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GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF TEXTILE & FIBER ENGINEERING

FINAL REPORT

ON THE

NASA/USRA ADVANCED DESIGN PROGRAM ACTIVITY 1990/91

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The NASA/USRA support of our design effort has been most helpful in enhancing the teaching of our design courses. The monetary award has the obvious advantage of providing needed Graduate Teaching Assistance support and also other funds for supplies, travel, etc. Our TA has also gained valuable experience by participating in the summer internship program. The interest shown by our Langley mentor, Dr. John Buckley, has been most helpful. One of the most important benefits has been that the students have been exposed to interesting and challenging problems which cause them to ponder constraints which they have not previously considered. I believe that working on these space-related problems has been a valuable experience which has greatly broadened their education.

Interdisciplinary Activity:

The School of Textile & Fiber Engineering continued to pursue design projects with the Mechanical Engineering School giving the students an outstanding opportunity to interact with students from another discipline. Four problems were defined which had aspects which would be reasonably assigned to an interdisciplinary design team. The design problems are summarized below:

Design of a Thermal Shield for a Lunar Telescope

The goal of this project was to design a shield to provide thermal protection for a lunar telescope. This design was required to meet specific objectives, including the following:

1) retract during nighttime viewing
2) close during lunar day
3) reflect infrared radiation
4) minimize temperature fluctuations
5) cover entire telescope
6) last 30 years

In addition, the design was subject to a number of constraints related to lunar conditions and shuttle cargo space; some of these include

1) 50 man hour assembly time
2) launch mass $\leq$ 4000 kg
3) transport length $\leq$ 27 m
4) transport diameter $\leq$ 7 m
5) serviceable within lunar temperature range
6) retain properties in vacuum
7) withstand severe solar radiation (β and uV).

The final design has been dubbed "The Rising Cylinder." The proposed structure will consist of two concentric cylinders 9.75 m high and a 10 m high third cylinder which will carry the cover. Figures 1 and 2 are schematics of the structure in the open and closed positions, respectively. The top two cylinders will be lifted into place using a bootstrap reeving system located in the support members of the cylinders. The cover will consist of two disk halves which open and close using a rack and motor system.

The primary thermal protection system will be gold-coated fiberglass woven fabric attached to the support frame. Specifications of this fabric are as follows

1) 5.5 tex continuous filament fiberglass yarn
2) 22 ends/ cm
3) 22 picks/ cm
4) plain weave
5) coated weight 194 g/ m^2

Gold will be vacuum deposited onto a polyester film which will then be adhesively bonded to both sides of the fiberglass substrate. The purpose of this double-sided coating is to prevent "curling" due to the differential between thermal properties of the coating and substrate. Gold was selected because of its reflectivity and because it does not oxidize.

This design has many advantages. The rigid structure will prevent folding and abrasion of the fabric. The structure will completely enclose the telescope, and the lifting mechanism technology already exists. There are, however, some disadvantages of this design. Opening and closing of the cover will be clumsy, and supporting the open cover will be difficult.

When the shield is closed, the telescope will be vertically positioned. When the shield is opened, the telescope may move away from the vertical position by a maximum of 15 degrees. See figure 2. The proposed shield is designed to have a lifetime of 30 years with a two year maintenance schedule.

Selenotextile Shielding Structure

The objective of this study was to design a structure to protect a lunar habitat from intense solar radiation. Included in the design is equipment for construction of the structure. The proposed protective structure is designed to withstand the extreme conditions of the lunar environment and to provide a 2 m maintenance space around the habitat. The construction equipment is designed to operate on less then 13 Hp. Packaged, the structure and construction equipment will fit into a space shuttle cargo bay.

The shielding structure will be 26 m in length, 12 m in width, and 9.5 m in height. The structure will be comprised of 26 tubes, rectangular in cross-section (1.5 m x 1.0 m), leaned like horseshoes at a 45 degree angle against a bank of regolith. See figure 3.

