NAVSHIPS 0967-316-3010

INSTRUCTION MANUAL

FOR

MICROWAVE RADIATION PROTECTIVE CLOTHING

DEPARTMENT OF THE NAVY
NAVAL SHIP ENGINEERING CENTER

OCTOBER 1971

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REPORT OF FAILURE

Report of failure of any component of this microwave radiation protective clothing during its service life shall be made to the Naval Ship Engineering Center, Code 6179C. The report shall cover all details of the failure and give the date of acquisition of the gear.

SAFETY NOTICE
WARNING
RADIATION HAZARD

The arc-preventive overgarment MUST be worn over the radiation protective coverall whenever the protective coverall is worn.

Under NO circumstances should this radiation protective clothing be worn in an RF field having a power density exceeding 200 milliwatts per square centimeter (200 mW/cm^2) or having a frequency outside the tested range of 200 MHz to 10 GHz.

FURTHER INFORMATION

For details on the exact construction of the radiation protective coverall and the test procedures employed in evaluating the garment, refer to Military Specification MIL-C-82296, Coverall, Microwave Radiation Protective.

CHANGE RECORD

CHANGE NO.	DATE	TITLE AND/OR BRIEF DESCRIPTION	SIGNATURE OF VALIDATING OFFICER

Section 1
GENERAL DESCRIPTION

1.1 PURPOSE AND BASIC PRINCIPLES

The Microwave Radiation Protective Clothing, shown in figure 1-1 (without storage bag), was developed primarily to protect personnel from radiation hazards associated with high-power radars. The components of the protective clothing are listed in table 1-1.

Table 1-1. Components of Microwave Radiation Protective Clothing

Quantity	Description
1 ea.	Microwave Radiation Protective Coverall
1 ea.	Radio Frequency Overgarment
1 ea.	Hardhat or peak utility hat 1/
1 pr.	Boots - rubber/plastic 2/
1 pr.	Gloves - rubber/plastic 3/
1 ea.	Repair Patch
1 ea.	Storage Bag and Box

1/ A hard hat suitable for the purpose intended is covered by Specification GGG-H-142 and may be obtained under Federal Stock Catalog Number 8415-823-7578.

2/ Overshoes suitable for the purpose intended are covered by Specification MIL-O-836 and may be obtained under the following stock numbers:

Size 5	8430-144-1672
Size 6	1673
Size 7	1674
Size 8	1675
Size 9	1676
Size 10	1677

