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Abstract

One of the concerns of Space Station designers was making sure that the suited crewmembers' gloved fingers are not trapped in the holes that may be present in the structures during extravehicular activities. A study was conducted on 11 subjects to determine the minimum and maximum possible hole sizes that would eliminate the possibility of finger entrapment. Subjects wore pressurized gloves and attempted to insert their fingers into holes of various sizes. Based on the experimental results, it is recommended that the smallest diameter should be less than 13.0 mm and the largest diameter should be greater than 35.0 mm in order to eliminate the possibility of finger entrapment while wearing gloves. It is also recommended that the current requirements specified by the Man-Systems Integration Standards (Section 6.3.3.4) should be modified accordingly.

1.0 Introduction

It is the responsibility of the designers of Space Station Freedom to ensure that the suited crewmembers have adequate safety while performing extravehicular activities (EVA) tasks. One area of concern is the possibility of having a crewmember's finger trapped in an opening or hole in the structure. Such a situation would lead to a potential safety problem. According to the Man-Systems Integration Standards (MSIS), Section 6.3.3.4 (NASA-STD-3000), the hole requirements are such that they should not fall within the range of 10.0 to 25.0 mm (0.4 to 1.0 in.). However, it was uncertain whether this specification was sufficient to prevent the above mentioned problem.

2.0 Objective

The primary objective of this study was to determine the range of hole sizes that would result in finger entrapment and to specify unacceptable hole sizes for future space structures which may require EVA service. The range of hole sizes was intended to be obtained by collecting finger anthropometry under gloved conditions and by using 5th and 95th percentile subjects.

3.0 Methodology

This study involved two phases. EVA series 3000 gloves were used in both phases. In the first phase, 2 small females and 2 large males were tested in a glove box (fig. 1). The males wore large (size ZI) and the females wore small gloves (size ZA). Negative pressure was applied to the glove box so that the gloves could be pressurized to 0.624 kPa (4.3 psi) differential. A vernier caliper and a circumference measurement device were used to measure the dimensions of the fingers. By holding the caliper in one hand, the subjects measured the breadth and depth of each finger at the proximal and the distal ends. The circumference measurements were also made at these two locations. These measurements were used to obtain the maximum possible diameters for each finger at proximal and distal ends. The results from this phase suggested that the minimum and the maximum diameters of a gloved finger under pressurized conditions were roughly 2.3 cm (0.9") and 5.1 cm (2.0").

Based on the data from phase I, sixteen holes were drilled in an aluminum block (25.4 cm X 15.2 cm X 7.6 cm). Figure 2 shows the front and side views of the aluminum block. A base plate was also attached to the block to prevent it from falling over during the data collection (fig. 3). The hole sizes varied from 1.3 cm to 6.4 cm. Five females and six males were recruited for phase II. In order to test the smallest and the largest hand sizes, hand anthropometric data from an earlier study was used to select subjects whose hand sizes belonged in either the 5th or 95th percentile (Rajulu, 1993). Three different EVA glove sizes (large–ZI, medium–ZG, and small–ZA) were used to accommodate different hand sizes. The ZI and ZA are the largest and smallest gloves made under the 3000 series. The 5 female subjects used the small glove, 1 male used the medium glove, and the remaining 4 males used the large glove. The aluminum block was placed inside the glove box within reach of the subjects' hands. Appropriate gloves were fitted to the glove box fitting, and negative pressure was once again applied to pressurize the gloves to 0.624 kPa (4.3 psi).

The procedure required the subjects to insert their fingers starting with the 5th digit (little finger) into the holes one at a time. They started with the smallest hole and proceeded to the successively larger holes. The hole that barely accommodated the tip of the finger was used to determine the smallest diameter that would not let that finger in. Once the smallest hole was determined, the subjects then tried other holes until they could insert the finger fully and pull it out completely with no resistance. The same procedure was repeated for the 4th digit (ring finger), 3rd digit (middle finger), 2nd digit (index finger), and 1st digit (thumb). Each subject performed the test on both hands. Figure 4 shows the subject performing the test.

