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TECHNICAL REPORT

TR 75-93-CEMEL

COMBAT BOOT WITH INTERCHANGEABLE OUTSOLE AND HEEL

January 1975

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UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Clothing, Equipment and Materials Engineering Laboratory

CEMEL - 157

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WARFARE	PROCESSING	

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This program addresses the problem of designing footwear with an interface for use with interchangeable molded outsoles.
A series of preliminary concepts was provided for selection by the US Army Natick Research and Development Command. The candidate concepts were refined and preliminary models constructed for final selection of a single candidate. Final prototypes were then manufactured in a limited production for delivery to the Army.

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20. Abstract (Cont'd)

A contract modification provided additional outsole models to illustrate multi-purpose function.

A total of 73 pairs of boots and 78 pairs of outsoles were delivered.

FOREWORD

The molded outsole process being employed in the manufacture of combat footwear permits the design of deeply figured outsoles for a more optional coupling, through compliance, to the roadway environment. The process, however, provides a permanent bond to upper materials which is difficult to repair in the event of premature failure of the outsole material through wear or cracking.

Further, molded outsoles have a potential application in special purpose and multi-function footwear which can aid the foot soldier to overcome terrain that is difficult to traverse.

This program considers a separable boot/outsole combination which will enable the replacement of the outsole for reasons of wear or special purpose function.

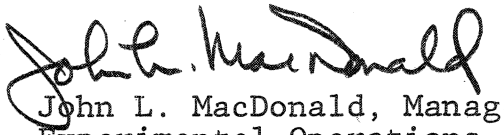
The program was conducted under the direction of Mr. D. Swain, Footwear Technologist, U.S. Army Natick Development Center, who was the project Officer. The work was accomplished by IIT Research Institute, Chicago, Illinois, with design and manufacturing subcontract assistance by Ro-Search, Inc., of Waynesville, North Carolina. The effort was conducted over a period of 17 months under Contract No. DAAG17-73-C-0251, Requisition No. 65-00034-R153 and modifications.

Of special note is the assistance contributed by Mr. D. B. Shepardson of the 3M Company in providing interface materials, adhesive samples, and technical data.

The Project Officer and program staff also wish to acknowledge the budgetary and technical planning consideration which resulted in this program. These judgements were provided by both Mr. J.V.E. Hansen, Director, Clothing, Equipment, and Materials Engineering Laboratory; and Mr. T. L. Bailey, Chief, Clothing and Equipment Systems Division.

Respectfully submitted,

IIT RESEARCH INSTITUTE



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1. INTRODUCTION

The adage which relates to the Army's traveling by foot may not be as literally true now as it was in the past, but in terms of tactical effectiveness, any inability to provide a significant and timely foot soldier presence seriously degrades the Army's tactical capability.

Combat footwear plays a vital role in providing and maintaining this presence in the field by increasing the soldier's ability to traverse difficult terrain for a variety of environmental conditions.

Foot locomotion over this environmentally modified terrain has required a series of special purpose footwear and devices to be designed to aid in accomplishing mission objectives.

The proliferation of these designs and the logistics related to service and replacement of the worn footwear has made the area of interchangeable soles and heels worthy of consideration by the U.S. Army Natick Development Center (NDC). The potential of a combat boot with an assortment of interchangeable soles and heels available in depot supply or in a field pack complies with NDC's basic mission objectives not only in terms of increased utility but in cost effectiveness as compared to a complete separate special purpose boot.

The most significant element in a footwear system with separable soles and heels is the interface between the lasted midsole and the outsole/heel combination which is, therefore, the subject of this program. The program is sponsored by U.S. Army Natick Development Center (NDC) through Contract No. DAAG17-73-C-0251.

A solution of this interface problem is mandatory before any meaningful applications of special purpose outsole/heel systems can be attempted. Accordingly, the main program activity is related to investigation of the interface, although illustrations of interface design include a variety of outsoles produced by Direct Molded Sole (DMS), injection molding and controlled foam molding.

The advent of these procedures and the development of wear resistant lightweight filled and foamed rubbers has provided the technology and material necessary to produce an acceptable outsole model for use in an interchangeable outsole/heel footwear system.

2. PROGRAM SCOPE

The program scope consists of four Contract Line Items (CLIN) to perform the effort necessary to design final footwear models with interchangeable soles and heels, furnish models of the outsoles/heels and footwear, and provide the substantiating data. A contract modification further required the delivery of six special purpose interchangeable outsoles and ancillary equipment.

A schedule of the contract scope is shown in the following table.

Table 1 CONTRACT LINE ITEMS

Item No.	Description Supplies/Services	Quantity
0001	Initiate materials and design techniques for interchangeable soles and heels for combat and dress boots.	As Required
0002	Interchangeable Soles/Heels (designed, developed, and fabricated using the design concept selected, as further described, delivered F.O.B. destination.	72 Pairs
0003	Combat Boots (designed, developed and fabricated incorporating a bottom feature, to accommodate Item 0002 above as further described herein, delivered F.O.B. destination. Size 9 Regular (D width), Size 10 Regular (D width).	36 Pairs each
0004	Data (in accordance with Contract Data Requirements List, DD Form 1423 designated in the Contract as Exhibit A.	As Required.

To comply with this schedule a series of three basic designs (Concept Numbers 2, 3, and 4) were selected by NDC from IIT Research Institute (IITRI) Proposal 73-461E entitled, "Combat Boot with Interchangeable Outsole and Heel," as the candidate concepts to fulfill the requirements of the schedule.

Two versions of each concept were designed on the contract and delivered to NDC for a total of six prototype designs. Of these designs four models were constructed and delivered to aid NDC in their final selection of the models for the CLIN 0002 and 0003, limited production.

The finally selected design was then fabricated in the 72 pair lot with the following additional contract requirements.

2.1 Outsole/Heel

- Shall incorporate a cleat type design.
- Shall meet physical requirements contained in Specifications MIL-B-43481B dated 24 May 1973, entitled, "Boots, Combat, Mens, Leather, Black, Direct Molded Sole" - Paragraph 3.34 Outsole and Heel, Rubber (with authorized variation of outsole compounds permitted).

2.2 Combat Boot Upper

- Shall incorporate "speed" lace hooks.
- Shall incorporate water resistant leather which shall meet the requirements of Military Specification MIL-L-3122F, dated August 1971, entitled, "Leather, Cattle Hide for Footwear Uppers, Chrome Tanned, Fat Liquored."
- Shall be provided in sizes 9R and 10R.
- The upper bottom shall consist of a "molded on" midsole or modified outsole either of which shall be capable of having outsoles/heels rapidly and securely attached by the individual wearer without the need of any tools.

The P0002 Contract Modification required the delivery of four additional items as follows:

1. 1 pair - outsoles
2. 5 pair - interchangeable traction outsoles (1 size)

3. 48 pieces - integrally molded gripper hardware (for 6 pair of outsoles).

4. 8 each - non-molded gripper hardware components (for 1 pair of outsoles).

3. PROPOSED CONCEPTS

Four conceptual ideas of interchangeable sole and heel footwear designs were presented for NDC's consideration. These concepts all require a midsole to be constructed on the boot. The interface then depends upon the mating of male and female components to provide the interference fit.

3.1 Concept No. 1

Concept No. 1 is illustrated in Figure 1 and requires a laminated leather or molded rubber midsole which incorporates a system of metal attachment points to which the sole/heel system is secured by a removable pin.

Several versions of midsoles are shown. One employs three individual inserts for clips and pin retention. Others show one piece thin metal shim stocks in flat or corrugated sheets. Points of wear or high strength are reinforced with metallic inserts on the molded sole and heel.

Peel strength, bone support, wear resistance, water resistance and spike protection are characteristics which should improve or be maintained with this version. Weight, stiffness, heat transfer and long term fatigue may be degraded if a detailed design solution is not evident.

3.2 Concept No. 2

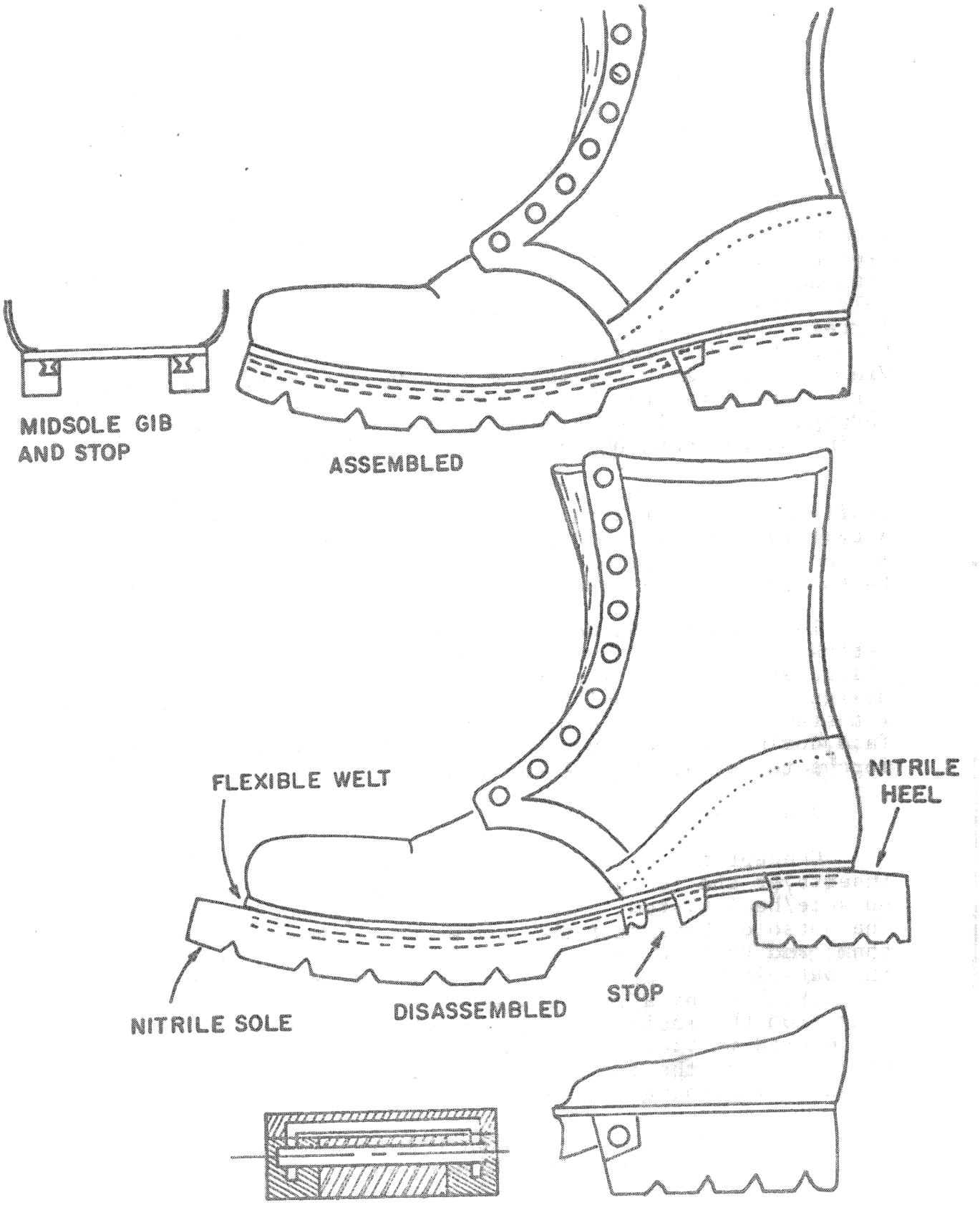
A flexible bonded or molded midsole, fabricated from a fiber reinforced plastic or rubber material capable of being molded in "V" notched gibs or runners, forms the design basis of Concept No. 2 of Figure 2. Mating surfaces molded in a separate outsole and heel section are assembled from the front and rear. The sections butt against the stop which is integrally molded in the midsole, and are restrained from separation by a knuckle lock which requires deformation for both installation and separation.

An alternate locking system employing a captured pin is also shown. Pin capture is obtained by molding a small section of reduced diameter on each end of the assembly hole system. During installation or removal this material must be deformed.

Most characteristics when compared with the Combat Leather Boot should be maintained or improved. Weight and stiffness are, however, of concern.

ONE PIECE STEEL MIDSOLE CONCEPT No. 1

Fig. 1



CAPTURED PIN LOCKING SYSTEM CONCEPT No. 2

Fig. 2

3.3 Concept No. 3

A Concept No. 3 model (Figure 3) also requires a molded midsole and a precision shaped welt for fitting to the removable outsole/heel system. The interface bond is provided by interlocking two strips of material. One material is woven with loop pile and the other is woven with hooks which interlock with each other. Several alternatives are shown on the sketch. View A illustrates a full patterned outsole/heel shape with an overlapping and interlocking edge fastened to the midsole. The lip is designed to resist peeling and toe stubbing forces. View B is a modified version of the shear lip covered by a pseudo welt for added protection against peeling forces. View C is probably the most viable version; peeling and shear forces are mitigated by design, as they must be transferred through the overlapping welt and resisted by the midsole bond as in conventional DMS design.

The two sketches of the outsole shapes indicate the configurations which may be considered for the inserts. Attractive features of this design include the simplicity and potential of reduced tariff on outsole/heel patterns due to the insert technique.

In general, the design should evidence adequate characteristics for physical properties while retaining conventional characteristics for fit and comfort. Some reservations on the design concern the ability of the hook and loop material to withstand the fretting or rubbing forces present at the interface during locomotion, or its ability to provide adequate forces to resist the use environment.

3.4 Concept No. 4

Concept No. 4 (Figure 4) requires plastic or metallic inserts at the toe and heel of the upper and a one-piece outsole/heel system. Assembly is accomplished by positioning the outsole shape at right angles to the toe retainer, mating them, and then twisting them to lock. The middle section of the outsole then mates with interference fitting pins which are assembled by a compressive load. The final securing is done from the inside of the boot where the rear or heel lock is secured in View A by twisting the self stored "D" ring which rotates the locking lug. The View B shows an alternative threaded fastening system.

A removable insole is then inserted to eliminate heel chaffing and promote ventilation.

