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HIGHLY ARTICULATE FULL PRESSURE GLOVE
FINAL REPORT

May 1971

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Prepared Under Contract No. NAS2-6154 by

SPACE-AGE CONTROL, INC.
Palmdale, Calif.

for

Ames Research Center
National Aeronautics and Space Administration

No Distribution Restriction

UNCLASSIFIED

Norman B. Foster
Norman B. Foster
President

1. SUMMARY

1.1 Work started on the Highly Articulate Full Pressure Glove development program at Space-Age Control, Inc. on October 1, 1970.

1.2 Objectives of the contract were the development of a full pressure glove that would provide maximum digital dexterity, tactility and stability at an operating pressure of 5 PSID.

1.3 The seven month program encompassed the development and fabrication of a Highly Articulate Full Pressure Glove in 3 tasks.

Task 1 - Thumb/Finger Development
Task 2 - Glove Development
Task 3 - Glove Fabrication and Assembly

1.4 A new technology report has been prepared and delivered. New technology judged to be a substantial advance in the art occurred in two areas.

1.4.1 Mini-convoluted nylon/neoprene laminated fabric was developed.

1.4.2 Axial restraints located in conduits compensate for pneumatic return force in the fingers.

1.5 The glove was shipped to NASA Ames Research Center on May 4th 1971.

2. INTRODUCTION

2.1 Techniques have been developed during the past few years which make possible the construction of highly mobile, stable, articulated sections for pressure suits. The hard space suits demonstrated stable, low torque joint elements using metal rings and linkages. Other developments brought low-torque, stable pressure suit joints into soft, all-fabric suit construction.

2.2 However, none of the pressure suit mobility techniques developed to date would lend themselves to reduction in size such that a finger or thumb-size joint element could be successfully fabricated. The small size of the fingers and their closeness to each other preclude the use of linkages or external mechanisms, yet in order for a man in a pressure suit to perform any meaningful tasks, he must have the maximum freedom of digital movement.

3. ACTIVITIES AND ACCOMPLISHMENTS

3.1 History of Development

3.1.1 Single Axis Joint. A single axis joint was developed utilizing a special developed random mini-convolute fabric. A restraint cord on each side of the finger was constrained by a bonded sleeve which allows some small translation of the cord during finger flexing. This translation compensates for the spring rate of the finger assembly caused by the volume increase which occurs when the finger is bent and the mini-convolutes extended. An orderly mini-convolute was developed during the program and was utilized on the deliverable glove (Photo 1).

3.1.2 Dual Axis Joint. It was recognized from the beginning that the most difficult problem in the glove development would be to achieve adequate performance in the thumb with its two axis requirements. The investigation started with a conical section base which was retained throughout the program. A cable transfer system was used. Gathered fabric was utilized with link net for a circumferential restraint. The cable transfer system first used small formed teflon turn arounds. These proved structurally inadequate and caused an interference problem. A later attempt utilized a thumb ring for one anchor and a teflon tube with stainless steel inserts at the tube terminations. The deformation under stress caused the cords to be cut by the stainless terminations at the teflon tube interface. The final configuration utilized an all stainless tube (Photo 2, 3, & 4). This did not provide an adequate joint and made the glove too small for the hand of the technical monitor. The cable transfer system was removed and the glove delivered with eyelets and two restraints cords. This solution was obviously unsatisfactory.

3.1.3 Palm Restraint. The palm restraint must of course stop any bollooning of fabric in the palm area and must also be without hot spots which cause discomfort. The proper location of the restraint is shown by the skin fold lines in the cupped hand. This was approached but could not be placed in the ideal location due to the large conical base of the thumb. The restraint went around the hand on only the thumb side to reduce the likelyhood of hot spots. The restraint was fabricated from 3/32 dia. 17-4 PH cres wire TIG welded and heat treated to condition H 1025.

3.2 Glove Design

3.2.1 Glove Development Model. The development model glove was fabricated to fit the program managers left hand. Random gathered mini-convolute fabric was used on the finger and metacarpal back. Smooth laminated fabric was used on the inside of the fingers for maximum tactility. The axial restraint cords were located in conduits of approximately 3/32 dia. A takeup strap and buckel was placed on the back of the glove. Satisfactory thumb mobility was not obtained.

3.2.2 Deliverable Glove. The deliverable glove was fabricated to fit the right hand of the technical monitor. A more advanced material which had an orderly mini-convolute was developed. This new material was used in the fabrication of the deliverable glove. The conduits for the axial restraint cords were increased to 1/8 inch. A certain amount of twist occurred in the development glove fingers, particularly in the little finger. The fabric was separated and reattached on the deliverable glove in a straighter manner on both the index and little finger (Photo 5). This did eliminate the twisting during finger flexion and extension.

In the metacarpal joint of the development glove there was significant ballooning. This was overcome by lengthening the fabric restraint which circumscribes the glove. This did overcome the ballooning. Unfortunately it was lengthened on both the palm and back side. The increased length on the palm side caused interference with the fingers when they were flexed. It was found that the take-up strap and buckel were not needed so these items were removed from the design prior to the fabrication of the deliverable glove (Photo 6). Satisfactory thumb mobility was still not obtained.

3.3 Fabrication Techniques

3.3.1 Gathered Fabric. The gathered fabric is made from laminated nylon ripstop which is described on SAC Drawing 100111. This fabric is placed on a tool SAC Number T100112-1 LM (See 5.3) by roving. The roving is covered with PVA Film and vacuum bagged. The fabric then is given an oven cure for one hour at 300°F. Following this cure the laiminated fabric is cut from the tool on both sides of the seam and placed on another layup mandrel for final cure and heat set.

3.3.2 Bonding. The bonding of laminated fabric is described on SAC specification 980008 which is included as an attachment.

3.3.3 Mandrels

3.3.3.1 Development Glove. The development glove started with a cast silicone rubber master hand. This was the left hand of the program manager. The master hand was modified to include a cylindrical sleeve to interface with the glove disconnect. The thumb base was enlarged to allow for additional fabric. From this silicone rubber mandrel, a plaster mold and then an epoxy mandrel was made. The epoxy mandrel was cut on planes for easy removal from the fabric glove after cure. During glove fabrication, it was determined the epoxy mandrel was not required.

3.3.3.2 Deliverable glove. The deliverable glove started with a customer furnished cast silicone rubber master hand. This was the right hand of th technical monitor. A smoothed plaster mold was made from the master hand. The thumb was increased in diameter by 10%. The thumb base was modified to the enlarged section. The wrist was enlarged to the cylindrical section required. Pattern development and glove final cure utilized this mandrel.

3.4 Operational Capabilities

3.4.1 Finger Phalanges. The glove is capable of bending over the finger phalanges to the capability of an ungloved man.

3.4.2 Finger Metacarpals. The finger metacarpals are capable of bending to approximately 90° without restriction. Greater bending would be achieved by shortening the fabric in the palm support.

3.4.3 Small Object Grip. The mobility of the finger phalanges and metacarpals allow the grip of objects the size of a lead pencil.

3.4.4 Tactility. The laminated material on the finger pads and dipped material on the finger tips provide tactil sensation equal that achieved in other pressure gloves. (Photo 7 and 8)

3.4.5 Finger Spread. The glove allows the fingers considerable spread and yet allows them to come in contact with each other. The spread can be changed thru adjustment of the cords.

3.4.6 Finger/Thumb Touch. Even with the thumb operation deficiency, the thumb and each of the finger tips can be brought together.

3.4.7 Side Arm Controls. If the glove is to be used with side arm controls, wrist mobility in both axis must be added. This was not a task of this contract.

3.4.8 Thermal/Micro Metorite Protection. There is no EVA capability without a TMG. This was not a task of this contract.

3.5 Recommendations for Further Study

3.5.1 General Recommendations. It is recommended that a glove be fabricated using the mini-convolutes in all areas except the palmal side of the hand and that the thumb and fingers be designed such as to take a half closed position. This would result in a basic glove to be used for development purposes in experimenting with various restraint systems, without changing the basic glove. This will result in ease of changes at a minimum of cost and time and will result in a glove having much improvement in single axis mobility. This method will demonstrate the amount of 2 axis mobility in the thumb and wrist (resulting from the mini-convolute method) without the use of additional hardware. A glove designed in this manner will definitely be a considerable improvement in the state of the art.

3.5.2 Mini-Convolute Fabric. Better utilization of the mini-convolute fabric could be achieved by continuing this material up the back of the hand and into the wrist. Smaller seam construction along the restraint lines would aid in reducing torque and would extend the neutral range of motion of the finger joints.

3.5.3 Finger Restraint Cord. The restraint cord that is attached between the fingers is a potential failure point. At this location, the cord should be replaced with nylon tape for improved reliability.

3.5.4 Thumb Improvement. The area that requires the most effort is the thumb. The size of the base of the thumb is critical to the location of the palm restraint and therefore effects the whole operation of the glove as well as the thumb itself. The thumb should be constructed as two single axis joints utilizing the very successful mini-convolute fabric. This would result in a minimum sized thumb with no cluttering hardware.

The thumb should be aimed in such a manner that when a large circumference, 1 7/8 inch diameter for the 60 percentile grip, is grasped the thumb would just come in contact with the middle finger. The thumb metacarpal should be constructed using mini-convoluted fabric on the palm side so that the convolutes would open when the thumb is extended. The thumb phalanges should be constructed with the mini-convolute fabric on the back so that the mini-convolutes would open when the thumb is flexed. This would place laminated fabric on the thumb pad for maximum tactility. Considerable testing would be required to place the axes of these joints in the proper planes to give maximum capability to the thumb.

3.5.5 Wrist Joint. A wrist joint with two axis mobility is a requirement when utilizing side arm controls. A two axis wrist that is extremely reliable, light weight and functional could be fabricated utilizing the mini-convolute joint technique and a light weight transfer ring. This joint would be located in the cylindrical sleeve. The wrist joint should be investigated separately prior to installation in a pressure glove.

3.5.6 Separate Restraint. Investigation should be made concerning the feasibility of fabricating the glove pressure barrier and the glove restraint separately. This should provide considerable flexibility in the design and use of the pressure gloves. It would allow different restraints to be investigated and evaluated without rebuilding the entire pressure glove. It would probably also reduce cost of glove production.

3.5.7 10 PSID Operation. The glove was pressurized to 9 PSID. It still had excellent finger dexterity and tactility. Following solution of the other problem areas a 10 PSID glove should be investigated.

4. CONCLUSIONS

The glove made a substantial improvement in the art in the area of finger dexterity. The tactility of the glove was also outstanding. These improvements were largely the result of the newly developed mini-convolute laminated nylon/neoprene material combined with the axial restraint system. There is a need for substantial improvement in the thumb area. This could be made using a mini-convolute material and single axis joints. A two axis wrist is required for certain operational capability and could be made light weight and reliable using the mini-convolute material and a ring for load transfer. The glove was pressurized to 9 PSI and the finger dexterity and tactility were still outstanding. This indicates that a 10 PSID glove is feasible.

5. APPENDIX

5.1 Bonding of Laminated Fabric. SAC Specification 980008

5.2 Photo Record

5.3 Tool, SAC Number T100112-1

APPENDIX

Photo Record

1. Mini-Convoluted Fabric
2. Glove Palm
3. Glove Front
4. Glove Thumb Side
5. Glove Finger Metacarpal
6. Glove Back
7. Glove Little Finger Side
8. Glove Finger Tips and Axial Restraints

SAC

SPACE-AGE CONTROL, INC.

CODE IDENT 34851	NUMBER 980008	REV -
SHEET 1 of 3	PREPARED BY C. Breslin	
RELEASE DATE 23 April 1971	ENGINEERING C. Breslin 23 APRIL 71	

DOCUMENT TYPE

PROCESS SPECIFICATION

QUALITY CONTROL L. Campbell 23 APRIL '71

TITLE

LAMINATED FABRIC, BONDING OF

CONFIGURATION MANAGEMENT C. Breslin 23 APRIL '71

APPROVED

REVISIONS

LTR	EC	DESCRIPTION	DATE	APPROVED

REV STATUS OF SHEETS	REV																														
	SHEET																														

1. SCOPE

1.1 Scope. The scope of this Process Specification is to establish the requirements for assembling laminated fabrics by bonding.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the issue in effect on the date of invitation for bids or request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATION

Federal

TT-T-548c	Toluene

3. REQUIREMENTS

The following paragraphs define the equipment, materials, and procedures required to assembly laminated fabrics.

