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STUDY FOR THE COLLECTION OF HUMAN ENGINEERING DATA FOR MAINTENANCE AND REPAIR OF ADVANCED SPACE SYSTEMS

FINAL STUDY REPORT

VOLUME II

DETAILED TECHNICAL REPORT

FACILITY FORM 602

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PREPARED UNDER
CONTRACT NO. NAS8-18117

FOR

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA 35812

GENERAL ELECTRIC
MISSILE AND SPACE DIVISION
Valley Forge Space Technology Center
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PREFACE

The final report for the study directed towards obtaining human engineering data for the maintenance and repair of advanced space systems is presented in three volumes. The volume designations are as follows:

Volume	Title
I	Summary Technical Report
II	Detailed Technical Report
III	Preliminary Handbook of Human Engineering Design Data for Reduced Gravity Conditions

The analytical and operational portions of the study program were performed and directed by the Advanced Manned Systems Engineering Operation of the General Electric Company Missile and Space Division with test operations and handbook development support from other components of the Division.

In addition, considerable support was provided at the Marshall Space Flight Center for the fabrication, installation, and maintenance of the test equipment and instrumentation during the study experiment operations. We would like to acknowledge those NASA and Hayes Engineering personnel who provided this support, plus those who volunteered to act as test subjects and underwater technicians.

Test Subjects

NASA-MSFC	Hayes Engineering
H. L. Brink, Test Lab	J. Stephenson
R.C. McCaffrey, TS-MP	W. Hunter
B.S. Cain, Test Lab	C. Williams

Operational Support

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	D. Perryman
	R. Brye
	H. Canier
	D. Trosper
	W. McBride

Engineering Support

P&VE	ME Lab	Comp Lab
Dr. J. Rogers	P.H. Schuerer	J. Means
H.Y. Grubbs	W.B. Cruise	B.R. Pace
R.D. Hall	C.R. Cooper	R. Rogers
R.T. Heckman	D.C. Neville	
E.C. Pruett	R. L. Nichols	
R.B. Sims	C.A. Torstenson	
J. Peebles	A. Bienert (Hayes)	

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SECTION 1

INTRODUCTION

The purpose of this final study report is to present the results of the work performed under Contract NAS8-18117,"Study for the Collection of Human Engineering Data for the Maintenance and Repair of Advanced Space Systems." The study was performed during the period 26 August 1966 through 31 December 1967 and encompassed:

a. The preliminary planning and experimental definition of eight contractually specified experiments

b. The development of a program plan for the implementation of these experiments, utilizing reduced gravity simulation techniques

c. The final design and implementation of one composite experiment, using neutral buoyancy submergence techniques for the simulation mdeia

d. The preparation of the protocol and design for a second experiment

e. The preparation of a Preliminary Handbook of Human Engineering Design Data for Reduced Gravity Conditions. This primarily consisted of the development of the format for the handbook and the initial collection of applicable content material.

In contrast with the relatively simple extravehicular tasks required in the Gemini missions, future space systems will require extensive manned operations of all kinds. The experiments developed and implemented during this study were, therefore, designed to fill a portion of the gap in our knowledge of man's capabilities to perform complex tasks in the zero-gravity environment. The content and depth of detail in the initial experimental definition was limited to that necessary for the evaluation and subsequent selection of the experiments for both immediate and future implementation. The composite experiment selected for implementation during this study program was designed for an objective evaluation of the specific behavioral characteristics, in this case force emission, and a rather sophisticated data gathering and reduction system was utilized in order to maximize the data return.

As this study was designed to provide selected human engineering data of the type which will be required by space vehicle designers during the post-Apollo period, no attempt was made

to provide applications research as part of the experimental program. However, the parametric bounds considered for the inidvidual experiments were realistically set by consideration of the known and predicted requirements for the maintenance and repair of future spacecraft systems.

SECTION 2

PROGRAM SCOPE

It was the purpose of this research program to begin the accumulation, evaluation, and publication of human engineering data, principles, and criteria related to man's maintaining and repairing advanced space systems in a form useful to the designer. Although past and other current studies-in-depth on the attributes and capabilities of the space-suited man provide some of the required information, much experimental work remains to be done. In that conceptual design of advanced space systems has already begun, it is necessary to develop rapidly, a supporting human engineering technology to facilitate these design efforts.

The scope of this study program included a literature review to obtain and collate available human factors data relative to maintenance and repair activities in zero-g. At the same time, an experimental program was developed to provide, through the use of zero-g simulation techniques, missing information in certain critical behavioral areas.

As is so often the case in research programs, it was necessary to modify the scope of the study somewhat during the course of the program, as a result of such things as the expanded scope of combined experiments after completion of the preliminary design, operational problems during testing, and the limited resources available for the study.

The scope of the program at the time of inception included:

a. A literature search to obtain and collate available information on zero and 1/6th g pertinent to human factors, with emphasis on maintenance and repair.

b. Preliminary definition and planning of eight experiments as follows:

   1. "Manipulation, Transport, and Maneuvering of Free Masses in Zero-g and 1/6 g Fields as a Function of Object Volume and Workspace Configuration."

   2. "Manipulation, Transport and Maneuvering of Free Masses in Zero-g and 1/6 g Fields as a Function of Mobility Aids."

3. "Modular Replacement in Zero-g and 1/6 g Fields as a Function of Module Size and Shape."

4. "Precision Torque Control in Zero-g as a Function of Body Posture and Accessibility."

5. "Modular Replacement in Zero-g and 1/6 g as a Function of Accessibility and Visual Environment."

6. "Component Part Replacement in Zero-g and 1/6 g Fields as a Function of Method/Tool Design and Component Density."

7. "Investigation of the Use of Conventional Tools under Zero-g Conditions."

8. "Investigation of Push-Pull Force Producing Characteristics Under Zero-g Conditions."

c. Initiation of research on three experiments selected by NASA

d. Preparation of detailed experiment plans and equipment designs for the additional maintenance and repair experiments not selected in c.

e. Identification and justification of critical maintenance and repair human engineering experiments requiring manned space-flight for their implementation.

The preliminary handbook contained as Volume III of this final report is a direct result of a, above. A summary of the contents and other pertinent information are contained in Section 8 of this volume.

Upon completion of the preliminary definition for the experiments identified in b, above, a meeting of the NASA inter-center Ad Hoc Committee on In-Space Maintenance was called to review the program and recommend an order of implementation as specified in c. The experiments selected, in suggested order of implementation, are Experiment No. 8 (modified), Experiment No. 1, and Experiment No. 2. The modifications to Experiment No. 8 included its combination with Experiment No. 4, and the elimination of some variable combinations in the combined experiment. The new experiment is referred to as Experiment 84.

Prior to the start of actual test operations on Experiment 84, further program changes were made which considerably expanded its scope, hence, the designation Experiment 84A. The scope changes included the expansion of the number of force receiver locations, the inclusion of both water and air as space suit pressurization media in the neutral buoyancy operations, and the addition of 1-g comparative data requirements. (See Section 6 for details.) In addition, Experiment Nos. 1 and 2, as such, were deleted, and a modified Experiment No. 1 substituted, hence, the designation Experiment 1A. In addition, scope items d and e were deleted.

During the conduct of test operations for Experiment 84A, it became apparent that the greatly expanded scope of the revised experiment (requiring over 27,000 force application trials) would require the full time commitment of test personnel and facilities greatly in excess of the resources of this study. It was therefore decided to limit the experimental program to Experiment 84A and the design, but not implementation, of Experiment 1A. The results of these efforts, plus the preliminary experiment definitions for all eight experiments, are reported in this document.

SECTION 3

EXPERIMENT DEFINITION AND SELECTION

3.1 EXPERIMENT PRELIMINARY DEFINITION

The effort during the initial study period consisted of defining the requirements for eight specified experiments. These were identified by NASA as a function of the type of data required by design engineers. The types and variations of the experimental variables were selected to assure broad applicability of the data to many potential space missions. While this generic approach tends to limit the precision of application to specific missions and hardware, the net result is a reduction in the amount of applied research and/or simulation required for as yet unidentified missions in the post-Apollo period. The resultant data will serve sufficiently in those cases where a preliminary estimate is all that is required and when highly accurate forecasting of performance variables is required. Also, the data resulting from these experiments will serve to bound the problem and focus applications research on the appropriate area for investigation. The eight specified experiments are entitled:

a. "Experiment No. 1-Manipulation, Transport and Maneuvering of Free Masses in Zero-G as a Function of Object Volume and Path Configuration."

b. "Experiment No. 2-Manipulation, Transport and Maneuvering of Free Masses in Zero-G as a Function of Mobility Aids and Path Configuration."

c. "Experiment No. 3-Modular Replacement in Zero-G as a Function of Module Receptacle Size."

d. "Experiment No. 4-Torque Generation in Zero-G as a Function of Accessibility."

e. "Experiment No. 5-Modular Replacement in Zero-G as a Function of Accessibility and Visual Feedback."

f. "Experiment No. 6-Component Part Replacement in Zero-G as a Function of Component Shape and Accessibility."

g. "Experiment No. 7-Investigation of the Use of Wrench and Torsion Type Conventional Tools in Zero-G."

h. "Experiment No. 8-Push-Pull Force Generation in Zero-G as a Function of Restraint Conditions."

In this preliminary definition phase the specified experiments were defined only to the level necessary for evaluation and implementation selection by NASA. The definition phase included a preliminary description of experimental protocol and procedures, a proposed listing of experiment equipment requirements, and an evaluative and comparative listing of estimated costs and schedules. The following sections present brief descriptions of the experimental conditions for the eight experiments and proposed implementation plans. As shown in a later section, the actual experiment which was implemented during this study is a composite of selected variables from two of these eight experiments.

The initial study effort required the consideration of 1/6 g as well as zero-g. It became evident early in the study that for most of the selected experiments, the simulation of multiple reduced gravity conditions required rather extensive modifications of both the experiment protocol and the equipment design. In addition, the considerable increase in test time (which would be necessary because of the replication of experimental procedures at various g-levels) put further consideration of multiple reduced gravity conditions beyond the scope of this study. Therefore, with the concurrence of NASA, the study effort was limited to the zero gravity condition only.

3.2 EXPERIMENT NO. 1 - MANIPULATION, TRANSPORT AND MANEUVERING OF FREE MASSES IN ZERO-G AS A FUNCTION OF OBJECT VOLUME AND PATH CONFIGURATION

3.2.1 OBJECTIVES

A number of potential areas require extensive study if an adequate understanding of the capability to predict the ability of a suited astronaut to move "cargo" in zero-g is to be developed. Although many factors influence man's ability to perform this function, this experiment is concerned with the two which appear to have the greatest effect on performance. These include the characteristics of the object to be transported and the characteristics of path which is to be traversed. The primary objectives of this experiment are, therefore, to:

a. Measure and evaluate the effects of the object volume, mass, and shape on the maneuvering, transporting, and manipulation of such objects in zero-g.

b. Measure and evaluate the effect of restricted workspace areas on the maneuvering, transportation, and manipulation of free objects in zero-g.

The primary purpose in establishing these research objectives is to obtain data which can be used by spacecraft designers in assessing the relative levels of performance degradation which will result from the adoption of different packaging design and workspace layouts. The actual packaging of operational and support equipments, as well as the selection of hatch and airlock dimensions for any specific system, requires a number of tradeoffs covering many considerations. This experiment is designed to supply a portion of the empirical data required for performing such tradeoff analyses and to enhance the validity of their decision.

3.2.2 EXPERIMENT DESCRIPTION

This experiment consists of timed traversals of a fixed three-dimensional course with varying simulated cargo objects. Zero-g will be simulated by the use of neutrally buoyant modules and a neutrally buoyant test subject in a water-pressurized space suit. A single, non-varying, one-hand mobility aid will be employed to assist the subject and provide the sole locomotion aid. Figure 3.2-1 is a conceptual sketch of a typical traversal course. Subtasks will include:

a. Removal of a modular assembly from a receptacle

b. A straight traversal

c. An enclosed right angle turn

d. Traversal through a tunnel

e. Manipulation through apertures of various sizes

f. Placement of a modular assembly in a receptacle

The 48 modular assemblies to be evaluated will consist of two basic configurations in each of eight volumes and three specific masses, and are described in Section 3.2.3. Forces will be applied through a simple D-handle mounted on the center of the front panel of each

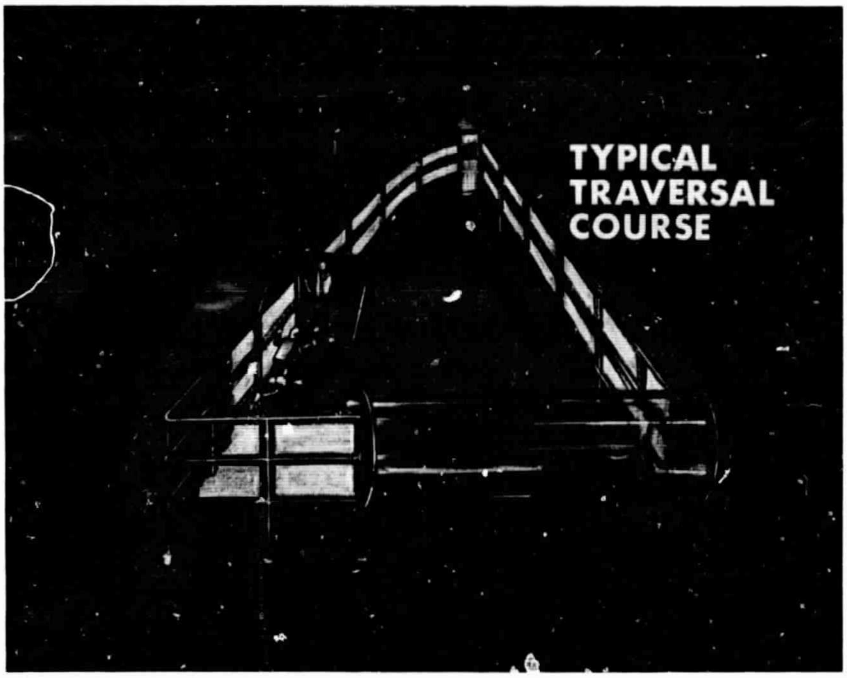


Figure 3.2-1. Typical Traversal Course

assembly. Directive forces can easily be applied by the subject because of the symmetrical design and location of the center of gravity at the physical midpoint of the object.

Each experimental run will begin with the subject grasping the D-handle on one of the experimental assemblies and removing it from a storage rack. The subject will then re-orient himself and the assembly and, utilizing the mobility aid with one hand, translate over a set distance to, and through, a hatch opening of a given size. The subject will then turn and translate to a different size hatch, which opens into a tunnel. He will enter the tunnel through this hatch and immediately make a 90-degree turn. After traveling the length of the tunnel, the subject will exit through another hatch opening of a different size. The subject will then translate the assembly back to the vicinity of the storage rack,with the run completed when the assembly is returned to a fixed location in the storage rack. The subject will be instructed to proceed through the course in such a way as to minimize impacts on the assemblies.

After a specified rest period, the subject will begin the next experimental run with a different assembly. Eventually, each subject will traverse the same course with each assembly a total of four times, as shown in the schedule of Section 3.2.7.

3.2.3 TEST VARIABLES

The variables in this experiment were selected on the basis of their potential criticality in affecting performance level when various assemblies must be transported in a zero-gravity environment. These include the object configuration, or shape, object mass, and object volume.

3.2.3.1 Object Configuration

The two configurations selected for study are the parallelepiped (box shape) and the cylinder. These configurations were chosen because of their general applicability to space flight packaging, i.e., ease of mounting and location of center of gravity. Other configurations such as spheres and asymmetrical shapes were considered to be less representative of the types of equipments to be required for space maintenance and repair.

3.2.3.2 Object Mass

The three masses which have been selected are:

a. 1 slug

b. 2 slugs

c. 4 slugs

These values sample the range of masses expected to be found in assemblies realistically sized for astronaut manipulation. The largest mass (4 slugs) when paired with smallest volume (2 cubic feet), may present a design problem for the neutral buoyancy technique; if so, the mass will be changed accordingly. If larger masses should be requested or desired, they can be incorporated into the larger objects. See Section 4 for a discussion of neutral buoyancy equipment design techniques.

3.2.3.3 Object Volume

Object volumes have been selected by systematically varying the box and cylinder sizes, utilizing dimensions which approximate those of components or subsystems which might be utilized in the maintenance and repair of future spacecraft. The seven volumes selected include a range from 2 to 37-1/2 cubic feet and include:

a. 2 cubic feet

b. 3 cubic feet

c. 5 cubic feet

d. 8 cubic feet

e. 16 cubic feet

f. 22-1/2 cubic feet

g. 37-1/2 cubic feet

Table 3.2-1 lists the dimensions of these experimental assemblies.

Table 3.2-1. Dimensions of Experimental, Assemblies - Experiment No. 1

ASSEMBLY NO.	BOX			CYLINDER		Volume cu. ft.
	H	W (in inches)	L	Dia. (in inches)	L	
1	12	12	24			2.00
2				13.6	24	2.01
3	12	12	36			3.00
4				13.6	36	3.02
5	12	12	60			5.00
6				13.6	60	5.04
7	24	24	24			8.00
8				27.1	24	8.00
9	12	24	60			10.00
10				19.2	60	10.04
11	24	24	48			16.00
12				27.1	48	16.01
13	30	36	36			22.50
14				37.1	36	22.50
15	30	36	60			37.50
16				37.1	60	37.51

3.2.4 TEST MEASURES AND ANALYSIS OF RESULTS

3.2.4.1 Physiological Data and Expected Results

The physiological data will be gathered by means of biomedical sensors attached to the subject's body or contained as an integral part of the backpack. The data collected will include (1) heart rate, (2) respiration rate, (3) oxygen consumption, (4) deep body temperature, and (5) tidal volume. These data will be recorded as dc levels on a magnetic tape recorder. located in an underwater backpack worn by the test subject, thus providing an experimental time history of the average and peak metabolic costs associated with various work activities and experimental conditions. The metabolic costs will be plotted as a function of time to denote differences between test variables, differences between subjects, fatigue effects, or a measure of efficiency of operation. In order to make these data meaningful, baseline metabolic measures will be taken on all subjects at rest before and during each day's experimental trials.

3.2.4.2 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Evolve optimal manipulative, maneuvering, and translation techniques

c. Ascertain work volume envelopes for various experimental tasks and conditions

d. Identify recurrent behavior patterns

e. Isolate problem areas for future research

3.2.4.3 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test director. A formal debriefing will be held with each subject after each experimental session to collect personal observation comments concerning problems, suggested procedural or equipment modifications. and comparative judgments about the experimental variables. An interview form or data questionnaire will be constructed and utilized when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.2.4.4 Assembly Instrumentation

Each of the experimental assemblies will be instrumented to provide a magnetic tape recording of the frequency, direction, and intensity of acceleration inputs incurred during each experimental run. The orthogonal placement of the accelerometers will also provide the capability to generate a complete force vector profile. The data will be utilized to provide information on (1) the number of impacts the assembly received, (2) the direction of force application with respect to traversal direction, and (3) a measure of work efficiency when compared with the physiological and time data.

3.2.4.5 Time Measures

Data will be collected for total task time and for work segments or part task times. Total task times will be compared across subjects and across experimental conditions. These two situations will provide gross measures of the speed and efficiency with which the subjects can transport themselves and an object in zero-gravity. Part task times will be collected for each important segment of the traversal course. These times will be compared across subjects and conditions to provide task performance times. Additionally, the part task times will be compared to the physiological data to provide differential measures of efficiency for the various part tasks.

3.2.5 EXPERIMENT EQUIPMENT

The experimental equipment will consist of 16 neutrally buoyant simulated equipment modules and a traversal course, along which the modules will be transported. The following paragraphs contain a brief description of each of these items.

3.2.5.1 Neutrally Buoyant Simulated Equipment Modules

All modules will have a D-type handle configuration as shown in Figure 3.2-2 with the handle located so that the translating force can be applied along the axis parallel to the longest dimension of the module. The center of gravity of each module will be located approximately at the physical center of the object. In order to minimize the moments that may be introduced on the simulated modules due to hydrodynamic effects, the core of the modules will be spherical in shape. Similarly, the drag effects of the water will be minimized by reducing both the size of the spherical core and the cross section area of the box or cylindrical frame as much as possible. A more detailed description of the techniques of neutral buoyancy and hydordynamic effects is contained in Section 4.

3.2.5.2 Traversal Course

Figure 3.2-3 shows a typical course through which the modules will be transported. It will contain the following components:

a. A mobility aid consisting of rigid tubular rail two inches in diameter. In order to simulate the proximity of the mobility aid to the external skin of a space vehicle, the rail will be located approximately four inches away from a surface. This may be the floor of the underwater facility or a partition wall erected so that it will be perpendicular to the floor.

b. A plexiglass tunnel as shown in Figure 3.2-4. This will require that the test subject gain access through a 52-inch diameter aperture, make a 90-degree turn and then travel approximately 130 inches within the 65-inch diameter interior. The exit port of the tunnel will be 58 inches in diameter and have provisions for varying this aperture diameter in the event that preliminary results indicate that this is necessary.

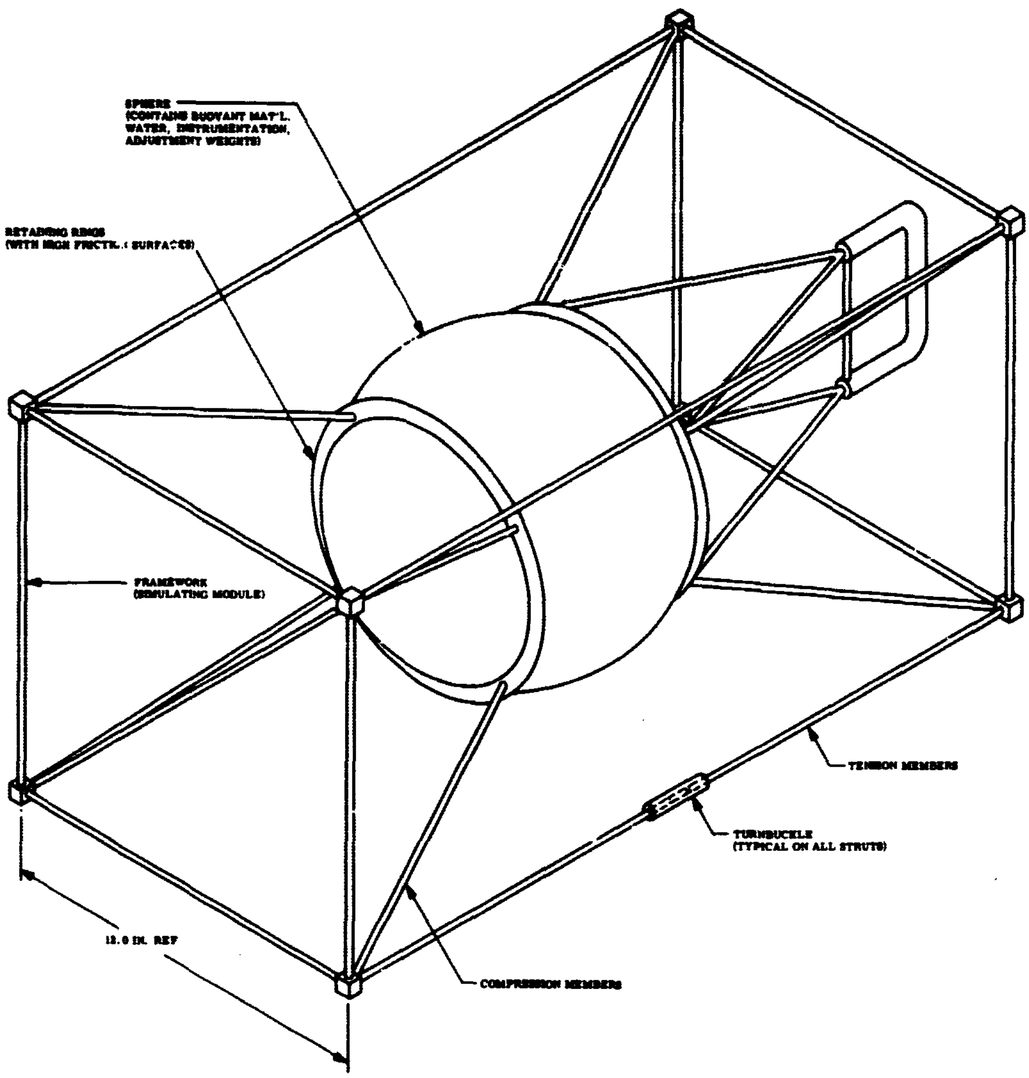


Figure 3.2-2. Simulated Equipment Module

c. An access aperture (or hatch) as shown in Figure 3.2-5. The aperture will have a cylindrical opening 12 inches deep and 52 inches in diameter. An insert shall be provided to change the opening diameter to 36 inches as required by the experiment.

3.2.6 EXPERIMENT SUPPORT EQUIPMENT

The support equipment requirements for this experiment are listed in Table 3.2-2. The acceleration recording system is called out separately and discussed below.

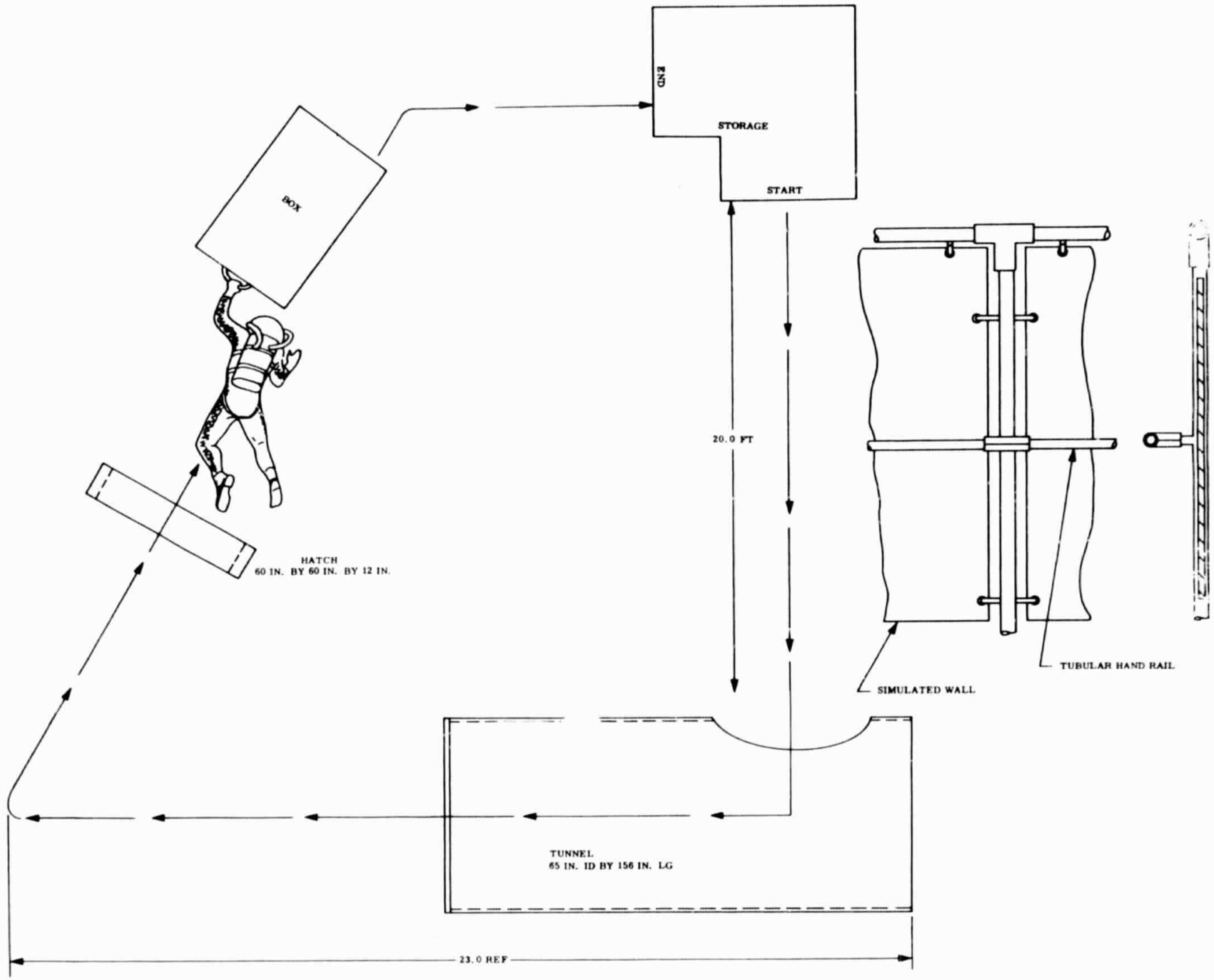


Figure 3.2-3. Traversal Course - Experiment No. 1

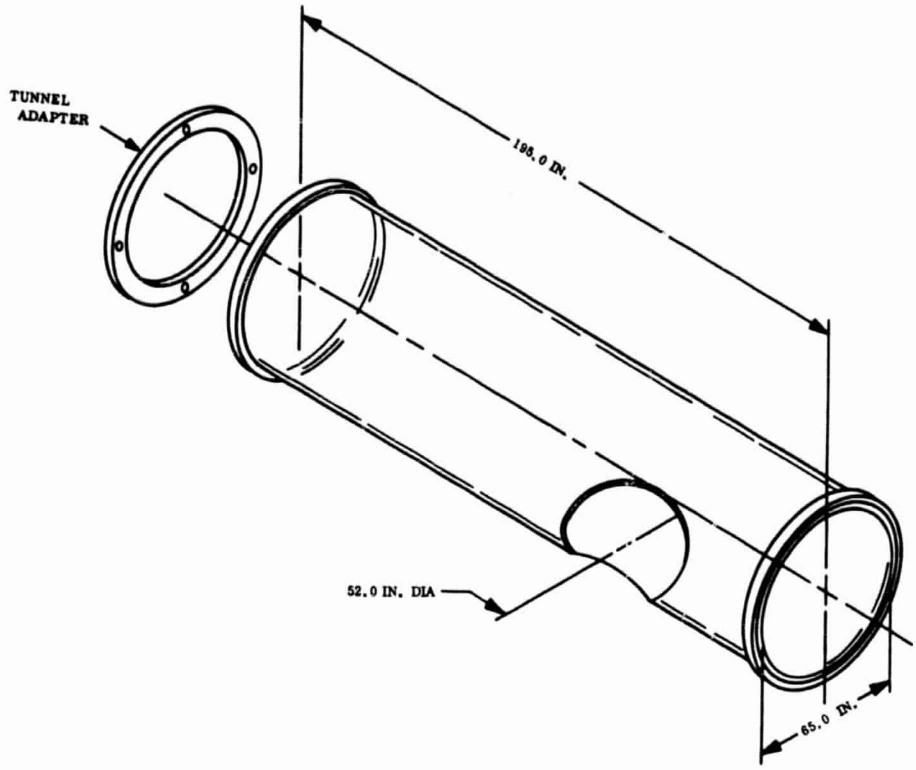


Figure 3.2-4. Simulated Tunnel

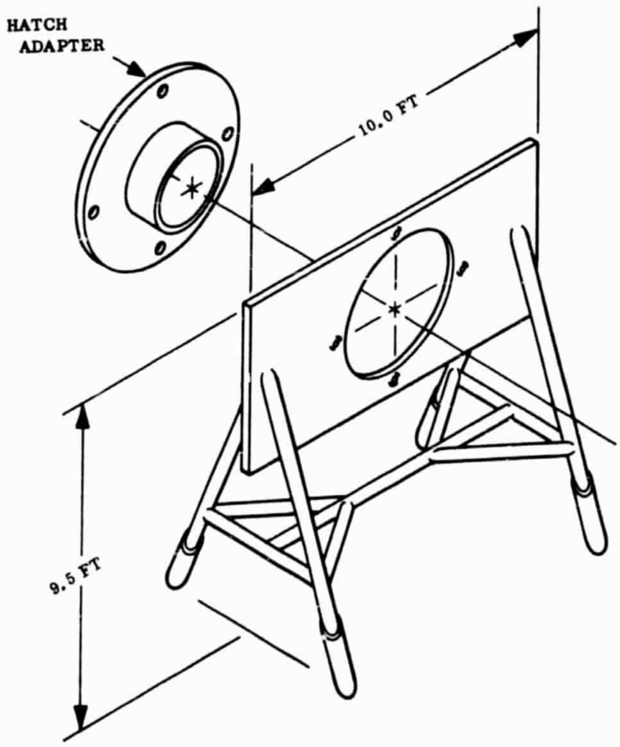


Figure 3.2-5. Simulated Hatch

Table 3.2-2. Support Equipment Requirements - Experiment No. 1

ITEM	QUANTITY REQUIRED
Underwater Movie Camera	1
Closed Circuit TV System	3
Video Tape Recorder	1
Underwater Lighting	As Reqd.
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Acceleration Recording System	3 Sets
Timing System	1

3.2.6.1 Acceleration Recording System

The instrumentation system, mounted within each experimental assembly, will measure the magnitude and direction of the accelerations imposed on the module during impact with the access tunnel, hatch, or mobility aid. Accelerometers capable of measuring peak loads in the range of 0 to 5g* will be required in the three orthogonal directions. In addition to these sensors, a battery power supply, signal conditioners, and tape recorder will be provided within the self-contained package in the module. The critical dimensions for this package will be approximately 9 x 5 x 4 inches, including a hermetically sealed housing.

3.2.7 SCHEDULE

3.2.7.1 Experiment Operations Schedule

The method of scheduling used at this level of preliminary planning has been chosen so as to counterbalance the effects of practice and transfer of training. Based on these preliminary considerations, Experiment No. 1, which requires 192 trials for each subject, will take 22 days to complete.

*Actual acceleration range will depend on final module structural configuration.

The basic experimental task requires that the subject remove a test module from a receptacle, traverse the course, and return the object to the receptacle rack.

It is estimated that the total time required for performance of this task is four minutes. At the end of the task, the support technician will remove the module and change the mass. An estimate of the time required to change the mass is two minutes. The subject will repeat the task with the same sized object twice, each time with a different mass. A typical complete experimental series is as follows:

a.	Perform task with Mass A	4 minutes
b.	Change mass	2 minutes (subject rest)
c.	Perform task with Mass B	4 minutes
d.	Change mass	2 minutes (subject rest)
e.	Perform task with Mass C	4 minutes
	Total series time	16 minutes

A 6-minute rest period will follow during which the support crew prepares a different sized module for the next series. The second and third series are conducted in a manner similar to the first; thus, a typical daily sequence takes approximately one hour.

The preliminary schedule developed for Experiment No. 1 provides additional time (0.5 hour per subject) to allow for:

a. Contingencies in the event that additional time is required for subject rest or the repeat of an individual run or a complete series

b. Preparation of the experiment set-up for the next subject

c. Preparation of the next subject for the experiment, including backpack refurbishing

d. Support crew change-over and/or rest.

3.2.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.2-6. In order to reduce the end-to-end time, the greatest amount of overlap possible has been incorporated into the 20 weeks required.

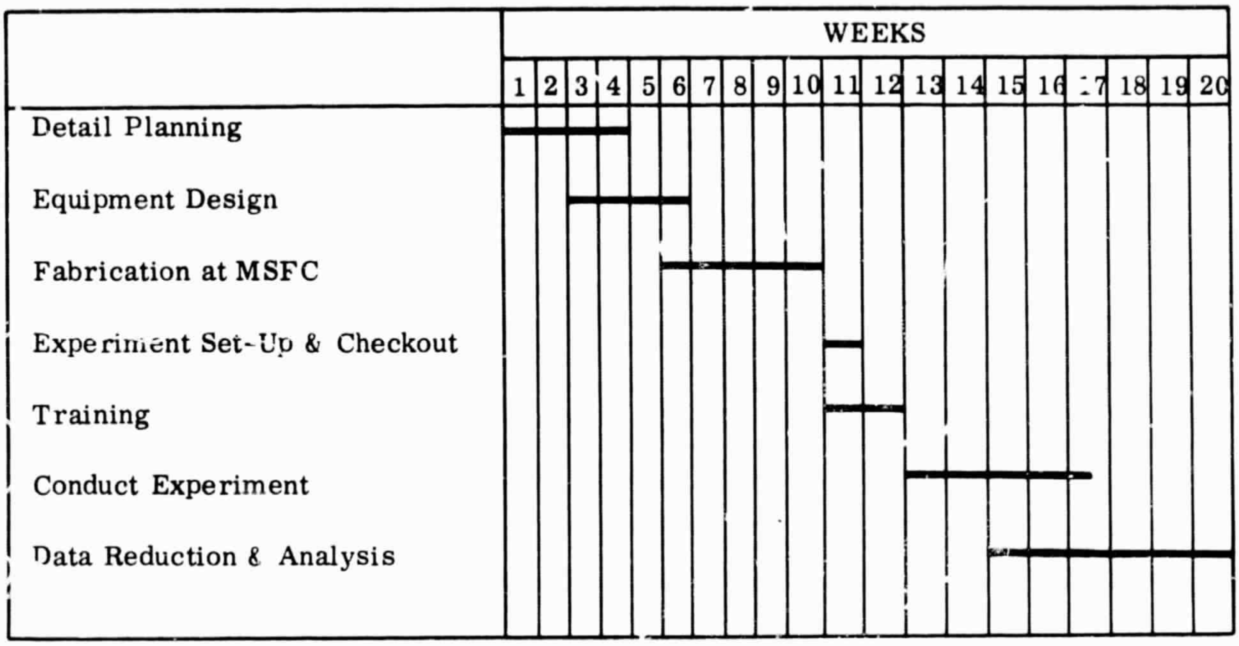


Figure 3.2-6. Total Schedule - Experiment No. 1

3.3 EXPERIMENT NO. 2 - MANIPULATION, TRANSPORT AND MANEUVERING OF FREE MASSES IN ZERO-G AS A FUNCTION OF MOBILITY AID

3.3.1 OBJECTIVES

This experiment was designed to explore man's capability to traverse significant distances in zero-gravity while carrying a relatively large object. Whereas the emphasis in Experiment No. 1 was placed on characteristics of the object being moved and potential path restrictions, this experiment is concerned with the type of mobility aid employed. Several representative mobility aids which might be utilized for traversing intra- and extravehicularly will be evaluated. The objectives of this experiment are to:

a. Measure and evaluate the effects of mobility aid type on the maneuvering, transporting, and manipulating on objects in zero-gravity.

b. Measure and evaluate the effects of object mass on the use of different mobility aids

c. Measure the number and intensity of forces which the objects will receive when transported over a course with different mobility aids

d. Measure the energy output required to transport free masses using different mobility aids

The aim of this experiment is to assess the differential effects on performance with various types of mobility aid. There are, of course, any number of potential designs for tethers which might aid an astronaut in traversing significant distances in zero-gravity, and it would be impossible to attempt an investigation of all of these. The intent of this research is to obtain sufficient empirical data to enable spacecraft designers to appraise various types of mobility aids for their usefulness under different conditions. By varying the mass of the object to be transported and requiring the traversal of semicircular as well as straight paths, the designer is shown the consequences of different specific-use applications for the types of mobility aids investigated.

Consistent with the approach taken throughout this study, the selection of variables, experimental design, and data collection has been directed towards providing information which can be used to set the limits for specific application and verification experiments which may be required to meet a specific operational need. This experiment is, therefore, primarily of the survey type which serves to focus future research on those areas which require detailed investigation. Each class or type of mobility aid selected is designed for both rigid and flexible applications, with data measures and behavioral analyses aimed at identifying the specific problems associated with using each type.

3.3.2 EXPERIMENT DESCRIPTION

The experiment consists of timed traverses of a fixed three-dimensional course with simulated cargo while utilizing various mobility aids. Zero-gravity will be simulated by the use of neutrally buoyant modules and a neutrally buoyant test subject in a pressurized space suit. A single, variable mass module will be used with several one-hand mobility aids to assist the subject and provide the sole method of locomotion.

The experimental course will be arranged in such a way to include a straight traversal, a 90-degree right turn, and two semicircular traversals. This arrangement has been devised in order to sample the major psychomotor behaviors required by an astronaut faced with the task of transporting himself and an object from one point to another in space. Six types of mobility aids will be installed in the course, so that the distance traveled and directional changes required will be replicated. The assembly to be transported over the test course will be a two-foot cube with a single D-handle mounted vertically on the center of the front panel of the assembly. The assembly will contain one of four different masses that can be mounted so that the center of gravity remains constant at the physical midpoint.

Each experimental run will originate with the subject grasping the D-handle on the experimental assembly and removing it from a receptacle rack. The subject will then grasp one of the six mobility aids and begin a straight translation along a fixed distance, as shown in Figure 3.3-1. At the end of the straight path, the subject will make a right angle turn and continue transporting the assembly around a curved path. The final turn will then be accomplished, and the subject will complete the run by repositioning the assembly into the receptacle. Each subject will traverse the course using each of the six mobility aids and each of the four specified masses. Replication will be obtained by having each of the four subjects repeat each run a total of four times, as shown in Section 3.3.7. Baseline data will be obtained by having the subject traverse the course with each of the six mobility aids but without transporting an experimental assembly.

3.3.3 TEST VARIABLES

The variables selected for this experiment include representative types of mobility aids which may be utilized for transport of typical object masses in the zero-gravity environment. When examined together, the variables of mobility aid and object mass are considered to have a major effect on the performance of humans transporting equipment in the zero-gravity environment.

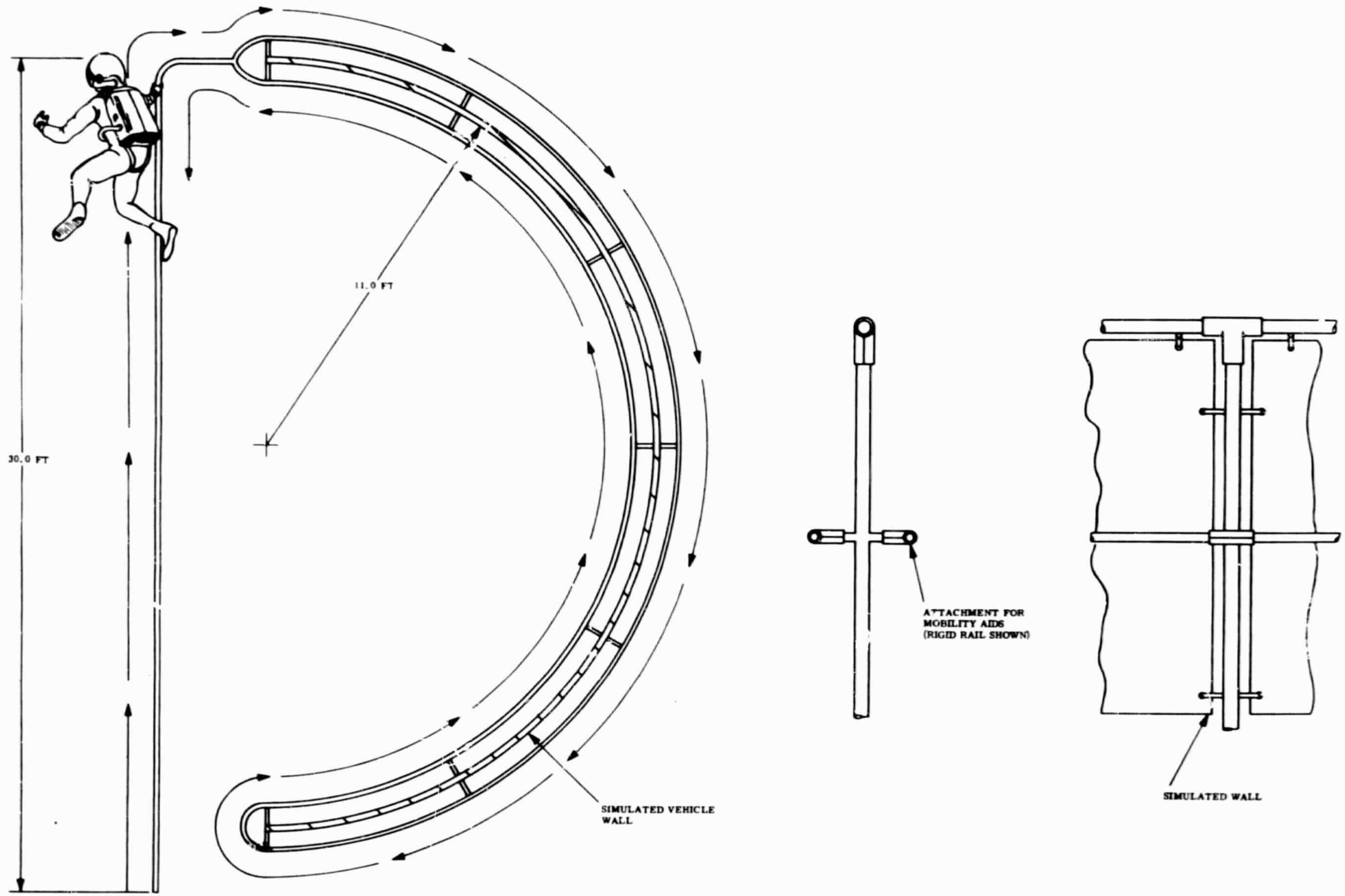


Figure 3.3-1. Traversal Course - Experiment No. 2

3.3.3.1 Mobility Aid

Several types of mobility aids have been proposed, or already developed, that could have been selected for this experiment. However, some of these were considered inappropriate for this research program. These include all of the thrust-generating or self-propulsive models that might produce hydrodynamic effects and interactions which would make their results questionable in underwater simulation. Also excluded are the ropes and umbilicals that classify as safety tethers rather than mobility aids. The aids listed below were selected as representing those types most likely to be used in space and most beneficial for investigation:

a. Rigid hand rail

b. Flexible stretched rope

c. Rigid steel mesh

d. Flexible fiber mesh

e. Rigid tubular reel-in device

f. Flexible reel-in device

3.3.3.2 Object Mass

The load or mass of the object being transported was selected as the second variable because of its assumed influence on locomotion performance in zero-gravity. In order to determine a performance baseline, one zero-load point will be obtained by having the subject negotiate the course using the various mobility aids but without carrying an object. This will provide information pertinent to the utility of the different mobility aids independent of load. The object volume, 8 cubic ft (2 by 2 by 2 ft), and configuration (cube) will be held constant. The loads selected are:

a. Zero - (no box, no mass)

b. Mass 1 - one slug

c. Mass 2 - two slugs

d. Mass 3 - four slugs

e. Mass 4 - six slugs

3.3.4 TEST MEASURES AND ANALYSIS OF RESULTS

3.3.4.1 Physiological Data and Expected Results

The physiological data will be gathered by means of biomedical sensors attached to the subject's body or contained as an integral part of the backpack. The data collected will include (1) heart rate, (2) respiration rate, (3) oxygen comsumption, (4) deep-body temperature, and (5) tidal volume. These data will be recorded as dc levels on a magnetic tape recorder located in an underwater backpack worn by the test subject, thus providing ar experimental time history of the average and peak metabolic costs associated with various work activities and experimental conditions. The metabolic costs will be plotted as a function of time to denote differences between test variables, differences between subjects, fatigue effects, or a measure of efficiency of operation. In order to make these data meaningful, baseline metabolic measures will be taken on all subjects at rest before and during each day's experimental trials.

3.3.4.2 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Evolve optimal manipulative, maneuvering and translation techniques

c. Ascertain work volume envelopes for various experimental tasks and conditions

d. Identify recurrent behavior patterns

e. Isolate problem areas for future research

3.3.4.3 Subjective Evaluation Data

Subjective data will be collected subsequent to each experimental session and will come primarily from two sources: the subjects and the test director. A formal debriefing will be held with each subject after each experimental session to collect personal observation comments concerning problems, suggested procedural or equipment modifications, and comparative judgments about the experimental variables. An interview form or data questionnaire will be constructed and utilized when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.3.4.4 Assembly Instrumentation

Each of the experimental assemblies will be instrumented to provide magnetic tape recording of the frequency, and direction and intensity of acceleration inputs incurred during each experimental run. The orthogonal placement of accelerometers will also provide the capability to generate a complete force vector profile. The accelerometer data will provide a time history of the force applications throughout the traversal of the experimental course. These data will provide information on the direction of force application with respect to various segments of the experimental course and a measure of efficiency relative to mobility aid type when compared to the physiological and time data.

3.3.4.5 Time Measures

Data will be collected for total task time and for part task times. Total task times will be compared across subjects and across experimental conditions as a gross measure of the efficiency of the various mobility aids. Part task times will be collected for each segment of the course and compared across subjects and conditions to note any differences and to provide task performance times. Time measures will also be compared to the physiological data to provide differential measures of efficiency for the task segments.

3.3.5 EXPERIMENT EQUIPMENT

The equipment for this experiment will consist of one variable-mass neutrally buoyant module and a course utilizing various mobility aids. The following paragraphs contain a brief description of each of these items.

3.3.5.1 Test Course

This experiment will require the installation of six different types of mobility aids along a traversal course. Figure 3.3-1 shows a suggested configuration for this course and is based on the following criteria:

a. The course should include a straight traversal length simulating the path of the astronaut along the long axis of a vehicle or through free space

b. The traversal of the astronaut circumferentially along the inside and outside wall of a vehicle will be simulated.

c. A 4-inch distance from the mobility aid to the simulated wall will be maintained constantly throughout the course.

Optimum layout of the total course will be provided during the detailed design phase. As it is time consuming to change mobility aids constantly, a desirable arrangement would have all mobility aids permanently located on a noninterference basis. The star arrangement of Figure 3.3-2 shows greatest promise for maximum coverage with the least relocation of test instrumentation and cameras. The three spokes of the star would each have two of the specified mobility aids displaced approximately seven feet in a vertical plane.

3.3.5.2 Mobility Aids

Six mobility aids were selected for evaluation in this experiment. They are listed and described below.

3.3.5.2.1 Continuous Rigid Handrail

This will consist of a segmented tube, 1-1/2 inches in diameter, supported from the simulated wall by attachments located six feet apart (minimum span). The nominal distance between the center of the handrail and the wall will be four inches.

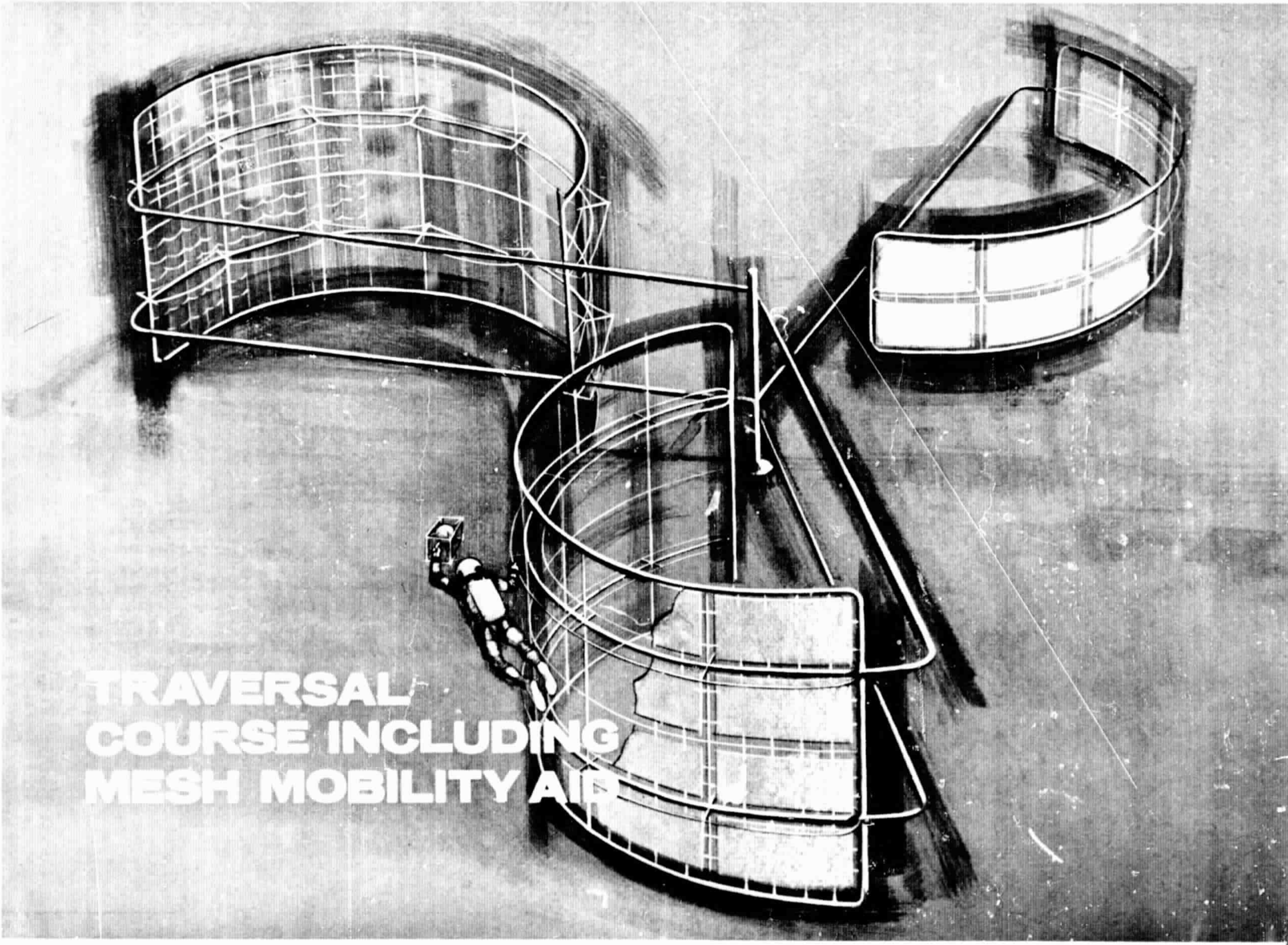


Figure 3.3-2. Multiple Mobility Aid Traversal Course

3.3.5.2.2 Flexible Handrail

A nylon braided cable 3/4 inch in diameter will be provided as a flexible mobility aid. This cable shall be supported by the same attachments used for the rigid handrail described in Section 3.3.5.2.1, although additional attachments may be required for the curved sections of the course. Tension between support points should be just sufficient to prevent contact of the test subject's hand with the wall during application of small forces on the cable, e.g., 1-3 lb radially.

