TECHNICAL REPORT

68-32-CM

SEALED INSULATED MILITARY BOOTS

by

L. H. L'Hollier and Alice Park

November 1967

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Clothing and Organic Materials Laboratory

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FOREWORD

The U.S. military nearly eliminated the problem of trenchfoot and frostbite of the feet when it developed the sealed insulated rubber combat boot during the Korean War. The boot provided the first successful protection against foot cold injuries -- a serious casualty producer among armies since the earliest winter campaigns.

The double vapor barrier principle of the boot was conceived under a U.S. Army Quartermaster Corps research program during World War II. This principle was later advanced and incorporated into a practical combat boot by the Marine Corps and the Army early in the Korean War.

This report reviews the historic need for and problems of protecting feet against cold injuries, the military's development of the boot, and recent improvements of the boot.

Grateful acknowledgement is made to Dr. Paul A. Siple, Scientific Advisor to the U.S. Army Research and Development Office, for his considerable contributions in information and technical guidance during the preparation of the report.

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ABSTRACT

Sealed insulated rubber boots protect U.S. military personnel against cold injuries to the feet in wet-and dry-cold climates. The boots are constructed on a double vapor barrier principle, with an air chamber and insulating material sealed between two impermeable barriers of rubber. The outer boot wall or barrier protects the insulation against environmental water and the inner barrier next to the foot protects the insulation against foot perspiration and water vapor. By keeping the insulation dry, the double barriers eliminate the evaporation of moisture from the foot and sockgear which is a major cause of cold injury. The conception of the principle of the sealed insulated boot during World War II, its design and fabrication for its initial use in the Korean War, and subsequent improvements are discussed.

SEALED INSULATED MILITARY BOOTS

1. Introduction

The sealed insulated boot has provided a defense for armies against foot cold injuries, the historic scourge of winter combat. In its initial use by American troops during the Korean conflict, the boot virtually eliminated casualties from frostbitten feet.

The real significance of the development of the insulated boot cannot be appreciated unless one is aware of the great need which it has met. Trenchfoot and frostbite have weakened armies since the earliest military campaigns: historians mention cold injury as a serious problem among Greek armies in Armenia late in the 4th century B. C. (1) Yet it was not until modern history when the first casualty figures were kept that the seriousness of cold injuries was acknowledged -- as a drain on military manpower and fighting effectiveness, and on medical resources and hospital facilities.

It has been recognized that foot cold injury can be as effective as enemy weapons in depleting frontline ranks and all armies have sought ways to prevent it. The multiple conditions which foster cold injury make prevention difficult, but the limitations of treatment also make it imperative. The U.S. military command has approached prevention in two ways: through instruction in anti-cold injury measures and foot care, and, through improvement of wet-cold footgear.

A review of the American military experience with cold injuries during World War II and of the problems encountered in footwear development will clarify the contribution of the sealed insulated boot.

2. Problem of Foot Cold Injuries

a. Cost and Causes

England became one of the first countries to keep detailed statistics of military cold injuries when British troops suffered heavy trenchfoot losses in World War I. American forces, which entered the war late and engaged in limited trench warfare, escaped the full impact of foot cold injuries. During World War II, however, the total number of American military casualties from foot cold injuries exceeded 90,500, and that numbered only personnel excused from duty, not those treated at outpatient facilities

Cold injuries were second only to battle wounds among American casualties in certain periods of fighting in the European Theater and Italy. During the campaign to take the Aleutian Island of Attu, Allied forces (mostly American) suffered more manpower losses from cold injury (1,200) than from battle wounds (1,148) [1].

The actual cost in terms of military effectiveness becomes apparent when one realizes an average of 83 days was lost from active duty per case. About 40 percent of the cases could not return to combat and about 20 percent were disqualified from further duty[2]. Since 90 percent of these casualties were riflemen, the strength of fighting units was affected more seriously than exact figures indicate. It has been estimated that cold injuries in World War II cost the U.S. forces the equivalent of 15 divisions of 15,000 men each[1]. The increased load on replacements and hospital facilities and medical costs must also be added.

Trenchfoot was the predominant type of cold injury among American troops, accounting for 64,590 cases; frostbite was next with 19,559 cases. Immersion foot and other cold effects accounted for the remaining 6,386[1]. Trenchfoot and immersion foot were more serious than frostbite in terms of over-all military cost since they were responsible for a greater proportion of temporary and permanent disabilities.