3.1 Equipment

Hand roller	Commercial item
Masking tape	
Air-circulating oven	Depatch oven

3.2 Materials

1.6 oz neoprene coated laminated rip stop
HT-16-41 neoprene coated nylon nomex
Toluene
Cement, white neoprene 16 EX7A-2

3.3 Required procedures and operations

3.3.1 Viscosity. Thin the cement with toluene as required.

3.3.2 Fabric preparation. Mask the laminated fabric adjacent to area to be coated with adhesive (Figure 1). All areas of the fabric to be coated with adhesive shall be cleaned with toluene and allowed to dry thoroughly (approximately 5 minutes) prior to adhesive application.

3.3.3 Fabric bonding. Apply three coats of adhesive to the fabric as shown in Figure 1. Allow 15 minutes drying time on the first two coats. Allow the third coat to dry until tacky prior to bonding together. One additional coat of adhesive may be applied to bring up the tack.

3.3.4 Roll fabric to ensure all air has been removed.

3.3.5 Curing

3.3.5.1 Oven cure. The fabricated assembly shall be oven cured at 300°F for 1 hour.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Assurance shall ascertain that fabric in laminated areas is free from air bubbles and wrinkles that would affect performance or integrity.

4.2 Quality Assurance shall perform or monitor random fabric pull tests to verify structural bond.

4.3 Quality Assurance shall monitor curing cycles as required.

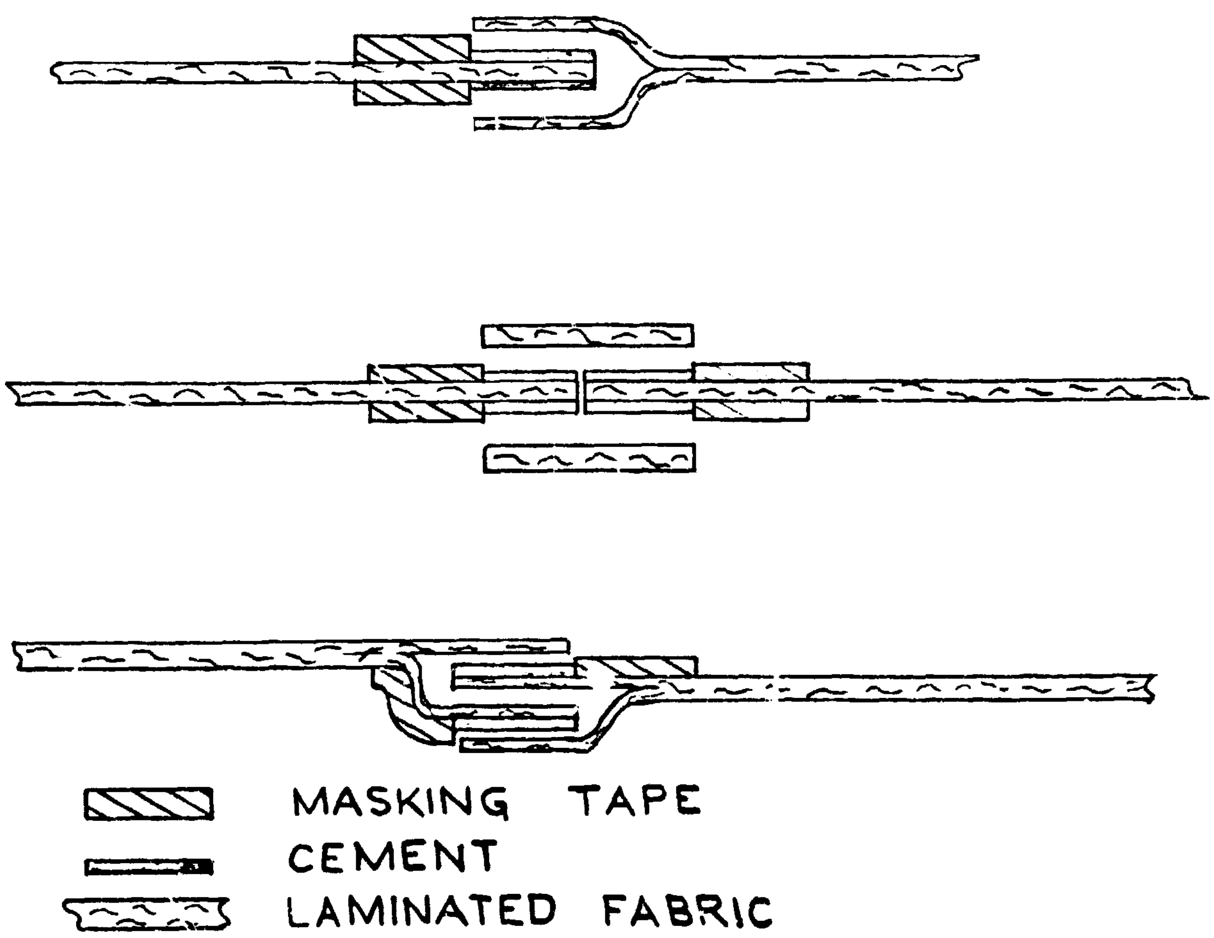
5. PREPARATION FOR DELIVERY

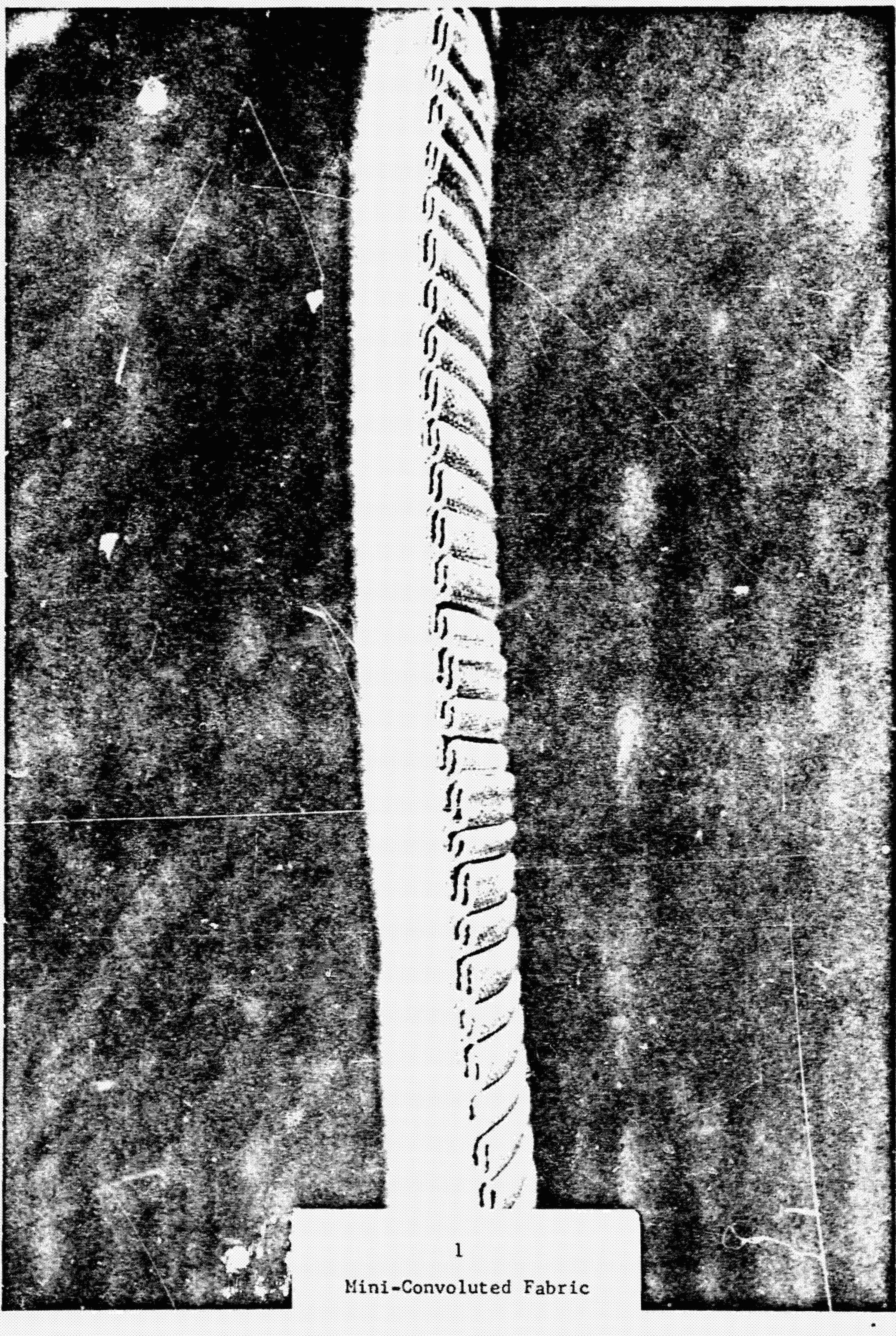
This section is not applicable to this specification.

6. NOTES

6.1 Intended use. This process is used for the assembly of laminated bladder fabrics.

Figure 1





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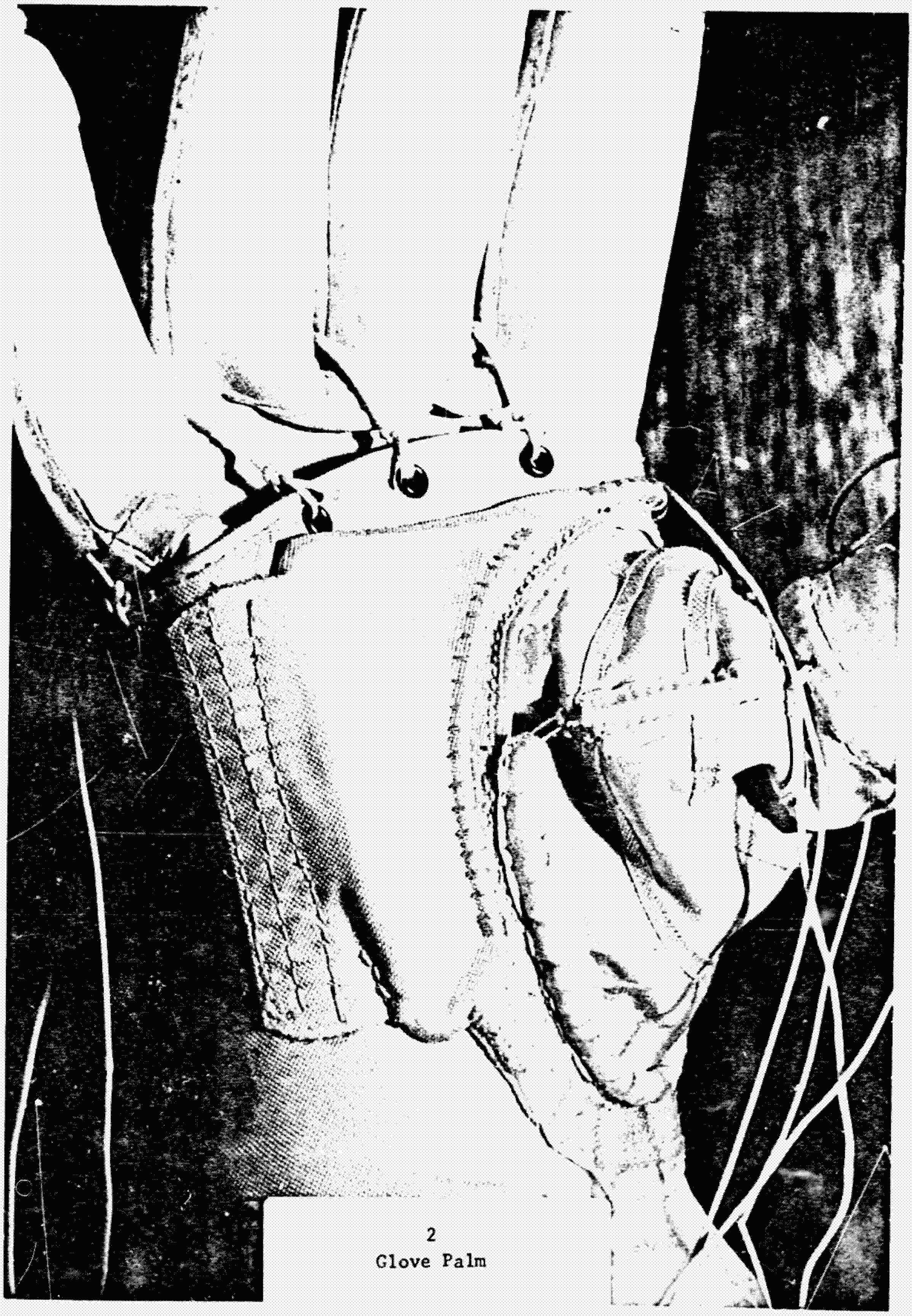
Mini-Convoluted Fabric