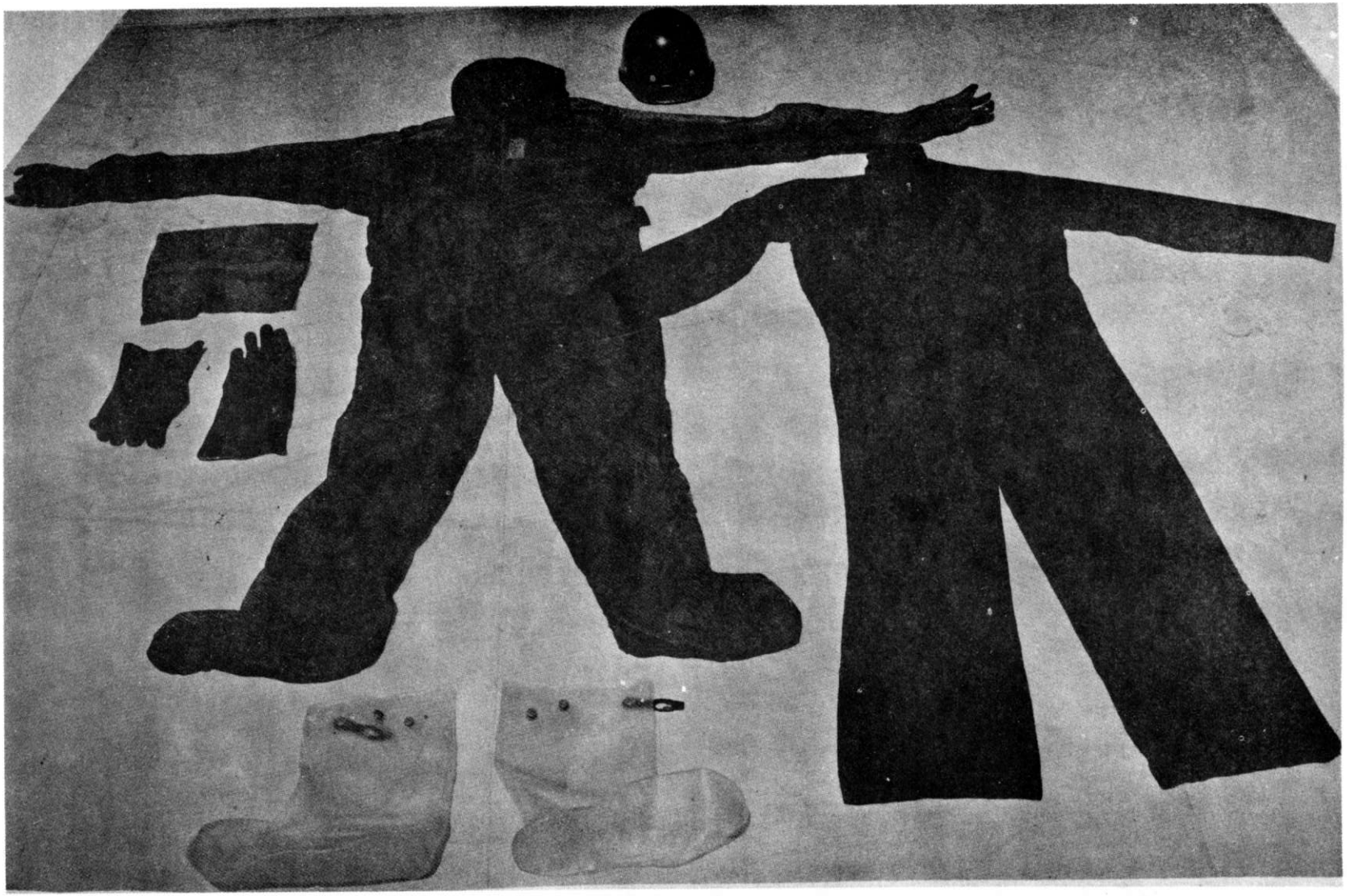

FIGURE 1-1. Microwave Radiation Protective Clothing: Radiation Protective Coverall; Arc-Preventive Overgarment; Hard Hat; Rubber Gloves; Plastic Boots; Repair Patch

Size 11	1678
Size 12	1679
Size 13	1680
Size 14	1681
Size 15	1682

3/ Gloves suitable for the purpose intended are covered by specification MIL-G-82253 and may be obtained under the following stock numbers:

Size	Medium	8415-916-2817
Size	Large	8415-916-2819

The clothing is designed for use over the frequency range 200 MHz to 10 GHz and in power densities up to a maximum of 200 milliwatts per square centimeter (mW/cm^2). It provides a minimum power attenuation of 20 dB in radiation fields within the stated frequency range. The protective coverall has been given a durable, water-repellent finish to make it resistant to most stains, soiling, salt spray, and other atmospheric contaminants which might alter its shielding effectiveness. In order to prevent possible arc-over (from one part of the coverall to another or from the coverall to a metallic object) in high density fields, plastic or rubber boots, plastic or rubber gloves and a suitable arc-preventive overgarment (cotton coverall) are provided and MUST be worn over the radiation protective coverall. Similar types of clothing can be used instead of the cotton coverall, depending on climatic and operating conditions (see paragraph 3-3). A hard hat is provided and should be worn under the hood to keep the fabric away from the face. A repair patch is provided to repair holes which may be torn in the coverall (see section 5).

1.2 DESCRIPTION OF RADIATION PROTECTIVE COVERALL

The radiation protective coverall (see figure 1-2) is fabricated from a silverized nylon mesh-type material (heavy marquisette, leno) having a maximum DC resistance of two ohms/square. The fabric is overlapped at all seams to provide maximum shielding. A brass zipper

FIGURE 1-2 Front View of Microwave Radiation Protective Coverall

is stitched on a special metalized tape runner to maintain electical continuity at the closures for the garment. Hook and pile nylon tape is used at the waist, ankles and wrists to adjust the fit of the coverall.