Trenchfoot develops under prolonged exposure to wet-cold conditions -- heavy rain or snow, mud and slush, and temperatures between 20°F. and 50°F. or more. The foot tissues suffer anoxia after 12 to 48 hours of reduced blood circulation caused by continuous chilling. The trenchfoot casualty usually feels no sharp pain warning him to stimulate his blood circulation or to warm his feet.

Frostbite involves actual freezing of the skin and subcutaneous tissues and is marked by sharp pain followed by numbness. The victim is often aware of the precise time at which he is frostbitten, and the pain may drive him to seek relief before the injury becomes too extensive. The military arbitrarily diagnosed cold injuries suffered at above freezing temperatures as trenchfoot and those at freezing or colder as frostbite.

The pathological process is similar in all cold injury. During World War II, the lag period between the beginning of exposure and the first clinical signs of damage averaged three days. After initial swelling and redness, the skin of the victim becomes mottled and bluish-gray. In severe cases blisters form, and ulceration and gangrene may develop. The victim's foot and toes may shed superficial layers of skin or require amputation. The severity of each case depends on the influence of various contributing factors.

The basic cause of tissue injury is cold. The extremities -- especially the feet -- are extremely vulnerable to cold since they rely on the blood circulatory system for their heat supply. When cold temperatures require more heat than the body is producing, the torso conserves its heat for the vital organs by reducing the blood flow to the extremities. Thus, even at moderately cold temperatures the feet will lose heat and become chilled if the body is not clothed warmly enough to maintain normal circulation to the feet.

Wetness exaggerates the effects of cold and is an important contributor to trenchfoot. Moisture reduces the insulative quality of socks and footgear and speeds the loss of body heat by the cooling action of evaporation. Wet feet can become chilled in relatively mild temperatures near 50°F. At freezing temperatures, the moisture condenses on the inside of the boot barrier, forming a layer of frost which further chills the feet upon melting.

While some of this moisture may enter the boots from the outside, much of it comes from foot perspiration. Without ventilation of the feet, perspiration inevitably builds up in sockgear during periods of exercise. This moisture continues to evaporate and cool the feet when the man is inactive -- long after the need to lose excess body heat by perspiration has passed. The feet also continually give off perspiration as water vapor, which condenses on the cooler boot material and dampens sockgear.

Physical inactivity -- often unavoidable in combat for tactical reasons -- facilitates cold injury by reducing the overall production of body heat and thus the amount of heat conducted to the feet. Other contributive factors to cold injury among soldiers during World War II were insufficient clothing, constriction caused by tight shoes or socks, fatigue, poor nutrition and individual susceptibility[1].

b. Attempts to Prevent Cold Injuries

(1) Training and Foot Hygiene

Identification of the causes of cold injury early in World War I made prevention and control measures possible. The British responded to their heavy trenchfoot losses in World War I with a vigilance against cold injuries that continued throughout World War II. The preventive measures the British developed and used so successfully demonstrated that much cold injury could be avoided.

British personnel at all levels were instructed in the importance of keeping the feet as warm, dry and clean as possible. Soldiers were told to remove their boots at least once daily to massage their feet and to change their socks; to carry an extra pair of dry, if not clean socks, and to remove their wet footwear at night before sleeping.

Troops were issued heavy wool socks and loose-fitting, non-constricting boots and overjackets. Experience had shown that trenchfoot generally occurred after 24 to 48 hours of relative immobility, so British commanders rotated soldiers at the front lines to give every man a chance to rest and care for his feet at least every two days.

Unfortunately, such preventive measures were not practiced widely among American troops during the early part of World War II. This was partly because of the different operational conditions faced by U.S. troops. The Americans fought over rough terrain and mountainous areas where it was difficult to dig deep foxholes which would permit a night's rest. Lack of replacements and intense combat often forced U.S. commanders to keep men in action for as long as 100 hours at a time without rest, dry clothing or adequate food.

Even when preventive measures were possible, however, American military personnel at all levels were unaware of the dangers of wet-cold conditions and the necessity for foot hygiene. Americans had not shared the bitter experience of the British with cold injury in World War I. By the time cold-injury prevention training reached the troops in all theaters, some of the worst trenchfoot epidemics had taken their toll.

The first trenchfoot disaster among American troops was suffered by units on Attu during May-June 1943. Later that year the Fifth U.S. Army fighting the first winter campaign in Italy experienced heavy losses to trenchfoot -- up to 20 percent of their casualties[3].

