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ARMORED MEDICAL RESEARCH LABORATORY
FORT KNOX, KENTUCKY

AMRL Project No. T13
SGO Project No. 611
SPMEA 727.3

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1. PROJECT AMRL NO. T13, SGO No. 611 - Survey of Foot Measurements and the Proper Fit of Army Shoes. Fourth Partial Report - Analysis of Characteristics of Footgear for Army Field Use.

a. Authority: First Indorsement SPMDO 421.3 - ASF-SGO, Washington, D. C., dated 24 September 1945.

b. Purpose: To present the considerations believed fundamental to Army field boots, and to apply these to practical design.

2. DISCUSSION: Studies which have been conducted at this Laboratory and elsewhere have revealed the need for reconsideration of boot design for the Army. It appears best to approach this problem unprejudiced by existing models. The implication is not that present Army boots are completely unsatisfactory, but that the desired results probably can be achieved best by starting anew from basic principles.

3. CONCLUSIONS:

a. The principles which are fundamental to the design of Army field boots are presented and discussed.

b. An experimental boot design believed to possess the most suitable features for Army field use under a wide variety of terrain and climatic conditions is proposed. It is illustrated in Figure 1. The proposed design is probably not appropriate for garrison use.

4. RECOMMENDATIONS:

a. That field studies using the suggested experimental model be conducted to determine:

(1) Its general utility for combat use, and the most suitable fabric and construction characteristics.

(2) The most satisfactory size intervals.

(3) The extent of the need for "support" for the normal Soldier's foot.



8

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2 Incls:
#1 - Appendix I
#2 - Figure 1

APPENDIX I

INTRODUCTION

1. Present Army footgear possesses many imperfections. The deficiencies fall generally into two categories: those of size and shape, and those of materials and construction. These are not independent of each other however. Studies of footgear and of foot casualties among marching troops emphasize the principle that every phase of shoe design is dependent upon, and in turn influences every other phase, and that a change in one element should take into account its effects on all other elements. From consideration of present footgear deficiencies, and of research investigations concerning physiological and physical factors involved, it is possible to outline what appear to be the optimal characteristics of an experimental boot and its sockgear, while recognizing that combat footgear appropriate to a variety of climatic conditions must involve a number of compromises, and keeping in mind that, under no circumstances, should the boot constitute an impediment to activity or a source of injury.

GENERAL PRINCIPLES

2. To the extent that present knowledge of physiologic and utilitarian requirements permit, the following may be stated to be the general characteristics of or specifications for an all purpose army combat boot. Such a boot should:

a. Provide thermal protection:
(1) High and low temperatures.
(2) Wet and dry conditions.

b. Provide physical protection:
(1) Ground and brush hazards.
(2) Insect and other animal bites.

c. Provide maximal flotation and traction.

d. Not prove an impediment to activity:
(1) Freedom of motion at the ankle joint, for the operation of vehicular pedals.
(2) Minimum weight.
(3) Put on and removed easily under adverse conditions of darkness, wet, and cold.
(4) Minimum interference with intrinsic foot circulation and muscle activity.

e. Not prove a source of injury:
(1) Shape and size.
(2) Seam and rivet location, nails, counter stiffness, creasing of upper leather.

INCORPORATION OF THESE PRINCIPLES IN THE DESIGN OF FIELD BOOTS

3. It is believed possible to combine the above considerations into the design of a field boot of high general utility. For simplicity of presentation, each item is considered as it relates to the appropriate portion of the completed boot.

a. Upper Material - Leather, rubber, and fabric are the three materials available:

(1) Leather, has a relatively high thermal conductivity (c = .00042), is easily wetted, is permeable to water when flexed, leaks at seams, adsorbs and retains a large amount of water (1,2), is slow to dry, and when dried stiffens unless adequately oiled. The thickness of the leather in Army shoes adds weight and favors creasing which may be productive of abrasion of the skin.

(2) Rubber, although impervious to water if unseamed, also possesses relatively high thermal conductivity (c = .00045). Because of its impermeability, the interior of a rubber boot remains wet when there is leakage at the top and when sweat secretion is abundant. Leakage at the boot top is inevitable during marching in heavy mud, during wading, and when men are supine in wet slit trenches.

(3) Fabric, on the other hand, may be made light in weight, easily flexed, at least partially resistant to water penetration, permeable to sweat vapor, retentive of a minimum of adsorbed moisture, and rapidly dried. At the same time it can be protective against snagging on brush, and against insect and animal bites. Protection against cold, however, derives only from its wind impermeability and from the thickness of sock gear contained, as is the case with Mukluks. Boots with fabric uppers have the advantage of being readily folded for inclusion of a reserve pair in the soldier's pack, and for easy transport to combat lines for front line issue.