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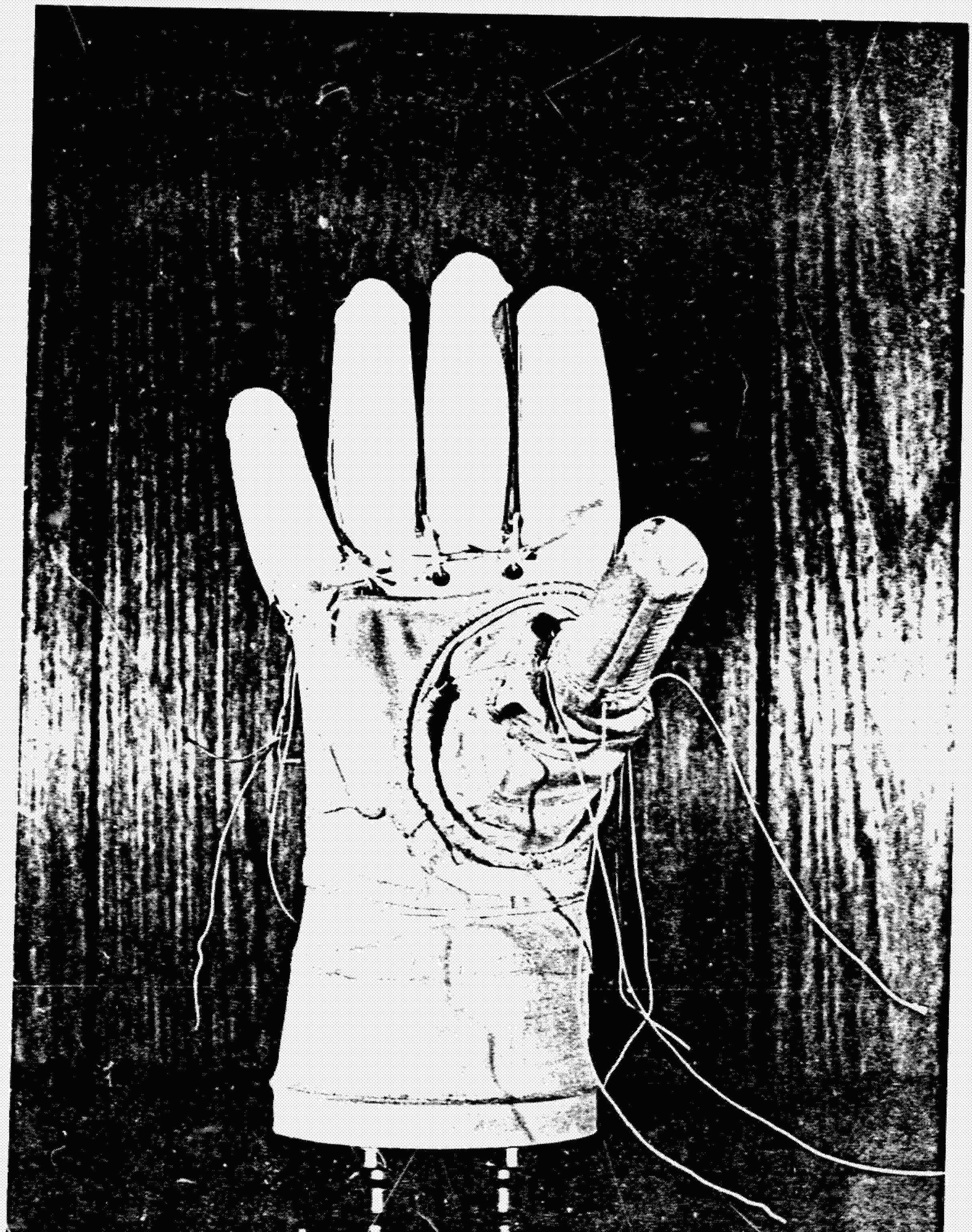
Glove Palm

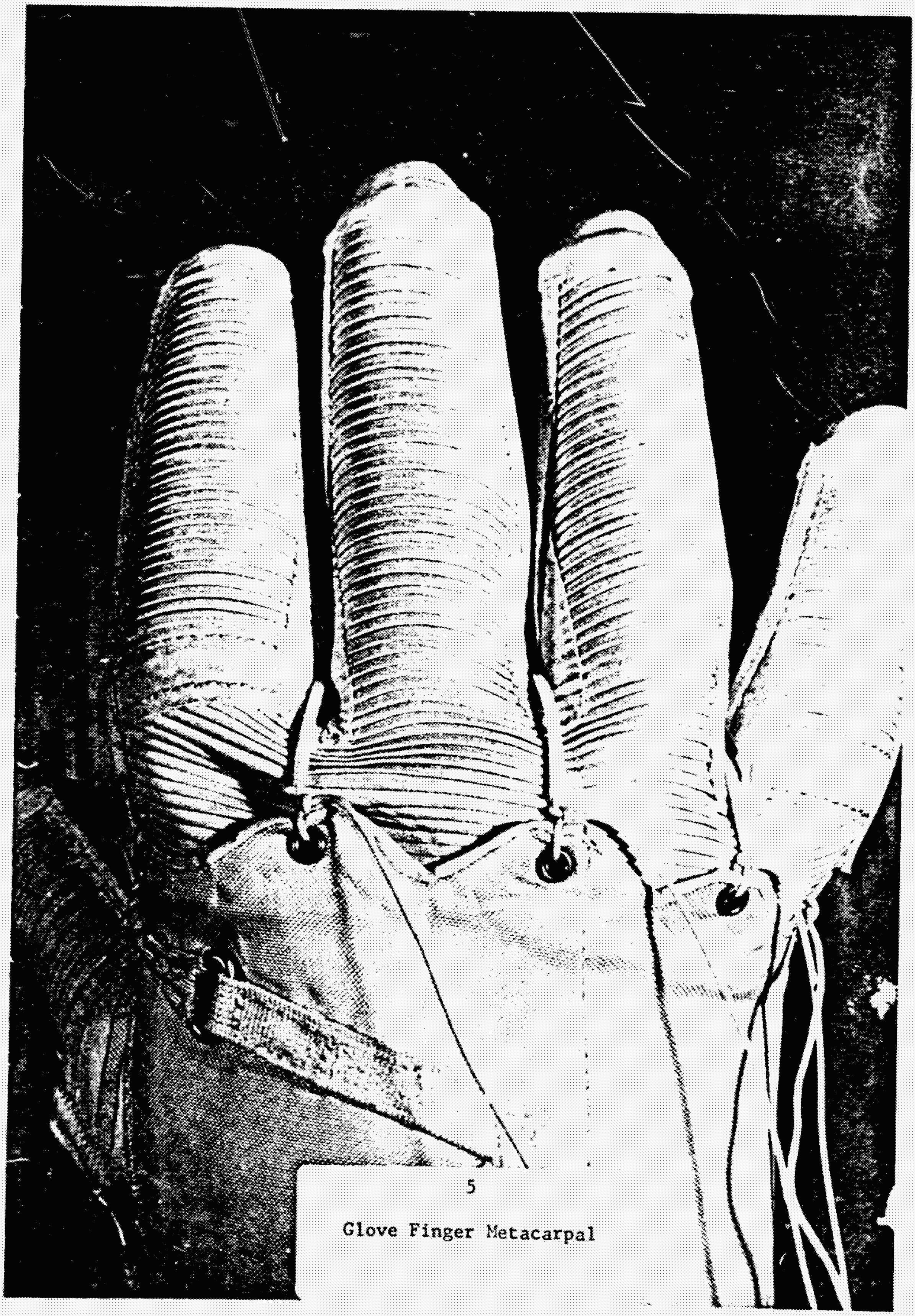


3

Glove Front

4

Glove Thumb Side



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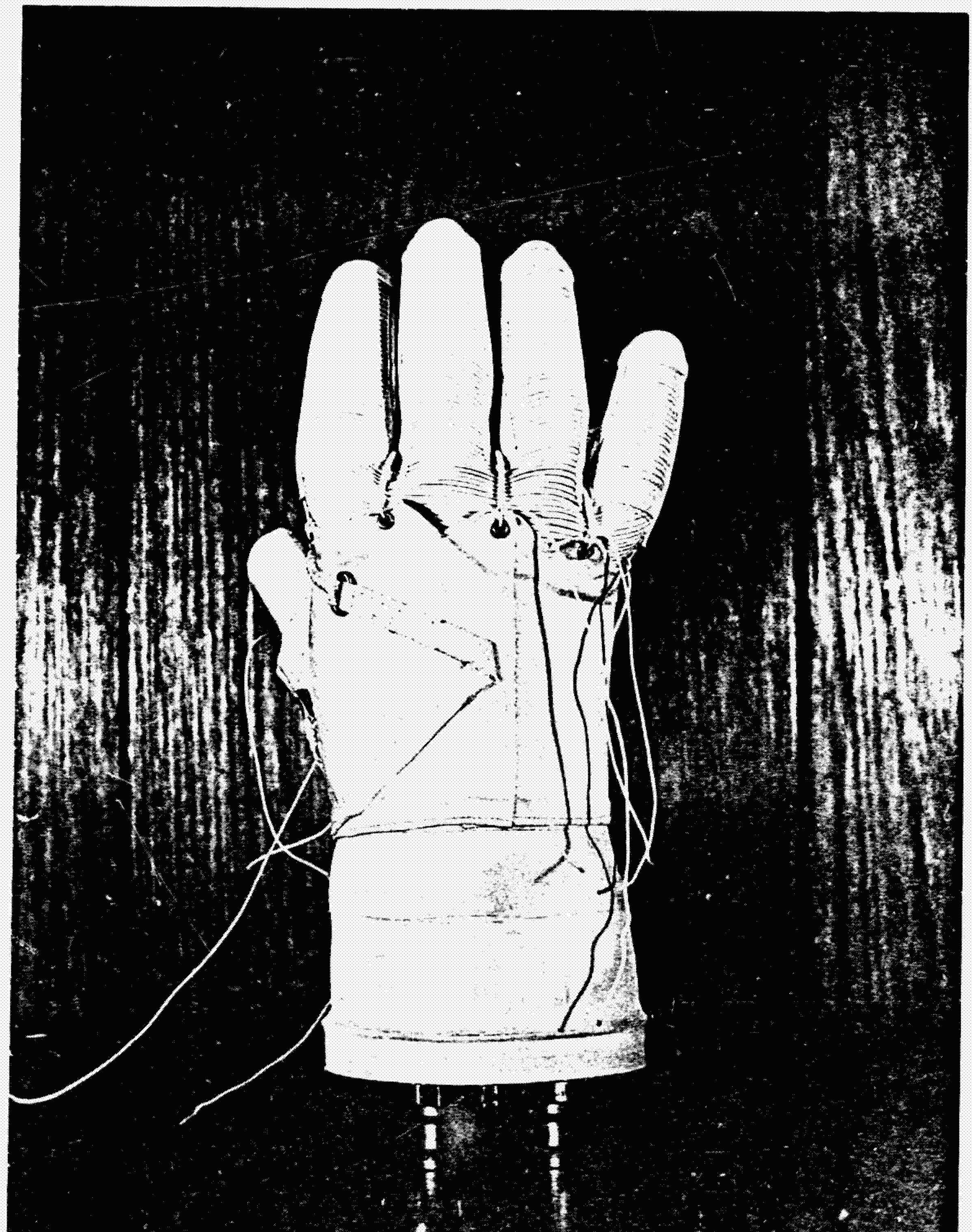
Glove Finger Metacarpal