1.3 SUMMARY OF OPERATION

a. Remove the coverall from the plastic storage bag and examine it for any visual or mechanical defects (see paragraph 3.1).

b. Before donning the coverall, remove all metal and protruding objects from clothing.

c. Put on the coverall and hard hat and fasten all closures securely. The garment is donned feet first.

d. Put on the arc-preventive overgarment, plastic boots, and rubber gloves.

e. After use, recheck the garment for any defects and replace it in the plastic storage bag.

Section 2
THEORY OF OPERATION

2.1 INTRODUCTION

For some time the Navy has been concerned with the rapid increase in the level of radio-frequency (RF) radiated energy aboard ships and at shore installations. In the past, these radiation levels have been moderate and could be effectively controlled with precautionary procedures, such as cutout cams on the radars, identification of the areas by warning signs, and other control devices. These precautions served to prevent the illumination of occupied areas with power levels greater than the 10 mW/cm^2 exposure level allowable for humans. Levels above this value are considered hazardous.

However, new, extremely powerful radars with peak output powers in the megawatt region are now operational. Some of these radars produce RF power densities up to and exceeding 150 mW/cm^2. Under special circumstances, it is anticipated personnel might be required to perform duties in such an environment. This protective clothing has been developed to provide complete protection to personnel who perform these special duties.

2.2 HARMFUL EFFECTS OF RF RADIATION

Radiated RF energy impinging on an individual may be reflected or absorbed, or it may pass through the body. Studies indicate that the energy passing through or reflected by the body has little or no effect on the individual. On the other hand, the portion of the energy that is absorbed produces heat, either on the skin surface or more deeply within the tissue and vital organs. An excessive amount of heating can damage the tissue or organ involved.

The areas affected and the amount of energy absorbed in the body are largely a function of the frequency and power density of the

electromagnetic wave. Table 2-1 indicates the percentage of electromagnetic energy absorbed and the relative depth of penetration as a function of frequency.

Table 2-1. Absorbed Energy vs. Frequency of Radiation

Frequency	Absorbed Energy	Penetration Depth
3000 MHz	40-50%	Skin heating only
1000 MHz	40-50% (below 500 MHz)	Deep tissue heating
1000-3000 MHz	Ranges from 20% to 100%	Combination of deep tissue and skin heating

At frequencies above 3000 MHz, the effect of the absorbed energy is limited to heating the skin. In this case, long-term exposure may result in an erythema or reddening of the skin, but the fact that the skin heating is actually felt acts as a warning to the individual. Below 1000 MHz, the effect varies among individuals, but, generally, the radiated energy penetrates deeply into the body with little or no sense of discomfort or physical warning of biological damage. The frequency range between 1000 and 3000 MHz is generally considered to be the most hazardous because absorption of the energy in a person's body may be as high as 100%, in which case the skin, surface tissues, and internal organs can be injured.

The hazards of RF radiation have been under investigation for some time and most of its effects are well known. In general, the areas of the body with good blood circulation will dissipate the incoming energy quickly, and will exhibit little or no effects from the RF radiation. However, areas with poor blood circulation (such as the eyes and testicles) are most likely to be damaged. Investigations have shown that sustained or repeated eye exposure to a field of 100 mW/cm^2 can increase the potential for development of cataracts. Cataracts may not become apparent immediately after exposure to RF energy, but may develop after a period of years. In addition, temporary sterility may result from prolonged exposure to high RF fields.

In total body exposure, the most serious hazard is the rise in body temperature. However, this will remain well within safe limits if the continuous exposure rate does not exceed 10 mW/cm^2. This is the basis for the present acceptable tolerance limit of 10 mW/cm^2.

It is worthy of note that the above-mentioned tolerance limits correspond to average temperate zone climatic conditions. In specific cases, consideration must be given to other factors such as humidity, ambient air temperature, solar radiation, and the individual's physical activity. All are factors in the absorption and dissipation of heat by the body.