Alerted by these experiences, the U.S. Command in the Mediterranean acted to prevent a recurrence of this condition the next winter and, in October 1944, initiated the first program to instruct American soldiers in anti-cold injury measures. Clean, dry socks were supplied with rations to frontline troops and forward troops were rotated. Despite more severe weather and an increase in forces, the number of trenchfoot cases among the Fifth Army in the winter of 1944-45 fell to less than a third of the total the previous winter.

It took trenchfoot incidences of 11,000 cases in November 1944 to spur the European Theater Command into similar preventive action. Cold-injury training of troops was launched in January 1945, too late, however, to meet the combat conditions most conducive to trenchfoot and frostbite. In March, a very effective training program opened in the Pacific Theater

These training programs, with variation among theaters and units, generally supplemented oral instruction with radio messages, articles in military publications, and visual aids, including films, brochures, posters and cartoons at clothing exchange points

The experience of two different American battalions on Attu illustrates the value of such training. One battalion, which was ignorant of cold weather survival measures and foot care, sustained 30 battle casualties after five days of fighting, the remaining 320 men suffered so much from exposure that only 40 were able to walk. A second battalion, which was carefully instructed and supervised in foot care, experienced similar battle losses but evacuated only 8 men for cold injuries[1].

Yet knowledge of anti-cold injury measures was effective only if it was applied, and the American soldier often neglected to practice foot hygiene even when so instructed. The consistently lower incidence of cold injuries among British soldiers as compared with Americans in all theaters throughout the War was attributed partly to superior British discipline regarding footwear. The British unit commander who did not enforce foot hygiene among his troops was liable to court martial. Also, the British soldier seemed to assume individual responsibility for foot care

As trenchfoot losses plagued front-line troops, the American press singled out foot discipline as the predominant reason for fewer cold injuries among the British. The public believed trenchfoot was a result of negligence by the soldier.

Trenchfoot and frostbite victims resented such charges. Convalescing soldiers presented their side in one of many letters to Life Magazine after a wartime article on cold-injury:

"Have you ever sat in a foxhole, 5 x 5 x 2 ft, in 16 inches of liquid mud, a heavy artillery barrage going on with rain and shrapnel dropping every which way? In this position the Army asks us to take off our shoes and massage our feet."

(2) Footwear in World War II

The U.S. Army Quartermaster Corps realized proper foot care could help the soldier avoid foot cold injury only up to a point. Battle conditions and tactical considerations made it imperative that a soldier's footwear provide a maximum of protection with a minimum of care. Yet American military footwear was inherited from World War I and it was not adequate for the cold-wet conditions of winter trench warfare. The wartime urgency for wet-cold footwear mobilized Quartermaster Corps' attempts to improve existing footwear, which finally led to the development of the sealed insulated boot.

The American soldier entered the Second World War wearing the service shoe of World War I (Figure 1). Early in the War, a new all-leather combat boot with lacing over the foot and a buckled cuff at the top was issued to troops (Figure 2). This combat boot eliminated the leggings worn with the service shoe which discouraged proper foot care because they were difficult to remove.

The combat boot and service shoe aggravated foot cold injuries. Both were designed to fit the foot snugly when worn with a single pair of lightweight wool socks. The close fit did not allow for extra pairs of socks which the soldier often wore for warmth, or for the tendency of the leather to shrink when it became wet. Often the soldier's feet swelled when he removed his boots and he found it difficult to replace his already overly tight footwear.

Besides being too close fitting for comfort or warmth, the service shoes and combat boots leaked through the welt inseam and through the upper leather. Footgear and socks were soaked quickly by wet conditions and foot perspiration, and the leather dried very slowly. Soldiers complained that it was futile to change to dry socks when their feet became wet soon afterward.

Figure 1

Leather Service Shoe of Type Worn with Leggings During World War I and Carried Over into World War II.

Figure 2

All-leather Combat Boot Developed Early in World War II, Combining Laced Bottom and Buckled Cuff.

One of the first efforts to solve this problem was an attempt to make the upper leather water-resistant by applying a dubbin or grease. While dubbing kept the leather soft and flexible, it did not effectively prevent water entry. The grease lessened the permeability of the leather enough to increase foot perspiration, however, which made the feet colder. The dubbin also froze at extremely low temperatures, stiffening the boot and making it extremely uncomfortable to wear until the heat of the foot restored some of the flexibility. Accordingly, the practice of dubbing was discontinued later in the War(4). Attempts to apply waterproof finishes to the leather combat boots were also unsatisfactory.