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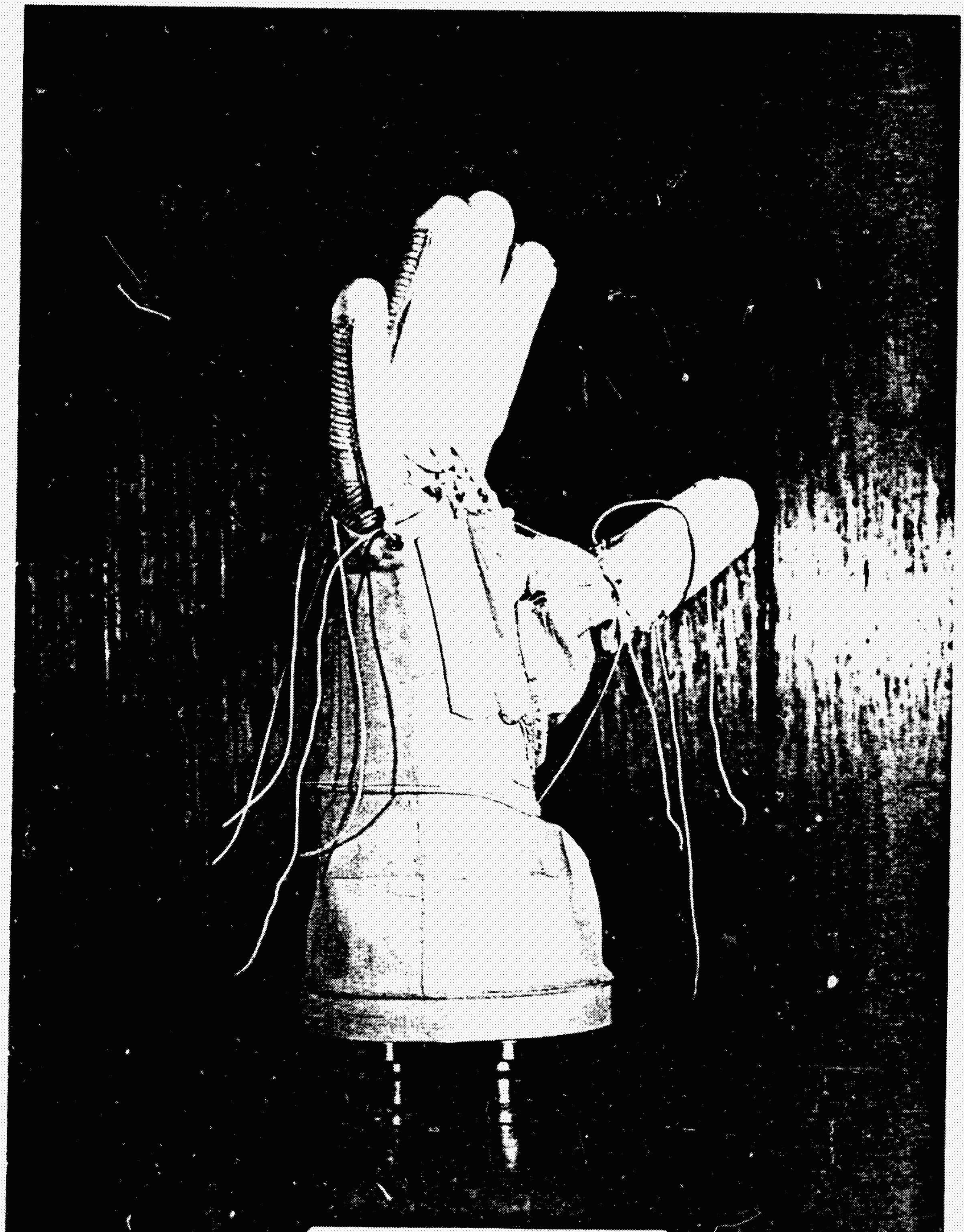
Glove Back



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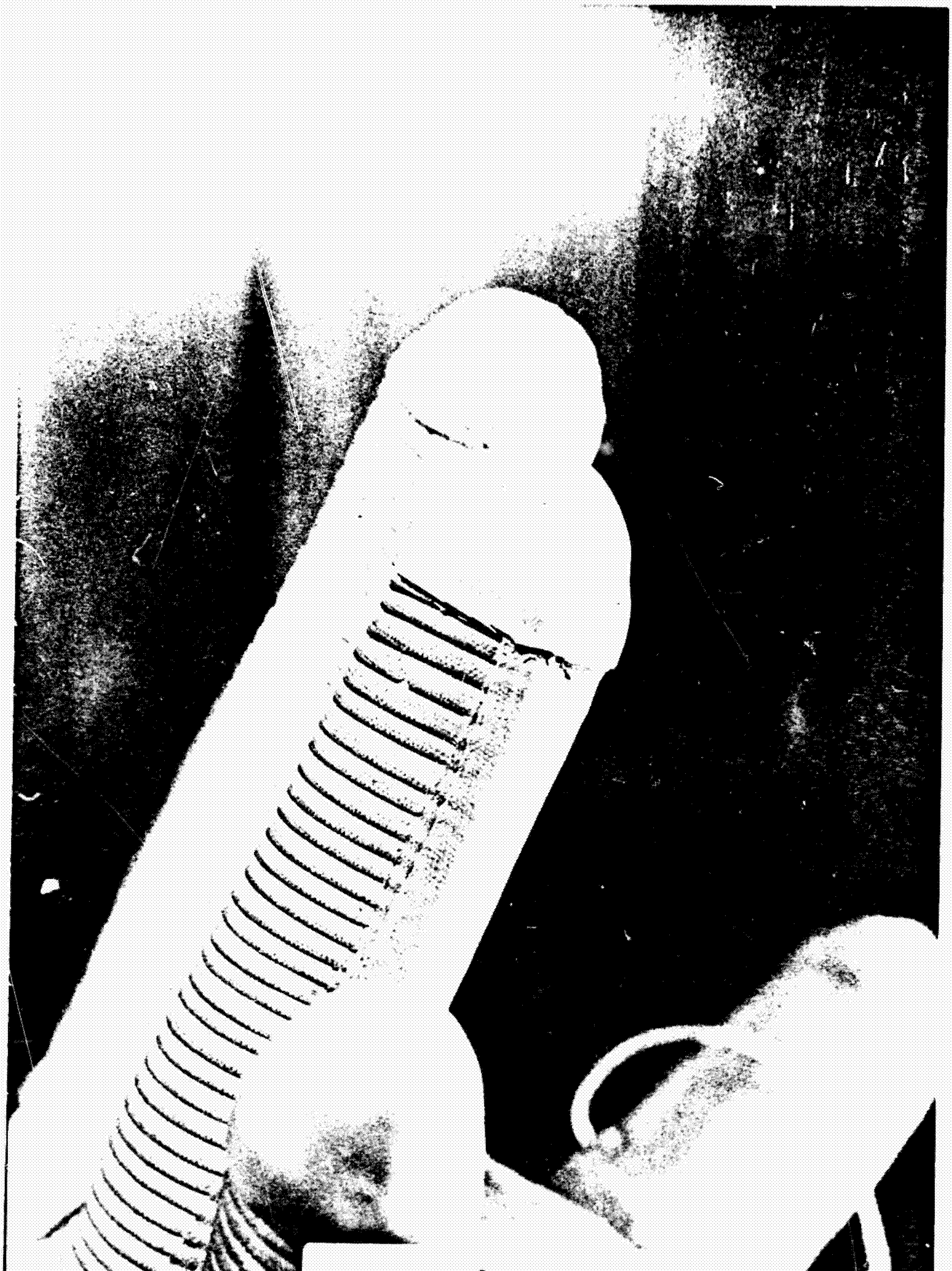
Glove Little Finger Side



8
Glove Finger Tips &
Axial Restraints

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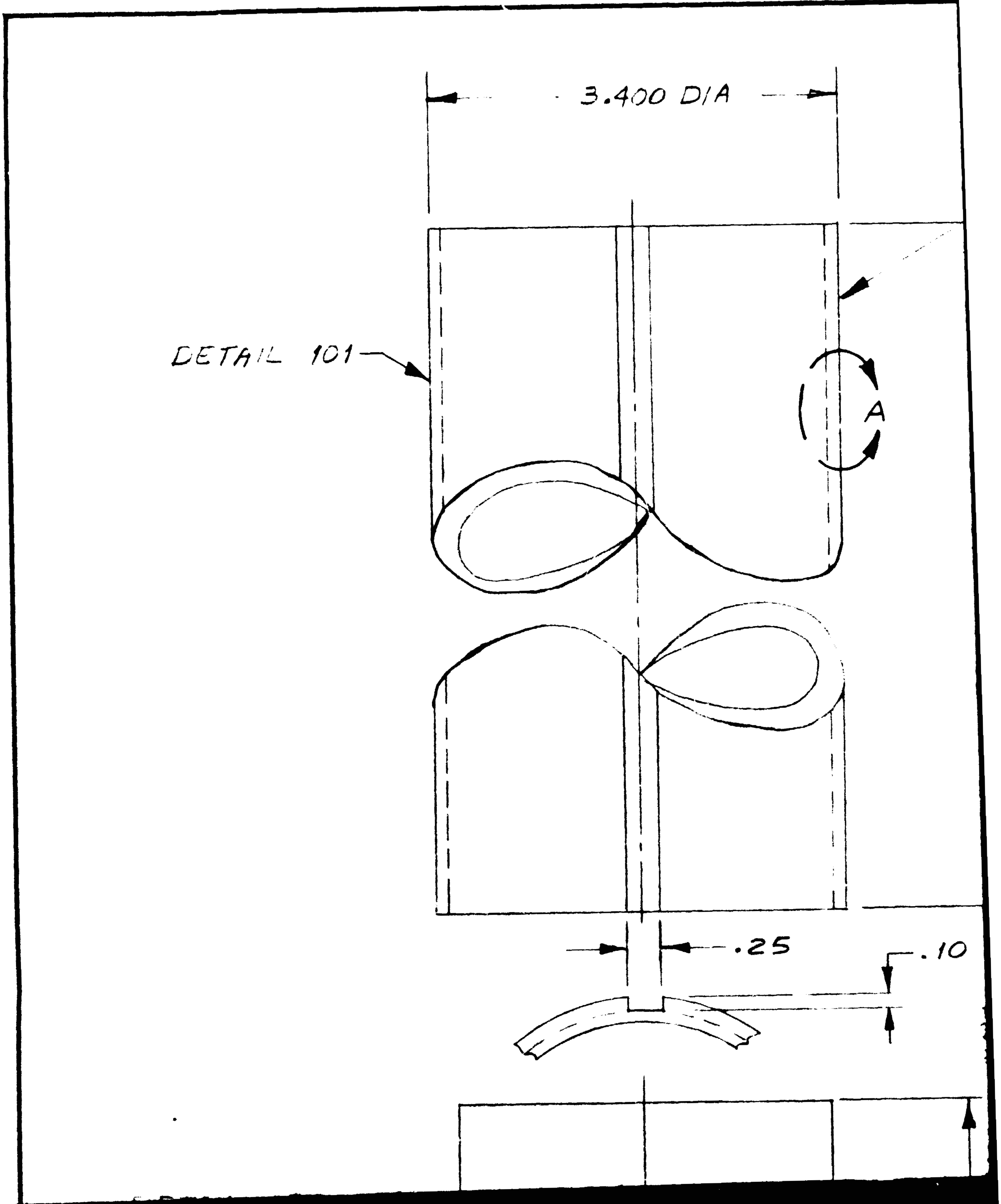

