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ARMSTRONG LABORATORY

STANDARDIZED TEST METHODOLOGY FOR MEASURING PRESSURE SUIT GLOVE PERFORMANCE AND DEMONSTRATION UNITS

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This report reflects the effort of a two-phase task for developing a standardized test methodology for comparing pressure gloves and for analyzing current pressure glove performance requirements to determine performance specifications required for an enhanced higher pressure (7 psid maximum) glove for use in high altitude aircraft cockpits and/or the National Aerospace Plane (NASP). To be functional at the higher pressure, new concepts for joint design and new material for glove construction were explored. The end result was a glove design concept that was functionally the best for the defined pressure.

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TABLE OF CONTENTS

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List of Figures

List of Tables

1.0 BACKGROUND and INTRODUCTION

The human body functions optimally at ground level. It is desirable therefore to try to maintain ground level conditions when people are called upon to operate in other than ground level surroundings. This is the justification for pressurized cabins in aircraft. For military aircraft, the need for providing a means of pressurization in the event of the loss of cabin pressure has great priority. This means is provided by wearing full pressure suits. Granted, a majority of flights occur in a vent mode where the pressure suit is unpressurized; however, good design mandates that pilots should have the equipment that would protect them when the need arises. Currently the pressure suit inflates to 3 psid for pressure protection/compensation. The next logical step is to increase that pressure envelope from 3 psid to 7 psid so as to attain a functional pressure closer to that at ground level. Because of the pressure increase, challenges arise in joint control, movement, and dexterity. There have been advances in joint design and in materials to curb the undesirable effects associated with higher operating pressures. The objective then is to build a suit capable of handling the 7 psi pressure with little degradation in performance in comparison with the current full pressure suit.

The purpose of this report is to summarize the technical effort accomplished under contract F33615-87-D-0652; Development of a Standardized Test Methodology for Measuring Pressure Suit Glove Performance and Demonstration Units, Phases I and II. Phase I consisted of a literature/document review of pressure glove test methodologies and development of a test methodology to be used for the comparison and performance evaluation of different glove designs. Phase II consisted of a task analysis of cockpit controls, establishment of a preliminary glove design requirements document, development of glove design trade matrices and glove component design concepts, materials investigation and a final proposed design concept. Details of these efforts a.. provided in the following sections.

2.0 Program Objectives and Approach

A research interest was expressed for increasing the operating pressure of the pressure suit. For this report, the focus is on the pressure glove. The current USAF full pressure glove is not designed to operate at pressures above 3 psid, therefore a new glove design is required to provide the needed protection with higher operational pressures without drastically compromising mobility and dexterity. The Human Systems Crew Technology Division of the Armstrong Laboratory at Brooks AFB (AL/BAFB) is researching viable pressure garments capable of operating at pressures up to 7.0 psid. AL/BAFB is pursuing the development of advanced full pressure suit technology due to large degradation in dexterity and tactile response associated at higher operating pressures. The anticipated applications will be in future high altitude reconnaissance aircraft and trans-atmospheric vehicles.

A glove design concept was developed in which the performance characteristics of the glove were optimized to the maximum extent possible. This glove design can then be evaluated against the existing

USAF full pressure suit glove (as well as any other gloves) utilizing the test methodology, located in appendix section 12.1, that was developed during Phase I. The data can then be utilized to tailor the design once a final application is defined.

3.0 Literature Review

ILC conducted a literature review and data search for test methodologies and studies related to testing of pressure suit gloves. This search included a NERAC search, (a modem access information service which includes both defense and non-defense related topics), a Defense Technical Information Center document search, and a review of ILC Extravehicular Activities (EVA) glove test protocols. Data obtained from the literature review and search were used for the development of the individual test protocols. The EVA Limitations Study by J. O'Hara et. al. was the principle document used for this effort. [1]

4.0 Test Methodology

Current test methodologies do not evaluate the relative performance of one glove design to another. The test methodology developed was intended to assess the key characteristics of a hand wearing a pressure suit glove relative to a bare hand. This data is then compared for different pressure suit glove designs, regardless of application.

One of the key issues during the development of the test methodology was whether or not the test success criteria should be included within the individual protocols. It was decided that the Test Methodology should be generic for a comparative evaluation of any pressure suit glove and test criteria should be included in a detailed test protocol and/or a design performance requirements document. These documents would be generated upon completion of a task analysis once the pressure suit glove application had been established. A functional schematic of the pressure suit glove test methodology development, design and evaluation is shown in Figure 1, which describes the relationship between and application of the documents identified above and the design and test process.

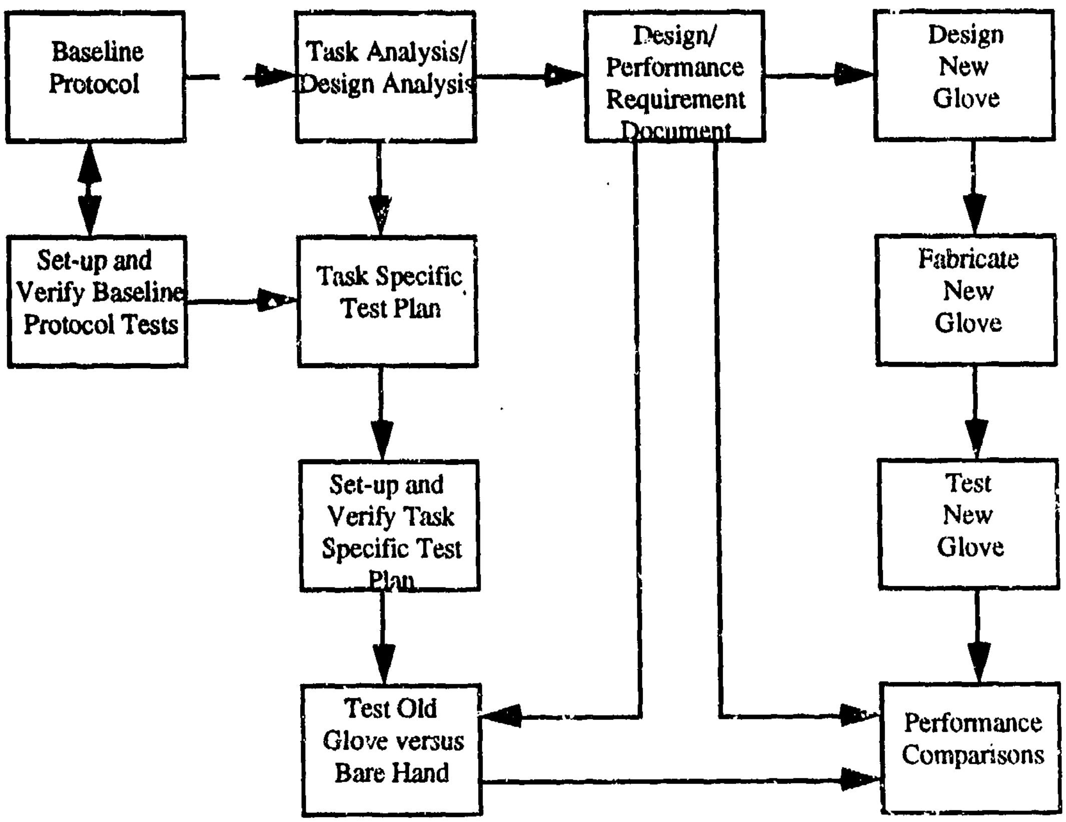


Figure 1
Pressure Glove Test Methodology Development, Design and Evaluation Flow Diagram

There are seven (7) key glove performance characteristics which were evaluated in the test protocols: 1) Range of Motion, 2) Hand Strength, 3) Tactile Perception, 4) Dexterity, 5) Fatigue, 6) Comfort, 7) Environmental Protection. A summary of these protocols is provided in Table 1.

Table 1 Test Methodology Protocol Summary

Attribute	Measured Value	Comments
Range of Motion with Torque Sensing	Thumb, fingers and wrist range of motion. Thumb, finger, and wrist forces required to induce glove geometry change.	Data will be electronically recorded with a time channel, a displacement channel and force channels as required to displace the glove geometry. Data will be reduced by computing the difference between bare handed maximum range of motion and gloved hand range of motion.
Strength	Maximum pinch/grip force. Maximum pinch/grip torque.	Data reported will consist of torque/grip force differences between bare hand and gloved hand.
Dexterity	Number of tasks completed. Number of errors.	Data reported will be the difference between the bare hand and gloved hand performance. Task and error z scores will be combined and reported as a single score.
Tactile Perception	Two point discrimination adjusted to prevent guessing. Grip force discrimination.	Data reported for point discrimination will be the difference between bare hand and gloved hand performance. Task and error z scores will be combined and reported as a single score. The difference between grasping force and slipping force will be reported.
Comfort	Test subject responses to an attribute rating scale.	Data reported will be by glove and combined.
Fatigue	Work capacity. Maximum contraction.	Data reported will be the difference between bare hand and gloved hand performance.
Environmental Protection	Thermal conductivity of the glove.	Thermal conductivity data of each glove will be reported.

Of the seven performance characteristics previously listed, methods for accurately measuring range of motion and force application were the focus for discrete, quantitative data collection. The better the resolution of the data collected, the assumption is that variances or changes in glove design will be more distinct so as to identify the best features.

The test protocols will utilize only right handed subjects. Two subjects shall be selected for each of two glove sizes. Each test subject will conduct three trials for each glove, for each protocol, for every test condition (bare handed, gloved hand vent pressure, gloved hand pressurized). The number of test subjects and trials were limited to the minimum number required to be statistically significant, due to potential time and funding restraints which may be imposed in the future and during actual testing. Additional test subjects and trials may be included if desired.

Test randomization will be done by subject, by iteration with a random selection routine which selects the test order of the protocols and the test condition. Although complete randomization of all tests would be optimal, it is impractical due to the length of time associated with each test set-up.

Subject training will be accomplished prior to testing. Each subject will be instructed on how to conduct the test and allowed three practice trials. This number was chosen since previous studies conducted at ILC indicate that the learning curve begins to level off at 4-5 trials.

Each test subject will be properly fit prior to testing. In addition, subject hand anthropometry will be taken to quantitatively evaluate the subjects fit in the glove.

There have been no significant advances in the test protocols for measuring glove performance characteristics, over the recent years. Generally, improvements were made to existing protocols to minimize variation between tests and test subjects as well as control the accuracy and repeatability of test measurements. However, the previous methods for measuring Range of Motion are antiquated with the recent evolution of sensor technology for hand joint location and its conversion into computer readable data. In addition, previous Range of Motion protocols never attempted to measure the force required to move a glove throughout a range of motion. This information is useful for glove designers in establishing the work load imposed by the glove on the hand.

4.1 Range of Motion (ROM)

In order to address the issue of collecting Range of Motion data, ILC conducted an investigation of potential glove joint sensing technologies. CyberGlove™ manufactured by Virtual Technologies and the DataGlove manufactured by VPL and distributed by Greenleaf Medical were identified as potential candidates.

Virtual Technologies' CyberGlove™ was developed for applications in virtual environments, robotics and sign language recognition. Virtual

Technologies is conducting further research with the CyberGlove™ to incorporate a tactile feedback system through the use of mini air bladders. The CyberGlove™ is robust, user friendly and offers many advantages over the DataGlove. The system is PC and SPARC compatible capable of providing output in a format of range of motion measurements or displacement as a function of time. Sensors are flat strips of coated plastic that lay flat over the joints extending considerably past the joint to accommodate different sizes. The CyberGlove™ currently incorporates adduction sensors which will need to be removed for application to the test methodology since they protrude from the CyberGlove™ and contact with the pressure glove may yield erroneous readings. (Adduction is not required for the collection of Range of Motion data.) DIP sensors should be utilized since the suit glove may affect the joint motion. The CyberGlove™ is almost transparent to the user and any contact of the sensors with the pressure glove will not affect them. The sensors can be adjusted for linear offset and gain for calibration purposes. Joint lengths are measured from the hand and input into the program so a visual depiction of the Range of Motion data can be realized on the CAD system. An on-screen calibration program allows for the individual adjustment of joints. In addition, virtual Technologies is developing objects to grasp to calibrate the glove and joint angles.

Greenleaf Medical is the licensed vendor for the VPL DataGlove and is involved in upgrading the glove to make it more accurate and tailored to meet the customers specific needs. Their derivative of the DataGlove is the Movement Analysis System, (MAS). Their system was basically developed for medical applications. The MAS system is Apple MAC compatible. The output data is automatically plotted, time vs. displacement and data from any joint can be overlaid on a plot. The glove uses fiber optic cables as sensors which have a tendency to degrade over a period of time. The MAS goal for accuracy is 5% or less over the estimated six month life of the item. The MAS glove also incorporates sliding cables in sleeves in order to not restrict motion, however these cables become less mobile with time and make data less accurate. The cable sensors are noticeable to the wearer and provide a slightly higher profile than the CyberGlove™. Calibration of the MAS glove is accomplished through general hand positioning, (i.e. "hold hand flat on table for zero degree flexion" and "bend finger MCP to 90 degrees") and is difficult to achieve a high degree of accuracy. Greenleaf is working on developing calibration standards to rest the back of the hand against instead of relying on a visual assessment of hand positioning. The MAS glove does not take into account subject joint lengths and hand measurements.

Upon careful evaluation and demonstrations of both the glove systems, the CyberGlove™ offers significant advantages over the MAS system including:

1) Higher accuracy and repeatability of data.
2) Lower profile and impact on pressure glove fit.
3) Longer useful life.
4) Greater flexibility and capability for tailoring and data collection.

For these reasons, the CyberGlove™ is recommended for use with the test methodology.

4.2 Force/Torque Sensing (through ROM)

A test protocol to measure the torque or force required by the hand to move a pressure suit glove through its entire range of motion has never been developed. This data would be a useful evaluation parameter when comparing two different glove designs. Two gloves may have identical Ranges of Motion, however, the force required to move one glove throughout this range may be significantly higher or lower, which will relate to the rate of fatigue and performance of the hand while wearing the glove. In recognizing the need for this information, ILC developed concepts for collecting torque sensing data in a pressure suit glove to be used in conjunction with the CyberGlove™.

ILC investigated the use of pressure sensitive foam or inks for sensing torque/force differentials. These sensors would be discretely located at different positions on either the CyberGlove™ or a comfort glove to be worn with the CyberGlove™ during testing. Data from the torque/force sensors would be collected as a function of time and integrated with the Range of Motion data.

ILC conducted preliminary studies to verify the application of pressure sensitive foam or ink technology to torque sensing in gloves. A glove was instrumented with either the foam or the ink in the palm pressurized in a step function at 1.0 psi intervals. The voltage reading across the foam or ink was then recorded as a function of time. Figures 2-4 and 5-7 respectively depicts the results of using the foam sensor and Tekscan techniques for range of motion measurement. With the foam sensor, runs 1-3, the pressure was increased by 1 psi every 60 seconds up to 5 psi and then decreased by 1 psi every 60 seconds. During the first and last 60 seconds of the test, the pressure in the glove was maintained at 0.25 psi. With the Tekscan ink sensors, run 1, the initial pressure of 0.25 psi was increased at 60 seconds by 1 psi every 120 seconds up to a maximum pressure of 2 psi and then it was reduced by 1 psi every 120 seconds to 0.25 psi. With the Tekscan ink sensor, run 2, the initial pressure of 0.25 psi was increased by 1 psi every 60 seconds up to maximum pressure of 3 psi and then reduced at the same rate to 0.25 psi. During this run at 2 psi and as the pressure was increased from 2 to 3 psi, problems were experienced with the electrical contact of the leads to the sensors resulting in the spikes noted in the data. With the Tekscan ink sensor, run 3, the initial pressure was increased at 60 seconds by 1 psi every 120 seconds up to a maximum pressure of 5 psi. Beginning at 3 psi considerable problems with the electrical leads were experienced resulting in the downward spikes in the data.

Further development of either the foam or the ink sensors would be required during the next phase. Unless the problems with the electrical leads with the ink sensor can be resolved, the foam appears to be the most promising. It may be possible to utilize soft leads attached to the sensor which would eliminate the problems exhibited during this initial investigation. Other problems with the mylar ink film include the

the sensor which would eliminate the problems exhibited during this initial investigation. Other problems with the mylar ink film include the potential for bending and shearing of the conductive ink. The mylar ink film must be kept flat in order to prevent this from occurring. There are also some disadvantages exhibited with the foam. As the pressure was increased, a clean step function in voltage was not experienced as it was in de-pressurization. Also as the foam becomes compressed, the difference in force becomes indistinguishable. For example with the foam, during de-pressurization, the voltage reading for 4 psi and 3 psi is relatively close and almost indistinguishable. It was also interesting to note with both the foam and ink sensors that the voltage reading for the same pressure was consistently higher during de-pressurization than it was for pressurization. Final application of one of these technologies to pressure glove testing will need to be accomplished during Phase III, if granted.