A more thorough discussion of the biological effects of RF radiation is given in NAVSHIPS 0900-005-8000, "Radio-Frequency Radiation Hazards."

2.3 SHIELDING EFFECTIVENESS

A coverall designed to shield an individual from RF radiation must incorporate a means to either reflect or absorb the energy incident on the garment. The absorption technique would require means to dissipate the energy absorbed, and would result in a coverall that would be too cumbersome to wear. The most feasible technique is to reflect the energy. The best reflection is obtained by using a material with a very low intrinsic impedance compared to the impedance of the impinging field. The greater the difference between these impedances, the larger the amount of RF energy reflected. It is not feasible to measure the intrinsic impedance of a meshed cloth directly; however, it is valid to assume that a material with a low DC resistance will also have a low intrinsic impedance. The silverized nylon mesh fabric used in the RF coverall has a DC resistance of 2.0 ohms or less per square. (In addition, its porosity affords good visibility, mobility and ventilation to the wearer.)

Measurements of shielding effectiveness of the radiation protective coverall require special techniques that are best used in the laboratory. Measurements have shown that the coverall has a minimum

shielding effectiveness of 20 dB at 10 GHz. This suggests that the coverall could be used in a power density of up to 1000 mW/cm^2. (A 20 dB reduction of this figure results in a field of 10 mW/cm^2 which is the accepted tolerance level.) However, limitations due to arcing (see section 2.4) have resulted in a recommended maximum level of 200 mW/cm^2 in which the garment can be used.

It must be emphasized that it is not enough just to provide a plane metallic shielding surface between the radiating source and the person to be protected. To provide complete protection, the coverall must completely and securely enclose the wearer's entire body from head to toe. Care must be taken to ensure proper and complete closure of all openings prior to entering an RF field. Any opening in the radiation protective coverall may serve to provide an entrance for RF radiation to the body.

2.4 PROTECTION AGAINST ARC-OVER

When the coverall is worn in a high-intensity RF field (100-200 mW/cm^2) without an overgarment, there is a tendency for arcing where adjacent areas of fabric come into close proximity such as in the armpit, neck and crotch areas. It is also possible to induce arcing by bringing a metal rod close to the coverall.

The occurance of arcing in the garment can be explained readily. Because the metallized nylon mesh fabric is not a perfect conductor, voltage gradients will be induced on the outside of the coverall by the RF field. When high-frequency currents produced by these voltage gradients reach areas of high inductance (such as the armpits), the air may offer a lower impedance path than the fabric and the current can produce a visible arc as it takes this ionized path through the air.

To eliminate this effect, an arc-preventive overgarment is supplied to wear over the radiation protective coverall. The overgarment tends to smooth out the fabric, thereby decreasing inductive reactance. In addition, it isolates adjacent areas from contact with each other and isolates the entire coverall (with exception of the head area) from

contact with metal objects such as stanchions and railings.

Since ventilation requirements make the use of an overgarment for the head area impractical, care must be taken to prevent arcing from the head area to nearby metal surfaces. Prolonged arcing can burn a hole in the coverall.

2.5 PROTECTION AGAINST SALT SPRAY DETERIORATION

If untreated silverized nylon mesh fabric is subjected to various degrees of salt spray exposure, the salt will destroy the silver content of the fabric and reduce or eliminate its shielding effectiveness. To prevent this, the radiation protective coverall has been treated with a durable, protective, and water-repellent finish.

Section 3
OPERATION

3.1 GENERAL

Severe damage can occur to the wearer if a defective suit is worn in a high-density RF field. The radiation protective coverall is shipped in a plastic bag and stored in a cardboard box and must be kept in this package except when it is in use or is being cleaned (see section 4). Prior to each use, the coverall should be removed from the storage bag and examined for open seams, holes, tears in the fabric, or a broken zipper. The garment must not be worn in an RF radiation area if any such defects are found (see section 5).