The concept has considerable merit for the attachment of special purpose outsole systems which required positive outsole retention; however, secondary fragmentation may be

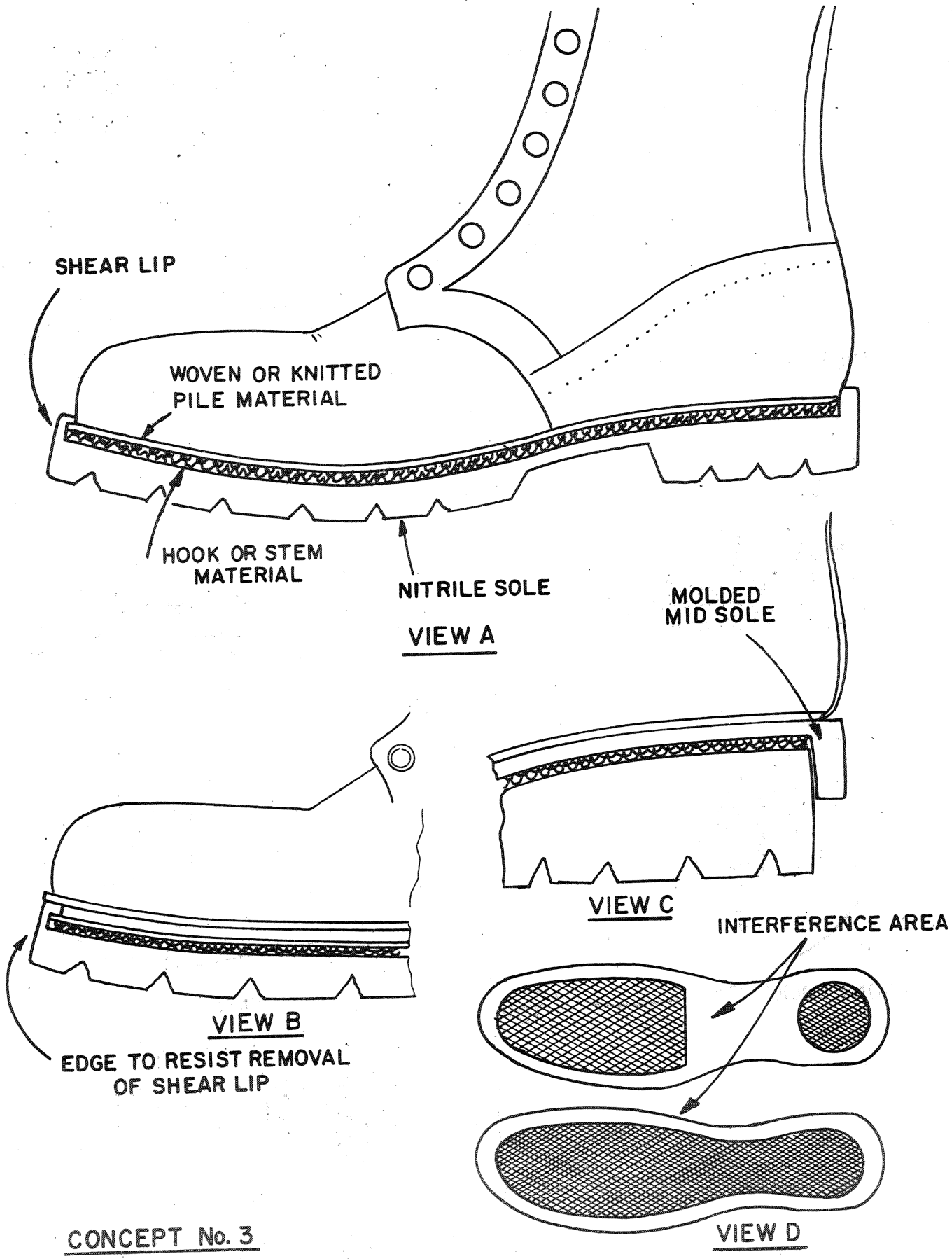
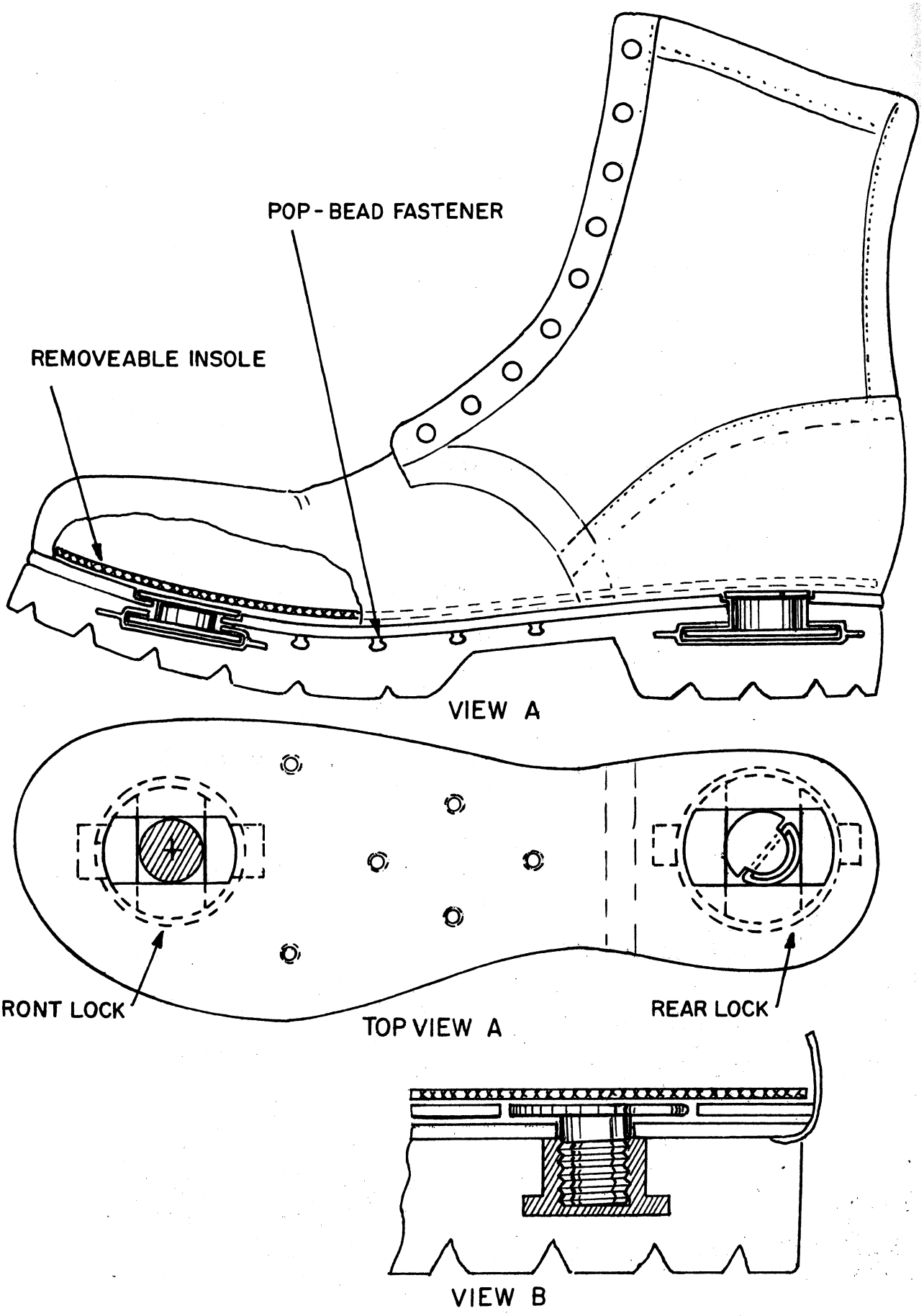

SHEAR LIP
WOVEN OR KNITTED
PILE MATERIAL
HOOK OR STEM
MATERIAL
NITRILE SOLE
VIEW A
MOLDED
MID SOLE
VIEW C
INTERFERENCE AREA
VIEW B
EDGE TO RESIST REMOVAL
OF SHEAR LIP
VIEW D
CONCEPT No. 3

Fig. 3



CONCEPT No.4

Fig. 4

increased, and thermal insulation may be degraded. Should such design tradeoffs be acceptable, all other physical characteristics should be potentially acceptable.

The concepts which have been presented are applications of technology employing several ideas based upon both conventional and innovative fastening systems. Exploitation of these concepts through a formal design period, selection of the most promising versions, and finally, construction of the prototype models constitute the effort discussed in the following text.

4. DESIGN CRITERIA

The evolution of new footwear concepts designed to overcome a specific threat should not degrade the fundamental requirements necessary to defeat the other aspects of the combat terrain and associated environment. One way of assuring that such requirements are served is by establishing design criteria for consideration during the design process. In the absence of traction related resitive forces, criteria were evolved which included general provisions based upon footwear design, experience and specific values which in turn are based on the Standard Combat Boot performance and military footwear specifications. The criteria include the generic areas of:

- Utility

  Reduced weight
  Improved bone support
  Improved wear resistance
  Permanent flexibility,
  Improved traction,
  Ease in donning and doffing,

- Environmental Resistance

  Mitigation of damaging effects on skin, soft tissue and bone,
  Insulation against cold,
  Improved water resistance,

- Comfort

  Improved transpiration,
  Better fitting,
  Reduced break-in time,
  Reduced long term fatigue.

In addition to the generic areas, it is necessary to consider the specific forces related to the separation of an outsole/heel from a footwear upper. These forces are not adequately documented in the literature and are not required to be defined in this program. As a consequence, the footwear versions presented in the following text have been designed to

illustrate the concept of interchangeability rather than a proven ability to overcome a currently unspecified hostile environment.

Some engineering assumptions, however, have been employed during the detailed design to provide an assumed substantial and hopefully adequate resitive force at the interface. Material dimensions and physical strength characteristics were selected so that the Concept No. 2 design would yield a resistive force estimated at 200 pounds before a significant interface deformation would occur. (For purposes of definition the interface resistive force is that force which results when a uniform tensile load is applied normal to the outsole). Greater separation forces can also be developed through other design approaches. As an example, the forces developed by the Concept No. 3 version when the two interface materials separate is estimated at 500 pounds. The resitive force increases to 800 pounds in the Concept No. 4 version at the point of maximum shear for the leather midsole material.

Peel forces are also criteria for adequacy. As an illustration, the military DMS boot requires a 135 pound peel force for acceptance. The rationale for this force, however, is based upon maintaining (rubber to leather) structural adequacy rather than a deliberately separable interface. The peel criterion is, therefore, only incorporated into the design of the permanent bonds. The design of replaceable elements, however, poses a question of what forces are required for a removable and replaceable interface. It is in this area that specific guidance is lacking.

When applicable, therefore, self-locking materials are selected based upon the best available inherent strength within a class. Those designs where a dimensional latitude exists have been structured to withstand a 135 pound peel force.

The need to resist these forces may be circumvented through a design by providing a shelter such as a lip or ledge over the outsole so that a terrain derived load cannot be applied directly to an interface. Another design approach is to bond a fastener material (which may be relatively weak in "T" peel), to a stiff substrate, thereby increasing the effective area during the peeling action. This results in an increased capacity for resistance which approaches the tensile separational values discussed above. Stem and loop or hook and loop material, furnished with a flexible tape backing, illustrates a typical design approach for greater resitance.

5. DESIGN AND FABRICATION OF PROTOTYPE SYSTEMS

Concepts 2, 3, and 4 were elected for further design study and design drawings were made taking guidance from the stated criterion. Two variations of each design including matching outsole patterns for a total of six detailed design versions of interchangeable boots and outsoles/heels which were evolved from these concepts will now be discussed. These designs and the four models constructed from the drawings formed the basis for selection of the model for the limited production discussed later.

5.1 Concept No. 2

Concept No. 2 of Figure 2 is presented in two versions which are illustrated in Figures 5 through 10. These versions are slide and lock designs wherein mating gibs and slides or buttons and keyholes are assembled for interlock.

The resistive material is a stainless steel stamping formed into the desired shape to accommodate the interlock system and for inclusion into the rubber sole compound.

5.1.1 Concept No. 2A

Concept No. 2A, drawing E6281-E-200 (Figure 5) is a sliding gib design. The material selected is 420 stainless Steel in a 28 gage thickness which will deform readily during foot flexure while transmitting the loads tending to separate the outsole from the boot.

The midsole slide and outsole and heel gibs are molded into the elastomeric material. This may be accomplished in a normal molding process with appropriate tools to position the components relative to the upper and the outsole pattern surface while maintaining the interlock location to control the interface dimensions. Assembly is accomplished by locating the tangs on the ousole in the spaces of the midsole one half space forward toward the toe. Sliding the outsole one half space toward the rear then positions the forepart of the outsole. The heel is assembled in the reverse order. When the forepart and heel are properly aligned with the midsole, the pin location at the breast of the heel will be aligned for assembly of a 1/4-inch locking pin completing the interface.

5.1.2 Concept No. 2B

The prototype model photograph (Figure 6) and the drawing E5281-E-220 (Figure 7) show the assembled elements of Concept No. 2B. Drawings E6281-E-221, 222, and 223 (Figures 8, 9, and 10) show the developed sheet metal blanks for the midsole and the outsole before molding.