The individual tubes will be made of woven polytetrafluoroethylene (PTFE) coated fiberglass fabric. Fabric specifications are as follows:

1) plain weave
2) 22 ends/ cm
3) 25 picks/ cm
4) coated weight 240 g/ m^2

Fabric sections (from which the tubes will be made) will be heat sealed together to form airtight seams, and thus prevent escape of regolith from the filled tubes. Each tube will have a top opening supported by a fiberglass hoop. Individual tubes will also be connected with an airtight joint to form the final structure.

The textile structure will be held in shape prior to and during filling by an interior cavity filled with compressed gas. Regolith will be supplied to the structure via the fiberglass hoops and a conveyor system. The primary conveyor system will be supported by a series of telescopic legs and will be fed regolith by a second conveyor resting on the support mound. These conveyors are shown in figure 4.

Pneumatically Assisted Elbow Joint Design for the NASA Zero-Prebreathe Suit

In the near future it is expected that NASA will establish a lunar colony. In order to assemble and operate this lunar base it will be necessary for astronauts to spend a significant amount of time working outside the base. The existing procedure for adjustment from cabin pressure to suit pressure takes 13 hours and 30 minutes. The proposed suit design will allow astronauts to make the transition from a high pressure internal environment to a lower pressure suit without spending time in an air lock. This suit, the Zero-Prebreathe Suit (ZPS), is pressurized to 57 kPa, while the current shuttle suit is pressurized to 29 kPa, and the shuttle's atmosphere is pressurized to 101 kPa.

The current ZPS design uses a toroidal joint to provide flexibility and has a bending resistance of 3.0 Nm. When used with a micrometeoroid shield, the resistance to bending increases to 5.4 Nm. This resistance, in conjunction with deconditioning caused by prolonged exposure to low gravity or weightless conditions, accelerates the onset of fatigue and can artificially limit the amount of work that an astronaut can do. The proposed design will counteract the resistant forces to regain some lost work time and to help optimize the astronaut's performance.

The assist mechanism to overcome the resistance of the elbow joint utilizes an inflatable structure that deforms asymmetrically to match the path that the elbow travels through. A rendering of the proposed solution to the problem of overcoming the resistance of the ZPS suit is shown in figure 5. Figure 6 shows sectional views of the design. The components of the assist mechanism are denoted in figure 6. The expansion pattern is shown in figure 7. The outer edge is exposed to a very high deformation, with approximately a 120% change in length. The inner edge expansion is relatively smaller, with a total elongation of approximately 70%. Note that the total angular rotation is 130°, as specified by NASA requirements. The upper sealing joint must be able to accommodate 15° of angular rotation. The proposed design meets this requirement by being compatible with the existing joint. Note that a 0.635 cm. ring thickness has been included in the sealing joint design to accommodate any later adaptation of the design. Similarly, the lower sealing joint must accommodate 180° of rotation.

The total cross sectional area of the structure is approximately 7.9 cm^2. The area is approximate because the segmented form has an area that varies slightly between the large and small diameters. The torque exerted by the structure is constant at 5.4 N, because the ends of the structure occur at the large diameter.

The assist mechanism is made from a plain woven polyester fabric cut with a saw-tooth pattern. In order to make the chamber deform as shown in figure 7, filling yarns of varying linear densities should be used to weave the fabric. Fine filling yarn should be inserted for flexibility (and chamber elongation) along the outer side of the fabric pattern, and coarser filling yarn is used to weave stiffer fabric along the inner axis of the fabric pattern. When the fabric is folded and assembled, the fine yarns meet at the saw-tooth seam, where greater elongation takes place. The chamber should be assembled to achieve the necessary response of the chamber upon inflation.

Fabric specifications are as follows:

1) plain weave
2) 14 ends/ cm
3) approximately 14 picks/ cm
4) nominal yarn diameter 0.013 cm

The finished, cut fabric should be impregnated with urethane before assembly of the structure.

This joint is designed to be incorporated with the NASA ZPS and to have a lifetime equal to that of the ZPS.