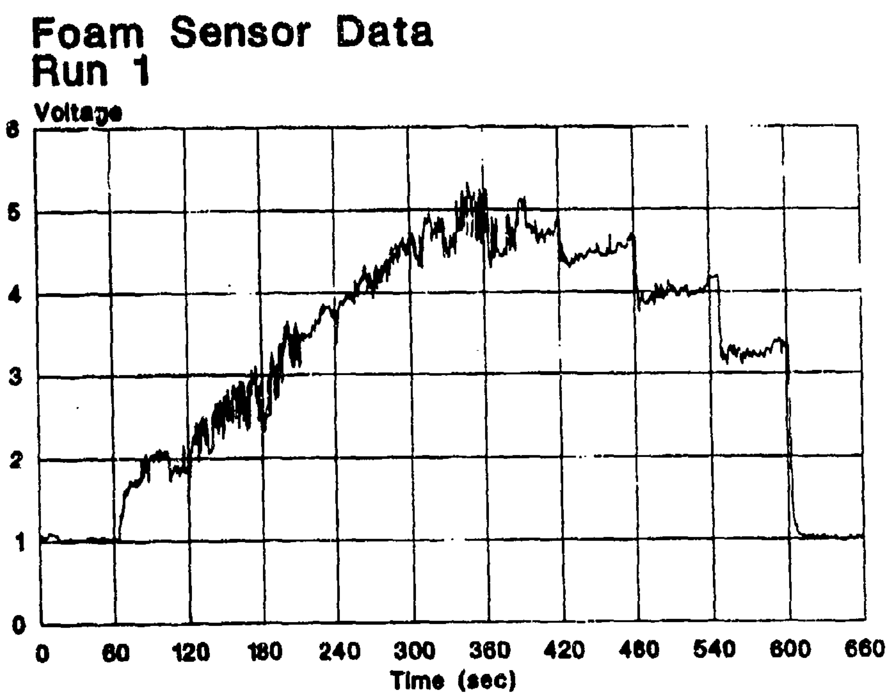


Figure 2
Foam Sensor Data: Run 1

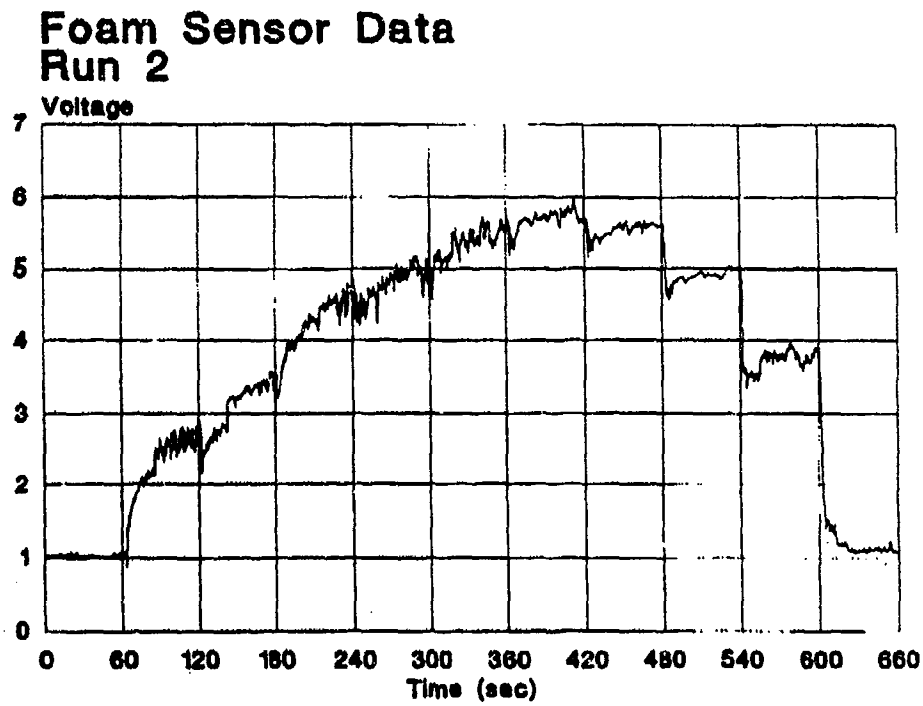


Figure 3
Foam Sensor Data: Run 2

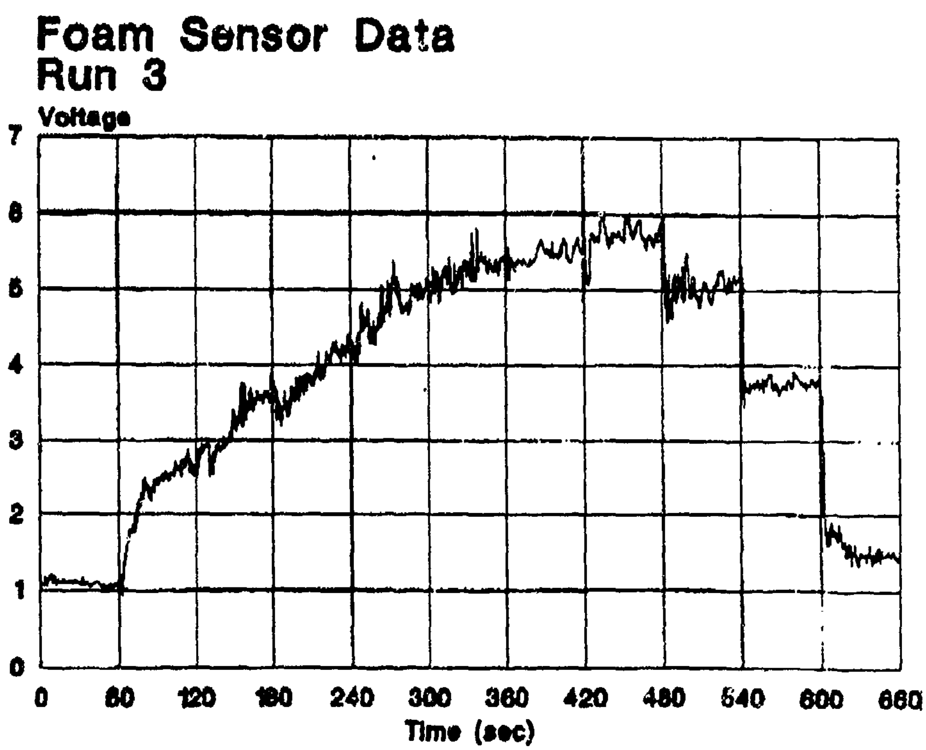


Figure 4
Foam Sensor Data: Run 3

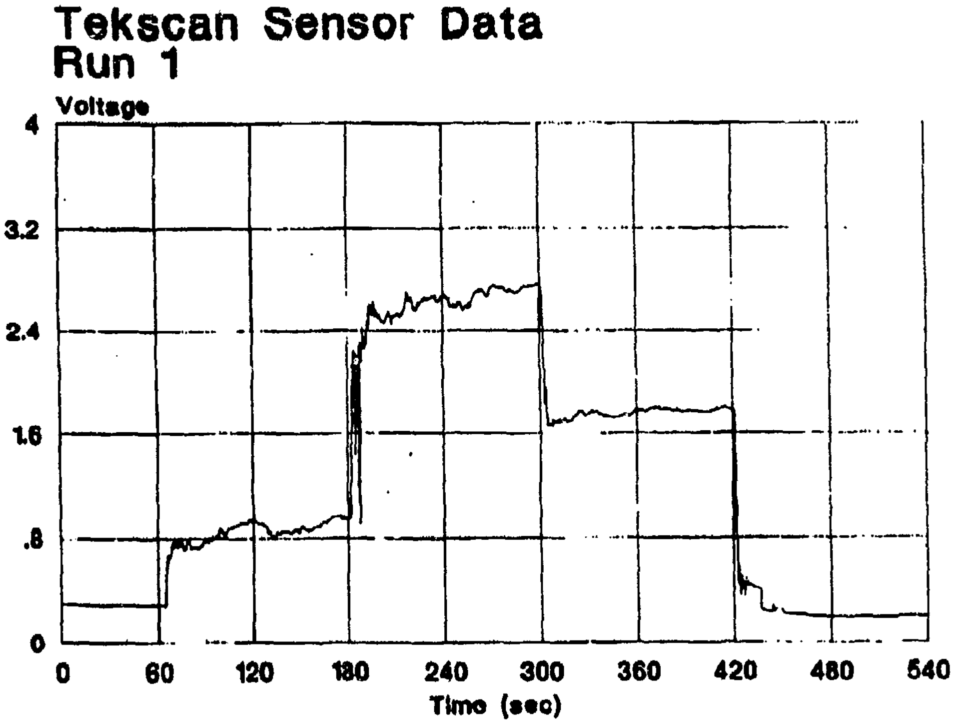


Figure 5
Tekscan Ink Sensor Data: Run 1

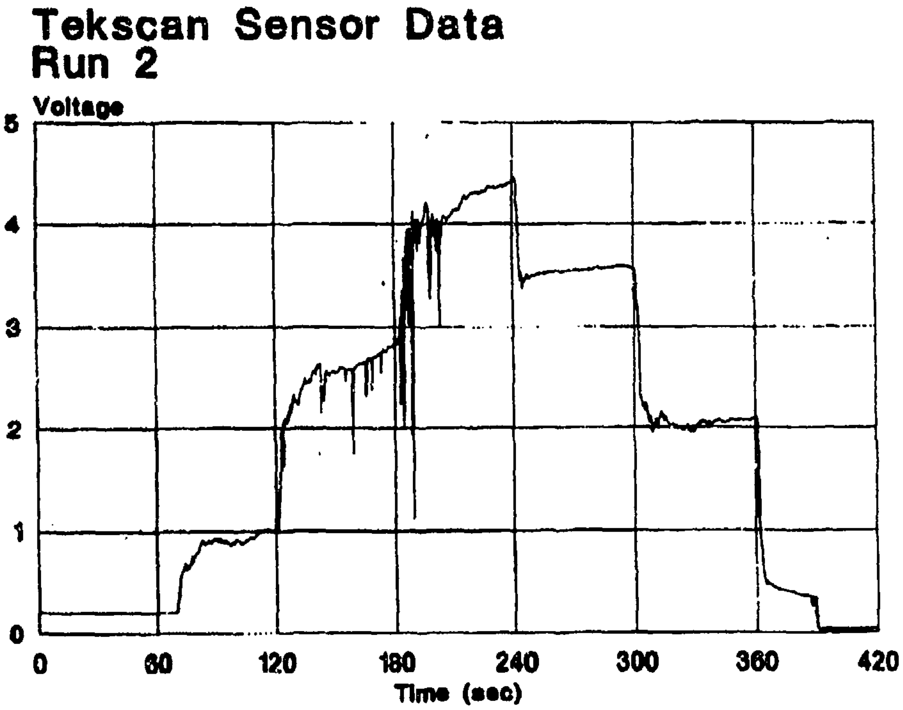


Figure 6
Tekscan Ink Sensor Data: Run 2

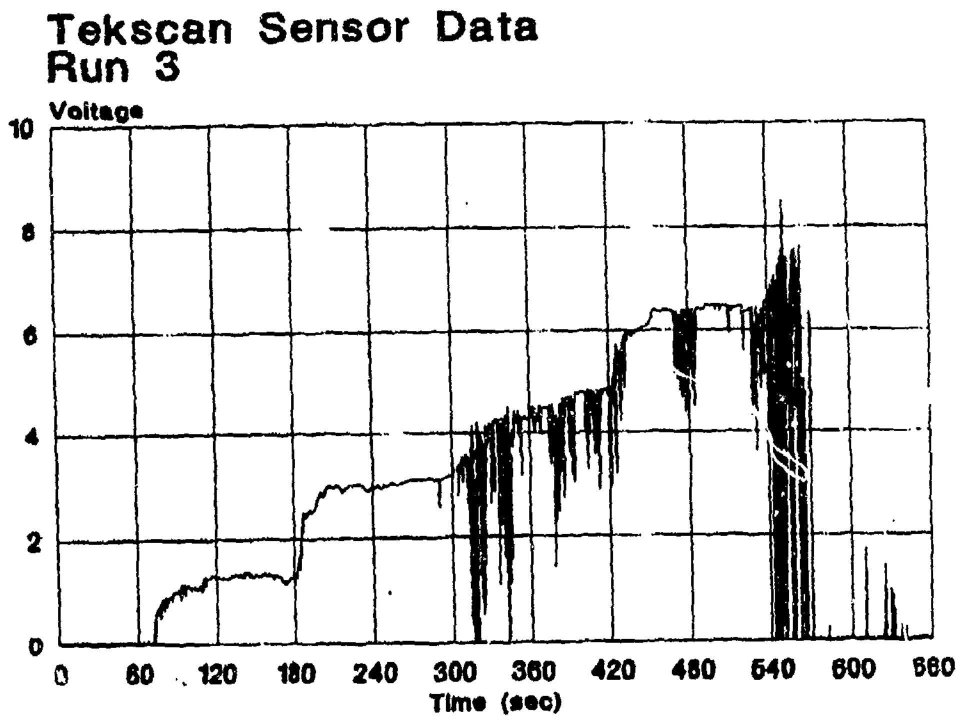


Figure 7
Tekscan Ink Sensor Data: Run 3

5.0 Task Analysis

A task analysis was conducted to obtain a qualitative perspective and where possible quantitative data to support definition of the requirements for design and testing of a pressure suit glove. Specific hand motions, movement and manipulations accomplished in the U-2 and SR-71 cockpits were evaluated since the anticipated applications of the pressure suit glove designed under this contract are in high altitude reconnaissance aircraft and trans-atmospheric vehicles. In order to accomplish the task analysis, a flight phase summary of the air crew tasks was established and is provided in Table 2.

Table 2 Flight Phases for Pressure Suit Glove Task Analysis
1. Equipment donning, safety checks and pre-breathing
2. Transportation to aircraft and preflight inspection
3. Cockpit insertion
4. Prestart activities and engine start-up
5. Taxi and takeoff activities
6. Flight Activities: a. Aircraft directional control and throttle b. Rotary controls/switches c. Linear controls/switches d. Push and toggle switches e. Joystick controls f. Keypad entry g. Emergency procedures
7. Escape a. Ejection seat activation b. Parachute modifications/control c. Emergency ground egress
8. Survival a. Landing/Water entry b. Release from parachute c. Raft boarding d. Activation of life support equipment

The following facilities were visited during the task analysis:

- NASA Ames EVA Systems Branch.
- NASA Ames High Altitude Flight Office.
- Edwards AFB PSD.
- NASA Dryden Flight Research Facility.
- Beale AFB PSD.

A summary of the data obtained from each facility is provided in Table 3.

Table 3 Task Analysis Data Summary

Facility	Results Summary
NASA Ames EVA Systems Branch	• NASA Ames is working on development of a glove test methodology, specifically an instrumented glove for gathering Range of Motion and Torque Data. Concerned expressed with using the VPL glove due to repeatability. • Zero G hand growth is currently being investigated at Ames.
NASA Ames, High Altitude Flight Branch	Comments on the performance of the current flight suits from U-2 pilot and suit technician: • Bladder bunching in glove is a problem. • Small buttons are difficult to operate when pressurized. • Inertial Navigation System (INS) is difficult to operate when pressurized. • Donning of the glove is difficult. • Flocking on the gloves wears off quickly and bladders must be replaced frequently.
Edwards AFB	The following summarized data was received from a Pressure Suit Indoctrination Class and S-1031 design discussions: • Pre breathing is accomplished on the ground for 1 hour for the U-2 and 30 minutes for the SR-71. • Vent pressure is 5.5 IWG, however, pilots may increase pressure for cooling or weight relief. • Helmet latching, use of food tubes, controller operations and torso hold down straps are hand manipulative tasks accomplished by air crew.
NASA Dryden	An SR-71 Cockpit Evaluation was conducted in both the front and rear seats. Noted were the following: Front Seat (Pilot) • Use of pitch control wheel is difficult in glove due to lack of tactile perception in the tips of fingers. • Circuit breakers on right rear panel are close together and difficult to operate. • Circuit breakers under left rear canopy rim are close to the wall and are difficult to operate. • Wrist disconnect size is limiting factor in operation of exhaust gas temperature controls. • Wrist motion required to operate the control stick. Rear Seat (Navigator) • INS push buttons are close together and difficult to operate. • Numbered rolling wheel difficult to operate. • Difficult to determine activation of ANS buttons. General • Windows in cockpit can reach 200°F. • Radio knobs are lift and rotate type and are close together and are difficult to operate.

(Con't. Table 3)

Edwards AFB	An S-1031 Suit Fit Demo was given and the comments, with respect to the glove, are: • Proper glove fit for tightness occurs when two fingers can be placed under the glove straps. • The glove is sized by hand circumference and length. • The glove bladder life is three years from installation, with a half life of 5 years. • Nominal flow for cooling is 100 - 150 L/min.
Beale AFB	Suit specialists were contacted to discuss S-1031 suit performance in the U-2. The following summarizes comments relative to the glove. • Loss of cabin pressure during flight does not occur frequently. • Palm bars are not currently used on U-2 flights. Previously, problems were experienced with the palm bars bending and causing discomfort. • The suit requires chemical protection. • Light colored materials are desired due the thermal absorption. • Long duration flights (up to 23 hours) have been accomplished. A U-2 cockpit evaluation was conducted with pilot input received. The following summarizes comments relative to the glove. • INS is difficult to operate. Pilots use their pencil to activate the INS. • The U-2 cockpit is tighter than the SR-71 but does not have as many controls. • Wrist rings and straps on the glove catch on things (i.e. canopy jettison switch, transponder). • Trim wheel is difficult to operate. • Reset of fuel counter is difficult to accomplish. • Current glove grip is good. • Pressurized suit flight activity includes operation of radio button on the throttle, radios on the left side, and yoke ops. • Hot spot in glove created by the vent tube. • Writing and turning pages in approach plate book are difficult with gloves. • Hands sweat profusely during missions. • The Wrist Ring causes difficulty in donning for large individuals. • Suede on palm side of the glove becomes slippery with wear. • Tabs for bladder indexing can be pressure points. • Evidence of wear/abrasion noted first on the fingertips.

Overall, results of the task analysis showed that cockpit technology utilizes basic MIL-STD-1472, MIL-STD-1333 and Aeronautical System Design handbooks DH 1-3, 2-2, and 2-8 as guidelines. Fingertip tactility and keeping gloves small and conformed to the hand are key characteristics for a pressure suit glove. The majority of use time is unpressurized and performance design should be weighed toward this mode of flight.

6.0 Requirements Document

A preliminary draft of a requirements document for a pressure suit glove was generated based upon the results of the task analysis and basic glove and life support equipment design parameters. A copy of this document is provided in Appendix 12.2. This document as written is incomplete concluding with Section 3 which outlines the estimated performance requirements of the glove. Section 4, will specify how the glove is to be tested to verify the design to the performance requirements. Section 3 should be updated and Section 4 should be written once the final glove application and mission profile is defined.

7.0 Design Methodology

With the performance characteristics and design requirements for a pressure suit glove defined by the Test Methodology and Requirements Document, ILC established design guidelines to achieve the desired attributes. This design methodology is provided in Appendix 12.3. The design guidelines for one performance characteristic may overlap or contradict the design guidelines for another characteristic. In order to resolve this, these guidelines were then used to develop component concepts for glove designs which were then collected and evaluated in trade matrices.