4.0 Results and Conclusions

Table 1 shows the raw data collected from the subjects. The data shows that the minimum diameter that will prevent insertion of any finger is less than or equal to 1.3 cm (0.50"), and the maximum diameter of a hole that will allow any finger to slide through easily has to be at least 3.5 cm (1.38"). Future EVA serviceable structures should not allow holes within this range. While the smaller diameter recommended by the MSIS is less than the data from this study (10.0 mm vs. 13.0 mm), the larger diameter is only 25.0 mm and is 10 mm less in diameter than the larger diameter that was needed in this study to allow free movement of any finger. If the holes are not made larger than 35 mm, then there is a possibility of finger entrapment. Hence, based on the results from this study, the MSIS-STD-3000 (6.3.3.4) requirements should be changed accordingly.

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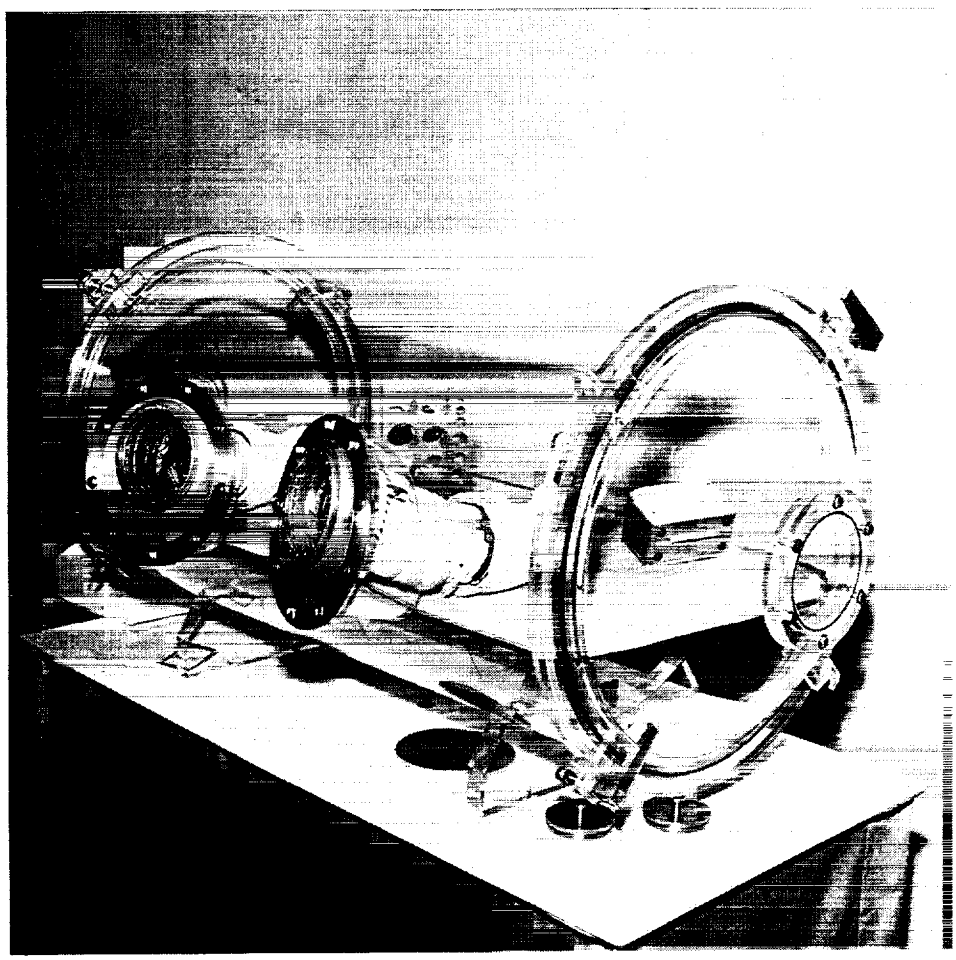