Electromechanical System to Power Assist an Astronaut's Finger Joints

The proposed design is an electromechanical system to power assist the movement of an astronaut's distal and proximal interphalangeal finger joints. Figure 8 shows these joints and their desired range of motion. The objectives of this project were to:

1) reduce astronaut fatigue
2) provide greater ease of movement

The design was subject to a number of constraints, including the following:

1) allow 90° range of motion at proximal interphalangeal joint
2) allow 45° range of motion at distal interphalangeal joint
3) compensate for 75% of suit's bending resistance
4) integrate with current suit
5) weigh $\leq$ 5 lbs/ arm
6) must not generate excessive heat
7) require little or no maintenance
8) have lifetime comparable to that of suit
9) must not hinder hand operation in event of failure

The approach taken is called the "Stacked Triangle" method; it includes design and selection of a force sensing system, electromechanical actuator, glove finger bending mechanism, actuator controls, and materials for the bending mechanism and motor mount construction. Figure 9 is an artist's rendering of the design. The force sensing system will consist of a poly(vinylidine fluoride) (PVDF) piezoelectric pressure sensing grid which will relay electrical voltage to an amplifier per unit of force. The proposed electromechanical actuator is an advanced linear electric motor with a rare earth magnetic core. The linear motor will move the finger apparatus by displacing a kevlar cable. This cable will force the aluminum structure to actuate due to off-center force derived moments about the distal and proximal interphalangeal joints. the automatic controls for the system will consist of sensor, amplifier, and motor transfer functions. The feedback loop will consist of an adjustable feedback gain. The entire system will be incorporated into the spacesuit between two Teflon coated textile layers. All components will be integrated into the suit with appropriate textile materials.

The electromechanical system will overcome the suit's bending resistance and provide force to achieve a range of motion of 45 degrees for the distal interphalangeal joint and 90 degrees for the proximal interphalangeal joint. Required operations will be power assisted as necessary. The system is designed to have a lifetime comparable to that of the spacesuit.

Challenges to Textile Engineering Students

The design projects briefly described above provided a unique challenge because of the harsh lunar environment which is hostile to most textile fibers. The extremely important requirement to minimize weight for space flight gave the students a new perspective on design constraints.

Challenges to our Curriculum:

Our present curriculum requires our seniors to take two quarters of engineering design in order to fulfill the ABET requirement for a capstone design course. The School has chosen to divide the courses into "wet-processing" and "dry-processing". This does constrain us to keeping the projects to a 10-week time period. If we were to carryover projects from one quarter to another, the students would not see the complete design cycle and the educational value would be diminished. We must ask ourselves how we may provide the best design experience and still provide NASA with a reasonable return on their investment.

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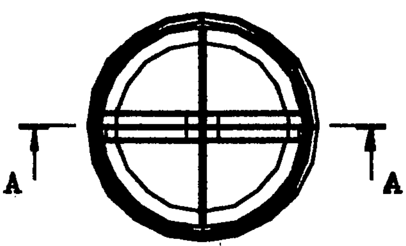
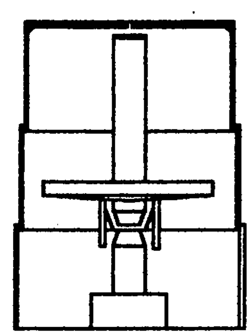