Concurrent with efforts to make shoe leather water-resistant, the Army initiated research to waterproof the inseams of the service shoes with various adhesives, cements and plastics. The Army Quartermaster Corps tested 49 different shoe treatments submitted by five companies between March and June 1945. None were satisfactory(5).

Rubber overshoes were issued to supplement leather shoes and boots, but there were never enough to outfit all the soldiers who needed them. Often soldiers who received the overshoes discarded them when they were not ostensibly needed.

To provide a more water-resistant boot, the Army started to issue shoepacs, boots in which a leather upper was stitched to a rubber foot (Figure 3). The upper leather was heavily greased to make it water-resistant and special care was taken to waterproof the seam joining the two components.

The shoepac was the most satisfactory wet-cold footwear worn by U.S. troops during World War II. Shoepacs had been issued to U.S. personnel in Alaska as a standard item since the 1920's and to special forces during World War I. Its suitability for general cold-wet use was tested during the winter of 1943-44 by 100,000 troops stationed in the States and improvements were made(6). To provide more warmth, the new shoepac was built over a last which left sufficient room in the bottom for a removable felt insole, a heavy wool sock and a lighter sock worn directly over the foot. Extra socks and insoles were supplied so the soldier could change his sockgear when it became soaked with sweat or water.

While the shoepac was an improvement over the combat boot and service shoe in cold weather, it was not entirely satisfactory. Heavy sweat accumulation occurred in the sockgear because of the lack of moisture vapor permeability in the rubber foot and the very reduced permeability in the heavily greased upper leather. When water entered over the top of his shoepac or leaked through a seam or puncture, the soldier had to dry several pairs of socks or risk almost certain cold injury.

Efforts to improve the shoepac continued until 1951, when it was replaced by a vastly superior item -- the sealed insulated boot.

3. <u>The Development of the Insulated Boot</u>

a. <u>The Idea</u>

The earliest sealed insulated boots were issued to troops in Korea. For the first time soldiers fought in footgear that protected their feet from cold injuries in the wettest and coldest field conditions. The insulated boot was radically different from existing military or commercially available footgear, yet the key to its superior warmth was a well-known principle -- the insulative value of air. The successful incorporation of this principle into a practical boot was largely the result of the contributions of Drs. Paul A. Siple and H. C. Bazett, and Mr. Leslie H. L'Hollier.

When the U.S. entered World War II, little was known by medical authorities or physiologists about the principles of protecting man from the cold with clothing. Dr. Paul Siple, a geographer and climatologist who participated in several Antarctic expeditions led by Admiral Richard E. Byrd, was called upon in 1941 to advise the Army Quartermaster Corps on cold weather clothing and foot protection.

Dr. Siple recommended combining the techniques of the physiologist, physicist, textile expert and climatologist to improve cold weather clothing. During 1942-43, the Quartermaster Corp established the Climatic Research Laboratories at Lawrence, Mass., where the extremes of cold and heat could be produced for clothing research and testing. Dr. Bazett, a physiologist with the University of Pennsylvania, was an advisor in the new Quartermaster Corp program. Together, Drs. Siple and Bazett conceived the principle of a double vapor barrier boot -- the precursor of the insulated boot.

They knew the warmth or insulating value of material was negated when the air entrapped within it was displaced with water. Sockgear could become wet from environmental water, from foot sweat and from perspiration given off as water vapor.

Conventional footwear such as the shoepac or combat boot acted as a "closed-circuit refrigeration system" in cold weather, according to Dr. Siple. Water vapor from the foot condensed when it reached the cooler outer boot shell, losing heat carried from the body. The condensed vapor or liquid soaked back to the foot, where it was rewarmed to vapor with a further loss of body heat. Boots with only a single layer could not halt the evaporative cooling action of this condensed water vapor and foot sweat[7].

Figure 3

Modified Shoepac Issued During World War II, with Leather Upper Stitched to Foot of Rubber for Water-resistance.

Figure 4

Rubber Sealed Insulated Boot, Black, Cold-wet Standard, Incorporating Modifications Made Since1951 Insulated Boot.

Their idea was to keep the insulation dry by sandwiching it between two impermeable layers or "vapor barriers." An outer impermeable layer would keep out environmental water; an inner layer next to the foot would protect the insulation from foot moisture.

