating, on a continuous basis, rainfall penetration through field clothing.

b. The experimental moisture detection method is functionally suitable and economically feasible for use in evaluating the moisture resistance characteristics of field clothing under dynamic test conditions.

c. The experimental method is easy to use and causes no discomfort to the wearer.

1.9 RECOMMENDATIONS

a. The experimental moisture detection method, using the available detector-sensing element systems, and the standard system be used concomitantly in future tests of wet weather garments to determine the comparative durability of the three experimental sensing elements in continued use.

b. The sensing element which proves most durable in continued use trials be reproduced in a sufficient quantity so that the experimental system may be adopted in lieu of that part of the standard method (7) which depends upon periodic visual inspection for the detection and location of moisture penetration through test garments.

1.10 ACKNOWLEDGMENT

The author gratefully acknowledges the cooperation of both Mr. John E. Cogle and Mr. Joseph R. Moore of the Quartermaster Field Evaluation Agency's Instrumentation and Analysis Branch in designing and constructing many of the electronic components used in this study.

including the Aquatek detector. Appreciation is also expressed to Pfc. Robert Dilks for his valuable assistance in designing and constructing the experimental sensing elements. Mention should also be made of Mr. William Newell and his associates at the Textile Research Center, North Carolina State College, for their technical assistance and advice regarding the materials, design and construction of the experimental sensing elements.

SECTION 2 - DETAILS OF TEST

2.0 INTRODUCTION

The proposed method for automatically detecting the instant and location of moisture penetration through field clothing is based on the principle of electrical resistance and the resultant changes in resistance activated by presence of moisture. The principle is identical to that which proved successful in detecting leaks in footwear under dynamic use conditions (6). The experimental design and the procedures employed in this study were directed toward the application and adoption of a similar technique for detecting and locating leaks in field clothing.

Preliminary to any testing was the determination of the design and the materials to be used in constructing the experimental sensing element. Consideration was given to several types of materials for the base fabric of the circuit system and numerous types of conducting materials for the circuits. Based on previous research and experience with fabrics and conductors in the development of a footwear sensing element (3, 6) the types of materials considered most suitable for evaluation were reduced to three types of fabrics and two types of conductor wire. In an effort to keep the initial design of the sensing element as simple as possible and yet effective in detecting penetration at critical leak areas, a sleeveless vest-type pattern was used.

Three experimental sensing element vests were constructed using different combinations of fabric and circuit wire. Two models were constructed with 4 separate circuits and one model with 8 separate circuits. Each vest model included a flexible lead cable to connect to the portable Aquatek leak detector. The sensing element vest and the Aquatek detector formed the experimental detection system.

The experimental detection system, employing each of the three experimental sensing elements, was evaluated on the Agency's Rain Course facility. Test participants wore the experimental system under the standard Army poncho while traversing the Clear Track Section of the Rain Course. The criteria for measuring the effectiveness of the system included the time period of exposure until the first automatic detection of a leak and verification of penetration and location by visual inspection of the undergarments. Since the standard

method will normally detect penetration only at the scheduled 20-30 minute inspection intervals, it was considered that any penetration detected between normal inspection intervals would represent an improvement over the standard technique.

2.1 DESIGN, CONSTRUCTION AND PRELIMINARY EVALUATION OF PROTOTYPE SYSTEMS

2.1.1 OBJECTIVES

To design and construct a sensing element which would meet the following requirements:

- a. Compatible for use with the Aquatek, M60-1, leak detector.
- b. Sensitive to slight amounts of moisture penetration.
- c. Sufficiently durable for repeated test trials.
- d. Comfortable for wear under field clothing or rain garments.

2.1.2 METHOD

2.1.2.1 Design of Pattern for Sensing Element

In an effort to cover the most critical leak areas and yet keep the basic design simple, the pattern for the experimental sensing element was made in the shape of a vest. The pattern was designed for a snug fit at the neck with an opening up one side which could be fastened with snaps or a zipper after donning and easily unfastened for doffing.

2.1.2.2 Selection of Base Fabric

The next step involved the selection of a base fabric to which the wired circuit could be sewn. The three most important factors for consideration in the selection of a fabric were weight, durability, and absorptivity. The fabric had to be heavy enough to provide stability to the circuit system and to permit multiple row stitching through the fabric without reducing the tear strength of the material. Several types of fabric were selected for their known desirable characteristics including various weights of cotton broadcloth and cotton sateen. A series of

simple absorption tests were run on the fabrics by dropping a measured quantity of water on each fabric with a dropper and then measuring the wetted area after fixed intervals of time to determine the rate of spread. This test was run on new fabrics and repeated on the same fabrics after laundering. It was found that the rate of absorption was substantially increased for all fabrics after one laundering. The three fabric types which, according to preliminary evaluation, seemed best to satisfy the requirements for both durability and absorptivity were the 6 oz. cotton broadcloth, 8 oz. cotton sateen and 8.5 cotton sateen. These three fabrics, therefore, were selected as the base fabrics for three experimental vests.