3.3.5.2.3 Reel-In Device

The Apollo stem device, or equivalent, will be utilized for translation along the straight portion of the test course.

3.3.5.2.4 Flexible Reel-In Device

This mobility aid will be similar to the stem device in Section 3.3.5.2.3, with the exception that the tension member will be a flexible cable.

3.3.5.2.5 Flexible Mesh

A strip of netting 15 inches wide and containing 5 by 5 inches square segments will be supported from the same attachments used in the mobility aids described in Section 3.3.5.2.1 and Section 3.3.5.2.2. The plane of the mesh will be oriented parallel to the simulated wall as illustrated in Figure 3.3-2.

3.3.5.2.6 Rigid Mesh

This mobility aid will be identical to that in Section 3.3.5.2.5, except that the 5 by 5 in. mesh will be constructed of rigid steel wire or thin tubular members.

3.3.5.3 Neutrally Buoyant Simulated Modules

The simulated modules to be used in this experiment will have apparent masses of 1, 2, 4, and 6 slugs and rectangular dimensions of 24 x 24 x 24 inches. Acceleration instrumentation in three orthogonal axes will be provided, as described in the Experiment Support Equipment Section for Experiment No. 1 (Section 3.2.6).

3.3.6 EXPERIMENT SUPPORT EQUIPMENT

Support equipment requirements are listed in Table 3.3-1.

Table 3.3-1. Support Equipment Requirements - Experiment No. 2

ITEM	QUANTITY REQUIRED
Underwater Movie	1
Closed Circuit T/V System	2
Video Tape Recorder	1
Underwater Lighting	As Required
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 sets
Acceleration Recording System	1 set
Timing System	1

3.3.7 SCHEDULE

3.3.7.1 Experiment Operations Schedule

As in Experiment No. 1, the method of scheduling used at this level of preliminary planning has been chosen primarily to counterbalance the effects of practice and transfer of training. Based on these preliminary considerations Experiment No. 2, which requires 120 trials for each subject, will take 22 days to complete.

The experiment requires that the subject initially traverse the course without carrying an assembly. After returning to the starting point the subject removes the first test object from the rack, traverses the course while carrying the object, and finally returns the object to the rack. At this point the support crew will remove the object and change the mass, while the subject is resting. The subject then repeats the task with the new mass. This procedure is repeated with the third and fourth masses. Course traversal time is estimated four minutes while the time to change the mass is estimated at two minutes. A typical experiment series is as follows:

a.	Perform task (no object)	4 minutes
b.	Change mass (subject rest)	2 minutes
c.	Perform task (Mass 1)	4 minutes
d.	Change mass (subject rest)	2 minutes
e.	Perform task (Mass 2)	4 minutes
f.	Change mass (subject rest)	2 minutes
g.	Perform task (Mass 3)	4 minutes
h.	Change mass (subject rest)	2 minutes
i.	Perform task (Mass 4)	4 minutes
	Total Series Time	28 minutes

A rest period will follow during which the support crew prepares a different restraint system for the next series. The second through sixth series are conducted in a similar manner to the first. As in Experiment No. 1, the preliminary schedule developed for Experiment No. 2 provides additional time to allow for contingencies, preparation of the experiment setup for the next subject, preparation of the next subject for experiment, and support crew change-over and/or rest.

3.3.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.3-3. In order to reduce the end-to-end time, the greatest amount of overlap possible has been incorporated into the 15 weeks required.

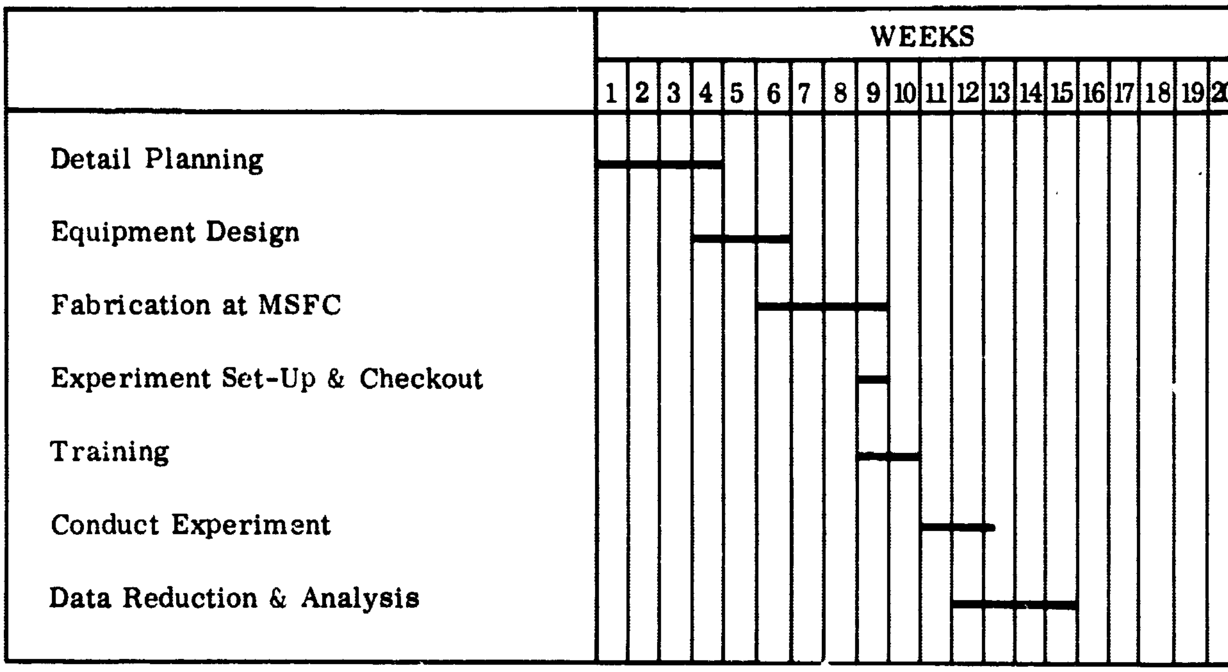


Figure 3.3-3. Total Schedule - Experiment No. 2

3.4 EXPERIMENT NO. 3 - MODULE REPLACEMENT IN ZERO-G AS A FUNCTION OF MODULE AND RECEPTACLE SIZE

3.4.1 OBJECTIVES

Modular replacement in advanced manned spacecraft will be a primary technique employed for corrective maintenance and, as such, deserves considerable investigation in simulation studies. Although an astronaut under perfect restraint conditions may be expected to duplicate the behavior he exhibits in one-g, it is unlikely that such a restraint system will be utilized. The investigation of modular replacement in zero-gravity therefore requires identification of the restraint systems likely to be employed and a study of those design features likely to significantly affect performance. This experiment focuses on module size and module/receptacle clearance as design factors affecting initial orientation and insertion of a module. The objectives of this experiment are to:

a. Measure the effects of module size on modular replacement in zero-gravity

b. Measure the effects of module/receptacle clearance on modular replacement in zero-gravity

c. Measure the effect of restraint condition on modular replacement in zero-gravity

d. Measure the energy output required to replace modules when different restraint systems are employed.

3.4.2 EXPERIMENT DESCRIPTION

This experiment has been planned to provide spacecraft designers with performance data related to a number of critical module design parameters. For example, module sizes have been chosen for their potentially broad applicability to many different systems and the clearances between the module and module receptacle have been selected so that the designer may set tolerance specifications on the basis of desired performance levels. The combinations of these variables will be utilized with each of three different restraint conditions so that specific solutions to potential problems may be sought on a realistic basis when considering the location at which the module is to be replaced and the restraint conditions likely to be available. The observed performance is limited to initial orientation and placement since it is assumed that insertion of the located module will be a simple function of the slide or keying mechanism employed. The forces for insertion may be quite high in some cases and, therefore, might present some difficulties in adequately performing the task. However, this is considered to be a general question of push-force generation for which data from Experiment 8 can be utilized.

The experiment requires the insertion of a neutrally buoyant simulated equipment module into a receptacle. In addition to the module/receptacle contact the sole source of orientation available to the test subject and the energy sink for force generation will be one of three specified restraint systems. For each restraint utilized, experimental runs will be made with each of 12 modules of different sizes and shapes and each of 4 different receptacle clearances. This results in 144 experimental conditions to be replicated 4 times by each subject.

Positioning and alignment forces will be applied to each module through a simple D-handle mounted vertically on the center of the front panel of each assembly. Directional forces can be easily applied by the subject because of the symmetrical design of each assembly and the location of the center of gravity at its physical midpoint. The apparent mass of the three modules does not constitute an experimental variable since the range and velocity of required movements in quite small.

Prior to the start of each experimental run the subject will be placed in a specific starting location and position. (See Section 3.4.5 for a description of the mounting frame and restraints.) Two of the three restraints will allow only one free hand for manipulation, while the third will permit two-hand freedom for manipulating the module assembly. The task will begin when the subject grasps the D-handle of a module which is installed in a fixed location storage container. The assembly will then be removed from the container and manipulated to a position in front of the experimental receptacle. After a series of gross and fine alignment maneuvers the assembly will be inserted into the experimental receptacle chamber. Each run will be terminated with the tripping of a microswitch in the receptacle.

3.4.3 TEST VARIABLES

The ability of a subject to exert fine alignment and control forces while wearing a pressurized spacesuit in a zero-gravity environment is influenced by several variables. Three of the variables considered to exert a major influence on fine manipulative behavior are the type of restraint, the module size and shape, and the receptacle clearance.

3.4.3.1 Subject Restraint

Three types of restraint were selected for use in this experiment, on the basis of their assumed representativeness and the range of behavior they sample. The restraints presented below contain one, two, and three attachment points and allow one-hand and two-hand availability for operations:

a. Handhold only (nonpreferred hand)

b. Handhold (nonpreferred hand) and rigid waist tether

c. Three point pedestal (toe, knee, waist)

3.4.3.2 Module Size and Shape

Twelve modules, with varying size and shape, were selected for this experiment. The shape chosen is basically a parallelepiped having a frontal geometry which is either a square or rectangle. (See Table 3.4-1.) In actuality, only eight modules are required, the other combinations are obtained by relocation of the handle.

Table 3.4-1. Dimensions of Experimental Modules - Experiment No. 3

ASSEMBLY NO.	WIDTH (INCHES)	HEIGHT (INCHES)	LENGTH (INCHES)
1	6	12	6
2	6	12	12
3	6	12	18
4	12	12	6
5	12	12	12
6	12	12	18
7	12	18	6
8	12	18	12
9	12	18	18
10	18	18	6
11	18	18	12
12	18	18	18

3.4.3.3 Receptacle Clearances

Four receptacle clearances were selected for investigation in this experiment. They sample the practical range of clearances to be expected for module removal and replacement. The clearances are:

a. 0.050 inch

b. 0.100 inch

c. 0.150 inch

d. 0.250 inch

3.4.4 TEST MEASURES AND ANALYSIS OF RESULTS

The basic data to be collected will be objective film/video data and subjective questionnaire evaluative data. In addition, precision modular placement data and task-time measures will be collected and analyzed.

3.4.4.1 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental study. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Evolve optimal manipulative techniques

c. Ascertain work volume envelopes for various experimental tasks and conditions

d. Identify recurrent behavior patterns

e. Isolate problem areas for future research

3.4.4.2 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test directors. A formal debriefing will be held with each subject after each experimental session to collect personal observations and comments concerning problems, suggested procedural or equipment modifications, and comparative judgments about the experimental variables. An interview form or data questionnaire will be made and used when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.4.4.3 Precision Modular Placement Data

The measure to be used to evaluate precision placement is the number of contacts between the simulated module assembly and the receptacle walls. The number of contacts will automatically be recorded and will be compared across subjects with respect to type of restraint, receptacle clearance, and module size. In addition, the magnitude and time history of the impact forces will be collected and analyzed to provide a summary of the g forces imposed on the modules by subjects under various conditions of restraint.

3.4.4.4 Time Measures

Total task time will be recorded for each experimental run. The times will be analyzed to determine the relationship between speed, clearances, number of contacts and magnitude of contacts. Time variations between subjects and between restraint systems will be evaluated and will be presented in relation to the appropriate experimental variables.

3.4.5 EXPERIMENT EQUIPMENT

An important consideration in the design of equipment for Experiment No. 3 concerns the efficiency of changing the clearance receptacles to accept the various module sizes listed in Section 3.4.3.2. The preferred sequence and timing of the various module-insertion sequences in this experiment dictate that the receptacle assembly be replaced on the panel without disturbing the position, restraint, or rest period of the test subject. One approach to meeting this requirement, while keeping the number of pieces in the assembly to a minimum, is shown in Figure 3.4-1. The mounting frame on which the panel is located is a simple box framework with a table surface on which the assisting technician will be able to perform the task of attaching adapters with various clearances. The adapter plate, shown in Figure 3.4-2 in the installed position, serves to accept the clearance adapter for each basic module cross-section (i.e.; 6 x 12 in., 12 x 12 in., 12 x 18 in., and 18 in. x 18 in.). It will also provide a guide and retainer for the test module as it is inserted in the receptacle, and permits the location of the receptacle assembly at various vertical locations. This is a requirement for Experiment No. 5 which used essentially the same equipment as this experiment.

In order to detect impacts of the simulated module with the clearance adapter, impact accelerometers will be mounted on the studs holding the adapter. These accelerometers should be sensitive to low level vibrations in order to detect minor contacts of the module as it is being inserted in the receptacle. Calibration tests will be performed on the entire assembly underwater to establish the proper placement of the accelerometers for maximum sensitivity.

The restraint systems to be used include a single handhold, a handhold plus a two-point rigid waist tether, and a pedestal having restraint points at the feet, knees, and waist. These restraints are shown in Figures 3.4-3 and 3.4-4.

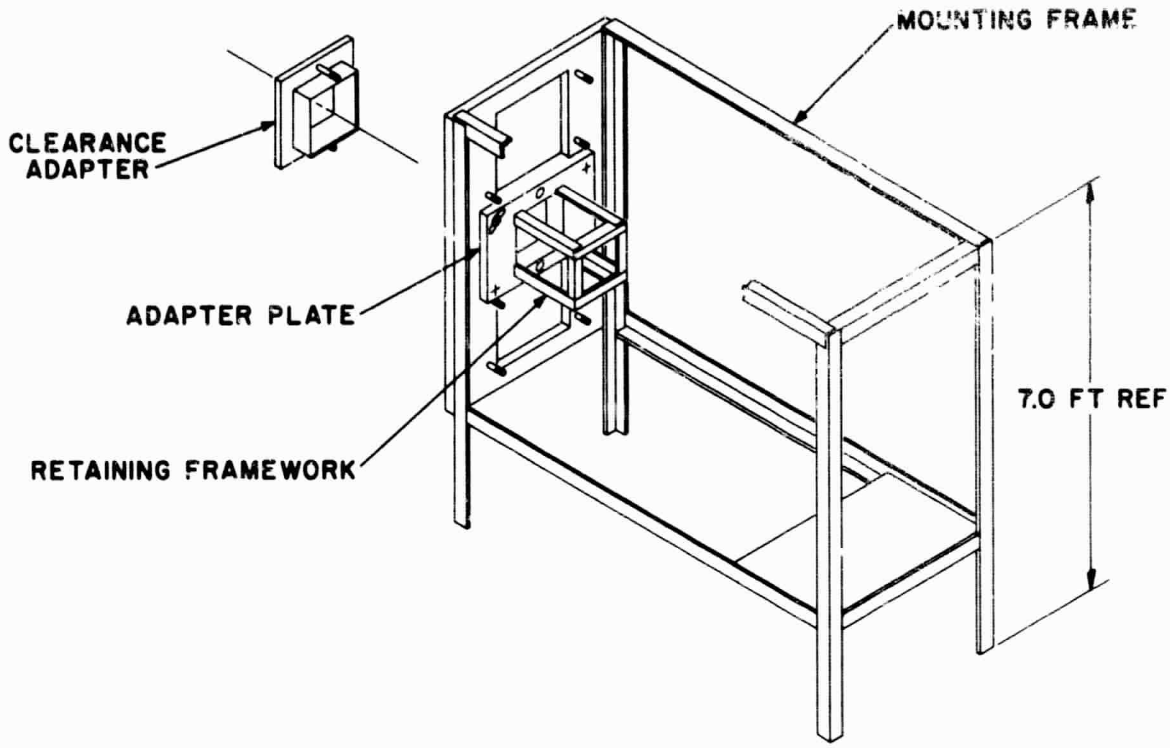


Figure 3.4-1. Experiment Equipment Mounting Frame

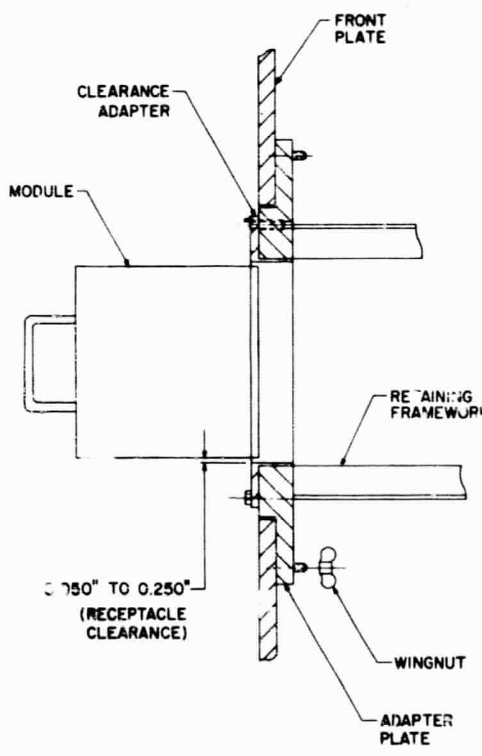


Figure 3.4-2. Module Adapter Plate - Experiment No. 3

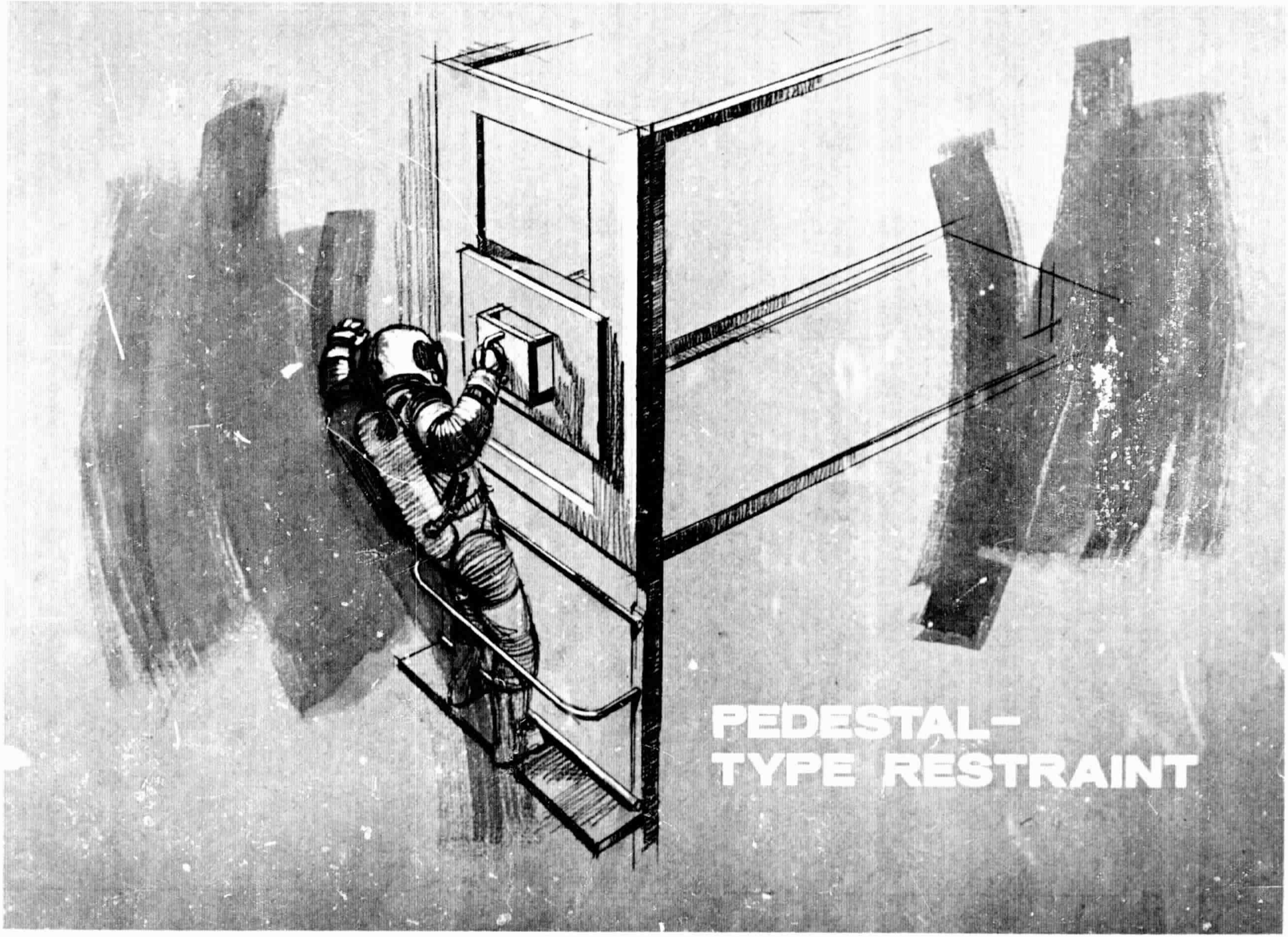


Figure 3.4-3. Insertion of Module Using Pedestal Restraint

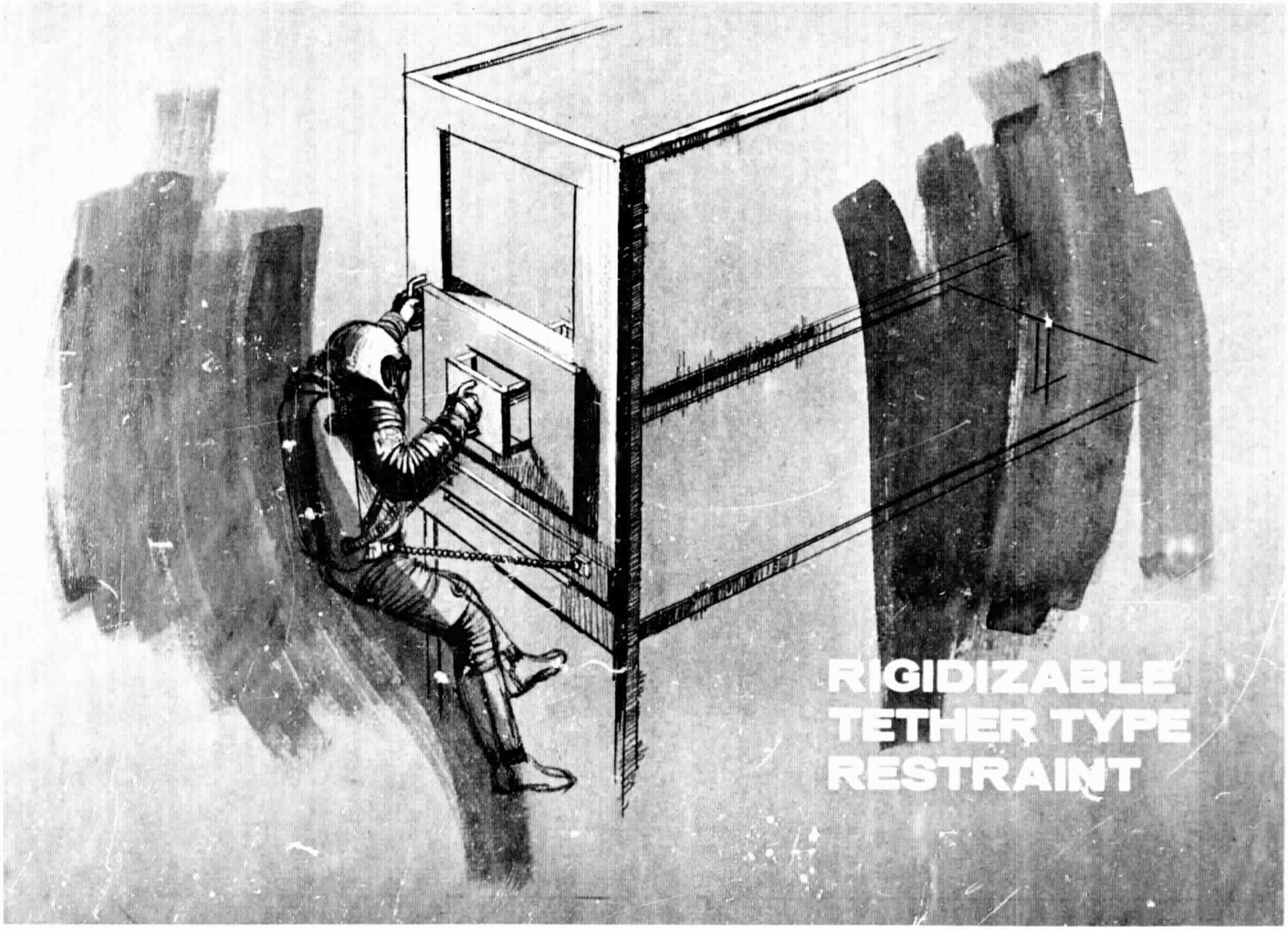


Figure 3.4-4. Insertion of Module Using Rigidized Tether Restraint and Handhold

3.4.6 EXPERIMENT SUPPORT EQUIPMENT

Table 3.4-2 lists the experiment support equipment required for Experiment No. 3. TV coverage for this experiment will be obtained by using two cameras, two monitors and a wideband video tape recorder. One of the TV cameras will be used for overall coverage of the test subject while the other camera will be used for close-up coverage of the area closely adjacent to the module receptacle.

Table 3.4-2. Experiment Support Equipment - Experiment No. 3

ITEM	QUANTITY REQUIRED
Closed Circuit TV System	2
Video Tape Recorder	1
Underwater Lighting	As Required
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Impact Accelerometers on Adapter Plate	2

3.4.6.1 Accelerometers

Two impact accelerometers will be mounted on the adaptor plate to sense the impact of the box while it is being inserted in the receptacle. The frequency response of these accelerometers will be 500 cps minimum, and the sensitivity threshold should be approximately 0.5 g peak. Development tests will be conducted to determine the optimum location of these accelerometers and the exact sensitivity requirements.

3.4.7 SCHEDULE

3.4.7.1 Experiment Operations Schedule

The basic experimental task requires that the subject remove a test module from the storage receptacle and insert it into the test receptacle. It is estimated that the time required for performance of this task is one minute. At the end of the task the support personnel will remove the test module and provide a new test module to the subject. At this time they may also change the subject restraint and clearance adaptor, as required by the experimental protocol. An estimate of the time required to make these changes is three minutes. The subject then repeats the task until he has performed 12 times (45 minutes). Similar experimental runs will then be performed by subjects 2, 3, and 4. During a second daily session the four subjects will repeat this series of trials resulting in the performance of 24 tasks each day per subject.

The total experiment requires 576 trials per subject and will necessitate a total of 24 days for experimental operations. The schedule for the 24 days will employ counterbalancing to eliminate order of presentation effects and to minimize the effects of practice and transfer of training.

3.4.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.4-5. In order to reduce the end-to-end time, the greatest amount of overlap possible has been built into the 19 weeks required.

3.5 EXPERIMENT NO. 4 - TORQUE GENERATION IN ZERO-G AS A FUNCTION OF ACCESSIBILITY

3.5.1 OBJECTIVES

One of the major demands to be made on man in future space systems will be the requirement to exert torque-type forces. The need to remove and stow, assemble and disassemble, and install various structural components will necessitate the application of forces by the space-suited astronaut in many conditions where optimum accessibility is not always present. In this experiment, static generation of impulsive and sustained forces will be

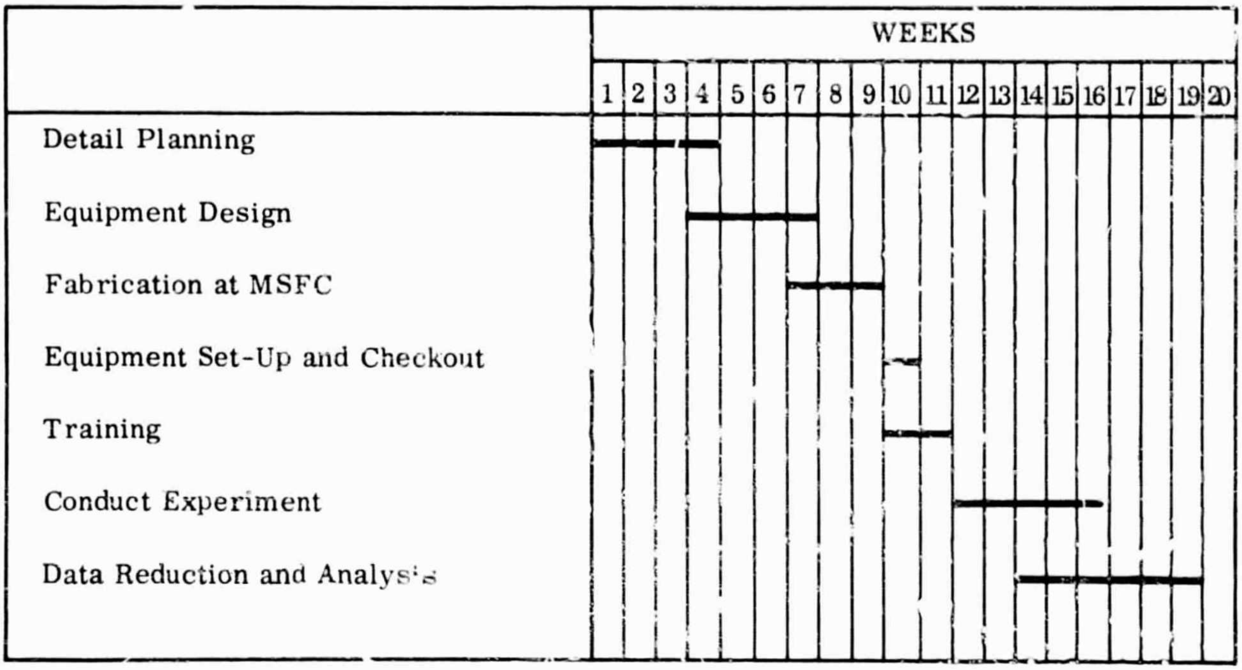


Figure 3.4-5. Total Schedule - Experiment No. 3

studied under conditions which simulate differential accessibility. The objectives of this experiment are to:

a. Measure and evaluate the effects of force receiver locus on impulse and sustained force producing capability in zero-g

b. Measure and evaluate the effects of force receiver orientation on force producing capability in zero-g

c. Measure the energy output required to apply impulse and sustained forces

This experiment has been designed to develop a range of data regarding the capability of of an astronaut to generate forces over a range of locations throughout the suit-constrained reach envelope. The orientation of the force receiver, which is an easily gripped handle, has also been varied, so that a more complete picture of the effects of accessibility on force generation may be gained. Specific tool use has been avoided here, so that the data may be broadly applied.

The data to be obtained is of special importance to spacecraft designers since it will provide the answers to two essential questions:

a. Given a torque generation requirement, what are the accessibility criteria which must be imposed on the workspace envelope?

b. Given a specific workspace envelope, what are the torque generation capabilities of a space-suited astronaut?

3.5.2 EXPERIMENT DESCRIPTION

This experiment is concerned with the influence of zero-gravity force emitting capabilities of subjects as a function of accessibility. Since the astronaut will be provided with a restraint system which limits his movements, force measurements as a function of force receiver locus can accurately be obtained. Variations in accessibility will be simulated by changing the locus of the force receiver (handle) and the orientation of the receiver relative to an assumed local horizontal. The subjects will perform all tasks in a simulated zero-gravity environment while wearing a spacesuit pressurized to 3.7 psig. The experimental apparatus will be constructed to allow multipositional placement of the force receiver with respect to a reference point located on the subject. The force receiver will be cycled through four handle orientations at each of 30 locations. Maximum impulse and sustained forces will be required in both directions perpendicular to the longitudinal axis of the handle, as shown in Figure 3.5-1.

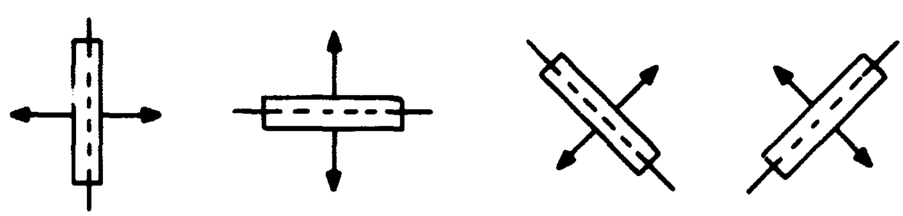


Figure 3-5.1. Force Application Directions

Each experimental run will begin with a subject wearing a two-point rigid waist restraint and holding onto a fixed position handhold with the nonpreferred hand. The force receiver will be mounted in a specified location in the subject's field-of-view, within reach of the preferred hand. At a given signal, the subject will grasp the force receiver and exert a maximum impulsive force in the specified direction. The same procedure will be repeated for a sustained force in each direction. These impulse and sustained force measurements will be made in both directions for all four handle orientations, resulting in 16 measurements for each force receiver location. The experiment will be completed when each subject has repeated the above procedure four times for each of the 30 locations.

3.5.3 TEST VARIABLES

The ability of a subject to emit forces in a zero-gravity environment is influenced by several variables. Some of the most important are listed below:

a. Type of restraint system

b. Position and location of the body relative to the force receiver

c. Type of force required -- impulse or sustained

d. Direction of required force

e. Orientation of force receiver

f. Type of space suit

g. Pressurization condition

Evaluating the effects of all possible combinations of the above variables would exceed the scope of this study; therefore, only a few were chosen for investigation. The variables selected were (1) location of force receiver, (2) orientation of force receiver, (3) direction of force required, and (4) type of force required. The remaining potential variables will be maintained as constants for this experiment.

3.5.3.1 Force Receiver Location

The locations of the force receiver will be analytically determined to obtain a representative sample within the reach envelope permitted by the Apollo State-of-the-Art suit. For example, the boundaries for a right handed subject are approximately 24 inches forward, 24 inches up, 16 inches down, 24 inches right, and 12 inches left from a reference point (or origin) defined as the right nipple on each subject's chest. Thirty points will be selected for evaluation from the area defined by the above parameters.

3.5.3.2 Handle Orientation

Studies have shown that the orientation of the force receiver handle with respect to the subject orientation affects a subject's force emission capability. Therefore, four handle orientations have been selected for investigation and are listed below:

a. 0 degree - local horizontal

b. 45 degrees - 45 degrees from local horizontal

c. 90 degrees - local vertical

d. 135 degrees - 135 degrees from local horizontal

3.5.3.3 Force Direction

The direction of force application was selected as a variable to be combined with handle orientation to provide a sampling of one hand force producing behavior. The force directions are defined as those being applied perpendicular to the longitudinal axis of the handle. (See Figure 3.5-1.) The directions of force application are dependent upon handle orientation and are listed below:

a. Up and down - on horizontal handle

b. Left and right on vertical handle

c. Diagonal down and diagonal up on 45 degree and 135 degree handles

3.5.3.4 Type of Force

Two types of force application were selected for this study and are listed below:

a. Impulse

b. Sustained

Impulse force is defined as the maximum force that can be generated during a 0.5 second application. Sustained force is defined as the minimum force maintained for 3.0 seconds.

3.5.4 TEST MEASURES AND ANALYSIS OF RESULTS

Both basic physiological data and motor performance data will be collected. In addition, force emission profiles will be collected and analyzed. The latter will be divided into both magnitude and direction profiles.

3.5.4.1 Physiological Data and Expected Results

The physiological data will be gathered by means of biomedical sensors attached to the subject's body. The data collected will include (1) heart rate, (2) respiration rate, (3) oxygen consumption, (4) deep body temperature, and (5) tidal volume. These data will be recorded as dc levels on a magnetic tape recorder located in an underwater backpack worn by the subject. This data will provide an experimental time history of the average and peak metabolic costs associated with various work activities and experimental conditions.

3.5.4.2 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experiment program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Ascertain work volume envelopes for various experimental tasks and conditions

c. Identify recurrent behavior patterns

d. Isolate problem areas for future research

3.5.4.3 Force Magnitude Profiles

Maximum impulsive and sustained forces will be required from all subjects at all experimental conditions. These forces will be recorded and analyzed with respect to the force receiver locus and orientation. Mean values and ranges will be presented. In addition, significant relationships between the force emission profiles and the physiological and motor performance data will be evaluated.

3.5.4.4 Force Direction Profiles

Each force is to be exerted in a direction perpendicular to the longitudinal axis of the force receiver handle. Means and ranges of force emission capability as a function of force receiver orientation will be presented. Any deviation from an exactly perpendicular force application will also be recorded. These deviations will be analyzed and any significant findings will be presented.

3.5.5 EXPERIMENT EQUIPMENT

The equipment requirements include a device to measure and record the forces that the test subject applies in the Z-Y plane (nominally parallel to the subject's centerline) and a restraint for the subject. Because of the commonality that exists between the requirements for this experiment and those of Experiment No. 8, where the primary interest is in the forces applied along the X-axis, the equipment concept described herein has been made applicable to both Experiments No. 4 and No. 8. Thus, it will be possible to measure the true force vector, which includes the components of force in the X, Y and Z axes. The following paragraphs briefly describe the proposed system.

3.5.5.1 Force Measuring Device

Figure 3.5-2 illustrates a typical position of the test subject relative to the test panel housing the force receiver. This relative position may be changed in the Y direction by sliding the force receiver carriage laterally, in the X direction by sliding the carriage to the front or back, and in the Z direction by raising or lowering the carriage along the vertical tracks. In order to facilitate changing of positions, each of the cylindrical sections which constitute the sliding joints on the tubular framework will be provided with roller bearings. These sliding joints will also have locking screws to fix the assembly in place, once the desired position has been reached. A simple pulley may be incorporated in order to raise or lower the assembly along the Z axis.

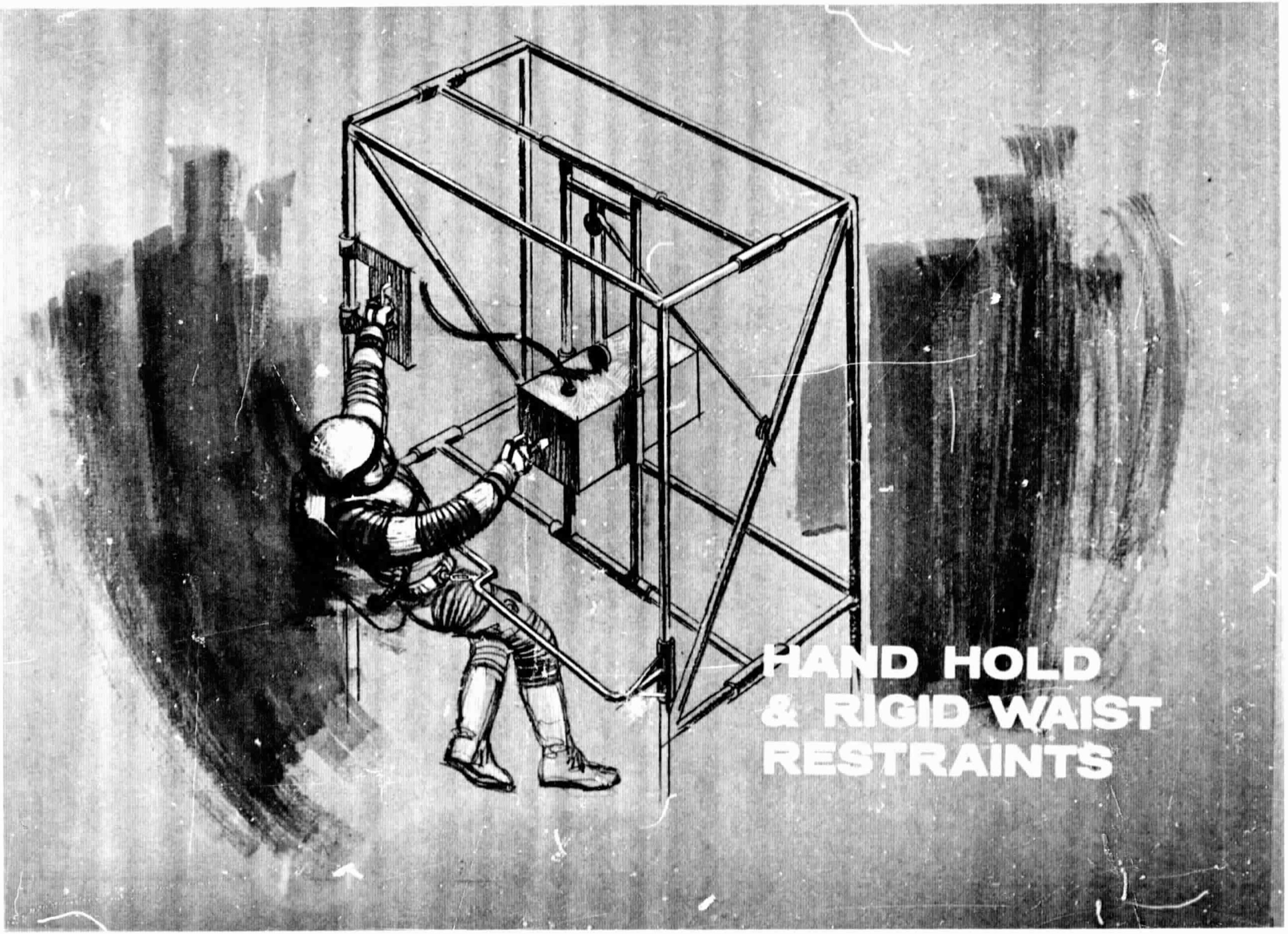


Figure 3.5-2. Typical Position of Test Subject - Experiment No. 4

The mechanism through which the force measurements will be made is shown in Figure 3.5-3. Forces along the Z-Y plane are measured as bending deflections in a tapered force shaft, whereas the forces in the X direction are measured as axial deflections in a calibrated coil spring that restrains the motion of the shaft in a longitudinal direction. The spring constant will be large enough to minimize errors in the measurement of Z and Y forces resulting from measuring these deflections at slightly different axial positions on the force shaft. In order to isolate the forces in each of the three axes so that no undesirable intereffects may be introduced, the extension of the tapered shaft that connects to the X-axis deflection transducer will slide on close tolerance ball bearings. In addition, the deflection of the shaft in the Z and Y direction will be transmitted to the transducer along a cylindrical bearing surface perpendicular to the transducer measuring axis. Any small torsional deflections that may be introduced due to net torque on the force receiver handle will not be sensed in the Z or Y transducers; however, a stop will have to be provided to prevent torsional forces from affecting the deflection of the X-axis coil spring. Since the torsional forces introduced on the force receiver handle during the application of forces along the three orthogonal axes may be of interest, it is proposed that a torque measuring transducer also be incorporated in the design. It should be noted that a firm requirement for measuring torsion does exist for Experiment No. 7.

3.5.5.2 Restraint System

The restraint system for this experiment will consist of a handhold and two-point rigid waist restraint. The waist restraint will consist of two rigid lines that will connect between a harness on the subject and two points on the force application supporting framework, as shown in Figure 3.5-2.

3.5.6 EXPERIMENT SUPPORT EQUIPMENT

Support equipment requirements for this experiment will be as shown in Table 3.5-1. TV coverage for this experiment will utilize two cameras, two monitors and a wide-band video tape recorder. One of the TV cameras will be used for overall coverage of the test subject, while the other will be used for close-up coverage of the area close to the force receiver handle.

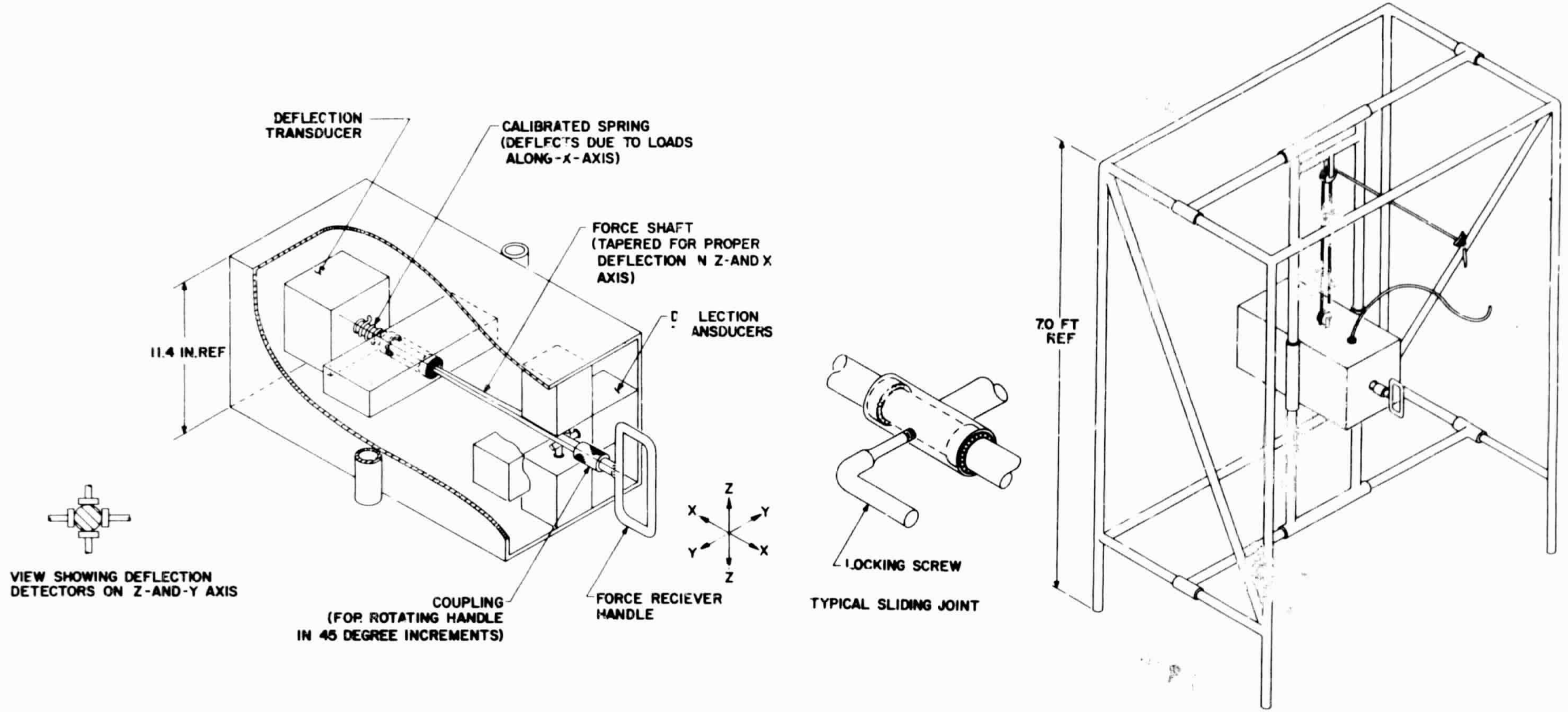


Figure 3.5-3. Force Measuring Equipment

Table 3.5-1. Experiment Support Equipment - Experiment No. 4

ITEM	QUANTITY REQUIRED
Closed Circuit TV System	2
Video Tape Recorder	1
Underwater Lighting	As Reqd.
Underwater Communication System	1
Back-pack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Direct Writing Oscillograph (6 channels)	1

3.5.6.1 Oscillograph

The monitoring device for the applied forces will be a direct writing 6-channel oscillograph such as the Sanborn or Brush strip chart recorder. Each transducer output will be read in one channel of the oscillograph. Analog computation of the resultant force amplitude and direction is also a requirement for this experiment.

3.5.7 SCHEDULE

3.5.7.1 Experiment Operation Schedule

The basic experimental run requires that the subject sequentially apply a maximum sustained force and a maximum impulse force in two directions. This series of force applications is conducted through four handle-orientation at each of 30 handle locations. After applying all forces at all handle orientations for a single handle location, the subject will surface while the second subject conducts the test, using a different handle location. The sequencing of both subjects and locations is illustrated in Table 3.5-2.

Table 3.5-2. Sequencing of Subjects and Tasks - Experiment No. 4

OPERATION	HANDLE LOCATION	TIME REQUIRED (Minutes)	FUNCTION SUBJECT 1	FUNCTION SUBJECT 2
Test Run	1	11	Operating	Rest
Change Handle Location		4	Rest	Get in Position
Test Run	2	11	Rest	Operating
Change Handle Location		4	Get in Position	Rest
Test Run	3	11	Operating	Rest
Change Handle Location		4	Rest	Get in Position
Test Run	4	11	Rest	Operating

Each test subject, therefore, has a rest period of 15 minutes between test runs. The entire experiment requires 120 such runs for each subject, six of which are performed each day. This requires a total of 20 days of experimental operations. The method of scheduling shown is specifically designed so as not to repeat sequence of handle positioning in consecutive orders. This is done to counterbalance the effects of practice and transfer of training which may confound the data.

3.5.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.5-4. In order to reduce the end-to-end time, the greatest amount of overlap possible has been built into the 17 weeks required.