In March 1944, Siple and Bazett constructed some footgear utilizing the double-barrier principle(8). The footwear consisted of four layers: (1) A thin wool sock next to the skin for tactile comfort; (2) A thin rubber sock; (3) A thick wool insulating sock, and (4) An outer waterproof barrier — either a rubber shoepac or a second rubber sock beneath an ankle boot.

The two researchers tested the footwear assemblies on a group of Canadian soldiers at Torbay, Newfoundland during five days of marching in wet conditions at temperatures around 32°F. They found the accumulation of moisture in the boots was reduced as much as 80 percent over a period of 12 to 24 hours when both barriers were worn. Medical officers who examined the men's feet after prolonged marches and wear periods of 36 hours could determine no harmful effects from the rubber socks.

Doubts remained over possible health hazards, however. An impermeable barrier over the foot contradicted long-standing belief in the desirability of material which would allow moisture vapor to escape. U.S. Army and Navy personnel conducted an experiment at the Medical Research Institute at Bethesda, Maryland, to determine if wearing a rubber sock would increase the hazard of athlete's foot. No such effects were found(9).

The double-barrier boot appeared to contradict a second accepted principle of footwear by keeping the feet warmer than standard footwear despite foot perspiration. Troops had been warned "dry feet mean warmer feet" because of evaporative cooling, but the vapor barriers prevented evaporation and the feet stayed warm even though they were enclosed in a saturated atmosphere.

Siple proposed the four layers of footgear used in these early studies be integrated into the wall of a waterproof boot. Siple and Bazett received and transferred to the Army Quartermaster Corps a patent on an insulated boot designed with an inner layer of fleece, a layer of rubber, a layer of fleece and an outer shell of rubber -- all laminated together into a single boot wall. The Quartermaster Corps produced a sample boot of this type in 1946 but encountered manufacturing problems; as a result, the boot was not satisfactory.

b. Production

That same year Leslie H. L'Hollier, then development manager for Hood Rubber Co. (later a division of B. F. Goodrich & Co.), conceived the design which ultimately led to the military's first sealed insulated boot. L'Hollier carried the principle of insulation by air one step further than Siple. He devised a way to trap an air chamber within the boot wall, while also keeping the insulating material dry between two impermeable barriers.

L'Hollier began developing his boot in 1946 when the Army Air Corps asked Hood Rubber Co. to design a warm, waterproof boot for its pilots and aircraft crews. Aviator's boots then were lined with sheepskin. The men's feet perspired at ground temperatures around 38°F. and became frostbitten at high altitude temperatures of -10°F. and colder when their wet sockgear froze.

L'Hollier and his workers made up several types of boots with two layers of deep-pile wool fleece facing each other but not cemented together, so that an air space remained between the layers. The boot last was dipped in latex once to form the inner surface and again later to form the outside, sealing the fleece layers and air chamber between two seamless rubber barriers. Three variations of this boot were sent to the Air Force; no further contact was made.

In 1949, when the U.S. Navy requested the Hood Rubber Co. to make a boot for use on its submarine washdecks, L'Hollier showed them the experimental rubber boot designed earlier for the Air Force. The boot satisfied the Navy's particular need for a warm waterproof boot which could be wiped out and worn immediately if water entered over the boot top. Space limitations prevented submarines from carrying replacements for boots that became wet. The Navy obtained and issued a limited number of these boots to its submarine crews.

When a serious frostbite problem appeared among American troops during the first winter of the Korean conflict, the Navy asked L'Hollier to convert the washdeck insulated boot into a marching boot for the Marine Corps. The result was a rubber boot with a broad, rounded bottom and rigid sole. The boot was laced to provide a closer fit for marching, rather than pulled on as the washdeck boot had been.

The Navy tested the new boot and compared it with the shoepac, the standard cold-wet item[10]. Field trials indicated much less foot moisture accumulated in the insulated boot than in the shoepac and the boot was equal to the shoepac in marching comfort and durability.

The insulated boot not only provided superior warmth, but it did so with a single pair of cushion sole socks, eliminating the 3-layer sock and insole assembly worn with the shoepac. This advantage simplified footgear supplies and reduced the number of socks the soldier had to carry.

The Army Quartermaster Corps recognized the promise of the new boot and began working with the Marine Corps to improve the boot. In the Spring of 1951, the Army tested the boot at Ft Churchill, Canada, at Mt. Washington, N. H., and at Big Delta, Alaska. The tests confirmed the Navy's earlier findings.