b. Outer Sole - Maximum traction, flotation, and flexibility, low heat conductivity to and from the ground, and minimum weight are the principal requirements. These appear to be best met by the use of a rubber cleated sole as described in the Quartermaster report on Traction (3). Rubber cleats reduce the area of contact with the ground and thereby diminish heat transfer, effect maximum gripping on most surfaces with no loss of flotation on muddy ground, and permit maximum thickness with minimum weight. The sole to which the cleats are attached is easily flexed since only the backing is required to bend. This may be of advantage to the extent that foot fatigue may develop from the muscular effort required to bend thick and relatively inflexible sole material. In the interest of reducing heat transfer, as well as eliminating sources of foot injury, nails are best omitted.

c. Removable Inner Sole - The material of choice would be one readily dried, not easily wet, and of the lowest possible thermal conductivity. In connection with its use, provision should be made to provide an air space between the outer and inner sole.

d. Construction of the Upper.- Seams and rivets are an invariable source of irritation. They should, therefore, be few in number and placed in such locations as not to be sources of irritation, and preferably omitted over the dorsum of the foot. Side wall construction is thought to possess advantages in this respect and, in addition, to afford sufficient broadth and height to accommodate the lateral and medial foot borders. The need for stiffening of the counter is not apparent.

e. Height of Boot, Ease of Putting On and Removing, and Methods of Closure - Boots may be 10" or 11" in height to reach to just below the calf fullness, or 16" or 17" in height to extend over it. The latter is more cumbersome but affords greater protection against water overflow. In either case, a bellows type front is needed for ease of putting on and removing. This would appear to be best closed with appropriately placed and designed straps rather than with laces, since laces are difficult to handle when wet or cold, are slow of management at all times, and especially in the dark, and are subject to snagging on brush. The fastening, of whatever type, serves only one purpose: to retain the boot snugly against the heel. When this is done, abrasion of the heel occurs less frequently and the foot and shoe operate as a unit in walking, even when the boot is "oversize" for the forepart of the foot. It is suggested that a single, broad, flexible strap across the instep, another at the boot top, and possibly a third above the ankle are sufficient to keep the boot on the foot securely. The instep strap should not interfere with ankle flexion - essential in the operation of vehicular pedals.

f. Size and Shape - A shoe fits, according to present standards, when (a) it is not so tight in the toe or metatarsal region as to be uncomfortable, (b) not so loose in the vamp as to produce abrasion from creasing of the upper leather, and (c) not so loose from the heel to the instep as to allow the foot to move independently of the shoe in walking. Obviously these are only gross qualitative criteria. The determination of the proper dimensions of boot sizes and of the most satisfactory intervals between sizes, therefore, requires additional study. The analysis by the Laboratory of the dimensions of soldiers' feet (4) reveals that there is no consistently close relationship between any one foot measurement and any other. Thus, for example, it is not possible to predict the heel width with accuracy from a known metatarsal width, nor may ball length be predicted from total foot length. On the contrary, it appears that the interrelationship of the various foot dimensions of one individual tend to be unique to that individual. Accordingly, it must be concluded that if semi-rigid upper materials are used for shoe construction, and close fitting is practiced, then the pressures which Yaglou (5) observed between the combat boot and the foot are inevitable. It remains to be determined whether such pressures are injurious or can contribute to injury in cold weather. The Laboratory studies on foot dimensions suggest that there will always exist a large number of individuals imperfectly accommodated by any single standard semi-rigid boot pattern.

This affords an additional and very cogent reason for the consideration of fabric for the upper construction of boots, inasmuch as improperly fitted boots will be least likely to produce injury if they are constructed of yielding material. Studies at the Laboratory (6) have indicated that oversize boots are associated with fewer casualties among marching troops than are undersize boots. If the point of view be taken that one of the prime functions of a boot is as a container for socks, then a fabric boot loosely fitted and held to the foot by means of straps, is likely to accommodate the largest number of men satisfactorily. Relatively few sizes would be required for such a plan.

g. Sockgear - High specific surface in socks is of advantage. This is true not only because the insulation value is thereby augmented, but also because such socks tend to adhere to the inner boot surface, and diminish the sensation of looseness in oversize boot fitting. Perhaps boots should be fitted to enclose socks of maximal thickness in winter and separately fitted for summer use. Socks and not boots are relied upon for ultimate thermal protection. It is suggested, in this connection, that no more than one pair of socks should be worn at a time, since otherwise wrinkling of the inner sock cannot be avoided. The design of socks of graded thickness for use at lower temperatures seems appropriate.

## ADDENDUM

### HEEL, SHANK STIFFENING, AND INSTEP SUPPORT

4. The dynamics of walking are imperfectly understood. In particular, orthopedic agreement is lacking concerning the relationship between the derangement of foot mechanics and the incidence of callus, pronation, and arch, leg, and back pain. There is a lack of uniformity of opinion regarding the need for prophylactic foot "support", the method of its accomplishment, and the techniques of therapeutic management of clinically manifest foot disabilities. Observations at the Laboratory (6) suggest that mechanical aids to walking are probably unnecessary for the normal soldier's foot. The assertion that the feet of normal young men do need the assistance of an elevated heel, and do need "support" implies that the foot is inherently an inadequate mechanism. This thesis appears untenable and does not seem to be borne out by the studies of Morton (8), and Wood Jones (9).