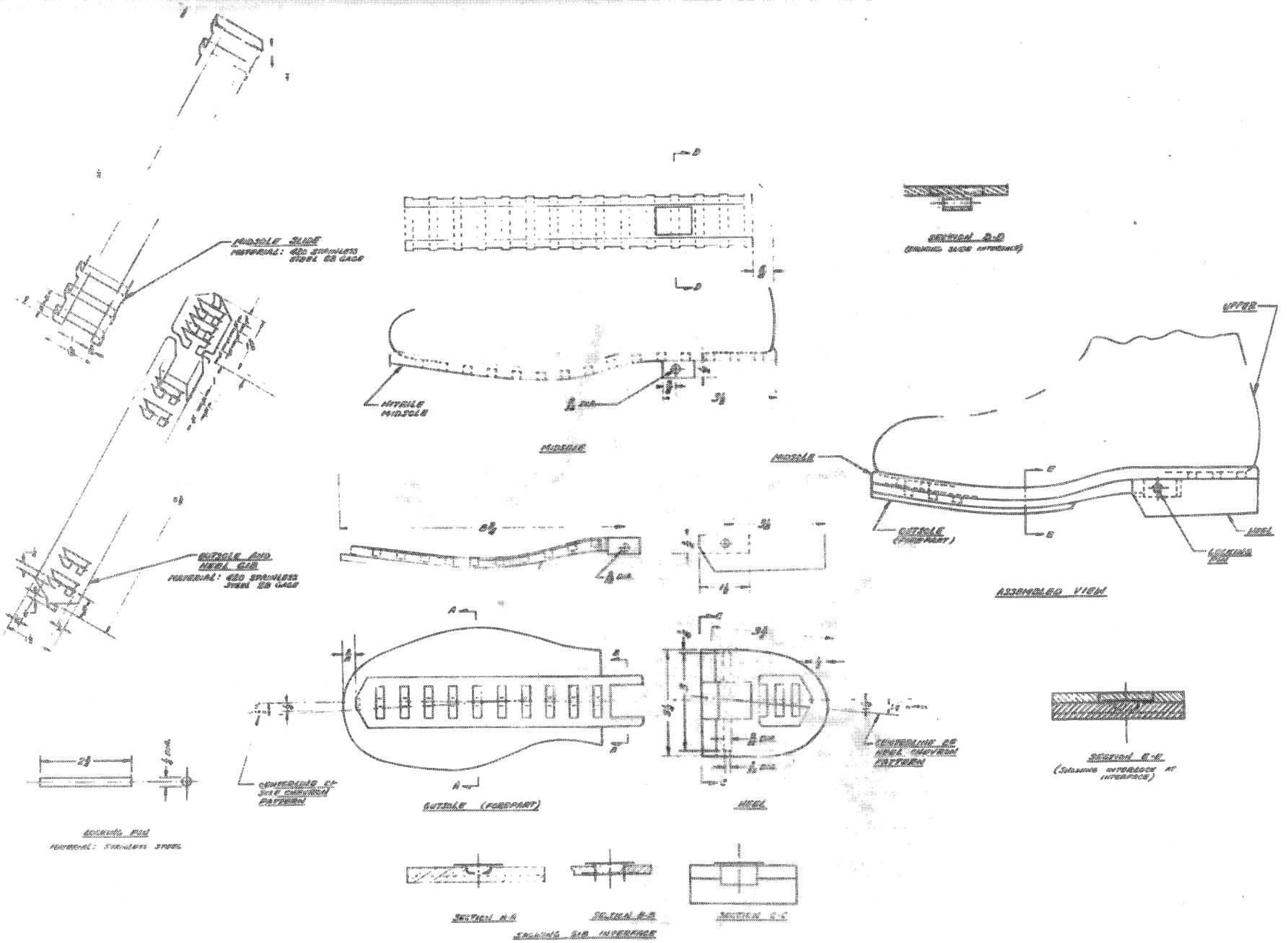


Figure 5 REPLACEABLE SOLE AND HEEL CONCEPT NO. 2A

Figure 6 PROTOTYPE MODEL - CONCEPT NO. 2B

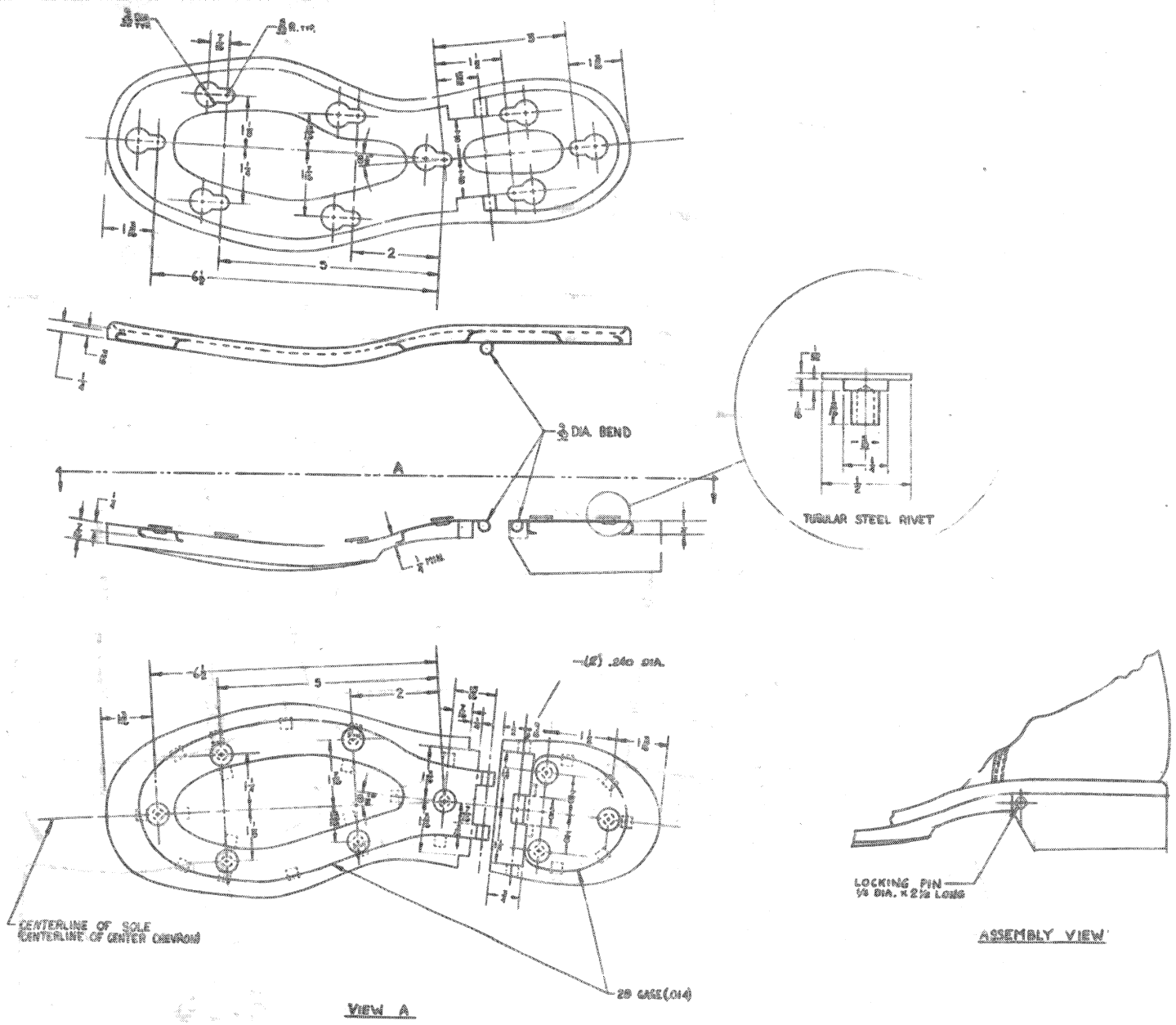


Figure 7 REPLACEABLE SOLE AND HEEL CONCEPT NO. 2B

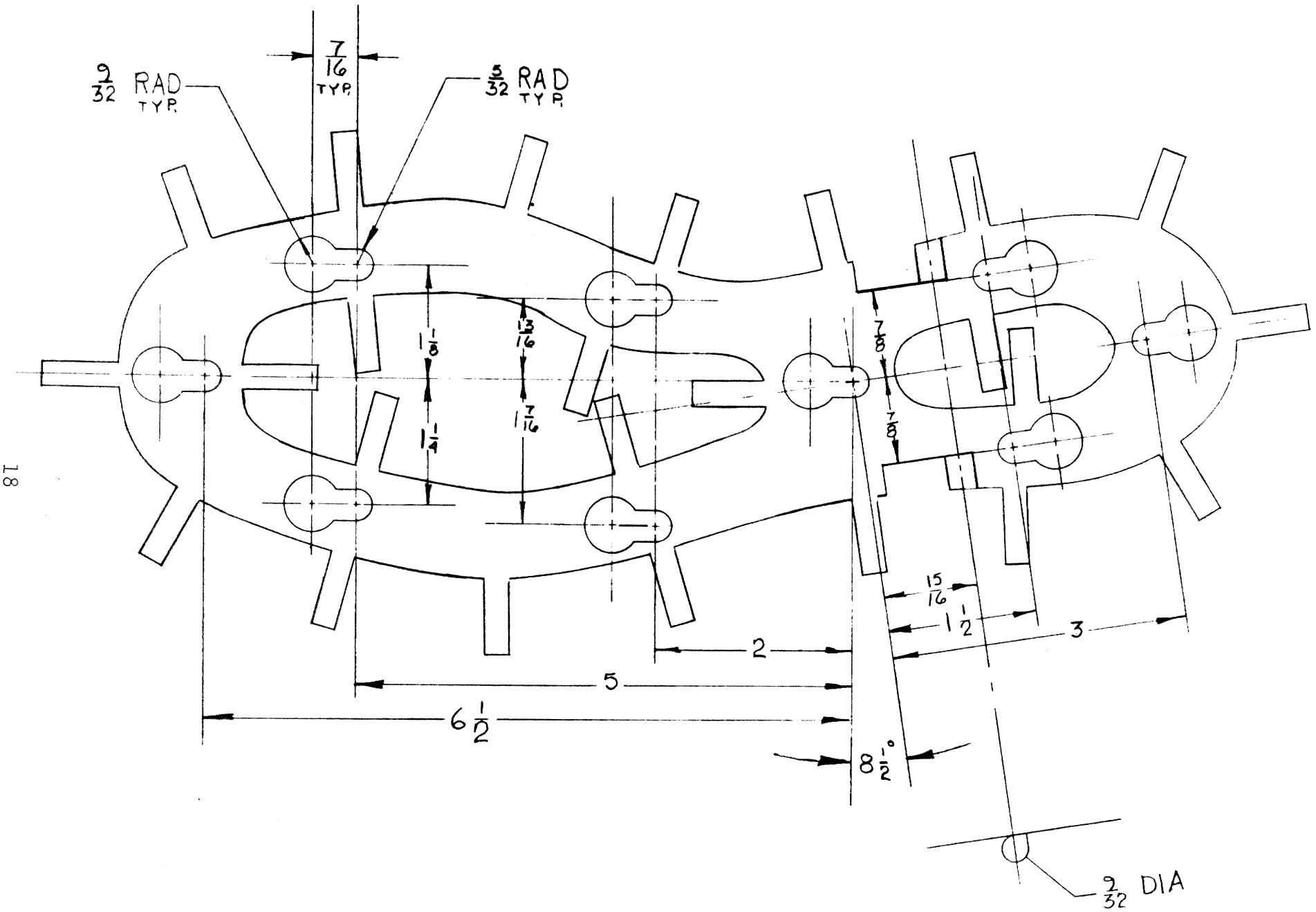


Figure 8 KEYHOLE PLATE - MIDSOLE

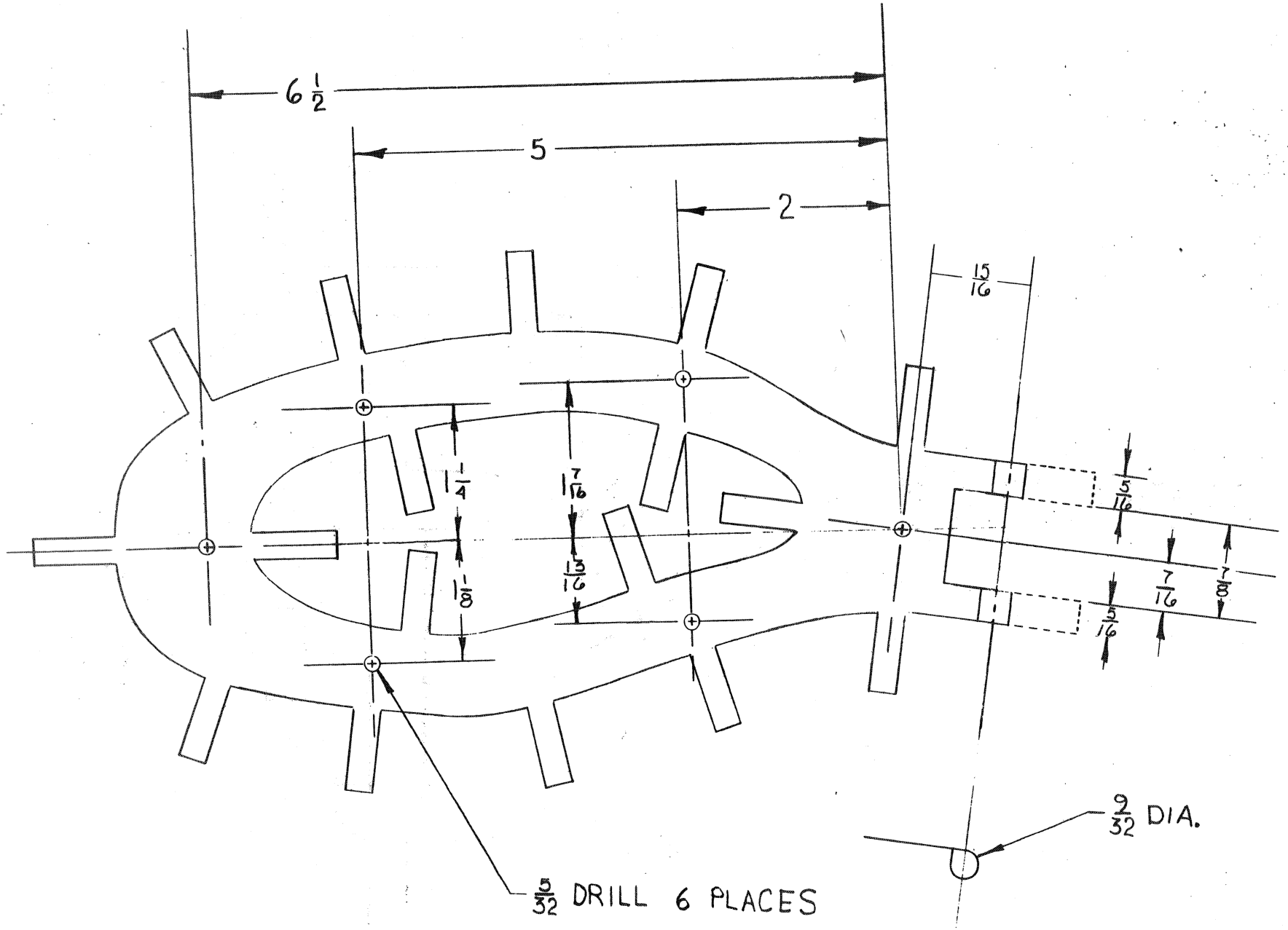


Figure 9 BUTTON PLATE - SOLE

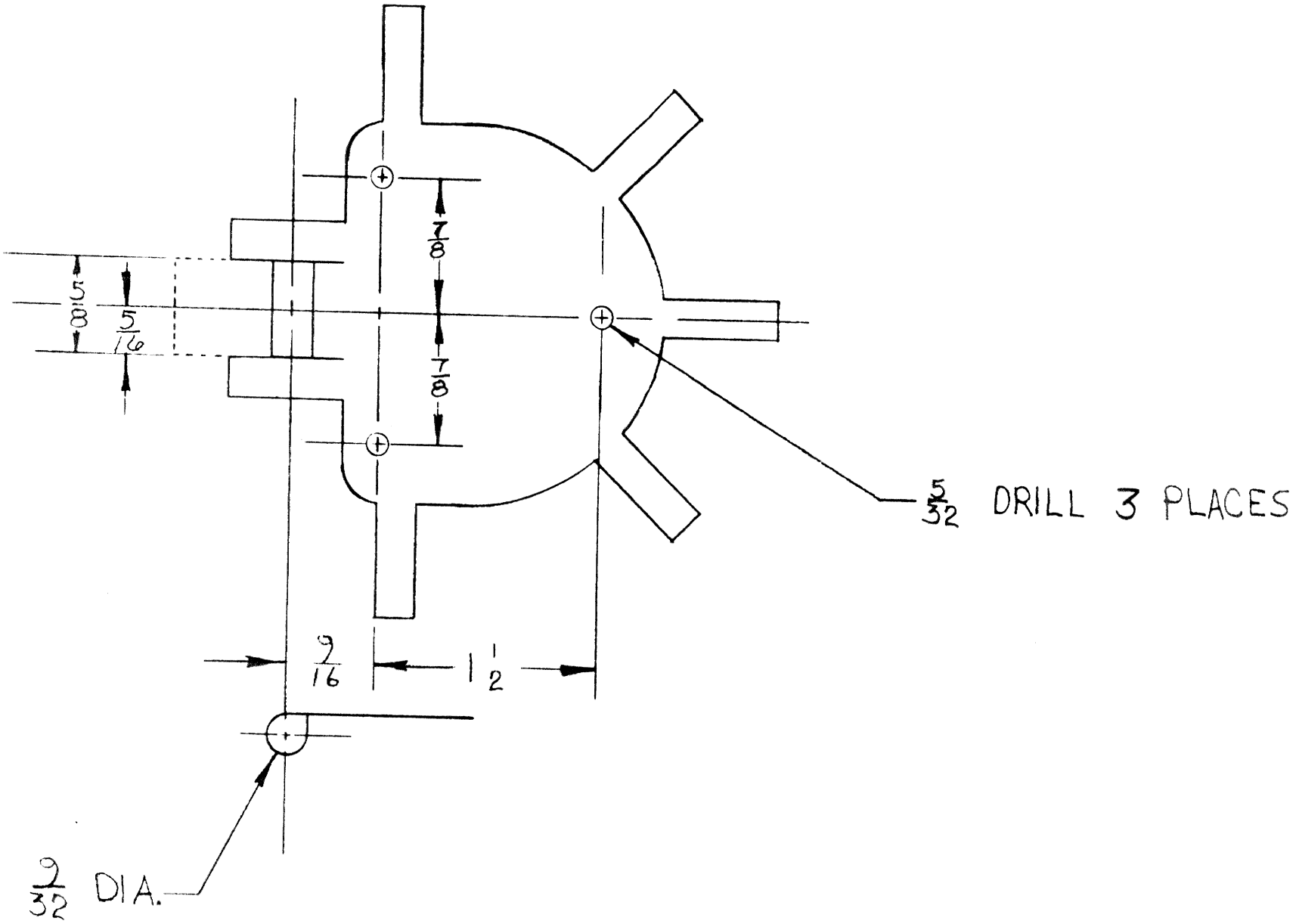


Figure 10 BUTTON PLATE - HEEL

This concept is similar to 2A but requires a steel button to provide the vertical interlock. The horizontal interlock is again provided by a pin common to all plate elements.

The design reduces the sensitivity of the vertical interlock to bending forces as the buttons are supported for more than 180° around the head. Assembly is accomplished by inserting the buttons of the sole and heel plates through the eyes of the keyhole openings in the midsole plate. The sole and heel plates are then closed toward the instep until the 9/32 inch holes are aligned and the locking pin can be inserted.

Preliminary to molding, the tubular steel rivets are assembled to the button plates. These plates, in conjunction with the keyhole plates, are then formed into "L" shapes (Figure 11) These preassembled and preformed components are then inserted into appropriate tooling and molded to form their respective subassemblies (Figure 12). Care must be exercised during tooling designs to provide for location of the inclusions to insure matching pattern edges at the midsole, outsole and heel interface.

5.2 Concept No. 3

The prototype models (Figure 13) and the drawing "Removable Outsole" Concept No. 3, E6281-D-302 (Figure 14) illustrate an A version where the heel is separable from the outsole and an alternate B version with a changeable unit sole.

The design incorporates the use of two mating textile materials which are cemented to complementing surfaces of the midsole and outsole. Figures 15 and 16 show two prototype models prior to assembly. The photographs also illustrate the potential versatility through availability of special purpose outsoles. Assembly of the outsole to the midsole is then accomplished by pressing the two together with nominal hand-applied force. Upon assembly, the textile materials are engaged in a hook and loop or burr and felt type interaction which can generate resistive loads if separation is attempted.