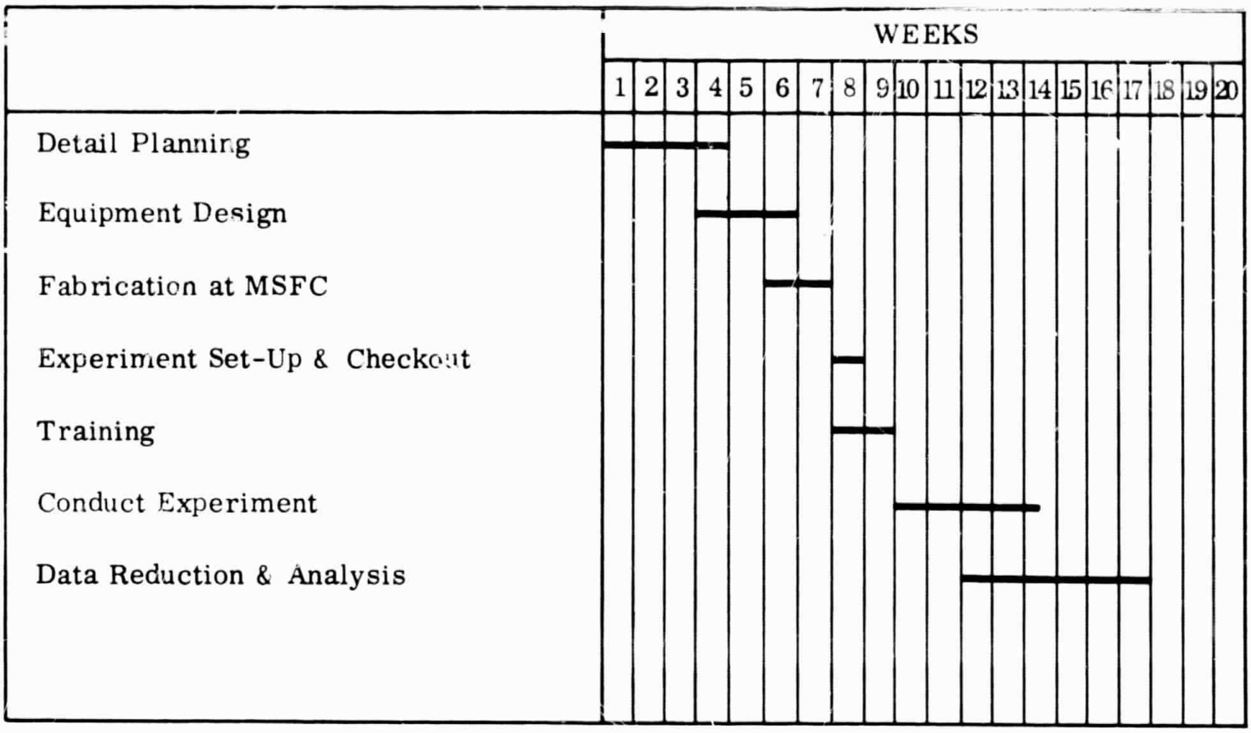


Figure 3.5-4. Total Schedule - Experiment No. 4

3.6 EXPERIMENT NO. 5 - MODULE REPLACEMENT IN ZERO-G AS A FUNCTION OF ACCESSIBILITY AND VISUAL FEEDBACK

3.6.1 OBJECTIVES

This experiment is designed to extend the data relating to modular replacement in zero-g which was initially covered by Experiment No. 3. Here, the aim is to obtain quantitative data on the speed and efficiency of modular replacement as it is affected by accessibility and visual feedback. Specifically, the emphasis is directed at the dimensions and location of an access tunnel through which the module must pass before it may be inserted into the appropriate receptacle. The specific objectives of this experiment are to:

a. Measure and evaluate the effects of accessibility and visual feedback on modular replacement in zero-g

b. Measure the energy output required to replace modules in zero-g

The applicability of the results of this experiment is similar to that of Experiment No. 3, but it is extended to include situations where the receptacle for the module is not located at a panel surface; in many instances, designers of future spacecraft systems will be unable to package subsystems so that all modules are located within direct reach of the astronaut-repairman. If it becomes necessary or desirable to package modules in layers, one behind another, it is imperative that data be available which will specify the consequences of using different clearance dimensions of the access envelope. The time required to orient and insert modules (as well as the expected proficiency in terms of contact of the module with the access tunnel walls) will enable the designers to make intelligent tradeoffs regarding potential designs. In addition, video tape data and observational reports will provide information on the body control problems arising when modules are replaced with a hand-and-waist restraint system.

3.6.2 EXPERIMENT DESCRIPTION

The goal of this experiment is to define and evaluate certain characteristics of the access envelope which differentially affect the removal and replacement of modules of the type which may be required for maintenance and repair of advanced space systems. The task to be performed requires that the test subjects guide a module through an access tunnel and insert it into a receptacle with limited visual cues. The subjects will perform all tasks wearing a spacesuit pressurized to 3.7 psig.

The experimental apparatus will be constructed to provide efficient selection of any one of 162 experimental conditions. These conditions result from the combination of three module lengths, three tunnel (access envelope) locations, three tunnel lengths, three tunnel clearances, and two receptacle clearances. The apparent mass of the three modules will be controlled within a range determined to correspond to approximately constant densities. The restraint for this experiment will be provided by a subject wearing a two-point rigid waist restraint and grasping a handhold located at the optimum position for the nonpreferred hand. The subject will be placed in a fixed position with respect to the longest access tunnel.

Each experimental trial will start when the subject grasps the D-handle of one of the experimental assemblies and removes it from the storage container. The module will be moved to a position in front of the access tunnel and guided through the tunnel until it contacts the entrance into the receptacle. The subject will then perform fine manipulations with varying visual cues to insert the module into the receptacle. The trial will be completed when the module has traveled a sufficient distance into the receptacle to trip a microswitch contact. A technician will then remove the module from the receptacle and change the experimental conditions in preparation for the next experimental run.

3.6.3 TEST VARIABLES

The ability of a subject to remove and/or replace modules in zero-gravity is affected by many factors. Two of the more important factors which are to be evaluated in this experiment are accessibility and the visual environment. Variables which affect these factors were selected for investigation and include (1) module length, (2) tunnel location, (3) tunnel length, (4) tunnel clearance, and (5) receptacle clearance.

3.6.3.1 Module Length

Three module lengths were selected for evaluation because of the interaction between length and accessibility. Module height and width will be held constant at 12 inches. The lengths to be considered include:

a. 6 inches

b. 12 inches

c. 18 inches

3.6.3.2 Tunnel Location

When a subject is restrained in a relatively fixed position, varying the height of the tunnel entrance simulates a change in accessibility and effects a modification of visual cues available for modular replacement. The three tunnel locations selected include:

a. Optimum height for visual feedback

b. Above optimum height

c. Below optimum height

3.6.3.3 Tunnel Length

Varying the length of the tunnel provides a simulation of different fore and aft receptacle access distances. Three tunnel lengths were selected to realistically sample the range of distances from the fixed restraint location.

a. 8 inches

b. 14 inches

c. 20 inches

3.6.3.4 Tunnel Clearance

This variable was selected because of its influence on the ease of controlling the module when visual cues are limited. The access clearances between the module and tunnel sides range from relatively small to large, and include:

a. 0.375 inch on each side

b. 0.750 inch on each side

c. 1.50 inch on each side

3.6.3.5 Receptacle Clearance

Two module receptacle clearances were selected to represent a relatively tight and relatively loose fit. These were chosen to provide an alignment and control task under different simulated access conditions and include:

a. 0.050 inch on each side

b. 0.250 inch on each side

3.6.4 TEST MEASURES AND ANALYSIS OF RESULTS

The basic data to be collected will be objective film/video data and subjective questionnaire evaluative data. In addition, precision placement data and time measures will be collected and analyzed.

3.6.4.1 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Evolve optimal manipulative techniques

c. Ascertain work volume envelopes for various experimental tasks and conditions

d. Identify recurrent behavior patterns

e. Isolate problem areas for future research

3.6.4.2 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test directors. A formal debriefing will be held with each subject after each experimental session to collect personal observation comments concerning problems, suggested procedural or equipment modifications, and comparative judgements about the experimental variables. An interview form or data questionnaire will be made l used when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.6.4.3 Precision Placement Data

An evaluation of precision placement will be accomplished by automatically recording the number of contacts between the experimental module and the walls of the access tunnel. The mean and range of the number of contacts will be presented for each of the experimental variables and compared across subjects. Also, the magnitude and time history of the impact forces will be collected and analyzed to provide a summary of the "g" forces imposed on the modules under the various experimental conditions.

3.6.4.4 Time Measures

Time data will be collected for total and part tasks. Total task time will be compared across all experimental conditions and will provide a gross measure of the effects on performance of manipulating the experimental variables. Part task times will be collected for the insertion of the module into the access tunnel and the insertion of the module into the receptacle. Time variations between subjects will be evaluated to determine significant relationships and will be presented in relation to the appropriate experimental variables.

3.6.5 EXPERIMENT EQUIPMENT

The equipment required for Experiment No. 5 will be the same as that described in Section 3.4.5 for Experiment No. 3, with the addition of provisions for varying the access envelope. Tunnel adaptors will be used to provide these desired access characteristics. The tunnel configuration will be as shown in Figure 3.6-1 with three depths of 8, 14, and 20 inches. The clearances between the simulated module and the tunnel will be 0.375, 0.750, and 1.50 inches on each of the sides of the tunnel, within a tolerance of ± 0.04 inch.

3.6.6 EXPERIMENT SUPPORT EQUIPMENT

Table 3.6-1 is a listing of the experiment support equipment required for Experiment No. 5. TV coverage for this experiment will be obtained by using two cameras, two monitors and a wideband video tape recorder. One of the TV cameras will be used for overall coverage of the test subject while the other camera will be used for close-up coverage of the area adjacent to the access tunnel and module receptacle.

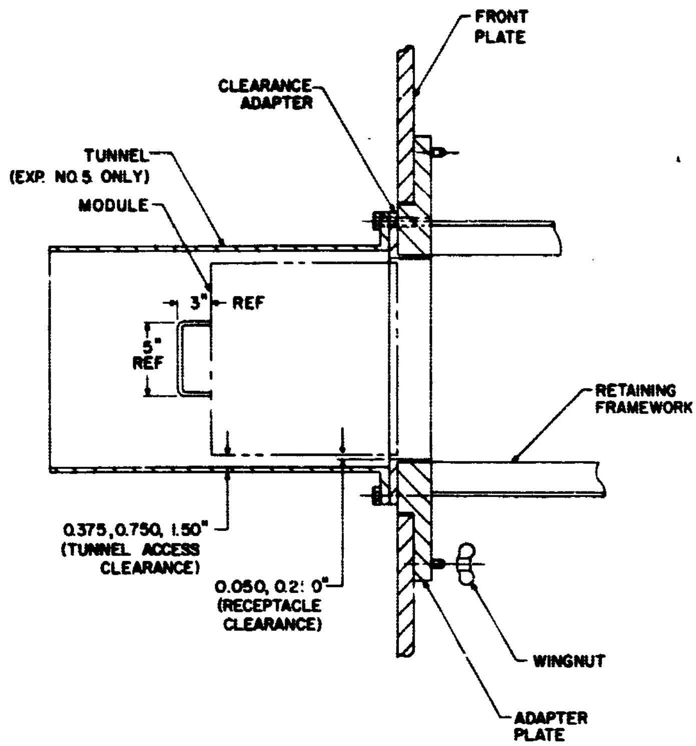


Figure 3.6-1. Module and Tunnel Adapters - Experiment No. 5

Table 3.6-1. Experiment Support Equipment - Experiment No. 5

ITEM	QUANTITY REQUIRED
Closed Circuit TV System	2
Video Tape Recorder	1
Underwater Lighting	As Required
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Impact Accelerometers on Adapter Plate	2

3.6.6.1 Accelerometers

Two impact accelerometers will be mounted on the adapter plate to sense the impacts of the box while it is being inserted in the receptacle. The frequency response of these accelerometers will be 500 cps minimum, and the sensitivity threshold should be approximately 0.5 g peak. Development testing will be conducted to determine the optimum location of these accelerometers and the exact sensitivity requirements.

3.6.7 SCHEDULE

3.6.7.1 Experiment Operations Schedule

The basic experimental task requires that the subject remove the test module from a fixed rack and insert it into the test receptacle. At the end of the task the support technician will remove the module and present a new module and receptacle to the subject. The subject repeats the task until he has performed it 12 times, for a total time of approximately 34 minutes. During each day, each subject will complete three such runs of 12 trials with substantial rest interposed.

The total experiment requires each subject to complete 54 such runs of 12 experimental trials, which, on the basis of this scheduling, result in 18 days of experimental operations.

3.6.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.6-2. In order to reduce the end-to-end time, the greatest amount of overlap possible has been built into the 18 weeks required.

3.7 EXPERIMENT NO. 6 - COMPONENT PART REPLACEMENT IN ZERO-G AS A FUNCTION OF COMPONENT SHAPE AND ACCESSIBILITY

3.7.1 OBJECTIVES

Whereas Experiments Nos. 3 and 5 investigate the replacement of relatively large modules in zero-g, this experiment explores some of the problems involved with the replacement of

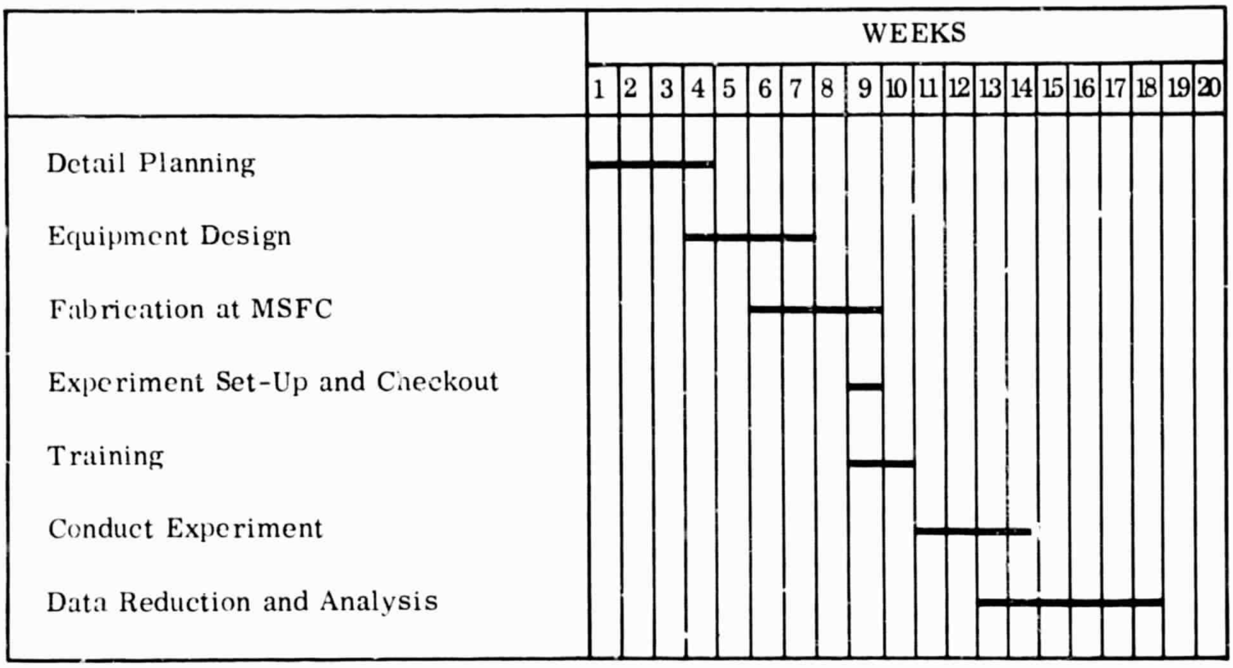


Figure 3.6-2. Total Schedule - Experiment No. 5

relatively small modules or components. When spacecraft designers begin to consider maintenance and repair on long-duration missions, attention will, of necessity, be directed at the replacement and potential repair of such small component parts. Upon consideration of the variables affecting such performance in zero-g, it becomes apparent that much of the data can be obtained in ground-based 1-g studies. There are, however, a few factors which would seem to particularly influence performance in the weightless environment, especially when the man is not perfectly restrained. The objectives of this experiment are to:

a. Measure and evaluate the effects of component shape on ease of replacement in zero-g

b. Measure and evaluate the effects of component connection type on ease of replacement in zero-g

c. Measure and evaluate the effects of component/receptacle clearance on ease of replacement in zero-g

d. Measure and evaluate the effects of restraint condition on ease of component replacement

e. Measure and evaluate the effects of insertion resistance on ease of component replacement

The results of this experiment are not as broadly applicable as many of the others. Essentially, this results from the tremendous potential variation in component and component receptacle characteristics and the lack of data regarding the direction which electronic and mechanical packaging may take in the next 5 to 10 years. Therefore, in order to select appropriate levels for each variable, primary consideration has been given to generalizable abstractions rather than potentially useful designs. In other words, an attempt has been made to select experimental conditions which will result in data useful in setting the broad limit of expected behavior, rather than being directly applicable to specific design applications.

3.7.2 EXPERIMENT DESCRIPTION

The general goal of this experiment is to evaluate the effects of zero-gravity on component part replacement. As a first step toward achievement of this goal, data will be obtained concerning man's ability to perform precision manipulations and force emissions with small component parts. All tasks will be performed by subjects wearing a spacesuit pressurized to 3.7 psig. The experiment will require the insertion of eight simulated components or parts through each of three different access clearances and into a receptacle. The latter will be designed to require each of three preselected forces for component insertion. Three different restraint systems will be utilized in this experiment. The above variables result in a total of 216 experimental conditions which will be replicated four times by each of the four subjects. The experimental apparatus will be designed to allow efficient selection of any combination of the experimental variables on successive trials.

Prior to each experimental run, the subject will be placed in one of the restraint systems so that he is positioned in front of the experimental apparatus. At a given signal, the subject will remove a component from a fixed location and insert it into the access opening.

The component will be guided through the access tunnel and manipulated into the receptacle until contact is made with a linear motion transducer shaft which is spring loaded to produce one of the preselected experimental insertion resistances. The subject will then exert sufficient force to overcome the resistance provided by the spring and continue the component insertion until a ball detent is engaged. At this point, the subject should terminate the forward force emission and remove his hand from the access tunnel. While the subject then rests for a specified period of time, a technician will change the experimental conditions in preparation for the next trial.

3.7.3 TEST VARIABLES

The fine alignment and control behaviors required for component part removal and replacement in zero-gravity are influenced by many factors. The factors selected for investigation in this experiment are (1) component shape, (2) component attachment type, (3) access clearance, (4) component locking resistance force, and (5) type of restraint.

3.7.3.1 Component Shape

Four component frontal shapes were selected for this experiment and are listed below:

a. Square (2 x 2 inches)

b. Rectangle (2 x 3 inches)

c. Cylinder (2 inch diameter)

d. Oval (2 x 3 inches)

Each component is six inches long.

3.7.3.2 Component Attachment Type

The two modes of component attachment selected for evaluation are:

a. Female (insert over)

b. Male (insert into)

3.7.3.3 Access Clearance

The access clearances selected for investigation in this experiment are:

a. 2.0 inches (on each side)

b. 2.5 inches (on each side)

c. 3.0 inches (on each side)

3.7.3.4 Component Lock Resistance

Three resistance forces were selected for evaluation in this study. These values cover the expected range of the forces required to insert a component into a receptacle.

a. One pound

b. Five pounds

c. Ten pounds

3.7.3.5 Type of Restraint

Three types of restraint were selected for use in this experiment on the basis of their representativeness and the range of behavior they sample. The restraints chosen represent groups of one, two, and three attachment points and allow one-hand or two-hand operations.

a. Handhold only (nonpreferred hand)

b. Handhold (nonpreferred hand) and rigid waist tether

c. Three point pedestal (toe, knee, waist)

3.7.4 TEST MEASURES AND ANALYSIS OF RESULTS

The basic data to be collected will be motor performance film/video data and subjective questionnaire data. In addition, precision placement data and time measures will be collected and analyzed.

3.7.4.1 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Evolve optimal manipulative techniques

c. Ascertain work volume envelopes for various experimental tasks and conditions

d. Identify recurrent behavior patterns

e. Isolate problem areas for future research

3.7.4.2 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test directors. A formal debriefing will be held with each subject after each experimental session to collect personal observations and comments concerning problems, suggested procedural or equipment modifications, and comparative judgments about the experimental variables. An interview form or data questionnaire will be made and used when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.7.4.3 Precision Placement Data

Precision placement data will be collected by recording the number of times either the subject's hand or the component part impact upon the access tunnel and receptacle. The mean number of contacts will be calculated for each of the relevant experimental variables and compared across subjects. An additional precision measure will be obtained after the component has engaged the receptacle, as the task requires that a specific force be exerted for a specific time to complete installation of the component. An insertion force profile will be recorded and will be evaluated as a gross measure of behavioral efficiency under various experimental conditions.

3.7.4.4 Time Measures

Time measures will be collected for the total time it takes to complete component insertion. Total task times will be compared across all experimental conditions and will provide a gross measure of the effects on performance of manipulating the experimental variables.

3.7.5 EXPERIMENT EQUIPMENT

The experiment equipment will consist of eight component simulators, a component receptacle test panel, and the test subject restraint system.

3.7.5.1 Component Simulators

There will be two types of components, male and female, to simulate the two basic insertion modes. The male components will be six inches long and will have cross sectional dimensions as shown below:

Shape	Cross-Sectional Dimensions	Tolerance
Square	2 x 2 inches	± 0.05 inch
Rectangle	2 x 3 inches	± 0.05 inch
Cylinder	2-inch diameter	± 0.05 inch
Oval	3-inch major axis x 2-inch minor axis	± 0.05 inch

The female components will have internal dimensions identical to those shown above, with a maximum wall thickness of 1/8 inch. The components are not required to be neutrally buoyant but will have a maximum specific gravity of 3.0 (e.g., aluminum material).

3.7.5.2 Component Receptacle Test Panel

The test panel will provide the access characteristics for the components and measure the insertion force applied by the test subject during the process of engaging the component.

Figure 3.7-1 shows the proposed configuration of this device. Positive engagement and retention of the module to the receptacle will be accomplished by means of a spring-loaded ball detent. One-half inch of compression in a bottom spring will be required prior to engagement of the ball-detent; however, the spring will be compressable beyond the point of engagement. The compression force will be measured by means of a linear motion transducer (e.g., linear potentiometer or differential transformer) since the compression spring will be calibrated. The spring constant and the position of the spring will be selected to present the desired 1-, 5-, and 10-pound resistance force when the spring deflection is one-half inch from the detent engagement position.

In order to facilitate the conduct of the experiment, the housing containing the force measuring instrumentation and the access tunnel will be maintained in the same position relative to the test subject, while the variable shape receptacle openings will be changed by moving a sliding panel laterally. The sliding panel will have as an index the ball detent shown in Section B-B of Figure 3.7-1. This will enable the test subject to proceed through an entire experiment sequence, including placing components in all male and female receptacles, without disturbing his restrained position.

3.7.5.3 Restraints

Three types of restraints will be utilized in this experiment: a handhold, a rigid waist tether and handhold, and a pedestal. These are illustrated and described in detail in Section 3.4.5.

3.7.6 EXPERIMENT SUPPORT EQUIPMENT

The experimental support equipment is listed in Table 3.7-1. TV coverage for this experiment will utilize two cameras, two monitors and a wideband video tape recorder. One of the TV cameras will be used for overall coverage of the test subject while the other will be used for close-up coverage of the area adjacent to the component receptacle.

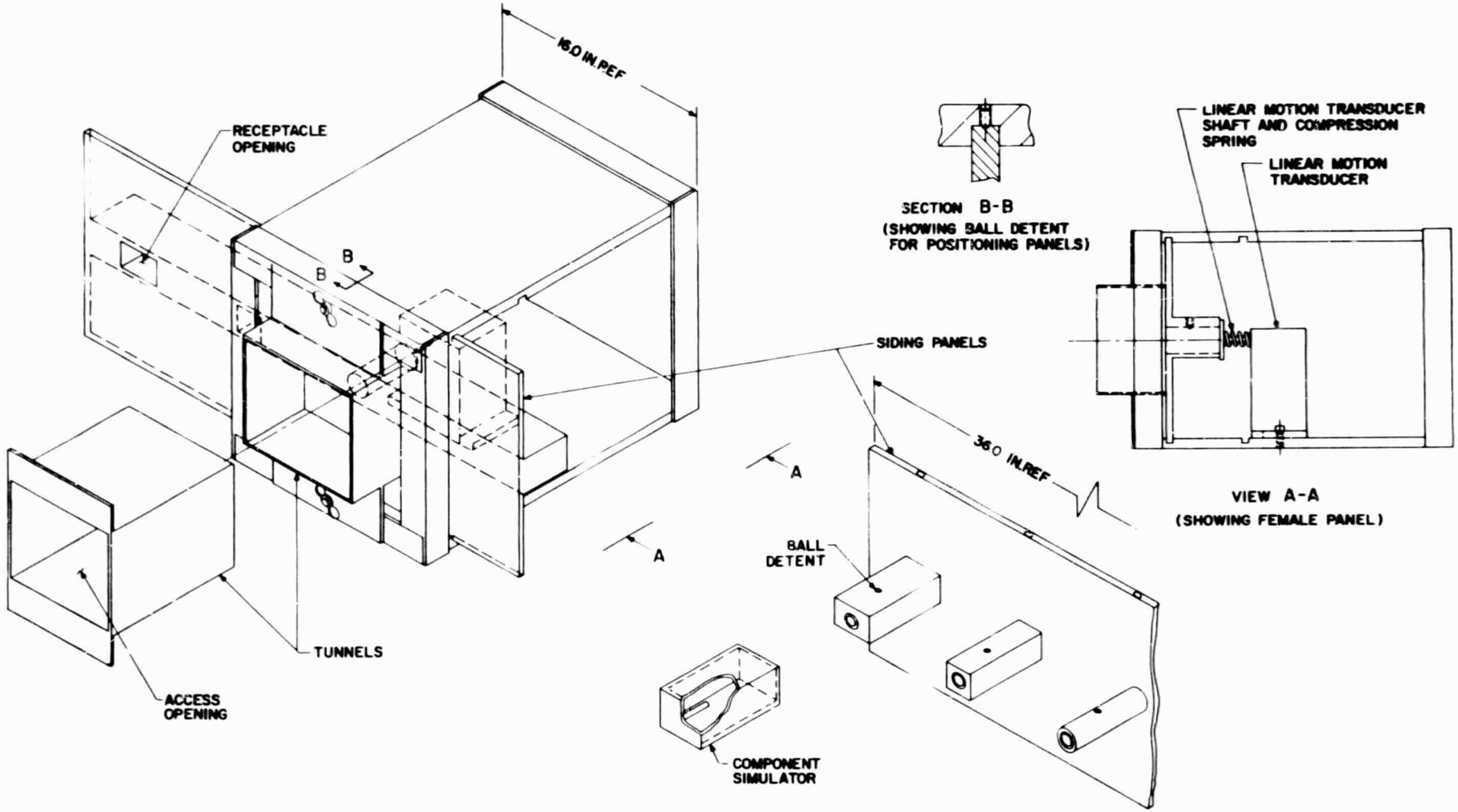


Figure 3.7-1. Component Re‹eptacle Test Panel - Experiment No. 6

Table 3.7-1. Support Equipment - Experiment No. 6

ITEM	QUANTITY REQUIRED
Closed Circuit TV System	2
Video Tape Recorder	1
Underwater Lighting	As Required
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Direct Writing Oscillograph	1 Channel
Impact Accelerometers	2

3.7.7 SCHEDULE

3.7.7.1 Experiment Operations Schedule

The basic experimental task requires that the subject remove the simulated component from its storage receptacle and attach it to the test receptacle. The subject repeats this task continuously until he has performed a total of 15 times (requiring approximately 57 minutes). Each run is performed twice during the day by each subject. The total experiment, therefore, requires 29 days of experimental operations.

A method of counterbalance will be used to account for any order of presentation effects and to minimize the effects of practice and transfer of training.

3.7.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.7-2. In order to reduce the end-to-end time, the greatest amount of overlap possible has been incorporated into the 18-week schedule.

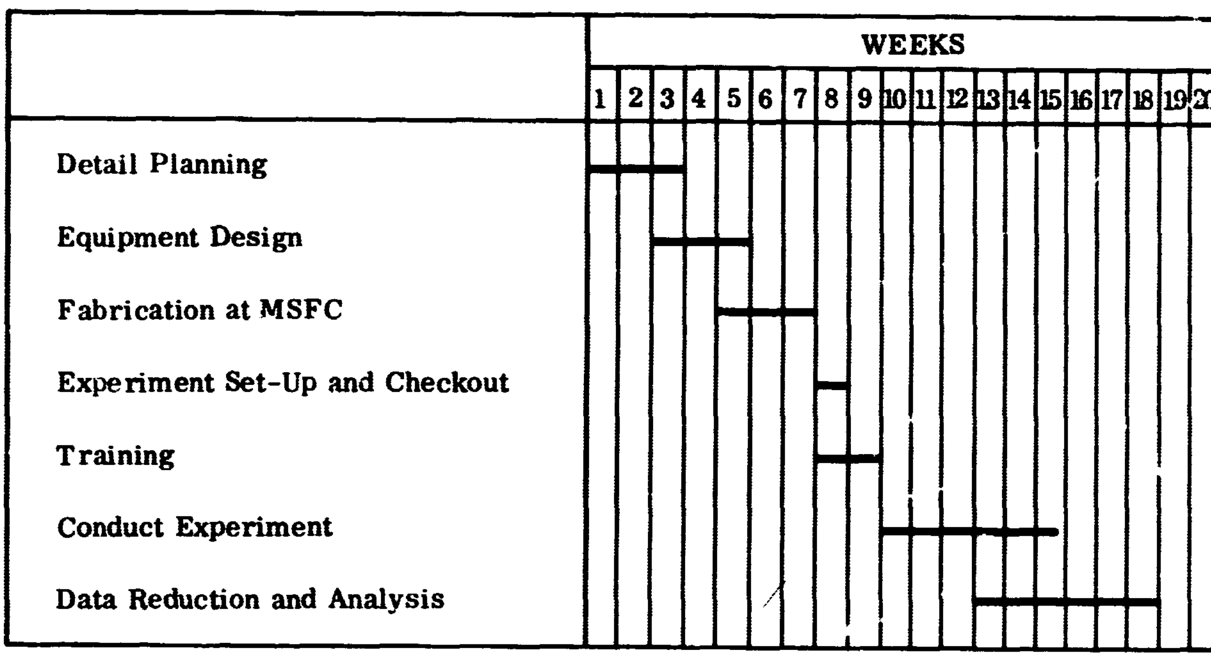


Figure 3.7-2. Total Schedule - Experiment No. 6

3.8 EXPERIMENT NO. 7 - INVESTIGATION OF THE USE OF WRENCH - AND TORSION - TYPE CONVENTIONAL TOOLS IN ZERO-G

3.8.1 OBJECTIVES

Within the broad scope of selecting and designing tools for use in zero-g, an important question concerns the utility of conventional nonpowered tools. Although powered tools may be highly desirable when the mission analysis shows the need for an extensive use of tools for maintenance and repair, as well as nominal operations, it is probable that conventional nonpowered tools will be carried at least for backup in the event of contingencies. This experiment is directed towards examining some of the performance characteristics when such tools are used in zero-g. Specifically, tools used for wrenching and torsioning have been selected for intensive investigation since the tasks in which they are required will probably constitute the majority of the total tasks requiring tool usage. Although Experiment No. 4 examines impulse and sustained force generations in a manner which may be highly applicable to the use of wrench type- and torsion-type tools, that investigation was limited to static force generation. In this experiment, actual prototypes of various conventional tools designed for use in an underwater neutrally buoyant simulation, will be employed dynamically to tighten appropriate bolts. The specific objectives of this experiment are to:

a. Measure and evaluate the relative effectiveness of conventional torque application tools for maximum and precision torques in zero-g

b. Measure the effects of restraint systems on the use of conventional torque application tools in zero-g

c. Measure the effects of force receiver (bolt) orientation on the use of conventional torque application tools in zero-g

d. Measure the energy output required for torque application with conventional tools in zero-g

The applicability of the results of this experiment are, of course, primarily limited by the selection of specific tool types. However, since those tools selected represent the most likely to be used, the results should be highly meaningful for designers of tool kits for advanced spacecraft systems. The experiment requires that the subjects use each of the selected tools in a dynamic task under restraint conditions which vary widely as to their potential aid to the astronaut. In addition, the orientation of the force receiver (or bolt) is varied, thus requiring each tool to be used with different body postures. These varying conditions under which the tools must be used should produce a body of information which is very useful to the designer. A primary source of this information will be derived from the video, tape and observational data, since the techniques used in manipulating a tool in zero-g will be a prime indicator as to the efficiency of its use.

3.8.2 EXPERIMENT DESCRIPTION

The goal of this experiment is to perform a comparative investigation of the utility of selected conventional tools in a zero-gravity environment. The tool selection was restricted to two general categories - wrenching and torsioning, or twisting. Several tools from each category will be evaluated to determine the effects of the zero-gravity environment on the ability of subjects to manipulate, position, localize and apply force with the tools. The subjects will perform all tasks wearing a spacesuit pressurized to 3.7 psig. The experiment consists of an evaluation of subjects using 11 different tools to apply both a maximum force and a precision force to a bolt having one of three different orientations. Subjects will utilize one of three different types of restraint systems on each trial. The above variables result in a total of 99 experimental conditions to be evaluated four times with each of four subjects. Prior to each experimental trial, the subject will be placed into one of the restraint systems in front of the force receiver apparatus. The latter consists of a bolt-head or screw-head mounted on an instrumented box which will provide a force readout and which is oriented along one of three axes with respect to the subject.

The task will begin when the subject removes a predetermined tool from a storage location and moves it to the immediate area of the force receiver. The tool will then be placed in contact with the force receiver and manipulated so as to tighten the force receiver bolt to a maximum. The bolt will then be loosened and backed up to a specific point by a technician and, after a prescribed rest period, the subject will again tighten the bolt. The second tightening will be accomplished to a precise level based on a fixed percentage of the maximum and monitored by the subject on a meter appropriately located in his field of view. The subject will then rest for a specified length of time while a new condition is set up. The restraints, tools, and force receiver locations will be systematically varied through all conditions, for all subjects.

3.8.3 TEST VARIABLES

The large number of conventional tools available for selection as variables for this experiment dictated the imposition of a limiting selection philosophy. An analytical investigation of tools resulted in a categorization by tool function. Further analysis resulted in the selection of two functional categories that appeared to encompass a majority of the requirements for spacecraft maintenance tools in the foreseeable future. The two tool categories selected were wrenching (torquing) tools and twisting (torsioning) tools. In addition, type of restraint and force receiver orientation were determined to be important for an evaluation of conventional tool usage in zero gravity.

3.8.3.1 Tools

3.8.3.1.1 Wrenching (Torquing) Tools.
The wrenching (torquing) tools selected were:

a. Socket wrench
b. Box-end wrench
c. Open-end wrench
d. Clutch torque wrench
e. Allen wrench

3.8.3.1.2 Twisting (Torsioning) Tools.
The twisting (torsioning) tools selected were:

a. Slot-head screwdriver
b. Phillips-head screwdriver
c. Nut driver
d. Slot-head T-handle
e. Phillips-head T-handle
f. Nut driver T-handle

3.8.3.2 Restraints

Three types of restraint were selected on the basis of their representativeness and the range of behavior they sample. The restraints listed below represent groups of one, two, and three attachment points and allow one-hand or two-hand operations.

a. Handhold only (nonpreferred hand)

b. Handhold (nonpreferred hand) and rigid waist tether

c. Three point pedestal (toe, knee, waist)

3.8.3.3 Force Receiver Orientation

The orientation of the force receiver (bolt or screw), with respect to the subject, was selected as a variable to sample the more representative wrenching and twisting behaviors. Three orientations were selected and include:

a. Center line of axis along local vertical

b. Center line of axis left and right along local horizontal

c. Center line of axis fore and aft along local horizontal

3.8.4 TEST MEASURES AND ANALYSIS OF RESULTS

The basic data to be collected will be the physiological, motor performance, and subjective questionnaire data. In addition, precision placement data, force magnitude profiles, force direction profiles, and time measures will be collected and analyzed.

3.8.4.1 Physiological Data and Expected Results

The physiological data will be gathered by means of biomedical sensors attached to the subject's body. The data collected will be (1) heart rate, (2) respiration rate, (3) oxygen consumption, (4) deep-body temperature, and (5) tidal volume. These data will be recorded as dc levels on a magnetic tape recorder located in an underwater backpack worn by the test subject, thus providing an experimental time history of the average and peak metabolic costs associated with various work activities and experimental conditions. Where appropriate or meaningful, the metabolic costs will be plotted as a function of time to denote differences between test variables, differences between subjects, fatigue effects, or a measure of efficiency of operation. In order to make these data meaningful, baseline metabolic measures will be taken on all subjects at rest, before and during each day's experimental trials.

3.8.4.2 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions
b. Evolve optimal manipulative techniques
c. Ascertain work volume envelopes for various experimental tasks and conditions
d. Identify recurrent behavior patterns
e. Isolate problem areas for future research

3.8.4.3 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test directors. A formal debriefing will be held with each subject after each experimental session to collect personal observations and comments concerning problems, suggested procedural or equipment modifications, and comparative judgments about the experimental variables. An interview form or data questionnaire will be made and used when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.8.4.4 Precision Placement Data

An evaluation of precision placement will be accomplished by recording the number of contacts between the tool and the force receiver and detailed examination of the video tape and movie film data. The number of tool approaches and changes required to tighten the bolt and the number of touch contacts prior to exerting a tightening force will be collected and presented for each of the experimental conditions.

3.8.4.5 Force Magnitude Profiles

Maximum-tightening forces and precision-tightening forces will be required from all subjects for all experimental conditions. These forces will be recorded and analyzed with respect to the experimental variables. In addition, significant relationships between the force emission profiles and the physiological and motor performance data will be presented.

3.8.4.6 Force Direction Profiles

Each force is to be exerted in a direction around the longitudinal axis of the force receiver. Means and ranges of force emission capability as a function of tool type and force receiver orientation will be presented.

3.8.4.7 Time Measures

Data will be collected for total task time and will be compared across all experimental conditions. The data will be presented as means and ranges and will provide a gross measure of the efficiency of operation. Time variations between subjects will be evaluated to determine significant relationships and will be presented in relation to the appropriate experimental variables.

3.8.5 EXPERIMENT EQUIPMENT

The experiment equipment will consist of a torque measuring device, shown in Figure 3.8-1, that will be adapted to the force measuring box used for Experiment No. 4 and described in Section 3.5.5. The adaptation for the torque measurement will be achieved by means of a coupling device which will be installed at the shaft that normally accepts the force application receiver handle in the referenced experiment. The coupling adapter will make it possible to install 3/8-24 UNF hex head, pan head-slot, pan head-recessed, and socket head screws. The instrumentation required will consist of a torque measuring load cell which will be installed adjacent to the deflection (force) transducer for the measurement of forces in the X direction. Thus, the device will be able to measure forces in the X, Y, and Z directions, in addition to the torque applied in a clockwise or counter-clockwise direction, thus permitting the detection of error forces induced while applying the desired torque.

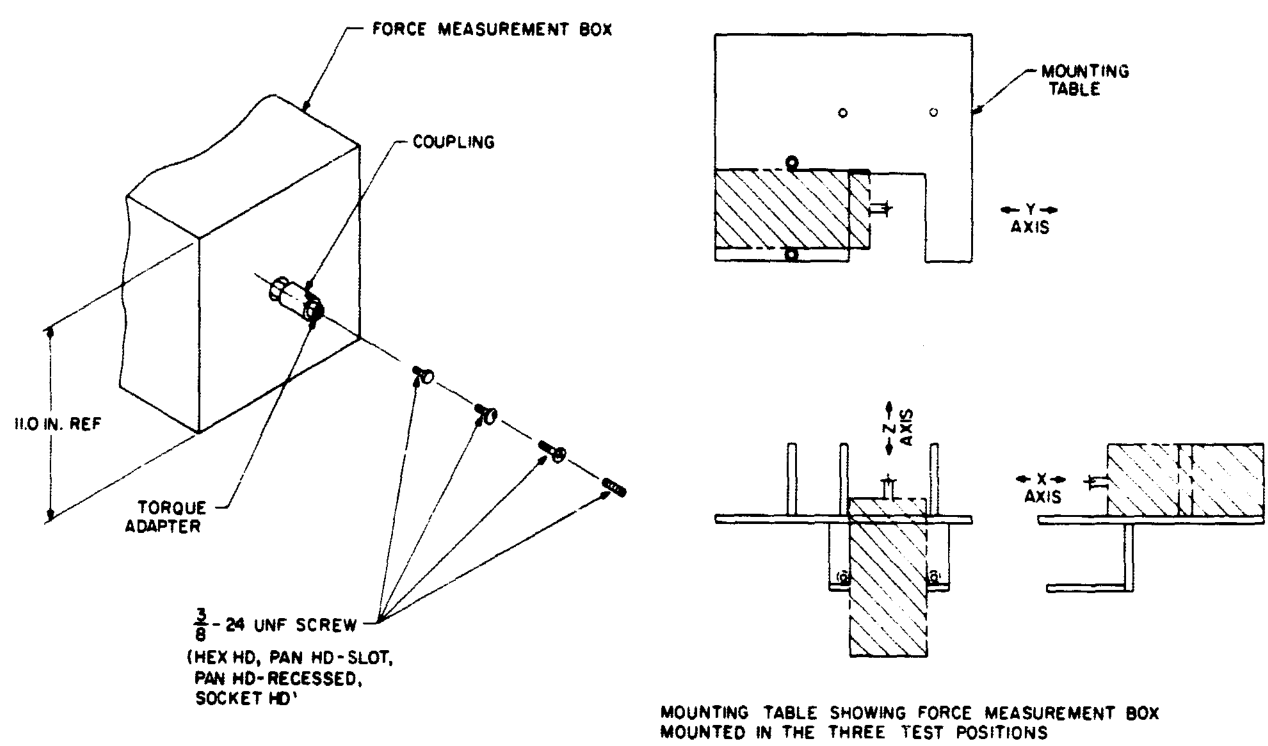


Figure 3.8-1. Torque Measuring Adapter - Experiment No. 7

The restraint systems for this experiment will include a handhold, a handhold and rigid waist restraint, and a pedestal. Figure 3.8-2 shows the test subject restrained at the waist and using the handhold while applying a torque to the force measurement box shaft while the shaft is in a position parallel to the subject's lateral axis.

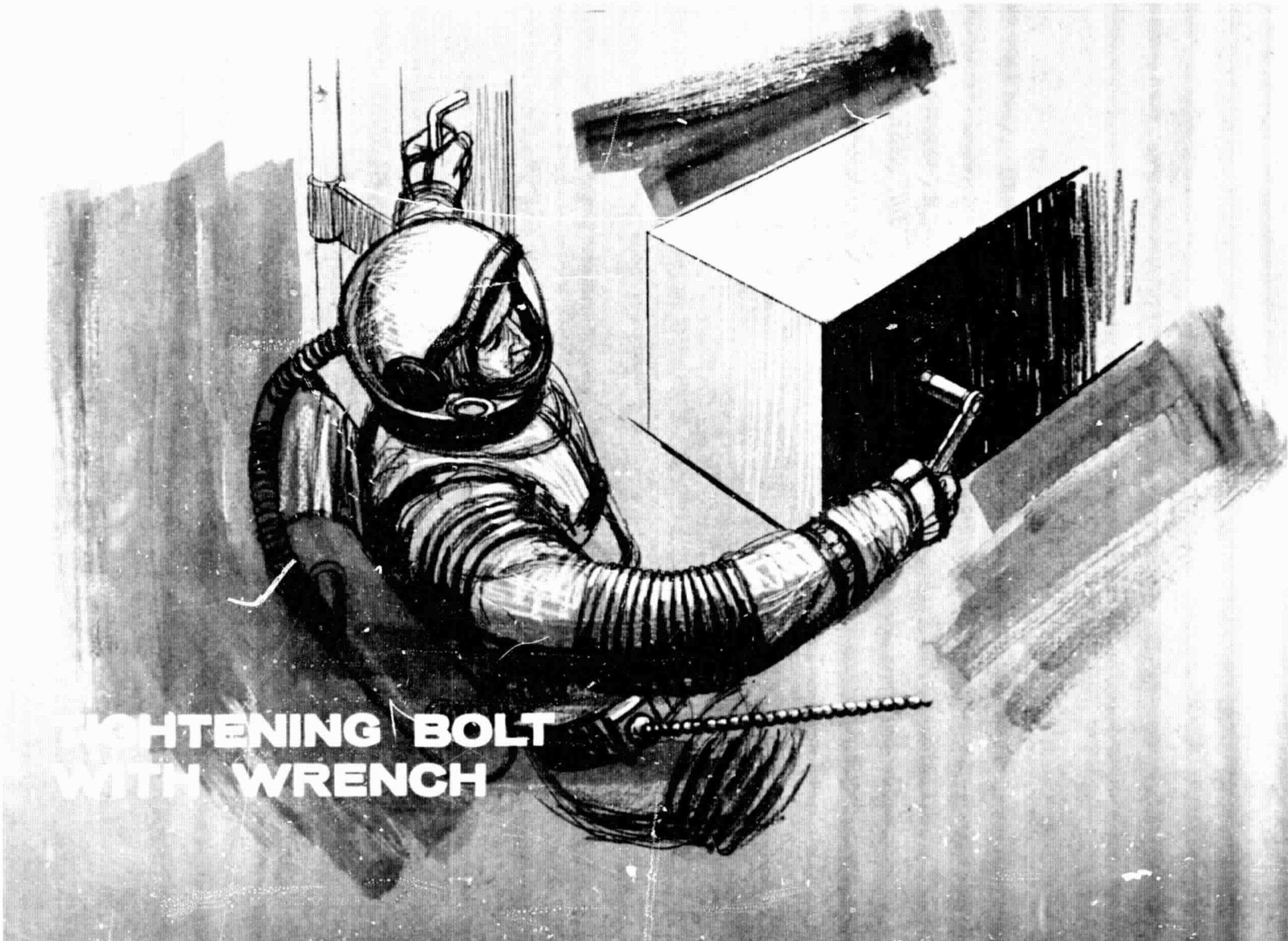


Figure 3.8-2. View of Test Subject Applying Torque

3.8.6 EXPERIMENT SUPPORT EQUIPMENT

Table 3.8-1 lists the support equipment required for this experiment. TV coverage for this experiment will utilize two cameras, two monitors, and a wideband video tape recorder.

Table 3.8-1. Support Equipment - Experiment No. 7

ITEM	QUANTITY REQUIRED
Closed Circuit TV System	2
Video Tape Recorder	1
Underwater Lighting	As Reqd.
Underwater Communication System	1
Backpack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Direct Writing Oscillograph	1

One of the TV cameras will be used for overall coverage of the test subject while the other will be used for close-up coverage of the area adjacent to the force receiver (bolt or screw).

3.8.7 SCHEDULE

3.8.7.1 Experiment Operation Schedule

The basic experimental task requires that the subject remove the tool from a storage receptacle and apply it to the force receiver to tighten the bolt. This task is repeated 14 times during each run, requiring approximately 59 minutes. Each of these runs is repeated twice each day by each subject with suitable rest periods interposed. Thus, each subject completes 28 of the 792 trials required by him for the entire experiment. At this rate, a total of 15 days of experimental operations are required.

3.8.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.8-3. In order to reduce the end-to-end time, the greatest amount of overlap possible has been incorporated into the 18 weeks required.

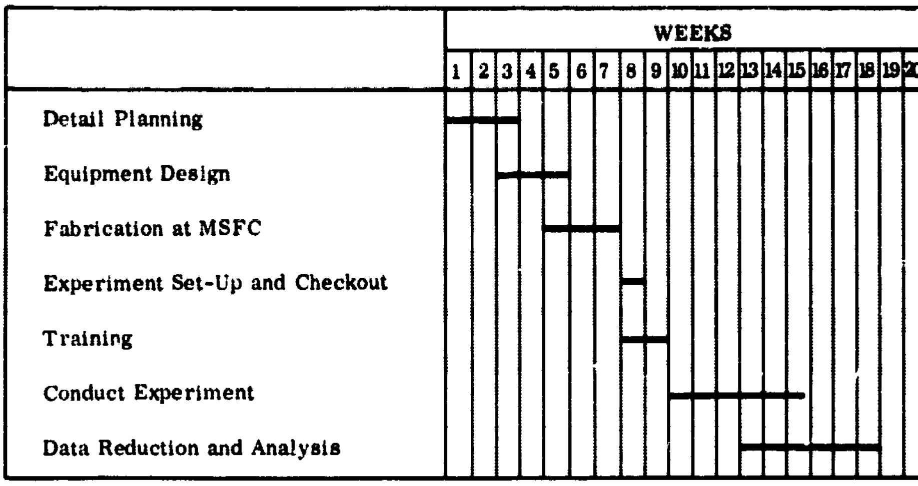


Figure 3.8-3. Total Schedule - Experiment No. 7

3.9 EXPERIMENT NO. 8 - PUSH-PULL FORCE GENERATIONS IN ZERO-G AS A FUNCTION OF RESTRAINT CONDITIONS

3.9.1 OBJECTIVES

This experiment is similar to Experiment 4, except that push-pull forces and the effects of restraint are of prime interest, rather than torque forces and accessibility. The importance of providing the astronaut with an adequate restraint system cannot be overemphasized, therefore this factor has been made a variable in many of the experiments included in this research program. In this experiment, restraint condition is a primary variable and is systematically varied throughout the experimental study. The major objectives of this experiment are to:

a. Measure and evaluate the effects of restraint system on the application of push-pull impulse and sustained forces in zero-g

b. Determine the push-pull impulsive and sustained forces which can be exerted in zero-g as a function of force receiver orientation

c. Measure the energy output required to exert push-pull forces in zero-g

The systematic variation of restraint conditions while measuring maximum impulsive and sustained force generation capability will provide the spacecraft designer with excellent comparative data on the value of each type of restraint. The design of an optimum restraint when a desired force emission capability is required will then be possible on a quantitative basis. While extension of the expected results of this experiment to include restraint requirements for other typical astronaut performance is necessary before a complete solution to the restraint design problem is achieved; these results should help immeasurably in the definition of future research needs, while also producing data of immediate usefulness.

3.9.2 EXPERIMENT DESCRIPTION

This experiment is concerned with the effects of restraint conditions on push-pull force producing capabilities of subjects in the simulated zero-gravity environment. The restraints selected will be varied with respect to the number and location of energy sinks provided to the subject. Additionally, push-pull force producing capability will be evaluated as a function of force receiver (handle) location and orientation. The subjects will perform all tasks wearing a spacesuit pressurized to 3.7 psig. The experimental apparatus will provide for the selection and rapid variation of the 54 experimental conditions. These are composed of nine types of restraints, three force receiver locations, and two force receiver orientations. Maximum push and pull impulsive and sustained forces will be required from each subject for each experimental condition. Impulsive forces are defined as those generated in 0.5 second and sustained forces are defined as those generated during a 3.0 second period.

Prior to the start of each experimental run the subject will be placed in one of the restraint systems so that he is stabilized in front of the force receiver handle. The force receiver handle will be set at one of the experimental distances, with a given orientation. The subject will grasp the force receiver handle and, at a given signal, will pull as hard as he can, maintaining the force application for only 0.5 second. After a suitable rest period the subject will again grasp the force receiver and, at a given signal, will pull as hard as he can, and maintain this force level for at least 3.0 seconds. After another rest period, the above procedure will be repeated in the push direction. Push and pull impulsive-force and sustained-force emissions will be made with the various restraint systems for each of the force receiver locations and orientations and will be replicated four times by each of the four subjects.

3.9.3 TEST VARIABLES

The ability of a subject to emit forces in a zero g environment is affected by several variables, some of which are listed below:

a. Type of restraint system

b. Position and location of the body relative to the force receiver

c. Type of force required - impulse or sustained

d. Direction of force application

e. Location of force receiver

f. Type of spacesuit

g. Pressurization condition

However, the evaluation of the effects of all these variables and the resulting combinations would be beyond the scope of this experiment. In addition, some of the variables have already been selected for examination in Experiment No. 4. Therefore, the variables selected for investigation in Experiment No. 8 are:

a. Type of restraint

b. Force receiver location

c. Force receiver orientation

The remainder of the potential variables listed above were held constant in this experiment.

3.9.3.1 Type of Restraint

Force producing capability in a zero-g environment is greatly dependent upon the characteristics of the restraint conditions provided for the subject. Such factors as the number of attachment points, location of attachment points, rigidity of energy sinks, and freedom of movement all affect the performance profile. Rather than exhaustively evaluating all variations of the above factors, an analytical attempt was made to limit the number of restraints on the basis of feasibility and probability of being available in future manned space stations. The nine restraint types selected, including a "none" category, are listed below:

a. None

b. Waist

c. Chest

d. Handhold only - optimum level

e. Handhold (optimum level) and waist

f. Handhold (above optimum level) and waist

g. Handhold (below optimum level) and waist

h. Handhold (optimum level) and knee

i. Handhold (optimum level) and foot

3.9.3.2 Force Receiver Location

Force receiver location in this experiment refers to the distance directly forward of the chest reference point (right nipple) at which the force receiver handle will be fixed. Three distances were chosen which result in approximate elbow angles of 90 degrees, 135 degrees, and 180 degrees. These elbow angles sample the largest variations in push-pull, force-producing capabilities in earth gravity. The distances forward of the reference point are listed below:

a. 15 inches

b. 19 inches

c. 24 inches

3.9.3.3 Force Receiver Orientation

Studies have shown that the orientation of the force receiver handle with respect to a fixed reference point (e.g., local vertical) affects the force-producing capability of the subjects. Two orientations were selected as being most appropriate for a push-pull experiment and are defined below:

a. 0 degrees - local horizontal

b. 90 degrees - local vertical

3.9.4 TEST MEASURES AND ANALYSIS OF RESULTS

The basic data to be collected will be physiological, motor performance, and subjective questionnaire data. In addition, force emission profiles will be collected and analyzed. These latter will include both magnitude and direction in the command, as well as error axes.