8.0 Trade Matrices

Trade Matrices were developed for the following glove components:

1) Bladder Concepts
2) Bladder Installation Concepts
3) Restraint Finger Concepts
4) Palm Restraint Concepts
5) Restraint Finger MCP Joint Concepts
6) Restraint Thumb CMC Joint Concepts
7) Wrist Concepts
8) Cover Glove Concepts
9) Cover Glove Indexing Concepts
10) Thermal Relief Concepts

Designs were developed with each of the above components and tabulated in trade matrices which may be found in Appendix 12.4. Sketches of the concepts may be found in Appendix 12.5. In each of the matrices, each of the concepts were evaluated against selected performance characteristics at both vent pressure and 7.0 psid. Performance characteristics were selected based upon the ability of the component to impact that characteristic in the final glove design. Each of the performance characteristics were then related back to a specific paragraph number in the requirements document (see Appendix 12.2). Each of the component concepts were then rated on a scale of 5 (best possible) to 1 (poor or unacceptable) based on the ability to optimize or maximize the performance characteristics. Each performance characteristic was then assigned a weighting factor from .1 to 1 at both 7 psi and vent pressure. Weighting factors were assigned assuming that the glove would be operating at vent pressure for the majority of the useful life and that the glove performance was paramount to maintainability, ease of manufacturing, cost and reliability. In addition, an accurate assessment of maintainability and reliability is difficult to achieve without the actual application and mission profile established. Assessments for cost were based on relative material costs among concepts. Assessments for ease of manufacturing were based upon the complexity of the glove design and the handling and manufacturing ability of the chosen materials.

Rating factors for the component concepts were then determined at 7 psi, vent pressure and a combination of both. A risk/benefit assessment was conducted for the top 3 concepts for each component. This summary is provided in Appendix 12.6. These top 3 concepts were also combined into 3 testbed glove designs for preliminary evaluation and selection of the final glove design.

9.0 Testbed Glove Concepts and Final Glove Design

ILC developed and fabricated 3 each Testbed Glove Concepts as shown in Figures 8 - 10, and summarized in Tables 4 and 5. Qualitative Engineering evaluations were then conducted to determine the proposed final glove design which is a combination of the testbed concepts. The final proposed glove design is shown in Figure 11 and defined by the following ILC drawings:

827-10004	7 PSI Glove Assembly.
827-20005	7.0 PSI Restraint Assembly.
827-20006	7.0 PSI Glove Bladder Assembly.
827-20007	7.0 PSI Cover Glove Assembly.
827-20003	7.0 PSI Glove Sections.
827-30008	Pattern, Glove, Restraint, 7.0 PSI.
827-30009	Patterns, Glove Cover, 7.0 PSI.
ST67E2931	Moisture Vapor Permeable Urethane.

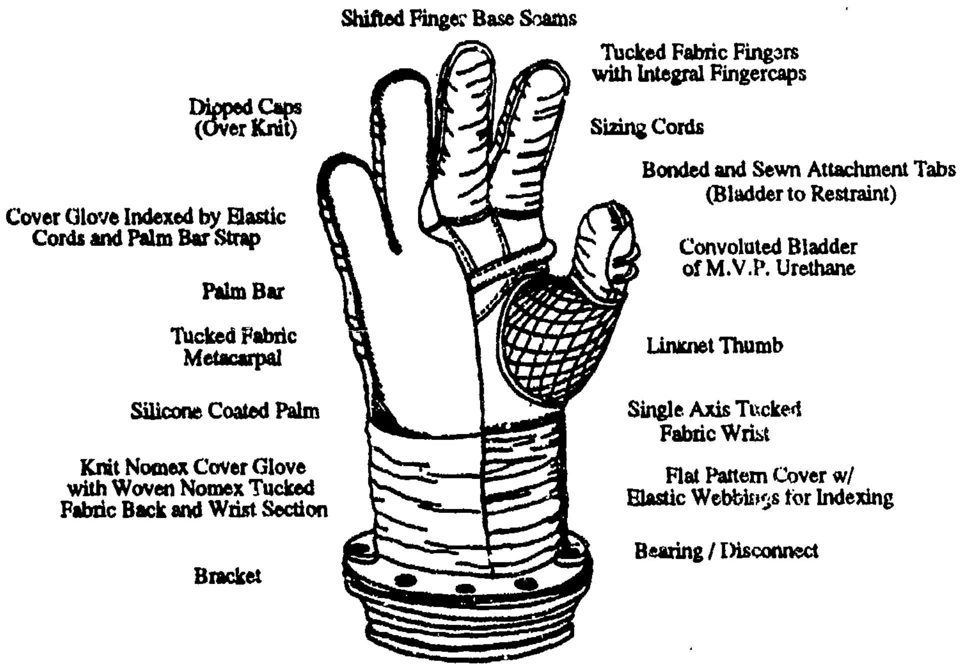


Figure 8
Testbed Glove Concept #1

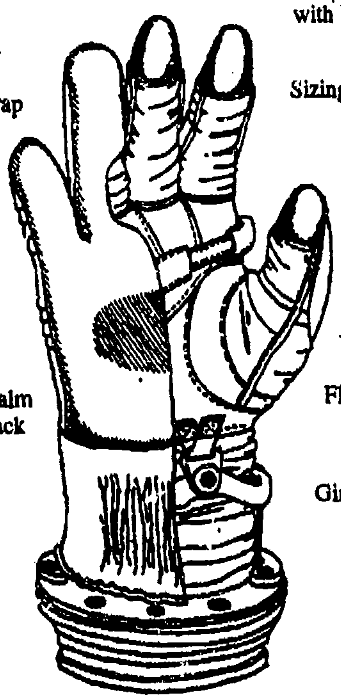


Figure 9
Testbed Glove Concept #2

Figure 10
Testbed Glove Concept #3

Table 4 USAF 7 PSI Glove Top Concepts

Glove Component	*Concept #1*	*Concept #2*	*Concept #3*
Bladder Design	Convoluted	Oversize	Line to Line*
Bladder Material	MVP Urethane	Latex	Urethane*
Bladder Attachment	Bonded Stripes	Sewn Tabs	Bonded Stripes and Elastic Webbings
Finger Restraint	TF with integral cap	TF with cap	TF Seams Inward
Finger Sizing	Standard & Sizing Cords	Standard	Custom
Finger Termination	Shifted Seams	Crotch Termination	Molded Sections*
Palm Restraint	Hand Back Bar*	Palm Bar*	Straps*
Finger Metacarpal	Tucked Fabric	Flat Pattern	Laminate*
Thumb Carpometacarpal	Linknet	Tucked Fabric	Flat Patterned
Restraint Materials	Polyester*	Nomex*	Laminate*
Wrist	Single Axis FP	Gimbal Ring	Sliding Cord*
Cover Glove	Knit Palm, FP Back	Knit Cover	No Cover*
Cover Glove Indexing	Elastic Cords in Fingers, Palm Bar through Cover, Elastic Webbings in Wrist	Localized Sewing, Palm Bar through Cover, Nothing in Wrist	No Attachment (w/ knit), Straps through Cover, Knit Material in Wrist

* Different than in corresponding test bed glove. Changed because concept was on an existing pressure suit glove or similar to one of the other top concepts.

Table 5 USAF 7 PSI Glove Test Bed Mock-ups

Glove Component	*Test Bed #1*	*Test Bed #2*	*Test Bed #3*
Bladder Design	Convoluted	Oversize	Convoluted
Bladder Material	MVP Urethane	Latex	Latex
Bladder Attachment	Bonded Stripes	Sewn Tabs	Bonded Stripes and Elastic Webbings
Finger Restraint	TF with Integral Cap	TF with Cap	TF Seams Inward
Finger Sizing	Standard & Sizing Cords	Standard	Custom
Finger Termination	Shifted Seams	Crotch Termination	Crotch Termination
Palm Restraint	Palm Bar	Hand Back Bar	Localized Stiffeners
Finger Metacarpal	Tucked Fabric	Flat Pattern	Tucked Fabric
Thumb Carpometacarpal	Linknet	Tucked Fabric	Flat Patterned
Restraint Materials	Polyester	Nomex	Laminate
Wrist	Single Axis FP	Gimbal Ring	Linknet w/ Convolutes
Cover Glove	Knit Palm, FP Back	Knit Cover	Knit Palm, FP Back
Cover Glove Indexing	Elastic Cords in Fingers, Palm Bar through Cover, Elastic Webbings in Wrist	Localized Sewing, Palm Bar through Cover, Nothing in Wrist	No Attachment (w/ knit), Straps through Cover, Knit Material in Wrist

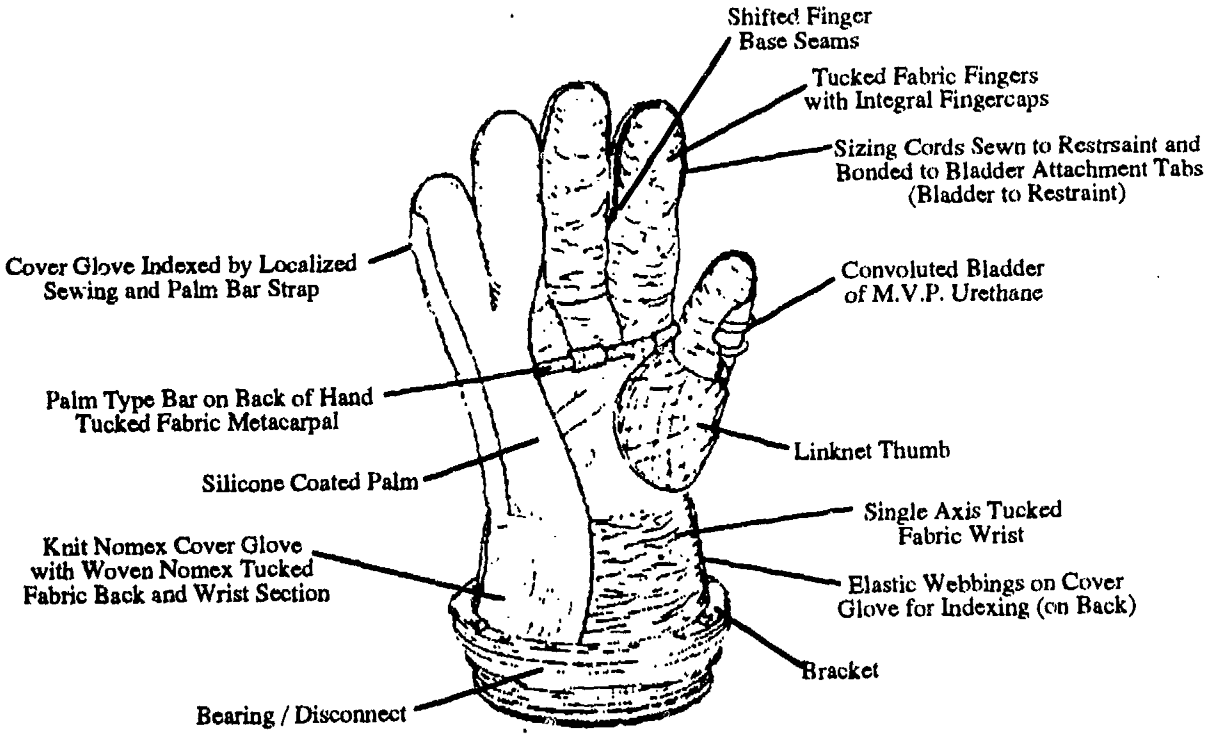


Figure 11
7 PSI Glove Assembly Proposed Design

A summary of the materials used in the final glove design is provided in Table 6. The following sections provide additional details of the bladder, restraint and cover glove.

Table 6 Materials List		
Component	*Material Description*	*Typical Properties*
Bladder:		
Primary	Moisture Vapor Permeable Urethane (ref. P/N ST67E2931)	• Inverted moisture vapor Transmission Rate at 6 mil thickness: 4700 g/m^2/day • Modulus: 950 psi • Tensile Strength: 5300 psi • Ultimate Elongation: 980%
Flange	Double Sided Urethane Coated Nylon (ref. P/N ST12N1225)	• Coating: Polyether Polyurethane • Weight: 4.2 oz/yd^2 • Tensile Strength: 70 lb/in • Heat Sealable
Flocking	Cotton Flocking (ref. P/N ST11C1935)	• 100% Cotton cuttings
Restraint Fingers:		
Basic Fabric	Polyester Ripstop (ref. P/N ST11P1932)	• Weight 3.0 ± 0.3 oz/yd^2 • Tensile Strength Warp: 119 psi Fill: 126 psi • Tear Strength: 11.5 lbs. • Elongation: 21%
Thread	Thread, Polyester (ref. P/N ST15P135-01 and -03)	• Size: B or F • per V-T-285 Type II, Class I
Cord Terminators	Anodized Aluminum Cord Terminators (ref. P/N 0106-27035-03)	• Material: Al 6061-T6 • Anodize: per MIL-A-8625, Type II, Class 2
Adhesive Tape	Double Backed Adhesive Tape	
O-Ring for Terminator	Viton O-Ring (ref. P/N ST60R2316-03)	• Shelf Life: 20 ye[illegible] • Durometer: 75
Bladder Anchor Strip	Double Sided Urethane Coated Nylon Material (ref. P/N ST12N1225)	• Coating: Polyether Polyurethane • Weight: 4.2 oz/yd^2 • Tensile Strength: 70 lb/in • Heat Sealable
Cord	1/16" Dia. Polyester Cord (ref. P/N ST14C1274-02)	• Min. Breaking Strength: 65 lbs. • Elongation: 7% min.
Cord, Thumb	1/32" Spectra Cord	• 185 Denier, 8 Carrier Braid
Thumb, Linknet Backing	Teflon Fabric (ref. P/N ST12T168-010)	• Weight: 5 oz/yd^2

(Con't. Table 6 Materials List)

Component	Material Description	Typical Properties
Restraint Palm:		
Palm Bar	17-4 PH Stainless Steel	
Webbing	1/2" Wide Polyester Webbing (ref. P/N ST13W128-03)	• Breaking Strength: 400 lbs.
Fabric	Polyester Cloth, 6.4 oz/yd^2 (ref. P/N St1 D587-02)	• Tensile Strength: Warp: 300 psi Fill: 250 psi • Elongation: 25% min. • Tear Strength: 15 lbs/in. min.
Velcro	Velcro Hook & Pile 1/2 in. wide (ref P/N ST12N060-14 and -03)	• per MIL-F-21840, Type II, Class I
Webbing	3/4" wide Polyester Webbing	• Breaking Strength: 1400 lbs.
Cord	1/16" Dia. Polyester Cord (ref. P/N ST14C1274-02)	• Min. Breaking Strength: 65 lbs. • Elongation: 7% min.
Thread	Thread, Polyester (ref. P/N ST15P135-01 and -03)	• Size: B or F • per V-T-285 Type II, Class I
Adhesive Tape	Double Backed Adhesive Tape	
Bladder Anchor Strip	Double Sided Urethane Coated Nylon Material (ref. P/N ST12N1225)	• Coating: Polyether Polyurethane • Weight: 4.2 oz/yd^2 • Tensile Strength: 70 lb/in • Heat Sealable
Buckle Assembly Palm Bar	Buckle Assy. (ref. P/N 0106-20745-02)	
Restraint Wrist:		
Fabric	Polyester Cloth, 6.4 oz/yd^2 (ref. P/N St11D587-02)	• Tensile Strength: Warp: 300 psi Fill: 250 psi • Elongation: 25% min. • Tear Strength: 15 lbs/in. min.
Thread	Thread, Polyester (ref. P/N ST15P135-01 and -03)	• Size: B or F • per V-T-285 Type II, Class I
Webbing	3/8" wide Polyester Webbing	• Breaking Strength: 300 lbs.
Brackets	Stainless Steel	

(Con't. Table 6 Materials List)

Component	*Material Description*	*Typical Properties*
Cover Glove:		
Basic Fabric	Multi-filament Nomex Knit	200 Denier Nomex Single Bar 28 Cut Tricot 24 ± 4 wales per inch 36 ± 4 courses per inch
Thread	Nomex	Size B and F
Anti-Slip Pads	Silicone, Dow Corning Silastic HS-30 (ref. P/N PE 100A409)	• Durometer: 31 • Tensile Strength: 1240 psi • Elongation: 1000% Tear Strength: 200 Lb/in.
Wrist Fabric	Nomex 2x2 Chain Weave Fabric (ref. P/N CP11-0166-2)	• Tensile Strength: Warp: 223 psi Fill: 200 psi • Elongation: Warp: 46% Fill: 39% • Tear Strength: Warp: 12.5 psi Fill: 13.8 psi • Weight: 5.04 oz/yd^2

9.1 Bladder

The glove bladder consists of a dipped moisture vapor permeable urethane with cotton flocking. A moisture vapor permeable material has the unique ability to hold pressure or prevent the diffusion of gas through the membrane however water vapor is transferred across the membrane by active diffusion. The Polymer Technology group developed the material for the glove bladder. To have a minimum inverted moisture vapor transmission rate (MVTR) of 4000 g/m^2/day at a 6 - 10 mil thickness, (i.e. the thickness of a dipped bladder). This MVTR is based upon the average rate of sweating in a male under high workload conditions.

This material offers significant advantages over a latex or urethane material. By adjusting the polymeric composition of the material, the tensile and abrasion resistance of a standard urethane may be achieved with the modulus and elongation of a latex as well as the moisture vapor permeation capability to reduce sweat build-up in the hands. Other desirable properties for this material include low modulus, high tensile strength and high ultimate elongation.

The glove bladder is convoluted over the back of the finger and thumb joints and around the wrist. Convolutes terminate at the neutral axis of the fingers and thumb. This design configuration allows for a constant volume joint throughout the range of motion.

9.2 Restraint

The restraint consists of a polyester ripstop within a single axis tucked fabric wrist, a back of hand palm bar, a linknet thumb and tucked fabric fingers with integral finger caps. The restraint is sewn to attachment pads and bonded to the fingers in order to achieve good indexing and minimize bunching and wrinkling of the slightly oversized bladder. (The bladder is slightly larger than the restraint to prevent any loading on the bladder.)

The tucked fabric fingers with integral finger caps allow for maximum fingertip tactility. Shifted seams biased towards the back at the fingertips minimize material build-up in this area and provide for improved tactility. Sizing cords are included in the fingers to provide the fingertips minimize material build-up in this area and provide for improved tactility. Sizing cords are included in the fingers to provide customizing the fit to the individual pilot. A linknet joint is included for the thumb CMC to provide for the full range of movement of this joint. The linknet consists of a continuous spectra cord over a teflon liner, to prevent wear or abrasion to the bladder. This joint also provides maximum mobility in the unpressurized condition.