The Army was still concerned about the effects of prolonged foot perspiration in the impermeable barrier boot. However, studies during that period which were sponsored by the Surgeon General's Office and the Quartermaster Corps indicated that the impermeable barriers were physiologically safe[11]. The impermeable barrier near the foot substantially reduced rather than increased the accumulation of perspiration. Once the cushion-sole sock was saturated, additional foot moisture was reabsorbed into the foot tissues and a new equilibrium was maintained.

In contrast, the multiple layers of shoepac socks absorbed more total moisture and each became wringing wet. The insulated boot also was safer than the shoepac when water entered over the top or through a puncture. The cold water was held next to the foot by the inner barrier where it was warmed quickly by body heat.

With plans to continue improvement of the boot, the Army adopted the L'Hollier sealed insulated boot in June 1951 to replace the shoepac for cold-wet conditions[13]. The Navy had already ordered 40,000 pairs of the boot for Marines in Korea. The first shipment of insulated boots arrived in Korea in December 1951 and 6000 pairs were issued to each forward division. The same troops later received an additional 1000 pairs. Quartermaster Corps Wet-Cold Training Teams distributed the boots and instructed personnel on the fitting, use and maintenance of the new boot among infantry companies.

The number of foot injuries from cold dropped dramatically from the proportions of the first Korean winter, 1950-51. Other factors such as less severe winter weather, adequate winter clothing and more thorough anti-cold-injury training contributed to the decline in frostbite. But an Army Medical Research Laboratory team investigating cold injury in Korea that second winter reported the new boot was far superior to the shoepac for cold-wet conditions and played a large part in the overall reduction of cold injuries[14].

Complaints of discomfort, tenderness and maceration of the skin from some soldiers wearing the boot on long marches stimulated physiological studies on the boot after the war. Investigators reported that with adequate foot hygiene and occasional removal of the boot, at least once during 14 hours of wear, the insulated boot was as comfortable and as safe as the leather combat boot[15].

4. <u>Improvements in the Insulated Boot</u>

The present insulated boot, made for all U.S. military services on a basic military last, is the result of modifications made to the original 1951 boot (Figures 4, 5a, 5b).

One change made was to correct the stiffness of the boot top, which chafed the soldier's leg during marching. This was done by eliminating the upper two inches of the nylon tricot lining which reinforced the outer boot shell.

A second source of discomfort in the insulated boot worn during the Korean War was the gusset design at the throat: a pleat folded at each side where the tongue joined the boot upper and caused leg chafing. After various attempts to improve the gusset[16,17], the Quartermaster Corps switched in 1959 to the new "batwing last", so named because of its lopsided bulge to one side of the boot top. The new last eliminated the irritating gusset by forming a one-piece molded upper without pleats or seams (Figure 5a). The seamless throat also eliminated former leakage through the gusset pleats.

Complaints that the boot was difficult to don and doff, especially over wet socks, were partly met by the wider throat of the new batwing last. In addition, the rubber inner lining with rayon chafing strips was replaced with a knit nylon which did not stick to damp sock gear (Figure 5b).

As the boot's construction was improved and simplified, its weight was decreased at least 6 ounces to under 3 pounds per boot. This weight reduction, plus an improvement in the sole's traction and a switch to a flattened transverse bottom, increased the marching ease of the boot.

Manually operated air release valves were introduced in the 1959 model (Figure 5c). With the valves, airborne troops and paratroopers could equalize the pressure in their boot air chamber with the environmental pressure at high altitudes and prevent the boot wall from expanding and pinching the foot (Figure 5d).

An extensive program was conducted during the 1950's to find a substitute for the fleece insulation, since the thermal insulation value of the fleece could be destroyed if the boots tended to leak through seal failures or punctures. Prototypes were constructed using various water-resistant, unicellular plastic materials for insulation, but none were satisfactory. While the experimental boots kept the feet warm when leakage occurred, test subjects still preferred the fleece-insulated boot. The standard boot was lighter, more flexible and comfortable for marching and much warmer when dry than boots with plastic type insulation[18].

Better materials and design in the newer insulated boots have reduced the possibilities of seal failures and punctures. If the boots become damaged, leakage can be prevented by patching the holes. Troops in Korea improvised with cold tire patches, air mattress patching materials and adhesive tape to stop leakage in their insulated boots. Such patching attempts were successful 95 percent of the time. More recently, kits of patching materials and instructions for repair have been developed to make repairs in the field even easier[19].