Disassembly of the footwear system is accomplished by applying a peeling force to the tip of the toe. Separation at the heel location is much more difficult due to the stiffer backing which is the process of bonding a flexible material to a substrate (in this application, either nitrile tiles or the actual midsole or outsole/heel subsystem). Stiffening the backing increases the effectiveness of the mating materials and subsequently increases the forces required for separation.

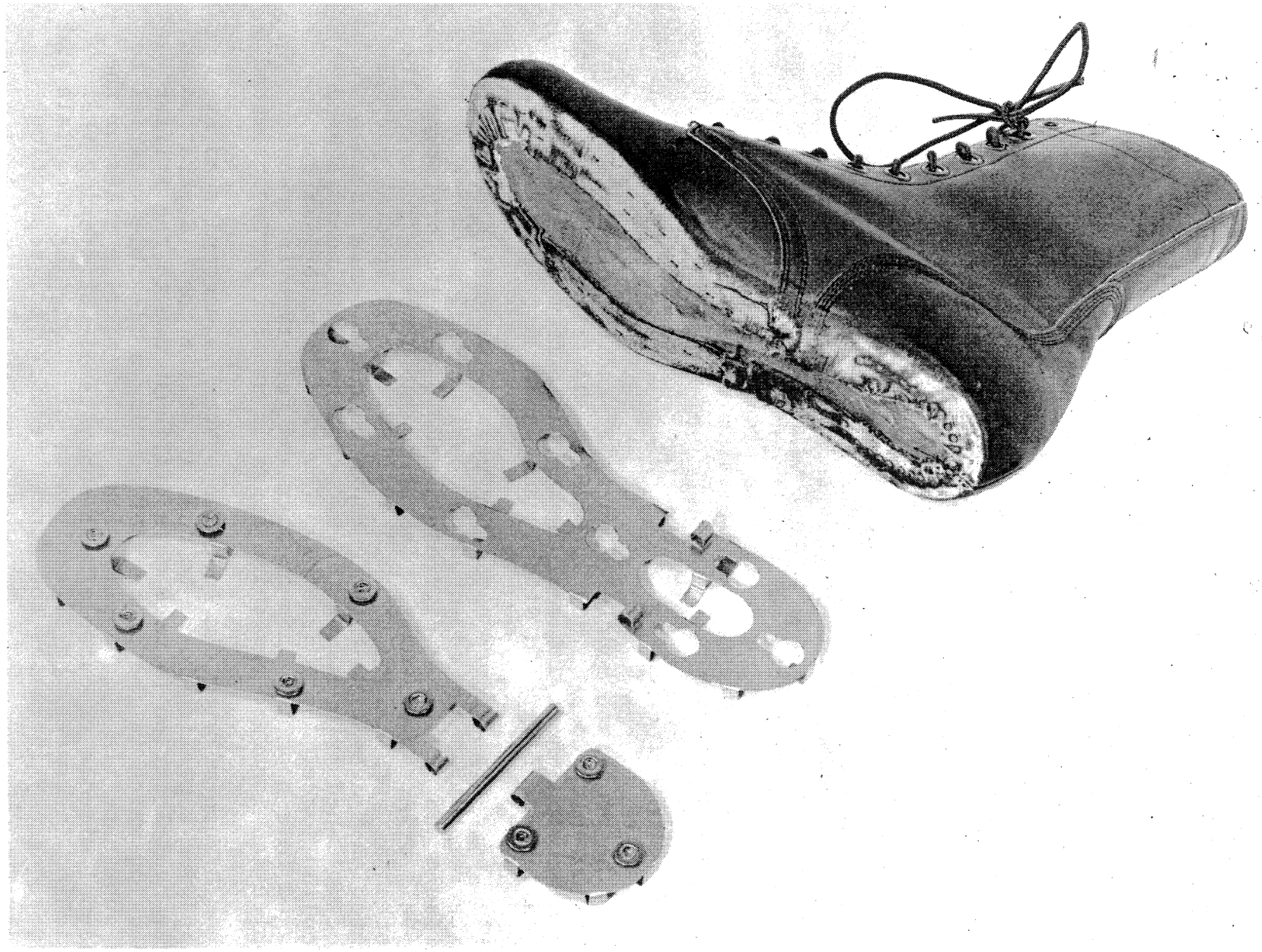


Figure 11 COMPONENTS PREPARED FOR MOLDING - CONCEPT NO. 2B

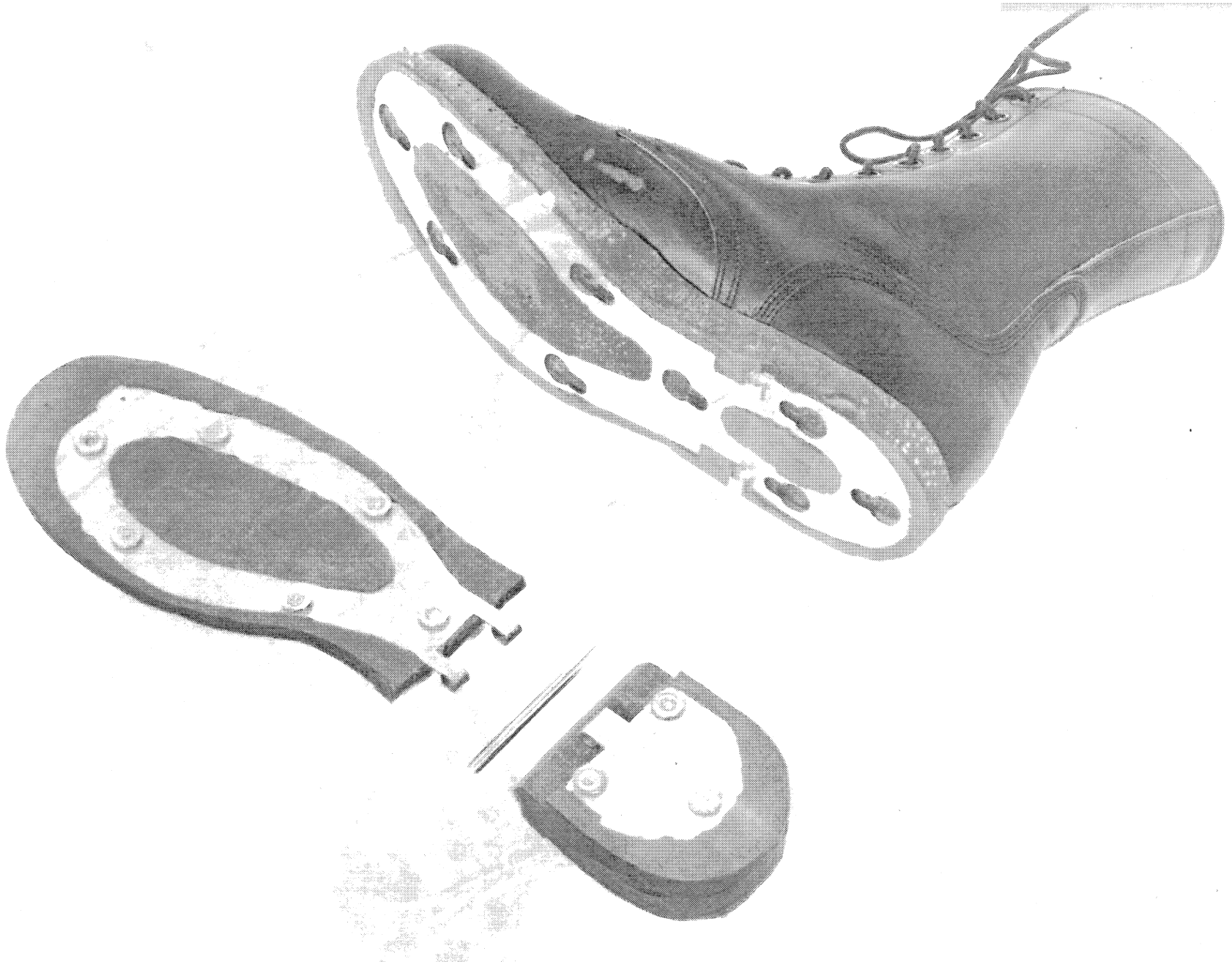


Figure 12 MOLDED COMPONENTS - CONCEPT NO. 2B

A B

Figure 13 PROTOTYPE MODELS - CONCEPT NO. 3

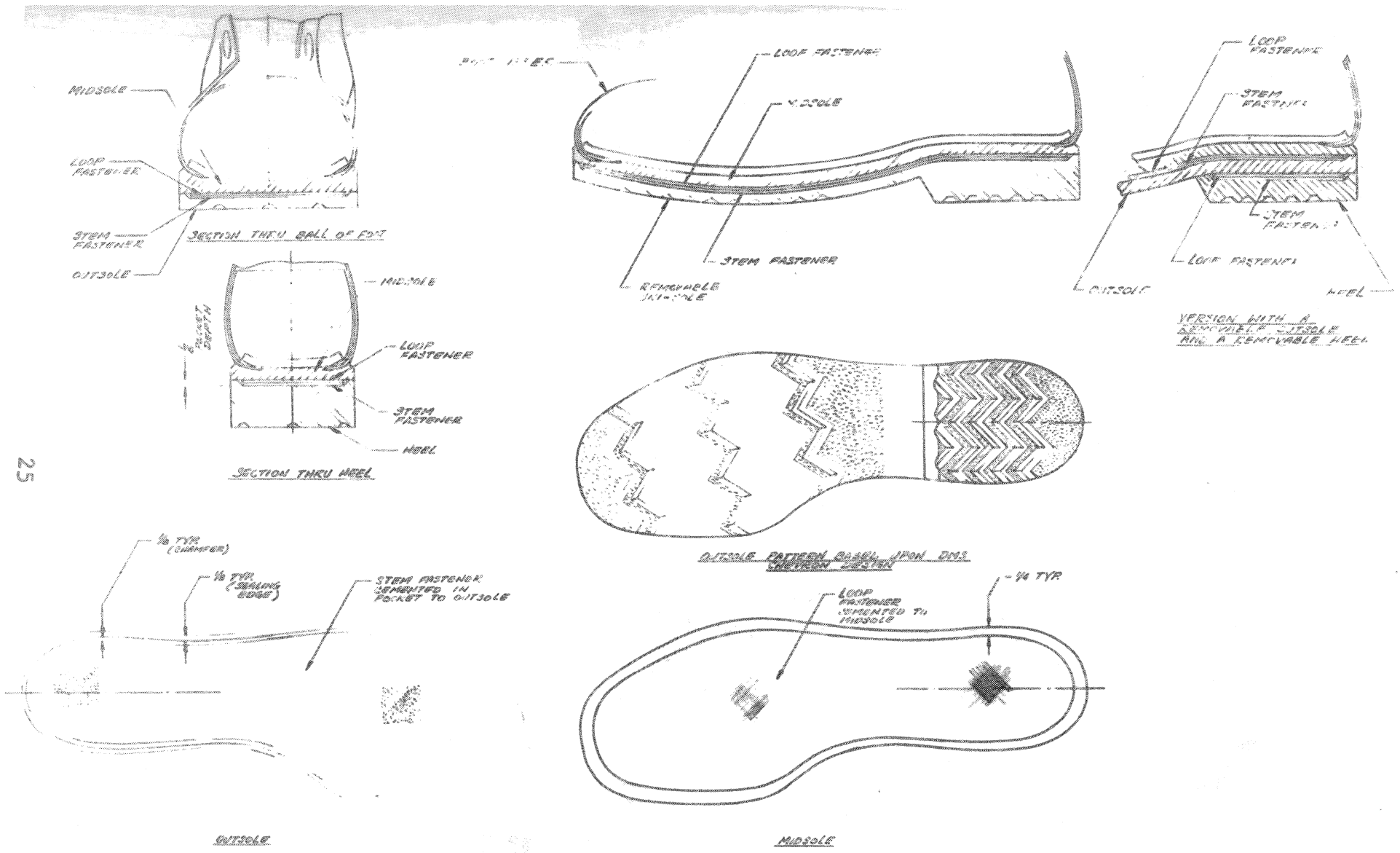


Figure 14 REMOVABLE OUTSOLE, CONCEPT NO. 3
(STEM AND LOOP FASTENER)

Figure 15 PROTOTYPE MODEL - CONCEPT NO. 3A

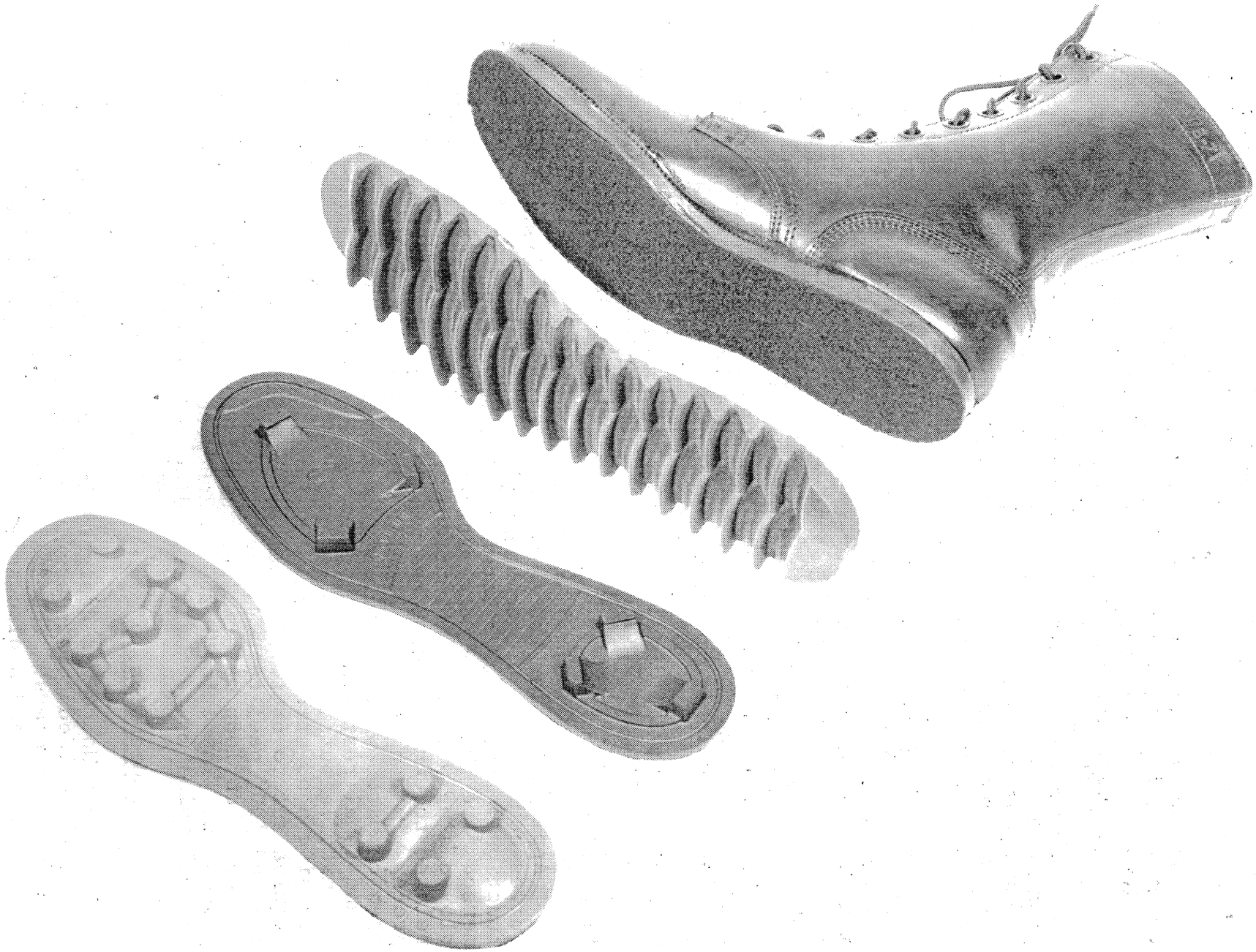


Figure 16 PROTOTYPE MODEL - CONCEPT NO. 3B

In early versions, a hook and loop material was initially considered for the interface fastening but was judged conditional for use in the anticipated environment. The basis of this judgement was information generated under Contract DAAG17-73-C-0147 (IITRI E6267) "Conceptual Combat Footwear Study". The information pertained to peel force limits which were 1/2 pound minimum to 1 pound maximum per lineal inch of engagement of the unbacked material. Although backing increases the peel strength appreciably, the forces were still considered to be inadequate for the anticipated service.