A flat patterned palm is included on the palm interior. A back of hand palm bar is utilized to preclude the use of anything hard in the palm interior which has a negative perception by the pilots as noted during the task analysis. Adjustments can be made to the palm bar via a strap located on the back of the hand. The back of the hand also incorporates a tucked fabric metacarpal for improved motion of this joint.

The wrist utilizes a single axis restraint with tucked fabric. This only allows for wrist flexion and extension however this should be sufficient for the intended application.

9.3 Cover Glove Assembly

The cover glove consists of a nomex knit in the palms and front of fingers with a woven nomex tucked fabric back and wrist section. The cover glove is indexed to the restraint by localized sewing, the palm bar straps and elastic webbings which extend from the wrist up the back of the hand. A silicone coating in the palms and on the fingertips provides for improved tactility.

10.0 Conclusions and Recommendations

The proposed design provides a baseline for an improved pressure suit glove capable of operating at 7.0 psi. The test methodology developed during Phase I of this contract provides a vehicle to evaluate this proposed design in comparison to other pressure suit glove designs.

Future efforts should include finalization and equipment set-up of the test methodology and fabrication and testing of prototype gloves. Further development of the CyberGlove™ and force sensing technology is required prior to implementation. Complete equipment set-up and methods of data collection is also necessary. Gloves should be evaluated against standard glove design utilizing the test methodology. Using this procedure, new glove concepts for an advanced pressure suit glove design can be evaluated.

11.0 REFERENCE

1. John M. O'Hara et al., "Extravehicular Activities Limitations Study," NASA Contractor Report AS-EVAL-FR-8701, 1988, Vol. II

12.0 APPENDIXES

12.1 Standardized Test Methodology for Pressure Gloves

1.0 INTRODUCTION

A Standardized Test Methodology was developed for comparing pressure gloves, specifically for aircrew applications in accordance with Phase I of Contract F33615-87-D-0652, Delivery Order Number: 0015. This test methodology can then be used for the assessment of Human Factors in glove design. This test methodology was intended to be used in conjunction with a Task Specific Test Plan, a Requirements Document, and a Detailed Test Plan as defined in Section 2.0 of this document.

Most test methodologies were previously developed to assess glove performance for the Shuttle EVA Space Suit Glove. Although these methodologies are applicable, modifications are required to address aircrew applications.

This test methodology developed measures aircrew performance capabilities while wearing a pressure glove in comparison to the bare hand. Seven test protocols (attributes) were identified; 1) range of motion, 2) strength, 3) dexterity, 4) tactile sense, 5) comfort, 6) fatigue and 7) environmental protection. The test protocols were designed to be objective, standardized, quantitative and sensitive to glove comparisons. All tests with the exception of environmental protection are to be conducted in a glove box.

This test methodology identifies test set-up, subject skills and training, method of conducting the test, data collection method and data analysis/reduction. The testing can be conducted at any pressure differential up to the capability of the glove box and/or glove design.

2.0 SCOPE

The test methodology was developed as a tool to be used by glove designers, engineers, and researchers for assessing human factors parameters in different glove designs. The Test Methodology was developed to be tailored to specific aircrew applications through the use of a Task Specific Test Plan, a Requirements Document, and a Detailed Test Plan. These documents will be generated upon completion of a detailed Task Analysis.

The Standardized Test Methodology was generated from a literature search conducted to review previous studies for comparison testing of pressure gloves. Data and results from these studies were refined, updated and used for the development of the test methodology presented in the following sections.

The Task Specific Test Plan will define specific test protocols for evaluating pressure suit gloves for a given application. The specific test protocols will fall under the seven major protocol headings: 1) range of motion, 2) strength, 3) dexterity, 4) tactile sense, 5) comfort, 6) fatigue, and 7) environmental protection.

The Requirements Document will define specific requirements for the performance characteristics of the glove. It will also identify the relative importance of the Standardized Test Methodology Protocols. The relationship between the application tasks and standardized test protocols will be identified in a matrix as shown in Figure 1. Each test protocol will be assigned a value from 1 - 5 for each task based on the ability to test for the performance of that task. Totals for each protocol will be calculated and relative scores of the test protocols will be determined. This will then be used in evaluating the data obtained from two gloves.

The Detailed Test Plan will be submitted to the Government for approval prior to conducting testing and will define the test location, actual schedule of testing and the facility or group responsible for testing. It will also specify by P/N and description the gloves to be tested and the pressure at which they will be tested. The glove size and how the glove will be sized will also be specified. It includes both the Standardized Test Methodology and the Task Specific Test Plan and it identifies the applicable requirements document.

FIGURE 1
TASK ANALYSIS MATRIX

Application Tasks	Range of Motion	Strength	Dexterity	Tactile Sense	Comfort	Fatigue	Environmental Protection
Task 1							
Task 2							
Task 3							
Task 4							
Task....							
Task X							
Total							
Relative Score (Total/5x)							

3.0 HAND CAPABILITY PARAMETERS

Six categories of hand performance were selected for study in this effort. These capability parameters were broken down within each test protocol to investigate particular areas of interest in the hand. Although great care is taken to reduce the number of variables that can affect the test from external sources, these tests will not be exclusive measurements of each of the parameters. Instead, performance parameters in one category will be affected by performance parameters in another category. The hand performance categories were selected based upon success of other evaluators of hand and glove performance and relevancy of the test to the evaluation of pressurized gloves for full pressure suits.

A good description of the hand capability parameters and their inter-relation was given in the SAE paper 881103 "The Development of a Test Methodology for the Evaluation of EVA Gloves". The following is an excerpt from that paper which directly relates to this study:

> The six categories of hand capability can be divided into two groups. The first group, Level 1, includes performance capabilities which are directly tied to major subdivisions of hand physiology/anatomy. These categories are range of motion, strength, and tactile perception. The range of motion of the fingers and hand is limited mainly by hand anatomy including the restrictions on the mechanics of joint motion imposed by the joint surfaces, joint capsule, ligaments and tendons. The strength of the fingers and hand is determined mainly by the muscle masses in the hand and forearm and the orientation of their tendinous attachments. Finally, the tactile perception of the fingers and hand is determined mainly by the types and number of sensory nerve endings. Tactile perception has two functional components: cutaneous sense and kinesthesis (1) Cutaneous sense refers to the sensation and perception of the physical environment, such as surface texture and temperature, caused by stimulation of cutaneous sensory elements. Kinesthesis refers to the awareness of body position associated with motor memory and proprioception. Emphasis in this study is on cutaneous sense.
>
> The second group of categories, Level 2, is more complex and represents integration of Level 1 capabilities as well as additional physiological and psychological capabilities. Level 2 capabilities are, therefore, multidimensional and, unlike Level 1 capabilities, not principally associated with single hand physiological/anatomical elements of the hand. It included dexterity, fatigue, and comfort.

Dexterity depends on integration of range of motion, strength and sensory input, the latter consisting of either tactile cues, visual cues, or some combination of the two. Limitations of any one of the Level 1 capabilities will limit dexterity unless some means of compensation is achieved, such as using visual information in the absence of tactile information, as if often the case when training for EVA.

Fatigue, like dexterity, is a complex, integrated phenomenon. At least three dimensions of fatigue have been identified: physiological, subjective or motivational, and performance. While the latter may be a function of physiological and subjective components, decay in performance over time is a commonly used indicator of fatigue. The measurement of fatigue generally involves the assessment of one or all of these dimensions over time.

The third Level 2 category is comfort. Like fatigue, it is based upon physiological and subjective dimensions. Unlike the other capability areas, comfort is not actually a hand capability area. It is more properly thought of as a set of parameters which address the hand-environment and hand-task interactions. For example, the hand may feel uncomfortable because a glove causes the hand to become hot, because it restricts movement, or because the hand movements required by a particular task were awkward and the hand became very fatigued. In the present study, central focus of comfort issues is the hand/glove interaction which is based upon three parameters: glove characteristics such as tenacity, suppleness, and protectiveness; glove-hand interactions such as fit, forces (pressure points), and friction; and the immediate environment created by the glove in terms of hand temperature and humidity/wetness.

With respect to glove characteristics, tenacity refers to a glove's resistance to sliding over a grasped surface, hence it is related to the coefficient of friction between glove and object. Suppleness refers to the ease with which the fingers can assume desired positions. Protectiveness refers to a gloves ability to protect the hand from injury.

4.0 PROTOCOL DEVELOPMENT

4.1 RESEARCH SUMMARY

An extensive data search was conducted by ILC in order to provide a large reference pool from which test protocols could be developed. (See Appendix B for a Bibliography.) This data search included a NERAC search, a Defense Technical Information Search, review of ILC EVA glove test protocols, and communication with cognizant Wright Patterson and ILC personnel. Following the review of these available resources, ILC determined that the EVA Limitations Study Phase II written by John O'Hara, John Cleland, and Daniel Winfield, would be used as the baseline for the development of the test protocols. This document was selected due to its applicability as well as thoroughness in this subject. Recommended test philosophies (i.e., test subject selection) were used from other documents. An ILC test plan used for the testing of EVA gloves was also used.

5.0 TEST PLANNING PROCEDURES

5.1 SUBJECT SKILLS

The tests subjects that will be selected for this testing effort will not have any prior experience with pressurized gloves. The rationale behind this decision is that experienced EVA glove wearers know how to overcome the limitations of the gloves and could subsequently alter the data obtained in this testing effort. The subjects selected will be right handed. The basis for this decision is as follows: Right handed subjects are selected because of their greater availability in the general population. All right handed subjects are selected to standardize the testing as the right hand glove is selected for the one handed tests. The subjects will not be informed of the program's intent and thus will not be biased toward a particular glove design during testing.

5.2 SUBJECT MOTIVATION

Prior to performing each Test Information Sheet, the test subject will be briefed on the test procedure and what data is gained during each test. The test progression (i.e., scheduling) of each test will be done in a random fashion. Such a test progression is expected to break the boredom, and the subsequent reduction in the apparent glove performance.

5.3 TEST SCHEDULING

As mentioned previously, the test scheduling will be such that the tests will be performed in a random fashion. A random test progression is recommended due to the small statistical base (4 test subjects) from which ILC wishes to make an evaluation. Also, the results of this testing are highly dependent on human factors, such as subject motivation and subject fatigue, which can vary highly from day to day. Randomizing the days on which the subjects complete each test will eliminate this variable from the testing results. Test randomization will be done by subject, by iteration with a random selection routine which selects the test order of the attributes (strength, ROM, tactility, etc.), and the test condition (bare handed, glove type, or pressurization). The result will be 12 data summary sheets (four subjects, three iterations) as shown on Page 16 with the characteristics column arranged in a random order. A formal schedule will be determined in Phase III of this program.

5.4 EFFECT OF TRAINING

The tests selected for this evaluation are quite simple in order to reduce the learning curve problems experienced with complicated tests. It is expected that the subject's performance of each test will reach an asymptote after only 3 practice trials. K. Robinette (Development of a Standard Dexterity Test Battery) found that learning curve asymptotes were reached after 5-12 trials, depending on the test being performed. With the tests selected by ILC (Purdue Pegboard, etc.), only slight improvements were noticed after the 4th and 5th trials. For this reason, 3 practice trials were selected for each TIS. These practice trials will be done prior to the actual performance of each test. Additional practice may be allowed pending dry runs of each test.

5.5 SUBJECT SIZING AND HAND ANTHROPOMETRY

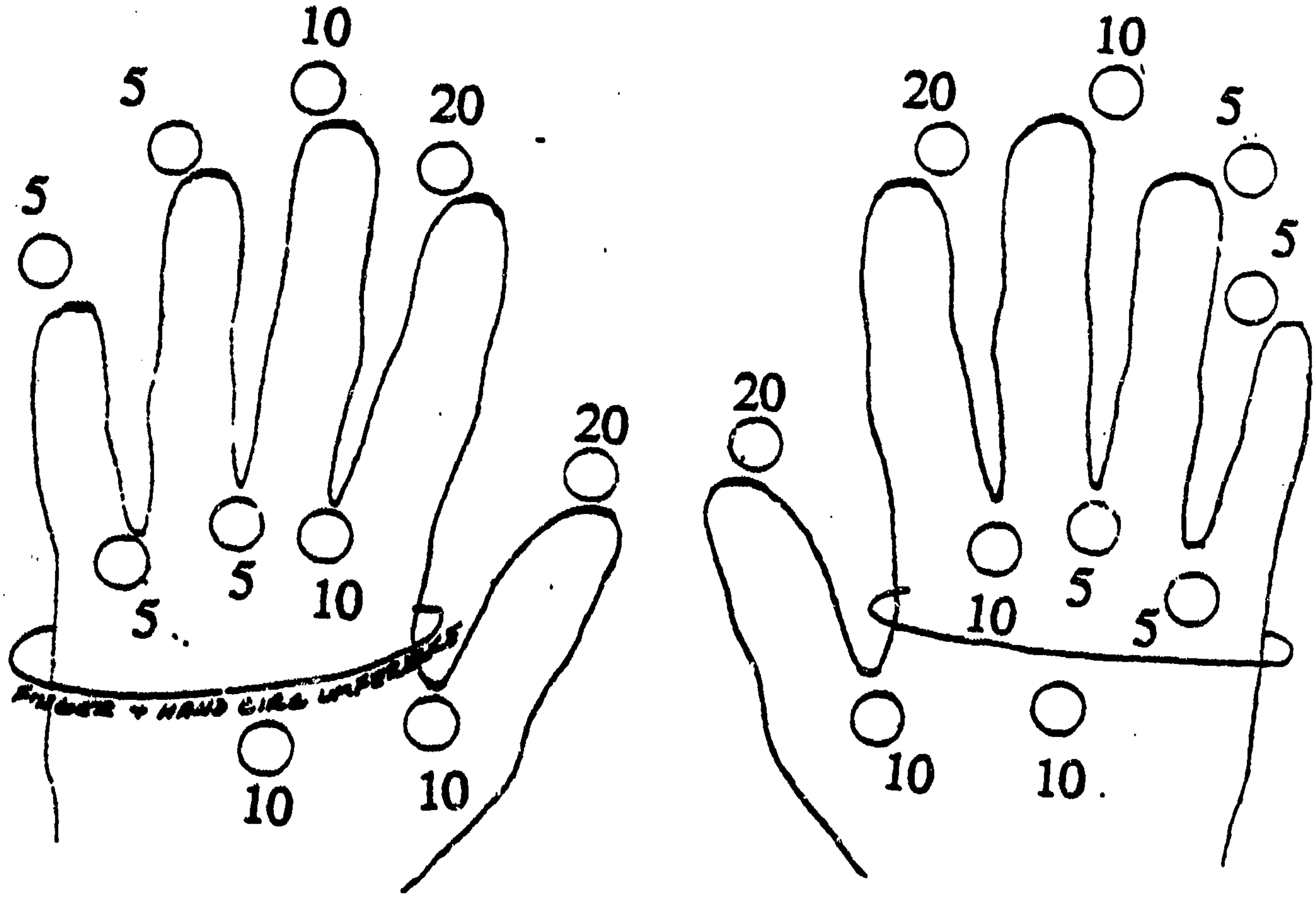
Proper subject sizing and fit of the glove is critical to performance. Variations in fit could introduce variations in the data from subject to subject. Prior to testing, each subject will be fit in the glove in accordance with applicable sizing documentation. The test subject will don the glove and fill out the fit evaluation sheet provided in Figure 2, for both the unpressurized and maximum glove operational pressure (data for intermediate pressures may be taken as applicable).

Subject Hand Anthropometry will also be taken prior to any testing to compare to the gloves being evaluated and the subjects hands. This data will be used to quantatively evaluate the subjects fit in the gloves. The measurements identified below will be taken as defined in report AMRL-TR-69-42, "Anthropometry of the Hands of Male Air Force Flight Personnel," by John W. Garret, March 1970:

1. Hand Length

2. Hand Breadth; Metacarpale
3. Hand Circumference; Metacarpale
4. Wrist Circumference
5. Hand Thickness; Metacarpale III
6. Hand Depth; Thenar Pad
7. Wrist Breadth
8. Digit 1 Height; Perpendicular to Wrist Crease
9. Digit 2 Height; Perpendicular to Wrist Crease
10. Digit 3 Height; Perpendicular to Wrist Crease
11. Digit 4 Height; Perpendicular to Wrist Crease
12. Digit 5 Height; Perpendicular to Wrist Crease
13. Crotch 1 Height
14. Crotch 2 Height
15. Crotch 3 Height
16. Crotch 4 Height
17. Digit 1 Length; Fingertip to Crotch Level
18. Digit 2 Length; Fingertip to Crotch Level
19. Digit 3 Length, Fingertip to Crotch Level
20. Digit 4 Length; Fingertip to Crotch Level
21. Digit 5 Length; Fingertip to Crotch Level

FIGURE 2
FIT EVALUATION SHEET



X = CONTACT
L = LIGHT CONTACT
# = HEAVY CONTACT
N = NO CONTACT
P = PRESSURE POINT
O = EVALUATION POINT

GLOVE EVALUATION SHEET

GLOVE SIZE: ______________ S/N: ______________ TEST DATE: ______________

CREWMAN/SUBJECT: ______________________________

TEST CONDUCTOR: ______________________________

SCORE: LEFT = ______________ RIGHT = ______________

PRESSURE: ______________________________

COMMENTS: ____

____

____

5.6 **PRE-TEST GLOVE CYCLING**

Prior to conducting any testing, all new gloves will be cycled 1000 times. The glove will be installed in the glove box and pressurized to its maximum operating pressure. Cycling will consist of competely opening the hand so that all fingers and thumbs are fully extended and closing the hand to form a fist.