3.9.4.1 Physiological Data and Expected Results

The physiological data will be gathered by means of biomedical sensors attached to the subject's body. The data collected will be (1) heart rate, (2) respiration rate, (3) oxygen consumption, (4) deep body temperature, and (5) tidal volume. These data will be recorded as dc levels on a magnetic tape recorder located in the underwater backpack worn by the test subject. This data will provide an experimental time history of the average and peak metabolic costs associated with various work activities and experimental conditions. Where appropriate or meaningful, the metabolic costs will be plotted as a function of time to denote differences between test variables, differences between subjects, and fatigue effects or a measure of efficiency of operation. In order to make these data meaningful, baseline metabolic measures will be taken on all subjects at rest, before and during each day's experimental trials.

3.9.4.2 Motor Performance Data and Expected Results

Video tape and movie film will be utilized extensively throughout this experimental program. The data will be gathered by the strategic placement of fixed TV cameras and an underwater photographer with a handheld movie camera. The video tape and film footage will be examined in detail to:

a. Evaluate performance characteristics in the simulated zero-gravity conditions

b. Ascertain work volume envelopes for various experimental tasks and conditions

c. Identify recurrent behavior patterns

d. Isolate problem areas for future research

3.9.4.3 Subjective Evaluation Data

Subjective data will be collected after each experimental session and will come primarily from two sources: the subjects and the test directors. A formal debriefing will be held with each subject after each experimental session to collect personal observations and comments concerning problems, suggested procedural or equipment modifications, and comparative judgments about the experimental variables. An interview form or data questionnaire will be made and used when dictated by the situation and determined by the test director. In addition, observer comments will be recorded for each experimental session by the test director for use during the debriefing sessions. These data will be used to provide experimental insight into the objective data and to determine problem areas and requirements for future research.

3.9.4.4 Force Magnitude Profiles

Maximum impulsive and sustained force profiles will be obtained from all subjects for all experimental conditions. These forces will be recorded and analyzed with respect to the experimental variables and mean values and ranges will be presented for each condition across all subjects. In addition, significant relationships between the force emission profiles and the physiological and motor performance data will be presented.

3.9.4.5 Force Direction Profiles

Each force is to be exerted in push (forward) and pull (back) direction through the longitudinal axis of the force receiver handle. Means and ranges of force emission capability as a function of force receiver orientation and restraint system type will be developed. Any deviation from an exactly perpendicular force application will also be recorded as an error force. These deviations will be analyzed and any significant findings will also be presented.

3.9.5 EXPERIMENT EQUIPMENT

This experiment will utilize the force-measuring device previously described in Section 3.5.5 for Experiment No. 4. This equipment will permit the measurement of both the command forces in the X direction and the error forces in the Y and Z directions. Force measurements will be recorded on a direct writing oscillograph with pictorial data obtained through the use of two closed-circuit TV systems and an associated video tape recorder. These are described in detail in Section 3.5.6. The restraint system capability for this experiment is depicted in Figure 3.9-1. Both the handhold and the fixed restraint for chest, waist, knees, or feet may be supported from the same framework that retains the force-measuring device. Adjustments in a vertical direction are possible by sliding the restraints up or down along the vertical bars of the framework. Provisions will be made to lock the restraint system once the desired position has been attained.

3.9.6 EXPERIMENT SUPPORT EQUIPMENT

Table 3.9-1 contains a listing of the support equipment required for Experiment No. 8.

The recording and monitoring device for the forces will be a direct writing oscillograph, such as a Sanborn or Brush strip chart recorder. Analog computations of the resultant force amplitude and direction will also be required. TV coverage for this experiment will utilize two cameras, two monitors, and a wideband video tape recorder. One of the TV cameras will be used for overall coverage of the test subject while the other will be used for close-up coverage of the area adjacent to the force receiver handle.

3.9.7 SCHEDULE

3.9.7.1 Experiment Operations Schedule

The basic experimental run for this experiment requires a subject in a fixed restraint to generate both push and pull, impulsive and sustained forces through a force-receiver handle at a given distance and orientation. This run of four trials is then repeated with a different handle orientation after a short rest period. The subject completes these runs with 12 restraint/force receiver location combinations during a single day with appropriate

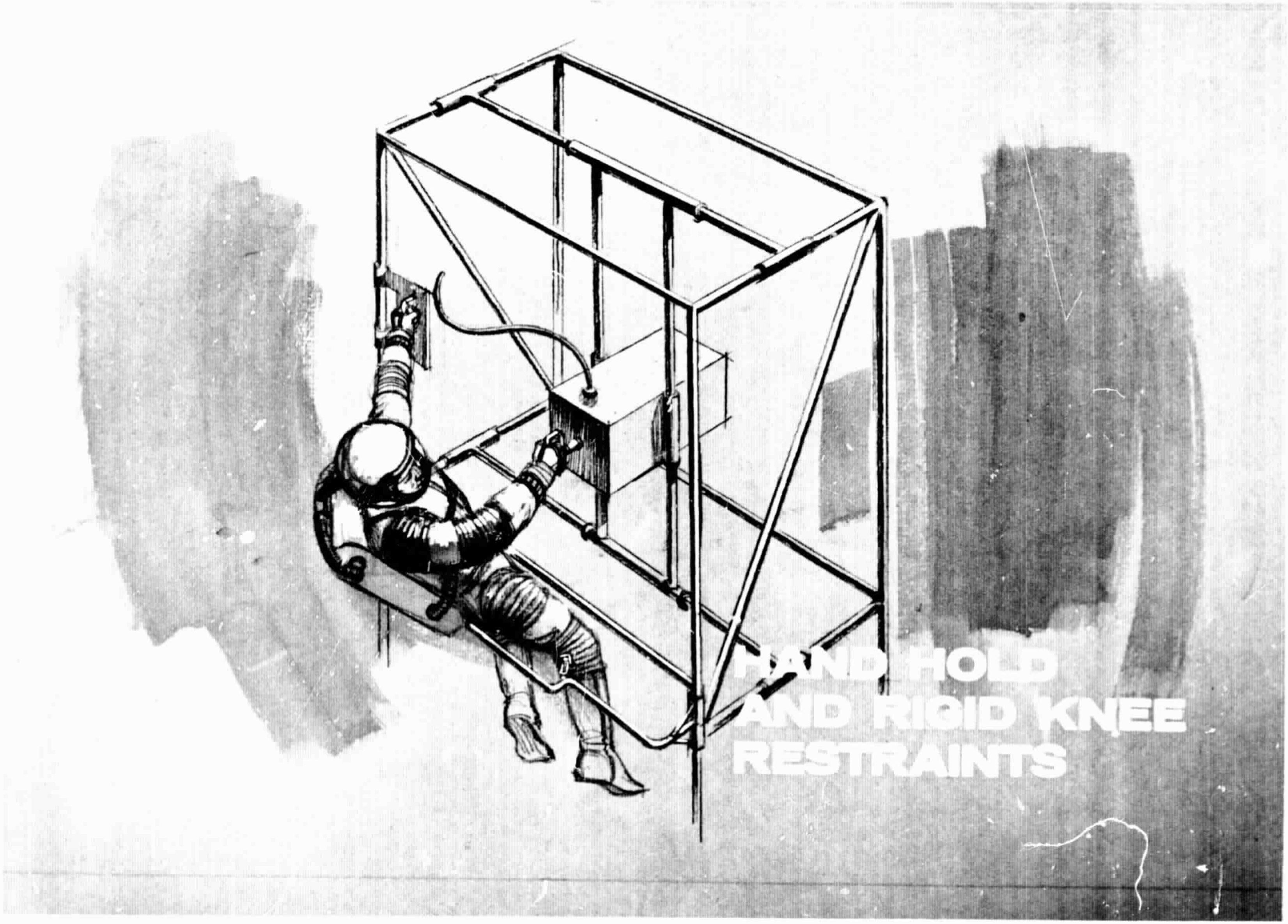


Figure 3.9-1. Handhold and Rigid Knee Restraints - Experiment No. 8

Table 3.9-1. Experiment Support Equipment - Experiment No. 8

ITEM	QUANTITY REQUIRED
Closed Circuit T/V System	2
Video Tape Recorder	1
Underwater Lighting	As Reqd
Underwater Communication System	1
Back-pack	2
Water-Pressurized Space Suit	2
Physiological Instrumentation	2 Sets
Timing System	1
Direct Writing Oscillograph	1

rest periods. Thus, each subject completes 96 trials out of the required 864 during each experimental day. On this basis, nine days of data collection are required to complete the experiment. This proposed schedule is based on estimates of the time to generate forces, change experimental conditions, and the time required for rest. This latter estimate especially must be reviewed very carefully before a final schedule is constructed. In addition, careful attention must be given to counterbalancing the potential effects of practice and transfer of training among the different restraint systems.

3.9.7.2 Total Schedule

The overall schedule for this experiment is shown in Figure 3.9-2. In order to reduce the end-to-end time, the greatest amount of overlap possible has been built into the 15 weeks required.

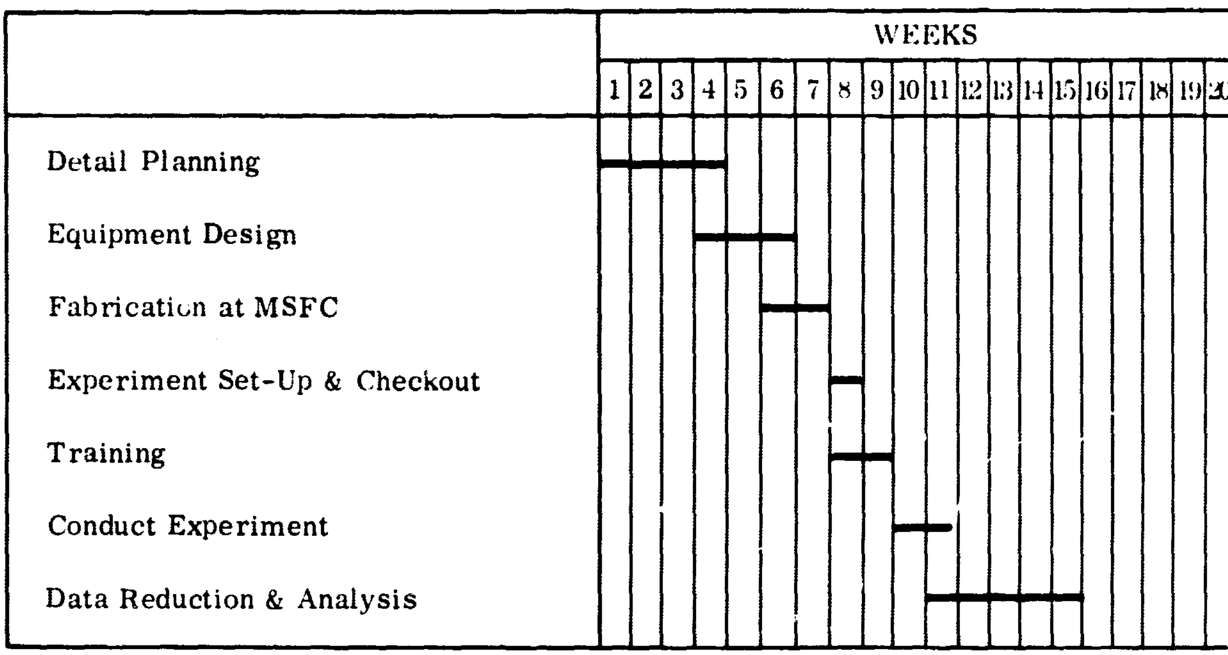


Figure 3.9-2. Total Schedule - Experiment No. 8

3.10 EXPERIMENT SELECTION

3.10.1 RECOMMENDED EXPERIMENT IMPLEMENTATION

The General Electric Company believes that all of the experiments defined in this report are important and, when implemented, will provide much of the valuable data which is required by engineering designers to provide adequate maintenance and repair capabilities for advanced space systems. However, utilizing priority determining factors such as the relative immediacy of need, common applicability, and prerequisite information requirements as described below, the following specific implementation recommendations were made at the conclusion of the preliminary definition phase of this study:

a. Experiments No. 4, 7, and 8 should be considered for immediate implementation because of their:

   1. Broad applicability to design problems

2. Relative ease of implementation (including schedule requirements, design complexity, and data requirements)

3. Common equipment usage

4. Relatively low cost of implementation (including procurement, fabrication, facility, and manpower considerations)

b. Experiments No. 1 and 2 should also be given serious consideration because of the:

1. Immediate and prerequisite need for the data to be applied to very near-term space programs

2. The availability of an operational facility of sufficient size which will allow immediate implementation, or even concurrent experimentation

In this initial effort the recommendations were made by considering the eight experiments and their relative ratings as a function of each of the following priority factors:

a. Breadth of applicability to manned spacecraft design problems

b. Immediacy of the requirement for data in terms of current space programs

c. Ease of experimentation in terms of schedule, equipment design, and interpretation of the experimental data

d. Degree of degradation of the data due to the limitations imposed by the simulation medium

e. Cost of experimentation, including experiment apparatus, support equipment requirements, facility, and manpower

3.10.2 NASA SELECTION AND MODIFICATIONS

Subsequent to the experiment definitions and recommendations indicated in the previous paragraph, a selection committee, composed of cognizant representatives of the various NASA Centers and NASA Headquarters, recommended the following experiment implementation schedule for this study program:

a. Experiment 84A. This is basically a combination of Experiments No. 8 and 4 as described in Sections 3.9 and 3.5, respectively, with the inclusion of additional variables simulating accessibility conditions and the limitation of the range and quantities of certain variables. The details of the final design and implementation of this experiment are presented in Section 6.

b. Experiment 1A. This is essentially Experiment No. 1 as described in Section 3.2, with the exclusion of shape and volume as experimental variables. The details of the final design of this experiment are presented in Section 7.

The experiments developed during the preliminary definition phase described in this Section were predicated upon the use of the General Electric closed-loop underwater backpack for subject support and instrumentation. This backpack contains the necessary equipment to provide suit pressurization (water), breathing oxygen, control circuits, and a physiological data monitoring and recording system. However, the Apollo fire and a subsequent ban on the use of 100 percent oxygen in system tests using Apollo spacesuits, combined with a NASA desire to include an air pressurization/water pressurization comparison in this study, eliminated the use of the General Electric backpack from utilization in this experimental program. The self-contained backpack was replaced with the umbilical backpack equipment (described in Paragraph 4.2.2.2), which provides only suit pressurization and breathing air.

This lead to the dropping of the physiological measurements from Experiment 84A, as a new measurement system (which would be required for the new umbilical backpack) could not be available in time to be of use in that experiment. However, for Experiment 1A the schedule allowed sufficient time for the measurement system to be developed and fabricated, and, therefore, it remained a requirement of this experiment.

Due to a considerable increase in the time required for completion of test operations for Experiment 84A, among which are delays due to the equipment changes previously discussed, suit maintenance problems, and the many small but time-consuming problems of instrumentation and personnel inherent in any experimental research program, it was not possible to completely implement both Experiments 84A and 1A during this study contract. Experiment 84A was completed and is discussed in Section 6. Experiment No. 1A was carried to final design and protocol preparation, but was not operationally implemented. The details of this experiment are discussed in Section 7.

SECTION 4
EXPERIMENTAL TECHNIQUES

The development of a multi-experiment program within the bounds of the specified contract scope naturally leads to the attainment of a high degree of commonality in experimental techniques as well as in support and operational requirements. For this program these include the neutral buoyancy zero-g simulation procedures, equipment design techniques, the underwater facility, and the use of the General Electric self-contained backpack.

4.1 NEUTRAL BUOYANCY SIMULATION

The experiment program was based upon the utilization of neutral buoyancy submergence techniques for the simulation of zero gravity. This technique provides a relatively simple way of attaining a 6-degree-of-freedom motion and overcomes some of the fundamental limitations of other simulation techniques. Zero-g can be simulated by making the buoyant force equal to the object weight with the center of buoyancy coinciding with the center of gravity in order to avoid introducing an orientation bias. Also, gravitational fields between zero and 1-g can be simulated by providing buoyant forces which are less than the object weight.

In general the advantages of the underwater simulation techniques are:

a. Added system inertia, such as that caused by mechanical simulation devices, is not imposed.

b. Every part of the body can be buoyed to null gravity; consequently, body motions do not cause gravitational imbalances.

c. The test subject is not strapped down or inhibited from free total body motions.

d. The test subject will require the same type of torsional and fixational restraints as he would in the zero-gravity environment.

e. Three dimensional movement through realistic volumes is possible.

A valid simulation must provide the subject with the proper visual and kinesthetic cues. When he impresses a specific force history on an object, that object should respond with a motion history approaching that which would occur in space. This can be accomplished to the degree that the following conditions are satisfied.

a. Six-degree-of-freedom motion must be provided.

b. The gravitational attractive force of the environment being simulated must be duplicated.

c. The model mass and moment of inertia must duplicate that of the space object.

d. The model must approximate the size and shape of the space object.

e. Extraneous effects, which are introduced by the simulation but which are not present in space, such as hydrodynamic forces and moments, must either be reduced to an acceptable level or analytical methods for accounting for these effects must be developed.

Underwater simulations employing neutral buoyancy for simulating activities in orbital operations satisfy conditions a and b above. Less obvious is how to satisfy conditions c, d, and e, simultaneously, i.e., make the model neutrally or partially buoyant, minimize hydrodynamic forces and moments, and at the same time simulate the mass, moment of inertia, and shape of specific space objects. However, by a thorough understanding of the cause and effects of the two main extraneous influences, hydrodynamic mass and drag, we can develop techniques which will satisfy these requirements to the maximum extent possible, thereby providing a high-fidelity simulation.

Hydrodynamic mass manifests itself as an apparent increase in the true mass of a submerged body. It derives from the acceleration of water that accompanies the acceleration of a rigid body in water. The hydrodynamic mass should not be confused with drag as the latter is a function of velocity only, for a given body and fluid medium, and is present only as long as there is a relative velocity. Hydrodynamic mass is a variable function of acceleration and vanishes at constant velocity. Drag and hydrodynamic mass are similar only in that both are functions of body geometry, size, and the mechanical properties of the fluid medium. While drag resists the velocity, hydrodynamic mass resists the change of velocity.

The problem that faces the neutral buoyancy simulation designer is to design both the simulation and the equipment so that the hydrodynamic mass and drag effects are either reduced to an acceptable level or are used to advantage. While the actual objects to be moved in space may be more or less dense than water and may be expected to have wide ranges of inertial characteristics, their neutral buoyancy counterparts are constrained to be the same density as water. Analyses have shown that by judicious selection of model shape and size, a neutrally buoyant model can be made to exhibit the mass and inertial characteristics of the actual equipment in space. This is accomplished by designing so that the hydrodynamic mass is employed to make up the difference between the actual equipment mass and the model mass. Note that a neutrally buoyant body accelerated in water can exhibit considerable hydrodynamic mass. For instance, a neutrally buoyant sphere has an additional hydrodynamic mass approximately equal to 50 percent of the mass of the sphere itself. Consequently, a 2-slug neutrally buoyant sphere will accelerate in response to an impressed force as though it were 3 slugs.

A derivation of the neutral buoyancy scaling laws, the model design equations, and a discussion of the experimental verification for this approach will be found in Appendix A.

4.2 PERSONNEL SUPPORT

4.2.1 PRESSURE SUITS

Apollo State-of-the Art pressure suits were used throughout the entire experiment program. (See Figure 4.2-1.) Although the state-of-the-art suit differs from the Block II suit now in use for the Apollo program, they are generically similar and the data obtained is considered valid.

During the course of the experiment operations for Experiment 84A, significant delays were encountered due to suit failures. Elbow and shoulder joint cables caused the most trouble--with an occasional broken neck ring, or blown elbow, or knee bellows. When a cable broke, the experiment session was aborted and the suit was repaired. Also encountered, but to a lesser extent, were suit leakage problems. However, in this case, the experiment session was not stopped unless the leak was such that the suit would not hold pressure.

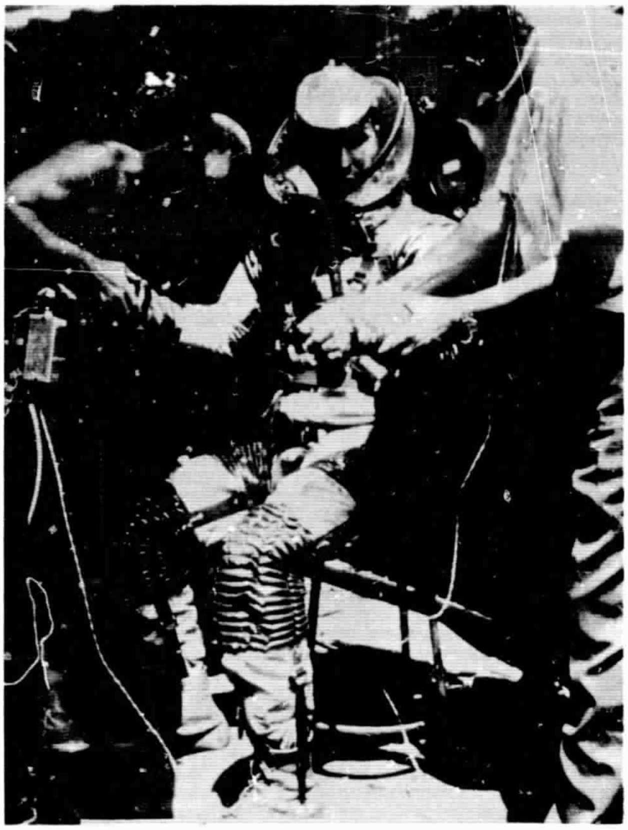


Figure 4.2-1. Apollo State-of-the-Art Pressure Suit

4.2.2 PRESSURIZATION/BREATHING SUPPLY

During the experiment suit pressure was maintained at 3.7 $\pm$ 0.2 psig. This pressure was imposed as the NASA requirement for the operating design pressure for the State-of-the-Art suits. However, some question exists as to the most desirable method of pressurizing a spacesuit for neutral buoyancy operations. One point of view is that the suit should be pressurized with air, since it represents the most natural condition for the astronaut in an actual space flight. The other point of view is that the suit should be pressurized with water, since this will provide the most realistic simulation with regard to suit dynamics.

At the conclusion of the preliminary definition phase of this study, it was decided to implement the experimental program utilizing both methods. Experiment 84A would provide comparative information on relatively static force applications, and Experiment 1A would allow a comparison of the two pressurization media under translational and manipulative conditions.

4.2.2.1 Water Pressurization

In practice the water pressurization technique requires the use of a SCUBA mask worn under the spacesuit helmet and a SCUBA mouthpiece to supply air, since water fills the helmet as well as the suit. The helmet which is provided as part of the State-of-the-Art suit does not allow sufficient space for the mask and mouthpiece. In addition, it is so designed that access to the subject's mouth, either by opening the visor or by removing the helmet entirely, is fairly difficult and unreliable. Therefore, a new helmet, shown in Figure 4.2-2, was designed and built by GE for this study. This helmet mates with the suit neck ring and requires no modifications to the suit. Its main features are the split hemisphere design which is held with a specially adapted quick-release Marmon clamp, and its size and shape, which allows the inclusion of underwater 2-way communications equipment. The quick-release clamp, operable by either the test subject or a safety man, enables safety personnel to provide a rapid supply of breathing air in the event of an emergency.

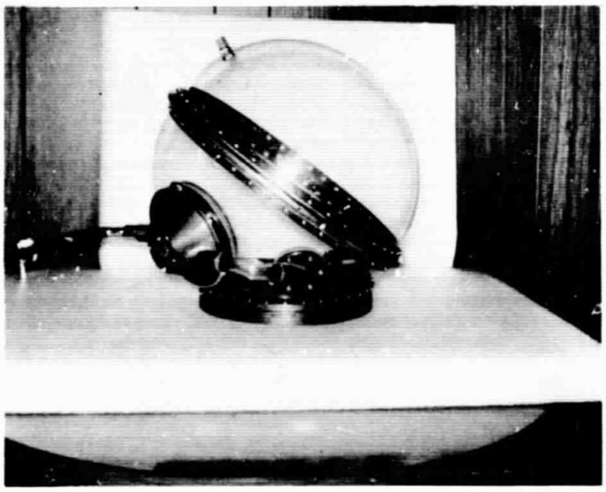


Figure 4.2-2. Underwater Helmet

The helmet also contains a specially designed second-stage demand regulator. Breathing air at 100 psi was supplied from the surface control station through a hookah. The control station acts as the first stage regulator in a standard SCUBA system, allowing the second-stage demand regulator to function in accordance with the man's breathing rate and depth. Water pressure is supplied through a pump and maintained at a preset value by redundant regulators located in the backpack shown in Figure 4.2-3 and schematically depicted in Figure 4.2-4.

The pump is a constant-flow device which continually pumps water from the surroundings into the suit. The regulators were preset to open at a pressure of 3.7 psig. This constant-flow system also eliminates problems associated with suit leaks as the pump is capable of providing 12 cfm of water into the system.

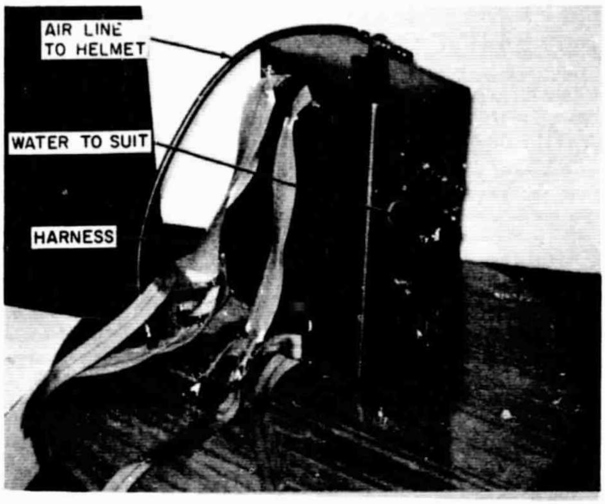


Figure 4.2-3. Underwater Backpack

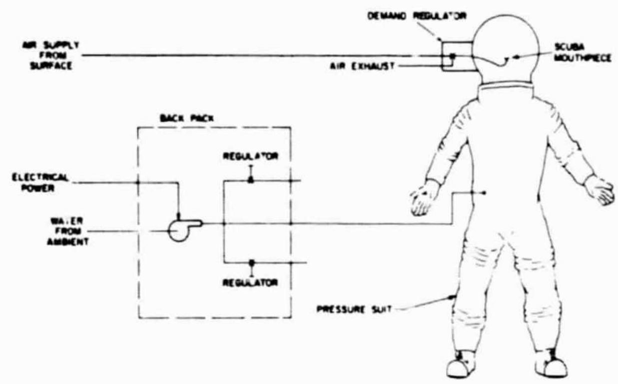


Figure 4.2-4. Water Pressurization/Air Breathing System

4.2.3 ATTAINMENT OF NEUTRAL BUOYANT

During the experiment, familiarization, and training activities a gross neutrally-buoyant state, in an upright position, was determined for each test subject in both the air and water pressurized conditions. For the water-pressurized conditions approximately 50 to 80 cubic inches of styrofoam flotation material, providing about 3 pounds of buoyancy, was required to attain neutral buoyancy. This buoyant material was located at the test subject's stomach. In order to account for slight daily changes in the subject's weight, the buoyancy was adjusted by adding or removing small amounts of floatation material each time the subject entered the water.

For the air-pressurized condition, approximately 130 pounds of weight was required to stabilize in a neutral condition. This was obtained by placing a large harness over the shoulders of the subject with weights distributed in front and back, with additional weights attached to the arms and ankles. Again, each subject was trimmed to the neutrally buoyant state each time he entered the water, to account for daily weight changes.

4.2.2.2 Air Pressurization

In order to provide the same subject/backpack mass and geometry as in the water pressurization case, the subject wore the same helmet and backpack with the air pressurization system. However, for this configuration, the helmet demand regulator was bypassed and a suit air pressurization regulator mounted in the backpack was utilized. As shown schematically in Figure 4.2-5, air for both suit pressurization and breathing is supplied to the suit regulator from the surface through a hookah, at about 100 psi and 4 cfm.

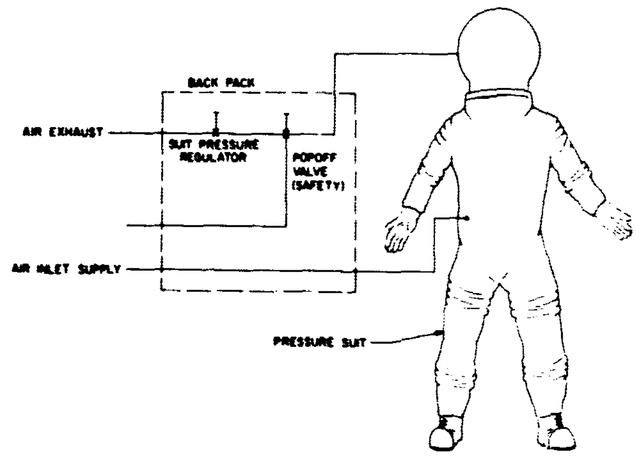


Figure 4.2-5. Air Pressurization/Air Breathing System

SECTION 5
FACILITIES

The facility used during the implementation of the experiment program discussed in this report is located at the Marshall Space Flight Center, Huntsville, Alabama, and consists of two below-surface water tanks, an instrumentation building, and a dressing room van.

5.1 NEUTRAL BUOYANCY TEST FACILITY TANKS

The experiment program was initiated utilizing the larger tank at the facility, Figure 5.1-1. This is an enclosed unit, 25 feet in diameter and 15 feet in depth. Approximately halfway through the experimental sessions, the experimental apparatus was shifted to a smaller tank, due to schedule maintenance and refurbishing of the larger facility. The small tank is 15 feet in diameter and 12 feet deep. For either facility, water heating was provided by a steam coil maintaining the temperature at $90^{o}F$.

5.2 INSTRUMENTATION BUILDING

The instrumentation required to operate the facility and conduct the experiment was located in a building adjacent to the tanks. All experiment-related activities and test operations were controlled from this building, with television controls, monitor, video recording equipment, communications, and data recording equipment located there. Figure 5.2-1 is a view of the interior of the instrumentation facility showing the test director's station.

The television equipment served the dual purpose of safety monitoring and data collection. In the safety function, two cameras were focused on the test subjects and monitored continuously by both the test director and safety monitor. In the data collection function, selected video was recorded together with an audio input from the test director. This was then available for motor performance analysis and detailed observation of bodily reactions to the force emissions under various restraint conditions.

5.3 PERSONNEL ACCOMMODATIONS

A locker room was provided in an air-conditioned van parked adjacent to the tank. This provided a convenient place for support personnel engaged in the test program to change clothes and for the test subject to suit up.

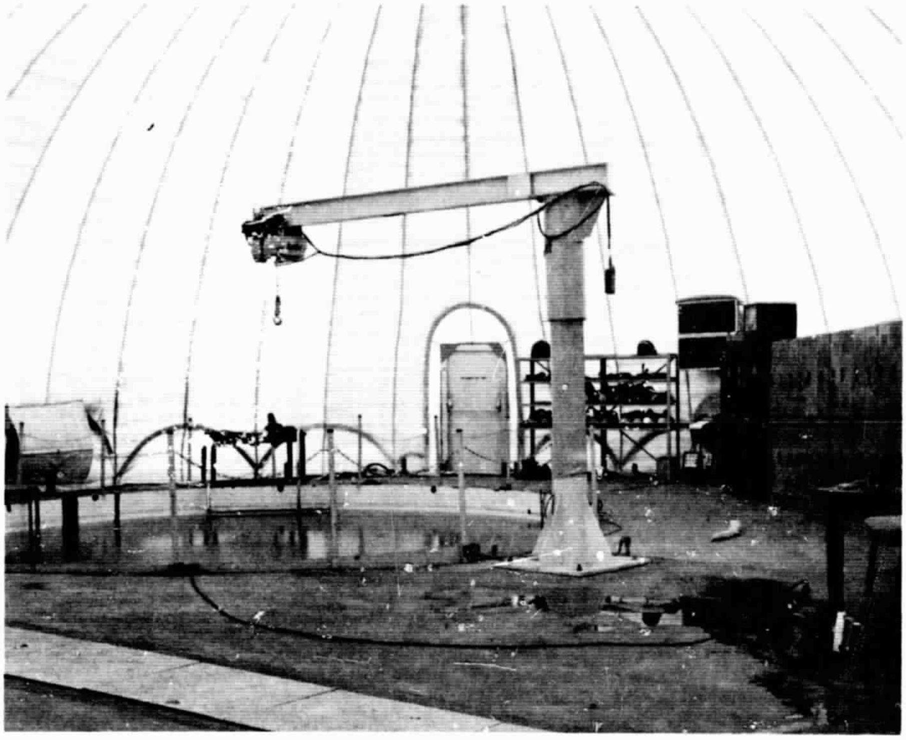


Figure 5.1-1. Neutral Buoyancy Simulation Facility

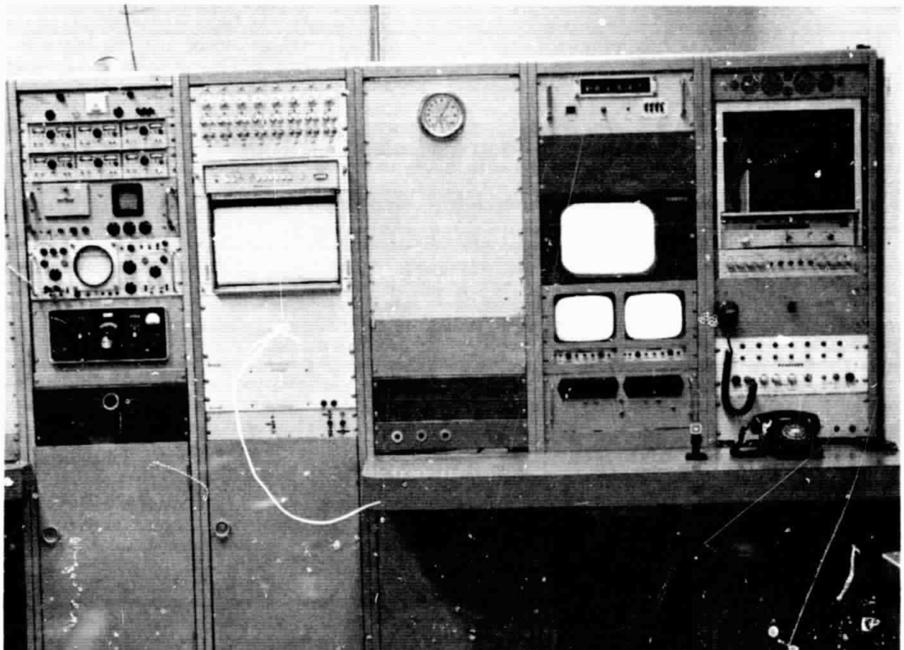


Figure 5.2-1. Instrumentation Facility

SECTION 6

EXPERIMENT 84A - FORCE APPLICATION IN ZERO-G

A detailed description of Experiment 84A, the first to be implemented in this study program, is contained in this section. As stated in Section 3.10, Experiment 84A is a combination of the variables of Experiments 8 and 4 as defined in that section, with modifications as required by the NASA selection committee. These, plus those changes which were necessitated by the more detailed final design and/or operational considerations, are also described in this section.

6.1 INTRODUCTION

One of the most basic demands to be made on man by space systems, present and future, is the requirement to exert forces of various types and directions. The need to remove and stow, assemble and disassemble, and install various structural components, as well as the need to move himself, will require the applications of forces by the space-suited astronaut. The experiment described here is designed to evaluate and quantify man's ability to generate impulsive and sustained forces under a variety of conditions which simulate various modes of restraint and accessibility. The resultant data is of special importance to spacecraft designers since it provides the answers to two essential questions:

a. Given a force generation requirement, what are the accessibility and restraint criteria which must be imposed on the workspace envelope?

b. Given a specific workspace envelope and restraint, what are the force generation capabilities of a space-suited astronaut?

6.2 OBJECTIVES

Measurement of the maximum impulsive and sustained force generation capability of man as a function of the systematic variation of restraint conditions will provide the spacecraft designer with comparative data on the relative values of specific types of restraint systems. By varying the orientation and location of the force receiver, it is also possible to provide comparative data to evaluate the relative effects of accessibility and variations of the work envelope on man's force application capabilities. While the restraint conditions selected for testing are not all applicable to present day spacecraft, this experiment is designed to generate sufficient information to assist the designer in specifying and designing new and better restraint systems than those presently available. The design of an optimum restraint when a desired force emission capability is required will be possible on a quantitative basis if the appropriate data are available. Also, since the astronaut will be provided with a restraint system which controls and limits his movements, the availability of force emission capability data as a function of force receiver location and orientation will assist the designer in the solution of the man/machine interface problems. Therefore, the major objectives of this experiment were to:

a. Measure and evaluate the effects of the restraint system on impulse and sustained force producing capability in zero-g

b. Measure and evaluate the effects of force receiver orientation on impulse and sustained force producing capability in zero-g

c. Measure and evaluate the effects of force receiver distance on impulse and sustained force producing capability in zero-g.

6.3 EXPERIMENT DESCRIPTION

6.3.1 GENERAL DESCRIPTION

This experiment was concerned with determining the effects of zero-gravity on the force-producing capabilities of subjects as a function of the type of restraint and simulated conditions of accessibility. In this study, the restraints were varied in the number and location of the energy sinks provided to the subject. Additionally, the accessibility conditions were evaluated by changing the location and orientation of the force receiver with respect to the subject. The subjects performed all tasks while wearing an Apollo State-of-the-Art spacesuit pressurized to 3.7 psig. Zero-gravity was simulated by the technique of neutral buoyancy submergence described in Section 4.0.

The experimental apparatus, Figure 6.3-1, was designed to provide efficient selection of the experimental condition combinations by an underwater technician. The experimental condition combinations consisted of eight types of restraint (including no restraint), three force

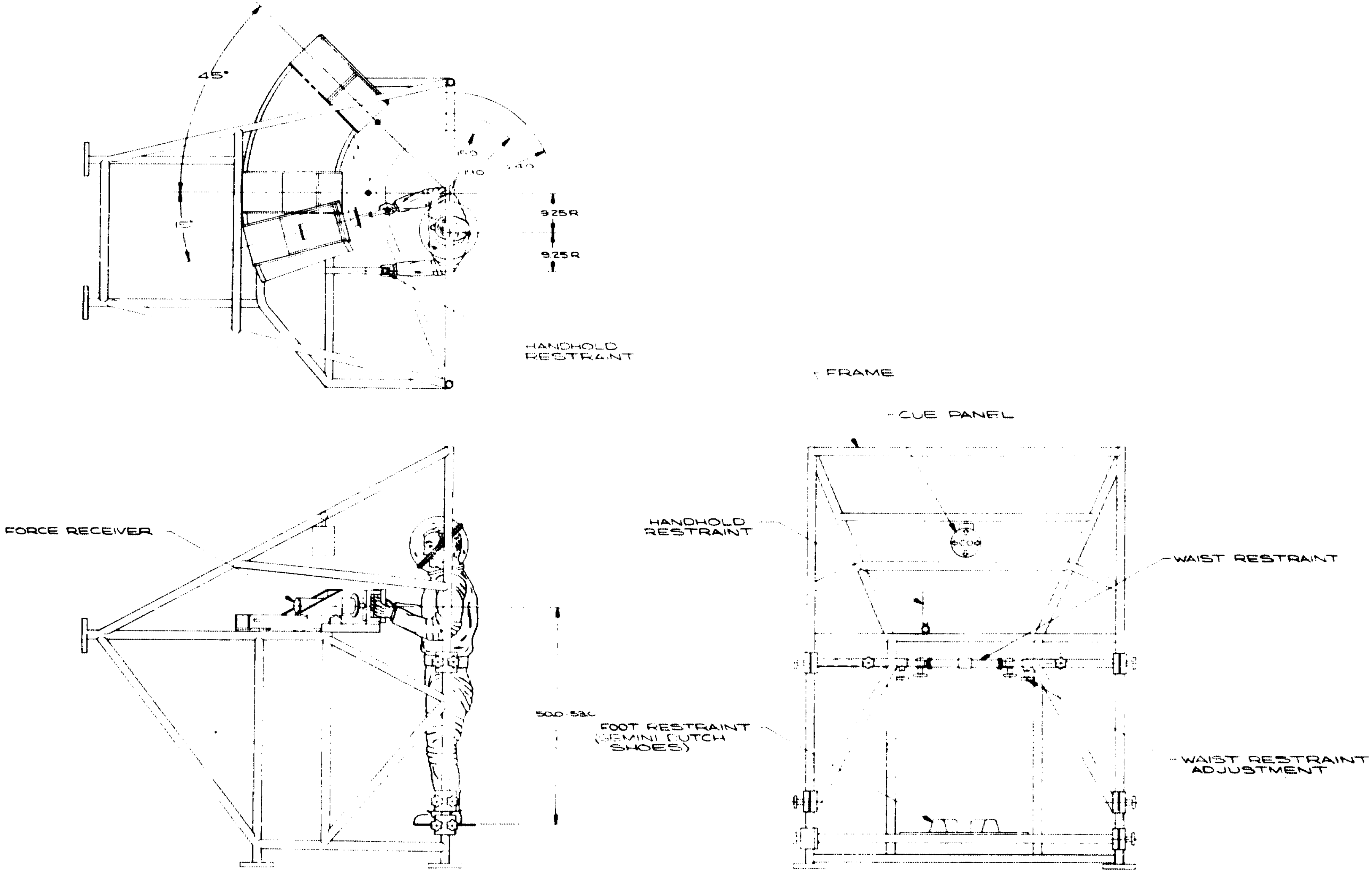


Figure 6.3-1. Experiment 84A Underwater Apparatus

receiver distances, three force receiver angles, and two handle orientations. Maximum impulse and sustained forces were obtained from each of four subjects for each experimental condition. Impulsive forces were defined as the peak forces exerted during a 1.0 second interval, while sustained forces are defined as the minimum force maintained over a 4-second interval. The required forces were applied in push, pull, left, right, up, and down directions, at all force receiver locations.

Prior to each experimental run, the subject was attached to one of the restraint systems and stabilized in front of the force receiver handle. The handle had been previously set at one of the experimental distances and angles, and at a selected orientation. When all personnel were ready, the experimentor initiated signals which displayed on the subjects cue panel the required direction and type of force to be exerted. After a 2-second cue time, a "go" signal was displayed to the subject, who was instructed to exert the appropriate force until the "go" signal extinguished. After a suitable rest period, new cue signals were displayed to the subject, and the above procedure repeated. After performing 12 trials of required force exertions (sustained and impulse forces in all six directions), the handle orientation and/or distance was changed, and a new sequence of 12 trials begun. An experimental session consisted of 96 trials and the experiment required 192 sessions to complete the data collection across all experimental conditions.

6.3.2 EXPERIMENT VARIABLES

The ability of an astronaut to exert forces in a zero-g environment is influenced by several factors, some of which are:

a. Type of restraint system

b. Location and number of restraint attach points

c. Position and location of the body relative to the force receiver

d. Manual or tool assisted force requirements

e. Type of force required - impulse or sustained

f. Direction of force application

g. Location and orientation of force receiver

h. Type of spacesuit

i. Physical size of subjects

j. Suit pressurization method

However, evaluating the effects of all parameters of these variables was beyond the scope of this experiment. The variables selected for investigation in this experiment were:

a. Type of restraint system

b. Receiver angle

c. Receiver distance

d. Receiver orientation

e. Force direction

f. Force type

g. Subject size

h. Suit pressurization method

The ranges of the variables used in this experiment were selected with the intention of establishing the parameters of the principal factors affecting force-emission capability in zero-gravity. These specific variables are defined in detail below.

6.3.2.1 Type of Restraint System

Restraint is perhaps the most important variable affecting force-emission capability in zero-gravity. The effectiveness of any given restraint is due to its efficiency as an energy sink and stabilizer in resisting the effects of the force emitted by the subject in any given direction. The restraints selected for this experiment were those which appear to be most representative of the current thinking on probable types and combinations, and include:

a. None (no restraint)

b. Handhold only

c. Waist only

d. Gemini Dutch shoes only

e. Handhold and waist

f. Handhold and shoes

g. Waist and shoes

h. Handhold, waist, and shoes

The implementation of each of the restraint conditions is described below.

6.3.2.1.1 No Restraint

In this condition, the subject used the left handhold and the force receiver handle to position himself properly in the apparatus. The proper position required that the subject stabilize himself vertically with his right nipple in the plane of the vertical restraint support members, facing forward toward the cue panel, level with the center of the force receiver handle as shown in Figure 6.3-1. Immediately prior to the application of force (during the 2-second cue time), the subject released the left handhold and maintained contact with the force receiver with only the right hand. The safetymen were positioned so that they could prevent the subject from colliding with the apparatus and helped the subject get back into position for the next force application. This assistance from safety personnel in preventing injury to the subject is an integral part of this test condition, since without such aid, the reaction to the forces exerted could have caused injury to the subject or damage to the space suit.

6.3.2.1.2 Handhold Only

In the handhold-only restraint condition, as in the no-restraint condition, protection by safetymen was required. The handhold restraint was located 19 inches forward of the subject's left shoulder, and its center was at the same height as the center of the force receiver handle.

6.3.2.1.3 Waist Only

The waist restraint consisted of a wide fabric belt attached to telescoping metal bars extending from the sides of the support structure. The telescoping bars permitted the positioning of the swivel plates against the side of the pressure suit to prevent rotation around the sagittal axis (yaw). The swivel plates permitted the subject to pitch freely, fore and aft, around the axis formed by the support bars. In the case of "pull" forces which pitched the subject toward the apparatus, the safetymen prevented him from colliding with the apparatus. The height of the waist restraint was adjusted for each subject such that the center of the force receiver handle was level with his right nipple. The waist restraint is shown in Figure 6.3-1.

6.3.2.1.4 Gemini Dutch Shoes Only

The shoe restraint used in this study was the Gemini Dutch Shoes, shown in Figure 6.3-1. The shoes effectively immobilized the subject against up and down movements and provided a pivot point for left right, push and pull forces. The height of the shoe restraint was varied such that the center of the force receiver handle was at the level of the subject's right nipple.

6.3.2.1.5 Handhold and Waist

This restraint was a combination of the handhold and waist restraints and represented a two-point energy sink.

6.3.2.1.6 Handhold and Shoes

This restraint was a combination of the handhold and Dutch Shoe restraints and represented a two-point energy sink that freed both hands for use at a work site.

6.3.2.1.7 Waist and Shoes

This restraint was a combination of the waist and shoe restraints and represented a two-point energy sink that freed both hands for use at a work site.

6.3.2.1.8 Handhold, Waist, and Shoes

This restraint was a combination of the handhold, waist, and shoe restraints and represented a three-point energy sink.

6.3.3 RECEIVER ANGLE

The location of the force receiver in the subject's reach envelope is a major determinant of force emission capability. However, the extremely high number of possible locations prohibits an all-inclusive study of the effects of location. One aspect of location selected for investigation was the horizontal angle subtended by the location of the force receiver with respect to a fixed point on the subject's frontal plane, assuming the subject to be oriented vertically. The origin in this case uses the reference point of the right shoulder, with the arm held straight out being zero degrees. All of the angles used were in the plane which was perpendicular to the sagittal axis and intersect the subject's right nipple. The angles selected were -15 degrees (left), 0 degrees (straight ahead), and +45 degrees (right) as shown in Figure 6.3-1. These angles were selected to bracket the probable range of angles which might be used in space.

6.3.4 RECEIVER DISTANCE

Another aspect of accessibility investigated in this experiment was the distance from the subject to the force receiver. The intent to bracket the range of possible distances can be seen in the theoretical definitions of the three receiver distances chosen for inclusion in this experiment. The distances, called near, medium, and far, were analytically determined to sample the reach envelope permitted by the Apollo State-of-the-Art pressure suit. "Near" was determined to be 15 inches forward of the shoulder reference point and, was defined as the closest position that could reasonably be reached, this resulted in an elbow angle of approximately 90 degrees. "Far" was determined to be 24 inches forward of the shoulder reference point, and was defined as the farthest position that could reasonably be reached, this resulted in an elbow angle of approximately 180 degrees. "Medium" was determined to be 19 inches forward of the reference point and was defined as approximately half-way between the near and far distances, this resulted in an elbow angle of approximately 135 degrees. The actual distance in inches varied slightly between subjects and were restricted slightly by equipment limitations.

6.3.5 RECEIVER ORIENTATION

Studies in 1 g and air-bearing sub-gravity simulation conditions have shown that the orientation of the force receiver handle with respect to a fixed reference point (e.g., local vertical) has significant effects on the force-producing capability of subjects. The two orientations having the greatest effect on force-producing performance were selected for this experiment, and are defined as:

a. 0 degrees (local horizontal)

b. 90 degrees (local vertical)

6.3.6 FORCE DIRECTION

Since force-producing capability varies greatly with the intended direction of force application, subjects in this experiment were asked to generate forces in both directions of the three orthogonal axes defining the location of the force receiver. The directions of force application were:

a. Push

b. Pull

c. Left

d. Right

e. Up

f. Down

6.3.7 FORCE TYPE

Two types of data concerning force-emission capability are especially useful to the designer of advanced space systems. These are impulse and sustained forces, with the former defined as the peak force that is exerted during a 1-second interval, and the latter defined as the minimum force capable of being maintained during a 4-second interval. These time intervals were increased from 0.5 and 3.0 seconds, respectively, as previously defined for Experiments 4 and 8 in Section 3, as a result of pilot studies that demonstrated the response time of pressure-suited subjects to a complex stimulus was between 0.4 and 1.0 seconds. Quantitative data for these two types of force emission will allow the equipment designer to answer the questions:

a. What is the peak force which the astronaut can be depended on to produce in a given condition combination?

b. What force can the astronaut maintain for a reasonable amount of time?

In this experiment, the subject was instructed to exert maximum force in the direction indicated on the cue panel, and to hold this force as long as possible, or unitl the "go" signal extinguished. The cue panel communicated the force type by presenting either the word "impulse" or "sustained" at the same time the instruction for force direction was presented. After the 2-second illuminated cue period, the "go" signal appeared and was maintained one second for impulse trials and 4 seconds for sustained trials. The instruction or cue signal also remained on until the termination of the "go" signal.

6.3.8 SUBJECTS

Six subjects were used in this experiment, four extensively and two as alternates. Three subjects were selected to represent the 50th percentile in height and three the 90th percentile*. The actual subject descriptive data is presented in Table 6.3-1 and summarized below. They ranged from 25 to 39 years in age (mean of 31), from 140 to 178 pounds in weight (mean of 163), and from 5'-10" to 6'-0" in height (mean of 5'-11"). All subjects had high school diplomas or equivalent, one had two years of college, and three had college degrees in engineering.

*Based on Anthropometry of Flying Personnel by Hertzberg, Daniels and Churchill, 1950.

All subjects were experienced SCUBA divers and had been pressure suit indoctrinated. All subjects had passed the Air Force Category III Flight Physical and had normal vision in both eyes.

Table 6.3-1. Subject Anthropometric Data

Subject No.	Age	Weight (pounds)	Height (inches)	Education (years)
1	37	170	72.25	16
2	39	150	70	12
3	33	178	71.50	14
4	30	140	69	16
5	25	165	72	12
6	25	178	70	16

6.3.9 PRESSURIZATION METHOD

Two methods were utilized to provide the required 3.7 psig pressure inside the space suits. The first was an air pressurization system attached to an underwater backpack with inlet and exhaust hoses attached to the suit to provide air flow for cooling and CO_2 removal. In the second a water pressurization system was located in the underwater backpack. This configuration provided continuously pumped water into the suit through a single umbilical and dumped it through preset, parallel dump valves. Both of these systems are described in detail in Section 4.3.

The two pressurization methods were included as an experimental variable in order to provide an initial determination of the differential effects, if any, of the two pressurization modes. This was primarily to evaluate the different simulation techniques and was not a variable which affected force producing capabilities.