To overcome this anticipated deficiency, a new fastener system was investigated. This new system may be described as a stem and loop interface. One side of the interface consisting of a nylon tape woven together with a mushroom head (stem) fiber that engages a mating tape with a random pile surface (loop). Figure 17 shows a magnified view of the materials (the head of the stem approximates .025 inch) and illustrates the interlock between the stem and the loops. This material was finally selected on the basis of a greatly increased peel force. See Table 2 which compares the performance of hook and loop vs. stem and loop. The resistive force for stem and loop material will vary from 2.5 lbs/lineal inch, F_p, at a 90° peel angle to 25 psi, in tension F_t and shear F_s separation when rigidly backed. Figures 18, A, B, and C illustrates the test configurations.

Application for the stem and loop fastener systems requires some method of permanently fastening the material to a functional substrate or backing. The most commonly used methods are thread or metal stitching or adhesive bonding employed singly or in combination. On this program, the effort related to Concept No. 3 has examined the adhesive bonding process in considerable detail. The results have been marginal when compared with established criteria for the desired 135 pound total resistance for bonds between the stem material and the nitrile outsole. The employed techniques have yielded adhesive bond strengths from 17 to 25 pounds per lineal inch (equivalent to 68 to 100 pounds for a size 9 sole width), in 90° and 180° peel test. However, techniques for the bonding of the nylon loop material to the midsole resulted in 50 to 60 pounds per lineal inch (200 to 240 pounds for a size 9 sole) in peel which is adequate according to criteria.

5.3 Concept No. 4

Concept No. 4 was designed in two versions which required integrally molded components in metal and plastic for the interface fasteners. The following test is a description of the components and a discussion of fabrication and assembly.

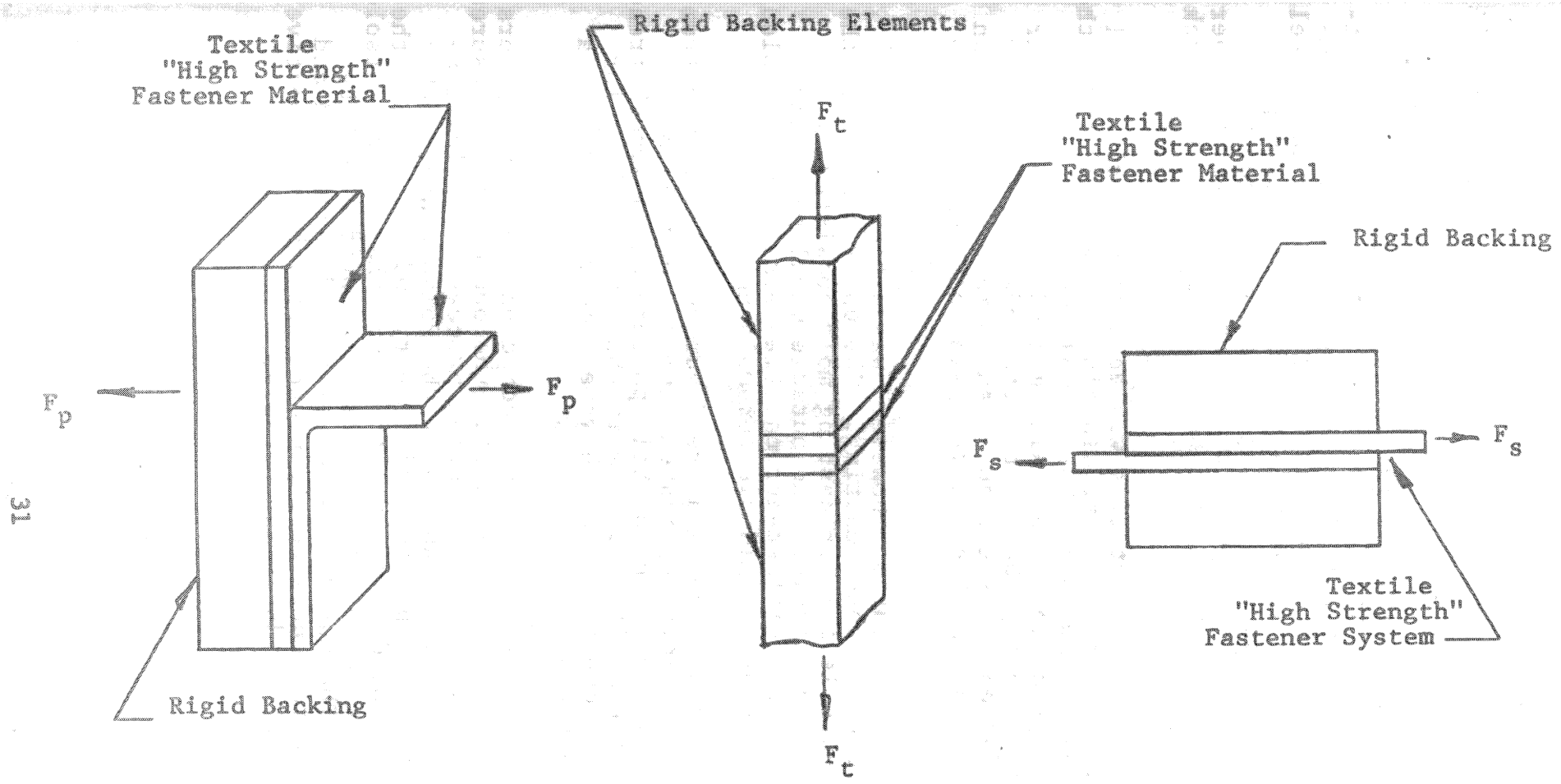
Figure 17 STEM AND LOOP MATERIALS SHOWING INTERLOCKING

Table 2

COMPARISON OF PHYSICAL DATA FOR
TWO TYPES OF TEXTILE FASTENER SYSTEMS

	Hook and Loop	Stem and Loop (High Strength)
90° Peel	1.0 Pounds per lineal inch	2.5 Pounds per lineal inch
Tensile	5.0 Pounds per square inch	25.0 Pounds per square inch
Shear (Single Overlap)	10.0 Pounds per square inch	25.0 Pounds per square linch
INTERFACE RESISTANCE		

See Bibliography for manufacturer's data.



90^{o} Peel Separation

A

Tensile Separation

B

Shear Separation

C

Figure 18

5.3.1 Concept No. 4A

A prototype model (Figure 19) is further illustrated in drawing E6281-D-402 entitled, "Concept No. 4A - One Piece Outsole and Heel," (Figure 20). The primary fastening is accomplished by a twist lock closure at the toe and a threaded heel stud at the rear which is assembled through the boot uppers (Figure 21). A secondary fastening was accomplished at the instep area through the use of a two-piece commercial fastener employing fields of stiff plastic headed stems which interlock when pressed together.

Fabrication of the prototype was accomplished with model making techniques employing hand crafting. Figure 22 shows the upper and fastening components before molding. Fabrication included the modification of a plain, molded midsole (similar to the midsole of Concept No. 3) to accommodate the fastener systems. The fasteners were then cemented into place with an epoxy. Small brads were used to maintain location while the adhesive set.

The outsole fabrication, however, was a flexible high density Polyurethane rubber casting. The upper portion of the fabrication's outsole form or casting mold consisted of the previously modified midsole. The outsole metal parts and spacers to form the stem fastener cavities were then assembled to the metal parts of the midsole for molding.

The outsole side shape and tread surface were formed from a temporary plaster mold duplicated from the outsole of a standard military boot. The outsole pattern was a smooth tread surface to provide additional room in the outsole shape for components. Subsequent designs, however, must accommodate a figured tread pattern.

Prepositioning of the fastener components and the spacers for the fastener cavities relative to the outsole shape insures proper matching following the casting process. Casting consisted of premeasuring a quantity of the Polyurethane rubber into the bottom of the plaster mold cavity and positioning the upper and preassembled components to ensure the desired outsole thickness. A time period of 24 hours was provided for the rubber to cure. The cured outsole was then disassembled and the headed field fasteners were cemented into their respective cavities (3 in each midsole and outsole).

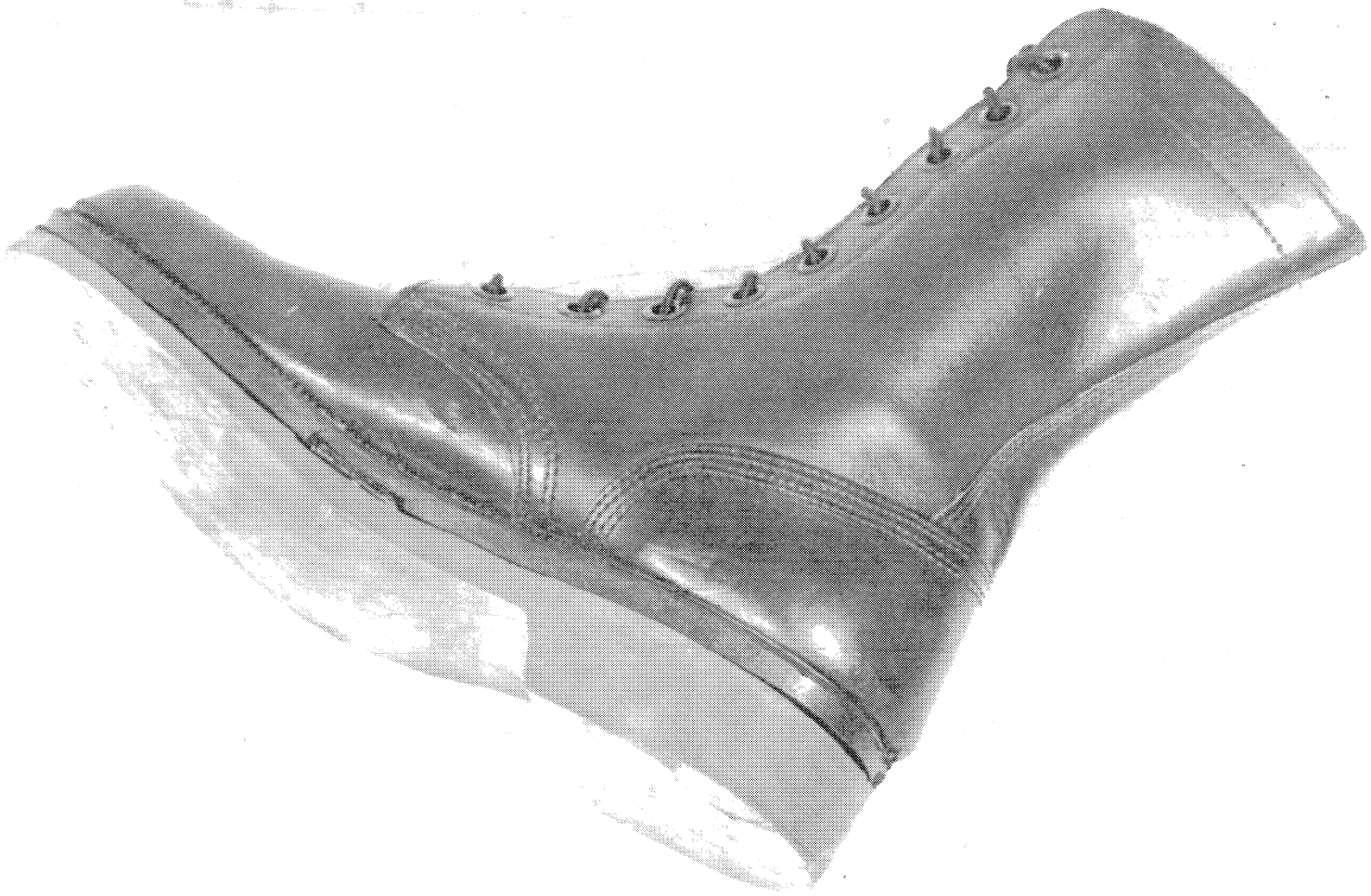


Figure 19 PROTOTYPE MODEL - CONCEPT 4A

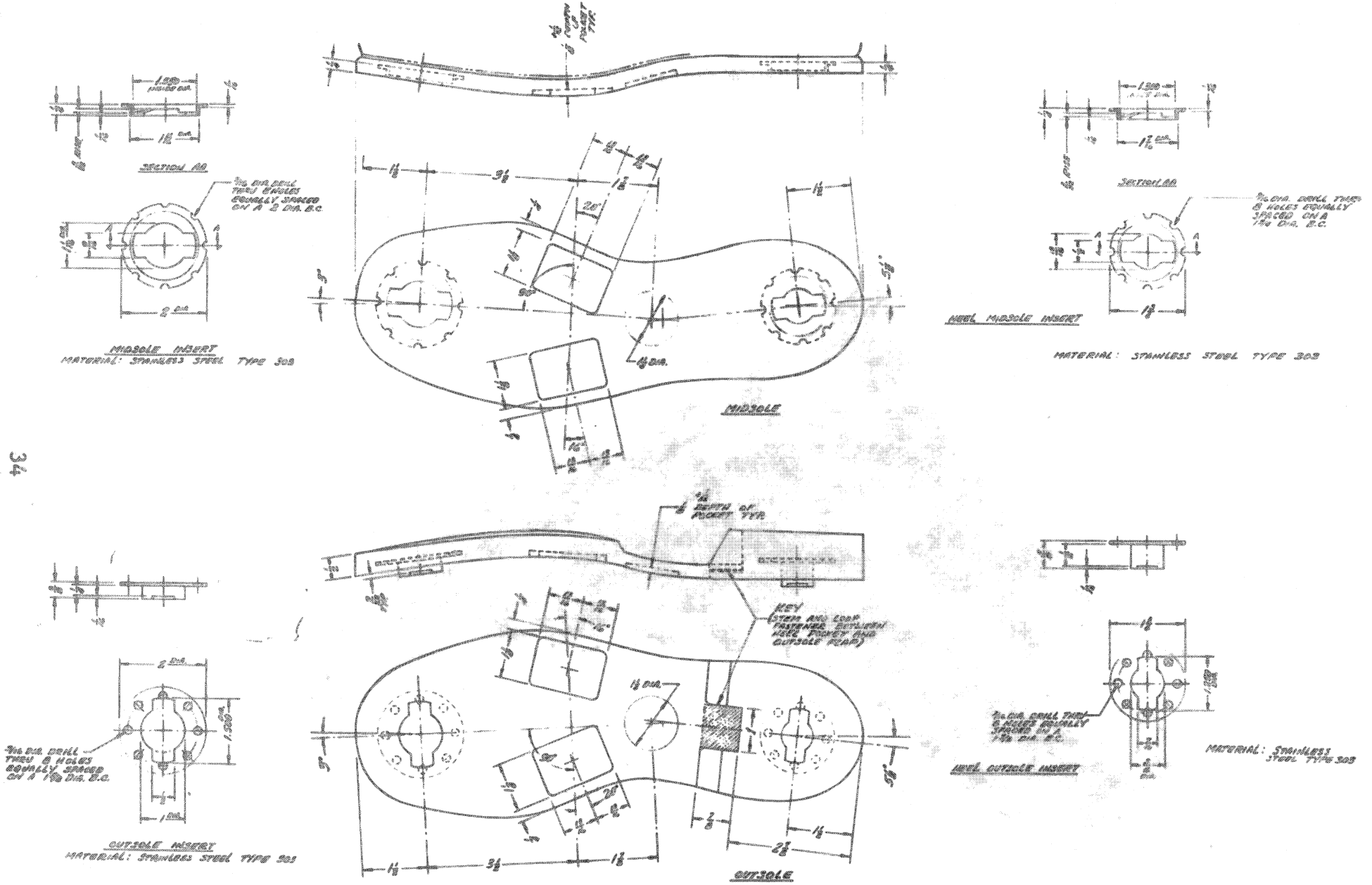


Figure 20 CONCEPT NO. 4A
ONE PIECE OUTSOLE AND HEEL

Figure 22 EXPLODED VIEW SHOWING FASTENING COMPONENTS - CONCEPT NO. 4A

Assembly of the Concept No. 4A is conducted by engaging the toe section and turning 90° to super-position the outsole over the midsole. The headed field fasteners are then engaged by hand pressing the outsole against the midsole until the heads interlock. The Heel Stud is then inserted inside the upper through the insole into the Heel Outsole Insert by turning clockwise to engage the threads. Disassembly is accomplished by reversing the process.