6.0 **SPECIFIC PROTOCOLS**

The specific test protocols are contained in Appendix A of this document. These tests shall serve as the baseline for glove performance testing. Numerous test protocols were reviewed for each glove characteristic (Range of Motion, Strength, Dexterity, Tactility, Comfort, Fatigue, and Environmental Protection). Each is addressed below:

- Range of Motion (ROM) – Previous ROM studies of hands and gloved hands have been conducted by utilizing still photography or video methods of hands in front of standardized grid patterns. These studies provided limited data due to visual blockage of one portion of the hand in front of another. The accuracy of the data was also limited by paralax of the single lens video method, and the method of data retrieval from the TV monitor. This method of data collection was also disassociated with the torque of the joints, stable range and programming of the joints being evaluated. These data were determined to be an integral part of the ROM evaluation, and overall quantitative glove evaluation. To this end, ILC has elected tc utilize a more advanced method of data collection to achieve all of the goals mentioned above. This will be done with the use of a specially instrumented VPL data glove. The data glove will be equipped with force sensors to indicate relative torques of the joints simultaneously with the ROM evaluation. By using the data glove, all joints can be evaluated simultaneously to an increased accuracy over the video methods, while expanding the test to include other quantitative data as well. If this method of utilizing the data glove is unsuitable to the user then the video method can be used as a fall back contingency and the relative joint torques will have to be determined from the strength and fatigue protocol.

- Strength – A nearly infinite number of tests exist for the measurement of finger anc hand strengths. Any adequate force/torque sensing device would be suitable for th: application. However, a hand held dynamometer and a BTE work simulator were selected for this application due to the availability and previous experience ILC has had with this equipment. Pulp pinch, chuck pinch, and cylinder grip measurements were determined to be most appropriate for cockpit scenarios, and were therefore selected for this phase of testing.

- Dexterity – K. Robinette (see reference 11) identified 26 dexterity tests in her 1987 paper. Most of the tests are redundant, and some are quite complicated. Three of these tests were selected for testing here. The Purdue pegboard test was selected for its simplicity, consistent results (as seen from previous testing), and its being accepted by the Air Force as the standard dexterity test. The nuts and bolts assembly and knot tying tests are two handed tests which were selected for their simplicity as well as for their more demanding two handed coordination requirements. Both tests are simple to learn and are easily performed in a glove box. These tests, therefore, are ideal for this application.

- Tactile Perception – Many tests, including object identification, two point discrimination, coin heads/tails identification, and grip strength perception exist to measure hand tactility. Two of these were selected. Two point discrimination is a good finger tactility measurement method that is related to cockpit scenarios such as missile launching button location and identification. Grip strength perception has been shown to be a good palm/finger tactility measurement means and has also been shown to indicate the level of fatigue a glove will create. For example, individuals wearing gloves tend to grip things with more force than necessary due to the loss of tactile perception. This results in excessive or premature fatigue. These two tests are easily integrated in the glove box and were therefore selected for this application.

- Comfort – Purely quantitative means to measure comfort currently do not exist. Subjective rating scales are used to assess the level of comfort afforded by pressure gloves. One such rating scale, a 0-8 point chart, was selected for this application due to its previous use and success here at ILC.

- Fatigue – A wide range of tests, ranging from complex electromyographic (EMG) median frequency measurement to simple hand held dynamometer cycling, are available to measure fatigue. Although quite accurate, the EMG was not selected due to cost constraints. A combination of difficult work load cycles followed by maximum voluntary contractions were selected due to previous success with such methods. Fatigue level has been found to be easily correlated to the reduction in the MVC over time. This method was therefore selected for this application.

- Environmental Protection – A hot challenge was selected for this testing effort. Unmanned gloved tests were selected for ease of test as well as for safety reasons. Upper temperature challenges were determined from standard military aircraft equipment specifications. Similar thermal testing of the Shuttle EVA gloves has been performed previously at ILC with good success.

Task Analysis specific tests may be added to the existing protocols, as part of the Task Specific Test Plan.

7.0 DATA REDUCTION

As discussed elsewhere in this document, ILC determined seven attributes and associated evaluation methods to measure the performance of pressure suit gloves. Six attributes; range of motion, strength, dexterity, tactile sense, fatigue, and environmental protection are objectively measurable. The seventh, comfort, although subjective is provided with an attribute scale to improve on its objectivity.

As required by the Statement of Work, ILC was tasked to develop a method of evaluation to verify that a new glove design is equal or better than the control glove, for example, the S1031 pressure suit glove. The most economical approach to achieve this goal with a reasonable confidence interval is to start out with measuring processes of high precision, i.e., a small standard deviation of error. The specific evaluations were designed with this objective. Measurements will be made with a relative high degree of precision and all glove performance will be rated against bare hand performance to remove the variance among test subjects.

The remaining control of test significance is the sample size. Based on the Statement of Work two sizes of gloves will be tested and after review, ILC determined that two test subjects of each size repeating each evaluation three times for the control and the prototype gloves will provide a suitable sample size of 24 to verify performance. Confidence intervals will be calculated using 23 degrees of freedom and the student's t distribution. ILC felt that it was important to limit the number of subjects to reduce performance changes induced be different size hands and at the same time avoid single point evaluations. Limiting test population to two personnel in each size accomplished both objectives. Three trials were considered a minimum to identify systematic errors during the testing and provide an adequate sample population for statistical significance.

Data reduction will be based on the hypothesis that the two gloves are equal in performance at vent pressure and full pressure exclusively. The detailed test plan will contain data sheets for each measurable attribute identified in Table 1. A sample data sheet is provided in Figure 3 and is the basis for the following discussion. The example provided is used to record maximum voluntary grip strength.

Column 1 contains the three iterations to be accomplished.

Column 2 contains the subject number, with 1 and 2 assigned to one glove size; 2 and 3 the second. Because the subjects are coded by size, no size definition is required on the data sheets.

Column 3 contains the maximun. bare handed grip strength measured.

Column 4 contains the maximum control, (S1031) gloves grip strength measured under a vent pressure condition.

Column 5 is the calculated difference between Column 3 and Column 4.

Column 6 contains the maximum prototype, (7-psi) gloves grip strength measured under a vent pressure condition.

Column 7 is the calculated difference between Column 3 and Column 6.

Column 8 contains the maximum control, (S1031) gloved grip strength measured under a full pressure condition.

Column 9 is the calculated difference between Column 3 and Column 8.

Column 10 contains the maximum prototype, (7-psi) gloved grip strength measured under a full pressure condition.

Column 11 is the calculated difference between Column 3 and Column 10.

Columns 12 and 13 are recorded for an intermediate (3.5 psi) pressure condition at the governments request but are provided for information only and are not part of the evaluation criteria between the two gloves.

The data summary contains the maximum column value (Max), the minimum column value (Min), the column Mean, and the column standard deviation (SD).

The trial mean and standard deviation are based on the combined mean value ($n = 24$) of Columns 5 and 7 for vent pressure; Columns 9 and 11 for full pressure, and is based on the hypothesis that both gloves are of equal performance.

The glove mean is based on the 12 replicate measurements for the control and prototype glove respectively and the confidence interval will be computed using the student's t distribution and the standard error.

The glove means and confidence intervals will be converted to standard scores of mean 0 and SD of one. Desirable direction will be in a nondescending direction which will be accomplished by negating the values for those scores which result in a nondescending desirable direction such as timed events.

8.0 RECOMMENDATIONS AND APPLICATION

The Standardized Test Methodology provides a baseline test protocol for evaluating pressure suit gloves. It is intended to be used in conjunction with a Task Specific Test Plan, a Requirements Document, and a Detailed Test Plan. These documents should be generated upon completion of a task analysis for a specific application. This test methodology can be adapted to the evaluation of pressure gloves for any application once specific task analyses have been accomplished and the documents noted above have been generated.

For this contract, this test methodology will be used to evaluate the performance of the existing S1031 pressure suit glove and a new glove design capable of operation at 7 psid.

DATA SUMMARY SHEET

TEST SUBJECT ______________________ DATE __________

TEST ITEMS ______________________ S/N __________

CHARACTERISTIC	7 PSI BARE HANDED	7 PSI 0 PSID	7 PSI 3.5 PSID	7 PSI 7.0 PSID	3.5 PSI 0 PSID	3.5 PSI 3.5 PSID
Range of Motion						
Raw Score						
Standard Score						
Strength						
Raw Score						
Standard Score						
Dexterity						
Raw Score						
Standard Score						
Tactile Sense						
Raw Score						
Standard Score						
Comfort[1]						
Raw Score						
Standard Score						
Fatigue						
Raw Score						
Standard Score						
Environmental Protection						
Raw Score						
Standard Score						

1 Raw score will be comprised of data obtained during measurement of the other six characteristics.

TABLE 1

ATTRIBUTE	MEASURED VALUE	COMMENTS
Range of Motion with Torque Sensing	Thumb, fingers and wrist riange of motion. Thumb, finger an wrist forces required to induce glove geometry change.	Data will be electronically recorded with a time channel, a displacement channel and force channels as required to measure forces required to displace the glove geometry. Data will be reduced by computing the difference between bare handed maximum range of motion and gloved hand range of motion.
Strength	Maximum pinch/grip force. Maxymum pinch/grip torque.	Data reported will consist of torque/grip force differences between bare hand and gloved hand.
Dexterity	Number of tasks completed. Number of errors.	Data reported will be the difference between bare hand and gloved hand performane. Task and error z scores will be combined and reported as a single score.
Tactile Perception	Two point discrimination adjusted to prevent guessing. Grip force discrimination.	Data reported for point discrimination will be the difference between bare hand and gloved hand performance. Task and error z scores will be combined and reported as a single source. The difference between grasping force and slipping force will be reported.
Comfort	Test Subject Responses to an attribute rating scale.	Data reported will be by glove and combined.
Fatigue	Work capacity. Maximum contraction.	Data reported will be the difference between bare hand and gloved hand performance.
Environmental Protection	Thermal conductivity of the glove	Thermal Conductivity Data of each glove will be reported.

7 PSI GLOVE DATA SHEET
STRENGTH

ITERATION	SUBJ	BASELINE	VENT PRESSURE CONTROL ABS	VENT PRESSURE DIFF	VENT PRESSURE PROTOTYPE ABS	VENT PRESSURE PROTOTYPE DIFF	FULL PRESSURE CONTROL ABS	FULL PRESSURE CONTROL DIFF	FULL PRESSURE PROTOTYPE ABS	FULL PRESSURE PROTOTYPE DIFF	3.5 REFERENCE PROTYPE ABS	3.5 REFERENCE PROTYPE DIFF
1	1	___	___	___	___	___	___	___	___	___	___	___
	2	___	___	___	___	___	___	___	___	___	___	___
	3	___	___	___	___	___	___	___	___	___	___	___
	4	___	___	___	___	___	___	___	___	___	___	___
2	1	___	___	___	___	___	___	___	___	___	___	___
	2	___	___	___	___	___	___	___	___	___	___	___
	3	___	___	___	___	___	___	___	___	___	___	___
	4	___	___	___	___	___	___	___	___	___	___	___
3	1	___	___	___	___	___	___	___	___	___	___	___
	2	___	___	___	___	___	___	___	___	___	___	___
	3	___	___	___	___	___	___	___	___	___	___	___
	4	___	___	___	___	___	___	___	___	___	___	___
DATA SUMMARY	MAX	___	___	___	___	___	___	___	___	___	___	___
	MIN	___	___	___	___	___	___	___	___	___	___	___
	MEAN	___	___	___	___	___	___	___	___	___	___	___
	SD	___	___	___	___	___	___	___	___	___	___	___
	TRIAL MEAN			___					___			
	TRIAL SD			___					___			
	UPPER CONFIDENCE LEVEL (Z)			___		___		___		___		___
	GLOVE MEAN (Z)			___		___		___		___		___
	LOWER CONFIDENCE LEVEL (Z)			___		___		___		___		___

FIGURE 3

12.1.9 Appendix A1: Individual Test Protocols

TEST INFORMATION SHEET

TEST TITLE: RANGE OF MOTION WITH TORQUE SENSING	**TEST NUMBER:** 1
APPLICABLE SPECIFICATION: NONE	**METHOD/APPROACH:** TEST
NUMBER OF PAGES: 1 OF 6	

TEST OBJECTIVE:

To measure the Range of Motion (ROM) and baseline contact force of the joints of the hand and wrist of a bare handed subject and a subject in a pressure suit glove to within ± 4 degrees of accuracy. The following motions are to be measured:

Fingers - PIP, DIP, MCP (flexion/extension)
Thumb - PIP, DIP, CMC [flexion/extension abduction/adduction (CMC only)]
Wrist - Adduction/Abduction, Flexion/Extension, and Pronation/Suppination

TEST ITEM DESCRIPTION:

The item to be tested is a right hand of a pressure glove pressurized as specified in the Detailed Test Plan. Bare handed performance will be used as a baseline. Two right handed subjects per size will be used in the evaluation.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

The testing shall be conducted at the location identified in the Detailed Test Plan. Tests shall be scheduled in a random manner such that the subjects are properly motivated and not fatigued from previous testing. Several tests can be run in succession because the test should not be very fatiguing. However, the subjects fatigue level should be monitored and the test halted if sufficient signs of fatigue are noted.

A single right hand glove will be used for each test.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The analysis will be conducted by the contractor. Video recordings of the testing will be made for the government review of the test. Photographs detailing the test set-up will also be taken.

TEST INFORMATION SHEET

TEST TITLE: RANGE OF MOTION WITH TORQUE SENSING	TEST NUMBER: 1
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 6	

INSTRUMENTATION/SUPPORT EQUIPMENT:

- Modified Virtual Technologies Cyber-Glove with ROM and force sensors (covered ROM sensors to prevent contact with the pressure suit glove, wrist and thumb ROM sensors). NOTE: Data Glove will be right handed
- Personal computer with Cyber-Glove software
- BTE (Baltimore Therapeutic Equipment) device with D-Handle attachment
- Video and 35mm camera
- Calibration standards for ROM of each joint motion
- Calibration device for force sensing
- Force sensing pads

TEST PROCEDURE:

NOTE: Prior to testing, test subjects will be instructed to discontinue testing if tired or fatigued. A 5 minute rest period will be allowed and testing will resume once the subject no longer feels fatigued.

A) Fit Verification:

1) Install pressure gloves to be used in test in the glove box.
2) Pressurize glove box to 1 psi.
3) Place subject's arms in glove box and position and fix foam pads between chest and glove box to simulate proper fit in suit.
4) Record subjects shoulder breadth as compared to the glove box opening breadth.
5) Evaluate and record subjects position in elbow and overall comfort.
6) Don the pressurized glove.
7) Instruct test subject to position any wrinkles in the glove bladder and verify that glove fit is adequate.

B) Have subject donn Data Glove on right hand. Position cable for Data Glove along arm to shoulder area and fix in place. Verify positioning of force and ROM sensors.

C) Connect Data Glove to PC and verify operation.

D) Calibrate Data Glove for each range of motion with calibration standards. Calibrate Data Glove for force sensing operation.

E) Position subject in glove box at desired comfortable position (standing), with right and left arms through glove box pressure suit arms, with no gloves on the disconnects (lock the shoulder seals). The position of the shoulder should be maintained throughout the test.

TEST PROCEDURE (CONT'D):

F) Perform ROM and force sensing analysis on bare handed subject (with Data Glove), with arm positioned such that elbow is flexed from 30 to 45 degrees and hand is directly in front of body torso centerline:

- From neutral position, perform flexion/extension of the fingers (together, and index finger alone) and thumb to their max ROM (DIP joint, PIP joint will be reported as 60% DIP joint). Keep metacarpal joints slightly flexed and in same position throughout the motion.
- From neutral position, perform flexion/extension of the finger MCP joints as a single unit to their max ROM, keeping the fingers only slightly bent so as to not contact the palm.
- From neutral position, perform flexion/extension and adduction/abduction of the CMC joint to its maximum ROM (flex/extend to base of pinky finger)
- From neutral position, perform flexion/extension and adduction/abduction of the wrist to their max ROM respectively.
- From neutral position, grasp the BTE and complete 1 each pronation/suppination motions to the max ROM.

Repeat above so that three complete assessments of range and torque are performed.

G) While still donned, remove the right and left pressure suit arms from the glove box and don the pressure suit glove to be evaluated (right) over the Data Glove and a support glove on the left hand, close the wrist disconnect, and insert both arms into the glove box (lock the shoulder seals).

H) Repeat step F above except with unpressurized glove on right hand and support glove on the left hand.

I) Allow the subject to rest if necessary and assess the subjects fatigue. Flow room temperature air (approx. 70°F) into the inflated arm to cool the subjects hands as necessary during the resting period. Then depressurize the glove box to create the desired differential in pressure across the gloves.

J) Repeat step E above. Determine and record stable range of each joint by positioning joint within extremes of ROM until no force inputs are required to keep the glove in that position. Note and record any instability in the joint or programming encountered. Test conductor to note any wrinkles in the bladder visually or by feel under the force sensors, and reposition bladder with glove at 1 psi to remove wrinkles in force sensor area.

TEST INFORMATION SHEET

TEST TITLE: RANGE OF MOTION WITH TORQUE SENSING	TEST NUMBER: 1
APPLICABLE SPECIFICATION:	METHOD/APPROACH:
NUMBER OF PAGES: 4 OF 6	TEST

TEST PROCEDURE (CONT'D):

K) Repeat steps H and I as necessary. Monitor subjects fatigue and stop test when necessary.

L) When test is complete, repeat step D to confirm maintenance of calibration.

NOTE: Force sensing readings can only be used for comparative measures due to their potential inaccuracies. These inaccuracies are caused by potential contact of the glove and hand away from the sensor location, thus sharing the load between the sensor and contact point, and reducing the apparent torque of the joint. The measurements may also be affected by discontinuities in the bladder, such as wrinkles, which may lead to inaccurate force sensor readings. Calibration is used to eliminate these potential problems. The calibration will consist of squeezing known force/resistance systems such as dynomometers. The ROM sensors shall be calibrated by gripping known angular blocks.