2.1.2.3 Selection of Conductor Wire for Circuit System

The selection of a suitable conductor for the circuit system of the experimental sensing element was facilitated by available data from the previous experimentation with various conductors for use in the sensing element of the footwear leak detection system (6). In this previous study, experiments were conducted using metallic paints, Nichrome, Alkathol², constantan and copper wire of various dimensions for the circuit system. The results of these experiments showed that flexible copper braid and bonding cable #24 x 36 AWG stranding sewn to a base fabric met the requirements of sensitivity, durability, flexibility, and comfort set for the footwear sensing element. Based on these previous findings, No. 41 Nichrome wire wound 26 T. P. I. on a 270 denier Fortisan Core and flexible copper braid and bonding cable #24 x 36 AWG stranding were selected as the experimental conductors to be used for the circuit system on the vest-type sensing elements. The Nichrome, which was not sufficiently durable for continuous use in the footwear sensing device, was selected because of its sensitivity, corrosion resistance, lightness of weight and ease of attachment. The Nichrome could be wound on the bobbin of an electric sewing machine and sewn directly into the base fabric with a straight stitch; and it was felt that the durability requirements for the vest circuits would be less than those for the previously tested footwear circuits. The copper bonding cable was chosen for its flexibility and known durability characteristics, although it is substantially heavier than the Nichrome.

²Driver-Harris corrosive resistant alloy, annealed.

2.1.2.4 Location and Design of Circuits on Vests

Critical areas of leakage through field clothing and rainwear were determined by a review of previous reports of tests of experimental wet weather garments which were tested on the Agency's Rain Course (1, 2, 4, 5). The most frequent areas of leakage were found to be at the neck or collar, top of the shoulders, center-chest and center-back areas. It was immediately apparent that these areas are the parts of the body most exposed to rainfall when the participant is in a standing position. It was also noted that these four particular locations are the areas of greatest body contact on the underneath side of outer garments; this would be true even for loose fitting garments such as the field coat or the poncho.

The maximum number of circuits on the current model, M60-1, of the portable Aquatek detection device is eight. It was felt that eight separate circuits on the sensing element would be more than adequate for locating or defining the designated critical leak areas of most garments which would be evaluated, using this technique.

Two metal templates, identical in shape to that of the vest pattern, were constructed with 1/8-inch dia. holes punched in the metal, outlining the circuit pattern to be used. The templates were then laid over the base fabric and the outline of the circuits was marked on the fabric with chalk to assure that the wire circuits would be properly located; all parallel wires in each circuit would be exactly 1/2-inch apart at all points; all wires within each circuit would be sewn to the vest running on a horizontal plane.

2.1.2.5 Construction of Experimental Sensing Elements

After determining the design of the sensing element, the types of fabric and conductors to be used, and the locations of the circuits, the next step was the actual construction of the vest-type sensing elements. Local tailor shops were contacted and shown the pattern and design for constructing the experimental vest. The five tailors contacted would not agree to attempt the job because it was not within the usual category of work for a small retail tailor shop; therefore, this approach was abandoned in favor of "in-house" construction. The services of an enlisted specialist with tailoring experience were obtained for the period of the study. The specialist, after consulting

with commercial tailors and seamstresses, spent several weeks experimenting with various methods of attaching the wire circuits to the base fabric before the first working model was constructed.

Three experimental vest-type sensing elements were constructed for use in the study. The first model, designated Type A, used an 8 oz. cotton sateen base fabric with four separate, sewn-on, circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding. The second model, designated Type B, used an 8.5 oz. cotton sateen base fabric and eight separate, sewn-on, circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding. The third model vest, designated Type C, used a 6 oz. cotton broadcloth base fabric with four separate, sewn-in, circuits of No. 41 Nichrome wire. All base fabrics were laundered prior to attaching the wire circuits to increase the absorptivity of the fabrics. The Type C vest was constructed after preliminary trials were conducted on the Type A and Type B Vests. Diagrams showing the locations of the circuits on each of the three experimental vests are shown in Appendix C-4.

2.1.2.6 Controlled Exposure Trials Under Dynamic Use Conditions - Rain Course Facility

A series of preliminary exposure trials, under closely controlled conditions, were conducted on the Agency's Rain Course to determine whether or not the experimental leak detection vest, when used in conjunction with the Aquatek leak detector, would function as a system, and as planned.