5.3.2 Concept No. 4B

Concept No. 4B as shown in drawing E6281-D-403 (Figure 23) depicts a second version. This version is again intended to employ integrally molded metal and plastic components to form the interface fastening system. The two versions of this concept differ in one significant detail. In the A version, a prerequisite to outsole attachment is the Heel Stud assembly through the empty upper. The B version, in contrast, can be assembled on foot if desired.

Concept B uses the twist lock hardware and the field type commercial fastener of the A version. In addition, a small piece of stem and loop material described in earlier test is used to retain a key section of the fore-sole to the heel. The flexible stem and loop material can also be used to replace the stiff plastic headed fastener in an alternative version.

Fabrication of this model seems amenable to conventional footwear practice although prototype construction should follow that described for the A version.

Assembly of the Concept No. 4B version may be accomplished as follows: the sole and heel sections of the outsole are positioned to engage the twist lock and then rotated to be super-positioned over the midsole; as the heel is the stiffer component, it will lay flat upon the midsole while the sole section is elevated by bending to permit axial alignment; once the sections are aligned, the final locking is attained by pressing to engage the field fasteners and engaging the keyed sections. Disassembly is accomplished by reversing the process.

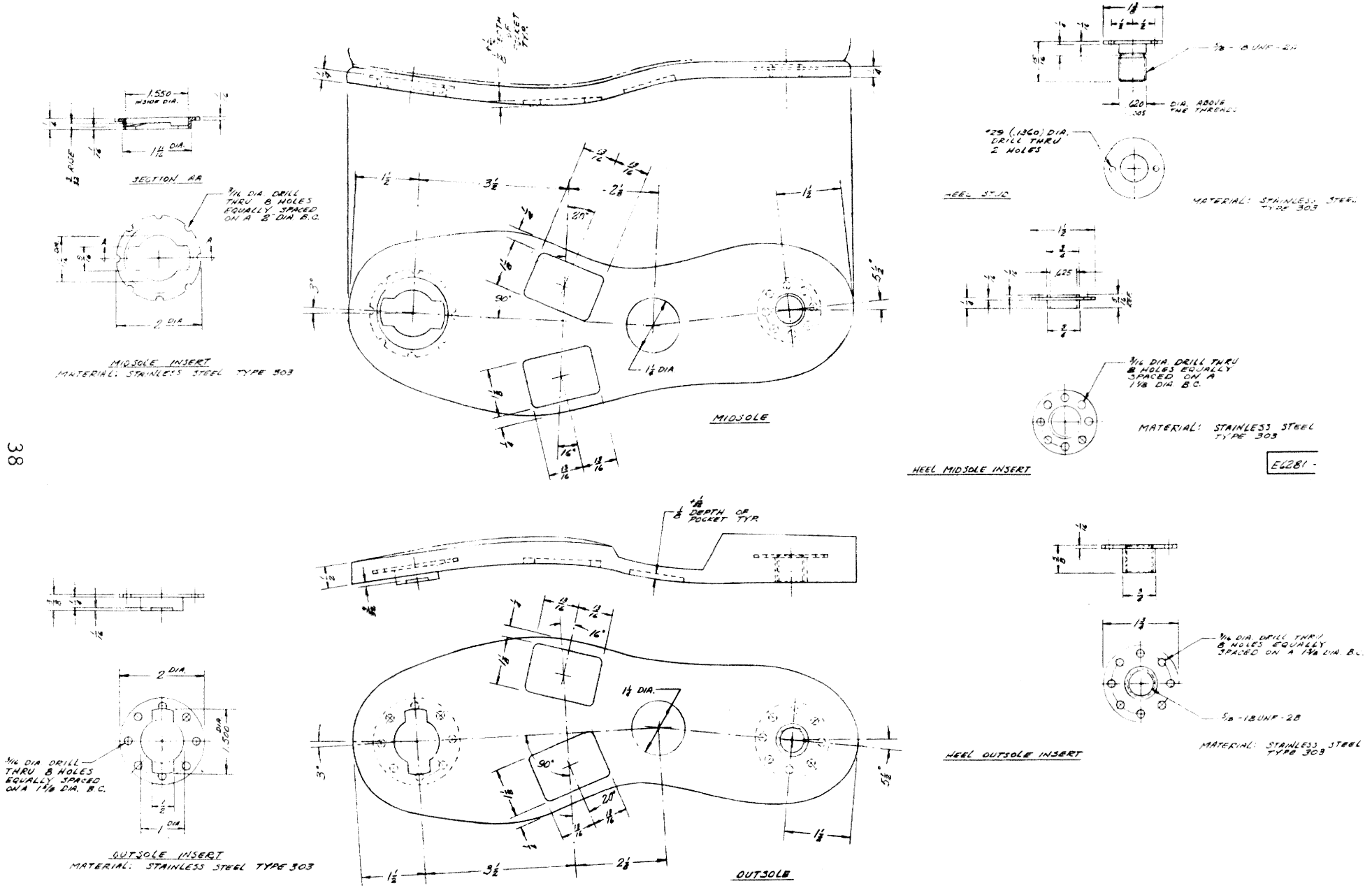


Figure 23 CONCEPT NO. 4B
SEPARATE OUTSOLE AND HEEL

6.0 FINAL PROTOTYPES

After reviewing the candidate design versions and models which were constructed for the three candidate concepts, a final selection was made for the originally contracted footwear, which was then fabricated. In addition, a contract modification required the delivery of a sample of traction aided outsoles which incorporated the selected interchangeable interface.

The prototype boots delivered on the contract are 8-1/2" high, dyed cattlehide uppers with midsoles and outsolde manufactured from nitrile and polyurethane rubbers. The footwear conforms in general to MIL-B-43481B dated 24 May 1972 entitled, "Boots, Combat, Mens, Leather, Black," with speed hooks or tunnel hooks replacing the specified eyelet as required.

6.1 Boot with Interchangeable Outsole (modified chevron pattern)

The selection of the Final Prototype was based upon the versions designed and models fabricated for Concept 3A and 3B using the textile stem and loop interface. Concept 3A is an outsole with a removable heel, and Concept 3B is the uni-sole version (Figure 14).

The selection was based primarily on simplicity of the design, ease of production and minimal requirements for assembly and disassembly. Also, it was estimated that the selected field type of non-metallic fastener would preduce the fewest problems in the military environment (i.e., adequacy of attachment, logistics, heat transfer and secondary fragmentation).

A production quantity of 72 pairs of combat boots and 72 pairs of interchangeable outsoles were constructed and delivered to NDC (Figures 24, 25, 26, and 27).

The boot is constructed in accordance with the Contract Schedule which is described in the section "Program Scope" of this report. The 72 pairs of outsoles were also constructed in accordance with the documentation and were delivered in sizes 9R and 10R, 36 pairs of each size.

Further, each size was provided in 2 versions consisting of uni-sole-outsoles and outsoles with a separate heel, as desired by the CTM.

Figure 24 FINAL PROTOTYPE - INTERCHANGEABLE OUTSOLE WITH A REMOVABLE HEEL (ASSEMBLED)

Figure 25 FINAL PROTOTYPE - INTERCHANGEABLE OUTSOLE WITH A REMOVABLE HEEL (DISASSEMBLED)

Figure 26 FINAL PROTOTYPE - INTERCHANGEABLE UNI-SOLE (ASSEMBLED)

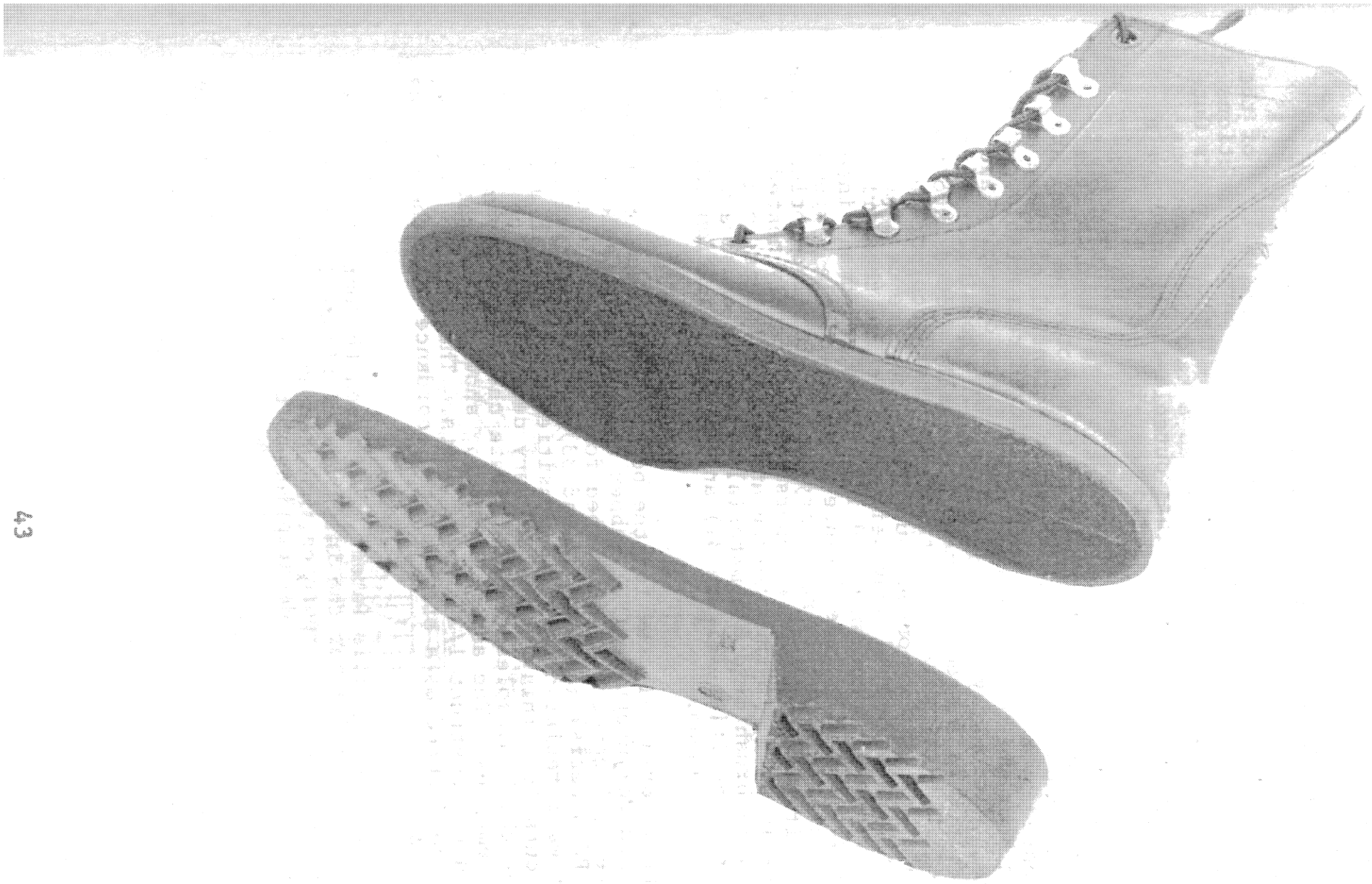


Figure 27 FINAL PROTOTYPE - INTERCHANGEABLE UNI-SOLE (DISASSEMBLED)

6.2 Improved Traction and Negative Heel Outsole

The model selected to illustrate the compatibility of the interchangeability of outsoles with special purpose functions was the Quick Closure Upper with the Retractable Grippers Outsole. These concepts were evolved as a task of a previous contract, DAAG17-73-C-0147. This outsole is intended for a traction aid over winter or Artic terrain.

The drawing of this outsole concept is shown in E6267-D-300, (Figure 28) and photographs of the prototype model are shown in Figures 29 and 30. Traction potential of these models is enhanced by a four-member set of hinged retractable grippers on each boot which are retained in both the operating and storage positions by a friction lock. The housing or carrier of this lock is a steel weldment integrally molded into the outsole. The grippers are metal forms that incorporate hardened material at the contact surface. They are designed in a configuration so normal body weight will cause the surface failure of hard packed snow and ice. This embedment into the surface provides the interference between outsole system and terrain material that is necessary to transmit locomotion shear and inhibit sliding. The grippers are intimately nested with the outsole shape in the storage and use positions to avoid catching on brush or other material which may cause a misstep. The storage position (Figure 31) and the use position (Figure 29) are both shown.

The material elected for the body of the traction outsole was foamed Polyurethane (PU) rubber. A sample outsole in a negative heel concept is furnished for engineering evaluation of the PU material (Figures 32 and 33). This material has excellent wear resistance at low densities resulting in a light weight outsole. This feature is very desirable due to the need for thick outsoles to incorporate the integrally molded tube assemblies. The assembly drawing shows all of the parts required to construct 1/2 pair of boots. The gripper, however, will be configured as a stamping in accordance with the drawing (Figure 34).

The interchangeable interface between the outsole and the upper is patterned after the interface of Figure 14, drawing E6281-D-302, which incorporates the stem and loop material installed according to the description of the previous section.