RANGE OF MOTION TEST DATA SHEET

SUBJECT NAME : ______________________________

TEST CONDUCTOR : ______________________________

TEST GLOVE IDENTIFICATION : ______________________________

DATE OF TEST : ______________________________

GLOVE BOX FITCHECK DATA :
- Thickness of foam padding in chest area : __________
- Subjects shoulder breadth : __________
- Glove box shoulder opening breadth : 18 in

CALIBRATION PERFORMED : ______________________________
(Before and after testing)

PHOTOGRAPHS/VIDEO TAKEN : ______________________________

TESTS PERFORMED : 3 EACH FOR EACH MOTION REQUIRED (BELOW)

FINGERS - FLEXION/EXTENSION
FINGER METACARPAL PHALANGEAL JOINTS - FLEXION/EXTENSION
CARPOMETACARPAL - FLEX/EXT, ADDUCTION/ABDUCTION
WRIST - FLEXION/EXTENSION
ADDUCTION/ABDUCTION
PRONATION/SUPPINATION

TEST TITLE: RANGE OF MOTION WITH TORQUE SENSING	TEST NUMBER: 1
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 6 OF 6	

RANGE OF MOTION TEST DATA SHEET (CONT'D)

SUBJECTS FATIGUE COMMENTS : ____________________

COOLING AIR USED : ____________________

SUBJECTS COMMENTS ON STABILITY, PROGRAMMING, AND OVERALL TEST : ____________________

____

____

____

TEST CONDUCTORS COMMENTS : ____________________

____

____

____

TEST INFORMATION SHEET

TEST TITLE: STRENGTH	TEST NUMBER: 2
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 1 OF 4	

TEST OBJECTIVE:

The objective of this test is to measure the effect of pressurize gloves on hand strength. Pulp pinch, key pinch, and cylinder grip strength evaluations will be done in this evaluation. Wrist torque for key pinch and chuck pinch shall be measured.

TEST ITEM DESCRIPTION:

Testing will be done on right handed pressure gloves. Bare handed performance will be used as a baseline. Two right handed subjects per size will be used in the evaluation.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing to occur at the location identified in the Detailed Test Plan. Testing will be performed in accordance with the schedule as defined in the Detail Test Plan.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The Government shall witness testing, if so desired.

INSTRUMENTATION/TEST EQUIPMENT:

A glove box, capable of maintaining the maximum pressure of the glove design, shall be used. Instrumentation shall include a differential pressure gage to measure glove pressure, a hand held dynamometer to measure cylinder grip strength, and a Baltimore Therapeutic Equipment (BTE) work simulator with the appropriate tools to measure pinch strengths and torques. Video and photographic equipment shall be used to provide details of the test set-up, instrumentation, and operation of equipment. A video recording shall also be made to document testing. All equipment used shall be calibrated to NIST standards to insure accurate test results.

TEST INFORMATION SHEET

TEST TITLE: STRENGTH	TEST NUMBER: 2
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 4	

TEST PROCEDURES:

Test procedures below will be performed in the bare handed condition to serve as a test baseline. Testing will also be done on the gloved hand at specified pressures. Prior to testing, the BTE work simulator must be placed in the glove box as per Figure 1. Only the right hand shall be tested for strength in order to standardize this testing effort.

Each of the contractions as defined below shall be done three (3) times. Prior to the gloved tests, the glove box shall be pressurized to 1 psi, the glove donned, and any bladder wrinkles removed from the glove. The glove box pressure shall then be changed to the desired test pressure.

NOTE: Prior to testing, test subjects will be instructed to discontinue testing if tired or fatigued. To prevent fatigue, A 1 minute rest period will be allowed between each muscle contraction.

1. Measure the maximum pulp pinch force using BTE Tool 162. (The pulp pinch is the force exerted between the palmar surfaces of the tip of the thumb and the index finger. This action is much like that used to pick up a pencil.) Record results on attached data sheet.

2. Measure the maximum key pinch force using BTE Tool 162. (The key pinch is the action one uses to hold and turn a key. It employs the thumb pulp applied to the medial surface of the DIP joint of the index finger. Digits 3-5 can provide support to the lateral side of the index finger.) Record results on attached data sheet.

3. Measure the maximum key pinch torque (pronation and suppination) using BTE Tool 202. Record results on the attached data sheet.

4. Measure the maximum chuck pinch torque using the BTE Knob Tool. (The chuck pinch uses the tips of digits 1, 2, and 3.) Record results on the attached data sheet.

5. Measure the maximum cylinder grip force using the hand held dynamometer. The wrist shall be in the neutral position, with the thumb facing up during the contraction. Record results on the attached data sheet.

6. Measure the maximum wrist (grip) torque in the pronation and suppination directions using BTE Tool 601. Record the results on the attached data sheet.

7. Steps 1-6 will be repeated in a random fashion in accordance with the Detailed Test Plan.

TEST TITLE: STRENGTH	TEST NUMBER: 2
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 3 OF 4	

DATA RESULTS

CHARACTERISTIC	BARE HAND	P_1 = _____ PSID	P_2 = _____ PSID	P_3 = _____ PSID
Pulp Pinch Force				
Key Pinch Force				
Key Pinch Torque: Pronation Suppination				
Check Pinch Torque: Pronation Suppination				
Cylinder Grip Force				
Cylinder Torque: Pronation Suppination				

SUBJECT: ______________________________

TEST ITEM: ______________________________

TEST DATE: ______________________________

TEST CONDITION: __________________________

TEST CONDUCTOR: _________________________

TEST INFORMATION SHEET

TEST TITLE: STRENGTH	TEST NUMBER: 2
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 4 OF 4	

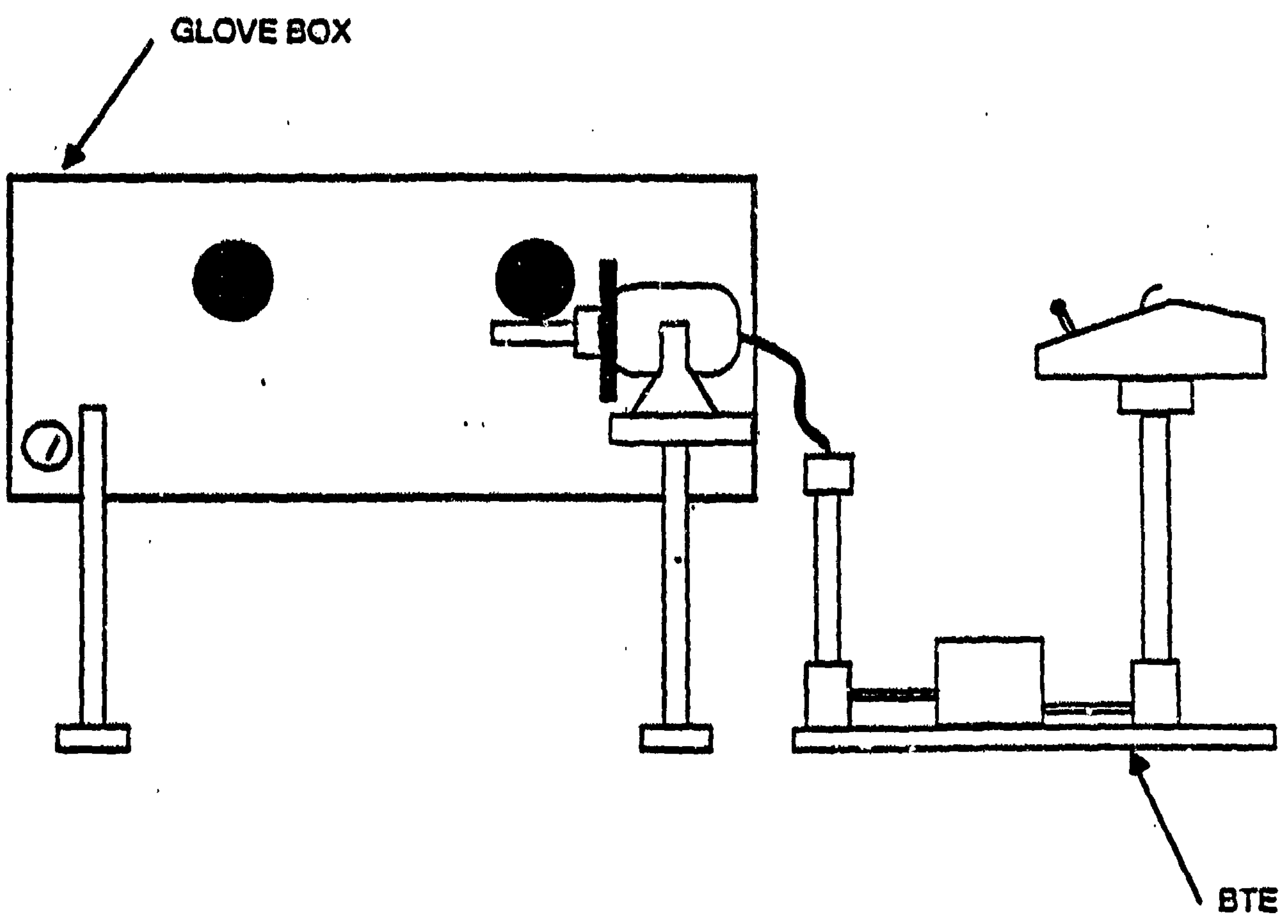


FIGURE 1

TEST INFORMATION SHEET

TEST TITLE: DEXTERITY	TEST NUMBER: 3
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 1 OF 5	

TEST OBJECTIVE:

The purpose of this test is to measure the effect of pressure gloves on hand dexterity. The Purdue Pegboard will be used to measure fine finger dexterity, the nut and bolt assembly will be used to measure two handed manipulation of rigid objects, and a knot tying task will be used to measure two handed manipulation of flexible objects.

TEST ITEM DESCRIPTION:

Testing will be done on pressure gloves at specified pressures. Bare handed performance will be used as a baseline. Two right handed subjects per size will be used in the evaluation.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing to occur at the location identified in the Detailed Test Plan. Testing will be performed in accordance with the schedule as defined in the Detailed Test Plan.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The Government shall witness testing, if so desired.

INSTRUMENTATION/TEST EQUIPMENT:

A two handed (left and right) glove box, capable of maintaining at least 7 psid, shall be used. Instrumentation shall include a differential pressure gage to measure glove pressure, a Purdue Pegboard modified for glove box use, a nut and bolt assembly, and a flexible rope to measure hand dexterity. Video and photographic equipment shall be used to provide details of the test set-up, instrumentation and operation of equipment. A video recording shall also be made to document testing. All equipment used shall be calibrated to NIST standards.

TEST PROCEDURES:

Test procedures below will be first performed in the bare handed condition to serve as a test baseline. Testing will then be done with gloved hands at the specified pressures. Prior to testing, the Purdue Pegboard, nut and bolt assembly, or the knot tying rope must be placed in the glove box depending on the test being run. Only the right hand shall be used for the Purdue Pegboard test. The other two tests are two handed tests. Between tests the subjects shall be permitted to take 5 minute breaks to reduce the effects of fatigue.

TEST TITLE: DEXTERITY	TEST NUMBER: 3
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 5	

TEST PROCEDURES (CONT'D):

Prior to gloved tests, the glove box shall be pressurized to 1 psid, the glove donned, and any bladder wrinkles removed from the glove. The glove box shall then be changed to the desired test pressure.

Three trial runs for each test shall be completed by the test subject prior to the actual test run. An additional trial may be done pending input from the test subject. Each procedure below shall be done three (3) times with each 50th and 75th percentile subject based on hand size.

NOTE: Test subjects will be instructed to discontinue testing if tired or fatigued. A 5 minute rest period will be allowed and testing will resume once the subject no longer feels fatigued.

1. Perform the Purdue Pegboard test as follows: Remove the 3/16" square, 3" long peg at the top right of the board and, using one hand, turn it around 180° and reinsert the opposite end of the peg into the board. If the peg is dropped, another spare peg at the top of the board will be selected and an error will be recorded. Allow subject to continue this process for 30 seconds, moving from right to left, top to bottom. Record the number of pegs turned around and the number of errors committed during the 30 second test run.

2. Repeat 1 using a 5/16" square, 4" long peg.

3. Repeat 1 using a 7/16" square, 5" long peg.

4. Allow the test subject 5 minutes of rest to reduce the effects of fatigue.

5. Repeat 1-4 with the glove hand at the specified pressures.

6. Perform the nuts and bolts assembly test as follows: The subject will pick up a bolt with the left hand and a nut with the right hand. The subject will then thread the nut on the bolt just far enough to form a secure mating. Once complete, the nut and bolt will be dropped and another nut/bolt assembly will be made. The subject will perform this task for 30 seconds. The total number of completed nut/bolt assemblies, as well as any errors (dropped incomplete nut/bolt assemblies) will be recorded following this timed test. This first trial will be accomplished with 5/16" - 18 x 1" bolts.

7. Repeat 6 using 1/2" - 13 x 1 1/2" bolts.

8. Repeat 6 using 5/8" - 11 x 2" bolts.

9. Allow the test subject 5 minutes of rest to reduce the effects of fatigue.

TEST PROCEDURES (CONT'D):

10. Repeat 6-9 with the glove hand at the specified pressures.

11. Perform the knot typing task as follows: Direct the subject to tie an overhand knot in a 36" long, 1/8" diameter, type III nylon parachute chord, per MIL-C-5040, pull it tight, and immediately drop it. Record the time to complete tying on the attached data sheet. Timing shall begin once the subject picks up the rope and end once the subject has finished tying the knot and has dropped it. The knot is considered finished when the ends are pulled tight and there is no noticable gap in the center of the knot.

12. Repeat 11 using a 36" long, 0.25" diameter rope. Record time to complete tying on the attached data sheet. Timing shall begin and end as in step 11 above.

13. Repeat 11 and 12 with the gloved hand at the specified pressures.

TEST INFORMATION SHEET

TEST TITLE: DEXTERITY	TEST NUMBER: 3
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 4 OF 5	

TEST DATA SHEET

PURDUE PEGBOARD

PEG SIZE	BARE HAND		P_1 = ______ PSID		P_2 = ______ PSID		P_3 = ______ PSID	
	PEGS	ERRORS	PEGS	ERRORS	PEGS	ERRORS	PEGS	ERRORS
3/16" X 3"								
5/16" X 4"								
7/16" X 5"								

NUTS/BOLTS ASSEMBLY

BOLT SIZE	BARE HAND		P_1 = ______ PSID		P_2 = ______ PSID		P_3 = ______ PSID	
	NUTS/ BOLTS	ERRORS	NUTS/ BOLTS	ERRORS	NUTS/ BOLTS	ERRORS	NUTS/ BOLTS	ERRORS
5/16" X 1"								
1/2" X 1 1/2"								
5/8" X 2"								

SUBJECT: ______________________

TEST ITEM: ______________________

TEST DATE: ______________________

TEST CONDITION: ______________________

TEST CONDUCTOR: ______________________

TEST TITLE: DEXTERITY	TEST NUMBER: 3
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 5 OF 5	

TEST DATA SHEET

ROPE TYING

ROPE SIZE	TIME TO TIE KNOT
36" X 1/8"	
36" X .25"	

SUBJECT: ______________________

TEST ITEM: ______________________

TEST DATE: ______________________

TEST CONDITION: ______________________

TEST CONDUCTOR: ______________________

TEST INFORMATION SHEET

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 1 OF 8	

TEST OBJECTIVE:

The objective of this test is to measure the tactility degradation caused by pressure gloves. A two point discrimination (V-test) and a coefficient of friction/grip force perception test will be used in this evaluation.

TEST ITEM DESCRIPTION:

The item to be tested is the right hand of the pressure glove. Glove pressures shall be as specified. Bare handed performance will be used as a baseline. Two right handed subjects per size will be used in this evaluation.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing will occur as specified in the Detailed Test Plan. Testing will be performed in accordance with the schedule as defined in the Detailed Test Plan.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The Government may witness testing, as desired.

INSTRUMENTATION/TEST EQUIPMENT:

A glove box, capable of maintaining at least 7.0 psid, shall be used. Instrumentation shall include a differential pressure gage to measure glove pressure, a "V" test apparatus as shown in Figure 1 to measure two point discrimination, and a "coefficient of friction" test apparatus as shown in Figure 2 to measure grip strength perception. A PC with the appropriate hardware and software shall be used to measure "real time" loads on the "coefficient of friction" test apparatus. Video and photographic equipment shall be used to provide details of the test set-up, instrumentation and operation of equipment. A video recording shall also be made to document testing. All equipment used shall be calibrated to NIST standards.

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH:
NUMBER OF PAGES: 2 OF 8	TEST

TEST PROCEDURES:

The test procedures shall be performed in the bare handed position to serve as a baseline. Testing shall also be done on the gloved hand at the specified pressures. Several test dry runs shall be done prior to actual testing to allow the test subject to become familiar with the test apparatus. The subject shall be permitted to take short rest periods anytime fatigue is felt in the hands. The right hand shall be used to standardize this test.

Prior to the gloved tests, the glove shall be pressurized to 1 psi, the glove donned and any bladder wrinkles removed from the glove. The glove box pressure shall then be changed to the desired test pressure.

NOTE: Prior to testing, test subjects will be instructed to discontinue testing if tired or fatigued. A 5 minute rest period will be allowed and testing will resume once the subject no longer feels fatigued.

1. Conduct the "V" test as follows: In a random fashion, move either the "V" shaped or straight 2 point discrimination apparatus within the subject's reach. The angle of the "V" test apparatus shall be optimized, (i.e., such that the test results are sensitive to glove pressures, etc.) during dry runs prior to the actual testing. The test apparatus shall be shielded from the subject's view at all times. Once in reach, the subject shall run his/her index finger along the apparatus starting at the hinged end and moving towards the wide end. Contact pressure shall be as consistent as possible from run to run. A contact force of 1-2 lbs., which will be measured with a force gage placed between the "V" test and its support apparatus, should be maintained throughout the test. In the "V" condition, the subject shall announce when 2 points are felt. The distance from the hinged end of the apparatus to the discrimination point shall then be recorded. The discrimination point shall be defined as the mid point of the contact area of the finger as the finger makes contact with the "V" test apparatus in an as nearly perpendicular fashion as possible. In the "straight" condition, the subject shall announce that the apparatus is not "V" shaped. Any errors (i.e. the subject stating that the "V" shaped apparatus is straight, or that the "straight" apparatus feels like 2 points) shall be recorded on the attached data sheet.

2. Repeat 1 twenty (20) times such that 10 "V" shaped and 10 "straight" tests are accomplished in a predetermined random fashion.

3. Repeat 1-2 for the gloved hand at the specified pressures.

4. Allow the subject 5 minutes of rest to reduce the effects of fatigue.

TEST INFORMATION SHEET

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 3 OF 8	

TEST PROCEDURES (CONT'D):

5. Conduct the "coefficient of friction" test as follows: Place the specified cover tube over the gripping beam. Place a determined amount of weight on the apparatus. With the subject's view obstructed, instruct the subject to grasp the bar in a normal fashion (i.e. normal gripping force) and raise the weight; hold for 10 seconds and gently lower the weight. Record this force as the grasping force on the attached data sheet. The subject shall then grasp the bar again and raise the weight. The grasping force shall then be slowly reduced until the weight starts to slip. At the moment of slipping, as indicated by the vertical force gage, record the grasping force. This force is called the slipping force. Calculate and record the safety margin factor by subtracting the slipping force from the grasping force. Repeat 6 times and compute and record the average safety margin.