The procedure for each of these trials was similar. Two volunteer participants were fitted with standard lightweight fatigues, helmet liners, plastic boots and experimental vests, Types A and B. The vests were worn over the fatigue jacket. Before donning standard Army ponchos, every circuit in both vests was tested to assure that they were working properly. The Aquatek detector was fastened to the trousers belt of each participant and the lead cable from the vest was plugged into the detector. Both participants then donned new ponchos which were carefully adjusted and secured about the head and face for wear under severe rainfall conditions. The participants were given a thorough orientation regarding test procedure and operation of the detection system and a final check was made of the system to assure that it was operating properly.

The two participants then entered the Rain Course simultaneously. The Rain Course facility was calibrated for a 1-inch per hour simulated rainfall for the first three preliminary trials, and for subsequent trials was increased to simulate a 3-inch per hour rainfall. The participants traversed the Clear Track section of the Rain Course, walking at a slow pace with heads slightly bowed to prevent rain from entering through the face opening of the poncho. The traversals continued for a maximum period of 2 hours. Whenever the participants heard an audible pitch change from the detector, signaling moisture penetration, the location of the leak was checked by turning off each numbered switch in the series of switches on the side of the detector until the signal stopped. Since the switch number on the detector coincided with the sensing element circuit number, the location of the leak was readily determined. Immediately upon hearing the detector signal, the participant raised his right arm at a 90° angle to his body signifying to the observer/recorder the occurrence of a leak in the garment. The participant then immediately proceeded to check the switch controlling the signal and the area of the leak and relayed the switch number to the observer/recorder who entered the number of minutes of exposure prior to the development of the first leak together with the location of the leak on the data record. The participant then reactivated all circuits except the one indicating a leak. This entire operation was performed by the participant while traversing the course in a normal manner and required approximately 30 seconds, resulting in a slight time lapse between the instant of detection and visual verification.

During the preliminary trials the participants were withdrawn at 30-minute intervals. The ponchos were raised, but not completely doffed, and the undergarments were checked for wet spots in the event that penetration occurred which was not detected by the experimental sensing element. Any wet spots were measured - inches in diameter - and recorded. The participants were also withdrawn, undergarments checked, and any wet spots measured and recorded at any time during the 2-hour period when the detector signalled a leak in one or more locations. This operation was performed to verify the accuracy of the signal. Exposure time prior to first penetration in each critical leak area was measured with a stop watch and these times were recorded to the nearest whole minute.

2.1.3 RESULTS

2.1.3.1 Design and Construction of Sensing Element

Design and construction data on the three types of experimental sensing element vests fabricated for evaluation and use in this study are shown in Table I. Photographs of the three experimental vests are shown in Appendix C-3.

2.1.3.2 Preliminary Evaluation On Rain Course

The results of the preliminary exposure trials conducted on the Rain Course facility using the Type A and the Type B vest are shown in Appendix B-1.

2.1.4 ANALYSIS

The data generated during the preliminary exposure trials show that the experimental detection system, employing either a Type A or Type B vest-type sensing element and the Aquatek detector, is a feasible method for automatically detecting and locating moisture penetration through rain garments on a continuous basis. Of the total of 39 charted time and location readings, there were only two instances in which the accuracy of the automatic signals was not verified by inspection. There were two instances, once in Trial No. 5 and once in Trial No. 8, when the detector attached to the Type A vest signalled penetration, but there was no observable wet area. A detailed physical inspection failed to reveal any observable indication of the presence of moisture. It is suspected that a sufficient quantity of moisture was present to emit a signal although there was no "spotting" or darkening of the fabric which usually occurred when there was sufficient quantity of moisture present to activate the signal. It is noted that following the erroneous detection in Trial No. 5 -- after 21 minutes of exposure -- a signal was emitted on the same circuit within 3 minutes after re-entry to exposure, and a follow-up visual inspection showed a wet area 1-inch in diameter which was not previously observed. There were five instances, three times on the Type B vest and twice on the Type A vest, where the visual inspection revealed wet spots indicating penetration but no signal was emitted. Of these five instances, one was caused by two parallel wires in the Type B vest touching and "shorting-out" the circuit, and two were traced to broken wires in the

TABLE I
DESIGN AND CONSTRUCTION DATA - EXPERIMENTAL SENSING ELEMENTS

Sensing Element Model	Base Fabric	Non-Insulated Circuit Wire	Number of Circuits	Wt. (Less Detector)	No. Hours To Construct	Approx. Cost (Material Only)
A	8.0 oz. Cotton Satin	Flexible copper braid and bonding cable #24x36 AWG stranding.	4	24 oss.	12	\$4.00
B	8.5 oz. Cotton Satin	Flexible copper braid and bonding cable #24x36 AWG stranding.	8	34 oss.	16	\$6.00
C	6 oz. Cotton Broadcloth	No. 41 Nichrome, 26 T.P. I. on a 270 denier Fort-leon Core.	4	14 oss.	8	\$12.00

^aPer weight of entire system add 18 oss.; includes weight of Agastek w/easphone
^bCorrosive-resistant alloy.