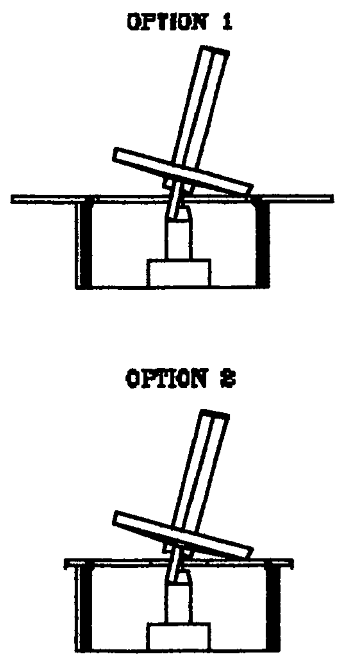
SECTION A–A



NOTE: GOLD PLATED FIBERGLASS REMOVED

FIGURE 1

OPEN



NOTE: GOLD PLATED FIBERGLASS REMOVED

FIGURE 2

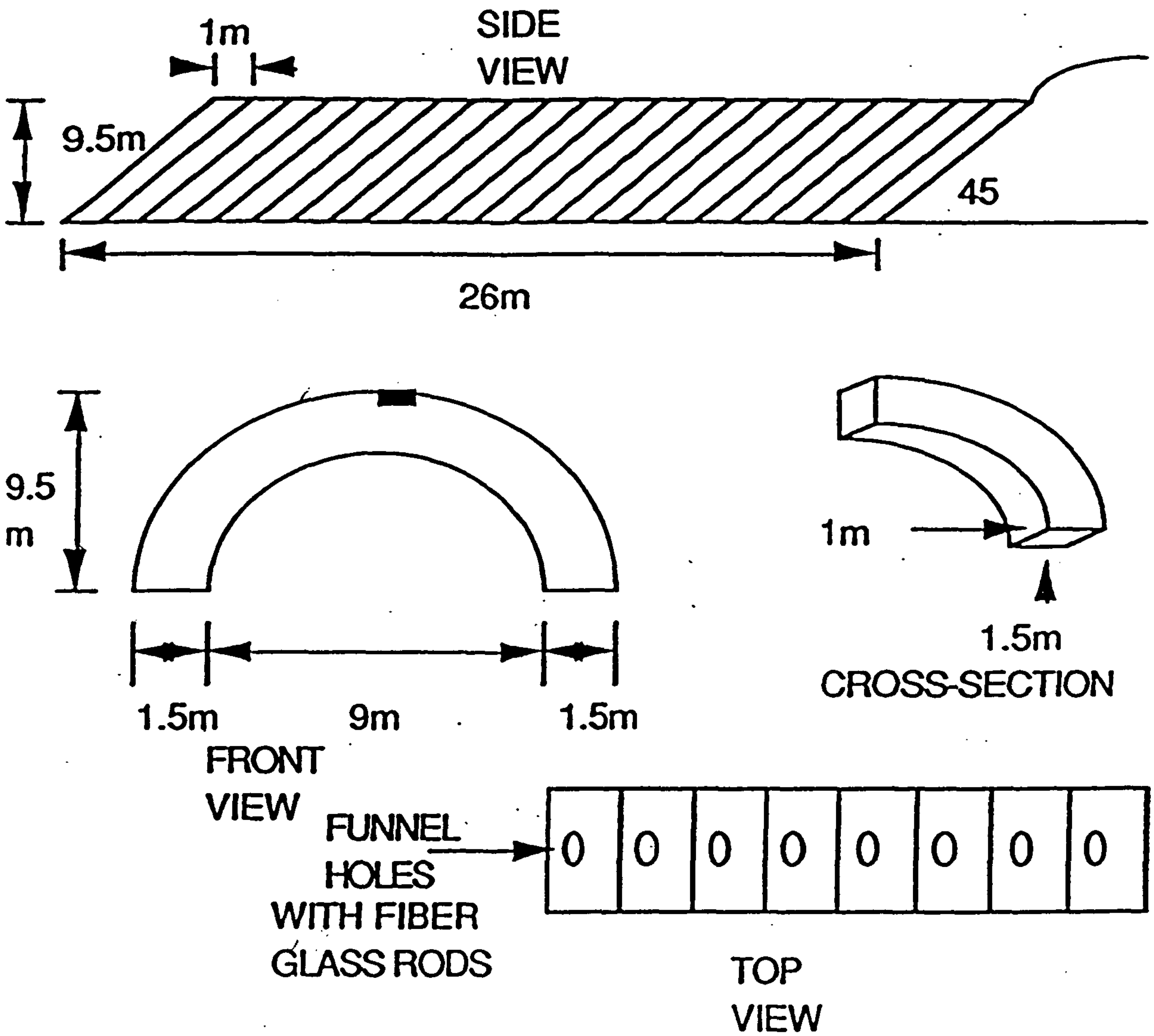


FIGURE 3 STRUCTURE SCHEMATIC

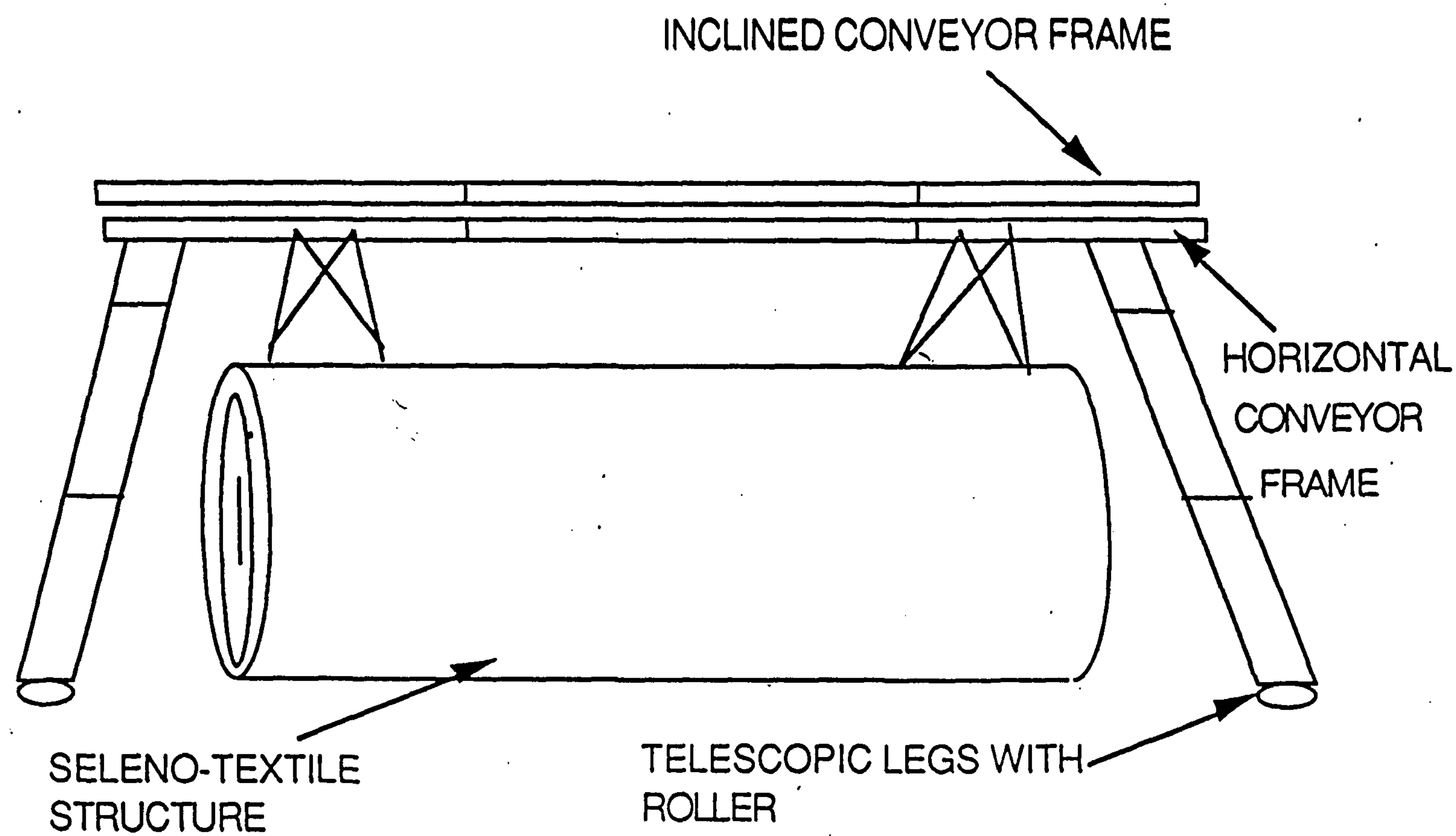


FIGURE 4 CONVEYOR STRUCTURE