6.4 EXPERIMENT APPARATUS

The underwater experiment assembly consisted of a force receiver that converted the forces applied by the subject into electrical output signals, a framework to support the force receiver and provide the proper restraints to the test subject, and a panel to display to the test subject the desired force direction and type. In addition to this equipment, a panel was provided to enable the test director to give instruction to the test subject in the water. Contained as Appendix B are descriptions of this equipment.

6.5 EXPERIMENT SCHEDULING

The large number of experimental conditions selected for investigation required that great care be exercised in scheduling and organizing the test sequences. The experiment was originally designed for 36 operational days, with 768 trials on each day. The four subjects were to be tested in each of the 3,456 experimental condition combinations twice, making a total of 27,648 data points or trials. The randomization of the variables and the schedule revisions are discussed below.

6.5.1 RANDOMIZATION OF VARIABLES

In order to preclude the occurrence of extraneous influences or systematic biases such as transfer-of-training and order-of-presentation effects on the reliability of the data, it would have been desirable to randomize the sequence of all the experimental condition combinations. Numerous practical considerations, however, made complete randomization impractical in that a large number of changes in subjects, suit pressurization method, restraint type, etc., would have extended the schedule beyond all reasonable bounds.

In actuality, the variable combinations were arranged into sessions with 96 force applications (or trials) each, resulting in a total of 288 sessions. Figure 6.5-1 shows a typical session format sheet. A working schedule of eight sessions a day was planned, with each subject participating in two sessions each day. The following constraints were placed on the randomizing, or scheduling, of the experiment:

a. Pressurization method remained constant within a day but was alternated each working day.

EXP 84 FORCE EMISSION CAPABILITY IN ZERO GRAVITY

SUBJECT 4   DAY 4 SESSION 8

REC. ANGLE 45°   DATE ----

PRESS. METHOD AIR   TIME START ---- STOP ----

EXPERIMENTER ----

RESTRAINT Waist

RO= 0° RD= N		RO= 90° RD= M		RO= 90° RD= F		RO= 90° RD= N	
TRIAL	FT/FD	TRIAL	FT/FD	TRIAL	FT/FD	TRIAL	FT/FD
1	I/B	13	S/R	25	S/L	37	I/U
2	S/R	14	I/F	26	I/D	38	I/R
3	I/U	15	I/D	27	S/F	39	S/L
4	S/U	16	S/U	28	I/U	40	S/U
REST 40 SEC		REST 40 SEC		REST 40 SEC		REST 40 SEC	
5	I/D	17	S/F	29	S/B	41	I/D
6	I/L	18	S/B	30	S/U	42	S/R
7	S/D	19	I/U	31	I/B	43	S/F
8	S/L	20	I/R	32	I/L	44	I/L
REST 40 SEC		REST 40 SEC		REST 40 SEC		REST 40 SEC	
9	I/R	21	I/B	33	S/D	45	S/D
10	S/F	22	S/D	34	I/R	46	I/F
11	S/B	23	I/L	35	I/F	47	S/B
12	I/F	24	S/L	36	S/R	48	I/B
REST 2 MIN		REST 2 MIN		REST 2 MIN		REST 4 MIN	

RESTRAINT Hand Hold & Foot

RO= 90° RD= M		RO= 90° RD= N		RO= 0° RD= M		RO= 0° RD= F	
TRIAL	FT/FD	TRIAL	FT/FD	TRIAL	FT/FD	TRIAL	FT/FD
49	S/D	61	S/L	73	S/U	85	I/R
50	I/L	62	S/D	74	I/D	86	S/D
51	S/L	63	I/F	75	I/R	87	I/D
52	I/D	64	I/B	76	S/D	88	S/L
REST 40 SEC		REST 40 SEC		REST 40 SEC		REST 40 SEC	
53	I/R	65	I/U	77	S/F	89	I/L
54	I/F	66	S/R	78	S/B	90	S/U
55	S/F	67	I/R	79	I/F	91	S/R
56	S/U	68	S/F	80	I/L	92	I/F
REST 40 SEC		REST 40 SEC		REST 40 SEC		REST 40 SEC	
57	S/R	69	I/D	81	I/B	93	S/F
58	I/B	70	S/B	82	I/U	94	I/B
59	S/B	71	S/U	83	S/L	95	I/U
60	I/U	72	I/L	84	S/R	96	S/B
REST 2 MIN		REST 2 MIN		REST 2 MIN			

LEGEND

RO = RECEIVER ORIENTATION (0°, 90°)	I = IMPULSE	U = UP
RD = RECEIVER DISTANCE	S = SUSTAINED	D = DOWN
FT = FORCE TYPE	N = NEAR DISTANCE (15'')	L = LIFT
FD = FORCE DIRECTION	M = MEDIUM DISTANCE (19'')	R = RIGHT
	F = FAR DISTANCE (24'')	F = FORWARD (PUSH)
		B = BACK (PULL)

Figure 6.5-1. Typical Session Format Sheet

b. The testing order of the four subjects was random for the first four sessions each day but the same order was repeated for the second four sessions each day.

c. The receiver angle remained constant within each session but was random across sessions.

d. Restraints remained constant within each half session (48 trials) but were randomly assigned across half sessions.

e. Receiver orientation and receiver distance remained constant within each block of 12 trials, but were randomly assigned across blocks of 12 trials.

f. Within each block of 12 trials every combination of force type and force direction occurred. The order of presentation was random within each block of 12, with the restriction that within each four trials (i.e., 1–4, 5–8, 9–12) two sustained trials and two impulse trials occurred.

Rest periods were spaced throughout the session to minimize fatigue effects. Table 6.5-1 shows the resulting protocol.

6.5.2 SCHEDULE REVISIONS

Operational constraints and problems required a number of revisions to the original experiment schedule which was developed in accordance with the procedure described in Section 6.5.1. These revisions resulted basically in a change in the running order of subjects and the number of replications of each trial point.

6.5.2.1 Subject Order Revisions

The completely random order of test subjects was constrained to meet the requirement that two subjects (1 and 2) be scheduled first during each day because of their availability only from 7:00 A.M. to 3:30 P.M. The other two subjects (3 and 4) were always scheduled last because of their availability from 9:30 A.M. to 6:00 P.M. In addition, the limited availability of Apollo State-of-the-Art pressure suits required that the two 90th percentile subjects (1 and 3) alternate with the two 50th percentile subjects (2 and 4) to reduce session changeover times. These revisions resulted in only two possible subject running orders: 1, 2, 3, 4 or 2, 1, 4, 3. It was decided to use one running order for two days then alternate with the other running order for two days.

Table 6.5-1. Sample Experiment Protocol

Time	Activity	Time (sec)	Location	Personnel
0730	Suit up Subject 1		Suit Room	S_1, SM_1
0730	Perform equipment activation check list		Control Room	TD
0740	Record environmental measures Air temp, water temp, water clarity, humidity, illumination level		Tank	TD
0740	Perform equipment calibration			ET_1, ET_2
0750	Perform suit/backpack operational check Verify suit pressure integrity and satisfactory operation of backpack		Suit Room	S_1, SM_1
0800	Prepare subject for experimental session		Tank	S_1, SM_1, ET_1
	Enter tank and go to test apparatus		Tank	S_1, SM_1
	Attach S1 to restraint 1		Tank	SM_1, ET_1
	Stabilize S1 in initial Expt 1. position		Tank	SM_1
	Take positions at experiment stations		Tank	SM_1, ET_1
0812	Conduct experiment session 1		Control Room and Tank	TD, S_1, SM_1, ET_1
	1. Run 1			
	Program push impulse		Control Room	TD
	Apply push impulse	1.0	Tank	S_1
	Rest	9.0	Tank	S_1
	Program push sustained		Control Room	TD
	Apply push sustained	4.0	Tank	S_1
	Rest	9.0	Tank	S_1
	Program pull impulse		Control Room	TD
	Apply pull impulse	1.0	Tank	S_1
	Rest	9.0	Tank	S_1
	Program pull sustained	4.0	Control Room	TD
	Apply pull sustained	40.0	Tank	S_1
	Rest		Tank	S_1
	Program up impulse	1.0	Control Room	TD
	Apply up impulse	9.0	Tank	S_1
	Rest		Tank	S_1
	Program down impulse	1.0	Control Room	TD

Table 6.5-1.A

FOLDOUT FRAME

Apply up impulse	9.0	Tank	S_1
Rest		Tank	S_1
Program down impulse	1.0	Control Room	TD
Apply down impulse	9.0	Tank	S_1
Rest		Tank	S_1
Program up sustained	4.0	Control Room	TD
Apply up sustained	9.0	Tank	S_1
Rest		Tank	S_1
Program down sustained	4.0	Control Room	TD
Apply down sustained	40.0	Tank	S_1
Rest		Tank	S_1
Program left impulse	1.0	Control Room	TD
Apply left impulse	9.0	Tank	S_1
Rest		Tank	S_1
Program right impulse	1.0	Control Room	TD
Apply right impulse	9	Tank	S_1
Rest		Tank	S_1
Program left sustained	4.0	Control Room	TD
Apply left sustained	9.0	Tank	S_1
Rest		Tank	S_1
Program right sustained	4.0	Control Room	TD
Apply right sustained		Tank	S_1

TOTAL (191 secs.)

2.	Rotate force receiver handle (2 minutes) and change distance	Tank	ET_1
3.	Run 2 (Repeat run 1, change order) (191 seconds)	Control Room/ Tank	TD, S_1
4.	Rotate force receiver handle (2 minutes) and change distance	Tank	ET_1
5.	Run 3 (Repeat run 1, change order) (191 seconds)	Control Room/ Tank	TD, S_1
6.	Rotate force receiver handle (2 minutes) and change distance	Tank	ET_1
7.	Run 4 (Repeat run 1, change order) (191 seconds)	Control Room/ Tank	TD, S_1
8.	Attach S_1 to restraint 2 change	Tank	S_1, ET_1, SM_1

FOLDOUT FRAME

TABLE 6.5-1.B

	7. Run 4 (Repeat run 1, change order) (191 seconds)	Control Room/ Tank	TD, S_1
	8. Attach S_1 to restraint 2 change receiver orientation and distance and rest (4 minutes)	Tank	S_1, ET_1, SM_1
	9. Repeat steps 1-7 on restraint 2 (18 minutes)	Control Room/ Tank	TD, S_1, ET_1
0830	Suit up subject 2	Suit Room	S_2, SM_2
0850	Perform suit/backpack operational check Verify suit pressure integrity and satisfactory operation of backpack	Suit Room	S_2, SM_2
0900	Complete experiment session 1 Remove S_1 from restraint and vacate water	Tank Suit Room	TD_1, S_1, SM_1, ET_1 S_1, SM_1, ET_1
0900	Prepare subject for experimental session Enter tank and go to test apparatus Attach S_2 to restraint 2 Stabilize S_2 in initial Expt 1 position	Tank	S_2, SM_2, ET_2
0912	Conduct experiment session 2 (See time 0812)	Control Room and Tank	TD, S_2, SM_2, ET_2

Legend

S - Subject
SM - Safety Monitor
TD - Test Director
ET - Experiment Technician
Subscripts are specific personnel identifiers

TABLE 6.5-1C

FOLDOUT FRAME

6.5.2.2 Replication Number Revisions

The original protocol design called for two replications of each experimental condition combination for a total of 288 sessions. Due to the considerable number of delays resulting from equipment failures and personnel problems, it was decided to terminate the experiment after obtaining only one replication of each condition combination and evaluate the feasibility of pooling two of the experimental conditions, specifically pressurization method and subjects.

Combining the data collected under the conditions of water and air pressurization modes appeared to be justified on the basis of preliminary data analysis and from the test directors' constant visual monitoring of the oscillographic tapes. In addition, it was decided that the percentile groupings of the subjects could be combined. This pooling of the subject factor also appeared to be justified from preliminary analysis of the data. This was because the subjects did not appear to represent a 50th and 90th percentile grouping, on the basis of force-emission capability, although they did represent the 50th and 90th percentile in height. Subsequent statistical analysis, presented in Section 6.7, confirmed these decisions.

After the decision to combine experimental conditions was made, it was found that 84 percent of the data for the first replication had been collected. For the remaining portion of the data, a revised session format was used. In the new session format the restraint remained constant for only 24 trials, as compared to 48 trials in the original sessions. Otherwise the session format remained unchanged. Approximately 14 percent of the data was collected under this new session format.

When the computer reduction of the data was completed, it was found that some data were missing due to instrumentation problems or excessive noise on the analog tape. These missing data, approximately 2 percent, were collected during make-up sessions using approximately the same session format, but with more frequent changes of the experimental variables.

6.6 INSTRUMENTATION

The instrumentation utilized in this experiment was designed to provide for computerized data reduction as well as real time monitoring of the data by the test director. These capabilities were provided by the use of magnetic tape and oscillographic recordings of both the instructions to the test subject and the outputs of the force receiver transducers. In addition to recording the applied force in the command direction, the forces in the other two axes were also recorded, to provide a measure of the error forces. Figure 6.6-1 is a block diagram of the instrumentation used.

6.6.1 CONTROL PANEL

A description of the operation of the control panel is in Appendix B and will not be repeated here except to note that the programmed instructions to the test subject in the water were recorded simultaneously on the magnetic tape and oscillographic recorders.

6.6.2 MAGNETIC TAPE RECORDING

The outputs of the force receiver transducers were recorded on channels 1-3 of an Ampex Model CP-100 recorder, with the remaining channels used to record identifying information for the computer and verbal comments made by the test direction. Channels 4 and 5 contained the trial identification numbers as listed on the session format sheet in Figure 6.5-1. The "go" signal, which was recorded on channel 7 was a 4-second or 1-second full-scale deflection that served to indicate a commanded force as "sustained" or "impulsive," respectively. Channel 8 identified the command force direction by coding as one of six discrete voltage levels, ranging from zero to full scale. Channels 9 and 10 recorded the IRIG "B" time code and the force receiver handle orientation.

The abort signal recorded on channel 11 was used to indicate to the computer that a particular trial should be discarded from the data processing. This was done to prevent erroneous data from being incorporated in the data output and to save unnecessary computation time. A digitizing signal (channel 12) served as a command signal for the A-D converter, beginning 2 seconds before the "go" signal and ending 1 second after the termination of the "go" signal. The data were later digitized during this 7 second (for sustained forces) or 4 second

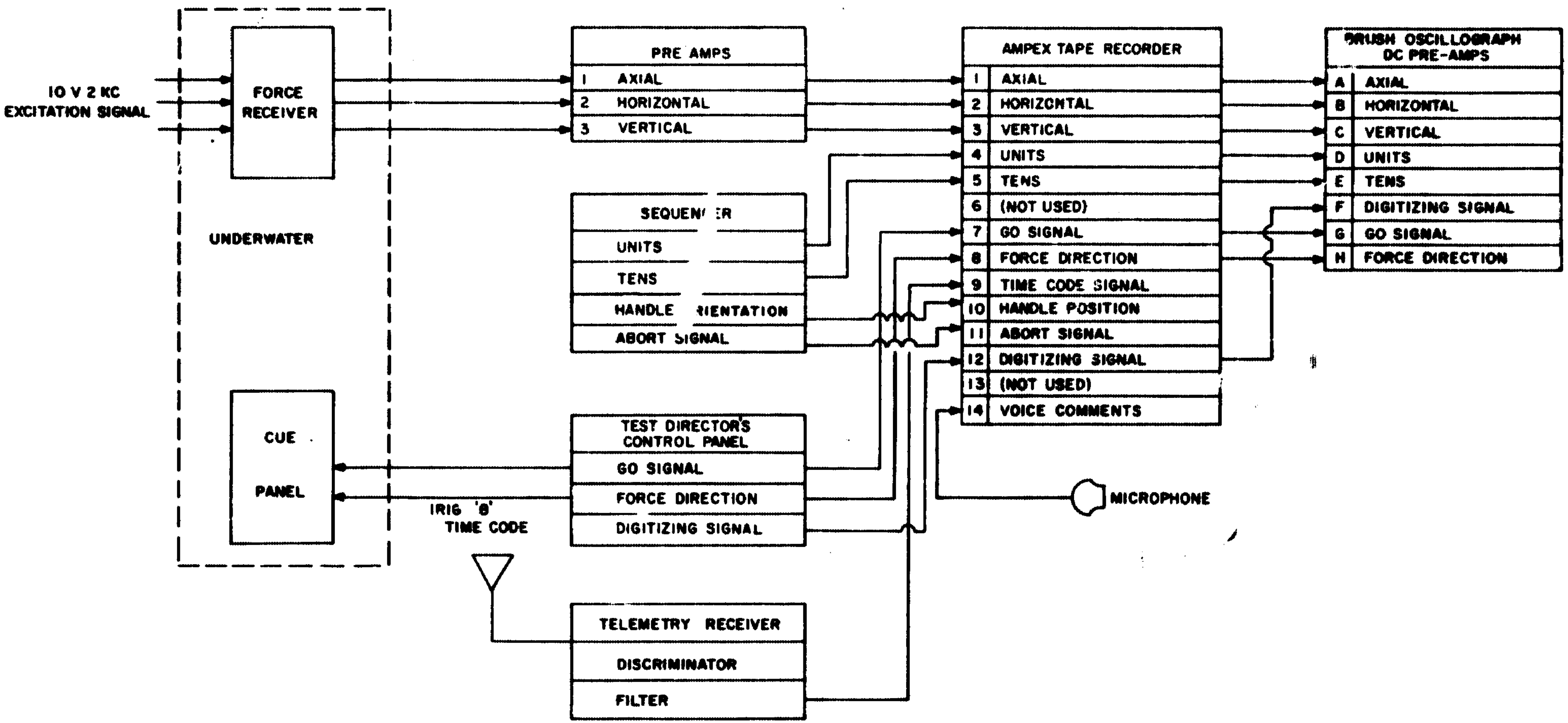


Figure 6.6-1. Instrumentation Block Diagram

(for impulsive forces) period, at a rate of 100 samples per second. Channel 14 was used to record verbal comments by the test director. Channels 6 and 13 were unused spares.

6.6.3 OSCILLOGRAPHIC RECORDING

Real time viewing of the data was provided by an 8-channel oscillographic recorder. The inputs to this recorder were obtained from selected playback heads of the analog tape recorder so that the test director could continuously monitor the status of pertinent recorded data. This was especially important in order to detect zero-level shifts in recording channels. Figure 6.6-2 is a sample of the oscillographic recording made during one of the sessions, at a paper speed of 2 mm/second. This section contains 8 of the 96 trials from Session 5, Day 16. The experimental conditions being used in this session were:

Pressurization Method:	Water
Restraint:	Hand Only
Receiver Angle:	45°
Receiver Orientation:	Vertical
Receiver Distance:	Far

The trial numbers, reading from right to left, are 17 through 24. As is seen in Figure 6.6-2, the force direction instruction, Channel H, indicates the command force direction according to the height of the pulse. Channel G records the "go" signal on and off, and also indicates the 2-second cue period described in Section 6.4. This channel also shows the 9-second rest period within the groups of 4 trials and the 40-second rest period between the groups of 4 trials. Channel F is the computer digitizing pulse which provides a rapid visual indication of the comparative span of data (across all channels) which will be accepted by the computer. Channels D and E record the trial number and Channels A, B, and C record the actual deflection of the transducers during a force application.

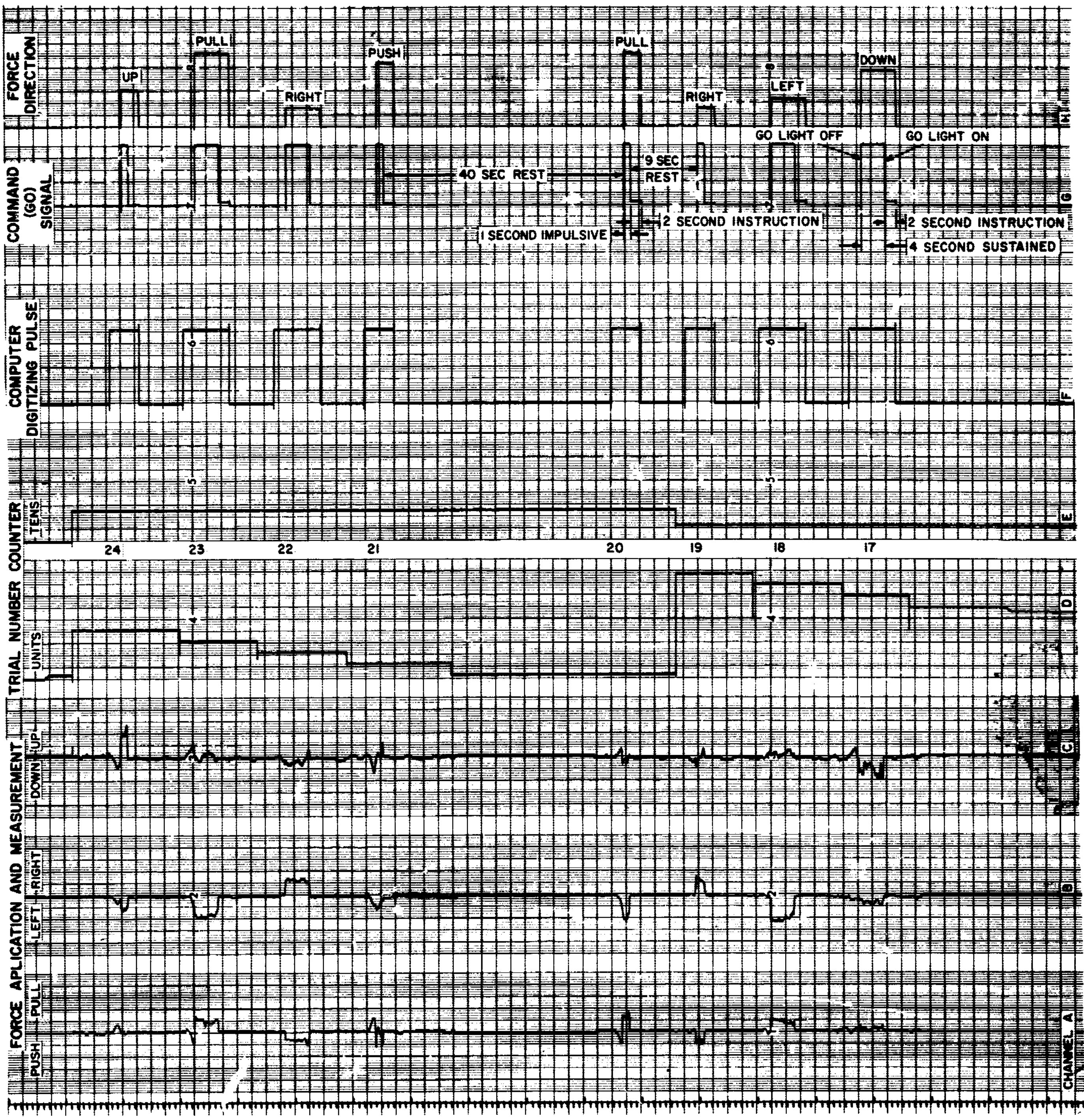


Figure 6.6-2. Sample Oscillographic Recording

6.6.4 TRANSDUCERS

A key element in the instrumentation system was the force transducers. These were linear motion differential transformers, electromechanically proportional to the displacement of a movable core. The output of the transducer had infinite resolution over its specified range, as displacement of the movable core on either side of a null point produced an increasing voltage directly proportional to the distance moved.

6.6.5 INSTRUMENTATION SYSTEM CALIBRATION

Calibration of the instrumentation system was performed each day prior to the start of the first experiment session. This consisted of attaching accurate weights to a holder which was attached to the force receiver handle. Weights were added in 5-pound increments up to 20 pounds, and then 10-pound increments up to 80 pounds. The calibration was performed for all three axes. During the calibration, the excitation voltage of each transducer was adjusted so that, after amplification, the output at full scale deflection was 1.0 volts, and was linear over the full range.

6.7 DATA REDUCTION

The data collection and recording system were described in Section 6.6. The important output of this system is the analog tape which contained all force data as well as identifiers of particular session conditions. These tapes formed the input to the data reduction system, as illustrated in Figure 6.7-1.

In the analog-digital conversion process, the following channels were digitized:

a. Axial force data

b. Horizontal/Vertical* force data

c. Vertical/Horizontal* force data

d. Trial number, units

e. Trial number, tens

---

*Depends on force receiver handle orientation

f. Go signal

g. Force direction

h. Force receiver orientation

i. Abort signal

Digitizing was performed by command of the 7-second (for sustained forces) and 4-second (for impulsive forces) digitizing pulse on channel 12. A sampling rate of 400 samples per second was used; however, since the analog tapes were played at a speed 4 times greater than the record speed, the effective sampling rate was 100 samples per second. Low-pass filters were applied to all channels, except channel 10, to eliminate as much noise as possible from the analog tapes. The filters had a cut-off frequency of 100 Hz, but the effective cut-off was at 25 Hz, due to the 4-to-1 ratio of playback speed to record speed. Neither the sampling rate nor the filter cut-off frequency caused any significant loss of data.

The digitized tapes then formed the input to the first of two computer programs, known as the Daily Output Program. The objective of this program was to provide a printout of the force data recorded for every trial in the experiment. A sample of the output of this program is shown in Figure 6.7-2. The program consisted of the following sequential operations:

a. The digitized data was numerically converted into forces in pounds

b. "Header cards," containing identification data not included on the tapes, (day, session, subject, pressurization method, receiver angle, and receiver distance), were read into the computer and combined with the proper data

c. Data was outputted in blocks of 12 trials, with a complete set of identifiers

Possible error messages were also printed out where applicable, and an editing feature was available for use, where necessary, to correct for errors.

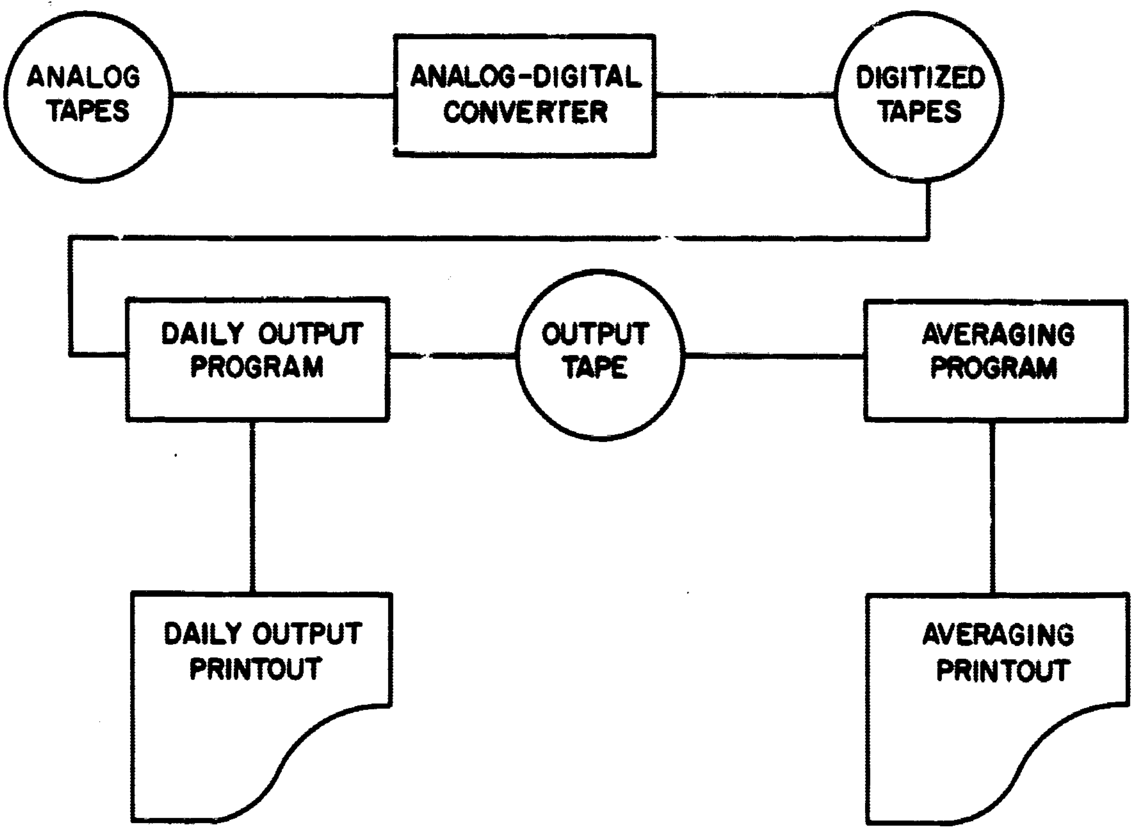


Figure 6.7-1. Data Reduction Block Diagram

Figure 6.7-2 illustrates the data printout for the first 12 trials of Day 18, Session 5. The force type and direction (command), as well as the handle orientation, in this case horizontal, are printed out for each trial. The significance of the printout headings of "MIN," "MAX," and "FIN" is explained below.

For sustained forces

a. In the correct (commanded) force direction:

- MAX is the largest force during the entire 4 second period the GO-light is on.

- MIN is the smallest force encountered during the last 3 seconds of the GO-signal <u>unless</u> the force changes sign (i.e., goes from positive to negative or vice-versa) in which case the minimum force is defined as zero.

- FIN is the force at GO-signal cut-off.

DAY 18
SESSIØN 5
BLØCK 1

DAY 18 SESSIØN 5 SUBJECT 1

PRESSURIZATIØN METHØD - WATER RESTRAINT - HAND,WAIST AND SHØES

RECEIVER ANGLE = 45 DEGREES RECEIVER ØRIENTATIØN - HØRIZØNTAL RECEIVER DISTANCE - NEAR

	TRIAL	TYPE	DIRECTIØN	FØRCE	XMIN	XMAX	YMIN	YMAX	ZMIN	ZMAX	FIN	
	1	SUS.	DØWN HØRIZ.	-Z	-6.33	1.55	-3.38	-0.17	-13.97	-14.47	-14.47	
	2	SUS.	RIGHT HØRIZ.	+Y	-27.32	-4.53	19.52	26.12	1.90	4.42	19.87	••
	3	IMP.	LEFT HØRIZ.	-Y	-16.55	1.55	0.00	-22.13	4.42	6.77	3.04	
••	4	IMP.	RIGHT HØRIZ.	+Y	-16.96	-0.11	1.39	29.93	-0.71	6.43	1.47	
••	5	IMP.	UP HØRIZ.	+Z	0.72	4.17	-3.73	0.87	6.10	27.59	6.26	
••	6	SUS.	LEFT HØRIZ.	-Y	-3.98	0.72	-15.88	-19.87	5.76	8.11	-16.05	
••	7	SUS.	PUSH HØRIZ.	-X	-43.49	-55.09	0.69	3.38	3.58	7.10	-49.43	
••	8	IMP.	PUSH HØRIZ.	-X	0.00	-53.02	-0.26	3.82	4.50	8.28	1.55	
	9	SUS.	PULL HØRIZ.	+X	42.30	53.76	-1.56	1.82	5.09	9.54	47.82	
	10	IMP.	DØWN HØRIZ.	-Z	1.53	5.41	-0.69	2.08	0.00	-23.21	6.10	
	11	IMP.	PULL HØRIZ.	+X	1.82	54.73	-9.20	2.43	1.06	9.29	7.21	
	12	SUS.	UP HØRIZ.	+Z	1.53	12.74	-2.43	0.35	16.25	26.16	26.16	

Figure 6.7-2. Sample of Daily Output Program

b. In the error axes:

- MAX is the largest force in either direction of an axis during the middle 3 seconds of GO-light

- MIN is the smallest force in either direction of an axis during the middle 3 seconds of GO-light

For impulsive forces

a. In the correct (commanded) force direction:

- MAX is the largest force that occurs for the 1 second the GO-light is on and 1 second afterwards, i.e., for a 2 second period.

- MIN is the smallest force which occurs during this period

- FIN is the force at GO-signal cut-off

b. In the error axes:

- MAX is the largest force in either direction of an axis while the GO-light is on

- MIN is the smallest force in either direction of an axis while the GO-light is on

Two of the four error message capabilities of the program are illustrated in the figure. The double asterisk (**) at the left of trials 4-8 indicates that the trial number on the digitized tape (and hence on the analog tape) does not agree with a sequentially increasing counter in the program. This is important to note, since this could result in a header card being combined with the wrong block of 12 trials.

The double asterisk on the right of the FIN column indicates that the force in the commanded direction for that trial is not the largest (in absolute value) force, i.e., an error force which is larger than the correct force has occurred. This message was required so that subject response errors could be detected and removed before final data analysis.

The program contains two other message capabilities which are not illustrated here. The twelve combinations of force type and force direction should occur once every twelve trials. In the event that a combination has not occurred, a message was printed stating what is missing. To the right of the force type-force direction columns, the word "HORIZ." appears, indicating a Horizontal force receiver orientation was recorded on the tape. The header card for this block also indicates this information. If these two do not agree, an error message is printed out. This is most important, since if the orientation is not indicated correctly the X- and Z-axis data will be interchanged.

These errors may result either from test director errors or from misinterpretation by the computer of the tape (due to noise, etc.). The last step of the program, the editing feature, allows for correction of errors when necessary. Punched cards with the correct information could be entered into the computer; when entered these cards tool precedence over any other input.

After all the data from the experiment had been processed by the Daily Output Program, a composite output tape was prepared. This tape contained all the information necessary to identify the conditions for all experimental trials and all the data associated with these trials. This tape then formed the input to the second computer program, the Averaging Program. This program provided the capability to average various combinations of experimental conditions. In particular, the following conditions could be averaged, either separately or in any combination:

- Subject
- Pressurization method
- Receiver angle
- Receiver distance
- Receiver orientation
- Restraint

A sample of the printout from the Averaging Program is shown in Figure 6.7-3. The asterisks (*) next to Subject and Pressurization Method indicate that these were the common factors for which all data points were considered; i.e., the data listed is an average of all the points which exist for all four subjects utilizing both the water and air suit pressurization methods. The numbers in parentheses to the right of the data indicate the number of trials contained in the average for the particular combination of force type and force direction and of the other specified conditions.

The meaning of "Range" in this data is best illustrated by an example. In the first column of data on Figure 6.7-3, it can be seen that a Sustained-Push force occurred six times under the conditions listed. For each of these trials, the Daily Output Program noted the minimum force which occurred, as previously defined. The Range shows that the minimum force for this condition ranged from 20.22 to 56.09 pounds, with a mean of 39.64 pounds. The interpretation of the remaining columns is similar.

Although the composite tape contains error forces, only the command direction forces are presented here. Furthermore, only the maximum forces in the impulse mode are presented. A graphic presentation of the mean and ranges of all experimental data is given in Section 6.8. A tabular listing of all means and ranges is given in Appendix A.

EXPERIMENT 84A FORCE EMISSION CAPABILITY IN ZERO GRAVITY CONTRACT NAS8-18117

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND, WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	50.37	31.96	64.43	75.97	39.58	92.40	(10)	76.09	50.12	90.58	(10)
PULL	28.85	0.00	48.33	48.70	30.85	81.58	(10)	51.58	22.67	66.93	(10)
UP	17.11	6.89	24.95	25.66	9.11	46.87	(9)	24.60	9.36	42.59	(9)
DOWN	18.86	7.37	31.39	27.54	11.34	40.89	(10)	26.76	10.94	39.35	(9)
RIGHT	20.59	3.85	38.58	36.17	24.28	49.87	(11)	36.76	25.51	46.78	(9)
LEFT	16.09	1.38	29.33	32.83	20.97	45.45	(9)	28.91	12.30	47.12	(10)

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	39.64	20.22	56.09	57.40	36.75	72.80	(6)	68.00	50.17	87.40	(7)
PULL	22.26	0.00	41.06	39.62	8.12	56.77	(8)	42.33	17.47	61.91	(8)
UP	16.04	2.04	24.52	23.86	4.88	36.05	(9)	22.80	8.55	32.62	(9)
DOWN	16.95	4.49	30.95	22.47	9.06	31.70	(9)	27.29	11.97	48.32	(9)
RIGHT	20.45	11.17	27.17	30.59	18.12	45.16	(8)	32.10	17.63	43.04	(8)
LEFT	22.20	13.82	34.87	33.53	22.[illegible]	51.93	(8)	35.85	27.16	51.08	(8)

Figure 6.7-3. Averaging Program Sample Printout

6.8 RESULTS AND CONCLUSIONS

6.8.1 METHODS OF ANALYSIS

The primary results of this experimental program are the means and ranges of the forces exerted under specific combinations of the experimental conditions. These means and ranges were derived from the Averaging Program described in Section 6.7 and are provided in a tabular listing in Appendix C. This listing, consisting of approximately 100 pages of tabulated information, provides all the design data collected in this study. However, the tabular listing is not the most efficient mode of data presentation for use by designers. The value of the data collected can only be realized by presentation in as efficient and utilitarian manner as possible. The resulting graphical presentation summarized the total data into 12 charts with 6 graphs on a page. These are presented in Figures 6.8-1 through 6.8-12. Table 6.8-1 is a Summary Data Chart Index that specifies the experimental condition combinations included on each of the charts.

Table 6.8-1. Summary Data Chart Index

Figure	Title	Force Type (F/T)	Receiver Angle (R/A) (degrees)	Receiver Orientation (R/O)
6.8-1	Summary Data Chart No. 1	Sustained	0	Horizontal
6.8-2	Summary Data Chart No. 2	Sustained	0	Vertical
6.8-3	Summary Data Chart No. 3	Sustained	-15	Horizontal
6.8-4	Summary Data Chart No. 4	Sustained	-15	Vertical
6.8-5	Summary Data Chart No. 5	Sustained	45	Horizontal
6.8-6	Summary Data Chart No. 6	Sustained	45	Vertical
6.8-7	Summary Data Chart No. 7	Impulse	0	Horizontal
6.8-8	Summary Data Chart No. 8	Impulse	0	Vertical
6.8-9	Summary Data Chart No. 9	Impulse	-15	Horizontal
6.8-10	Summary Data Chart No. 10	Impulse	-15	Vertical
6.8-11	Summary Data Chart No. 11	Impulse	45	Horizontal
6.8-12	Summary Data Chart No. 12	Impulse	45	Vertical

In addition to the primary design data discussed above, statistical comparisons were made across parameters of the experimental variables to determine the existence and direction of significant relationships. The data used for the statistical comparisons were the overall mean forces determined across experimental conditions and are presented in Table 6.8-2.

Nonparametric statistical analyses were considered appropriate for the analysis of these data because of the inability to meet the assumptions concerning the underlying distribution of the population of variables required by parametric analysis. Certain assumptions are also associated with most nonparametric statistical tests, i.e., that the observations are independent and that the variables under study have some underlying continuity, but these assumptions are fewer and more easily met than those for parametric tests. Moreover, most nonparametric tests apply to data in an ordinal scale, and some even apply to data in a nominal scale. The primary advantage of the nonparametric tests is that they can be used when the sample size is small.

Two nonparametric statistical analysis methods were selected for the data analysis. In situations where matched pairs of measures occur in two groups and the measures are in an ordinal scale, Siegel, 1956, recommends the use of the Wilcoxon Matched-Pairs Signed Ranks Test. This method was utilized to compare the following parameters: overall means across force types (sustain and impulse), mean forces across pressurization methods (air and water), and mean forces across receiver orientations (horizontal and vertical). In situations where K related samples of basically nonparametric measures on at least an ordinal scale are taken, Siegel recommends the Freedom Two-way Analysis of Variance. This method was utilized to compare the following parameters: mean forces across subjects, mean forces across receiver angles, mean forces across receiver distances, and mean forces across restraints.

6.8.2 STATISTICAL ANALYSES AND RESULTS

6.8.2.1 Sustained Versus Impulsive Forces

The results of the Wilcoxon Matched Pairs Signed Ranks Test indicate that the sustained mean forces were significantly different from the impulsive mean forces at the 0.01 level

	Overall	
	Sustain Min	Impulse Max
Push	20	52
Pull	21	51
Up	12	25
Down	16	29
Right	12	23
Left	14	26

	Subjects						
	1		2		3		4
	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min
Push	18	51	24	51	21	59	16
Pull	24	58	24	49	18	54	18
Up	12	26	15	26	13	27	10
Down	11	25	18	29	21	36	12
Right	9	20	14	25	13	29	9
Left	11	23	16	27	16	32	11

	Receiver Angle					
	-15^{o}		0^{o}		45^{o}	
	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max
Push	18	49	19	51	22	54
Pull	20	51	19	50	23	53
Up	13	26	13	25	12	24
Down	17	31	15	28	15	27
Right	13	25	12	24	10	21
Left	15	28	14	27	12	24

	Receiver D		
	Near		Mediu
	Sustain Min	Impulse Max	Sustain Min
Push	23	53	20
Pull	17	46	21
Up	14	27	12
Down	16	29	16
Right	12	24	11
Left	15	28	13

	Restraints										
	None		Hand		Waist		Shoes		Hand & Waist		Hand & Sh
	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min
Push	0	35	1	41	15	43	4	46	29	57	30
Pull	0	43	2	43	22	46	4	48	31	51	33
Up	0	19	5	21	10	23	17	28	14	23	18
Down	2	23	9	26	10	23	21	33	16	26	26
Right	0	18	10	22	12	22	9	22	15	25	16
Left	0	18	17	29	12	22	8	23	17	28	21

All Forces in Pounds

FOLDOUT FRAME

TABLE 6.8-2A

Table 6.8-2. Summary Data - Means Across all Variables (in pounds)

3		4	
...ain ...n	Impulse Max	Sustain Min	Impulse Max
	59	16	45
	54	18	45
	27	10	22
	36	12	24
	29	9	19
	32	11	23

	Pressurization			
	Air		Water	
	Sustain Min	Impulse Max	Sustain Min	Impulse Max
Push	20	52	20	51
Pull	22	53	20	50
Up	13	25	12	25
Down	15	27	16	30
Right	12	23	12	23
Left	14	27	13	26

Receiver Distance					
Near		Medium		Far	
...in ...n	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max
	53	20	52	17	49
	46	21	52	25	56
	27	12	25	11	24
	29	16	29	15	28
	24	11	24	11	22
	28	13	26	13	25

	Receiver Orientation			
	Horizontal		Vertical	
	Sustain Min	Impulse Max	Sustain Min	Impulse Max
Push	20	53	19	50
Pull	21	50	21	52
Up	11	21	14	30
Down	14	26	17	31
Right	15	29	9	18
Left	14	26	14	26

...nts						
... & Waist	Hand & Shoes		Waist & Shoes		Hand, Waist & Shoes	
Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max	Sustain Min	Impulse Max
57	30	62	35	58	43	69
51	33	61	37	57	38	61
23	18	31	17	28	17	29
26	26	37	19	30	21	32
25	16	28	14	23	16	27
28	21	34	15	25	19	30

...in Pounds

FORCE TYPE: **SUSTAIN**

RECEIVER ANGLE: **0°**

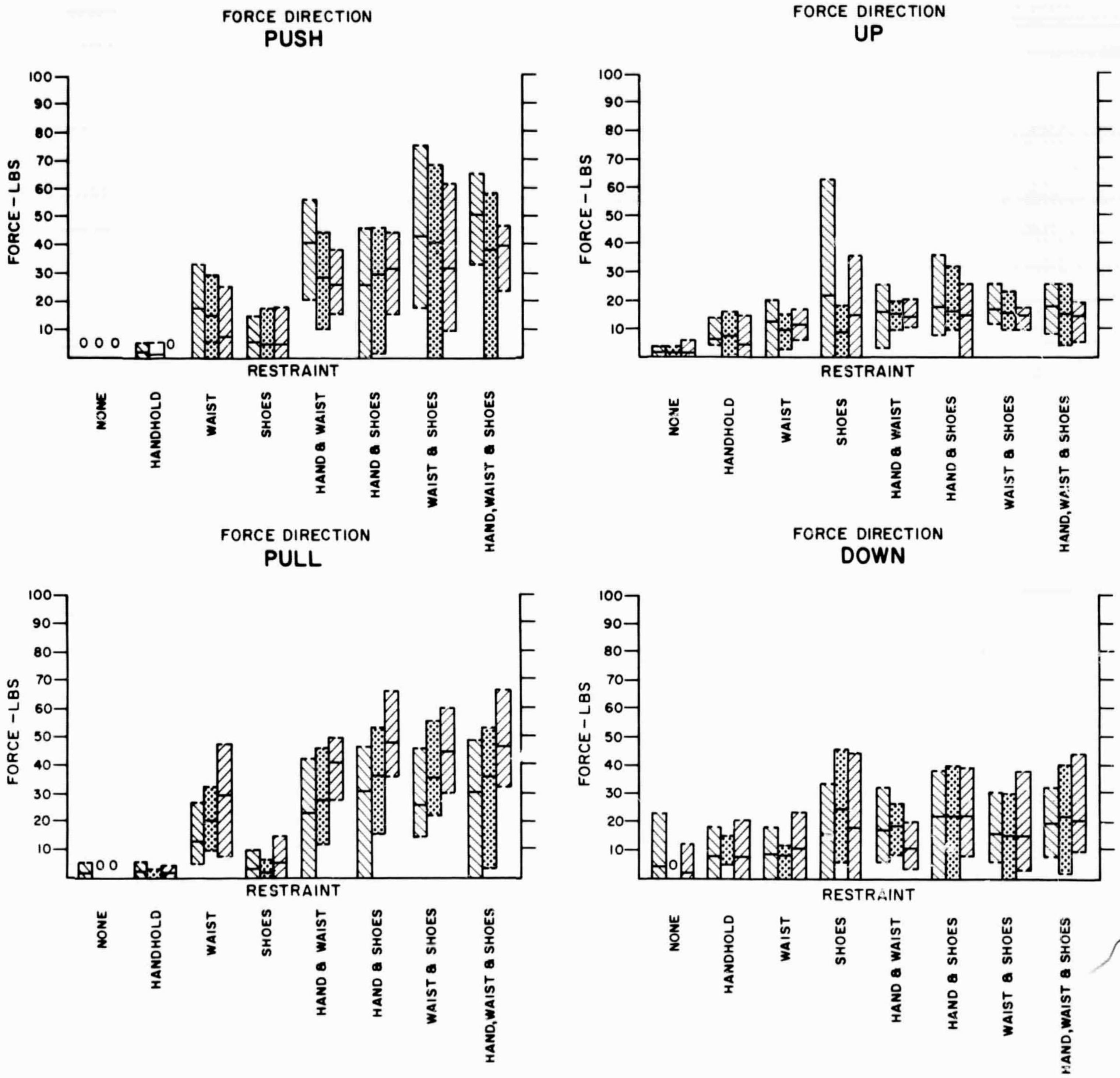
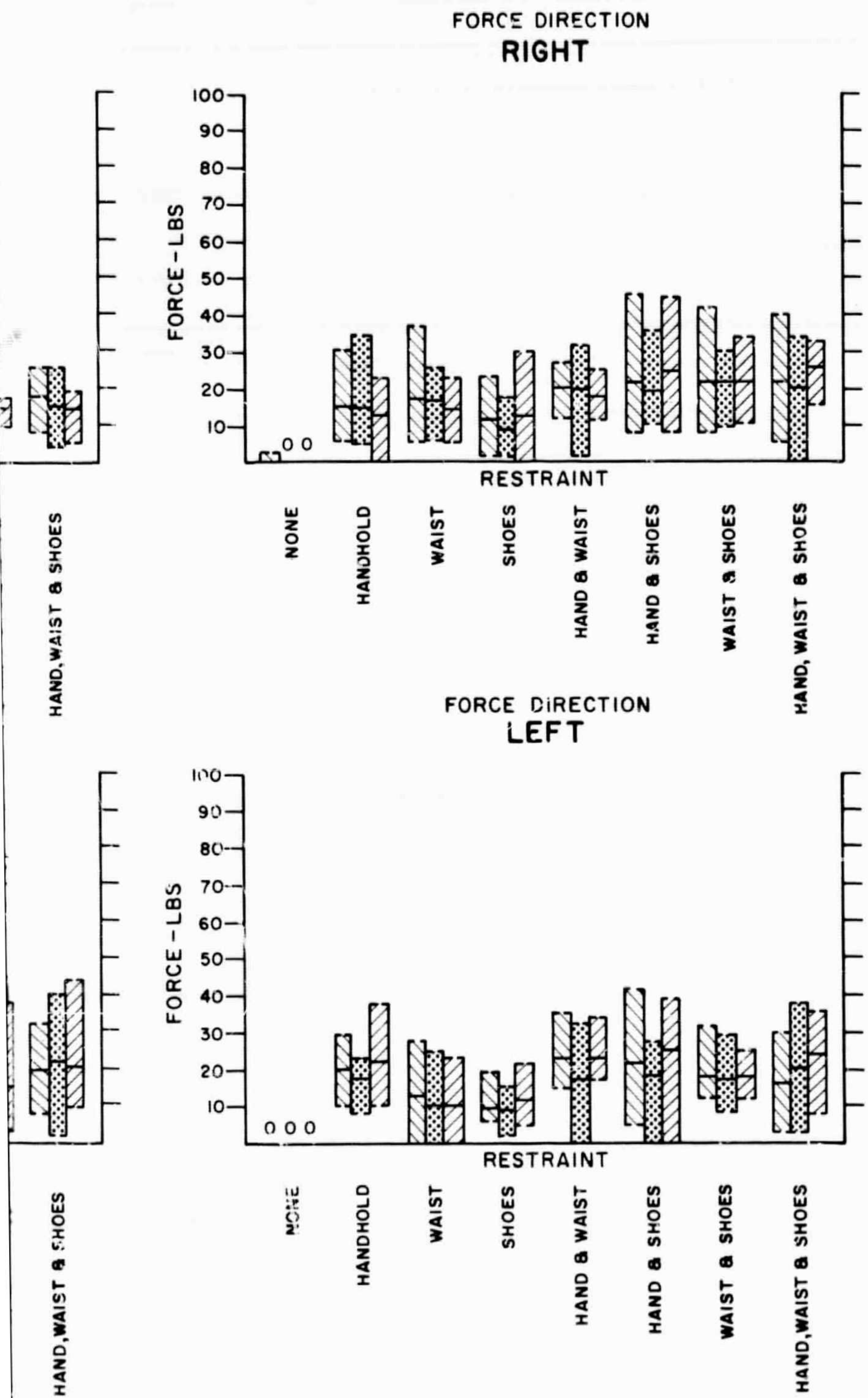


Fig. 6.8-1A

FOLDOUT FRAME

HANDLE ORIENTATION: **HORIZONTAL**



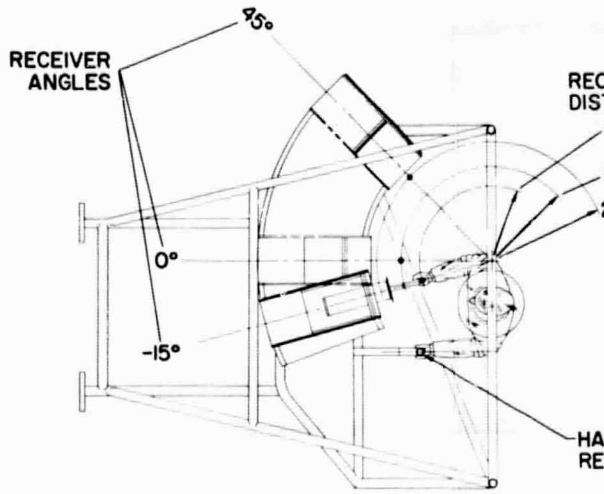
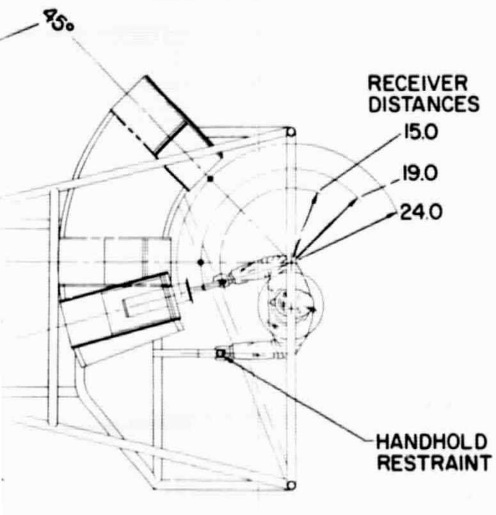