Type A vest. Although the cause of the other two instances could not be positively determined, it is believed that both failures were caused by malfunctioning of the wire circuit rather than the detector.

The most noteworthy result of the preliminary trials was the unusually small size of the wet areas at the time of detection in any location by the experimental method. Although there was a brief lapse of time, approximately 30 seconds, between the emission of the signal indicating penetration and the visual verification and recording of the results, the size of the wet area was seldom more than 2-inches in diameter and was frequently less than 1-inch in diameter. The overall average size of the wet area at the time of first detection of penetration for these trials was 2.8 square inches compared with 22.0 square inches (1" rainfall) and 70.0 square inches (3" rainfall) detected on first inspection in a previous test (5) using standard ponchos and the standard detection method. It is also important to note the frequency with which penetration was detected at intervals of less than 20 minutes of exposure, as well as those instances between 20, 40 and 60 minute intervals. Using the standard detection method, these instances of penetration would have been observed only during the designated inspections at 20 or 30 minute intervals during a two-hour exposure period.

During these trials several test participants stated that they had some difficulty hearing the detector signal because of the background noise created by the rainfall. In an effort to overcome this objection, several locations for the detector other than the trousers belt were tried, including underneath the arms, the jacket pocket and inside the helmet liner. Although hearing was improved in most of these locations, none of these alternate locations were as comfortable for the participants as the trousers belt.

2.2 MODIFICATION OF PROTOTYPE DETECTION SYSTEM AND FINAL EVALUATION

2.2.1 OBJECTIVE

To modify the experimental sensing element and Aquatek detector to correct deficiencies found during the preliminary trials and to determine the functional adequacy of the modified system for detecting and locating penetration through rain garments.

2.2.2 METHOD

2.2.2.1 Modification of Prototype Detection System

Based on the results of the preliminary trials, several modifications were made in the design of the vest-type sensing element and the detector in an effort to eliminate the cause of malfunction of the wired circuits and to improve the overall operating efficiency of the detection system. The Aquatek detector unit was modified by adding an earphone jack, extension cable and miniature earphone to enable the participant to hear the penetration signal over the background noises on the Rain Course while wearing the detector in the most comfortable position--on the trousers belt. Another improvement in the detector was the addition of an operating signal. This operating signal was a low frequency, intermittent, "beeping" sound emitted by the detector when the operating switch was turned on, indicating that the detector was functioning. The sensing element vest was modified to overcome the problem of parallel wires touching and causing a short-circuit by using a button-hole stitch attachment on the electric sewing machine, in lieu of the zig-sag stitch. This modification increased the number and proximity of stitches covering the wire. This closer stitching offered more stability and protection from breakage to the wire circuit system. The Type C vest, using a 6 oz. white cotton broadcloth base and No. 41 Nichrome wire, was constructed to incorporate the aforementioned modifications. In addition, the Type C vest was immersed in a 4% aqueous solution of cobalt chloride ($\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$). It was then oven-dried at 150°F. until the pink color changed to blue. The vest was then sealed in a plastic bag until ready for use. The intended purpose of the cobalt chloride treatment was to facilitate identification and location of moisture penetration.

2.2.2.2 Evaluation of Modified Components

The modified Aquatek detector and the modified Type A and Type B sensing element vests, together with the newly constructed Type C vest using Nichrome wire, were subjected to a series of exposure trials. These exposure trials consisted of traversing the Clear Track of the Rain Course under a 1-inch per hour simulated rainfall for a maximum period of 1 hour. The participants in these trials wore the experimental detection components under experimental, Quarpei

treated, ponchos. The Aquatek detector was worn on a belt at the waist and the earphone with extension cable was used for listening. The detection and data recording procedures used during these trials were identical to those used previously in the preliminary trials, except that participants were not withdrawn on the occurrence of each detection, but only at approximately 30 minute intervals for visual verification of results. Participants were also withdrawn whenever all circuits were activated indicating penetration in all circuit areas.

2.2.3 RESULTS

The results of the final exposure trials conducted on the Rain Course using the modified detector and sensing elements, together with the results of the exposure trials using Type C vest, are shown in Appendix B-2.