3.2 DRESSING INSTRUCTIONS

The radiation protective coverall can be worn over regular work clothing, hard hat, and shoes. The coverall should be donned with the assistance of another individual and be checked by him to insure proper closure. A hard hat should be worn under the hood to keep the fabric away from the face. Entry to the coverall is made by placing the feet in first, via the back-opening zipper, and pulling the garment up, over the shoulders and head. Be sure that the back zipper and the zipper closures located in each sleeve are tightly closed to prevent any RF leakage. The sleeve openings are provided for hand removal during standby periods. Figures 1-2 and 3-1 show the front and back views of a properly donned suit.

Next, the arc-preventive overgarment (cotton coverall) is put on, followed by the rubber or plastic boots and gloves. Depending on climatic and operating conditions, any of the following or similar types of clothing can be used in place of the cotton coveralls as arc-preventive overgarments:

Cold Weather use: Standard A-1 Extreme or Intermediate Cold Weather Jackets and Trousers.

Wet Weather Use: Standard Parka and Trousers, Wet Weather.

In addition, any standard Navy or commercial rubber or plastic-coated overshoes and gloves may be substituted for the boots and gloves supplied. Figure 3-2 shows an individual completely dressed (except for hard hat) preparatory to entering an RF radiation area.

Upon completion of the work in an RF radiation area, the coverall should be reexamined for defects and then returned to its storage bag after repairs have been made.

WARNING
RADIATION NAZARD

Severe damage can occur to the wearer in an RF field if the RF integrity of the garment is destroyed by an open zipper or by a fabric failure due to arcing or tearing. Use of the coverall is governed by the limitations previously stated about frequency (200 MHz - 10 GHz) and power density (maximum of 200 mW/cm^2). Care must be taken not to allow the head area to come in close proximity with metal objects (see section 2.4).

Although the metalized nylon fabric is durable, excessive abuse may result in a rip or tear in the fabric. If a fabric failure occurs in the radiation protective coverall or the arc-preventive overgarment while the wearer is in a high-intensity RF field, he should leave the area immediately and repair the damage (see section 5) before re-entry into the RF field.