6. Repeat 5 for at least 3 different weights and 2 different tube covers (for a total of 36 tests).

7. Repeat 5-6 for the gloved hand at the specified pressures.

TEST INFORMATION SHEET

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 4 OF 8	

TEST DATA SHEET

1. 2 POINT DISCRIMINATION:

PRESSURE: ___________PSID

TRIAL	"V" OR "STRAIGHT"	DISCRIMINATION DISTANCE/CORRECT RESPONSE	ERROR	
			YES	NO
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

NUMBER OF ERRORS: ____________________

SUBJECT: ____________________ (include hand size percentile)

TEST ITEM: ____________________ (include P/N and S/N)

TEST DATE: ____________________

TEST CONDITION: ____________________

TEST CONDUCTOR: ____________________

TEST INFORMATION SHEET

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 5 OF 8	

TEST DATA SHEET

2. "COEFFICIENT OF FRICTION":

PRESSURE: ________ PSID

TRIAL	TUBE COVER	WEIGHT (LB)	GRASPING FORCE (LB)	SLIPPING FORCE (LB)	SAFETY MARGIN (LB)
1					
2					
3					
4					
5					
6					
AVG:					

COMMENTS: ____

____

____

SUBJECT: ____________________

TEST ITEM: ____________________

TEST DATE: ____________________

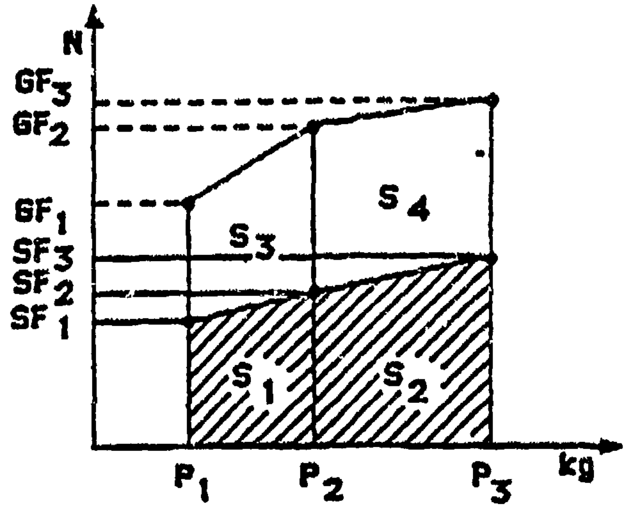
TEST CONDITION: ____________________

TEST CONDUCTOR: ____________________

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH:
NUMBER OF PAGES: 6 OF 8	TEST

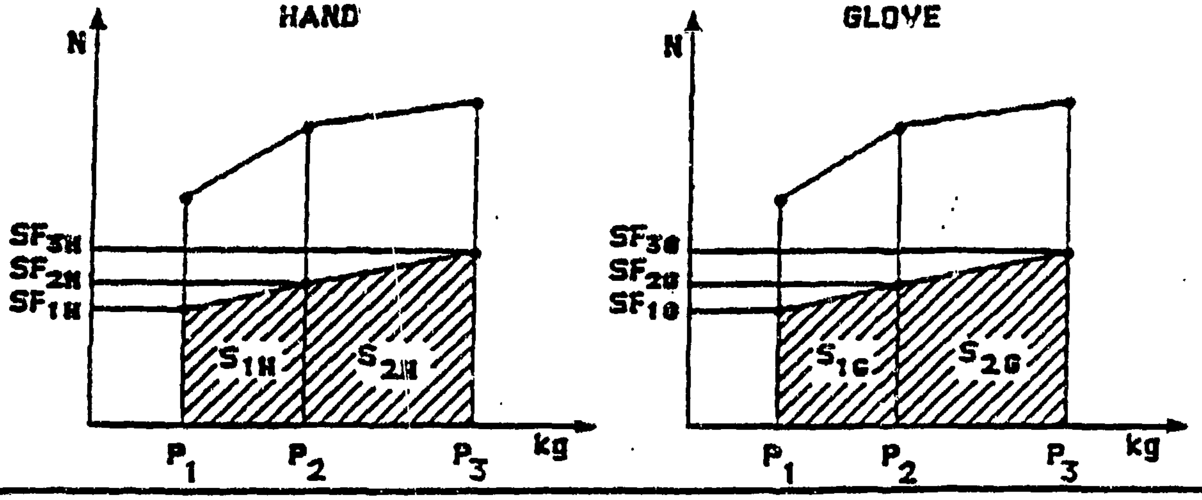
DATA REDUCTION

CREATE GRAPH AS BELOW USING AVERAGE GRIPPING FORCES (GF) AND SLIPPING FORCES (SF).



SAFETY INDEX = $(S3 + S4)/(S_1 + S_2)) - 1$

CREATE GRAPH AS BELOW USING AVERAGE SLIPPING FORCES (SF) FOR THE BARE HAND AND GLOVED HAND:

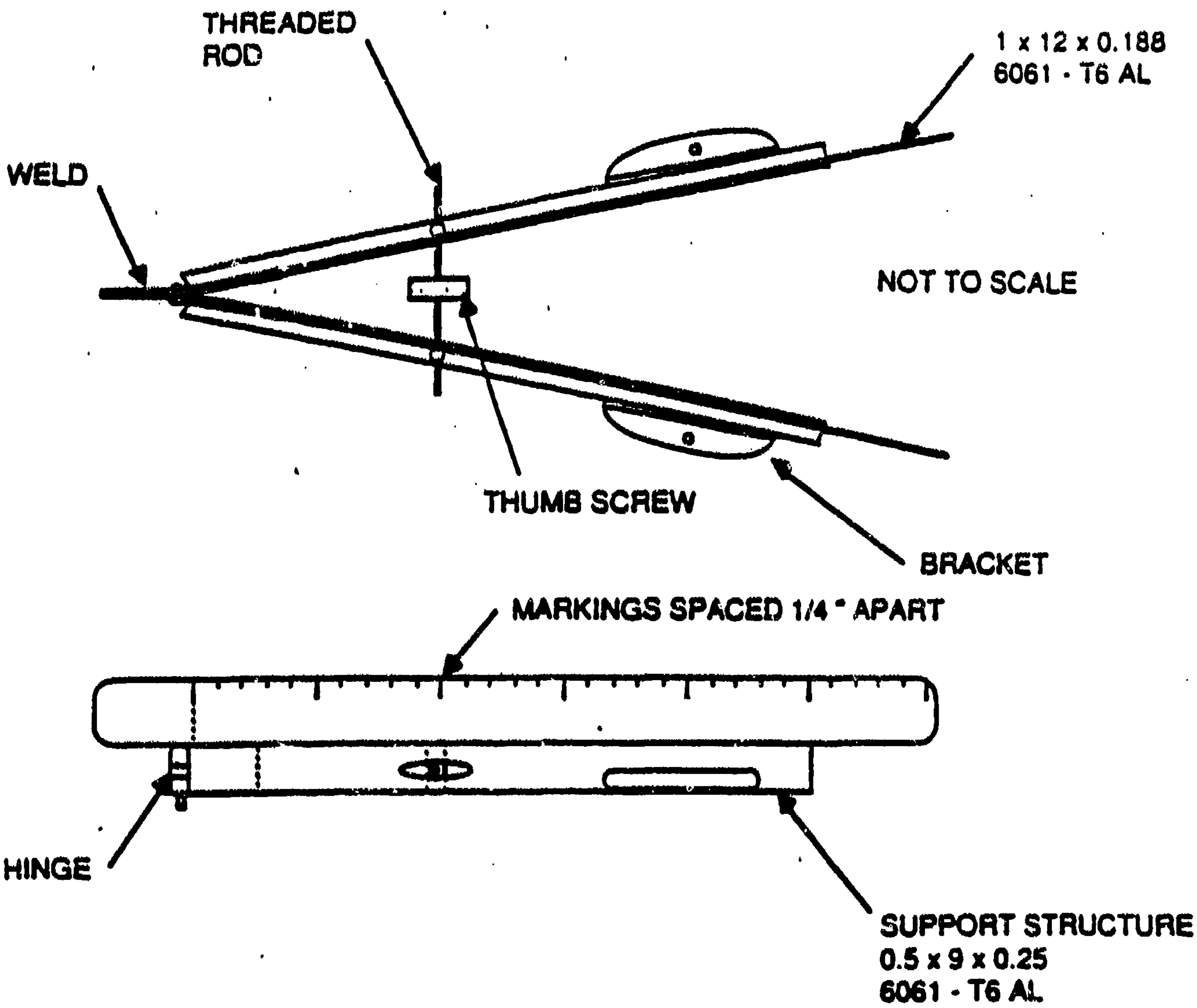


FRICTION INDEX = [(S1G + S2G / S1H + S2H) -1] *100

TEST INFORMATION SHEET

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 7 OF 8	

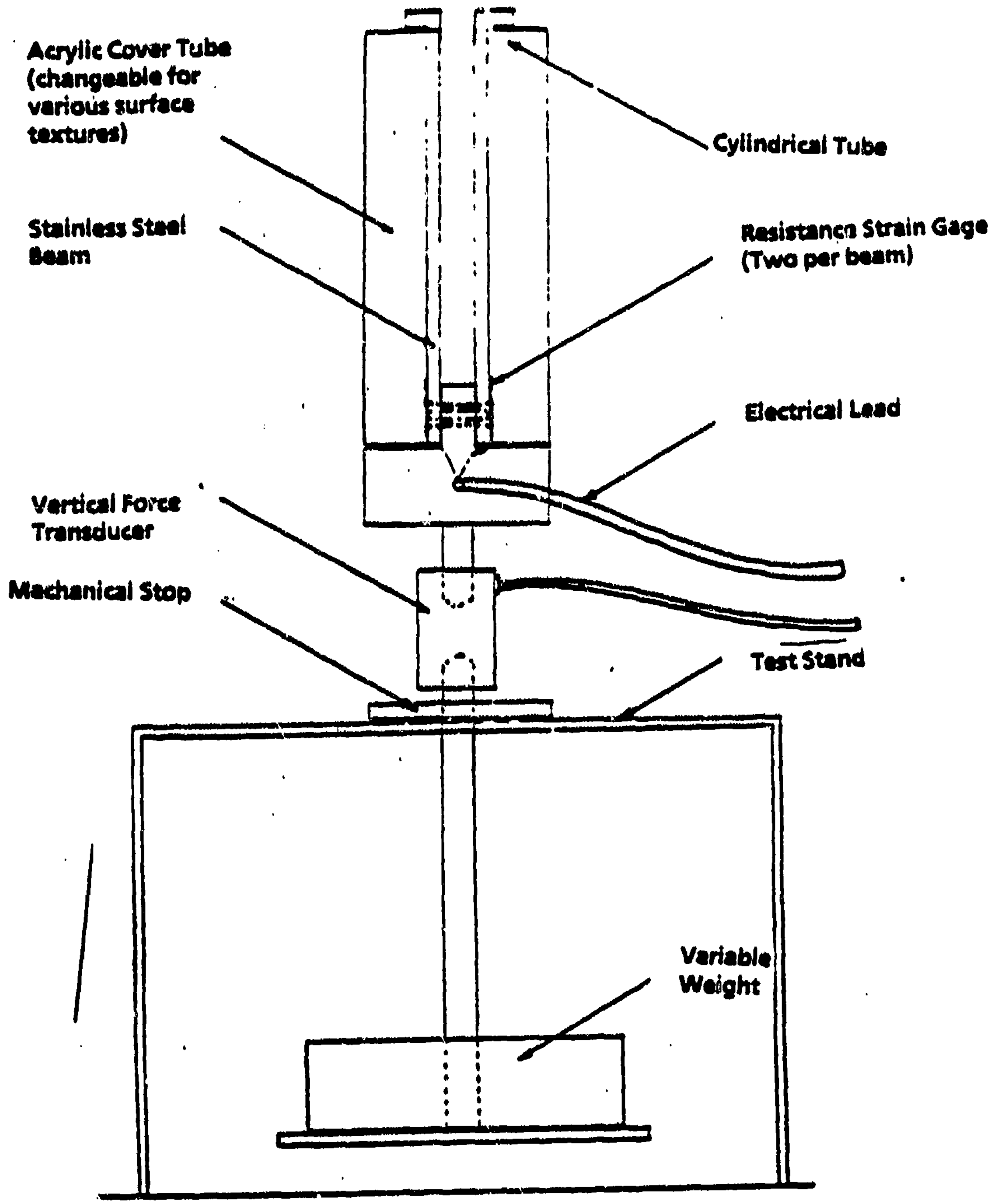
FIGURE 1



"V" Test Apparatus With Adjustable Gap Width

TEST TITLE: TACTILE PERCEPTION	TEST NUMBER: 4
APPLICABLE SPECIFICATION:	METHOD/APPROACH:
NUMBER OF PAGES: 8 OF 8	TEST

FIGURE 2



Perception Of Coefficient Of Friction Test Apparatus

TEST INFORMATION SHEET

TEST TITLE: COMFORT	TEST NUMBER: 5
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 1 OF 3	

TEST OBJECTIVE:

The purpose of this test is to characterize the level of comfort afforded by pressure gloves.

TEST ITEM DESCRIPTION:

Testing will be done on pressure gloves at specified pressures.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing will be conducted at the location identified in the Detailed Test Plan. Test scheduling will also be specified in the Detailed Test Plan. The evaluation of comfort will be an ongoing process that will occur throughout the entire testing effort. The comfort and fit evaluations contained in this TIS will be performed following each TIS contained in this document.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The Government shall witness testing, if so desired.

INSTRUMENTATION:

Instrumentation used in the assessment of glove comfort shall include a glove box capable of maintaining 7.0 psid, as well as the instrumentation associated with the operation of the glove box. Video and photographic equipment shall be used to document any comfort anomalies and areas on the hand which exhibit pressure marks, blisters, chaffing, pinching, cutting, etc., caused by the presence of the glove.

TEST PROCEDURES:

The determination of glove comfort is based solely on subjective input by the test subject and the test conductor. The following shall be recorded to characterize the level of comfort:

1. Following each test in this Test Protocol Document, the test conductor shall document any abnormalities (i.e. blisters, chaffing, pinching, cutting, etc.) caused by the presence of the glove. The test conductor shall also make an evaluation of the glove fit during donning and doffing of the glove (i.e. did the glove slide on and off easily). Document the results on the attached data sheet.

TEST INFORMATION SHEET

TEST TITLE: COMFORT	TEST NUMBER: 5
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 3	

TEST PROCEDURES (CONT'D):

2. Following the completion of each TIS in this document, record the results of the comfort assessment attached. Separate values shall be determined for the gloves at the specified pressures.

TEST RESULTS

1. ANOMALIES FOLLOWING TESTING

TIS 1: RANGE OF MOTION: ______________________________

____

____

TIS 2: STRENGTH: ______________________________

____

____

TIS 3: DEXTERITY: ______________________________

____

____

TIS 4: TACTILITY: ______________________________

____

____

TIS 6: FATIGUE: ______________________________

____

____

TIS 7: ENVIRONMENTAL PROTECTION: ______________________________

____

____

TEST INFORMATION SHEET

TEST TITLE: COMFORT	TEST NUMBER: 5
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 3 OF 3	

TEST RESULTS (CONT'D)

2. COMFORT ASSESSMENT:

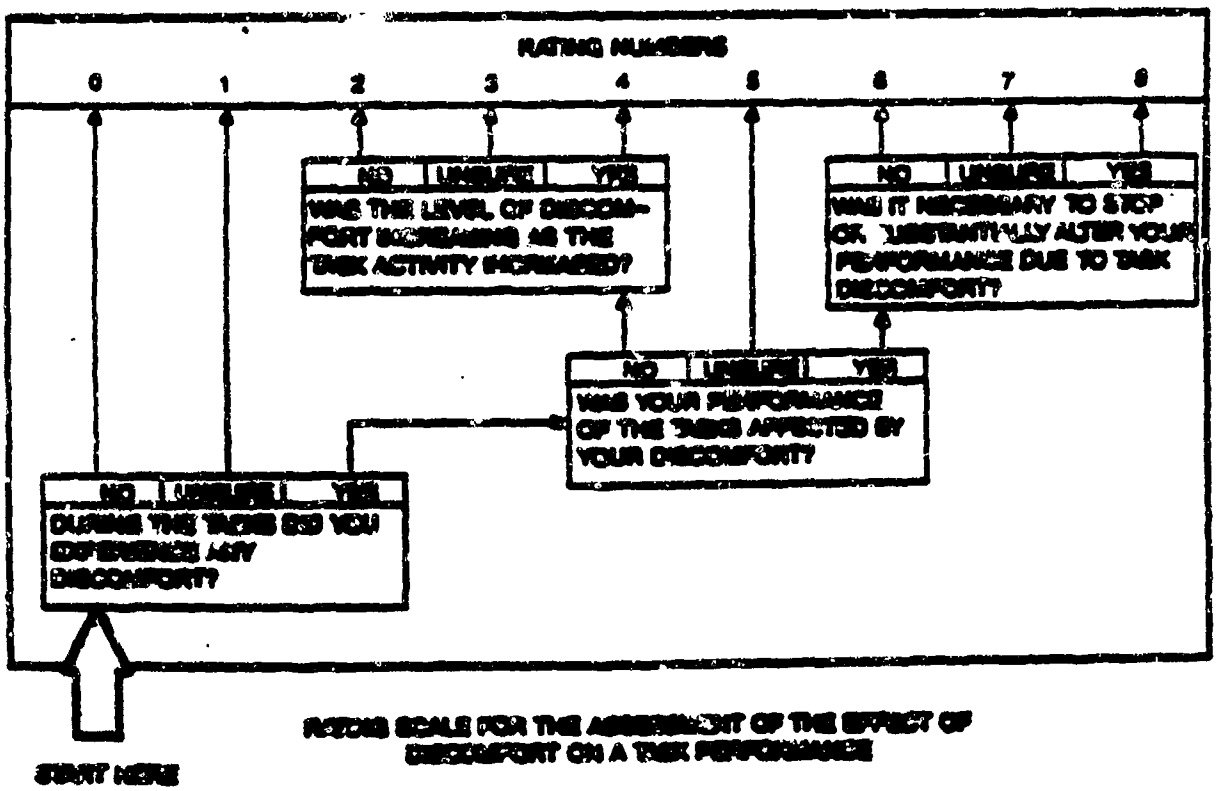
SCALE RATING AS DEFINED BELOW: ____________ PRESSURE: ____________

OBSERVATIONS: ____

____

____

DIRECTIONS: BEGIN YOUR ASSESSMENT AT THE LARGE ARROW LABELED START HERE. ANSWER THE APPROPRIATE QUESTIONS AND FOLLOW THE ARROWS UNTIL YOU REACH THE RATING NUMBERS AT THE TOP OF THE TABLE. WHEN YOU HAVE REACHED THESE NUMBERS CIRCLE THE NUMBER CORRESPONDING TO THE ARROW YOU FOLLOWED AND THEN GO ON TO THE NEXT PAGE.