2.2.4 ANALYSIS

The results of the exposure trials using the modified experimental detection systems showed that all three types of experimental sensing element vests were functionally adequate and equally satisfactory for use in automatically detecting and locating moisture penetration through field clothing on a continuous basis. During this series of exposure trials, there were no instances of penetration not detected by the sensing elements, and no signals were emitted that were not able to be verified by visual inspection. There were no malfunctions in the vests or in the Aquatek detector in these trials. The test participants experienced no difficulty in hearing the detector signal using the earphone and there were no complaints of any discomfort resulting from wear of any of the three vest models. The cobalt chloride treated, Type C, vest turned from a dark blue to a very light blue color when removed from the plastic bag and extreme care was necessary to prevent extraneous moisture from getting on the vest before donning the poncho. The treatment, however, remained effective and was an aid in identifying areas of moisture penetration.

All systems were more thoroughly checked before beginning this series of trials than before the preliminary trials. Checks in the laboratory and again before use in the field for broken or short circuits in the vest and for proper operation of the detector prior to any testing with this technique is considered essential for accuracy.

The sensing element vest with 8 separate circuits (Type E) functioned as well as those with only 4 separate circuits (Types A and C). Since 8 circuits afford better discrimination as to the location of penetration, the 8-circuit system is better for most test purposes and allows sufficient circuits for the possible addition of sleeves to the vest or for extending coverage to other areas if desired.

The three sensing element vests were equally durable throughout the test trials. Additional trials over a longer period of time are required to determine which type of vest and wire conductor material is most durable.

The Type C vest, using 6 oz. cotton broadcloth and Nichrome wire circuits sewn directly into the fabric, is lighter in weight and takes less time to construct than the Type A or the Type B vests. One disadvantage of the Nichrome wire circuit, however, is that breaks in the wire are extremely difficult to detect and much more difficult to repair than the copper wire. The copper wire is easily repaired by soldering; whereas heat applied to the Nichrome wire during soldering melts the Fortisan Core. The Nichrome circuit can be repaired by "over-stitching" the break, but experiments with this method of repair have shown that this method results in a decrease in sensitivity and accuracy of detection.

SECTION 3 - APPENDICES

Appendix A - Test Directive

Appendix B - Test Data

Appendix C - Illustrations

Appendix D - Distribution List

APPENDIX A

**HEADQUARTERS
U. S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND**

AMSTE-GE

25 Jan 1963

SUBJECT: Test Methods Research Studies

**TO: Commanding Officer
U. S. Army Quartermaster Research and
Engineering Field Evaluation Agency
Fort Lee, Virginia**

- - E X T R A C T - -

1. Reference is made to your letter STEFA-TS dated 9 November 1962, requesting the inclusion of certain test methods research studies on the current test program. The following studies are approved and have been included on the program.

*** * * * ***

**7E-3903-01-- The Development of a Technique for Objective
Measurement of Rainfall Penetration Through
Field Clothing.**

*** * * * ***

FOR THE COMMANDER:

**/s/ John W. Rodgers
/t/ JOHN W. RODGERS
Colonel GS
C. Admin Div**

APPENDIX B-1 (1)

RESULTS OF PRELIMINARY EXPOSURE TRIALS - RAIN COURSE
(Two Participants Wearing New Standard Ponchos)

Trial Number	Sensing Element Type - No. Circuits	Traversal Element Location of Penetration Circuit Nos. Activated	Traversal Time to Detection of Penetration (Minutes - Seconds)	Location of Penetration Vest Area (Body Area - Position)	Size of Wet Area ^c (Sq. Inches)
1	A-4	(7)	3, 4	B-R, S-L	1, 4
	B-8	(13)	3	S-L	1
2	A-4	(5)	3	S-R	1
	B-8	(13)	3	S-R	1/2
3	A-4	(5)	3, 4	S-R, S-L	4, 6
	B-8	(13)	3, 4	S-R, S-L	1/2
4	B-8	(13)	2, 3, 7, 8	S-R, M-F, W-F, M-B, W-B	140 ^d
	A-4	(11)	3, 4	S-R, S-L	4, 6
5	B-8	(13)	1, 2	S-R, S-R	1, 4
	B-8	(14)	3, 4	S-L, S-LF	1, 4
6	A-4	(11)	3, 4	M-B, M-B	2
	B-8	(13)	1, 2, 3	M-F, W-F	1, 4, 1
7	A-4	(17)	4	M, W, S-R	1, 4, 1
	B-8	(17)	4	(Signal-no observable penetration)	1
8	A-4	(14)	3, 4	S-L, S-LF	3/4
	B-8	(17)	7, 8	M-B, W-B	1
9	A-4	(2)	1, 2	S-R, S-R	2
	B-8	(17)	3, 4	M-F, W-F	1
10	A-4	(5)	3	S-R	3/4
	B-8	(13)	4	S-L	2
11	A-4	(13)	1	M	1/2
	B-8	(17)	2	M	2
12	A-4	(5)	5	M-F	1/4
	B-8	(13)	-	S-R, S-R (Penetration-No signal)	3/4
13	A-4	(13)	3, 4	S-L, S-LF	2
	B-8	(17)	7, 8	S-R, W-B	2