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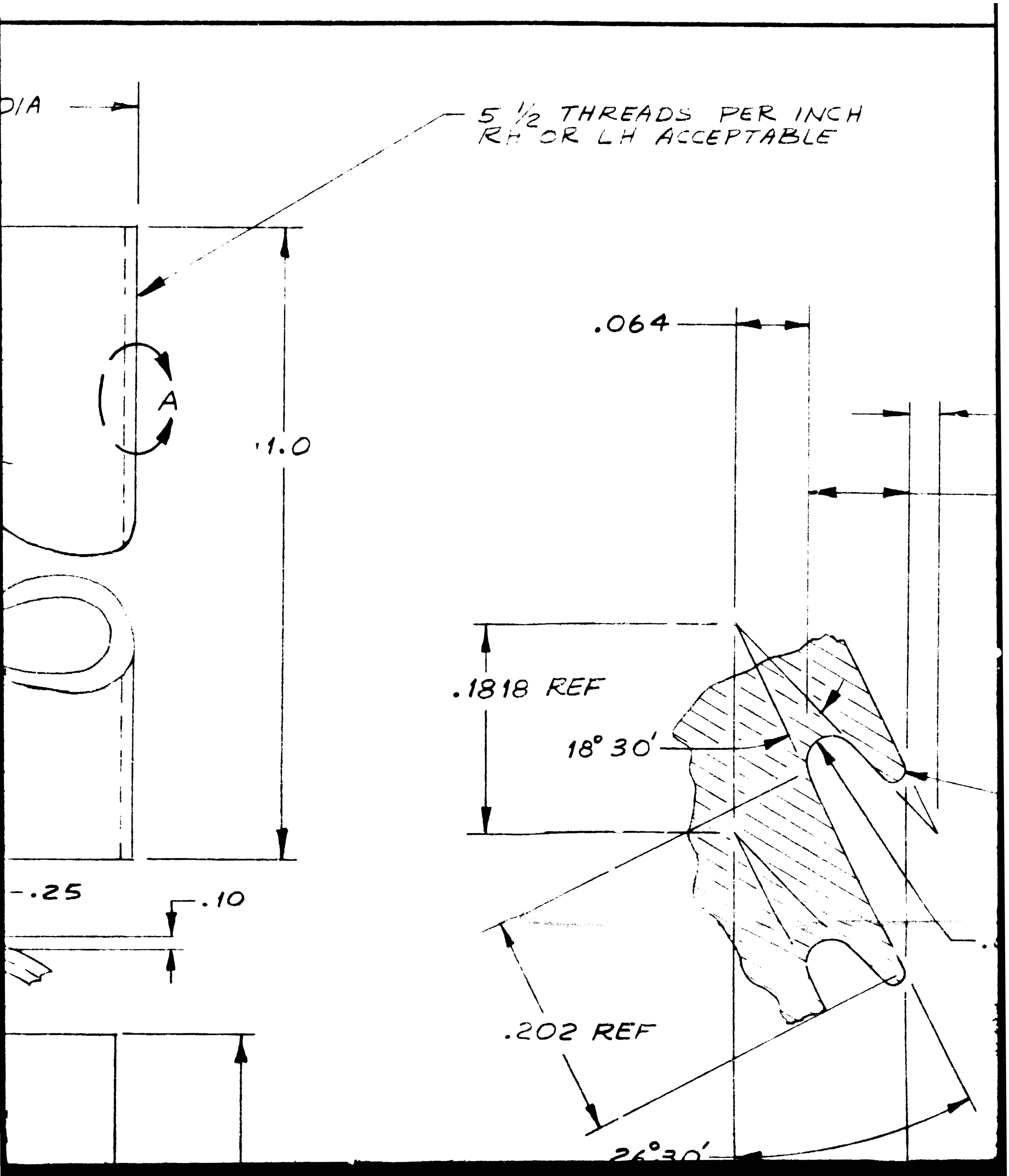

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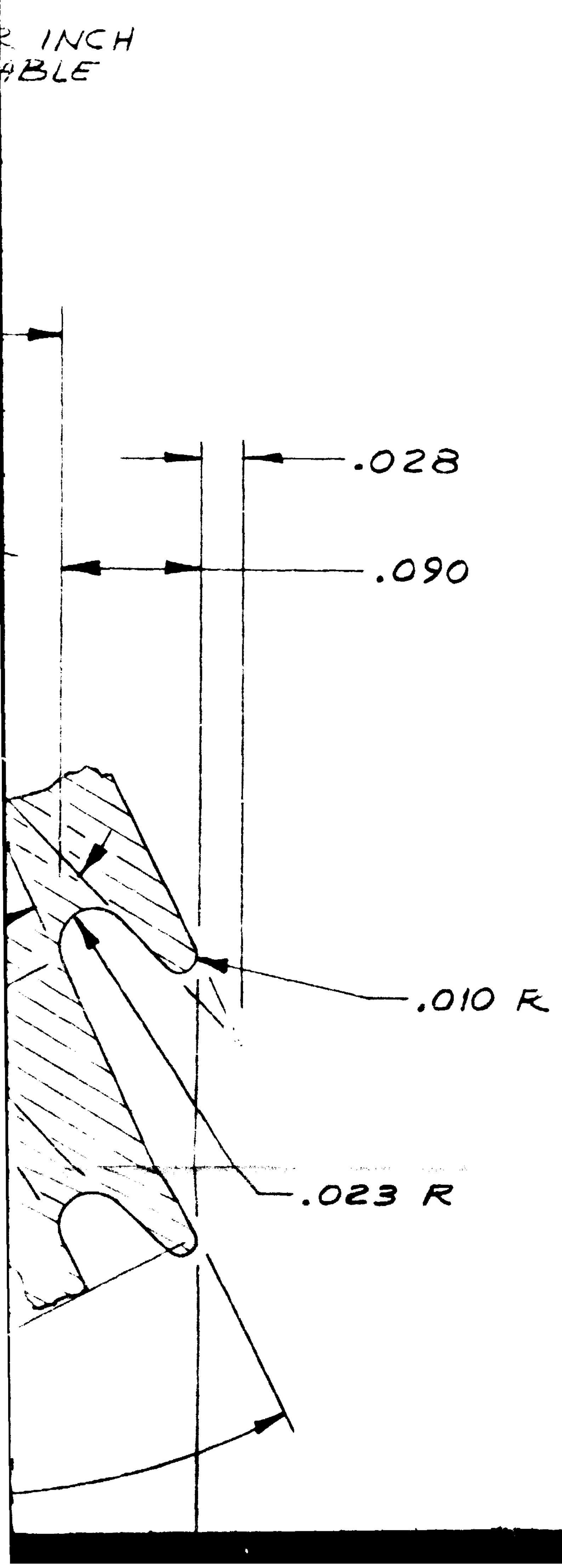