Forming the PU bottom requires a precisely measured quantity of hardening and foaming agents to produce an adequate bottom. The formulation of the compounds and establishment of the process cycle require a trial and error procedure. Once established, the process is relatively fixed and amenable to

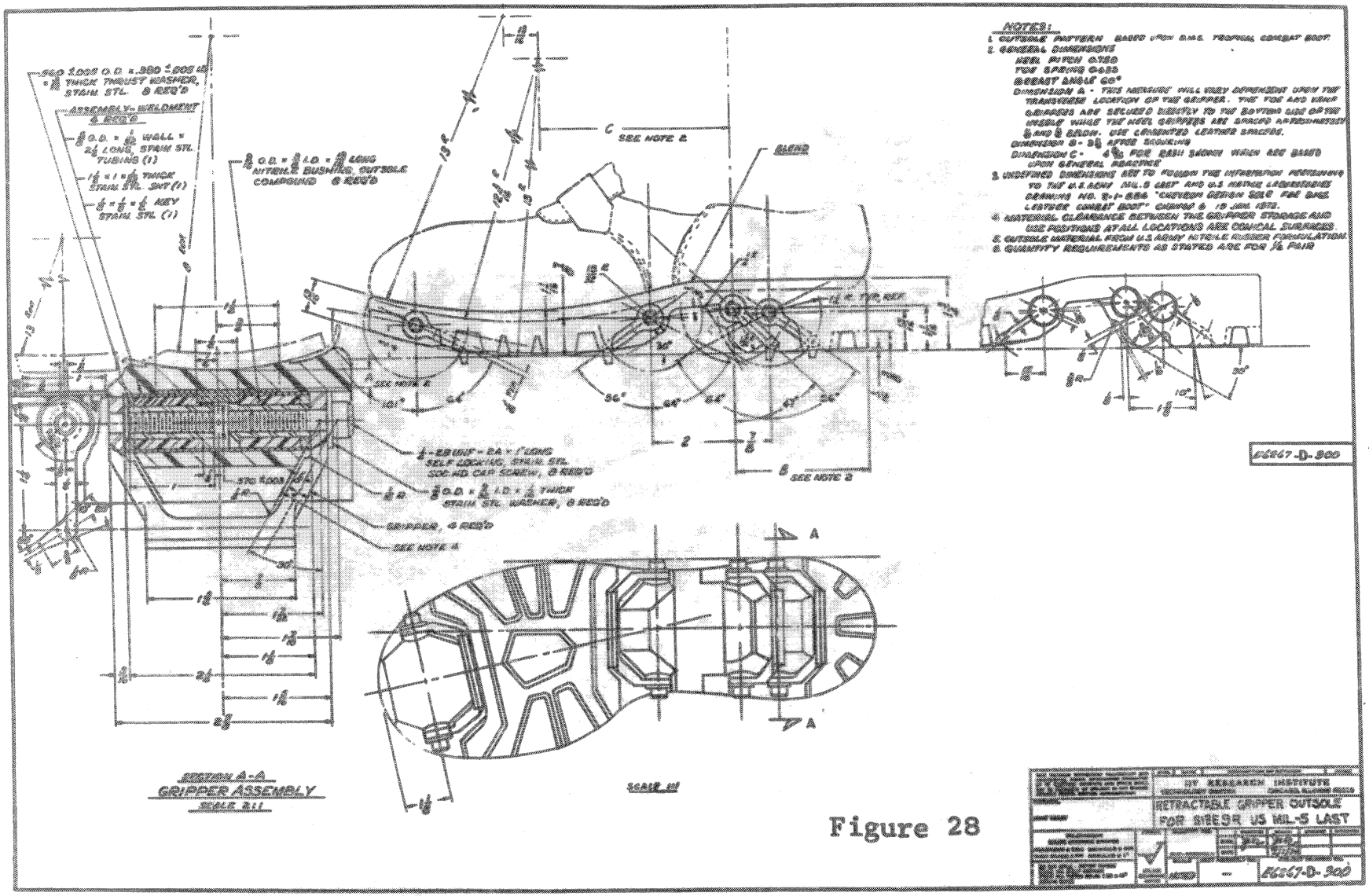

NOTES:
1. OUTSOLE PATTERN BASED UPON U.S.A. TROPICAL COMBAT BOOT.
2. GENERAL DIMENSIONS
HEEL PITCH 0°30'
TOE SPRING 0°30'
BREAST ANGLE 60°
DIMENSION A - THIS MEASURE WILL VARY DEPENDENT UPON THE TRANSVERSE LOCATION OF THE GRIPPER. THE TOE AND HEEL GRIPPERS ARE SECURED DIRECTLY TO THE BOTTOM SIDE OF THE INSOLE WHILE THE HEEL GRIPPERS ARE SPACED APPROXIMATELY 3/8 AND 5/8 BELOW. USE CALIBRATED LEATHER GAUGES.
DIMENSION B - 3/8 AFTER SKIVING
DIMENSION C - 4 3/16 FOR 8EE9 SIZING WHICH ARE BASED UPON GENERAL PRACTICE
3. UNDEFINED DIMENSIONS SET TO YOUTH THE INFORMATION APPEARING TO THE U.S. ARMY MIL-S LAST AND U.S. NAVAL LABORATORIES DRAWING NO. 2-1-888 "CHEVRON DESIGN SOLE FOR BASE LEATHER COMBAT BOOT" DATED 6 JAN. 1972.
4. MATERIAL CLEARANCE BETWEEN THE GRIPPER STORAGE AND USE POSITIONS AT ALL LOCATIONS ARE CONICAL SURFACES.
5. OUTSOLE MATERIAL FROM U.S. ARMY NITRILE RUBBER FORMULATION.
6. QUANTITY REQUIREMENTS AS STATED ARE FOR 1/2 PAIR
SEE 2.005 O.D. x .990 ± .005 I.D. x 1/16 THICK THRUST WASHER, STAIN. STL. 8 REQ'D
ASSEMBLY-WELDMENT 8 REQ'D
3/8 O.D. x 1/16 WALL x 2 1/4 LONG, STAIN STL. TUBING (1)
1/4 x 1 1/8 THICK STAIN STL. SHT (1)
3/8 x 1/8 x 1/4 KEY STAIN STL. (1)
3/8 O.D. x 1/4 I.D. x 1/8 LONG NITRILE BUSHING, OUTSOLE COMPOUND 8 REQ'D
SEE NOTE 2.
MACRO
1/4-28 UNF-2A x 1" LONG SELF LOCKING, STAIN STL. SOCKET CAP SCREW, 8 REQ'D
3/8 O.D. x 1/4 I.D. x 1/16 THICK STAIN STL. WASHER, 8 REQ'D
GRIPPER, 4 REQ'D
SEE NOTE 4
SECTION A-A
GRIPPER ASSEMBLY
SCALE 2:1
SCALE 1:1
66267-D-900
ST. REGIS PAPER CO.
RETRACTABLE GRIPPER OUTSOLE
FOR 8EE9R US MIL-S LAST
66267-D-900

Figure 28

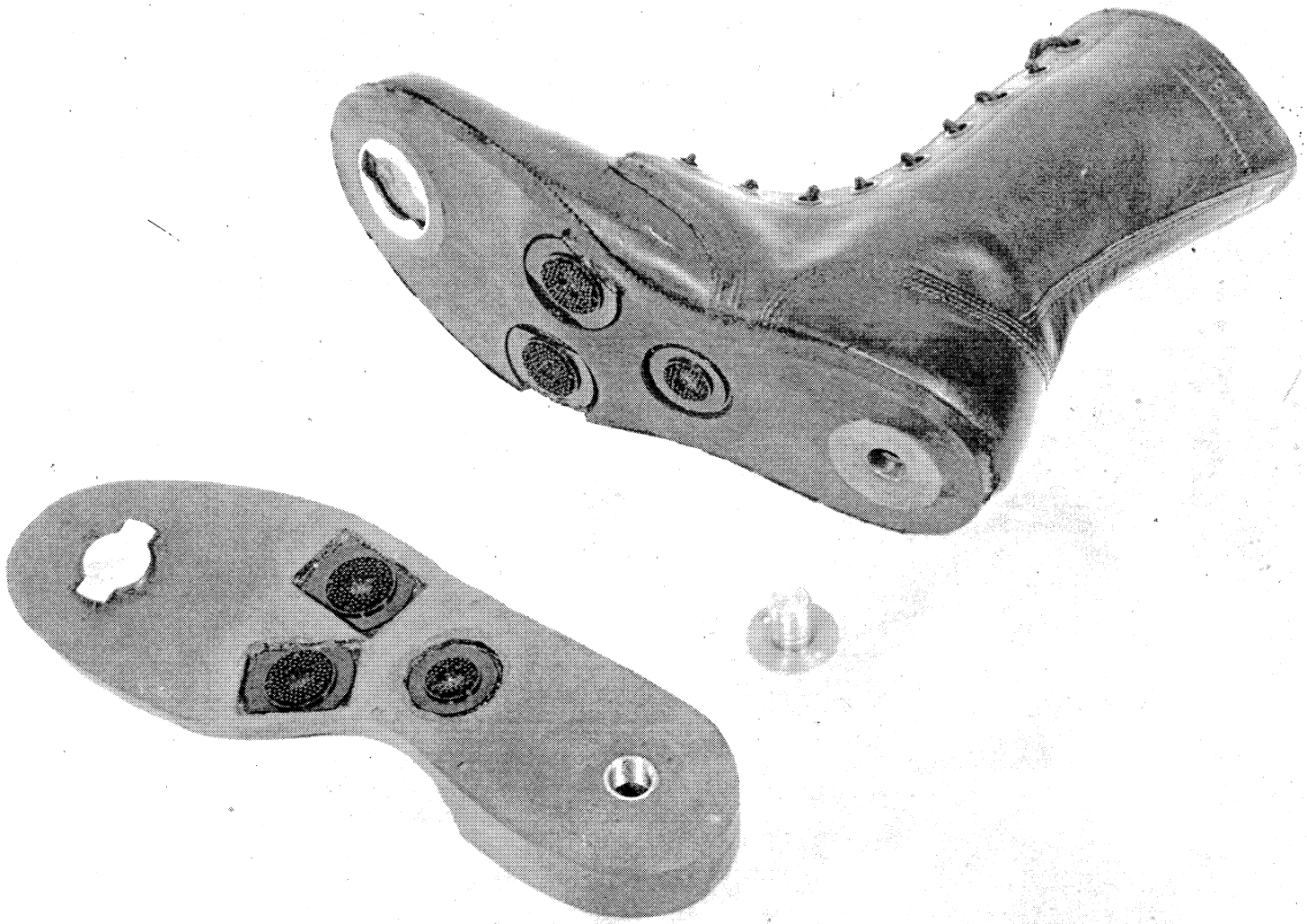


Figure 21 LOCKING SYSTEM - CONCEPT 4A

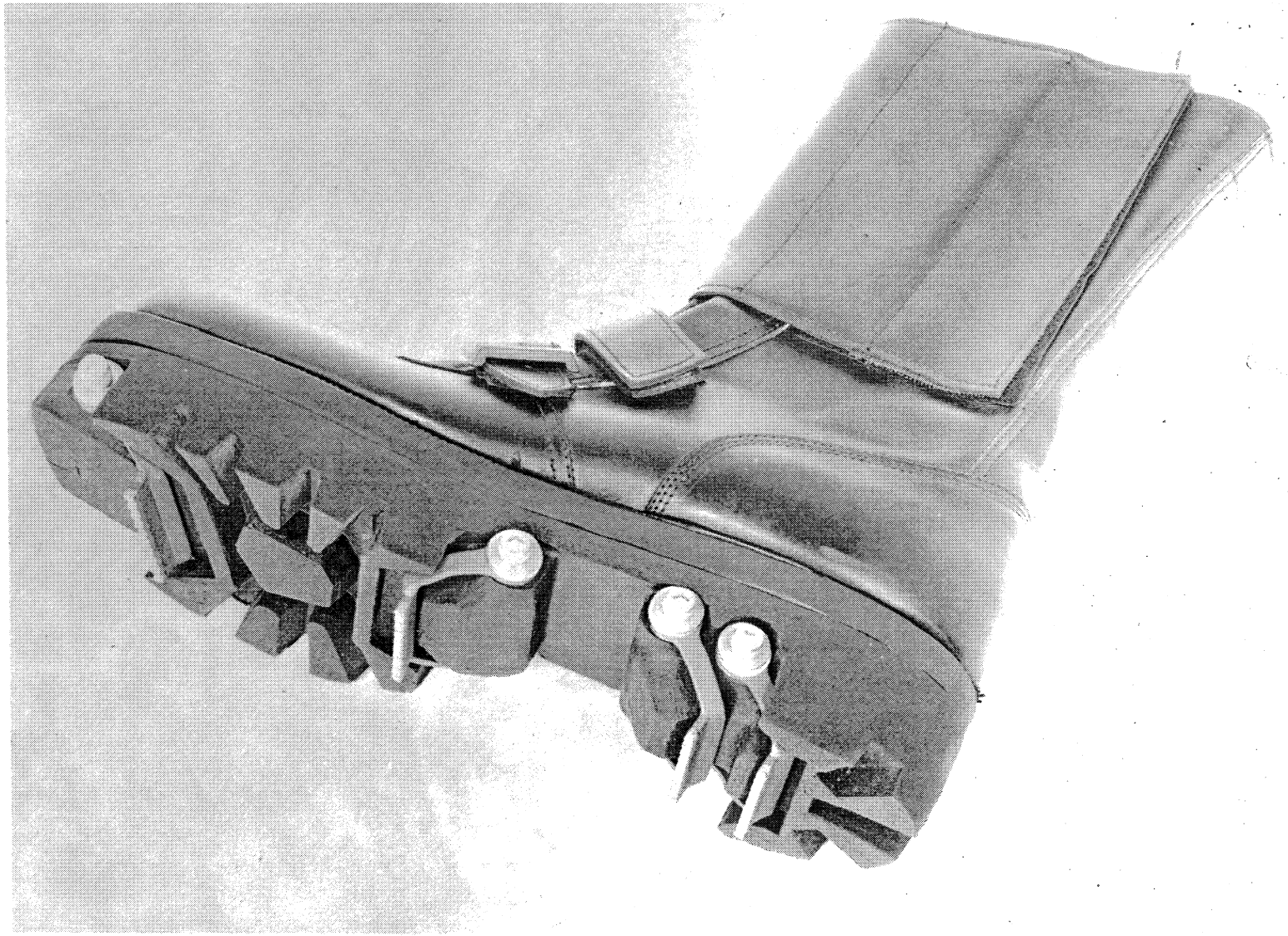


Figure 29 INTERCHANGEABLE OUTSOLE WITH TRACTION AID IN USE POSITION ON A QUICK CLOSURE UPPER (ASSEMBLED)

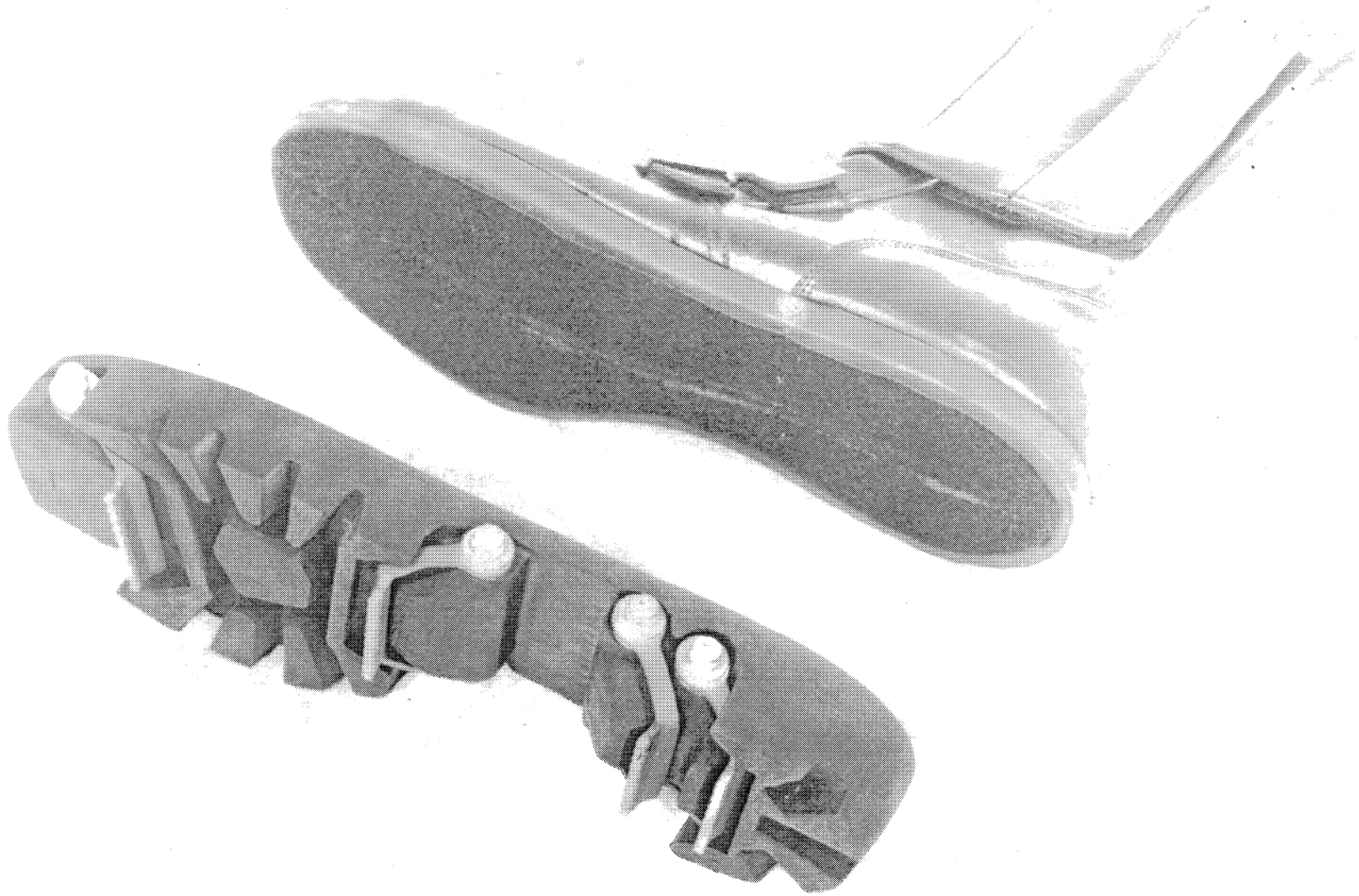


Figure 30 INTERCHANGEABLE OUTSOLE WITH TRACTION AID ON A QUICK CLOSURE UPPER (DISASSEMBLED)