(CONTINUED)

APPENDIX B-1 (2)

(Continued)

Trial Number	Sensing Element Vest (Type - No. Circuits)	Traversal Time to Detection of Penetration ^a (Minutes - Cumulative)	Location of Penetration		Size of Wet Area ^c (Sq. Inches)
			Circuit Nos. Activated	Vest Area ^b (Body Area - Position)	
7	A-4	42 (18)	3	S-R	1/2
		45 (15)	1,2	H,W	1/4
	(47)	-	S-L, (Extensive penetration - No signal)	4	
	B-8	29 (11)	1,2	S-RZ, S-RB	2
(30)		-	S-LB, S-LF (Penetration-No signal)	1/2	
8	A-4	44 (16)	8,5,6	W-B, H-F, W-F	1, 1/4
		(30)	-	S-L (Penetration-No signal)	1/2
		34 (6)	2	W (Signal-No penetration)	-
		44 (16)	3	S-R	3/4
	B-8	72 (8)	1	H	1-1/4
		15 (5)	1,2	S-RZ, S-RB	1
	(30)	-	-	S-LB, S-LF, H-F, W-F (Penetration-No signal)	1, 1/4, 2
		70 (10)	7,8	H-B, W-B	1/4, 3/4

^aFirst column shows cumulative minutes exposure prior to detecting penetration for each circuit; numbers in parentheses in second column are additional minutes of exposure time which would have occurred before detection using the standard method at 20 minute interval.

^bVest Area Code: S = Shoulder; W = Waist; H = Hips--F = Front; B = Back; R = Right; L = Left.

^cWet areas were measured at longest and widest points and recorded in approximate square inches.

^dGeneral saturation due to accidental leak through face opening - man looked up.

^eNOTE: A 2-inch per hour rainfall was used in Trials 1, 2 and 3. The rainfall was increased to 3-inches per hour for all subsequent trials.

APPENDIX B-2 (1)

RESULTS OF EXPOSURE TRIALS USING MODIFIED DETECTION SYSTEM - RAIN COURSE
(Two Participants Wearing Exp. Quarrel Treated Ponchos^a)

Trial Number	Sensing Element Vest (Type - No. Circuits)	Traversal Time to Detection of Penetration ^b (Minutes - Cumulative)	Location of Penetration Vest Area ^c (Body Area - Position)	
			Circuit Nos. Activated	
1	A-6	19	(1)	H-F, W-F, S-R S-L
		23	(17)	
	B-8	27	(13)	S-RF, S-RB S-LB, S-LF H-B, W, B H-F, W-F
		43	(17)	
		51	(9)	
		56	(4)	
A-6	23	(17)	1,2,3,4	H-F, W-F, S-R, S-L
	B-8	16	(2)	1,2,3,4
A-6	27	(13)	1,2,3,4	H-F, W-F, H-B, W-B H-F, W-F S-R, S-L
	28	(12)	5,6,7,8	
	34	(6)	1,2	
	34	(6)	3,4	
A-6	29	(11)	2,3	S-RB, S-LB W-F, S-R H-F
	12	(8)	2,3	
	22	(16)	1	
	22	(16)	1	
B-8 C-6	16	(4)	1,3	S-RF, S-LF S-L S-R W-F, W-B
	17	(3)	2	
	25	(15)	1	
	47	(13)	3,4	
B-8	10	(10)	2,3,4	S-RB, S-LB, S-LF H-F, W-F, H-B, W-B S-RF
	16	(4)	5,6,7,8	
	29	(11)	1	
	29	(11)	1	

(CONTINUED)

APPENDIX B-2 (2)

(Continued)

Trial Number	Sensing Element West (Type - No. Circuits)	Traversal Time to Detection of Penetration ^b (Minutes - Cumulative)	Location of Penetration Circuit Nos. Activated	Vest Area ^c (Body Area - Position)
6	C-4	15 (5) 35 (5)	1,3 2,4	S-R, W-F S-L, W-B
7	C-4	20 (0) 40 (0)	1,2,3 4	S-R, S-L, W-F W-B

^aDiffers from standard poncho in that cloth, cotton, poplin, cotton/nylon (intimate blend) 6 oz./yd². Quarrel Treated is substituted for the coated fabric.

^bFigures in first column show cumulative minutes of exposure time prior to detecting first penetration on each circuit; numbers in parentheses in second column show additional minutes exposure time which would have occurred before detection using the standard method at 20 minute intervals.