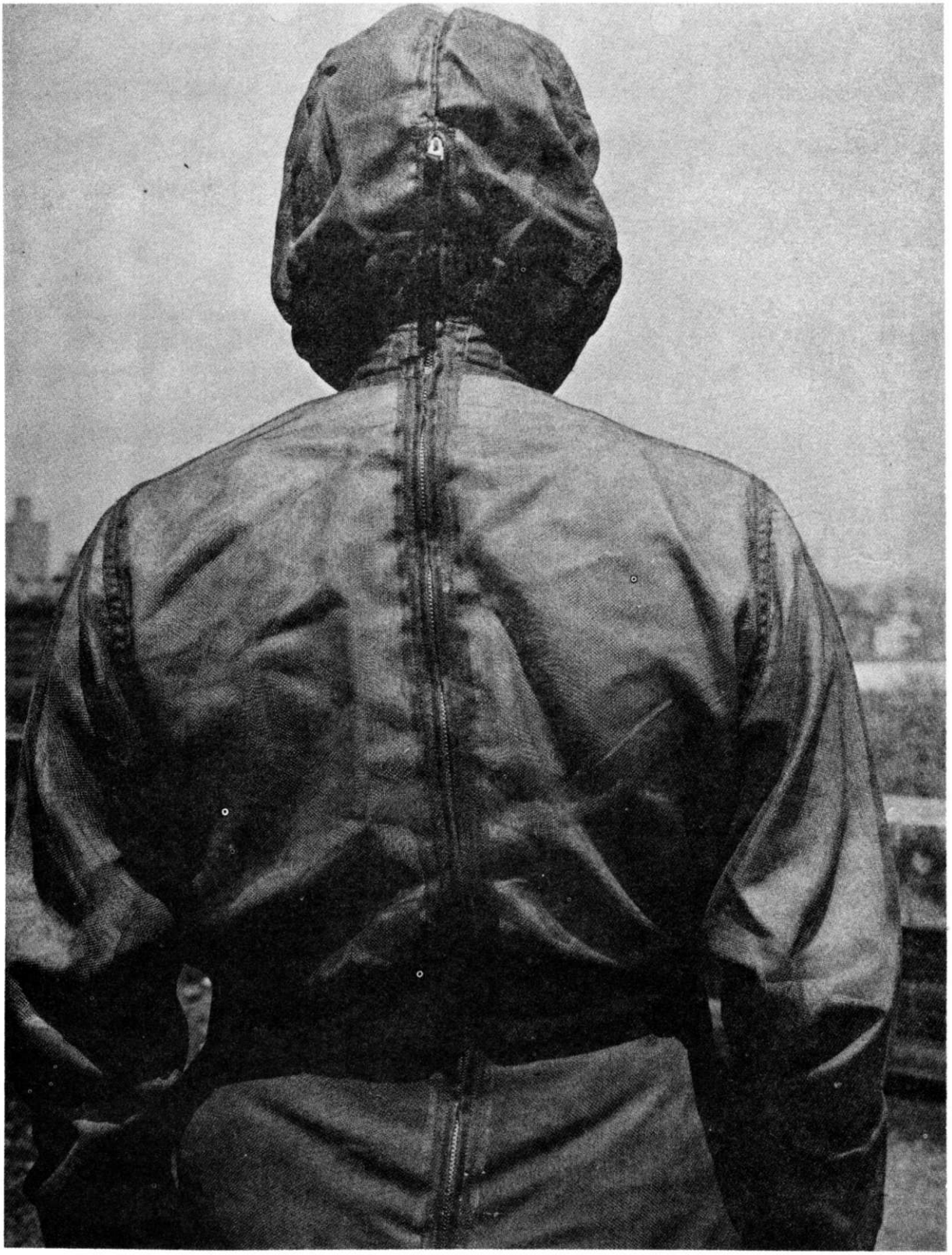

FIGURE 3-1. Rear View of Microwave Radiation Protective Coverall Showing Zipper Closure