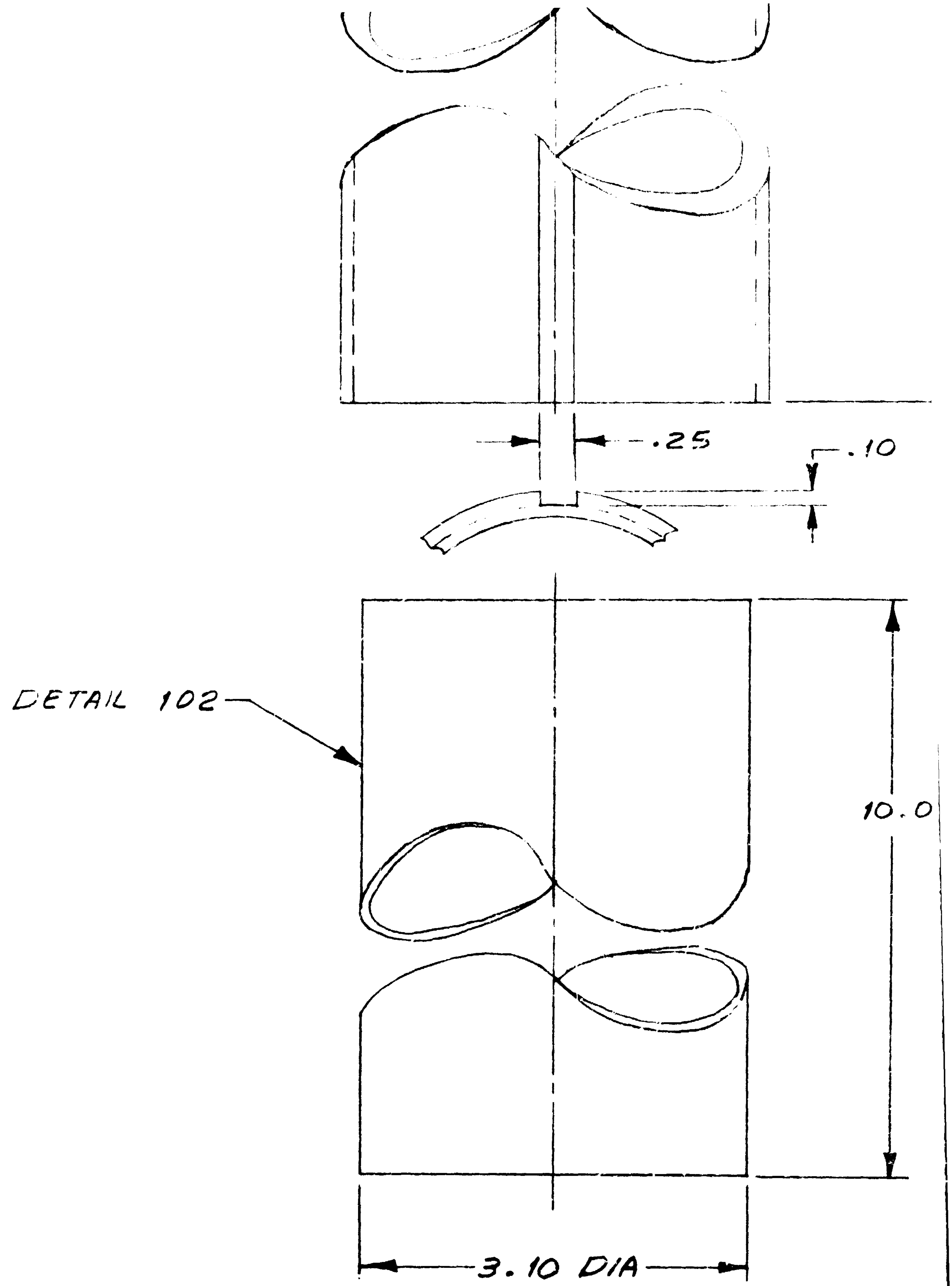

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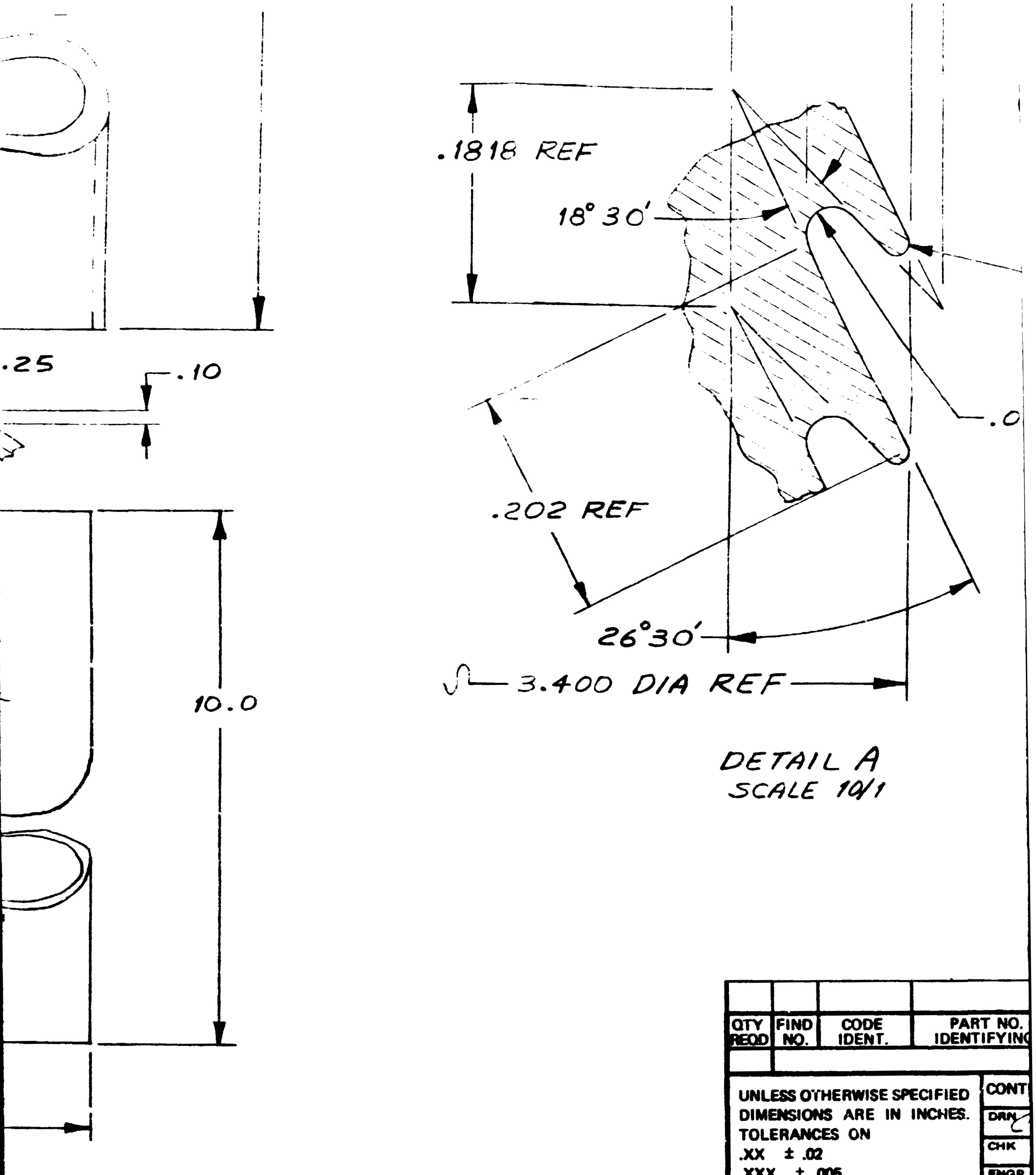

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PROPRIETARY INFORMATION

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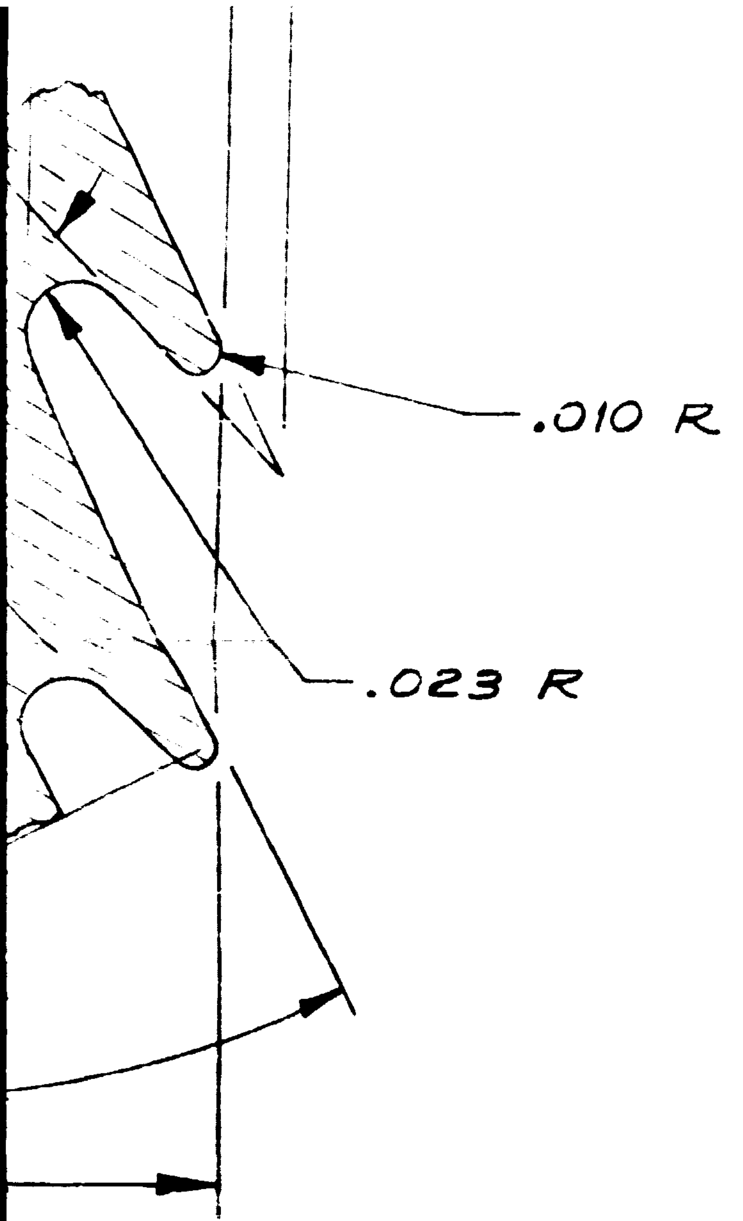

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SAC SPACE-AGE CONTROL, INC.
PALMDALE, CALIFORNIA

TITLE
TOOL,
GATHERED FABRIC,
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NUMBER T100112-1 LM

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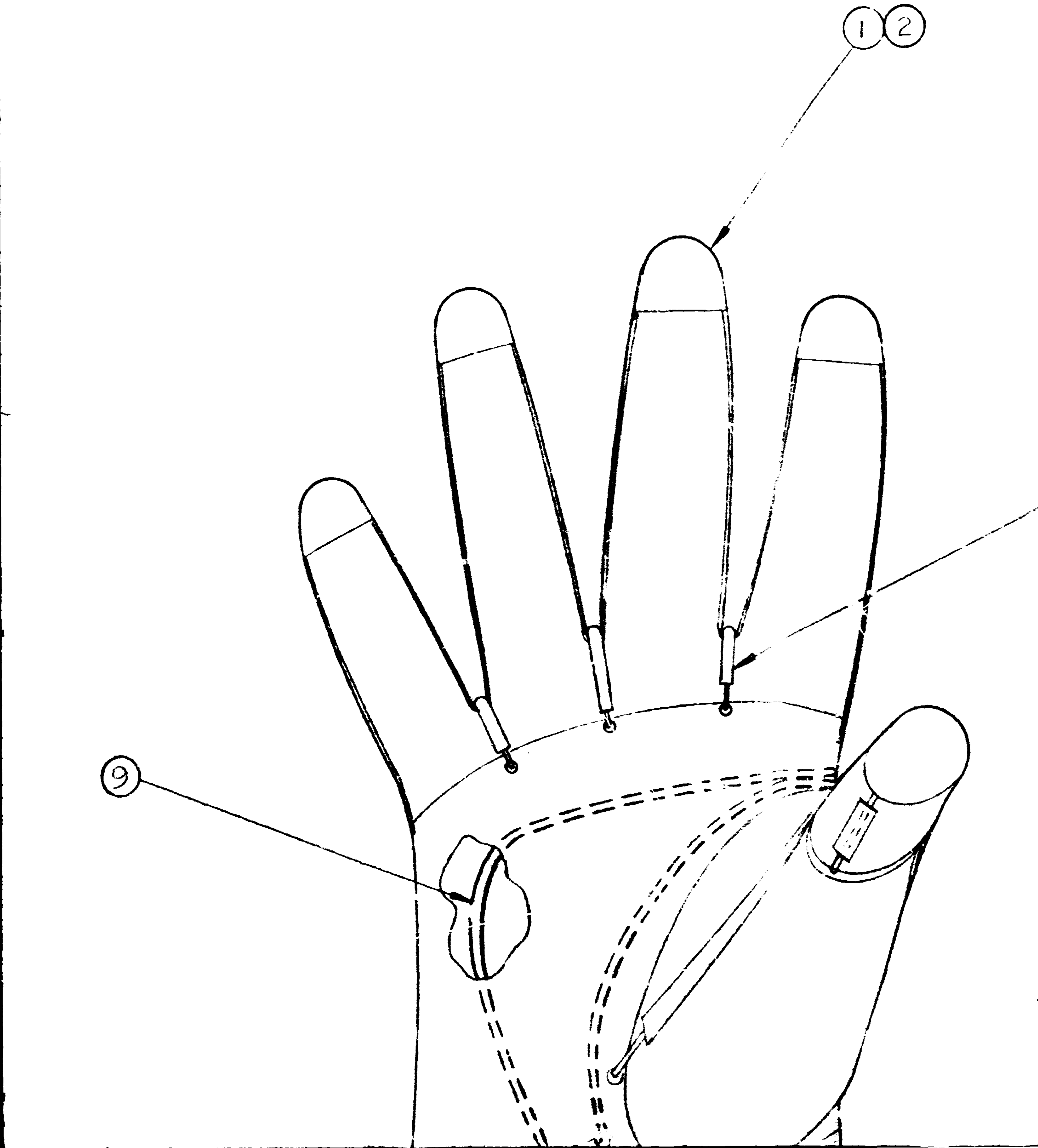