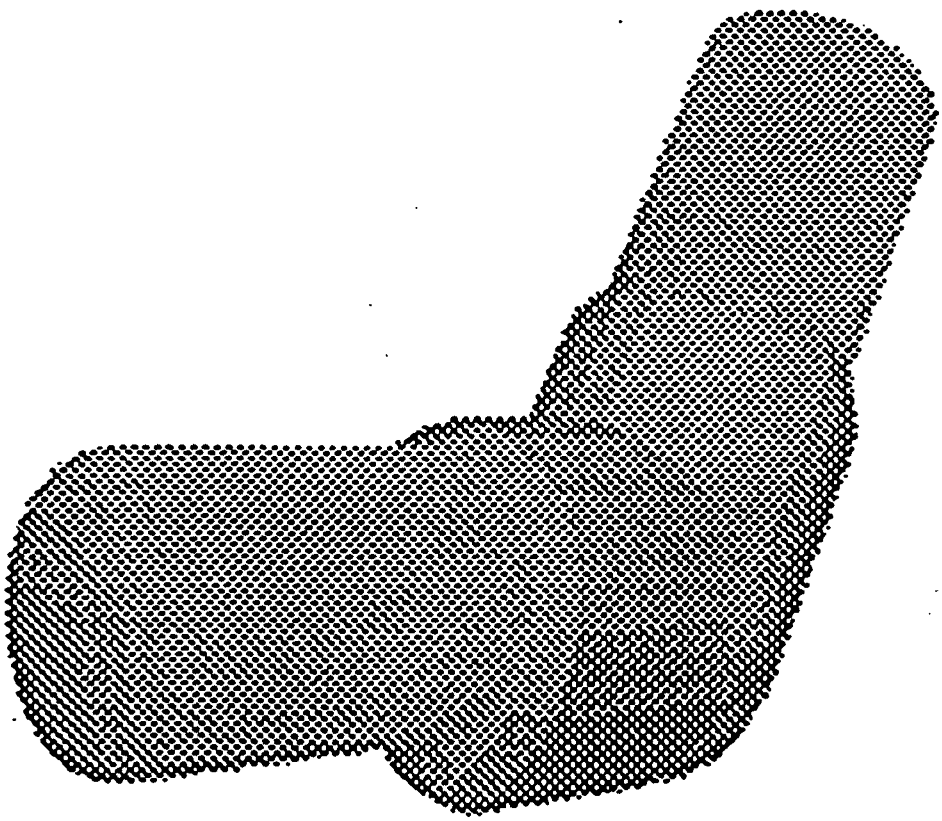


FIGURE 5 RENDERING OF ELBOW

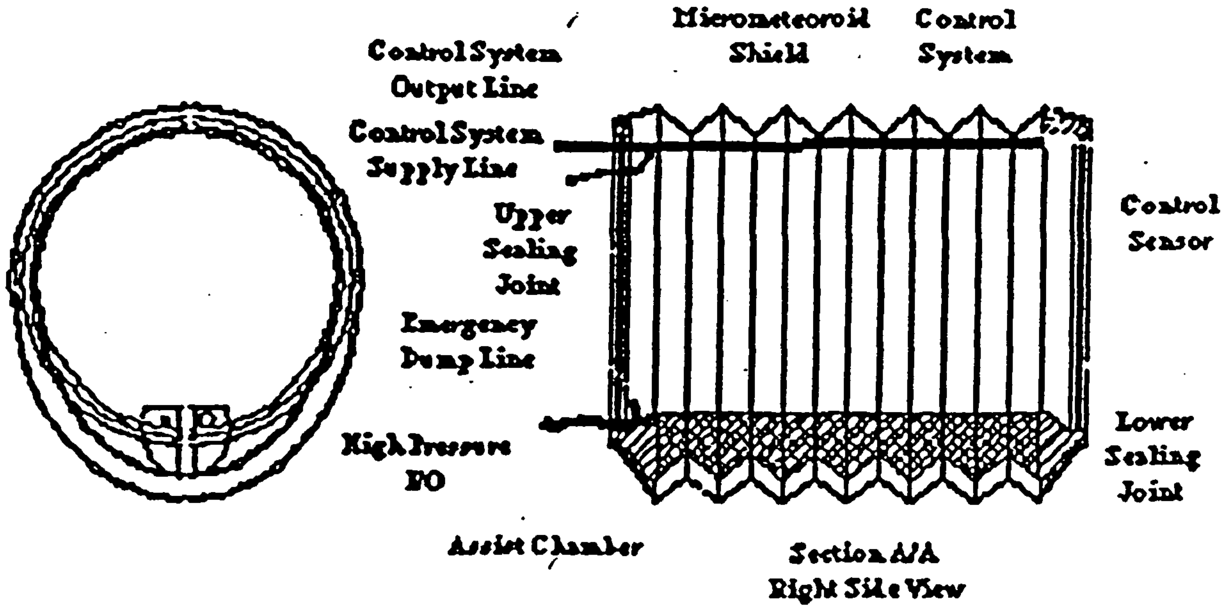


FIGURE 6 CROSS-SECTIONAL VIEW