RATING SCALE FOR THE ASSESSMENT OF THE EFFECT OF DISCOMFORT ON A TASK PERFORMANCE

TEST CONDUCTOR: ______________________________

TEST INFORMATION SHEET

TEST TITLE: FATIGUE	TEST NUMBER: 6
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 1 OF 4	

TEST OBJECTIVE:

The objective of this test is to measure the effect of the pressure gloves on hand/finger fatigue.

TEST ITEM DESCRIPTION:

Testing will be done on the right hand of pressure gloves at specified pressures. Bare handed performance will be used as a baseline. Two right handed subjects per size will be used in this evaluation.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing will be conducted at the location identified in the Detailed Test Plan. Due to the fatiguing nature of this test, only one fatigue test may be run per day to allow for full recovery of the hand muscles and avoid interference with other testing. The schedule for testing will be specified in the Detailed Test Plan.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The Government shall witness testing, if so desired.

INSTRUMENTATION/TEST EQUIPMENT:

A glove box capable of maintaining the maximum pressure of the glove design, shall be used. Instrumentation shall include a differential pressure gage to measure glove pressure, a Baltimore Therapeutic Equipment (BTE) work simulator to measure the reduction in work over time due to fatigue, a clock to pace each contraction, and a hand held dynamometer to measure maximum voluntary contraction. Video and photographic equipment shall be used to provide details of the test set-up, instrumentation and operation of equipment. A video recording shall also be made to document testing. All equipment used shall be calibrated in accordance with NIST standards.

TEST INFORMATION SHEET

TEST TITLE: FATIGUE	TEST NUMBER: 6
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 4	

TEST PROCEDURES:

The following procedures will be used to assess fatigue caused by the pressurized gloves. No practice run is given due to the simplicity of this test. Testing shall occur for the bare hand and gloved hand at various pressures at a rate of one test per day. Prior to gloved tests, the glove box shall be pressurized to 1 psid, the glove donned, and any wrinkles removed from the glove bladder. The glove box pressure shall then be changed to the specified test pressure.

NOTE: No rest periods shall be allowed during this testing, however, if the subject becomes fatigued to the point that it is impossible to continue, the test shall be terminated and it shall be noted on the data sheet and the test shall be repeated with a reduced resistance on the BTE on another day.

1. Adjust the size of the hand held dynamometer such that the subject feels comfortable with the maximum voluntary contraction (MVC) movement.

2. Measure and record the subject's MVC load on the hand dynamometer. The force gage should face away from the subject.

3. Using the BTE work simulator, instruct test subject to grip the BTE tool at a rate of 30 cycles per minute, for one minute. Contraction rate shall be maintained by counting with a clock. The subject shall squeeze the tool to its full closed position for each contraction. Test subject shall be instructed to squeeze with the same amount of force each time and release immediately upon reaching the full closed position. Subject shall place his chest against the pads on the glove box and shall not be permitted to alter his body, arm, and hand position during the testing. The BTE resistance for each subject shall be determined in a dry run prior to testing and shall be recorded on the attached data sheet.

4. Following the one minute cycling, the subject will again squeeze the hand held dynamometer to the maximum voluntary contraction. Record the value on the attached data sheet. Again, body, arm, and hand position should remain constant for each contraction to insure that different hand/arm muscles are not being used for each MVC.

5. Repeat 1-4 seven (7) times.

6. Complete the attached rating scale based on the subjects input. Areas of fatigue should be noted in the observations section.

7. Repeat 1-6 for the gloved hand at the specified pressures. One test per day.

TEST TITLE: FATIGUE	TEST NUMBER: 6
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 3 OF 4	

TEST DATA SHEET

TRIAL	MAX. VOLUNTARY CONTRACTION (LB)	WORK DONE
INITIAL		N/A
1		
2		
3		
4		
5		
6		
7		

GLOVE PRESSURE: ______________________ PSID

OBSERVATIONS (i.e. LOCATIONS OF FATIGUE): ______________________

SUBJECT: ______________________
TEST ITEM: ______________________
TEST DATE: ______________________
TEST CONDITION: ______________________
TEST CONDUCTOR: ______________________

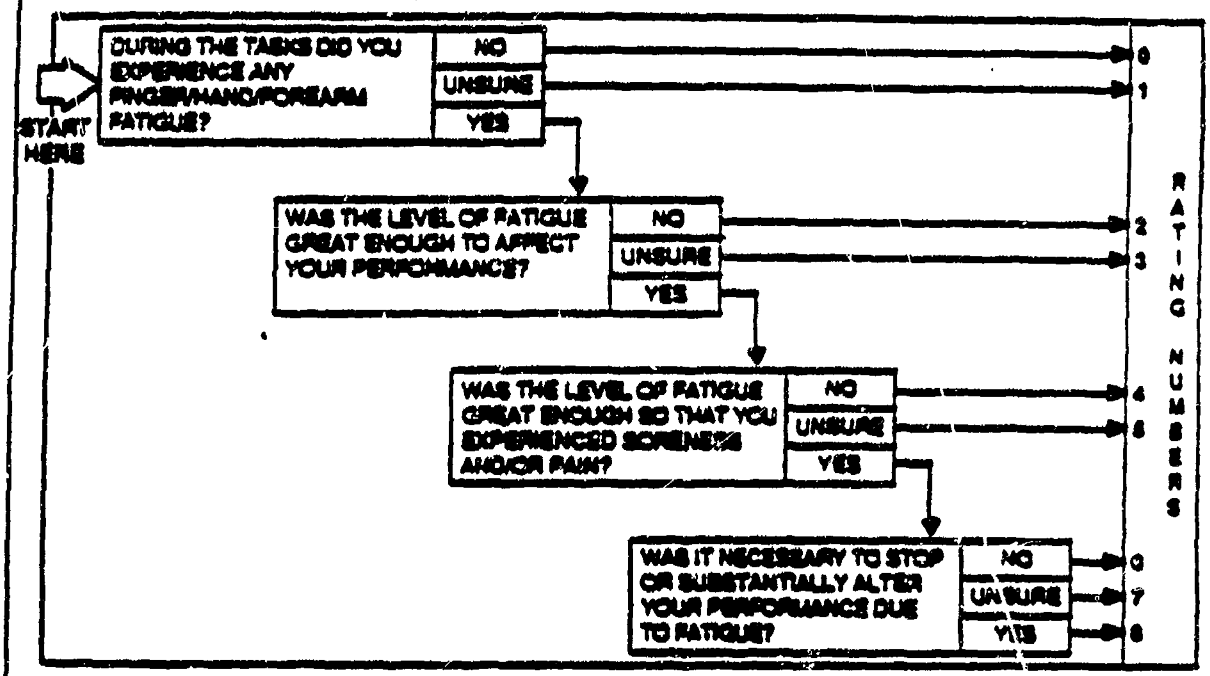
TEST INFORMATION SHEET

TEST TITLE: FATIGUE	**TEST NUMBER:** 6
APPLICABLE SPECIFICATION:	**METHOD/APPROACH:** TEST
NUMBER OF PAGES: 4 OF 4	

TEST DATA SHEET

FATIGUE ASSESSMENT:

DIRECTIONS: BEGIN YOUR ASSESSMENT AT THE LARGE ARROW LABELED "START HERE". ANSWER THE APPROPRIATE QUESTIONS AND FOLLOW THE ARROWS UNTIL YOU REACH THE RATING NUMBERS ON THE RIGHT SIDE OF THE TABLE. WHEN YOU HAVE REACHED THESE NUMBERS CIRCLE THE NUMBER CORRESPONDING TO THE ARROW YOU FOLLOWED AND THEN GO ON TO THE NEXT PAGE.



RATING SCALE FOR THE ASSESSMENT OF THE EFFECT OF HAND FATIGUE ON TASK PERFORMANCE

SUBJECT: ______________________

TEST ITEM: ______________________

TEST DATE: ______________________

TEST CONDITION: ______________________

FATIGUE RATING (0-8): ______________________

TEST CONDUCTOR: ______________________

TEST TITLE: ENVIRONMENTAL PROTECTION	TEST NUMBER: 7
APPLICABLE SPECIFICATION:	METHOD/APPROACH:
NUMBER OF PAGES: 1 OF 2	TEST

TEST OBJECTIVE:

To determine the hot and cold environmental protection provided by pressure gloves. Testing will be performed for free air temperatures challenges.

TEST ITEM DESCRIPTION:

Test item shall consist of the right hand pressure glove.

LOCATION, SCHEDULE, NUMBER OF TESTS, DURATION:

Testing will be conducted one time only on the right hand of each size of the glove pressurized as specified in the Detail Test Plan. Test duration is anticipated to be two days.

CONTRACTOR/GOVERNMENT PARTICIPATION:

The government shall witness testing if so desired.

INSTRUMENTATION:

Thermal sensors will be placed inside the glove as follows:

- Two in the palm area of the glove
- One on the first and last pad of each finger of the glove
- One on the last thumb pad of the glove
- One to record test challenge temperature

Sampling rate will be one per second minimum.

Video and photographic equipment shall be used to provide details of the test set-up, instrumentation and operation of equipment.

TEST INFORMATION SHEET

TEST TITLE: ENVIRONMENTAL PROTECTION	TEST NUMBER: 7
APPLICABLE SPECIFICATION:	METHOD/APPROACH: TEST
NUMBER OF PAGES: 2 OF 2	

TEST PROCEDURES:

Testing will be conducted using a thermal chamber.

1. Install thermocouples in the glove locations specified. The glove will be pressurized as specified in the Detailed Test Plan.

2. Place ambient thermocouple in chamber and heat to 165°F.

3. Place instrumented glove in heated chamber. Verify that glove pressure is per the Detailed Test Plan.

4. Begin data acquisition. Record temperature vs. time for each thermocouple for 5 minutes.

DATA REDUCTION AND ANALYSIS :

The following data will be recorded:

High Temperature
- Air at 165 degrees F

Time/Temperature plots will be prepared for each test configuration.

12.1.10 Appendix B1: Bibliography

1. Bradley, J., Human Factors, 1969

2. Chochran,D., et al, Proceedings of the Human Factors Society-30th Annual Meeting, 1986

3. Cleland, John G., et al, NASA Workshop Proceedings: Extravehicular Activity Gloves, 1985, pp. 50 - 54

4. Farquhar, M., EVA Glove Evaluation with the Work Simulator System Test Plan, 1986

5. Garrett, John W., Anthropometry of the Hand of Male Air Force Flight Personnel, AMRL-TR-69-42, March 1970

6. Garrett, John W., Clearance and Performance Values for the Bare-Handed and the Pressure Gloved Operator (AMRL-TR-68-24)

7. Little, Arthur D., Glove Testing Protocol Description, 1987

8. Nice, David A., Development of the Hermes EVA Space Suit Glove, 1992

9. O'Hara, John M., The Development of a Test Methodology for the Evaluation of EVA Gloves (18th Intersociety Conference on Environmental Systems), 1988

10. O'Hara, John M., et al., "Extravehicular Activities Limitations Study," NASA Contractor Report AS-EVAL-FR-8701, 1988, Vol. II

11. Peacock, B., et al, EVA Suit Design, Proceedings of Space Tech Conference, Dearborn, Michigan: Society of Manufacturing Engineers, 1985

12. Robinette, Kathleen M., et al, A Nine Size System for Chemical Defense Gloves, 1986

13. Robinette, Kathleen M., et al, Development of a Standard Dexterity Test Battery, 1987

14. Robinette, Kathleen M., et al, Dexterity Test of Chemical Defense Gloves, 1986

15. Ross, Jo and Ervin, Cal, Chemical Defense Flight Ensemble, 1987

16. Shepherd, C. K., EVA Gloves: History, Status, and Recommendations for Future NASA Research, 1990

17. Wyatt, Steve, 4000/5000 Series Glove TMG Test Program, 1991

12.2 Preliminary Draft of: Technical Requirements for the Pressurized Flight Glove

1. SCOPE

1.1 General. This specification establishes the performance, design, and qualification requirements for the Pressurized Flight Glove. The Pressurized Flight Glove hereinafter will be referenced to as the item.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the exact issue shown form a part of this specification to the extent specified herein; if undated, then the latest issue in effect on contract go ahead shall be used. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall govern.

SPECIFICATIONS:

STANDARDS:

OTHER:

3. REQUIREMENTS

3.1.1 Critical item definition. The item is the Pressurized Flight Glove. The item is required to enable the performance of normal and emergency actions at a pressure of 7.0 pounds per square inch (PSI). The item provides physiological protection in low pressure environments as well as physical, thermal and chemical warfare agent protection. The item interfaces physically and functionally with the AHADS pressures suit. Item design shall give consideration to maximize hand mobility and flexibility pressurized and unpressurized as well as reduced thermal and moisture buildup.

3.1.2 Interface definition. The design shall be functionally and physically compatible with the interfacing systems. The following interfaces are defined.

a. Pressure suit - The item will interface at the wrist ring of the AHADS pressure suit and the pressure suit ventilation system.

b. Crew Station - The item shall interface with the designated aircraft crew station, and ejection seat.

c. Aircrew - The item shall interface with the aircrew and the personnel flight equipment as defined herein.

d. Maintenance - The item shall be compatible with existing test equipment and maintenance tools.

3.1.3 Major components list. TBD

3.1.4 Government furnished property list. TBD

3.1.5 Government loaned property list. TBD

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Personal equipment compatibility. The item shall be compatible with the interfacing pressure suit.

3.2.1.2 Donning/doffing. The item shall be designed for easy and rapid unassisted donning/doffing.

3.2.1.3 Ingress/egress. The item shall not interfere with assisted ingress into the aircraft and connection of life support equipment. The item shall not interfere with the aircrew member's ability to normally egress from aircraft or perform emergency ground egress.

3.2.1.4 Survivability. The item, when worn as a part of the pressure suit ensemble, shall not hinder the ability to egress nor interfere with the normal opening of the parachute after emergency escape. The item shall permit performance of necessary survival functions while descending by parachute and after parachute landing on land and into water.

3.2.1.5 Escape system compatibility.

3.2.1.5.1 Windblast. The item shall remain structurally intact and not cause harm to the wearer during a windblast of 600 KEAS (Knots Equivalent Air Speed).

3.2.1.6 The item shall be designed to minimize degradation of basic hand capabilities required for user task performance. When tested on the following attributes using ILC Dover Document 827-70002, Standardized Test Methodology for Pressure Suit Gloves, the item's performance up to a pressure of 7 PSI shall be equal or better than the S-1031 Pressure Suit Glove.

a. Range of Motion and Torque.

b. Strength

c. Dexterity

d. Tactile Perception

e. Comfort

f. Fatigue

g. Thermal Conductivity

3.2.1.7 Pressures.

3.2.1.7.1 Operating pressures. The item shall operate at a normal operating pressure of 5.0 inwg (inches of water) in the vent operating mode and a maximum 7.0 psi (Pounds per Square Inch) in the fully pressurized mode.

3.2.1.7.2 Proof pressure. The item shall withstand without damage, 10.5 psi.

3.2.1.7.3 Burst pressure. The item shall withstand 14 psi pressure without rupture, break apart, or catastrophic failure. Permanent deformation is allowed.

3.2.1.8 Leakage. The item shall not leak more than 0.5 scc/min when subjected to a 7 psi pressure.

3.2.1.8 Strength. The item shall withstand momentary man loads of 59 pounds and sustained loads of 35 pounds.

3.2.1.9 Physiological protection. The item shall provide the wearer up to seven psi internal pressure to avoid injuries associated with aircraft decompression at high altitudes. In addition, the item shall protect the wearer's hand against the following temperature exposures:

Hot Ambient	125 deg F
Cold Ambient	-69 deg F
Hot Grasp	+160 deg F for 30 sec (212°F goal)
Cold Grasp	-20 deg F for 30 sec

3.2.1.10 Endurance. The item shall be capable of being pressure cycled (inflated and deflated) 1728 times to the maximum operating pressure without developing any structural defects or leakage as defined by 3.2.1.8. The item shall meet the requirements of this specification following testing.

3.2.1.11 Comfort. The item shall not be prone to wrinkles, creases, or lumps following proper donning. The glove shall prevent the build up of moisture internally with perspiration rates associated with the inflight workload.

3.2.1.12 Mobility, Tactility and Grasping. The item shall not restrict the wearer's ability to reach and operate workspace controls and displays. Desirable characteristics of movement and their associated displacement torque are listed in the following table:

Location[1]	Torque (inch pounds)	Displacement (Degrees)
DIP/PIP Joints	Less than 3	Greater than 60
MCP/CMC Joints	Less than 20	Greater than 30
Wrist Flexion/Extension	Less than 22	Plus/Minus 30
Wrist Adduction/Abduction	Less than 20	Plus/Minus 20
Wrist Pronation/Supination (Rotation)	Less than 3 during displacement of 90 degrees/sec	180

Note 1: Joint Types

Carpometacarpal Joint (CMC) - Joint at the base of the thumb metacarpal and associated carpal bones where circumduction of the thumb takes place.

Interphalangeal Proximal Joint (PIP) - Second, or middle finger joint.

Interphalangeal Distal Joint (DIP) - third finger joint located near tip of finger.

Metacarpalphalangeal Joint (MCP) - Primary finger joint allowing flexion/extension and abduction/adduction of the first phalanx bone of each digit.