Figure 1. Glove Box

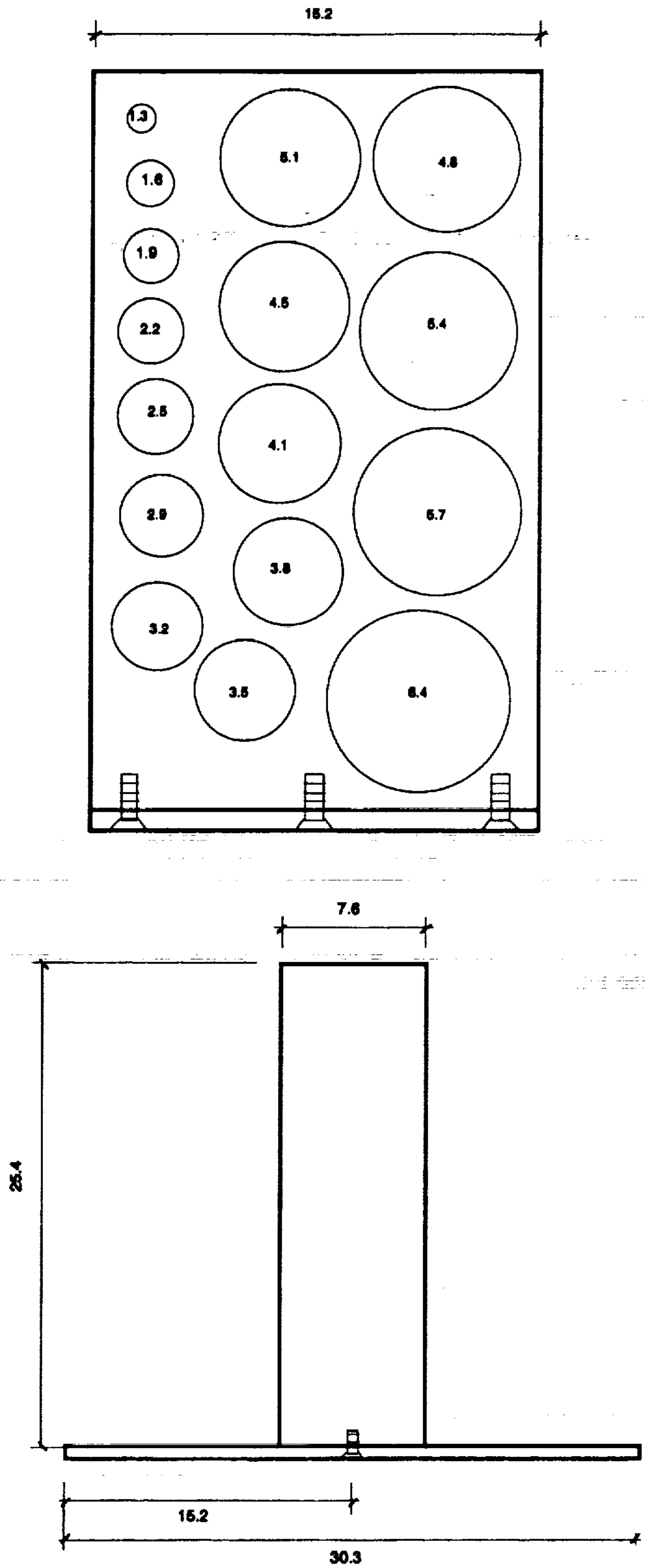

Figure 2. Front and Side Views of the Aluminum Block (Note: All dimensions are in cm)