Fig. 6.8-1 B

6-35 B

FOLDOUT FRAME



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

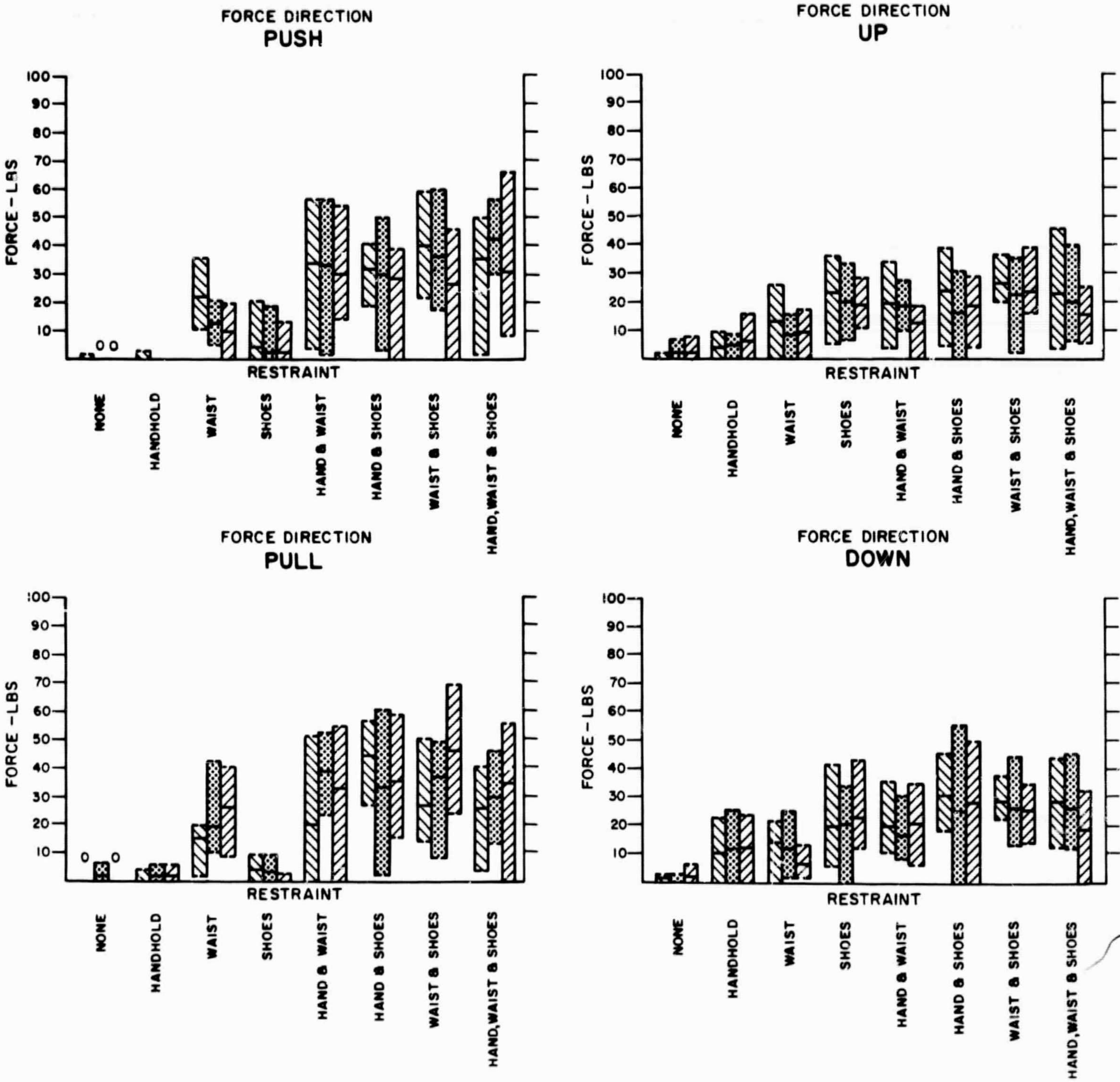
HANDLE ORIENTATION

LOCAL VERTICAL
LOCAL HORIZONTAL

– RANGE – MAX = LARGEST FORCE
– MEAN = AVERAGE OF ALL FORCES
– RANGE – MIN = SMALLEST FORCE

Figure 6.8-1 Summary Data Chart No. 1

FORCE TYPE: **SUSTAIN** RECEIVER ANGLE: **0°**

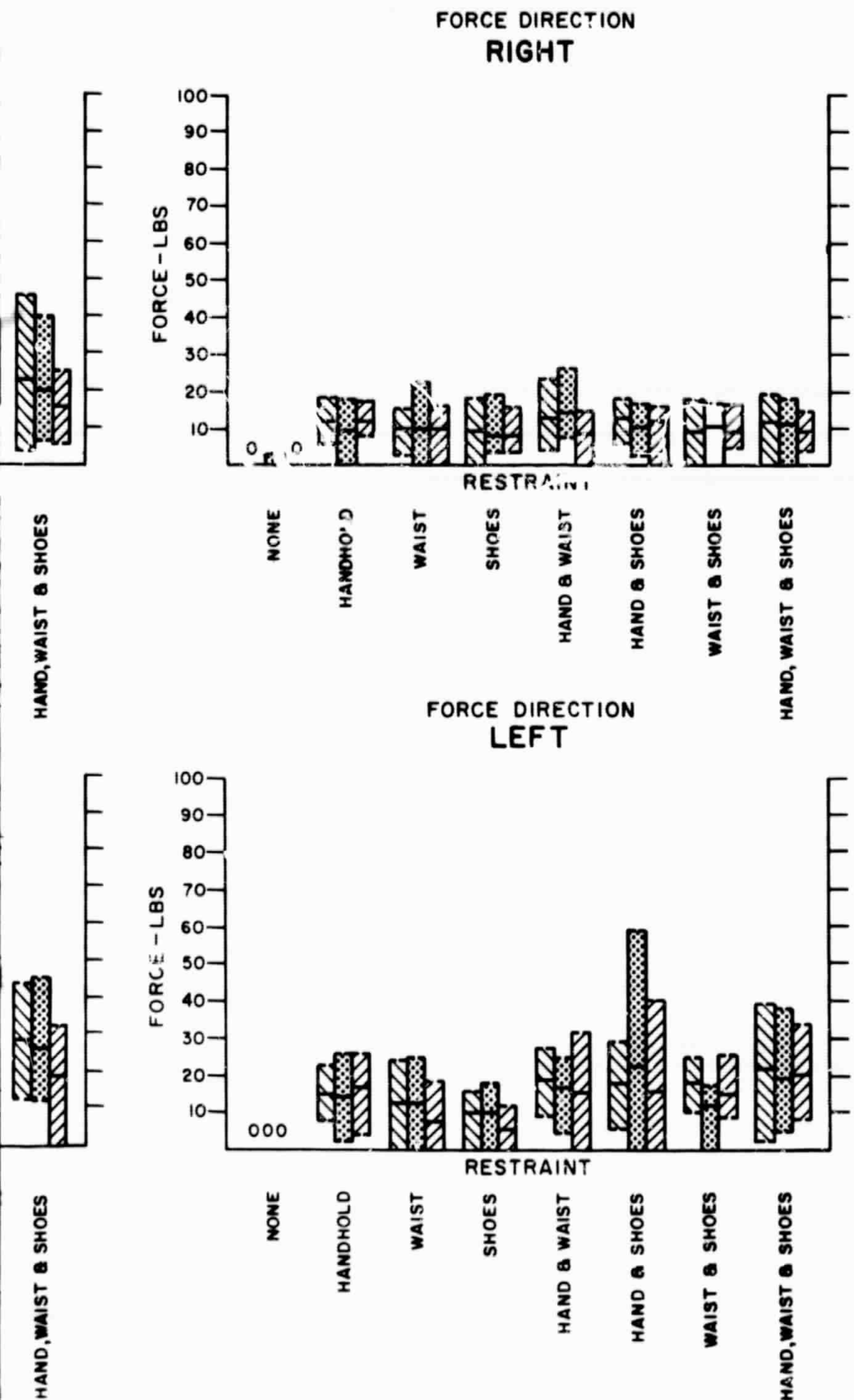


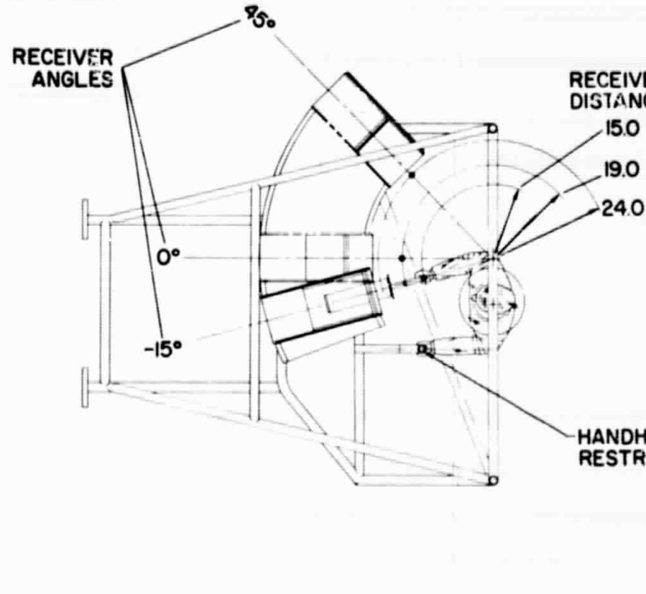
6-37 A

FOLDOUT FRAME

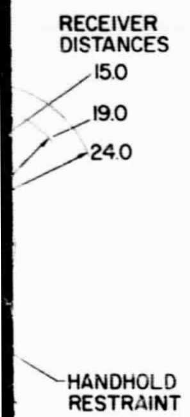
Fig. 6.8-2.A

HANDLE ORIENTATION: VERTICAL





6-38B
Fig. 6.8-2.B



FORCE TYPE

SUSTAINED - FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

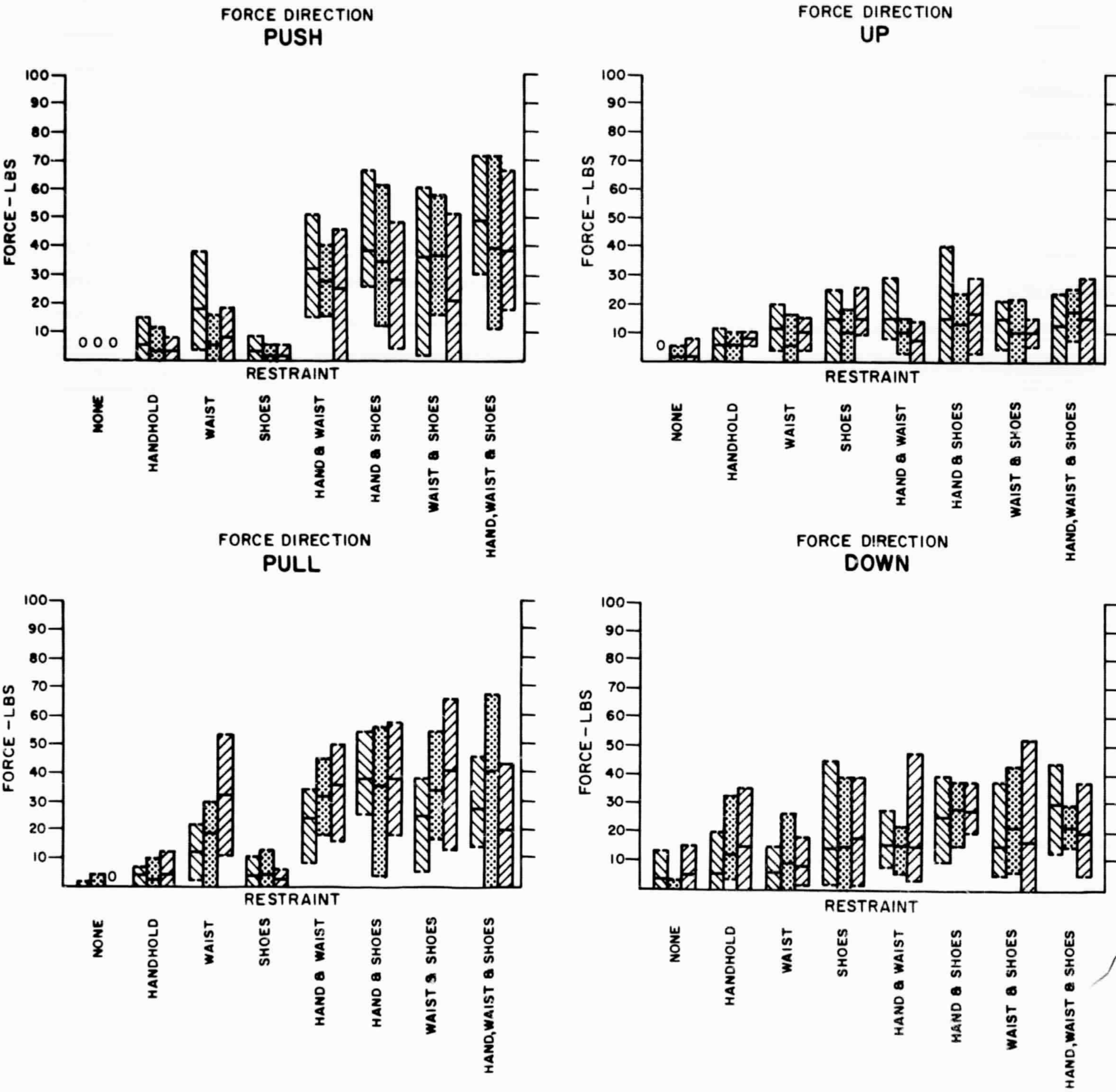
LOCAL VERTICAL
LOCAL HORIZONTAL

— RANGE - MAX = LARGEST FORCE
— MEAN = AVERAGE OF ALL FORCES
— RANGE - MIN = SMALLEST FORCE

Figure 6.8-2C Summary Data Chart No. 2

FOLDOUT FRAME

FORCE TYPE: **SUSTAIN** RECEIVER ANGLE: **-15°**

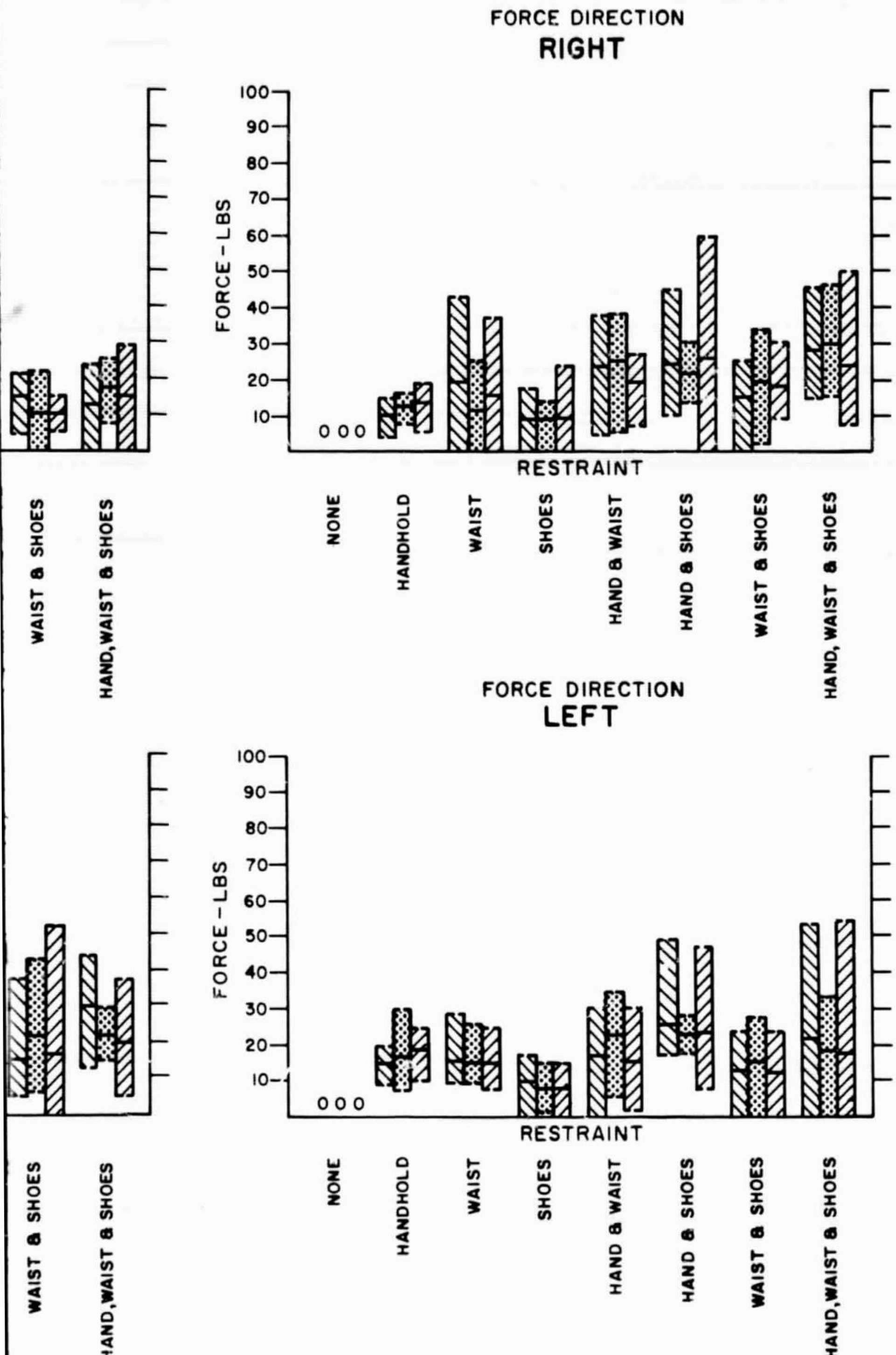


FOLDOUT FRAME

Fig. 6.8-3.A

6-39 A

HANDLE ORIENTATION: **HORIZONTAL**



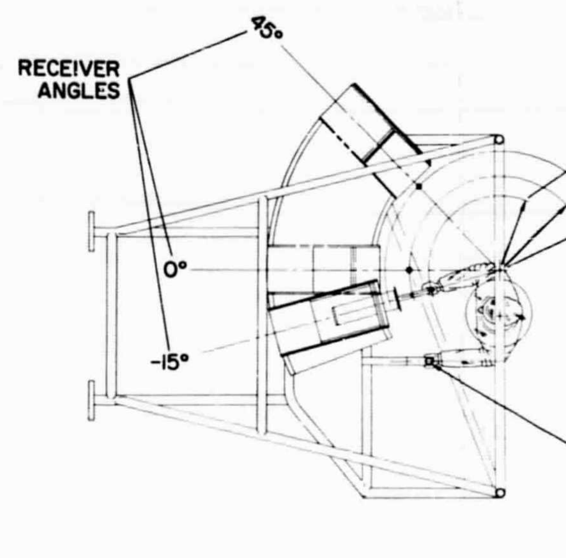
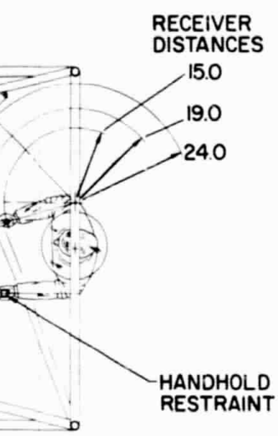


Fig. 6.8-3.B

FOLDOUT FRAME



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

LOCAL VERTICAL
LOCAL HORIZONTAL

RANGE – MAX = LARGEST FORCE
MEAN = AVERAGE OF ALL FORCES
RANGE – MIN = SMALLEST FORCE

Figure 6.8-3.c Summary Data Chart No. 3

FORCE TYPE: **SUSTAIN** RECEIVER ANGLE: **-15°**

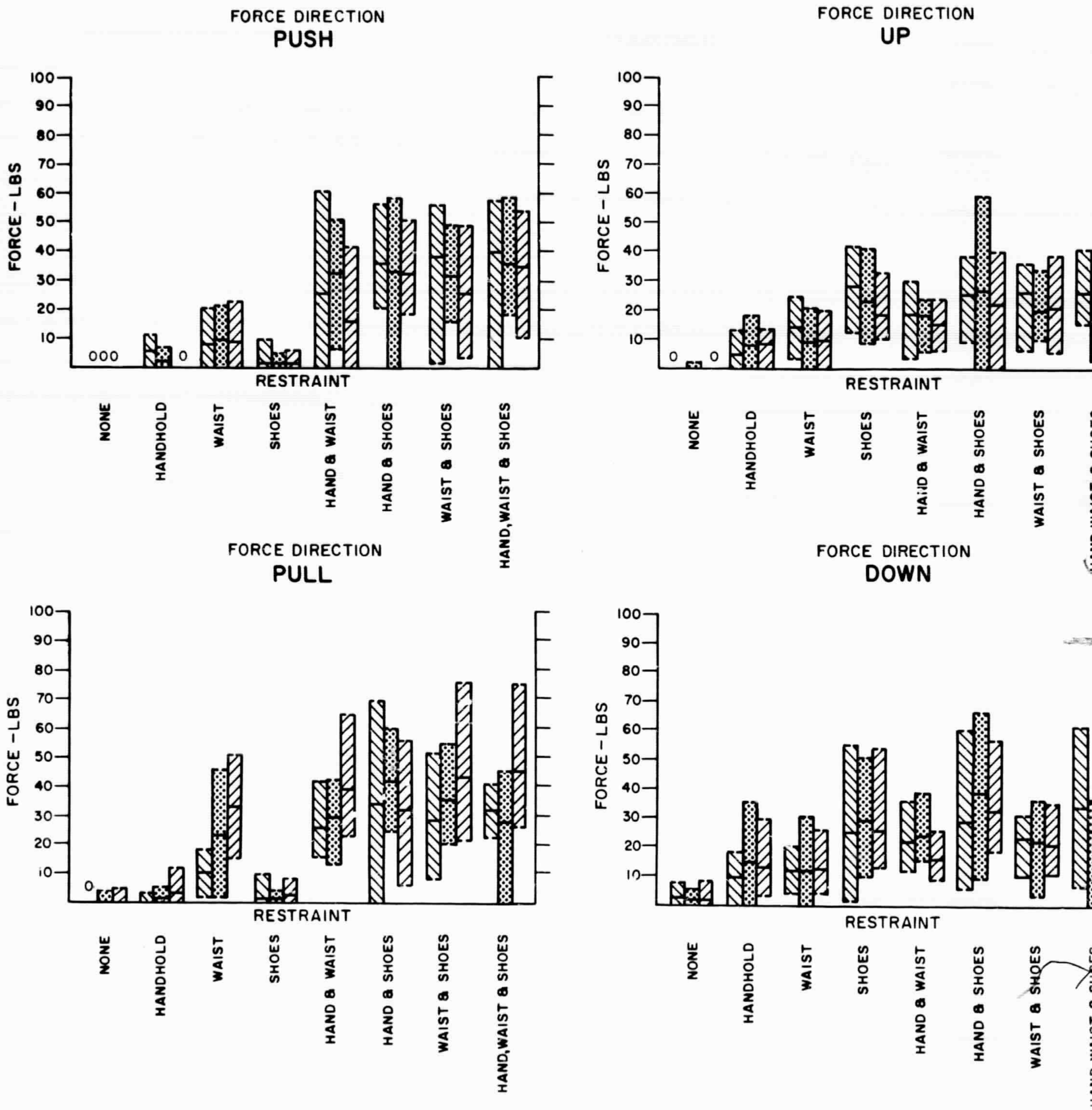


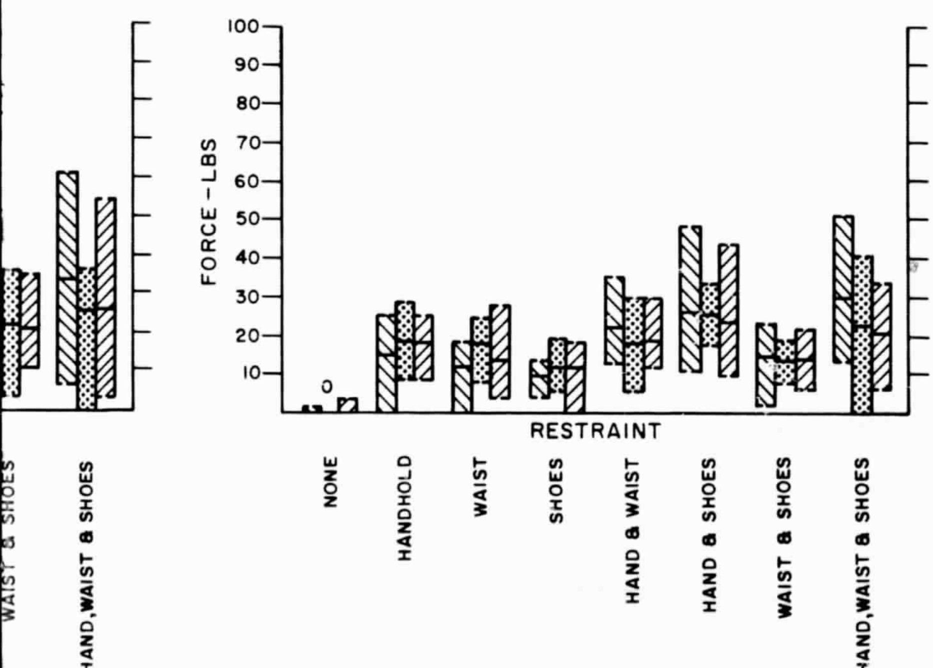
Fig. 6.8-4A

FOLDOUT FRAME

HANDLE ORIENTATION: VERTICAL

FORCE DIRECTION
RIGHT

FORCE DIRECTION
LEFT



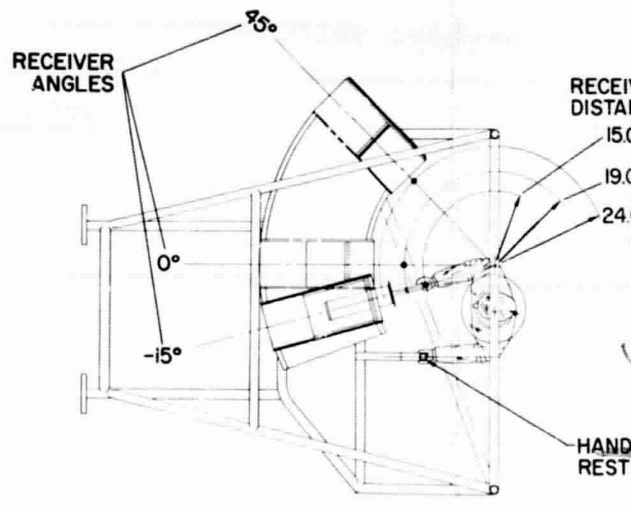
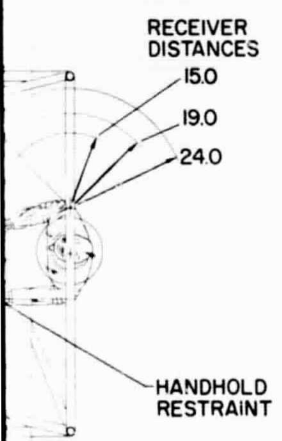


Fig. 6.8-4.B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

LOCAL VERTICAL
LOCAL HORIZONTAL

— RANGE – MAX = LARGEST FORCE
— MEAN = AVERAGE OF ALL FORCES
— RANGE – MIN = SMALLEST FORCE

Figure 6.8-4.c Summary Data Chart No. 4

FOLDOUT FRAME

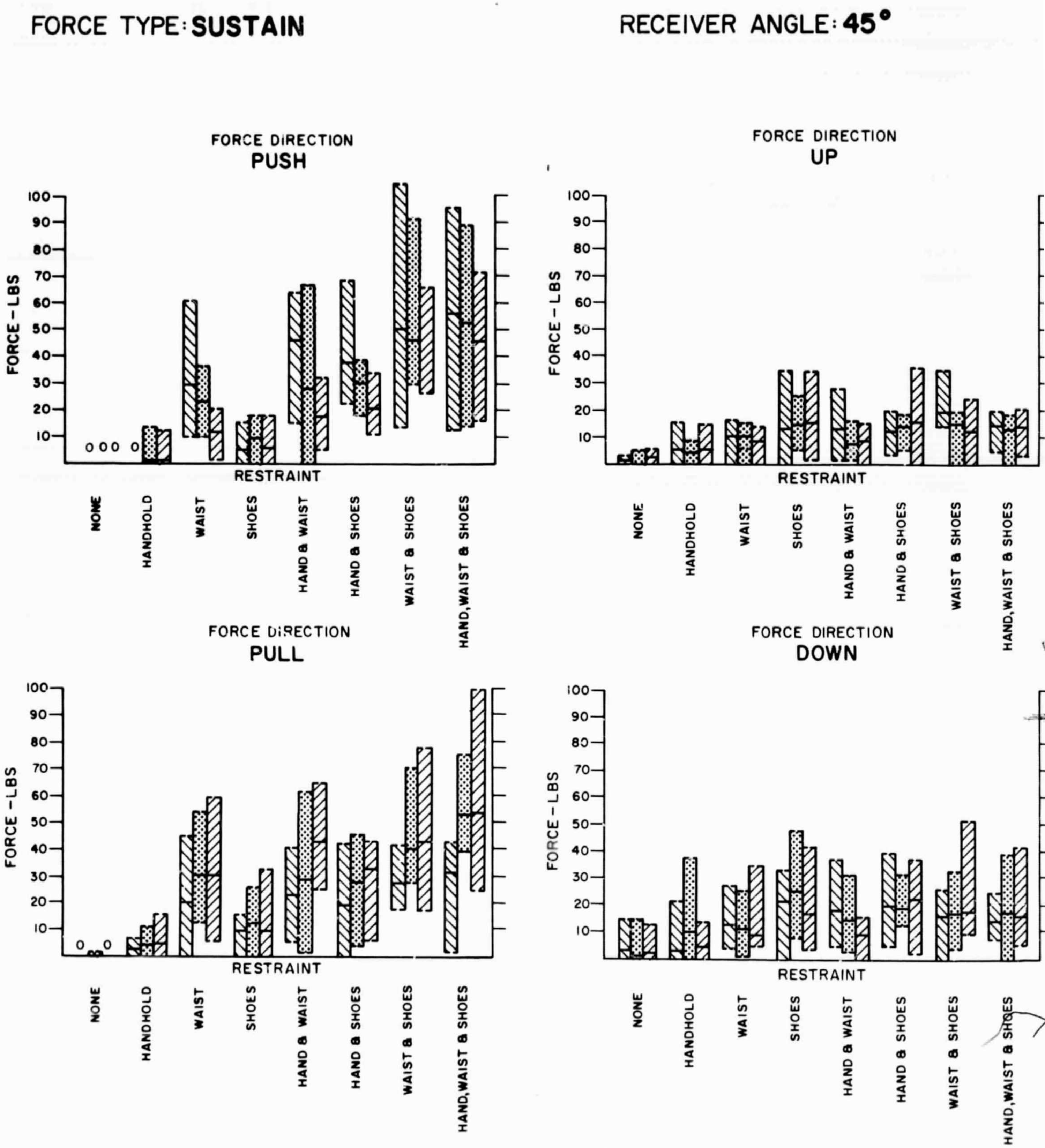
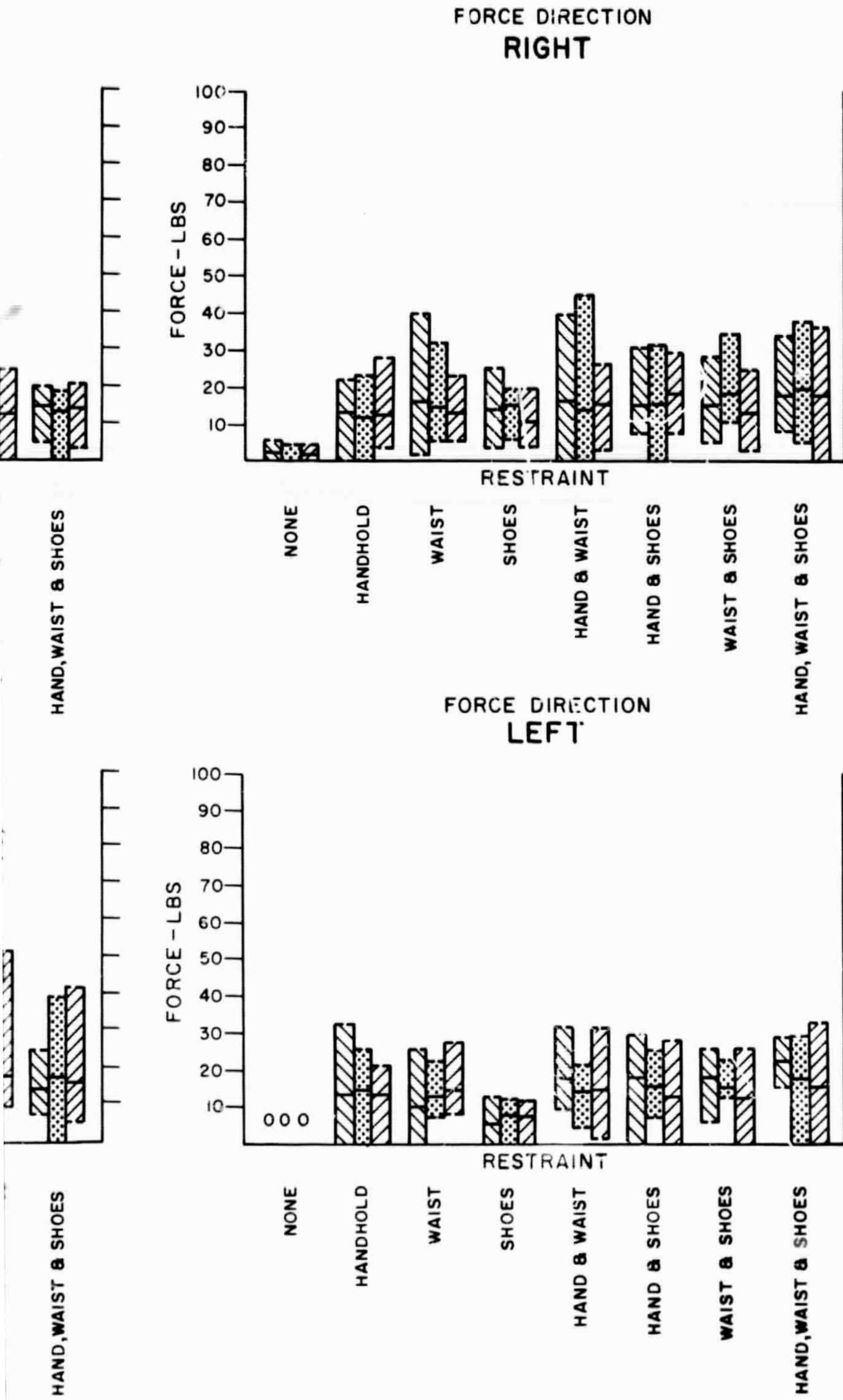


Fig 6.8-5 A

FOLDOUT FRAME

HANDLE ORIENTATION: **HORIZONTAL**



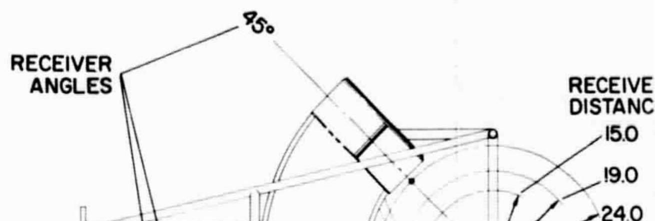
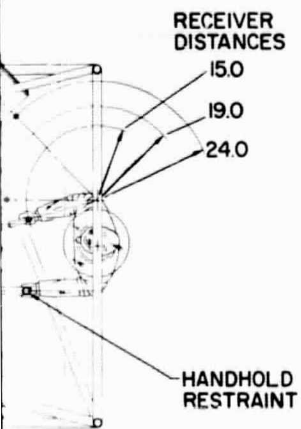


Fig. 6.8-5B

FOLDOUT FRAME 6-43B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS

IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

- 15" ≃ 90° ELBOW ANGLE
- 19" ≃ 135° ELBOW ANGLE
- 24" ≃ 180° ELBOW ANGLE

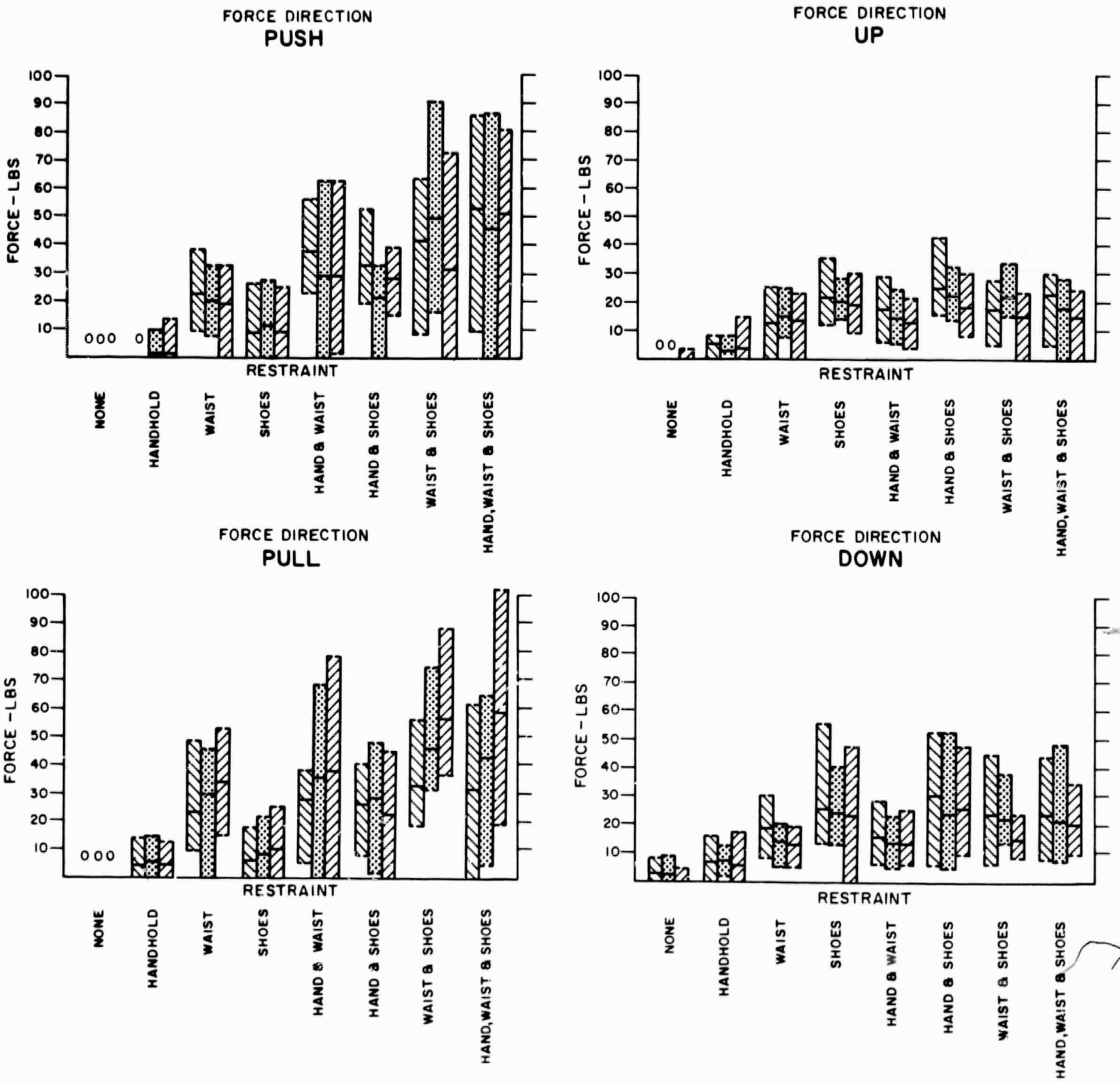
HANDLE ORIENTATION

- LOCAL VERTICAL
- LOCAL HORIZONTAL

- RANGE – MAX = LARGEST FORCE
- MEAN = AVERAGE OF ALL FORCES
- RANGE – MIN = SMALLEST FORCE

Figure 6.8-5. Summary Data Chart No. 5

FORCE TYPE: **SUSTAIN** RECEIVER ANGLE: **45°**



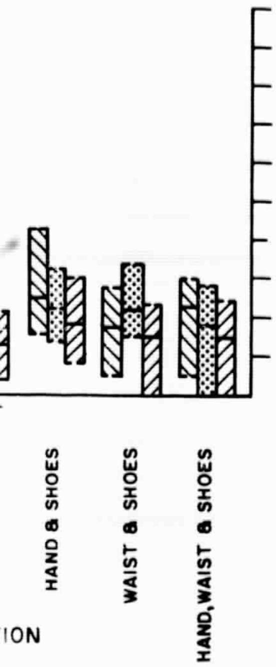
FOLDOUT FRAME

Fig. 6.8-6.A

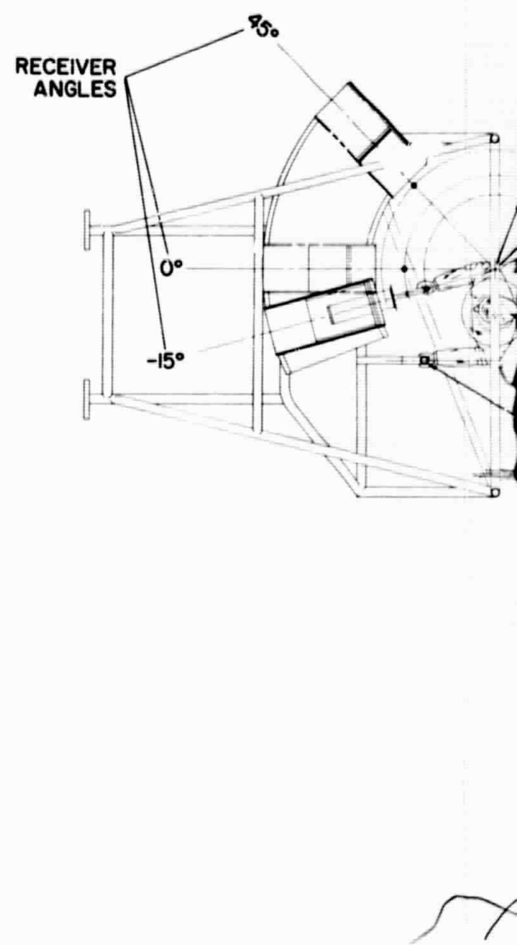
5°

HANDLE ORIENTATION: VERTICAL

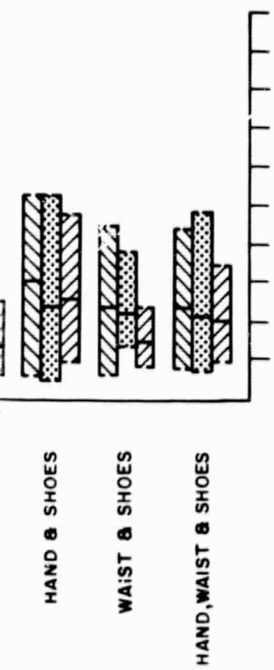
TION



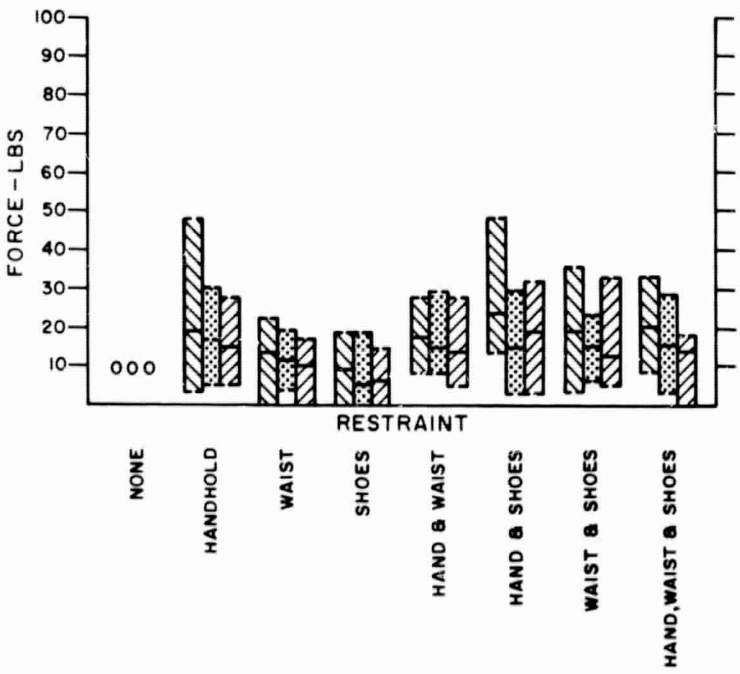
FORCE DIRECTION
RIGHT



ION

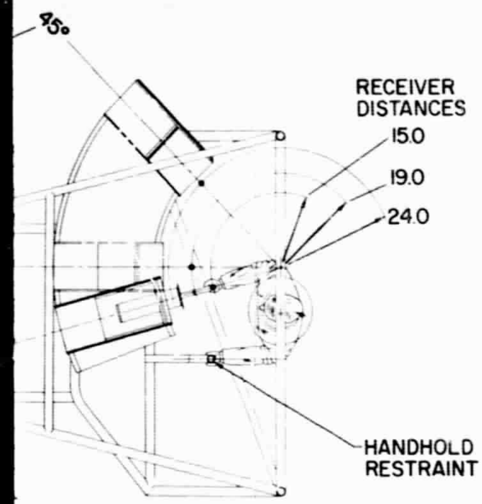


FORCE DIRECTION
LEFT



FOLDOUT FRAME

Fig. 6.8-6B
6-45 B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

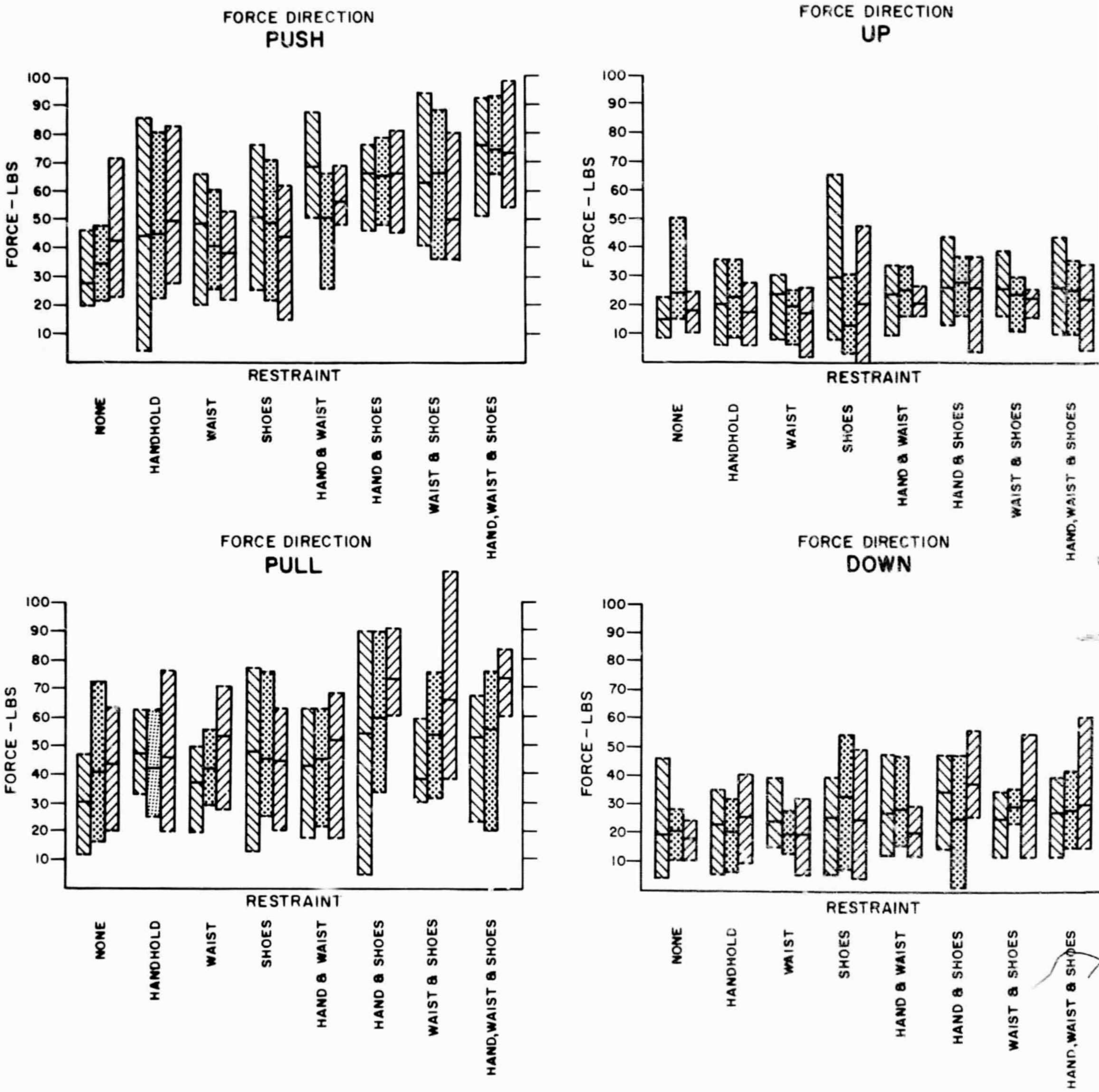
LOCAL VERTICAL
LOCAL HORIZONTAL

RANGE – MAX = LARGEST FORCE
MEAN = AVERAGE OF ALL FORCES
RANGE – MIN = SMALLEST FORCE

Figure 6.8-6. Summary Data Chart No. 6

FORCE TYPE: **IMPULSE**

RECEIVER ANGLE: **0°**

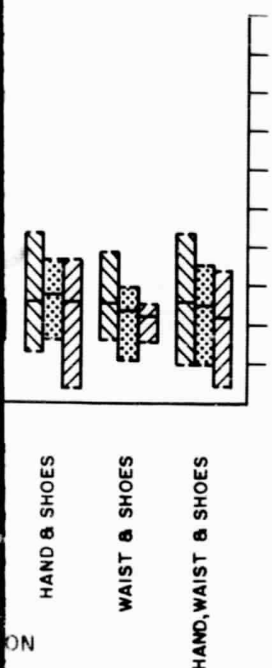


FOLDOUT FRAME

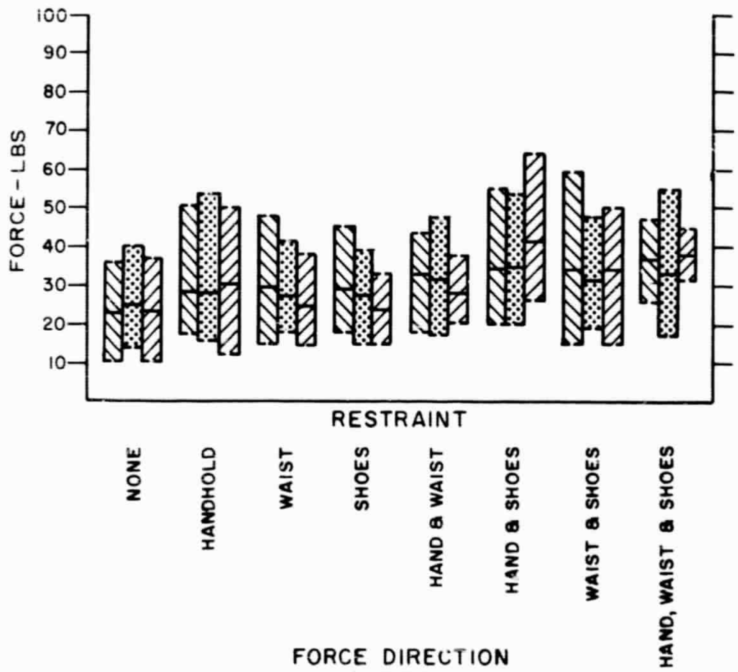
Fig 6.8-7A 6-47A

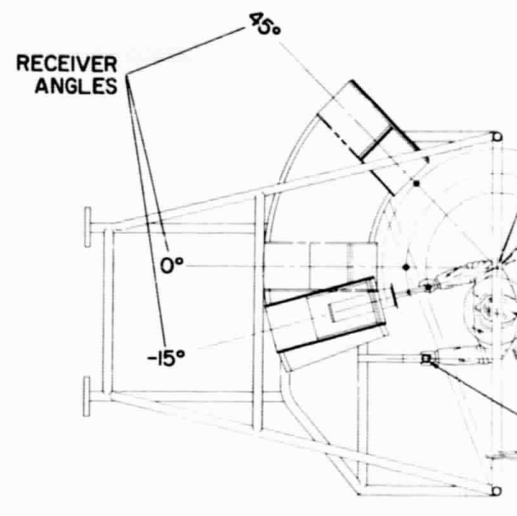
HANDLE ORIENTATION: **HORIZONTAL**

ION

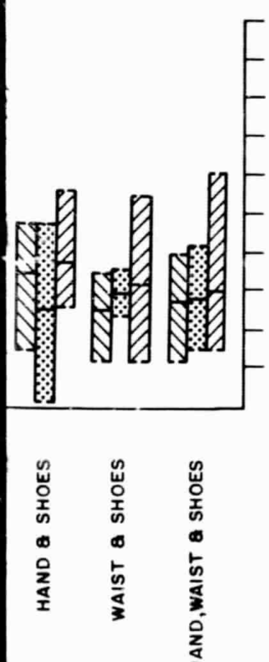


FORCE DIRECTION
RIGHT

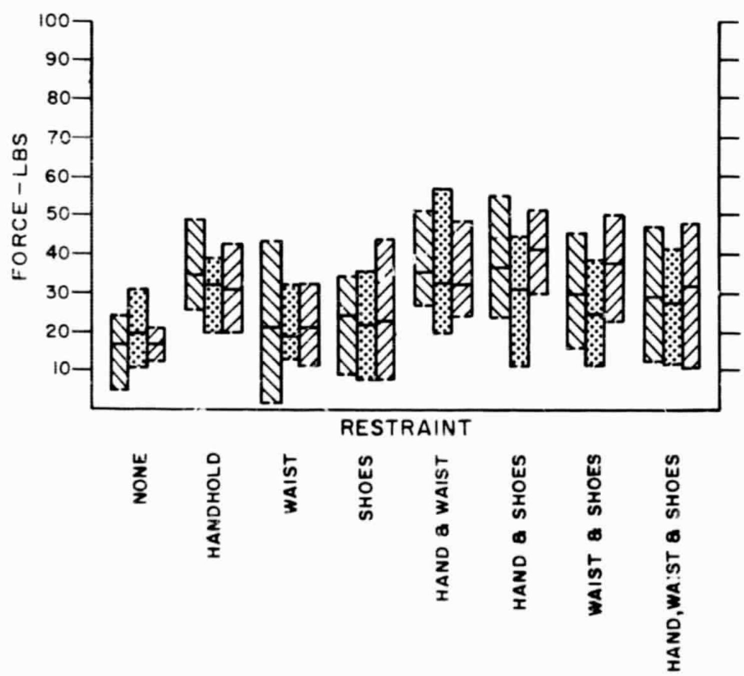




ON

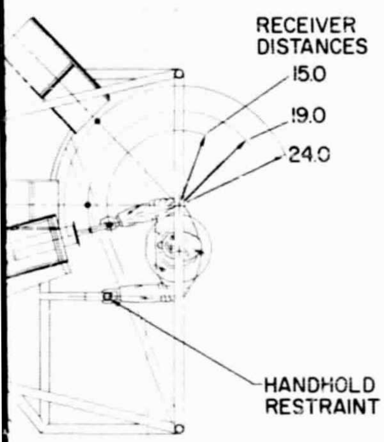


FORCE DIRECTION
LEFT



FOLDOUT FRAME

Fig. 6.8-7B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

- 15" ≃ 90° ELBOW ANGLE
- 19" ≃ 135° ELBOW ANGLE
- 24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