Figure 31 OUTSOLE PAIR WITH TRACTION AIDS IN STORAGE POSITION

Figure 32 INTERCHANGEABLE OUTSOLE WITH NEGATIVE HEEL ON A QUICK CLOSURE UPPER (ASSEMBLED)

Figure 33 INTERCHANGEABLE OUTSOLE WITH NEGATIVE HEEL WITH A QUICK CLOSURE UPPER (DISASSEMBLED)

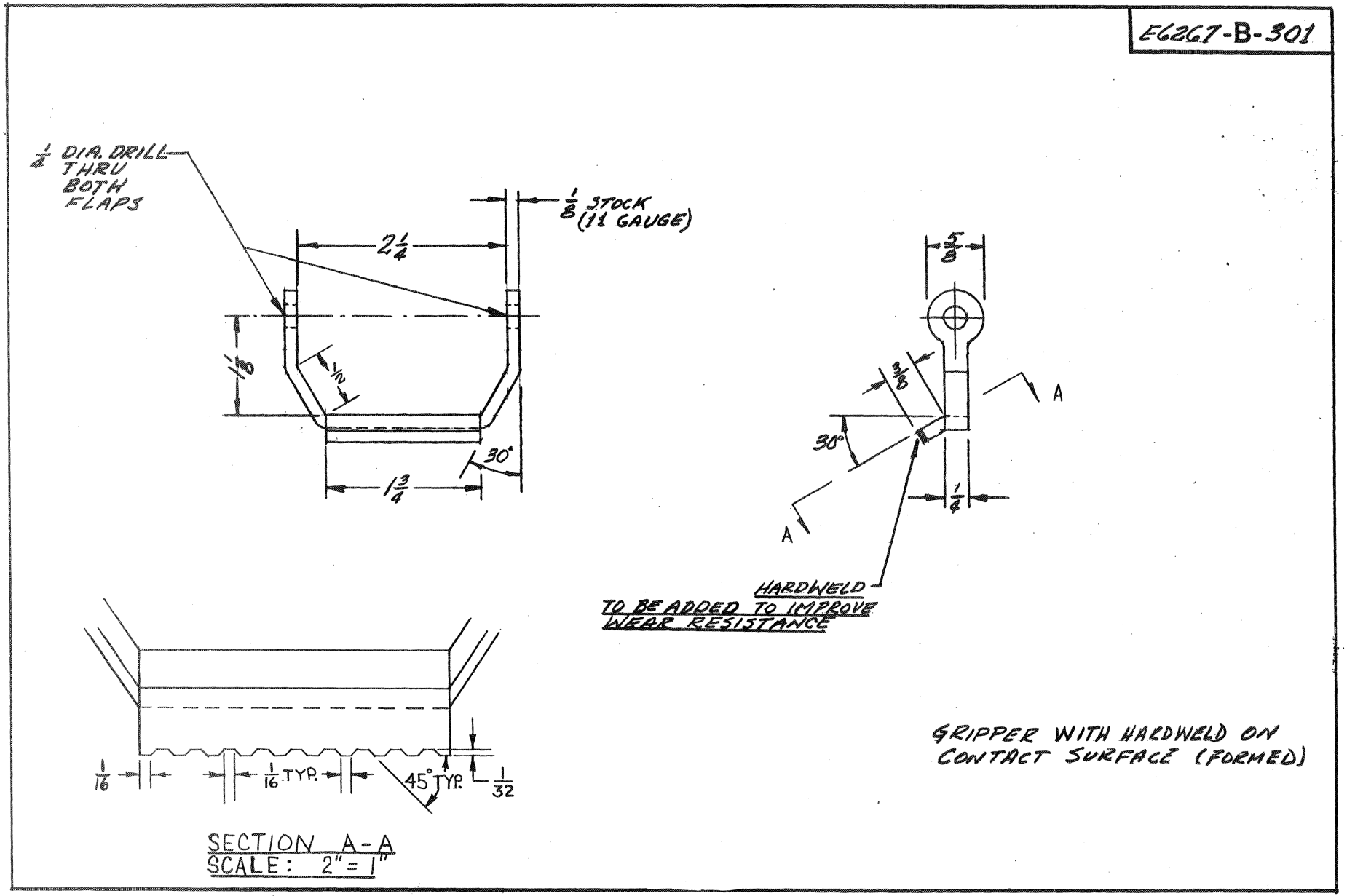

E6267-B-301
1/2 DIA. DRILL THRU BOTH FLAPS
1/8 STOCK (11 GAUGE)
2 1/4
1/8
1/32
30°
1 3/4
5/8
3/8
A
30°
A
1/4
HARDWELD TO BE ADDED TO IMPROVE WEAR RESISTANCE
GRIPPER WITH HARDWELD ON CONTACT SURFACE (FORMED)
1/16
1/16 TYP.
45° TYP.
1/32
SECTION A-A
SCALE: 2" = 1"

Figure 34

the requirements of production. For this program, a Ro-Search, Incorporated in-process procedure and material was employed.

The bottoming process requires prepositioning the four tube weldment assemblies within the outsole mold cavity. Figure 35 shows the tooling.

It is essential that each tube assembly position be maintained with respect to the outside surface of the finished outsole to assure adequate gripper location or nesting in the functional and storage positions. Tube weldment location is assured by inserting four removable pins into the outsole mold, which serve both to locate and to plug the inside of the tube weldments during molding.

6.3 Comparison of Weights Between Models

A table of the weights (Table 3) of 1/2 pairs of a variety of configurations has been generated for the purpose of comparison. In general, the prototypes are heavier than the 24 ounce standard one-piece construction. It is the writer's opinion, however, that it is possible to construct a combat boot with a midsole and a thin reinforced interchangeable nitrile outsole in a modified chevron pattern that compares favorably in weight with the standard. It is also the writer's opinion that special purpose footwear, whether the outsoles are interchangebale or otherwise, will in general, be heavier than conventional footwear. The uppers with midsoles furnished under contract are not of an optimum weight. The prototypes, as manufactured, weigh 24 ounces for the Speed Hook Upper and 24 ounces for the Mil-Quick Upper, which is very close to the 24 ounce Standard Combat Boot. The standard boot, however, includes the full outsole shape (foresole and heel). Both of the prototype models include a steel shank, which increases the weight. This shank may not be required in the interchangeable design as foot support may be provided due to the increased stiffness of the thicker outsole/midsole combination. The weight of an interchangeable outsole in either version of uni-sole or removable heel is about 17 ounces. The outsole includes a 1-3/8 inch rubber heel and a 5/8 inch foresole. The solid core section varies from 1-5/32 in the heel to a range of 1/4 to 3/8 inch in the instep and foresole area. Optimal design could reduce this weight by 50% with thinner core sections, fillers and/or lightweight materials.

The weight of a 1/2 pair of 9R boots, 8-1/2 inches high standard upper construction, with Speed Hook closures and an interchangeable nitrile uni-sole is 39 ounces. This same upper with the negative heel PU outsole weighs 31 ounces.

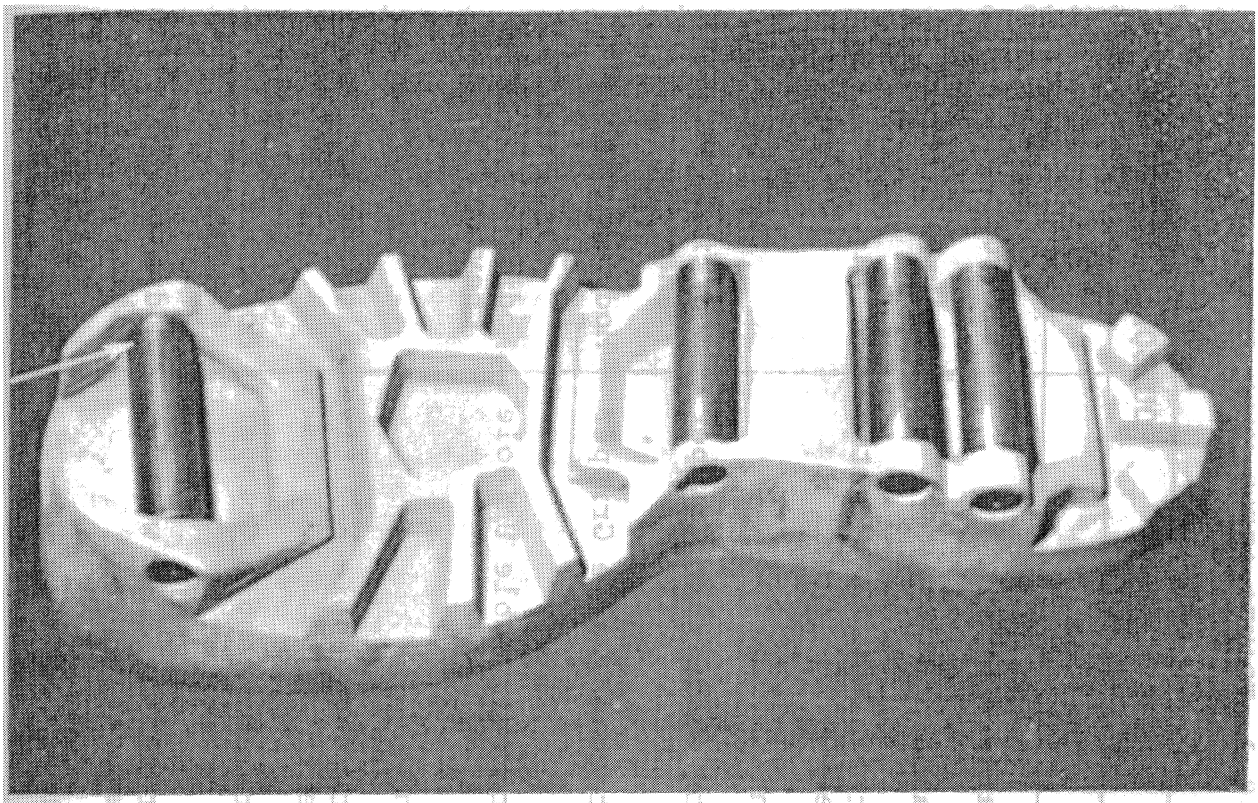


Figure 35 POSITION OF INTEGRAL COMPONENTS

Table 3 WEIGHT TABLE SIZE 9R

UPPER	MIDSOLE	OUTSOLE			WEIGHT
		Type	Pattern	Material	Total Oz.
Std., Combat Boot	None	Standard DMS	Chevron	Nitrile	24
Mil-Quick Closure	None	Standard DMS	Chevron	Nitrile	29
Mil-Quick Closure	Nitrile	Interchangeable Negative Heel	Plain	PU*	33
Mil-Quick Closure	Nitrile	None			24
Mil-Quick Closure	Nitrile	Interchangeable Gripper	Modified Panama	PU	47
Std., Eyelet	Nitrile	Interchangeable Gripper	Modified Panama	PU	42 (est)
Mil-Quick Closure	Nitrile	Interchangeable Unisole	Modified Chevron	Nitrile	41
Std., Speed Hook	Nitrile	None			22
Std., Speed Hook	Nitrile	Interchangeable Negative Heel	Plain	PU	31
Std., Speed Hook	Nitrile	Interchangeable Gripper	Modified Panama	PU	44
Std., Speed Hook	Nitrile	Interchangeable with Removable Heel	Modified Chevron	Nitrile	39
Std., Speed Hook	Nitrile	Interchangeable Unisole	Modified Chevron	Nitrile	39

*PU -- Polyurethane Rubber.

The weight of a 1/2 pair of prototype boots incorporating the speed hook uppers and the Retractable Gripper outsoles is 44 ounces. This weight includes 22 ounces for the upper and 22 ounces for the complete outsole. The basic outsole which includes the integrally molded weldment assembly weighs 12.6 ounces for 1/2 pair. The weight of the stamped and welded gripper with associated non-molded components is 2.26 ounces per assembly or 9.04 ounces for the four units in the 1/2 pair.

The weight of the boot with the Quick Change upper and the Traction Aid outsole is 47 ounces, and the weight of a standard combat boot 8-1/2 inch upper with the Traction Aid outsole is estimated at 42 ounces.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The program has accomplished the stated objective of producing footwear with an interchangeable outsole. The resulting product is adequate structurally for a preliminary model and furthermore, seems to be of sufficient quality to evaluate performance in initial wear and engineering tests.

Additional consideration, however, should be provided for four areas of investigation, if preproduction or engineering models are desired.

1. Conduct a series of tests based upon biomechanical forces and the terrain environment to determine if the midsole/outsole interface performance will be compromised. Tests should include walking, running, and jumping in varying terrain conditions of sand, clay, water, and other materials, and at varying temperatures.

2. Develop an adhesive process to provide a more peel resistant bond of the stem tape to the outsole, or develop a stem material which is compatible with high temperature coating and available heat curing adhesive materials and processes.

3. Study various methods and materials for edge sealants to improve the long term sealing and esthetic appearance of the interface edge. A suggested material is Black Butyl Rubber applied from the tube as a caulking or a thin flexible tape that adheres to nitrile which can be used to seal the edge if desired.

4. The traction aided outsole with the Retractable Grippers employed foamed polyurethane rubber in construction. Evaluate light-weight foamed polyurethane rubber to determine the influence of a reduced wet friction coefficient on footwear performance. Any test should consider the effect of outsole patterns, structural configuration, floor materials and contaminating agents to obtain a comprehensive evaluation. (The literature provides conflicting testimony on the adequacy of polyurethane sole material against water wet floor surface materials. Further, there is scarcity of information for viscous contaminating agents, such as petroleum products, which are of major concern. These tests could be conducted with the equipment developed for material evaluation by the NDCS CEMEL Rubber Laboratory.)

BIBLIOGRAPHY

1. "Metals Properties", edited by S. L. Hoyt, ASME Handbook, McGraw Hill Book Company, 1954.

2. "Design Guide Scotchmate Hook and Loop Fasteners", 3M Company.

3. "Temporary Design Guide (Scotchmate Brand High Strength Fasteners and Supplementary Temporary Data Sheet on High Strength 'Scotchmate'", 3 M Company.

4. "Design Guide Hedlok I Fasteners", 3M Company, Industrial Specialties Division.

5. "Marks Standard Handbook for Mechanical Engineers", Seventh Edition, McGraw Hill Book Company.

6. "Conceptual Combat Footwear Study", U. S. Army Natick Laboratories, IITRI Report No. E6267, J. L. MacDonald and E. Swider.

7. "The Language of Rubber", E. I. DuPont Nemours and Company Elastomer Chemicals Department.

8. Military Specifications: A. MIL-B-43481B, dated May 1972, "Boots, Combat, Men's, Leather, Black, Direct Molded Sole, Paragraph 3.34 - Outsole and Heel, Rubber; B. MIL-L-3122F, dated 5 August 1971, "Leather, Cattlehide for Footwear Uppers, Chrome Tanned, Fat Liquored".

9. Various letter communications, Ro-Search Incorporated, Waynesville, North Carolina, with A. Biebscher, 1972-1974.

10. "Horizontal Static Forces Exerted by Men Standing in Common Working Positions on Surfaces of Various Tractions-Including Coefficients of Friction Between VArious Floor and Shoe Materials," by K. H. E. Kroemer, et al., Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, January, 1971.

11. "Investigation of Methods for Improving the Frictional Properties of Rubber Compounds Used in Footwear", U. S. Army Natick Laboratories, by P. J. Mahoney, 1971, AD733312.

12. "Development of Techniques for Evaluating Frictional Properties of Rubber Sole and Heel Compounds," U.S. Army Natick Laboratories, A. F. Wilson, et al., 1970, AD713868.