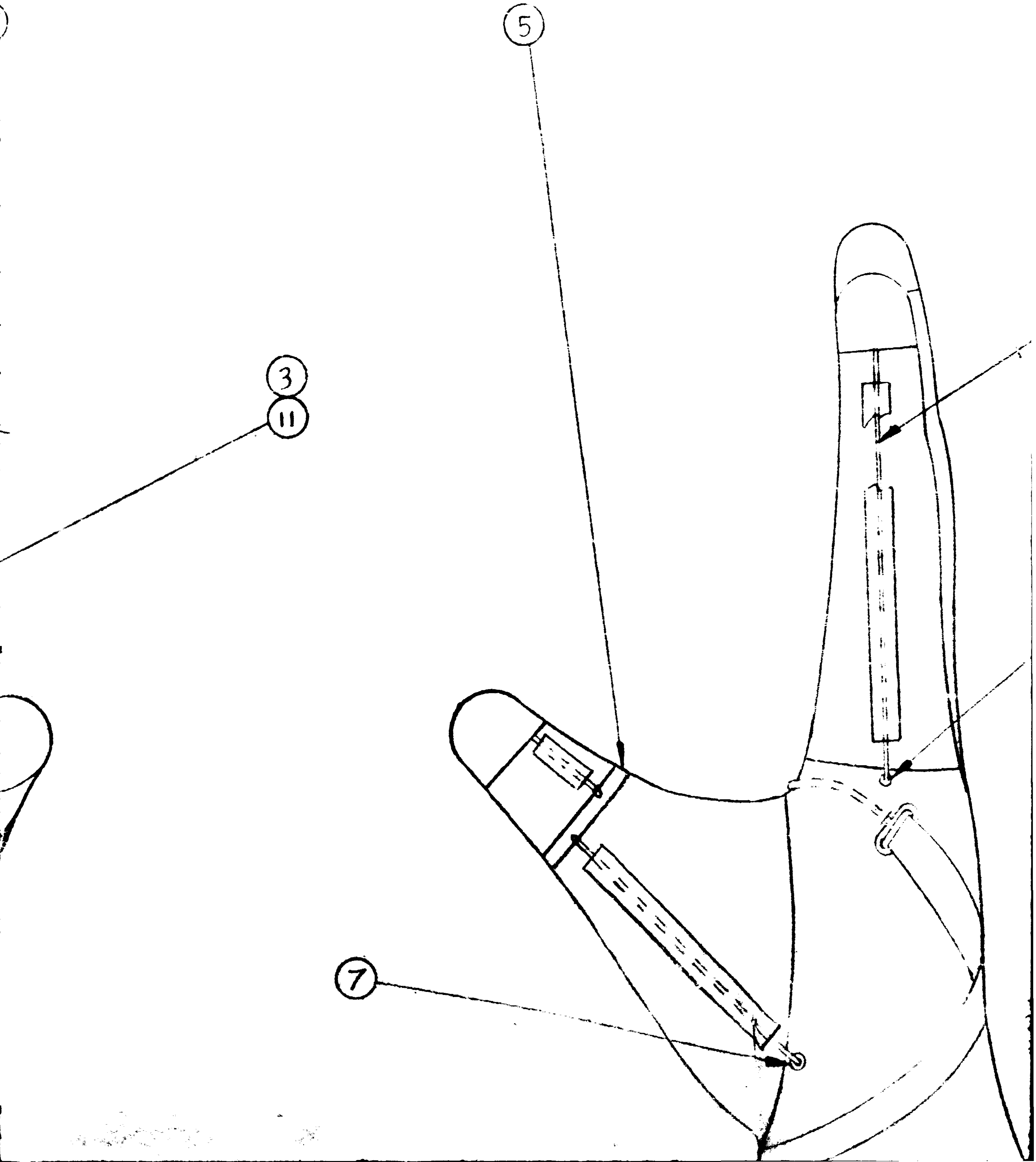
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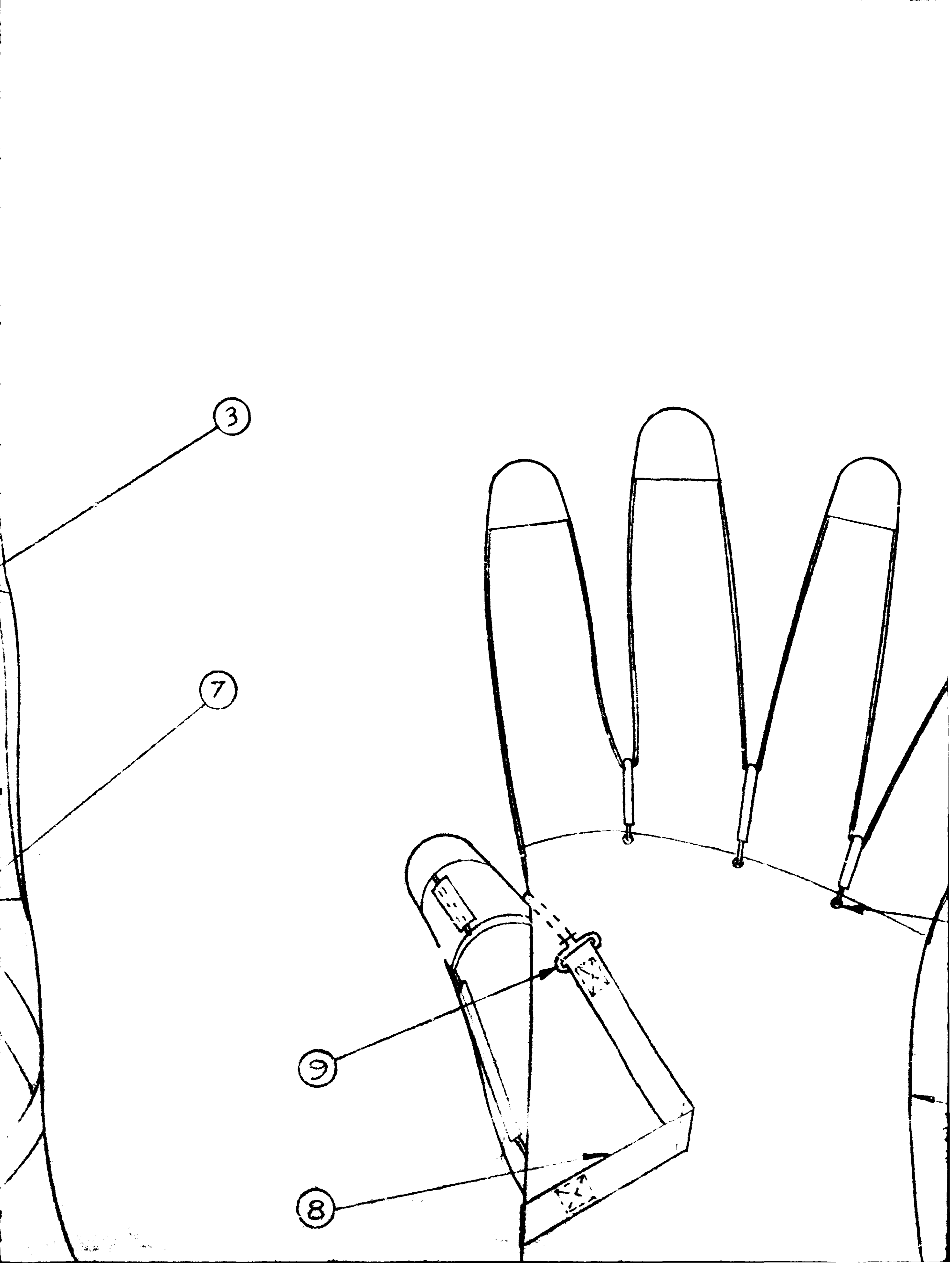
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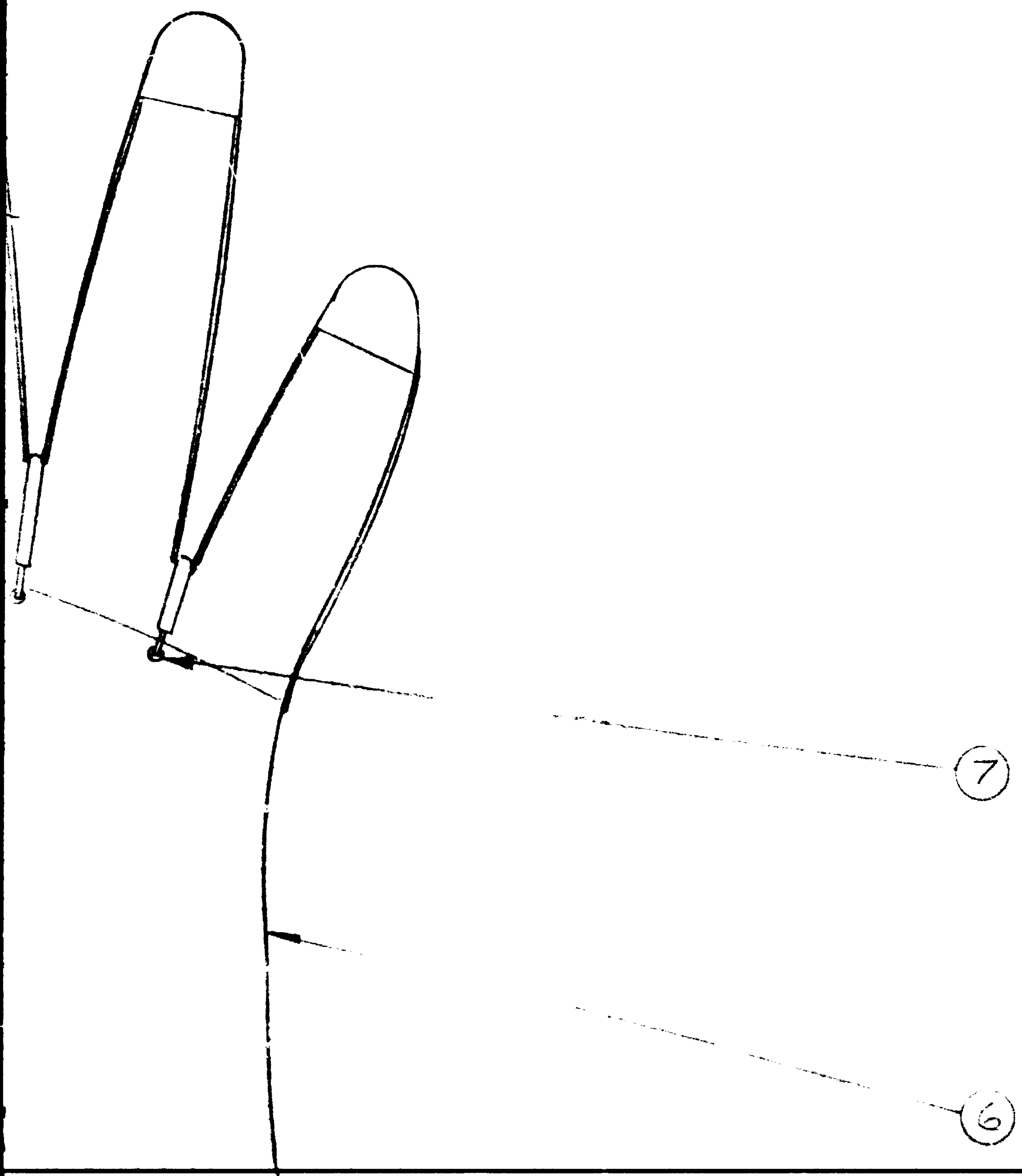