5. Present army shoes appear to require additional foot muscle action for their flexion over and above that required for propulsion of the body. It is possible that this may contribute to the incidence of foot, leg, and back pain. The elimination of the heel (Fig. 1) and of the shank stiffening in a shoe might materially reduce the weight of shoes, increase their flexibility, and materially reduce the muscular strain associated with walking. The acceptability of such modifications can be determined by experiment by comparing the incidence of anatomical and functional complaints among men (1) marching barefoot, (2) marching in shoes with cleated soles and without heels, and (3) marching in shoes of conventional manufacture. This should reveal whether shoes are aids to walking or are in themselves productive of injury. Such an experiment would best be conducted on a surface not injurious to the unshod foot, e.g., a hard packed sand beach.

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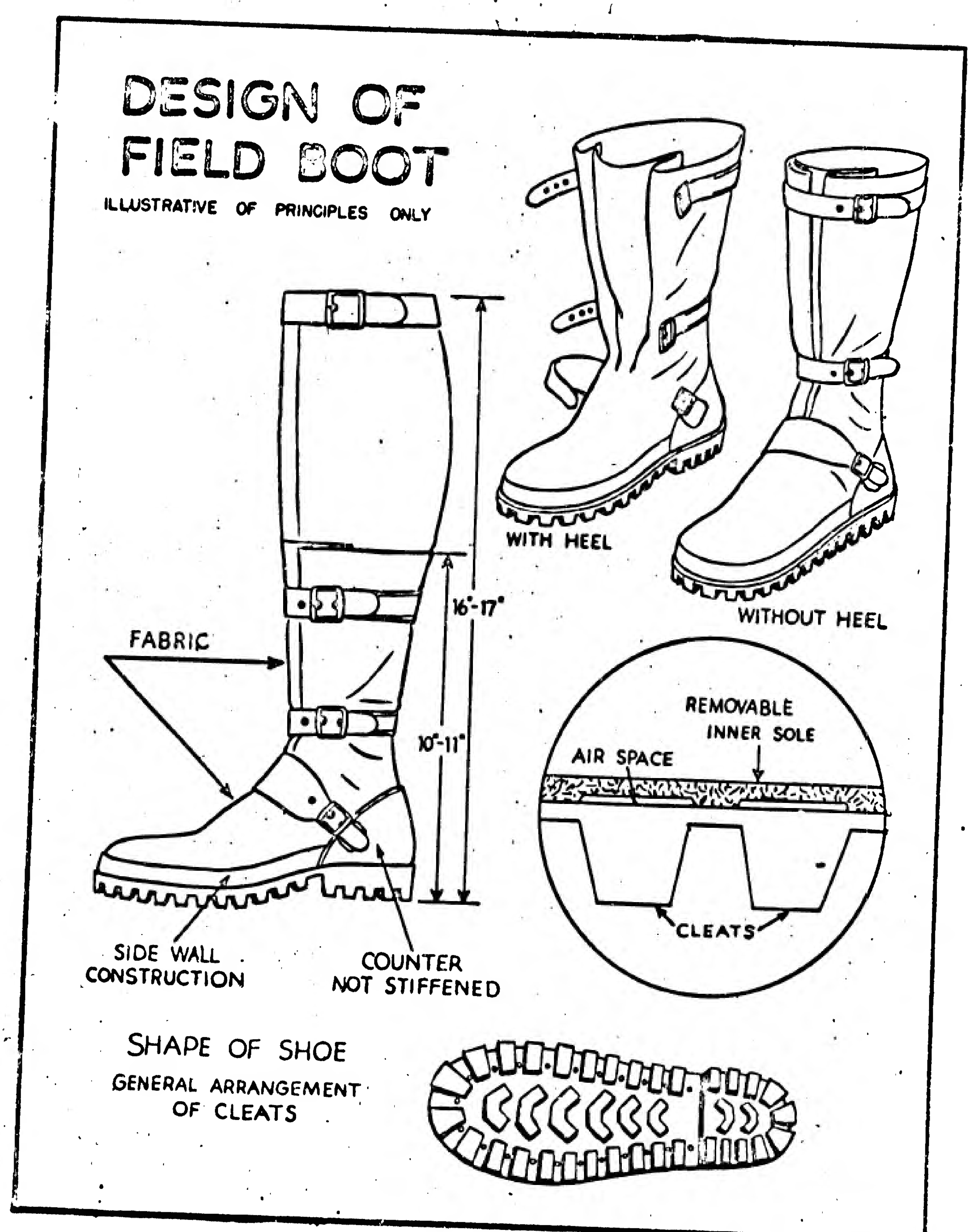
DESIGN OF FIELD BOOT
ILLUSTRATIVE OF PRINCIPLES ONLY
WITH HEEL
WITHOUT HEEL
16"-17"
10"-11"
FABRIC
REMOVABLE INNER SOLE
AIR SPACE
CLEATS
SIDE WALL CONSTRUCTION
COUNTER NOT STIFFENED
SHAPE OF SHOE
GENERAL ARRANGEMENT OF CLEATS