- LOCAL VERTICAL
- LOCAL HORIZONTAL

- RANGE – MAX = LARGEST FORCE
- MEAN = AVERAGE OF ALL FORCES
- RANGE – MIN = SMALLEST FORCE

Figure 6.8-7. Summary Data Chart No. 7

FORCE TYPE: **IMPULSE**

RECEIVER ANGLE: **0°**

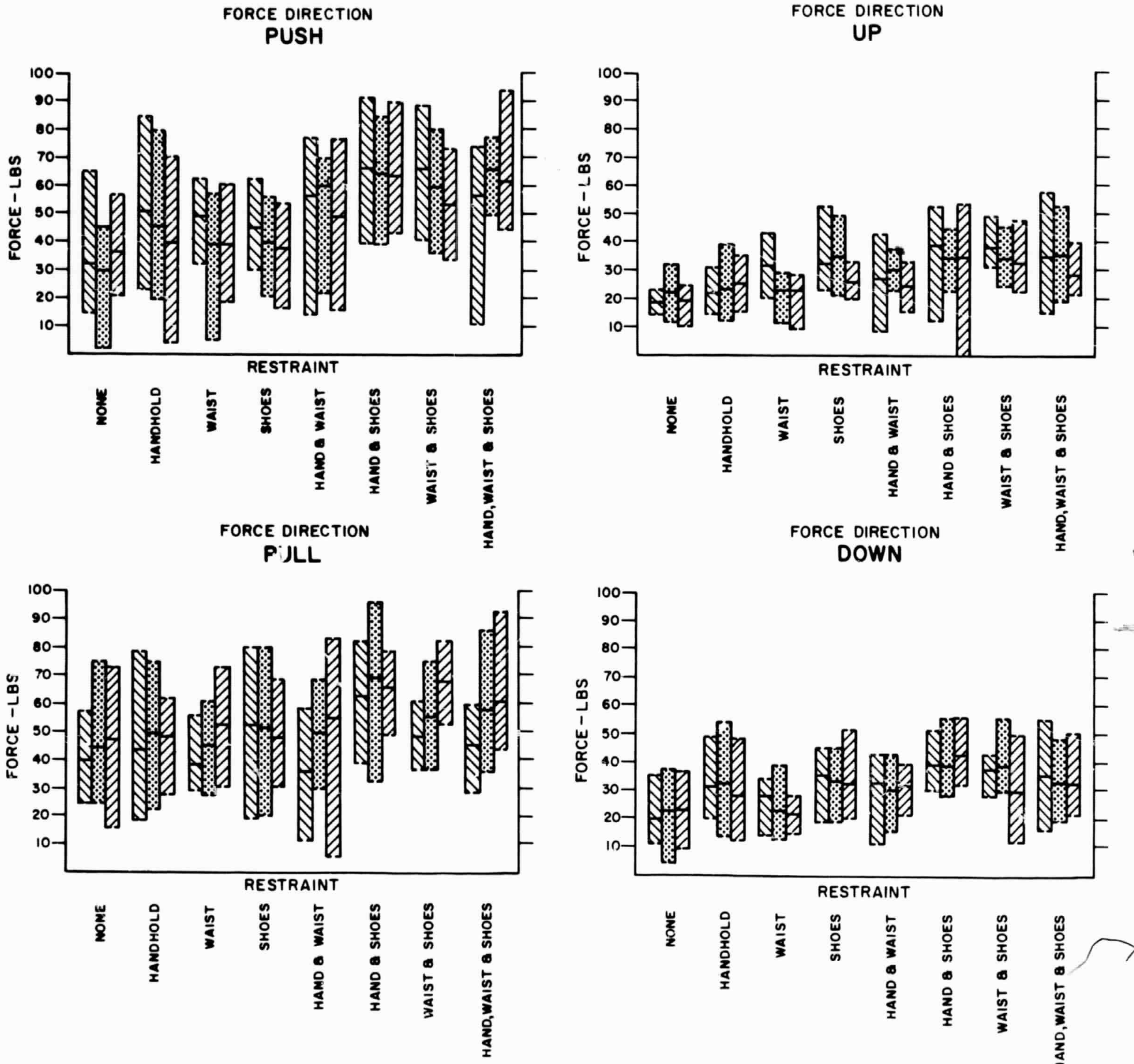
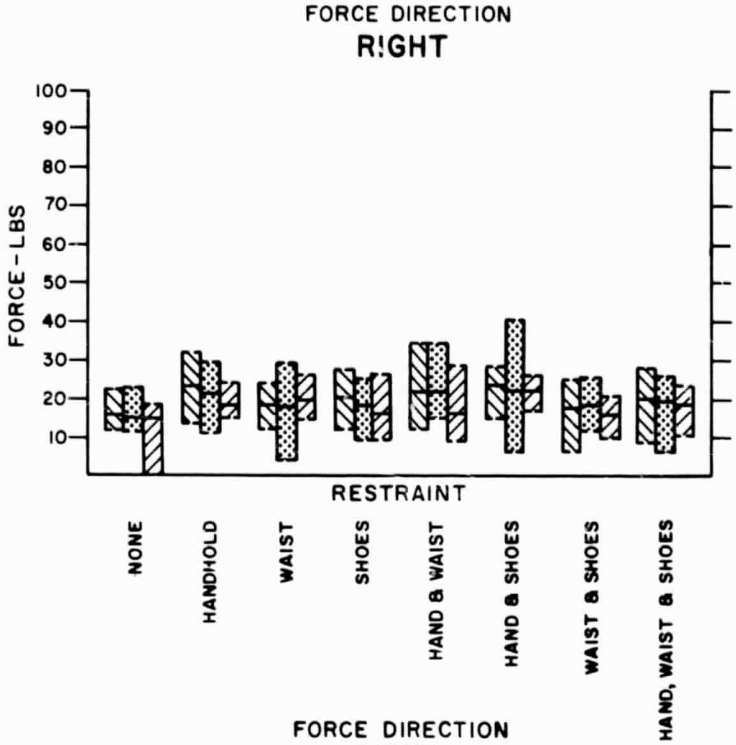
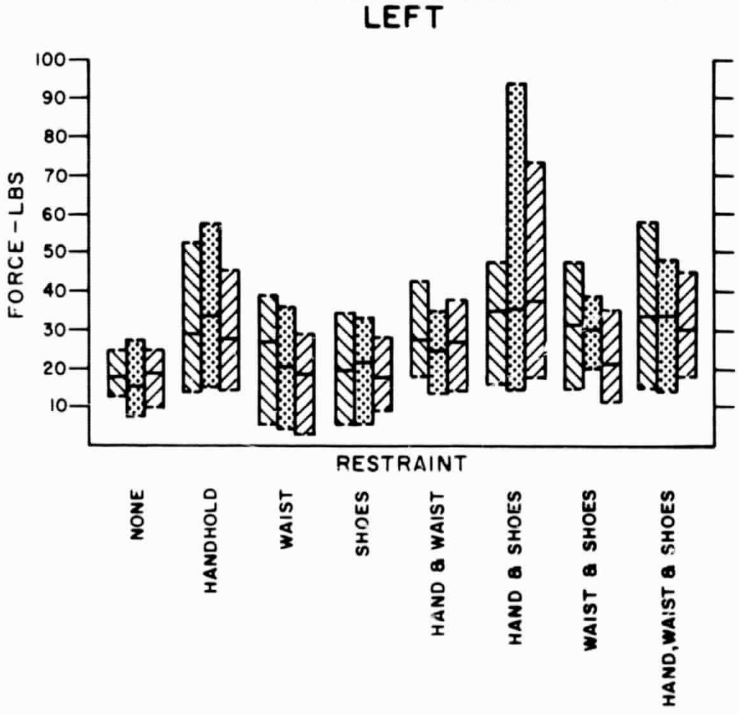


Fig. 6.8-8A

FOLDOUT FRAME

HANDLE ORIENTATION: **VERTICAL**





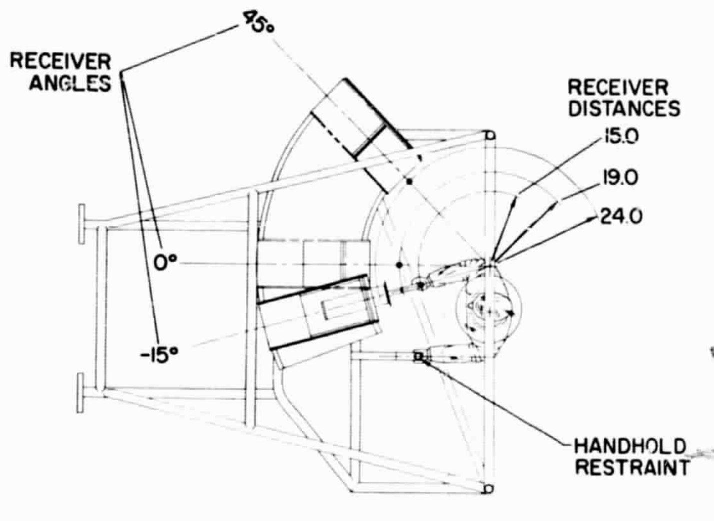
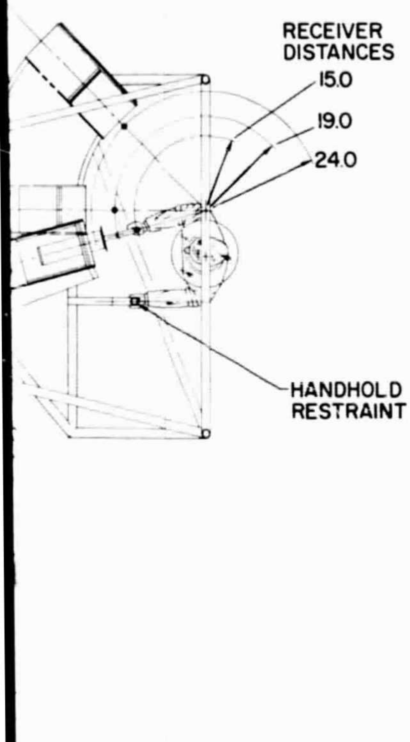


Fig. 6.8-B.B

 FOLDOUT FRAME



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

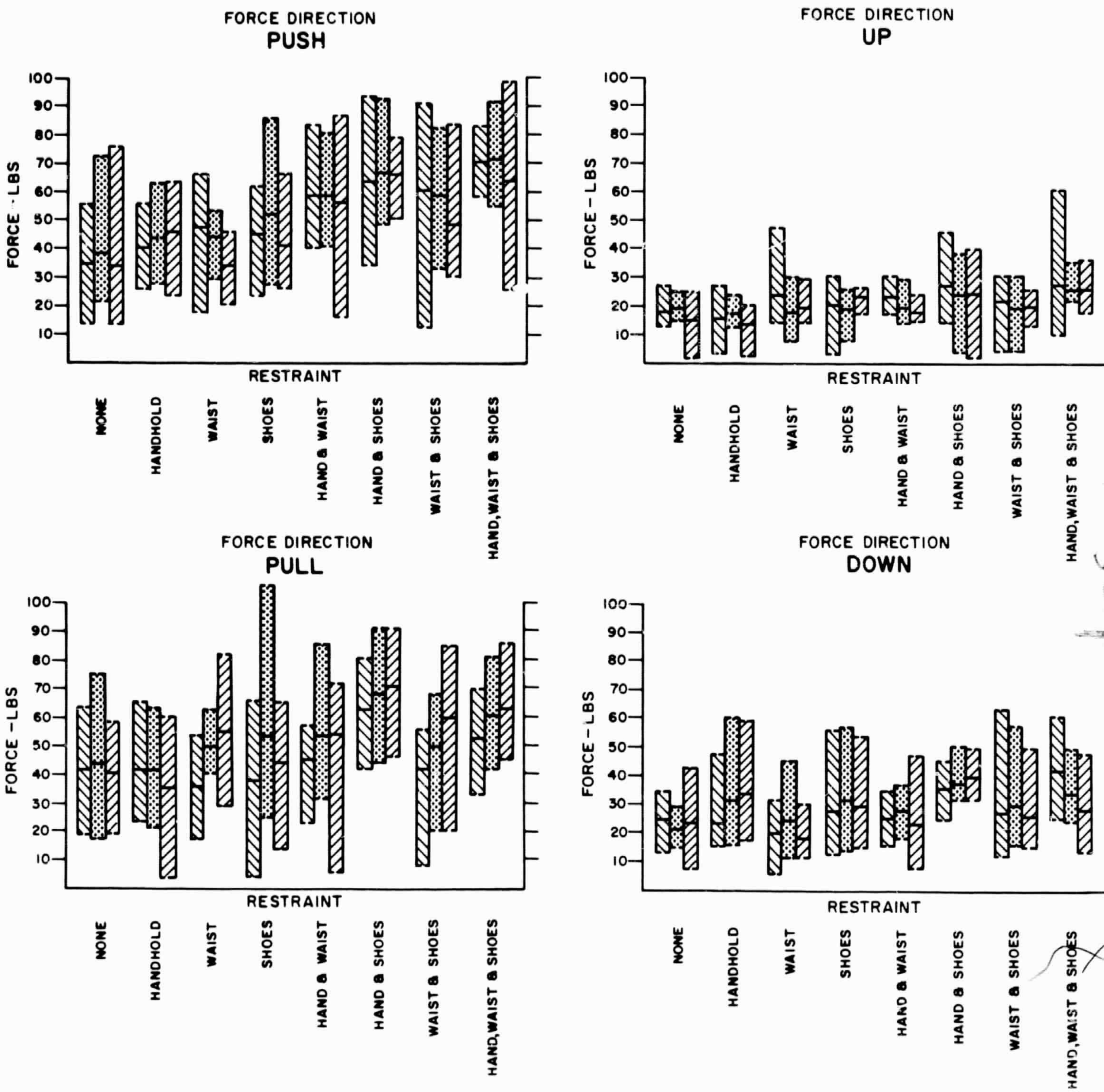
LOCAL VERTICAL
LOCAL HORIZONTAL

RANGE – MAX = LARGEST FORCE
MEAN = AVERAGE OF ALL FORCES
RANGE – MIN = SMALLEST FORCE

Figure 6. 8-8. Summary Data Chart No. 8

FOLDOUT FRAME

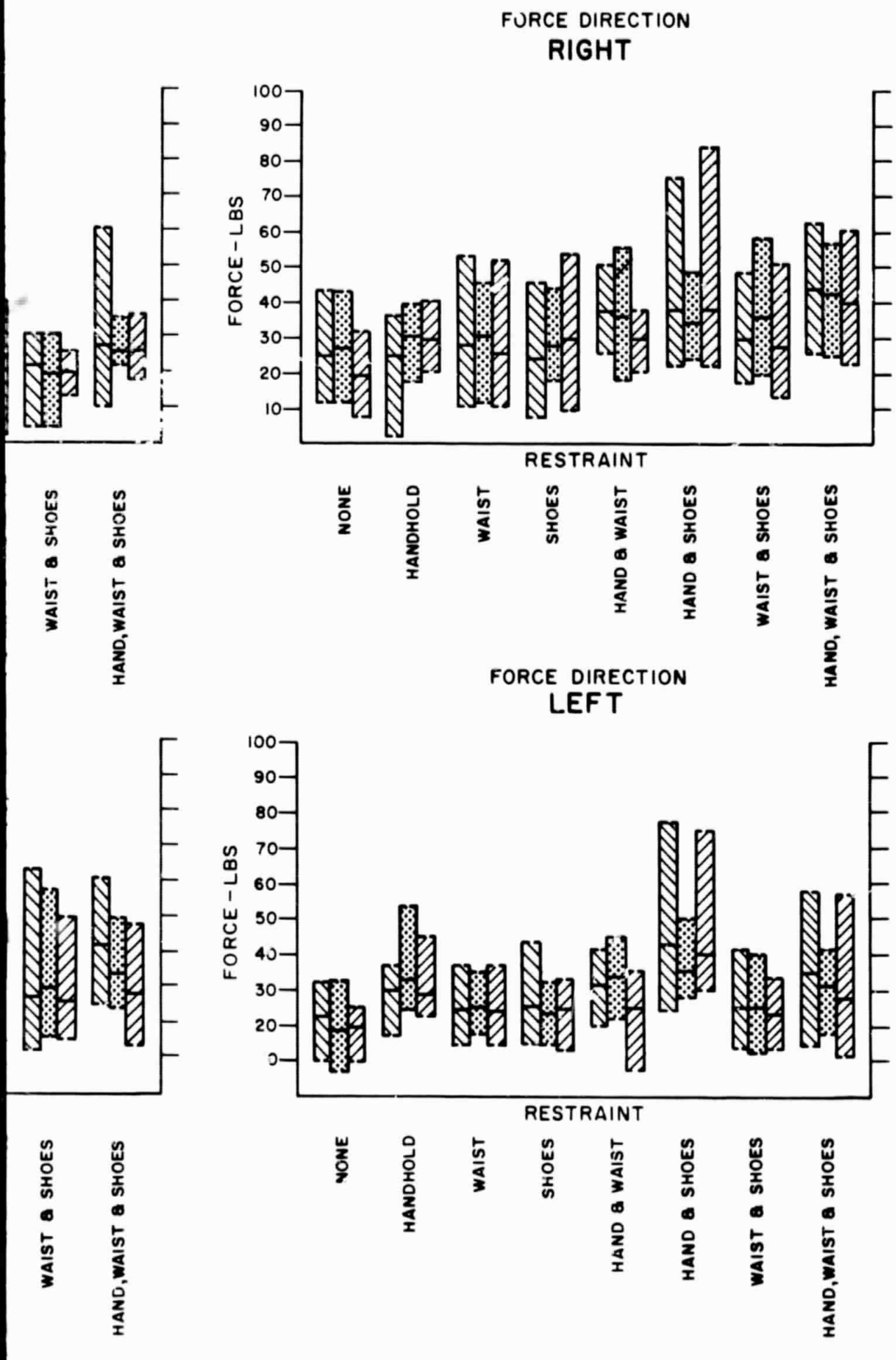
FORCE TYPE: **IMPULSE** RECEIVER ANGLE: **-15°**

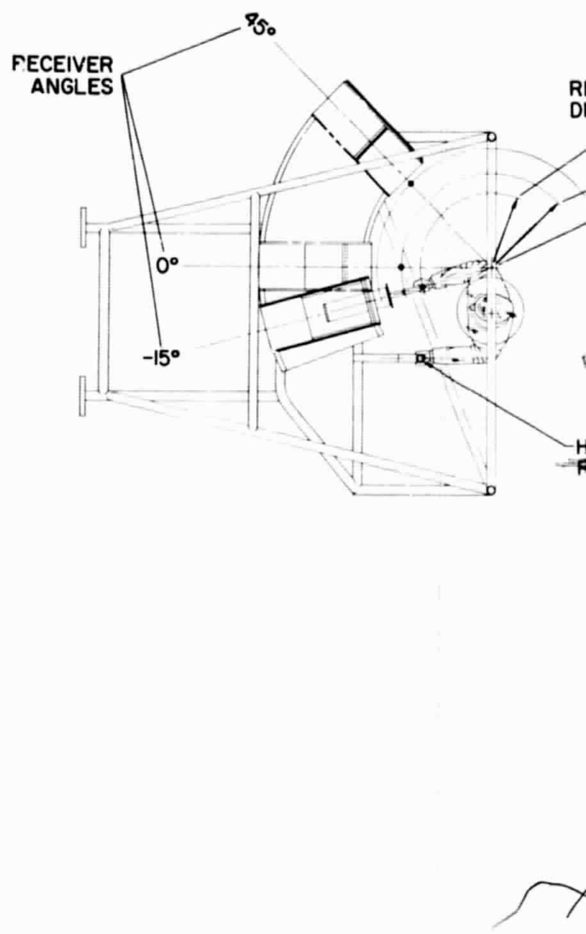


FOLDOUT FRAME

Fig 6.8-9A

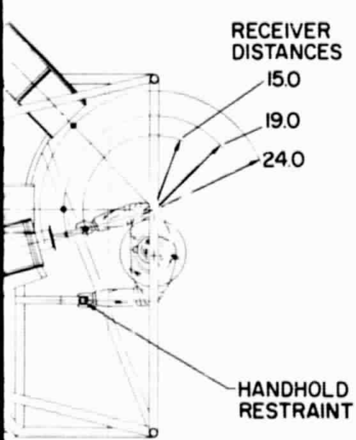
HANDLE ORIENTATION: **HORIZONTAL**





FOLDOUT FRAME

Fig 6.8-9B
6-51B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

- 15" ≃ 90° ELBOW ANGLE
- 19" ≃ 135° ELBOW ANGLE
- 24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

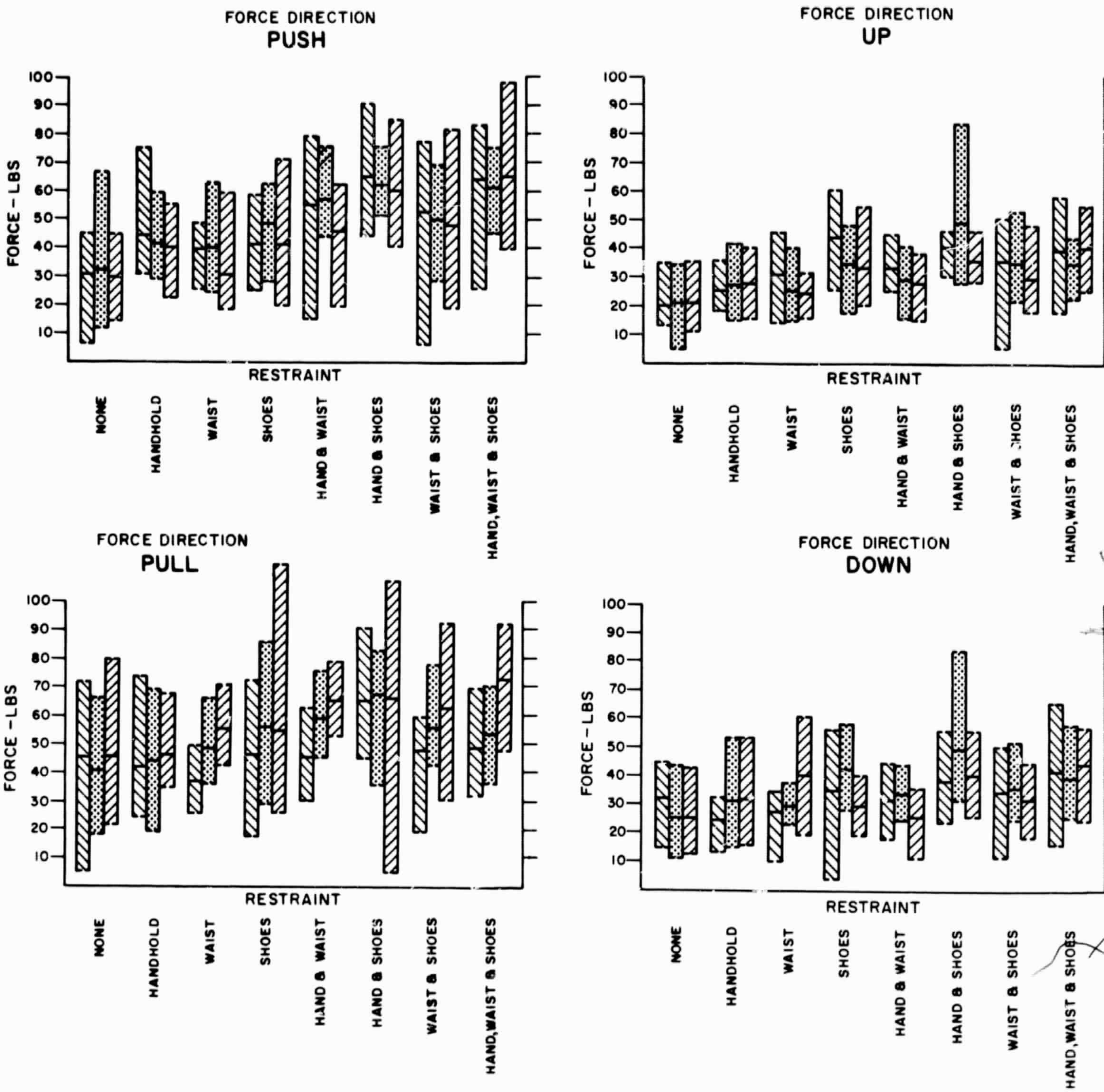
- LOCAL VERTICAL
- LOCAL HORIZONTAL

- RANGE – MAX = LARGEST FORCE
- MEAN = AVERAGE OF ALL FORCES
- RANGE – MIN = SMALLEST FORCE

Figure 6.8-9. Summary Data Chart No. 9

FOLDOUT FRAME

FORCE TYPE: **IMPULSE** RECEIVER ANGLE -**15°**

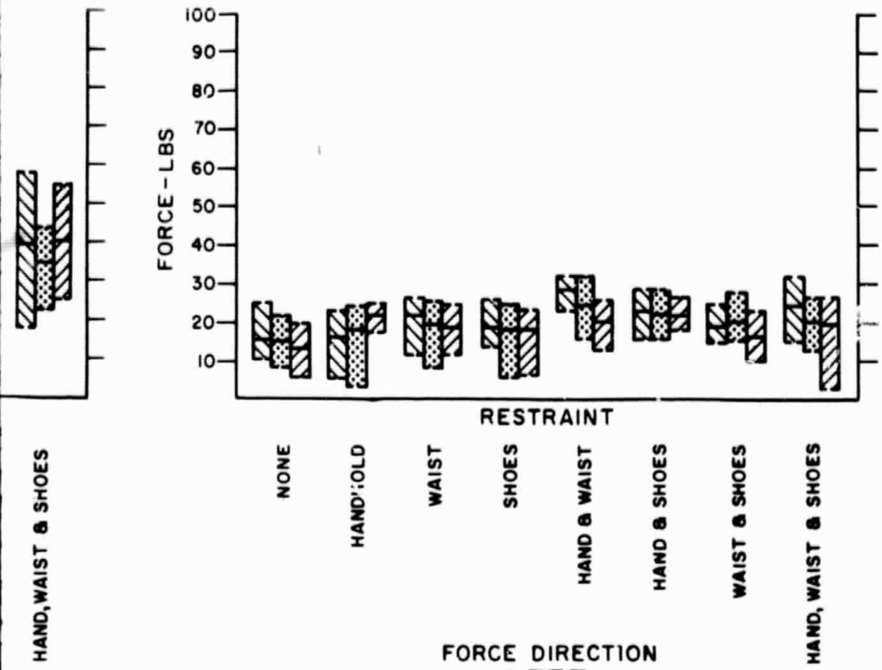


FOLDOUT FRAME

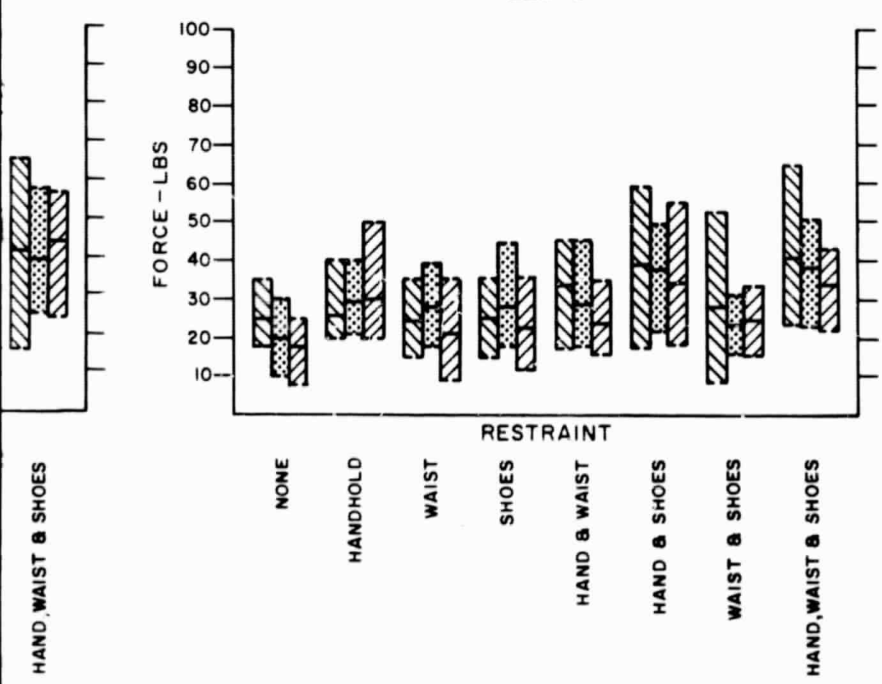
Fig 6.8-10A
6-53A

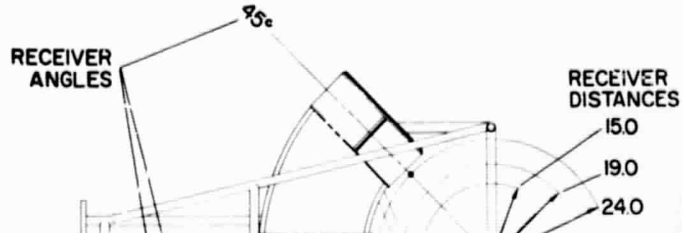
HANDLE ORIENTATION: **VERTICAL**

FORCE DIRECTION
RIGHT



FORCE DIRECTION
LEFT

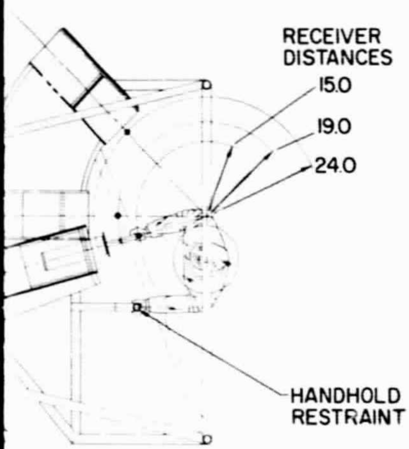




FOLDOUT FRAME

Fig. 6.8-10B

6-53B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

LOCAL VERTICAL
LOCAL HORIZONTAL

– RANGE – MAX = LARGEST FORCE
– MEAN = AVERAGE OF ALL FORCES
– RANGE – MIN = SMALLEST FORCE

Figure 6.8-10. Summary Data Chart No. 10

FORCE TYPE: **IMPULSE**

RECEIVER ANGLE: **45°**

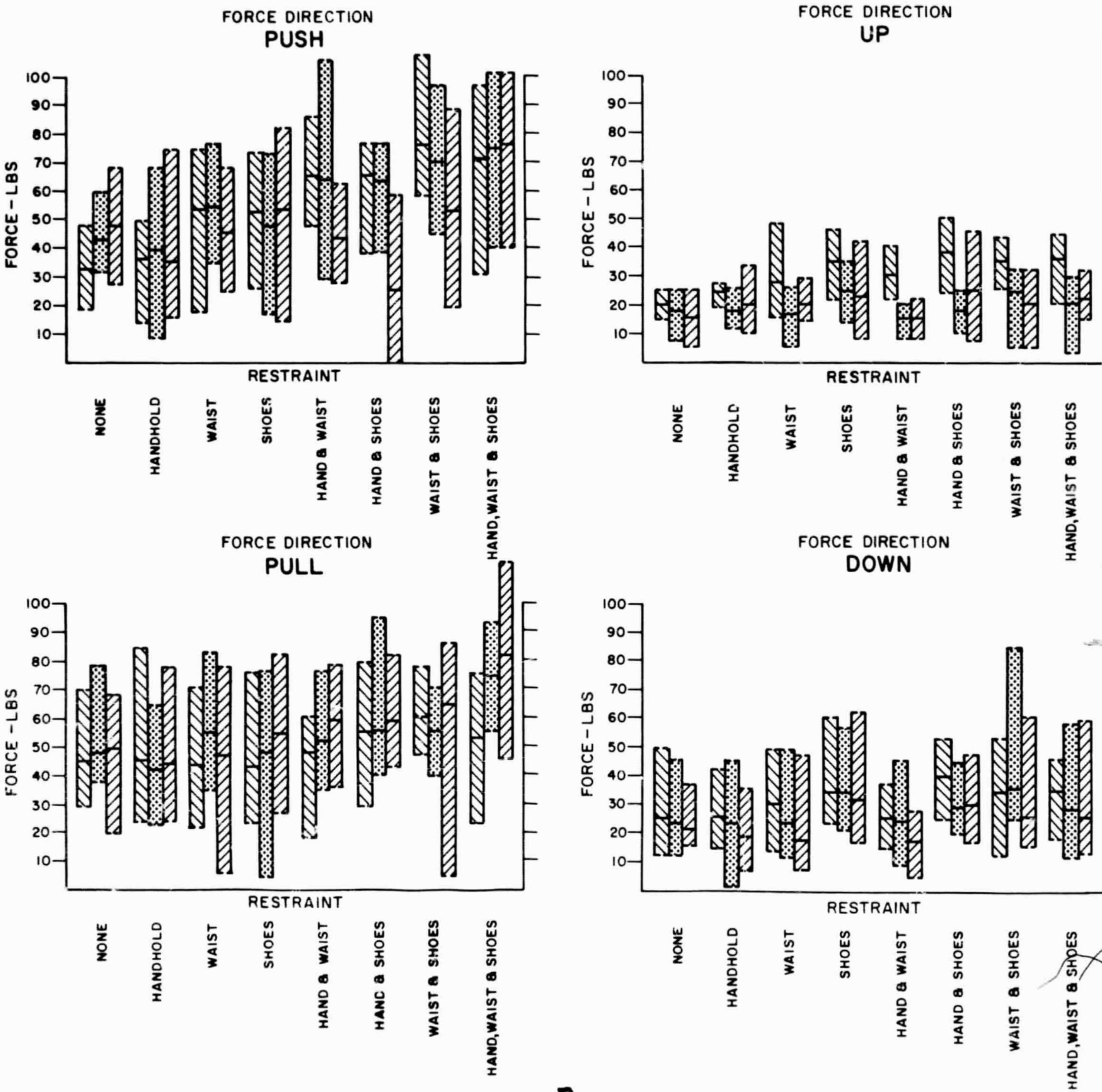
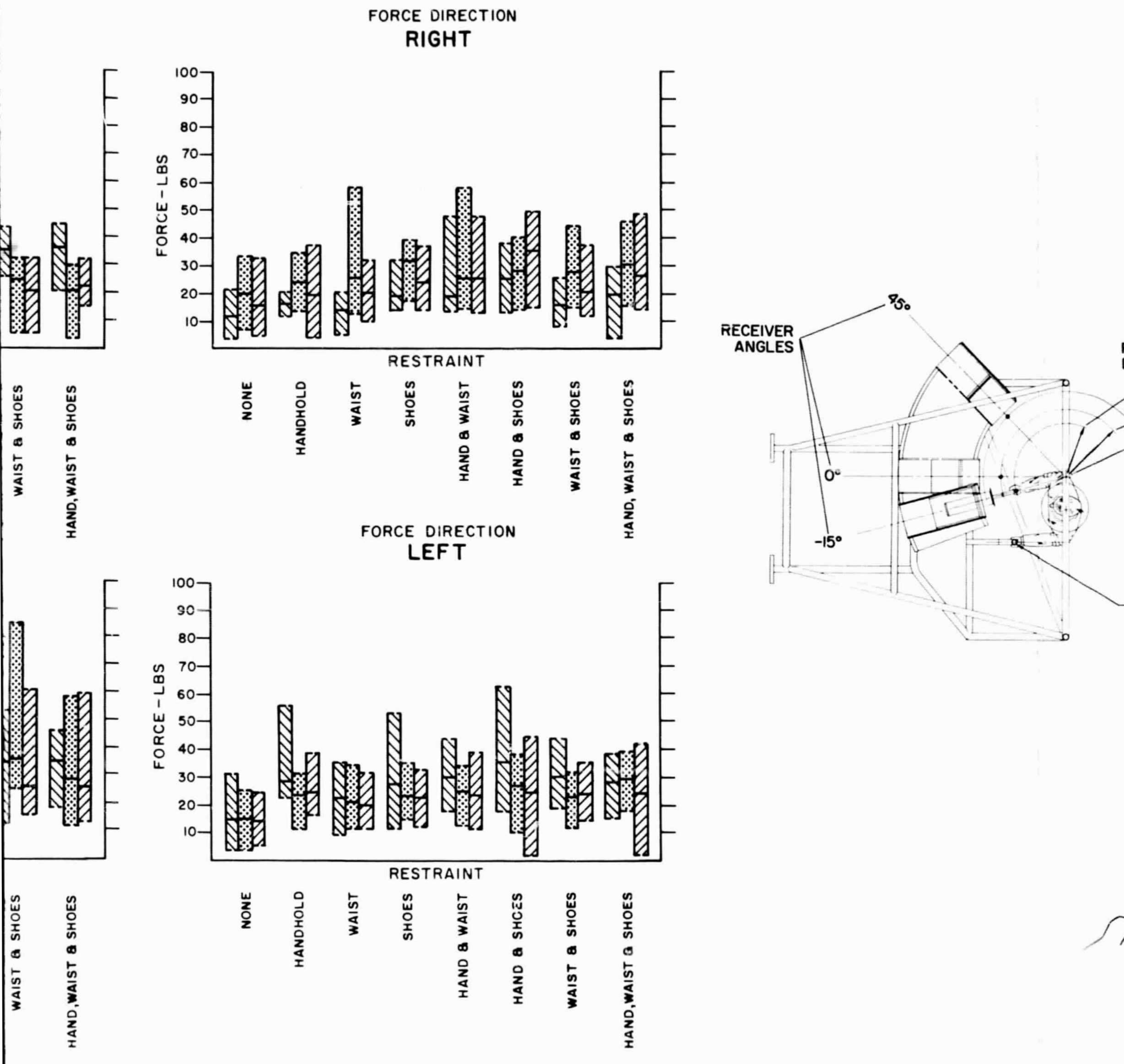


Fig. 6.8-11 A

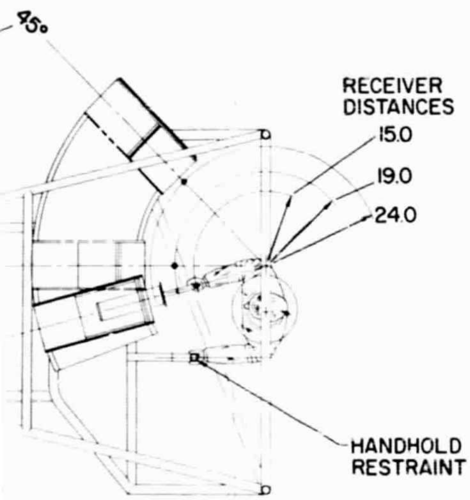
FOLDOUT FRAME

HANDLE ORIENTATION: **HORIZONTAL**



FOLDOUT FRAME

Fig. 6.8-11B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

- 15" ≃ 90° ELBOW ANGLE
- 19" ≃ 135° ELBOW ANGLE
- 24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

- LOCAL VERTICAL
- LOCAL HORIZONTAL

- RANGE – MAX = LARGEST FORCE
- MEAN = AVERAGE OF ALL FORCES
- RANGE – MIN = SMALLEST FORCE

Figure 6.8-11.C Summary Data Chart No. 11

FORCE TYPE: **IMPULSE** RECEIVER ANGLE: **45°**

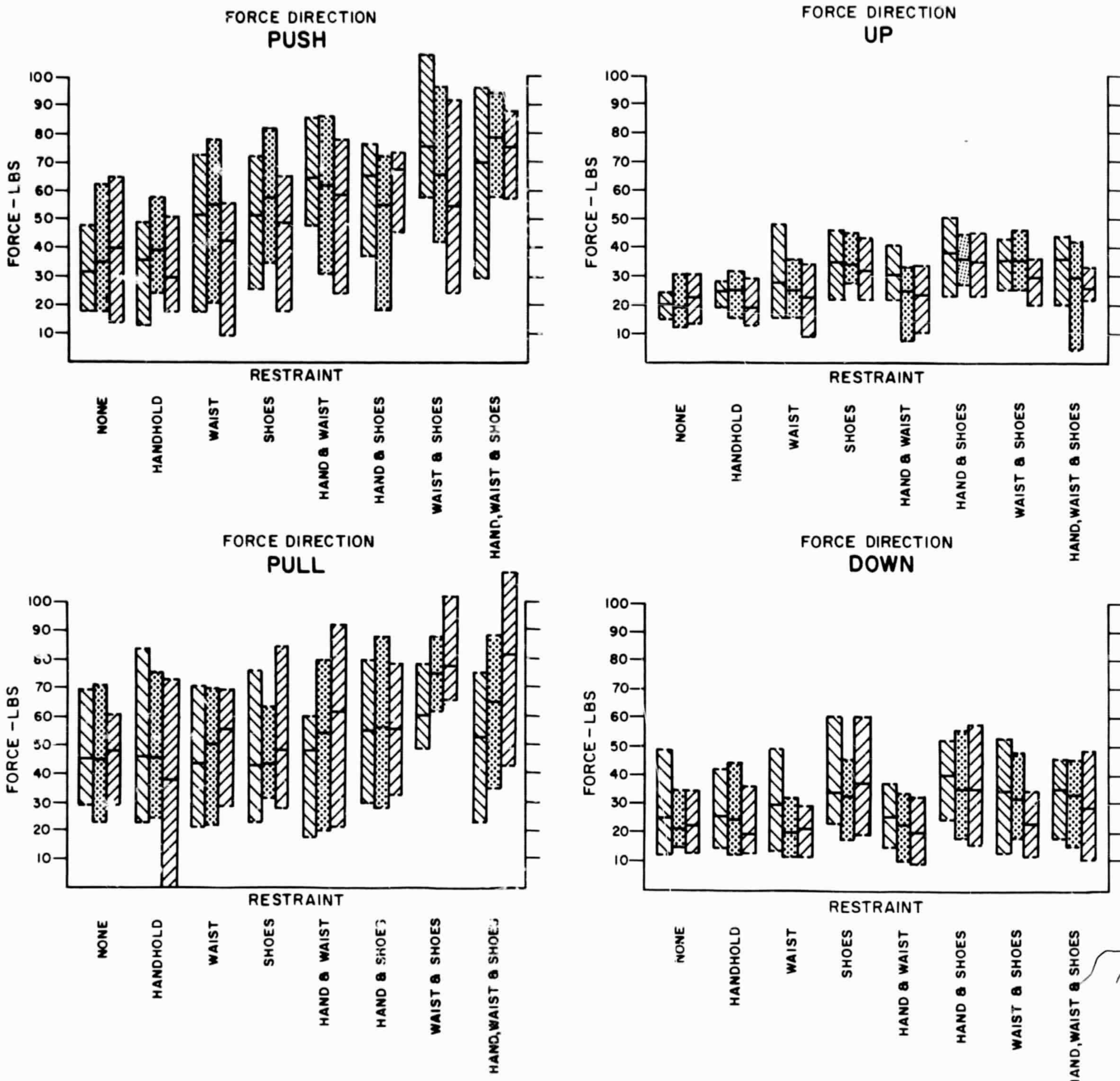
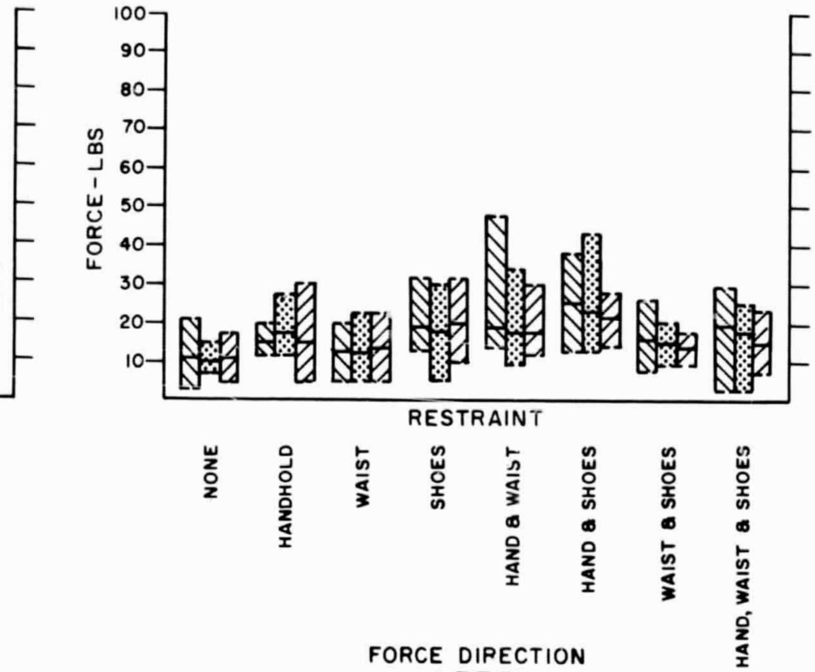


Fig 6.8-12 A

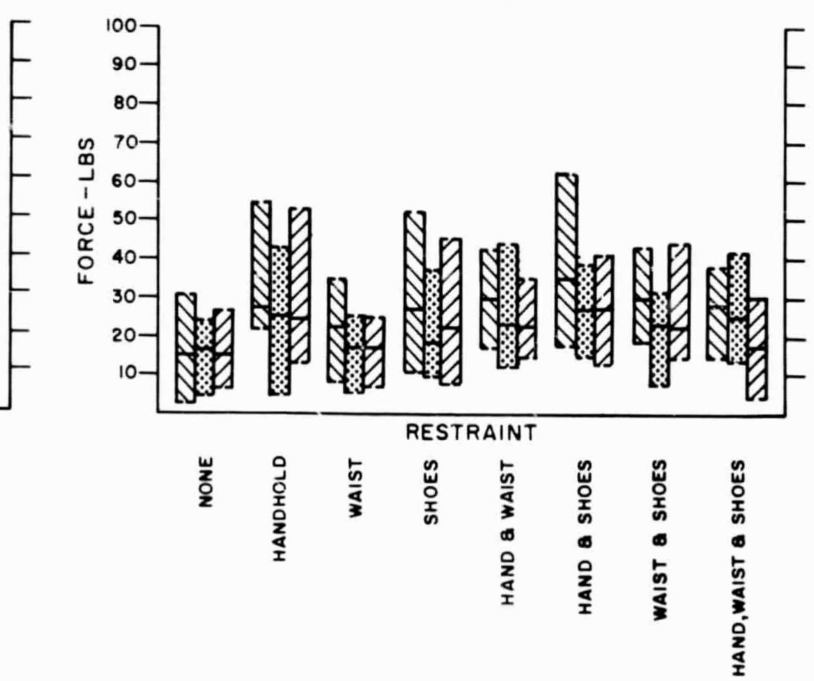
FOLDOUT FRAME

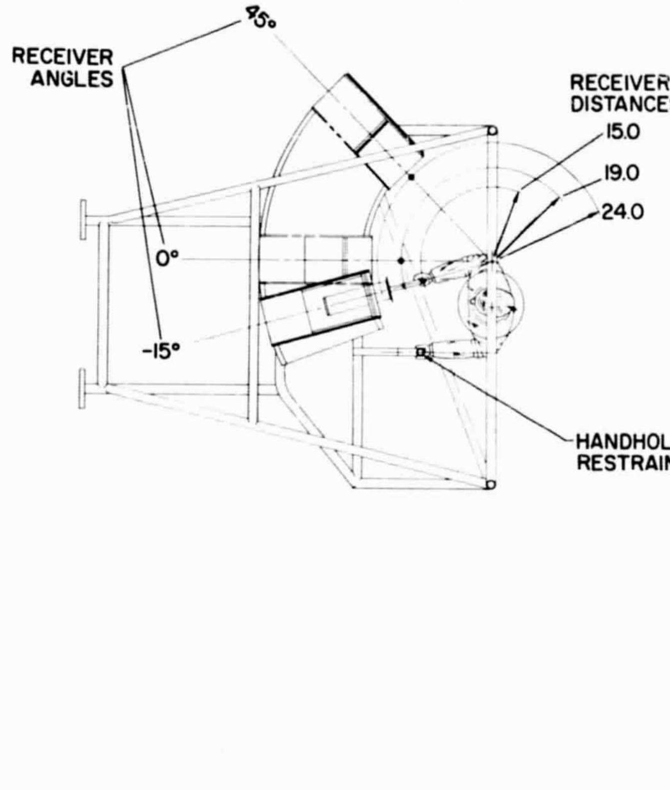
HANDLE ORIENTATION: VERTICAL

FORCE DIRECTION
RIGHT



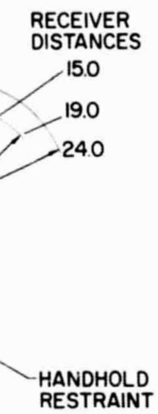
FORCE DIRECTION
LEFT





FOLDOUT FRAME

Fig. 6.8-12 B



FORCE TYPE

SUSTAINED = FORCE MAINTAINED FOR 4 SECONDS
IMPULSE = PEAK FORCE OBTAINED IN 1 SECOND

RECEIVER DISTANCES

15" ≃ 90° ELBOW ANGLE
19" ≃ 135° ELBOW ANGLE
24" ≃ 180° ELBOW ANGLE

HANDLE ORIENTATION

LOCAL VERTICAL
LOCAL HORIZONTAL

RANGE – MAX = LARGEST FORCE
MEAN = AVERAGE OF ALL FORCES
RANGE – MIN = SMALLEST FORCE

Figure 6.8-12.C Summary Data Chart No. 12

FOLDOUT FRAME

of significance (Table 6.8-3). Sustained forces were those force magnitudes that could be maintained over a 4-second interval. Impulsive forces were the peak magnitudes that could be exerted in a 1-second interval.