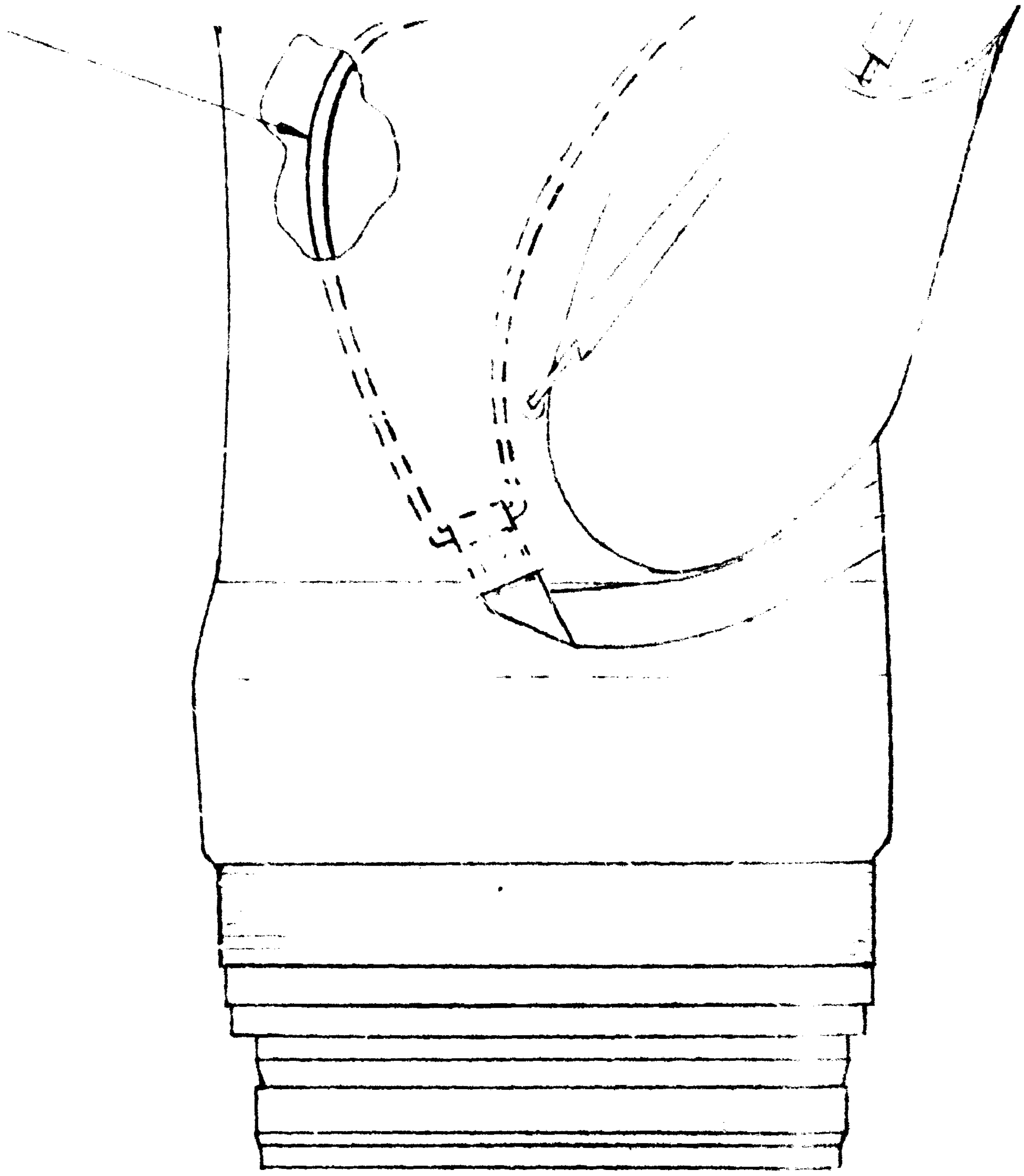

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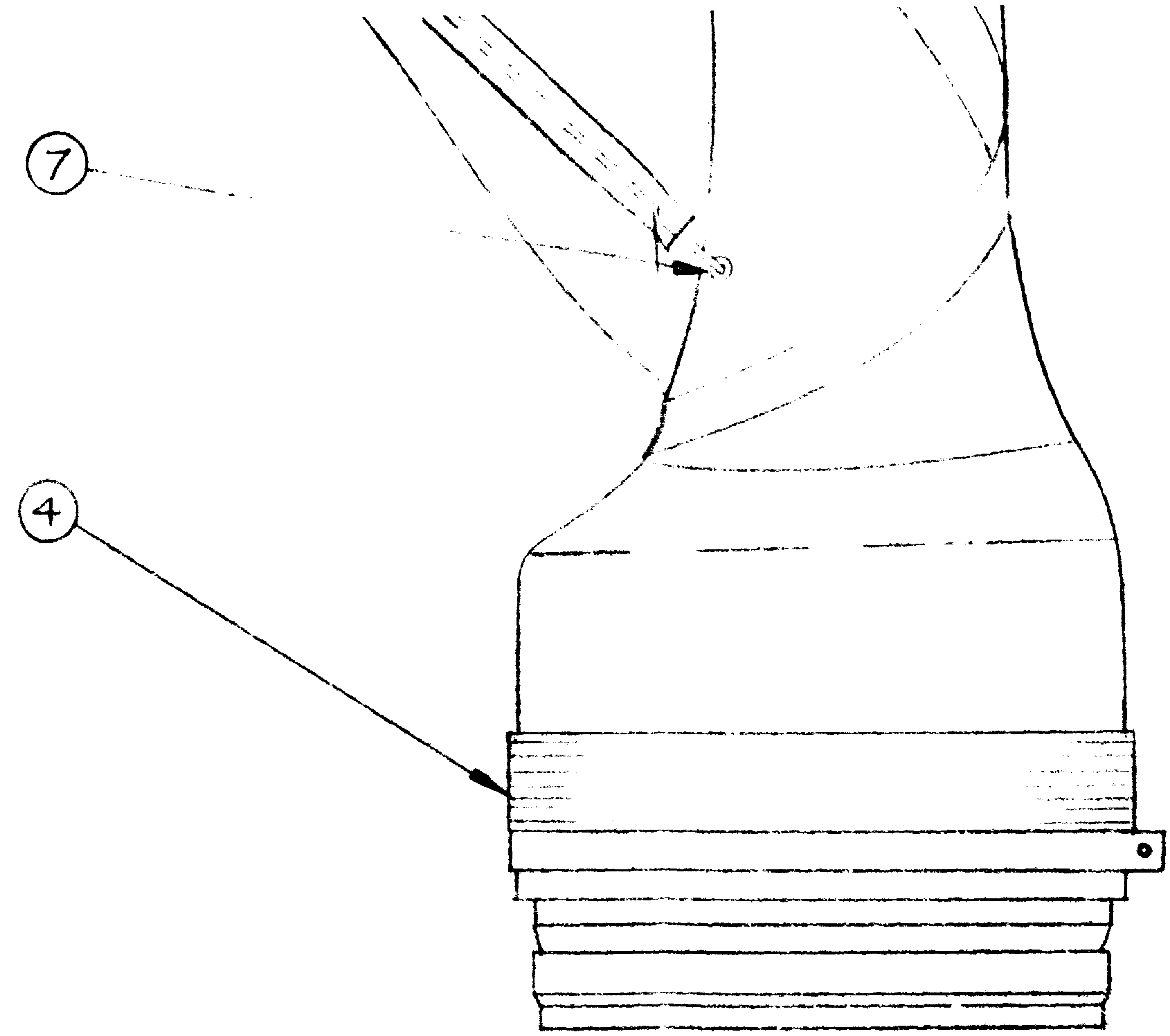
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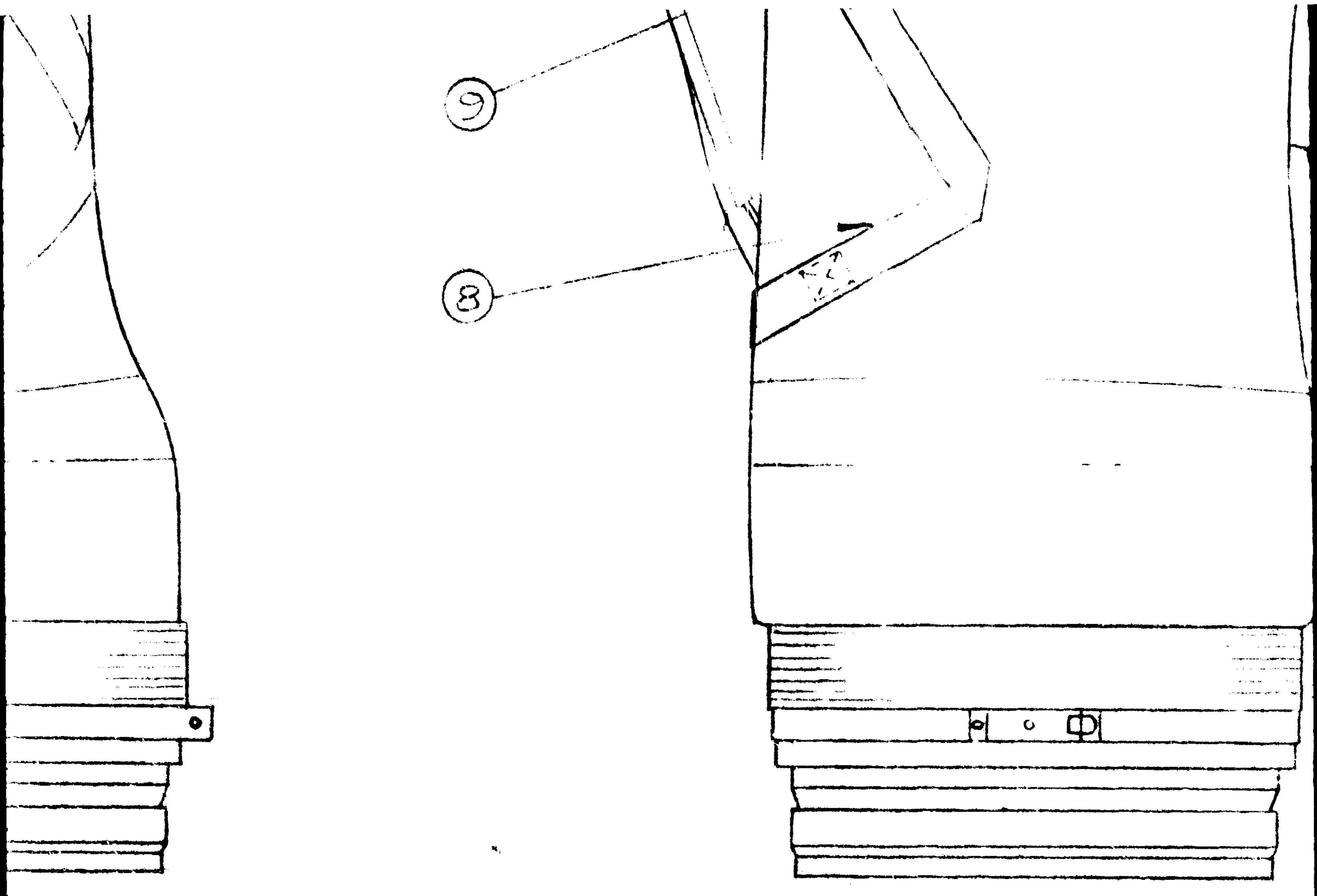

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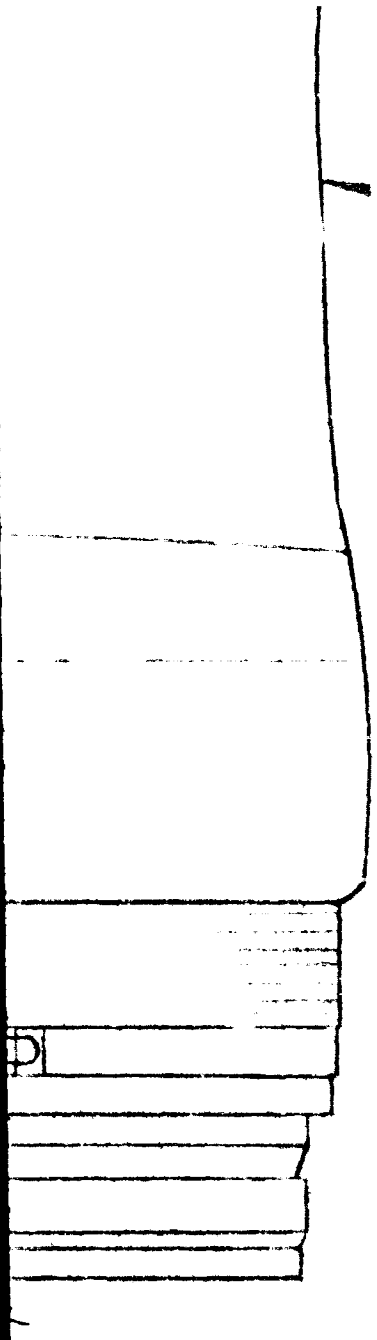

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SAC SPACE-AGE CONTROL, INC.
PALMDALE, CALIFORNIA

TITLE HIGHLY ARTICULATED FULL PRESSURE GLOVE

SIZE D | CODE IDENT 34851 | NUMBER 100106

SCALE 1/1 | SHEET

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SAC

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ITEM OR FIND NO.	QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS
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				# 15320	HORNELL, NY
2	AR		16 EX7A-2	CEMENT, WHITE NEOPRENE	INDUSTRIAL RUBBER
					CITY OF INDUSTRY,
					CA 91744
3	AR		#C220/1	CORD, BRAIDED DACRON, 1322	SYNTHETIC TEXTILES
					LA, CA 90039
4	1		ACS C1172-2	GLOVE DISCONNECT	
5	1		100110-1	RING, THUMB	
6	1		100111-1	GLOVE, FABRIC PATTERNS	
7	2		SE 44	EYELET	UNITED SHOE MACHINERY
					SHELTON, CONN
8	AR			WEBBING, NATURAL NYLON, 5/16	EON CORP, LA, CA 90065
				WIDE, 350 LB, MIL-T-8363A, TYPE 1	
9			100108-1	RESTRAINT, PALM	

SAC 120

SAC

PARTS LIST	SPACE-AGE CONTROL, INC. PALMDALE, CALIFORNIA	CODE IDENT. 34851	PL 100106	REVISION LTR DATE	SHEET 2

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				.034 ID X .016 WALL	NORRISTOWN, PA

SAC 121