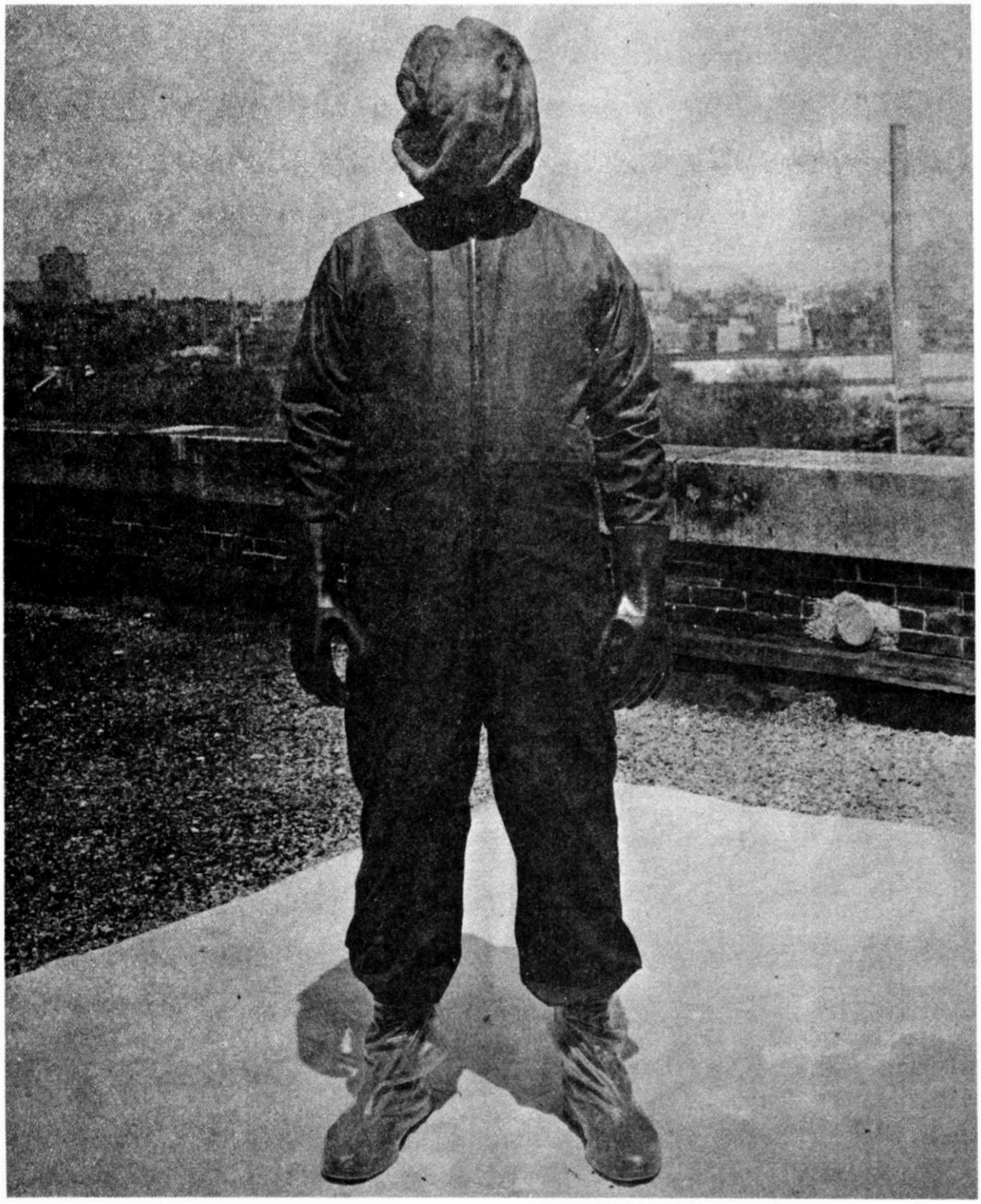

FIGURE 3-2. Full Attire of Protective Clothing for Entrance into RF Radiation Area

Section 4
PREVENTIVE MAINTENANCE

4.1 STORAGE IN PLASTIC BAG

The radiation protective coverall should be stored in its plastic bag when not in use so as to prolong the life of the coverall. Although the water-repellent coating on the silverized nylon mesh retards oxidation of the silver, oxidation, characterized by a purple color on the surface of the coverall, may occur slowly with continued use of the garment. Although the shielding effectiveness of the discolored cloth is not affected, this oxidation makes the garment more susceptible to outside influences, such as laundering and abrasion, which can then degrade its attenuation properties.

4.2 CARE AND CLEANING INSTRUCTIONS

The radiation protective coverall is not designed for rough use but neither is it delicate. Handling of the coverall in a manner comparable with articles of street clothing is permissible. Excessive laundering should be avoided since this will shorten the life of the water-repellent finish. If cleaning is required, the garment can be hand-laundered with a plain fresh-water rinse to remove any salt residue that might dry on the fabric.

4.3 CHECK OF SHIELDING EFFECTIVENESS

A thorough visual inspection of the radiation protective coverall must be made before each use to assure the RF integrity of the garment. The coverall must not be worn in a high-intensity RF field if there are holes in it or if the closures do not work properly. If any such defects are found and they cannot be eliminated by corrective maintenanace, the coverall should be discarded and replaced by a new one. The discoloration caused by oxidation of the silver coating is not cause for discarding the coverall, since silver oxide is equivalent to silver as a conductor.

Section 5
CORRECTIVE MAINTENANCE

5.1 DAMAGE PRECAUTIONS

Excessive wear or an accident may result in tearing the fabric of the radiation protective coverall. This can result in a serious loss of shielding effectiveness even though the hole is relatively small. At high frequencies, a tear or hole in the fabric will effectively simulate a large waveguide thereby permitting possible hazardous power levels of electromagnetic radiation to pass through and endanger the wearer.

5.2 REPAIR PATCH AND ITS USE

A 12- by 12-inch piece of metalized fabric is provided with the radiation protective coverall to serve as an emergency repair patch. A rip or hole in the garment is repaired by sewing a patch of this silverized nylon mesh on each side of the defect. As shown by Figure 5-1, the patch should be large enough to extend beyond the defect by a minimum of 1/2 inch on all sides, and to provide a 1/4-inch fold-under hem to prevent raveling. Care should be taken in sewing so that the seams lie flat with no puckering.