Today, three variations of the sealed insulated boot are used by the American military forces. The standard black boot for cold-wet conditions is issued during the winter to troops in the northern half of the U.S., Canada and parts of western and northern Europe and northern Asia. A variation of this boot is issued to the Navy for shipboard use. It is essentially the same as the marching boot but has a flexible sole, less rugged reinforcement, and is about 5 ounces lighter.

A third type is the white insulated boot formally adopted in 1959 for military personnel in cold-dry areas, mainly the Arctic and Antarctic, northern Alaska and Greenland where extremely cold temperatures are expected. This boot has an extra interlining of insulation and it is white for camouflage purposes. In a size 9, the white boot weighs about 50 ounces per boot compared with the black boot's 40-43 ounces.

COMPARISON OF MODIFIED AND ORIGINAL (1951) INSULATED BOOTS

Figure 5a

One-piece Molded Throat of Modified Boot, left, Built Over Batwing Last Eliminates Gusset Pleats in Original Boot, right, which Chafed Legs.

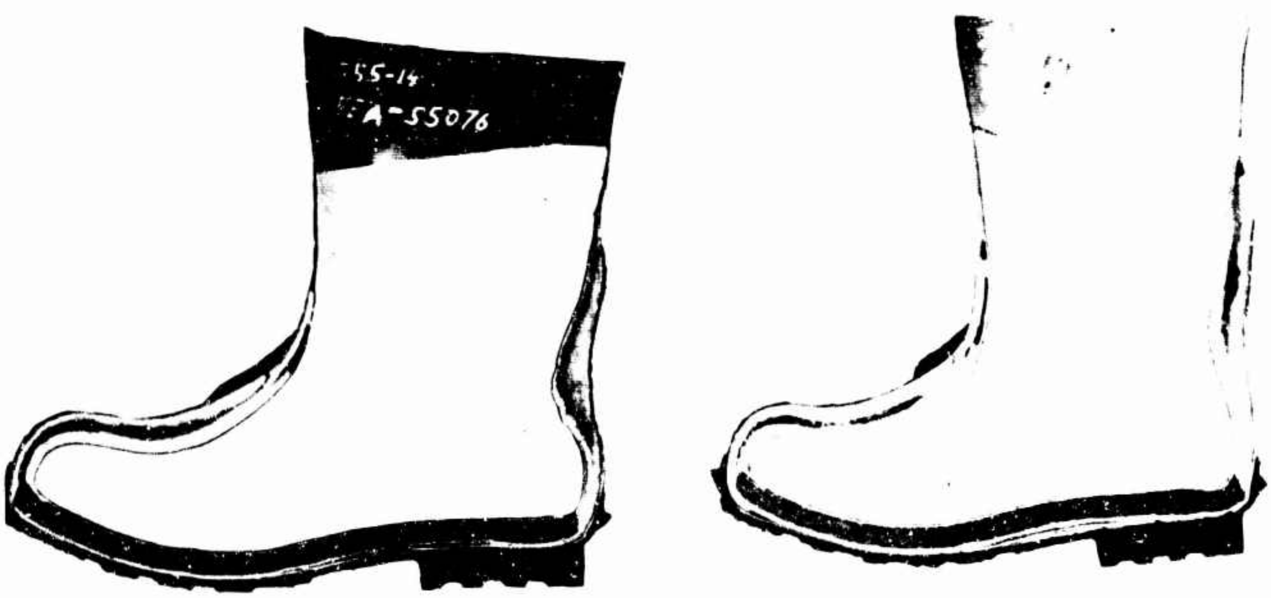


Figure 5b

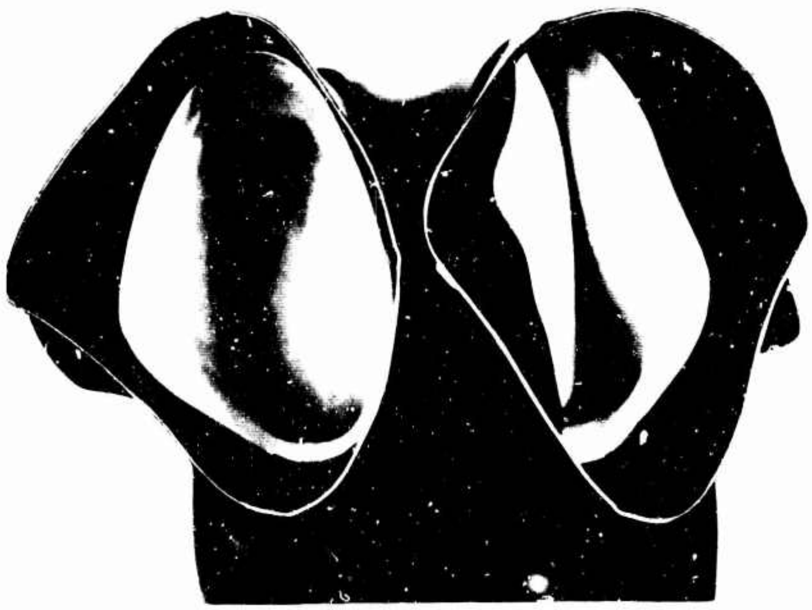
Interior: Note Double Impermeable Rubber Barriers of Boots, and Two Fleece Insulation Layers Enclosing an Air Chamber. Full Nylon Filament Lining in Modified Boot, left, Replaced Rayon Chafing Strip Lining of Original Boot, right, for Easier Donning and Doffing.

Figure 5c

Exterior: Note Air-release Valve and Operating Instructions and Fox Strip Added to Modified Boot, left. Round Bottom of Original Boot, right, Was Flattened for Better Traction.

Figure 5d

Pinching Effect Observed in Boot, right, Occurs under Lower Pressure during Airborne Conditions Unless Boot's Air Chamber Pressure is Relieved by Air-Release Valve.



The white boot was developed to satisfy early Army requests for a single waterproof item to replace the mukluk, felt boot and shoepac - all worn by personnel in Alaska since the 1940's. The black insulated boot was tested in Alaska in 1953-54 for cold-dry use[20,21]. It proved superior in water resistance and durability to the mukluk, felt boot and shoepac and it was warmer than the shoepac. The Quartermaster Corps added extra insulation with the white boot to achieve a thermal protection range of -20°F. to -65°F. A member of an Antarctic expedition reported he walked in the boot for more than two hours at -107°F. without suffering frostbite[22].