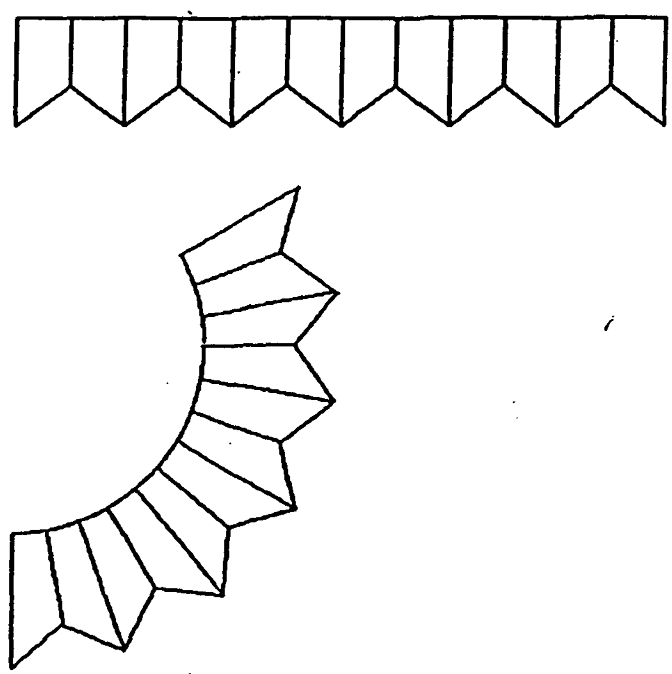


FIGURE 7 DEFORMATION PATTERN

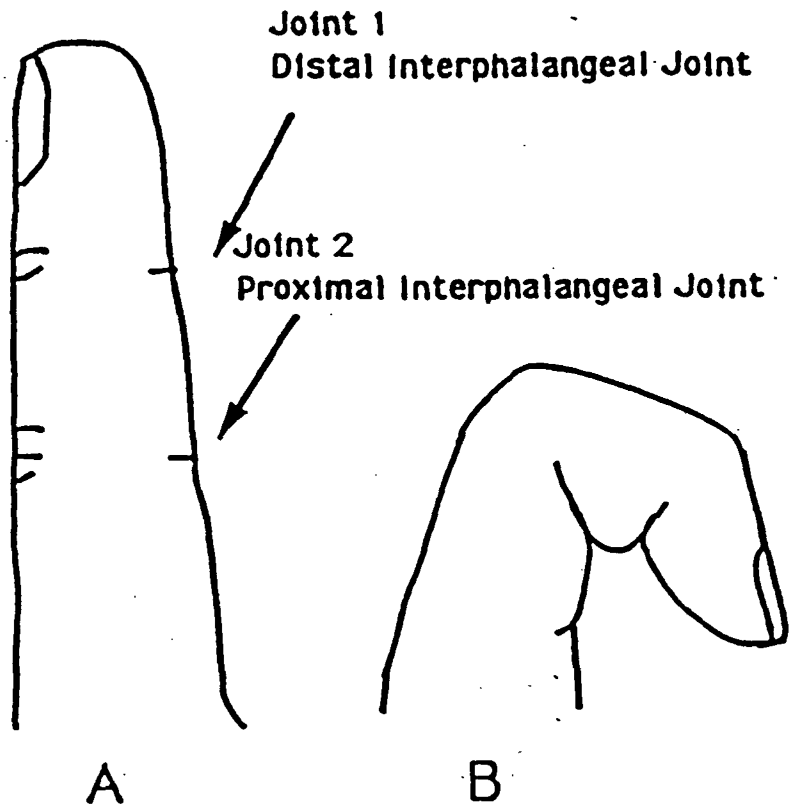