5.3 ZIPPER CLOSURES

Radiation protective coveralls having broken or otherwise damaged zippers must be discarded and replaced.

5.4 CARE OF ARC-PREVENTIVE OVERGARMENT

A rip or tear in the arc-preventive overgarment, though not as serious as one in the radiation protective coverall, should be repaired to prevent any possibility or arcing. The damage should be repaired by following standard Navy procedure for mending fabric shirts or trousers.

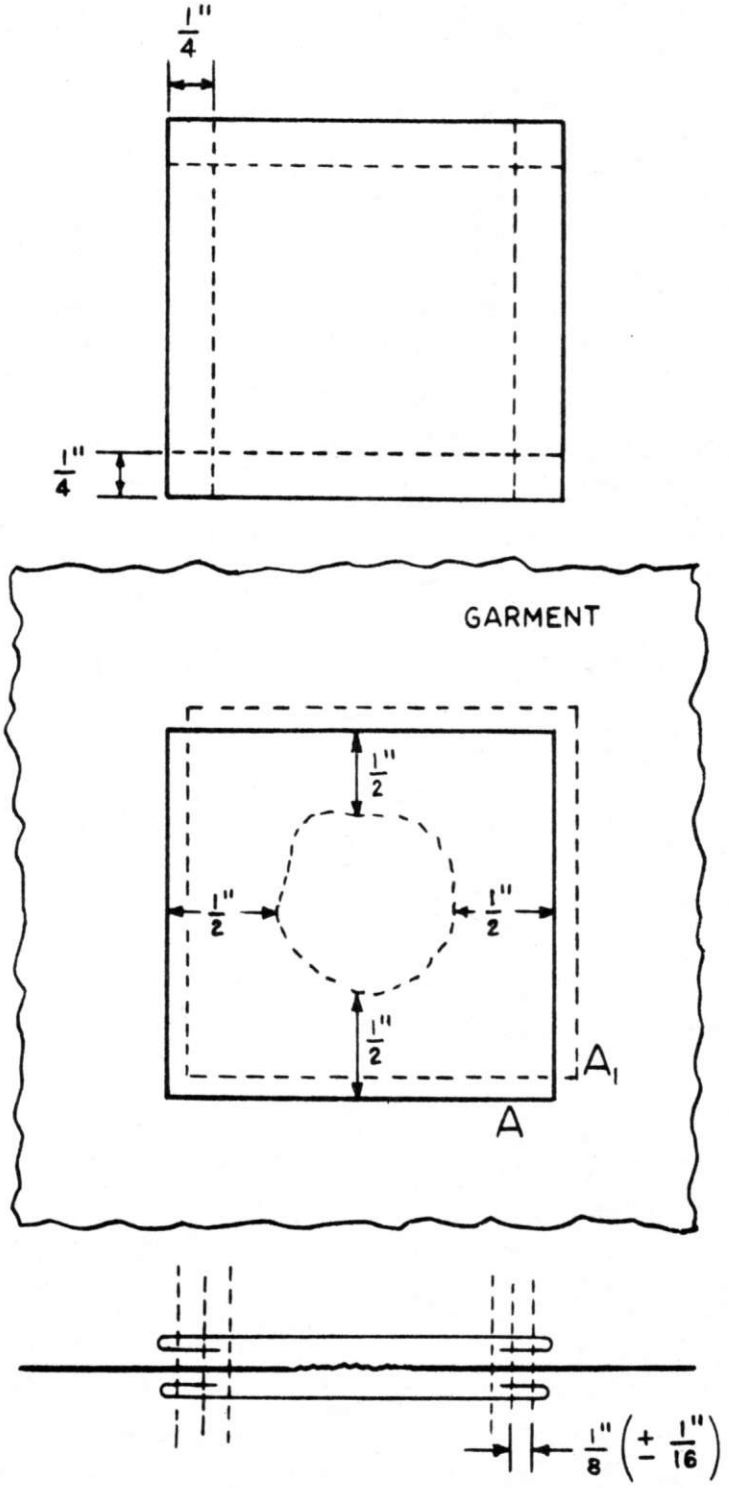

FIGURE 5-1. Illustration of Patching Method.

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