^cVest Area Code: S = Shoulder; W = Waist; H = Hips; F = Front; B = Back; R = Right; L = Left

NOTE: All trials using 3-inch per hour rainfall with 60 minute maximum exposure time.



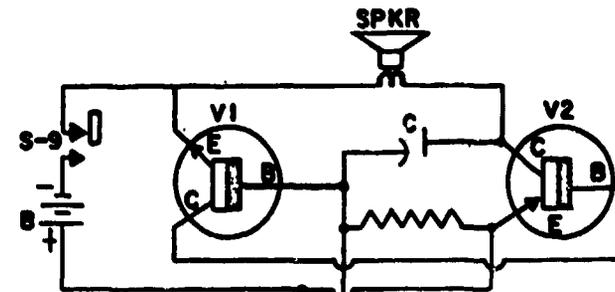
AQUATEK, M60-1, PORTABLE LEAK DETECTOR

Aquatek, M60-1, Portable Leak Detector, component parts and completely assembled model. The completely assembled unit measured 4" x 4" x 2" in size, weighs only 18 ounces and was constructed "in-house" at a cost of approximately \$25.00 for material and parts.

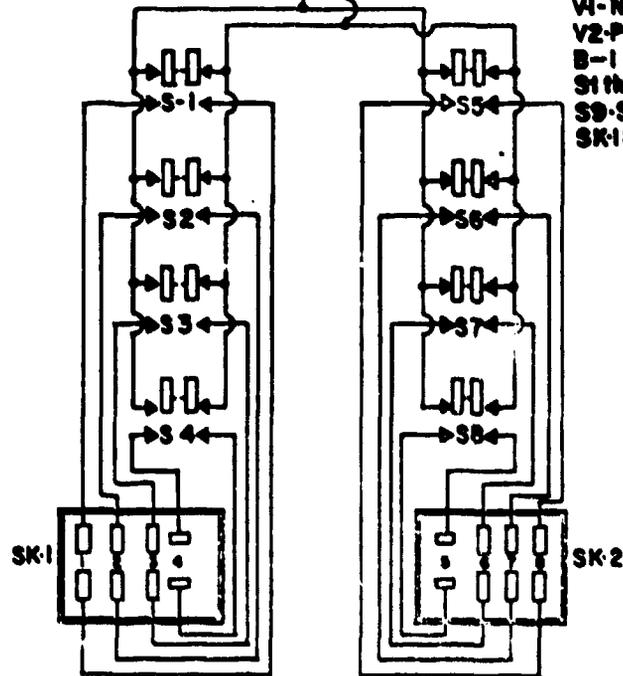
UNITED STATES ARMY
ON 804
FIELD EVALUATION
AGENCY
FORT LEE, VIRGINIA
NSI **TECOM 7-3-0903-01E**
NEGATIVE **MRS 59-7L-12**
APPROX **C-1**

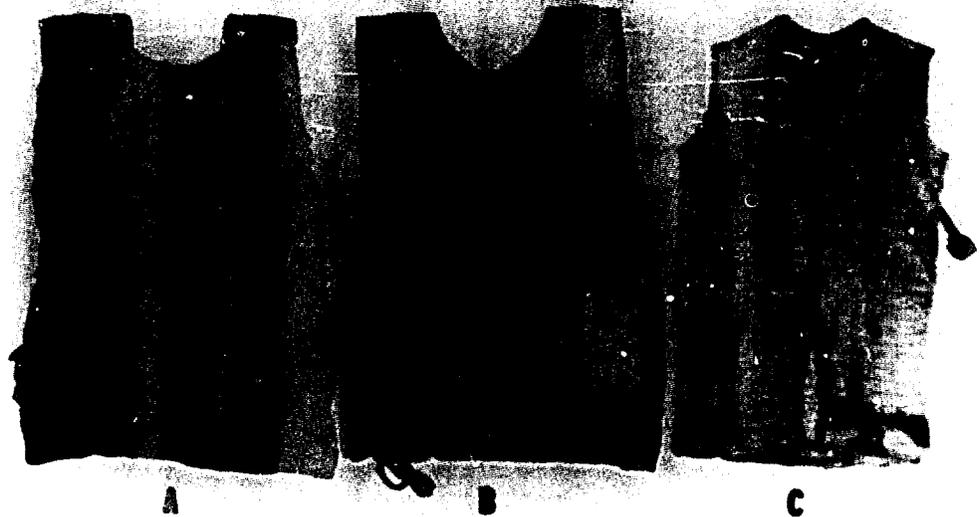
APPENDIX C-2

OSCILLATOR CIRCUIT DIAGRAM - AQUATEK LEAK DETECTOR



- SPKR-3.2 r Speaker
- C-.25mfd 100volt capacitor
- R-150,000 r 1/2 watt resistor
- V1-NPN Transistor type 2N233
- V2-PNP Transistor type 2N34
- B-1 1/2 volt Battery (Penlite size)
- S1 thru S8-DPST-Slide switch
- S9-SPST-Slide switch
- SK-1 & SK-2-Socket 8 pin