The Army's efforts to perfect the insulated boot continue. A long-range program is underway to lighten the black boot to 15 ounces a boot by utilizing new materials. Preliminary studies with prototypes indicate such a boot is possible but problems of durability, wearing comfort, and production must be resolved[23]. Attention is also being given to the provision of better foot support.

Various methods of ventilating the black boot have been investigated, to remove moisture and to relieve the excessive warmth of the boot at temperatures above 40°F[24]. A decrease in the insulation of the black boot for more comfort at milder temperatures is being considered now that the white boot covers the extreme cold range.

There are limitations to improvement, of course. The insulated boot cannot be expected to eliminate the need for foot hygiene. Foot problems such as erythema, blistering and maceration will occur in any footwear if it is worn for prolonged periods over dirty, perspiration-soaked socks. When a soldier cannot care for his feet properly because of combat conditions, he may suffer discomfort and even loss of skin. Fortunately, the insulated boot can prevent frostbite and trenchfoot. The wearer will not lose several toes or risk amputation. With proper use of the insulated boot, the painful and costly toll of foot cold injuries among combat troops can be practically eliminated. Simultaneously, the combat effectiveness of troops in cold weather is increased by the assurance that their feet are protected by the insulated boots.

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13. ABSTRACT

Sealed insulated rubber boots protect U.S. military personnel against cold injuries to the feet in wet-and dry-cold climates. The boots are constructed on a double vapor barrier principle, with an air chamber and insulating material sealed between two impermeable barriers of rubber. The outer boot wall or barrier protects the insulation against environmental water and the inner barrier next to the foot protects the insulation against foot perspiration and water vapor. By keeping the insulation dry, the double barriers eliminate the evaporation of moisture from the foot and sockgear which is a major cause of cold injury. The conception of the principle of the sealed insulated boot during World War II, its design and fabrication for its initial use in the Korean War, and subsequent improvements are discussed.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Design	8					
Fabrication	8					
Development	8					
Evaluation	8					
Boots	8,9		9		10	
Rubber	9		10			
Sealed	0					
Insulated	0				0	
Impermeable	0					
Protection	4		8			
Foot	4		9			
Protective Clothing	4					
Armed Forces equipment	4					
Insulation			8			
Vapor barrier			10			
Fleeces			10			
Linings			10			
Prevention					8	
Cold injury					9	
Frostbite					9	