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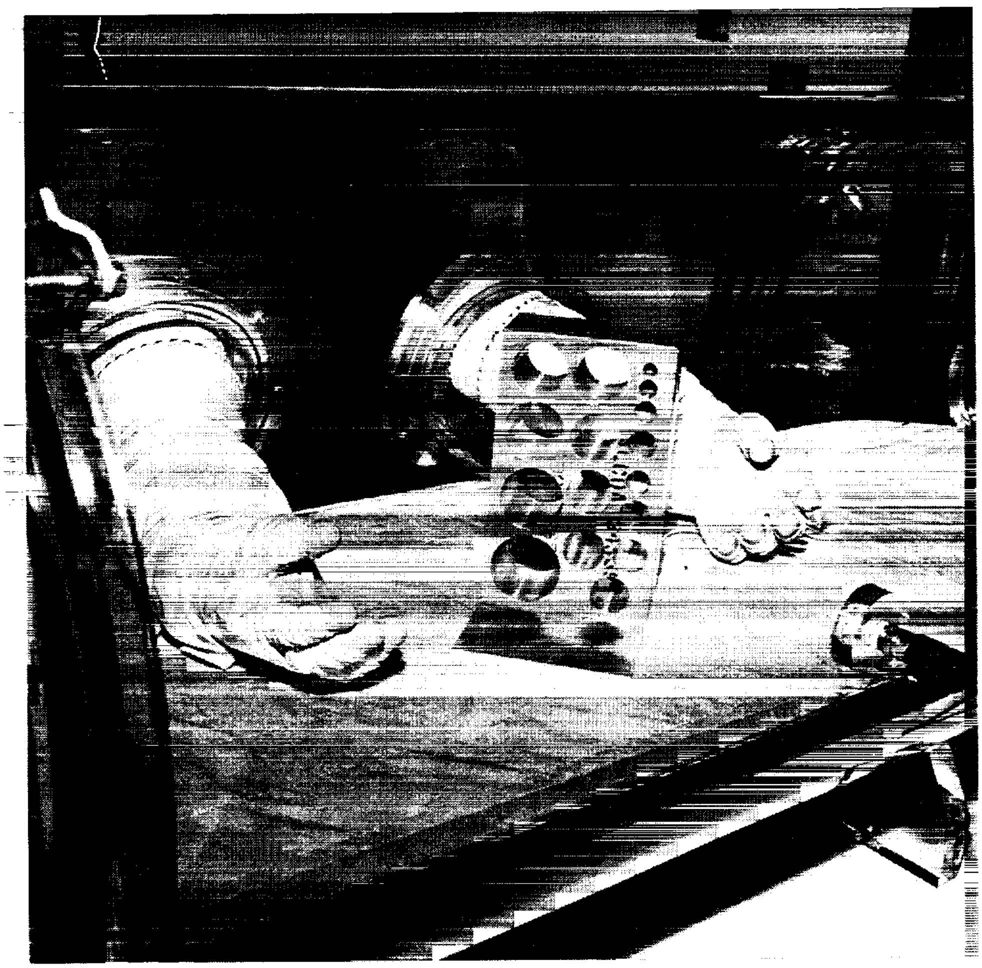

Figure 3. Experimental Setup with the Aluminum Block

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Figure 4. Subject Performing the Experiment

Table 1. Subject, Glove, and The Hole Diameter Data

Subject ID #	Sex	Glove Size	Small Diameter (No - Go) (cm)	Large Diameter (Go) (cm)
1	M	Large (ZI)	1.6	3.5
2	M	Large (ZI)	1.6	3.8
3	M	Large (ZI)	1.6	3.5
4	M	Large (ZI)	1.6	3.8
5	M	Large (ZI)	1.6	3.5
6	M	Medium (ZG)	1.3	3.2
7	F	Small (ZA)	1.3	3.2
8	F	Small (ZA)	1.6	3.5
9	F	Small (ZA)	1.6	3.8
10	F	Small (ZA)	1.6	3.8
11	F	Small (ZA)	1.3	3.5

Note: Small Diameter (No-Go) refers to the diameter that prevented insertion.

Large Diameter (Go) refers to the diameter that allowed the fingers to slide through easily.

References

Man-Systems Integration Standards. Lyndon B. Johnson Space Center, Houston, Texas, October 1989. NASA-STD-3000, Revision A.

Rajulu, S.L. and Klute, G.K.: A Comparison of Hand Grasp Breakaway Strengths and Bare-Handed Grip Strengths of the Astronauts, SML III Test Subjects, and the Subjects From the General Population. National Aeronautics and Space Administration, Washington, D.C., Jan 1993. NASA TP-3286.

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One of the concerns of Space Station designers was making sure that the suited crewmembers' gloved fingers are not trapped in the holes that may be present in the structures during EVA activities. A study was conducted on 11 subjects to determine the minimum and maximum possible hole sizes that would eliminate the possibility of finger entrapment. Subjects wore pressurized gloves and attempted to insert their fingers into holes of various sizes. Based on the experimental results, it is recommended that the smallest diameter should be less than 13.0 mm and the largest diameter should be greater than 35.0 mm in order to eliminate the possibility of finger entrapment while wearing gloves. It is also recommended that the current requirements specified by the MSIS-STD-3000 (Section 6.3.3.4) should be modified accordingly.

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