EXPERIMENTAL SENSING ELEMENT VESTS

- Type "A" - 4 separate circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding, 8.0 oz. cotton sateen.
- Type "B" - 8 separate circuits of flexible copper braid and bonding cable #24 x 36 AWG stranding, 8.5 oz. cotton sateen.
- Type "C" - 4 separate circuits of No. 41 Nichrome wire, 6.0 oz. cotton broadcloth.

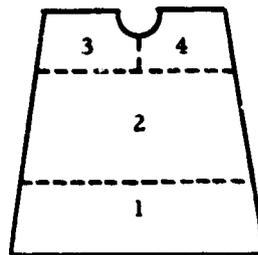
UNITED STATES ARMY
CIVILIAN
FIELD EVALUATION
AGENCY
FORT LEE, VIRGINIA
DIST. TECOM 7-3-0405-012

FIGURE 2

APPENDIX C-3

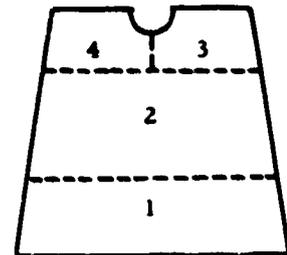
APPENDIX C-4

DIAGRAMS OF CIRCUIT LOCATIONS ON SENSING ELEMENT VESTS

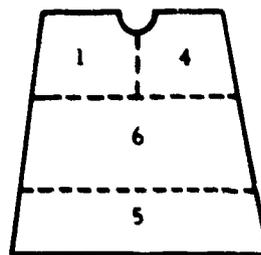


Front

Vest Type A - 4 Circuits

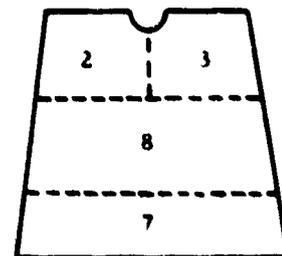


Back

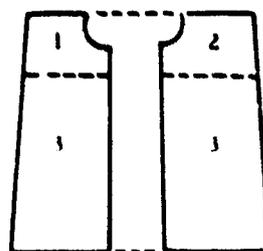


Front

Vest Type B - 8 Circuits

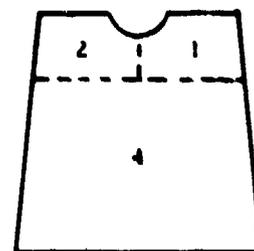


Back



Front

Vest Type C - 4 Circuits



Back

APPENDIX D (1)

DISTRIBUTION LIST

USATECOM PROJECT NO. 7-3-0903-01E

- 3 - Commanding General
U.S. Army Test and Evaluation Command
ATTN: AMSTE-GE
Aberdeen Proving Ground, Maryland 21005**
- 4 - Commanding General
U.S. Army Natick Laboratories
ATTN: Assistant Deputy Scientific Director
for Engineering
Natick, Massachusetts 01762**
- 1 - Commandant
U.S. Army Quartermaster School
ATTN: QM Library
Fort Lee, Virginia**
- 4 - USQM, Technical Representative
Directorate of Inter Service Development
220 Wellington Street
Ottawa, Canada**
- 4 - QM Representative
U.S. Army Standardization Group UK
Box 65, USN 100, FPO
New York, New York**
- 1 - Chief of Naval Research
ATTN: Code 4025
Washington 25, D. C.**
- 1 - Director of Research and Development
Office of Chief of Staff
Washington 25, D. C.**

APPENDIX D (2)

- 1 - National Research Council
2101 Constitution Avenue
ATTN: Advisory Board on Military Personnel Supplies
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- 1 - The Army Library
Pentagon Building
Washington 25, D. C.
- 20 - Commanding Officer
Defense Documentation Center
ATTN: Document Service Center
Cameron Station
Alexandria, Virginia 22314
- 1 - Marine Corps Equipment Board
Marine Development Center
Marine Corps School
Quantico, Virginia
- 1 - U. S. Department of Agriculture Library
Washington 25, D. C.
- 1 - Headquarters
U. S. Army Medical R&D Command
Main Navy Building
ATTN: NP&PP Research Laboratory
Washington 25, D. C.
- 1 - Commanding General
U. S. Army Materiel Command
ATTN: Deputy Director, Research & Development
Washington, D. C. 20315