FIGURE 8 RANGE OF MOTION DESIRED IN ELECTROMECHANICAL SYSTEM

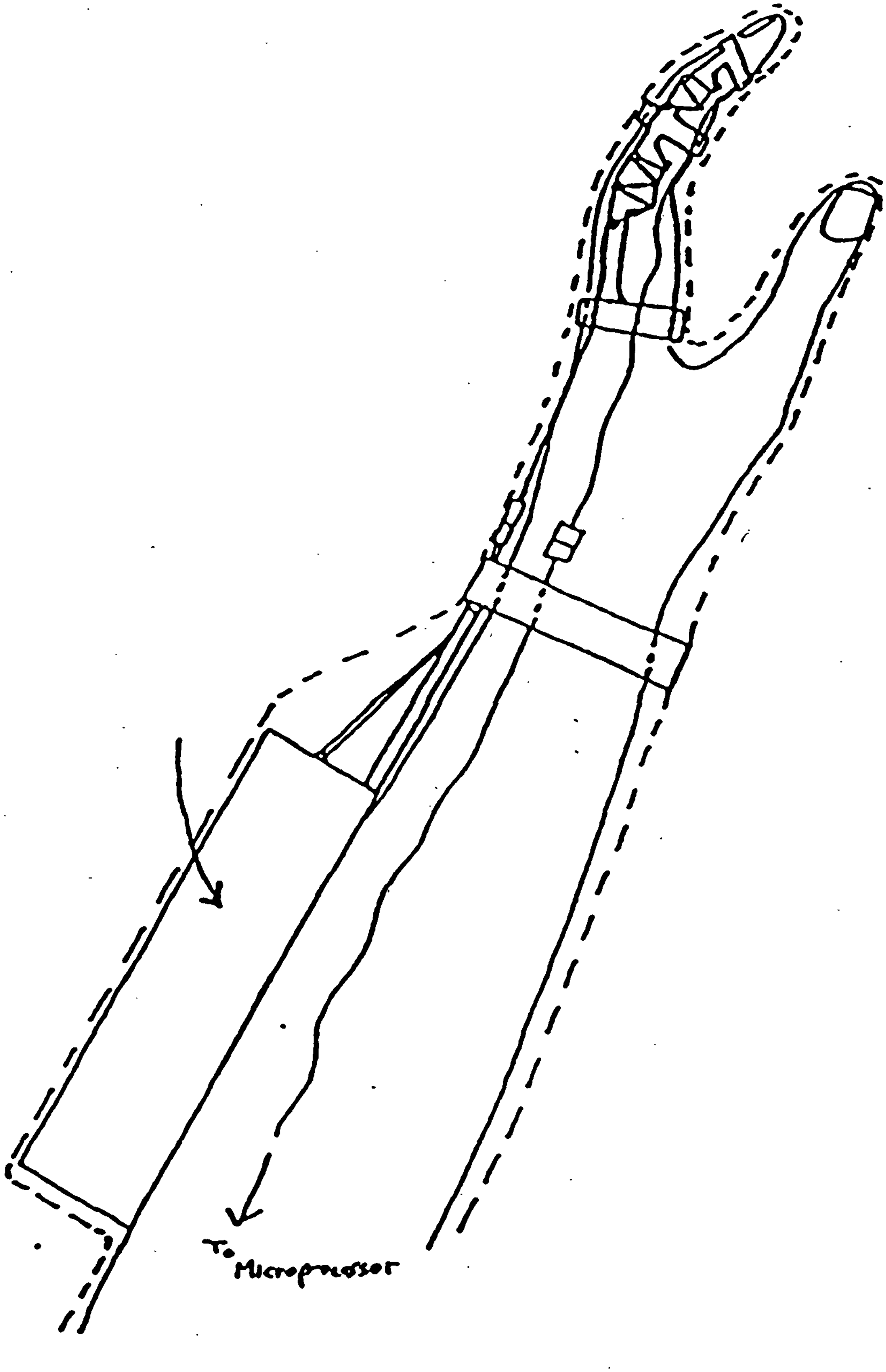


FIGURE 9 ARTIST'S RENDERING OF ELECTROMECHANICAL SYSTEM