In general, it can be seen that Push/Pull impulsive force emission capability is approximately 2 1/2 times as great as sustained Push/Pull force capability. Secondly, impulsive force capability in the Up/Down, Right/Left directions is approximately twice as great as sustained force capability in the corresponding directions. Finally, Push/Pull impulsive force emission capability appears to be about twice as great as the Up/Down, Right/Left force capability.

6.8.2.2 Air Versus Water Pressurization

The results of the Wilcoxon Matched Pairs Signed Ranks Test indicate that the sustained mean forces for air and water pressurization modes did not differ significantly (Table 6.8-4). Table 6.8-5 indicates that the impulsive mean forces for air and water pressurization modes also did not differ significantly.

The general conclusions regarding Push/Pull and impulsive over sustained force advantages presented in Section 6.8.2.1 above also apply here.

6.8.2.3 Horizontal Versus Vertical Handle Orientation (Tables 6.8-6 and 6.8-7)

The results of the Wilcoxon Matched Pairs Signed Ranks Test indicate that the sustained mean force for horizontal and vertical handle orientations did not differ significantly.

In general, it appears that handle orientation has little effect on force emission capability in the Push/Pull and Left directions. Also, it appears that a vertical handle orientation increases the capability to exert Up/Down forces and a horizontal handle orientation increases the capability to exert Right direction forces.

Table 6.8.3. Wilcoxon Test - Sustained Versus Impulse Mean Forces

Force Direction	Sustained Means (lb)	Impulse Means (lb)	Diff. Between Means (lb)	Rank	Least Common
PUSH	19.7	51.5	-31.8	-6	
PULL	20.8	51.2	-30.4	-5	
UP	12.4	25.2	-12.8	-3	
DOWN	15.6	28.7	-13.1	-4	
RIGHT	11.7	23.4	-11.7	-1	
LEFT	13.7	26.3	-12.6	-2	
					T = 0

T = 0 with an N of 6 - Significant at 0.01 level

Table 6.8.4. Wilicoxon Test Air Versus Water Pressurization, Sustained Means

Force Direction	Air Means (lb)	Water Means (lb)	Diff. Between Means (lb)	Rank	Least Common
PUSH	19.8	19.6	0.2	1	
PULL	21.7	20.1	1.6	6	
UP	12.7	12.2	0.5	3	
DOWN	15.2	15.8	-0.6	-4	4
RIGHT	11.9	11.5	0.4	2	
LEFT	14.2	13.3	0.9	5	
				T =	4

T = 4 with N of 6- Not significant

Table 6.8-5. Wilcoxon Test Air Versus Water Pressurization, Impulsive Means

Force Direction	Air Means (lb)	Water Means (lb)	Diff Between Means (lb)	Rank	Least Common
PUSH	51.8	51.3	0.5	2.5	
PULL	53.0	49.9	3.1	6	
UP	24.9	25.4	-0.5	-2.5	2.5
DOWN	27.5	29.6	-2.1	-5	5
RIGHT	23.3	23.4	-0.1	-1	1
LEFT	27.0	25.9	1.1	4	
				T =	8.5

T = 8.5 with an N of 6 - Not significant

Table 6.8-6. Wilcoxon Test-Horizontal Versus Vertical Handle Orientation, Sustained Means

Force Direction	Air Means (lb)	Water Means (lb)	Diff Between Means (lb)	Rank	Least Common
PUSH	20.2	19.2	1.0	3	
PULL	21.0	20.6	0.4	2	
UP	10.6	14.2	-3.6	-5	5
DOWN	13.8	17.3	-3.5	-4	4
RIGHT	14.7	8.6	6.1	6	
LEFT	13.8	13.6	0.2	1	
				T =	9

T = 9 with an N of 6 – Not Significant

Table 6.8-7. Wilcoxon Test-Horizontal Versus Vertical Handle Orientation, Impulsive Means

Force Direction	Air Means (lb)	Water Means (lb)	Diff Between Means (lb)	Rank	Least Common
PUSH	53.0	50.1	2.9	3	3
PULL	50.2	52.3	-2.1	-2	
UP	20.7	29.5	-8.8	-5	
DOWN	26.3	31.0	-4.7	-4	
RIGHT	28.8	17.9	10.9	6	6
LEFT	26.5	26.1	0.4	1	1
				T =	10

T = 10 with an N of 6 - Not significant

6.8.2.4 Mean Forces Across Subjects

The results of the Friedman Two-way Analysis of Variance Test indicate that the sustained mean force emission capability across subjects differed significantly at the 0.05 level (Table 6.8-8). Table 6.8-9 indicates that the impulsive mean force emission capability across subjects also differed significantly, but at the 0.01 level. Subjects 1 and 3 corresponded to the 90th percentile grouping and Subjects 2 and 4 corresponded to the 50th percentile groupings on the basis of stature.

In general, however, the force emission capability of the subjects did not follow these percentile groupings. Subjects 2 and 3 generally exerted the greatest mean forces which indicate a differential force capability within percentile groups. Also, there appears to be a differential force capability within subjects for sustained and impulsive forces. Subject 3 exerted the greatest impulsive forces, but Subject 2 generally exerted the greatest sustained forces.

6.8.2.5 Mean Forces Across Receiver Angles

The results of the Friedman Two-way Analysis of Variance Test indicate that the sustained mean force emission capability across receiver angles did not differ significantly (Table 6.8-10). Table 6.8-11 indicates that the impulsive mean force emission capability across receiver angles also did not differ significantly.

It appears, however, for both sustained and impulsive forces, that the capability to exert both sustained and impulsive Push/Pull forces increases as the location of the force receiver is moved away from directly in front of the subject. However, this tendency appears to reverse for the other directions. That is, the Up/Down and Right/Left sustained and impulsive force emission capability tends to decrease as the force receiver is moved laterally from in front of the subject.

6.8.2.6 Mean Forces Across Receiver Distances

The three receiver distances were Near (15 inches), Medium (19 inches) and Far (24 inches) and roughly corresponded to the elbow angles of 90 degrees, 135 degrees, and 180 degrees respectively. The results of the Friedman Two-way Analysis of Variance Test indicate that the sustained mean force emission capability across receiver distances did not differ significantly (Table 6.8-12). Table 6.8-13 indicates that the impulsive mean force emission capability across receiver distances also did not differ significantly.

It appears from the data that as the distance between the subject and the force receiver increases, the ability to exert Push forces decreases. Conversely, as the distance between the subject and the force receiver increases, the ability to exert Pull forces increases. Additionally, there appears to be a lesser tendency for the Up/Down and Right/Left force emission capability to increase as the distance between the subject and force receiver decreases.

6.8.2.7 Mean Forces Across Restraints

The eight restraint conditions were none (no restraint); handhold; rigid waist; Gemini dutch shoes; the combinations of handhold and waist; handhold and shoes; waist and shoes; and handhold, waist, and shoes. The first four, excluding the no-restraint case, were single-point restraints. The last four were considered as multiple point restraints. The results of the Friedman Two-way Analysis of Variance Test indicate that the sustained mean force emission capability across restraints differed significantly at the 0.001 level (Table 6.8-14). Table 6.8-15 indicates that the impulsive mean force emission capability across restraints also differs significantly at 0.001 level.

In addition to the statistical analysis, the data also appears to indicate the following design implications. It appears that a force cannot be sustained in a no restraint condition. Secondly, the single-point restraints have differential value for different force directions. For sustained forces, the waist restraint is best for Push/Pull, the Gemini Dutch shoes are best for Up/Down, and the handhold is best for Left directions. In addition, all single-point restraints are about equal in their inability to provide an assist for Right direction forces.

Table 6.8-8. Friedman Test Across Subjects, Sustained Mean Forces

Force Direction	Subject Means (lb) 1	2	3	4	Ranks by Rows 1	2	3	4
PUSH	18.0	23.8	20.7	16.2	2	4	3	1
PULL	24.4	23.9	17.6	17.7	4	3	1	2
UP	11.8	14.8	12.8	10.2	2	4	3	1
DOWN	11.1	17.9	20.8	12.0	1	3	4	2
RIGHT	9.4	14.3	13.4	9.4	1.5	4	3	1.5
LEFT	10.1	15.7	16.4	11.3	1	3	4	2
				ΣR_j	11.5	21	18	9.5

K = number of conditions = 4
N = number of replications = 6
R_j = sum of ranks in the j^{th} row

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(4)(4+1)} \left[(11.5)^2 + (21)^2 + (18)^2 + (9.5)^2\right] - 3(6)(4+1)$$

$$\chi_r^2 = \frac{12}{120} (132.25 + 441 + 324 + 90.25) - 90$$

χ_r^2 8.75 with K-1 or 3df - Significant at the 0.05 level

Table 6.8-9. Friedman Test Across Subjects, Impulsive Mean Forces

Force Direction	Subject Means 1	2	3	4	Ranks by Rows 1	2	3	4
	(forces in lbs)							
PUSH	50.9	50.9	59.4	44.5	2.5	2.5	4	1
PULL	57.9	49.3	53.5	44.5	4	2	3	1
UP	25.8	25.8	27.3	21.8	2.5	2.5	4	1
DOWN	25.3	29.1	35.8	23.8	2	3	4	1
RIGHT	20.2	24.8	28.7	19.2	2	3	4	1
LEFT	22.8	27.4	31.5	23.0	1	3	4	2
				ΣR_j	14	16	23	7

K = number of conditions = 4
N = number of replications = 6
R_j = sum of ranks in the j^{th} column

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3\,N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(4)(4+1)} \left[(14)^2 + (16)^2 + (23)^2 + (7)^2 \right] - 3\,(6)\,(4+1)$$

χ_r^2 = 13 with K-1 or 3 df - Significant at the 0.01 level

Table 6.8-10. Friedman Test Across Receiver Angles, Sustained Mean Forces

	Receiver Angle Means (lb)				Ranks by Rows		
Force Direction	-15°	0°	45°		-15°	0°	45°
PUSH	18.1	18.7	22.2		1	2	3
PULL	20.3	19.4	22.7		2	1	3
UP	13.0	12.5	11.7		3	2	1
DOWN	17.2	14.9	14.5		3	2	1
RIGHT	12.6	12.4	10.1		3	2	1
LEFT	14.7	14.0	12.3		3	2	1
				ΣR_j	15	11	10

K = 3 receiver angles
N = 6 replications
R_j = Sum of the ranks in the j^{th} row

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (Rj)^2 - 3(6)(3+1)$$

$$\chi_r^2 = \frac{12}{(6)(3)(3+1)} \left[(15)^2 + (11)^2 + (10)^2\right] - 3(6)(3+1)$$

χ_r^2 = 2.3 with K-1 or 2 df - Not significant

Table 6.8-11. Friedman Test Across Receiver Angle, Impulsive Mean Forces

Force Direction	Receiver Angle Means (lb) -15°	0	45°	Ranks by Rows -15°	0°	45°
PUSH	49.4	51.0	54.2	1	2	3
PULL	51.2	49.9	52.7	2	1	3
UP	26.4	25.2	24.0	3	2	1
DOWN	31.2	28.1	26.7	3	2	1
RIGHT	25.0	24.3	20.8	3	2	1
LEFT	28.2	27.1	23.6	3	2	1
			ΣR_j	15	11	10

K = 3 receiver angles
N = 6 replications
R_j = Sum of the ranks in the jth row

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(3)(3+1)} \left[(15)^2 + (11)^2 + (10)^2\right] - 3(6)(3+1)$$

$\chi_r^2 =$ 2.3 with K-1 or 2 df - not significant

Table 6.8-12. Friedman Test Across Receiver Distance, Sustained Mean Forces

	Receiver Distance Means (lb)			Ranks by Rows		
Force Direction	Near	Medium	Far	Near	Medium	Far
PUSH	22.8	19.7	16.6	3	2	1
PULL	16.5	20.7	25.0	1	2	3
UP	14.3	11.6	11.5	3	2	1
DOWN	16.2	15.5	14.9	3	2	1
RIGHT	12.2	11.5	11.4	3	2	1
LEFT	14.7	13.4	13.0	3	2	1
			ΣR_j	16	12	8

K = 3 receiver distances
N = 6 replications
R_j = Sum of the ranks in the jth row

$$\chi_r^2 = \frac{12}{NK(k+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(3)(3+1)} \left[(16)^2 + (12)^2 + (8)^2\right] - 3\,(6)\,(3+1)$$

χ_r^2 = 5.33 with K-1 or 2 df - Not Significant

Table 6.8-13. Friedman Test Across Receiver Distance, Impulsive Mean Forces

Force Direction	Receiver Distance Means (lb) Near	Medium	Far	Ranks by Rows Near	Medium	Far
PUSH	53.2	52.4	49.0	3	2	1
PULL	45.6	51.7	56.1	1	2	3
UP	27.0	25.0	23.7	3	2	1
DOWN	29.2	29.3	27.6	2	3	1
RIGHT	24.2	23.8	22.2	3	2	1
LEFT	28.0	25.9	25.1	3	2	1
			ΣR_j	15	13	8

K = 3 receiver distances
N = 6 replications
R_j = Sum of the ranks in the jth rows

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(3)(3+1)} \left[(15)^2 + (13)^2 + (8)^2\right] - 3(6)(3+1)$$

χ_r^2 = 4.33 with K - 1 2df - Not Significant

Table 6.8-14. Friedman Test Across Restraints, Sustained Mean Forces

	Restraint Means (lb)							
Force Direction	None	Hand	Waist	Shoes	H&W	H&S	W&S	H, W&S
PUSH	0.0	1.3	14.6	4.1	29.2	29.7	35.5	42.5
PULL	0.2	2.1	22.3	4.3	30.6	33.0	36.5	37.6
UP	0.5	4.8	10.4	17.5	13.6	18.0	17.2	17.0
DOWN	1.6	6.6	10.4	20.8	15.8	25.6	19.3	21.6
RIGHT	0.1	10.5	12.3	9.4	15.3	16.3	13.6	16.1
LEFT	0.1	16.6	12.1	8.4	17.4	20.6	14.8	19.3

Force Direction	Ranking by Rows							
PUSH	1	2	4	3	5	6	7	8
PULL	1	2	4	3	5	6	7	8
UP	1	2	3	7	4	8	6	5
DOWN	1	2	3	6	4	8	5	7
RIGHT	1	3	4	2	6	8	5	7
LEFT	1	5	3	2	6	8	4	7
ΣRJ	6	16	21	23	30	44	34	42

K = 8 restraints
N = 6 replications
R_j = Sum of the ranks in the jth column

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(8)(8+1)} \left[(6)^2 + (16)^2 + (21)^2 + (23)^2 + (30)^2 + (44)^2 + (34)^2 + (42)^2\right] - 3(6)(8+1)$$

χ_r^2 = 30 with K - 1 or 7 df - Significant at .001 level

Table 6.8-15. Friedman Test Across Restraints, Impulsive Mean Forces (lb)

	Restraint Means							
Force Direction	None	Hand	Waist	Shoes	H&W	H&S	W&S	H, W&S
PUSH	35.4	40.9	43.3	45.8	56.6	62.4	58.5	69.2
PULL	43.2	43.2	46.0	47.6	50.7	61.3	56.8	60.9
UP	19.3	21.3	22.7	27.8	23.3	30.6	27.6	28.8
DOWN	22.5	25.8	22.8	32.7	26.0	36.6	30.4	32.1
RIGHT	17.5	22.2	21.8	22.1	25.4	28.2	22.8	26.7
LEFT	18.2	29.0	22.2	23.0	28.0	34.3	25.4	29.9

Force Direction	Ranks by Rows							
PUSH	1	2	[illegible]	4	5	7	6	8
PULL	1.5	1.5	3	4	5	8	6	7
UP	1	2	3	6	4	8	5	7
DOWN	1	3	2	7	4	8	5	6
RIGHT	1	4	2	3	6	8	5	7
LEFT	1	6	2	3	5	8	4	7
ΣR_j	6.5	18.5	15	27	29	47	31	42

K = 8 restraints
N = 6 replications
R_j = Sum of the ranks in the jth row

$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(K+1)$$

$$\chi_r^2 = \frac{12}{(6)(8)(8+1)} \left[(6.5)^2 + (18.5)^2 + (15)^2 + (27)^2 + (29)^2 + (47)^2 + (31)^2 + (42)^2\right] - 3(6)(8+1)$$

χ_r^2 = 32.8 with K-1 or 7 df - significant at .001 level

The handhold, waist, and shoes restraint combination resulted in the greatest Push/Pull forces with the waist and shoes combination very close behind. The handhold and shoes restraint combinations resulted in the largest mean sustained forces for the Up/Down and Right/Left directions. Finally, the data would indicate that Right direction sustained forces should be avoided whenever possible.

For impulsive force emissions, there is very little difference between the means for the single-point restraints, including the no-restraint case. Also, all the multiple restraint conditions are better than the single-point restraints. The handhold and shoes combination permits the greatest impulsive mean force emissions in all six directions. Finally, the handhold and waist is generally the poorest of the multiple point restraint conditions for impulsive force emissions.

6.8.3 CONCLUSIONS

The conclusions resulting from this experimental program are divided into two general groups. In the first are those conclusions that can be drawn from the data analysis and results. The second group contains those conclusions that resulted from the operational experience of conducting an underwater experimental program of such a large magnitude as Experiment 84A.

6.8.3.1 Data Conclusions

The following major conclusions are summarized from the findings reported above in the analysis and results section.

a. The statistical analyses were performed on means derived across experimental conditions and should not be used to generalize to the individual case. The reader should go directly to the specific condition combination presented in the graphical or tabular format to obtain the pertinent design data.

b. The handhold and shoes restraint combination resulted in the greatest Up/Down and Left/Right sustained and impulsive force generating capability.

c. The handhold, waist, and shoes restraint combination and the waist and shoes restraint combination resulted in the greatest Push/Pull sustained forces.

d. The waist restraint was the only single-point restraint in which a significant sustained (above 10 pounds) mean Push/Pull force could be exerted.

e. The handhold restraint provided the capability for sustaining significant (above 10 pounds) mean forces in only the Left/Right directions.

f. The shoes restraint provided the capability for sustaining significant (above 10 pounds) mean forces in only the Up/Down directions.

g. The mean capability to exert impulsive forces in a no-restraint condition did not differ greatly (4 to 14 pounds differential range) from the capability provided by the single-point restraints (handhold, waist, and shoes restraints).

h. The mean capability to exert impulsive forces did not differ greatly (5 to 12 pounds differential range) across the multiple-restraint conditions (handhold and waist; handhold and shoes; waist and shoes; and handhold, waist, and shoes).

i. The space suit pressurization mode did not differentially affect the ability of subjects to exert forces.

6.8.3.2 Operational Conclusions

The following operational conclusions were drawn from the considerable number of experiences and observations noted during the conduct of this experimental program.

a. Planning of extensive underwater pressure-suited operations should include a 100 percent contingency time factor.

b. Extreme care should be exercised to insure the cleanliness of the neutral buoyancy facility, especially to minimize the frequency of ear infections.

c. Neutrally buoying space-suited subjects for an upright, nontranslational operation is a relatively simple and easy task.

d. The water pressurization mode was more efficient, from a subject preparation and experimental session changeover time-saving standpoint, than the air pressurization mode.

e. Future water pressurized suit operations should include a face mask that can accommodate a communication system.

f. The possible hazard resulting from the physical reaction of a pressure-suited subject exerting forces under minimal restraint conditions should be carefully considered when selecting restraints for space operations.

SECTION 7

EXPERIMENT 1A - TRANSPORT OF FREE MASSES IN ZERO GRAVITY

The second experiment selected for impelementation in this study program is described in detail in this section. As indicated in Section 3.10, study program constraints limited the effort on Experiment 1A to a detailed design only, and actual test operations were not conducted. As for Experiment 84A, described in Section 6, modifications to the original Experiment 1 were made at the request of the NASA. These primarily consisted of variations in the course and limitations to the number of experimental modules.

7.1 INTRODUCTION

The problems associated with the transport of free masses through the interior of a spacecraft across its surface, and between spacecraft in a zero-gravity environment represents a major area of conjecture with respect to potential astronaut performance capabilities. While the Gemini program demonstrated the fact that man could maneuver through the open three-dimensional volume of space, it did not assess man's capability to transport objects external to himself. At this point in time, and in light of the complex intra- and extra-vehicular operations contemplated for the next generation of spacecraft, it is essential that an analysis be made of those considerations which could and would affect the orbital astronaut's capability to transport, maneuver, and manipulate objects in free space.

While it is understood that a rather large number of conditions affect the astronaut's final performance, preliminary studies in the neutral buoyancy facilities of the General Electric Company have demonstrated that three generic areas have major impact on the question. These are defined and discussed in the following sections.

7.1.1 OBJECT CHARACTERISTICS

Object characteristics include those parameters relating to the mass, volume, and configuration of the item involved. Included under the heading of mass are not only the absolute values involved, but the physical distribution of the mass and the resulting center of mass in the object. In the area of volumetric affectors, it can most readily be seen that the absolute volume involved would interfere not only with the astronaut's visual field, but with his ability to be aware of the orientation and physical location of the item in respect to maneuvering it through orifices or narrow throughways. The configuration of an item while interacting strongly with overall mass distribution and volume could determine the locus of thrust points, restraint sites and, once again, problems in maneuvering and manipulation.

7.1.2 METHOD TRANSPORT

This area is concerned with those problems related to the manipulative techniques utilized by the astronaut, as well as problems relating to size, configuration, and clearance criteria. These include the number and location of handholds, the method of attachment of the object to either the astronaut or the mobility aid, the mode of traversing from one point to another, and the type of mobility aid or assist device to be utilized by the astronaut. Finally, the method of transport dictates the type of support equipment necessary for task accomplishment.

7.1.3 THE CHARACTERISTICS OF THE THREE-DIMENSIONAL PATH TO BE TRAVERSED

Here considerations regarding control of acceleration and velocity of the object come into effect. The complexity and severity of the convolutions in the three-dimensional path to be traversed will most certainly affect man's capability to successfully complete them. It is conceivable that pathways can be varied from the simple ballistic trajectory to the complexity of controlled movement across a path of several degrees of freedom simultaneously.

7.2 OBJECTIVE

While it is recognized that no single experimental procedure can answer the preceding questions in detail, the following experimental series is suggested in order to generate criteria which accurately define the limitations imposed by a selected sample of variations in these factors. The objectives of the proposed experimental design will enable:

a. Evaluation of the effects of the object mass on the maneuvering, transporting, and manipulation of such objects

b. Determination of the limits of mass transport capability for various modes of transport and attachment locations

c. Evaluation of the effect of restricted work space areas or path complexity on the maneuvering, transporting, and manipulation of objects in zero-g.

The resultant data will allow the equipment designer to determine whether a particular mass can be handled, the reasonable way to handle it, and information related to establishing the sizing and configuration of the route along which it should be transported. It will still be necessary for the designer to consider additional variables, such as volume and configuration (if clearance is in doubt), center of gravity, mass distribution within the transported object, and mobility aid availability.

7.3 EXPERIMENT DESCRIPTION

This particular experiment is designed to establish the parameters of man's nominal ability to manually control and transport various masses in a simulated zero-gravity environment while utilizing an umbilical ECS. The masses will be controlled by being either handheld or attached to various locations on the subject's body. These will then be manually transported over a predetermined course utilizing either one or two hands on an Apollo-type single handrail.

The course consists of a series of straight and curved traversals, right-angle turns, a wall simulating the sides of a spacecraft, and an airlock mock-up. The course was designed in such a way to make maximum use of the space available in the particular underwater facility which was specified for use during this study and to evaluate the problems related to transfer of masses along pathways having different three-dimensional configurations. The subjects will perform all experimental tasks wearing Apollo State-of-the-Art spacesuits pressurized to 3.7 psig, using both water and air suit pressurization methods. Zero-gravity will be simulated by the technique of neutral buoyancy described in Section 4.

The experimental apparatus will be constructed to provide efficient interchange and control of the experimental conditions. The four simulated masses will be designed to permit easy exchange between the four attachment locations, i.e., handheld, upper back, lower back, and feet. An instrumentation pack will be designed to provide both accelerometer and physiological data to be hardwired to surface recording equipment.

Each experimental session will commence when the subject and the simulated mass are in a predetermined starting position on the traversal course. On instruction from the test director, the subject will traverse the entire experimental course and return to the starting point. The safety men will observe the subject and manipulate the umbilical and instrumentation lines in order to minimize inappropriate drag or fouling problems during the course traversal. The experiment will be completed when all subjects have repeated each of the experimental conditions twice in air-pressurized suits and twice in water-pressurized suits.

7.4 TEST VARIABLES

As previously stated, the ability of a subject to transport masses in a zero gravity environment is influenced by several variables. Some of the more important are:

a. Characteristics of the transported object - mass and center of gravity

b. Relationship of mass to test subject position and attachment point

c. Type of traversal, work site restrictions, and assist devices available

d. Type of spacesuit worn and pressurization conditions

To the extent limited by practical experimental limitations and facility availability, variations and combinations of the above are included in the experimental protocol. The range of each variable and the extent of these limitations are briefly discussed.

7.4.1 OBJECT MASS

Selection of object mass was made on the basis of a pilot study using non-suited divers. Four masses, intended to bracket man's mass handling capability, were selected. These are as follows:

a. 1.5 slugs (12-inch sphere)

b. 3.4 slugs (16-inch sphere)

c. 6.8 slugs (20-inch sphere)

d. 11.8 slugs (24-inch sphere)

For this experiment, no attempt will be made to vary the module center of gravity, which will be fixed at the center of the spherical module.

7.4.2 OBJECT TRANSPORT METHOD

Four object transport methods were selected as representative of feasible manual mass transport methods. These consist of:

a. No attachment: subject pulls himself with one hand and controls the mass with the other

b. Upper back attachment: mass located at shoulder blades with both hands on mobility aid

c. Lower back attachment: mass located below waist with both hands on mobility aid

d. Module attached to shoes with both hands on mobility aid

In order to assist in interpreting the data, two baseline conditions are also included:

a. One hand on mobility aid, no mass

b. Two hands on mobility aid, no mass

7.4.3 SPACESUIT PRESSURIZATION

In addition to the above variables, the method of pressurizing the spacesuit has also been selected for experimental manipulation. Both air and water will be used as pressurization media to provide information for the determination of any differential effects due to the difference in simulation approaches.

7.5 TEST MEASURES AND ANALYSIS OF RESULTS

This section contains a brief description of the test measures, the data to be collected to satisfy the experimental program test objectives, and a general discussion on the analysis and presentation of results. The data to be collected can be generally categorized as gross motor performance observations, acceleration profiles, physiological data, and subjective observations.

7.5.1 MOTOR PERFORMANCE DATA

Motion picture or video tape recordings and observational data will be gathered throughout this experimental program. The data will be analyzed to determine the following types of information:

a. Task completion tactics or procedures utilized by individuals to permit successful transport of the mass around the traversal course

b. Errors - types, causality, frequency, and safety considerations

c. Motor effectiveness - mobility envelopes, frequency of starts/stops, thrust direction changes, strategy effectiveness in maneuver and manipulation procedures

7.5.2 ACCELERATION HSITORY PROFILES

Acceleration profiles for each experimental condition will be analyzed in terms of frequency of direction change and average magnitude in the forward direction and in the pitch axis. These acceleration profiles will be compared for each portion of the course configuration and each type of traversal condition and will be used to further assess the motor effectiveness of the subject's performance.

7.5.3 PHYSIOLOGICAL DATA

The physiological data will be gathered by means of biomedical sensors attached to the subject and hardwired to surface-located recording apparatus. The data collected will be heart rate, respiration rate, oxygen consumption, deep body temperature, and tidal volume. This data will provide an experimental time history of the average and peak metabolic costs associated with various course profiles and transport modes. Where feasible and meaningful, the metabolic costs will be plotted as a function of time and in respect to absolute levels of deviation from baseline values to denote differences between test variables, differences between subjects, or fatigue effects. In order to make these data meaningful, baseline metabolic measures will be taken on all subjects in a rest condition.

7.5.4 SUBJECTIVE DATA

Subjective data will be collected after each experimental session and will come primarily from two sources, the subjects and the test director. A formal debriefing will be held with each subject after each experimental session to collect subjective comments concerning experiential problems, suggested procedural or equipment modifications and comparative judgements about the experimental variables. An interview form or data questionnaire will be constructed and utilized when dictated by the situation and determined by the test director. These data will be used to provide assessments of crew acceptance of the various techniques as compared with interpretation of the objective data.

7.5.5 RESULTS

The data will be analyzed as required to provide the following information:

a. An evaluation of performance characteristics in the simulated zero-gravity conditions

b. Comparions of the relative effectiveness of the various object transport and attachment methods tested

c. The determination of criteria for work volume envelopes for the selected experimental tasks and conditions

d. The identification of recurrent performance related problem areas for future research

e. The identification of hardware related problem areas for future research

7.6 EXPERIMENT APPARATUS

7.6.1 TRAVERSAL COURSE

In this experiment the course is not a true variable as it is systematically and not experimentally varied. That is, the order of conditions of traversal are constant, but several types of traversal are involved. The fixed, three-dimensional course shown in Figure 7.6-1 consists of:

a. Straight traversals

b. Curved traversals - inside and outside surfaces

c. Right angle turns - enclosed and open area

d. Traversal through a tunnel and a hatch

e. Traversals adjacent to and away from simulated walls

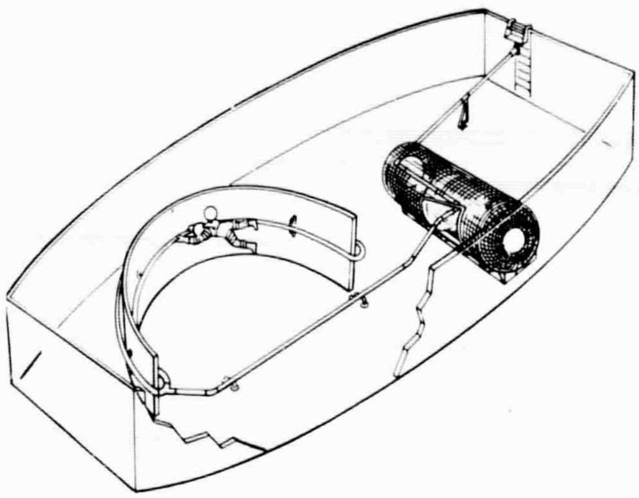


Figure 7.6-1. Traversal Course

7.6.2 MOBILITY AID

A single, non-varying mobility aid, similar to that planned for use in the Apollo Applications Program, will be employed to assist the subject and provides the sole aid to locomotion.

7.6.3 MODULE ATTACHMENTS

Figure 7.6-2 illustrates the various locations for attaching the experimental mass to the test subject. The attachment will be accomplished by connecting the mass to a specially modified SCUBA tank backpack or to Gemini dutch shoes.

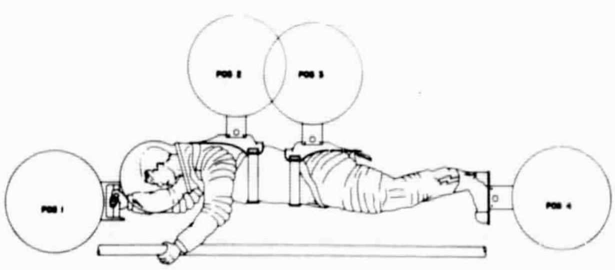


Figure 7.6-2. Module Attachment to Test Subject

7.7 EXPERIMENT SUPPORT EQUIPMENT

The support equipment required for this experiment and the functions provided by these equipments are listed below.

a. Close circuit television equipment: Video tape or photographic recording of subjects motor performance and real-time display of the video to the test director

b. Communications equipment: Communications between all experiment personnel at all locations

c. SCUBA equipment: Self-contained breathing apparatus for underwater support personnel

d. Audio recording equipment: Audio recording of test director's comments during and subsequent to experimental operations

7.8 PERSONNEL REQUIREMENTS

A minimum of 13 personnel will be required each day during the actual conduct of this experiment. The total of 13 personnel is composed of one test director, 4 test subjects, 2 safety men, 2 experiment technicians, 1 suit technician, 1 photographer, 1 on-site medical monitor, and an experiment engineer. In addition, four additional persons will be required to provide backup to the primary experiment team in the event of illness or injury. These additional personnel will consist of two backup subjects (one 50th and one 90th percentile), one safety man, and one experiment technician.

The test director will be in charge of all activities related to conduct of the experiment. He is particularly responsible for insuring that the appropriate experimental variables are selected, the test equipment has been calibrated and is functioning properly, the data recording equipment is operating, the environmental conditions are controlled appropriately, and the subjects have been properly briefed.

The test subjects are required to be available at a predetermined time each day, suited up, and ready to enter the water and perform the experimental conditions. They may assist each other in donning and doffing the pressure suits but should hold all other out-of-the-water activities to a minimum.

The safety men are responsible for the safety of all men in the water. The specific safety man who is in the water during data collection activities has responsibility for the subject and nothing else. As a part of their responsibility for personnel safety, safety men will assist the subject in donning and doffing the pressure suit and verifying that all breathing equipment is operating properly.

The experiment technicians will be responsible for attaching the objects to the subjects, neutrally buoying the subjects and assisting them into the starting position. During the experimental run, the technician will control the hookah and instrumentation lines and will be prepared to assist the safety man in the event of an emergency.

The experiment engineer will provide direct backup support to the test director in ensuring that all experimental equipments are operating in a satisfactory manner. He will be familiar with all experimental systems and provide instruction and training to the experimental technicians for the maintenance and operation of these equipments. He will also assure the timely availability of all test-related facilities.

The medical monitor will be responsible for assuring that all underwater personnel are in good general health and have no medical problems which would limit or prohibit their normally required activities. In addition, he will specifically check out all subjects each day to assure that they are physiologically sound and can operate successfully in a pressure suit. He is also responsible for evaluating any medical emergenices which may arise and assuring appropriate treatment.

The suit technician and photographer will be required, as necessary, to assist in the repair of spacesuits and the set-up of TV or movie cameras, respectively.

7.9 SCHEDULE

The basic experimental trial requires that the subject complete a traversal of the experimental course described in Section 7.6.1. This consists of starting at the platform at the side of the tank, going through the tunnel and around the half-circle simulated wall, and returning to the starting point. Each session consists of three trials with appropriate rest periods interspersed. The session schedule is presented in Table 7.9-1.

Table 7.9-1. Sample Session Schedule

	Time (min)	Subtotal
Trial 1	6.6	6.6
Rest	6.0	12.6
Trial 2	6.6	19.2
Rest	6.0	25.2
Trial 3	6.6	31.8 min

The daily operational schedule is presented in Table 7.9-2. The position of the subjects within each experimental day will be randomly varied throughout the experimental program. The randomization is performed to counterbalance the effects of practice and transfer of training which may confound the data.

Table 7.9-2. Daily Operational Schedule

	Time (min)	Subtotal
Set Up	60	60
Session 1 (Subject 1)	31.8	91.8
Set Up	30	121.8
Session 2 (Subject 2)	31.8	153.6
Set Up	30	183.6
Session 3 (Subject 3)	31.8	214.4
Set Up	30	244.4
Session 4 (Subject 4)	31.8	276.2
Set Up	30	306.2
Session 5 (Subject 1)	31.8	338.0
Set Up	30	368.0
Session 6 (Subject 2)	31.8	399.8
Tear Down	60	459.8 = 7.66 hours

SECTION 8

PRELIMINARY HANDBOOK OF HUMAN ENGINEERING DESIGN DATA FOR REDUCED GRAVITY CONDITIONS

The preliminary handbook structure contained in Volume III of this report was prepared as a "level of effort" development in conjunction with the experimental design and implementation phases of this study program. The primary purpose was to develop a structure upon which a handbook of human engineering data could be built for the use of engineers, designers, and human factors specialists during the developmental and detail design phases of manned spacecraft programs. The following tasks were sequentially implemented in order to achieve this objective:

Task A. Determination of the probable usage of such a document

Task B. Based on a consideration "probable usage," a first-draft content and structure was developed.

Task C. Based on preliminary content requirements, a broad-band literature search was initiated and implemented.

Task D. Consultation with Tufts University, HEIAS personnel for the taxonomy, indexing, and overall structure of such a document was implemented.

Task E. Preliminary analyses of abstract material developed during the literature search were completed. Selected documentation was ordered, reviewed in detail, and pertinent information, figures, and tables selected for possible inclusion in the Handbook.

Task F. Based on all preceding efforts, a "second" but still "preliminary" structure, content and index rationale were established.

Task G. Selections from the collected materials were compiled in coarse form in order to evaluate generic labels selected for the Table of Contents and to establish areas where additional data were needed but not available.

8.1 HANDBOOK DEVELOPMENT

In the process of accomplishing Task A (i.e., the probable usage of such a text), it was determined that the basic handbook would not only be used as an authoritative reference source for individual designers in respect to establishing specifications and requirements for physical man/machine interfaces, but could also provide the basis for standardization of operational protocol development. The publication and common use of authoritative absolute descriptors of the various needs, capabilities and tolerances of crewmen might also provide the basis for the establishment of standardized levels of capabilities for describing crew selection and training criteria in respect to the designation of specific maintainability tasks to individual crewman.

With this in mind, it was decided to follow the precedents set by such documents as the Handbook of Chemistry and Physics, Biology Data Book, etc.; i.e., the selected format for the document should consist of a repository of detailed, quantified data in tabular or graphic form wherever possible.

A secondary purpose was also identified, namely a need to provide a single and comprehensive document for use in manned EVA design activities by the neophyte or newcomer to the field, in order that he might be made aware of those areas where the presence of a human worker could, and should, influence the design of orbital hardware or processes. The final document therefore, must provide readily accessible detailed data describing all pertinent functional or survival-critical interactions between man, his working environment, his vehicle, and support hardwares.

While, as previously stated, it is hoped that widespread utilization of the text material will permit standardization of design practice in respect to vehicle, equipment and operations, the document must also be capable of providing custom-tailored specifications for unique mission/equipment/environment interactions.

8.2 SOURCE MATERIAL

Literature searches were requested from the National Aeronautics and Space Administration's Scientific and Technical Information Division as well as the Defense Documentation Center (DDC) regarding human performance in a reduced gravity environment. These searches were reviewed, and those items that appeared to contain required human performance data were ordered for review. The services of the Tufts University Human Engineering Information and Analysis Service (HEIAS) were also utilized during this effort. Volumes I and II of the HEIAS bibliographies were searched for space-related categories most relevant to the task. As a result of this search, a printout of approximately 500 references was developed. Items to be entered in the upcoming Volume III of the HEIAS Bibliography were also reviewed for relevancy. The NASA and DDC searches were arranged in ascending "AD" and "STAR" accession numbers, respectively, when they were received. The basic HEIAS system carries the titles and abstracts of documents by accession number, but cross-indexes the accession numbers of the documents by an alphabetical listing of primary categories relevant to human factors interests. In order to eliminate title duplication, and facilitate the location of titles and abstracts, the HEIAS system was utilized as the basic collation system.

The fact that the DDC, NASA and HEIAS information sources had different cutoff dates was considered, and an effort to complement the searches, insofar as possible, was made. This could not be accomplished until nearly all the major work of the search was completed and a three-way cross-reference system established between the DDC, STAR and HEIAS accession numbers. An informal check from approximately a 50 percent sampling of STAR accession numbers indicates that routine acquisition of NASA reports was fairly complete and current for HEIAS. An item-by-item check against the DDC search was undertaken, and items which were either missing from, or possibly not yet processed through, the HEIAS system were ordered and examined. A basic review of currently available documentation was initiated, and basic data regarding human operator performance was collected. In this, an attempt was made to primarily gather empirical data generated in an actual reduced gravity environment.

A preliminary outline for tape storage of information was also developed. It was considered that future continued effort regarding the development of the handbook would result in the accumulation of an enormous amount of documentation. An indexed information storage system outline, with an appropriate amount of flexibility incorporated, is available for preliminary utilization.

8.3 APPLICATION

It was felt that a document of this type should permit deliberate and detailed data to be available for the four basic tasks that are currently deemed necessary when designing for maintainability in a manned orbiting system. For optimum maintainability potential, the following discrete tasks must be accomplished.

Task A. The vehicle and all its subsystem housekeeping, structural, and mission-related hardwares must be deliberately analyzed in respect to the possibility of needing in-orbit maintenance. In those instances where maintenance during orbital operations is deemed both possible and feasible, specific efforts must be expended in order to insure ease of diagnostics, access, institution of corrective procedures, and checkout capabilities. These hardware designs shall also consider packaging and general corrective processes involved in respect to minimizing "unique" technological skills, special tooling, instrumentation, facilities, and man-hours necessary to effect the repairs, while maximizing the safety and efficiency of access to the work site.

Task B. The designer should detail all crew support facilities and equipments necessary to accomplish the transport and the restraint/tethering of the crewman and his materials at the work sites, as well as to provide an environment that is conducive to both work and survival.

Task C. The responsible system designers should develop specifications necessary to describe the physical and functional characteristics of the maintenance interface including sizing, configuration and information flows across the man/machine interfaces at the various potential work stations.

Task D. The designers must, as part of their maintainability tradeoffs, consider the capabilities of man in light of the constraints imposed by the system and the environment in the design and assignment of maintenance roles to the "orbital man."

To reiterate, the large preponderance of material selected for this document will be expressed in graphic and/or tabular form, with prose commentary limited to explanations of techniques utilized in the application of specific data. Prose is also utilized in "term definition" as indicated.

8.4 ORGANIZATION OF THE HANDBOOK

In selecting the basic generic headings for Human Engineering Handbook, heavy emphasis was placed on potential usage. Part I contains that information related to the description of human characteristics. Provisions are made for information which will permit allowances for man's physical and functional dimensional requirements as well as descriptors of his general motor, sensory, and cognitive performance capability. Information regarding his tolerance to various forms of physical, emotional, and environmental stressors will also be provided in this section.

Part II has provisions for absolute value data which describes the composition and the various phenomena present in the orbital extravehicular environment.

Part III has provisions for data which will describe the minimal and/or optimal physical and functional characteristics of hardware design where it might interface with man and modify his performance. Data in this area will include sizing, configurational, operational, and dynamic considerations for the vehicle and all its facilities, including unique mission equipments, packaging, and access.

Part IV will contain special considerations pertaining to various support hardware, special constraints and environmental modifiers that must be considered in order to provide an acceptable working environment.

The Handbook development efforts performed during this study were directed towards establishing a point of departure for subsequent efforts. As such, some extra work was expended in developing the content of Part I in order to demonstrate not only the potential utility of such a Handbook, but to emphasize the wealth of information available, but not readily utilized by those who need it most, because of its dispersion in bits and pieces throughout the literature of several disparate professional areas.

SECTION 9

PROGRAM CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

Those conclusions which are directly or indirectly related to the Experiment 84A efforts are detailed in Section 6.8.4.

In general, it can be concluded that the gathering of statistically significant neutral buoyancy simulation data, which implies a relatively large quantity of repetitive trials, is only possible with a full-time, well-motivated, and competent team. That for this program we were fortunate enough to obtain these qualities in a multi-organization team effort is evident in the quantity and type of data obtained.

It can also be concluded that the problems associated with neutral buoyancy simulation are well understood and can be overcome; this can be evidenced by the analyses and tests discussed in Section 4.

9.2 RECOMMENDATIONS FOR FUTURE STUDY

The completion of the analytical and empirical portions of this study program is but a first step on the road to providing design engineers with the information necessary to insure that the capabilities of man are maximized in the design for maintenance and repair of space vehicles. It is recommended that the several areas discussed in this section be strongly considered for future experimental and study effort.

9.2.1 HANDBOOK OF HUMAN ENGINEERING DESIGN DATA FOR REDUCED GRAVITY CONDITIONS

It is strongly recommended that the handbook effort be continued and expanded. Although it is felt that the limited preliminary effort which was a part of this study will provide a firm foundation upon which to build the final handbook, considerable additional effort must be applied to obtain a final, reduced gravity design handbook. In addition to the continued attainment of zero-gravity design data, it will be necessary to apply an in-depth analytical effort to these data in order that nonconflicting, qualified criteria can be provided for the various design facets necessary for spacecraft development and operations.

9.2.2 SIMULATED ZERO-GRAVITY EMPIRICAL DATA COLLECTION

In order to satisfy the goals and purposes of the handbook as described in Section 8 and above, considerable future study effort should be applied toward increasing the data available to the aerospace community. Although it would be desirable to derive such data from actual space flight experience, the length of time and cost required for experimentation in that medium makes it more practical to use empirical data derived from experiments using simulated reduced gravity techniques.

The first experiment recommended for implementation is Experiment 1A, dealing with the transport of masses, as described in Section 7. Among the reasons for this recommendation are (1) the data is urgently needed for implementation of the AAP program and (2) a considerable amount of the work required to design the experiment has already been completed during this study. Although the AAP first flight vehicle is well along in its design, the data from this experiment would serve either to confirm the design decisions or point out possible serious shortcomings. If the latter were to happen, design changes would be necessary in order that the planned flight stand the greatest chance of success.

The implementation of Experiment 1A should be followed up by the conduct of Experiment 2 in order to fully develop the data bank relative to the transport and manipulation of objects in free space. These experiments should be followed by Experiments 3 and 5 (singly or combined), 7, and 6, in that order.

9.2.3 EXPERIMENT 84A BASELINE DATA

It is recommended that a selective program be conducted to obtain baseline data for Experiment 84A. This would involve the replication of a limited number of data points with the test subject in a neutrally buoyed shirtsleeves configuration or a 1-g suited condition. The former would provide comparative data relative to the effects of the spacesuit itself, while the 1-g trials would provide for a comparison of force-producing capabilities as a function of the gravitational environment.

9.2.4 SIMULATED 1/6-g EMPIRICAL DATA COLLECTION

Although 1/6-g data was deleted from this study effort due to the expansion of the zero-g effort and the limitation of resources, it should be emphasized that the need for this data is as great as the need for zero-g design information, if not greater. With the first lunar landing a definite probability in this decade, we find ourselves facing a similar problem in the design of lunar operational equipment as we race for zero-gravity designs today. The designers of lunar exploration systems, lunar bases, etc., must have the necessary information for use in this decade if we plan to expand our exploration during the next. Therefore, it is recommended that further short-term study efforts be made to identify critical 1/6-g data requirements and that an organized program be subsequently implemented to obtain these data.

9.2.5 SIMULATION VALIDATION

It can be expected that design data will continue to be derived primarily through the application of reduced gravity simulation techniques. In addition, simulation techniques have been, and are being used to train crews and verify the adequacy of vehicle designs for extravehicular, zero-gravity operations. However, these are being used prior to having established a sound technological data base regarding the validity of extrapolating from these ground simulation data to predicted flight results. Therefore, it is essential to know how well the technique utilized to simulate a particular behavioral activity relates to the actual reduced gravity condition.

There are at present several techniques in use for the simulation of reduced gravity conditions. These are:

a. Mechanical simulators, including frictionless support devices (air bearing) and force balance devices (Peter-Pan)

b. Keplerian trajectory flights

c. Neutral buoyancy

Each of these has been used extensively and have attendant limitations and strong points as a function of the type of behavior/study being simulated.

It is therefore recommended that a program be instituted to determine the most valid simulation methods for specific behaviors and therefore the features of each simulation technique which should be exploited in future programs. This would require the simulation of a known flight experiment utilizing each of the accepted techniques in order to gather empirical data on the fidelity of the various ground-based, subgravity simulation techniques, and the comparison of actual flight data with that obtained during simulation.

APPENDIX A

NEUTRAL BUOYANCY DESIGN CRITERIA

A.1 DERIVATION OF MODEL SCALING LAWS

The scaling laws for underwater simulation are developed by (1) defining the equations of motion in orbit or in a partial-g environment and underwater in a condition of neutral or partial buoyancy, (2) setting the coefficients of like terms in the equations of motion in space and underwater equal to each other, and (3) solving for the model characteristics.

A.1.1 EQUATIONS OF MOTION IN SPACE

The following is a model of the motions of a body with respect to an orbiting parent body. The motion is caused by an applied force and moment, F and T, representing the input of an astronaut, as shown in Figure A.1-1. Consider rectangular coordinates, X_s, Y_s with orgin fixed in a body which moves at orbital velocity, and with the Y_s axis oriented to the local vertical. Insert into this coordinate system a second body, s. This second body has an initial velocity equal to that of the X_s, Y_s coordinate system and represents the body acted upon by the astronaut. Included in Figure 4.1-1 is a local weight vector, $M_s g$, in order to make the derivation applicable to zero-g or partial-g environments; g_1, the local apparent gravity, equals zero for zero-g applications. For simplicity, only three degrees of freedom are considered: translation in the X and Y directions and rotation θ. By considering only short time periods compared to the orbital period, i.e., on the order of 5 minutes or less, the Clohessy-Wiltshire equations of relative orbital motions may be omitted.

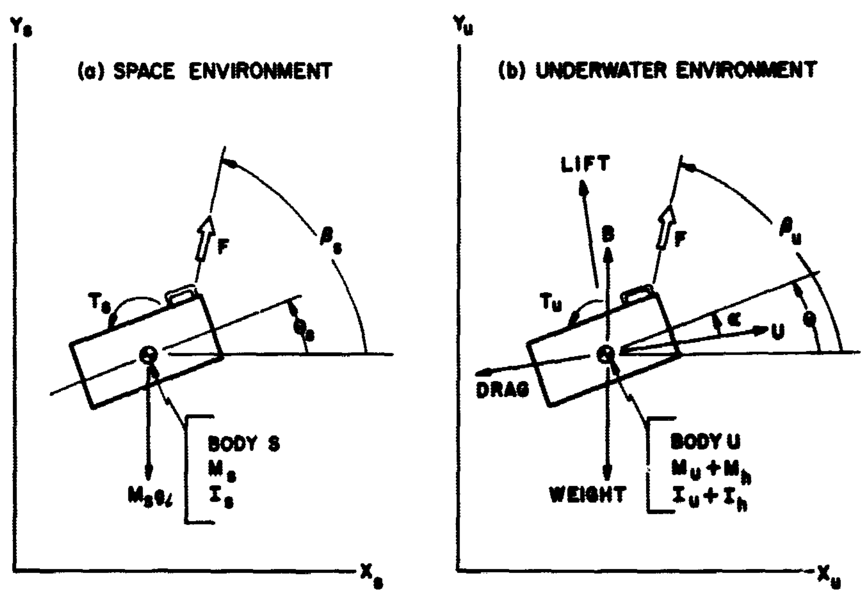


Figure A.1-1. Forces and Moments in Space and Under Water

The equations of motion are:

$$\ddot{X}_s - \frac{F \cos \beta_s}{M_s} = 0 \qquad (1)$$

$$\ddot{Y}_s - \frac{F \sin \beta_s}{M_s} + g_\ell = 0 \qquad (2)$$

$$\ddot{\theta}_s - \frac{T_s}{I_s} = 0 \qquad (3)$$

The nomenclature is as follows:

A	Reference Area (ft^2)
B	Buoyant Force $= \rho_w V_u g_e$
C_D	Drag coefficient
C_m	Moment coefficient $= \dfrac{\text{Moment about c.g.}}{q\,A\,L}$
F	Applied Force (lb)
G	Drag-to-mass ratio parameter $= \dfrac{C_D A \rho_w}{2 M_s}$
g	Gravitational attraction
I	Moment of inertia (slug-ft^2)
K	Hydrodynamic mass factor $= \dfrac{M_h}{\rho_w v}$
K_θ	Rotational damping coefficient $= \dfrac{2\,T}{\rho_w \dot{\theta}^2 A L^3}$
L	Reference Length (ft)
M	Mass (slugs)
q	Dynamic pressure $= \rho_w \dfrac{U^2}{2}$
t	Time (seconds)

T	External moment produced by F_s or F_u
U	Velocity of the underwater test subject = $\sqrt{\dot{X}^2+\dot{Y}^2}$
v	Reference volume for hydrodynamic mass factor (ft^3)
V	Displaced volume (ft^3)
X	Distance moved by subject parallel to X axis (ft)
Y	Distance moved by subject parallel to Y axis (ft)
α	Angle of attack
θ	Rotational displacement (radians)
ρ	Density (slugs/ft^3)
σ	Specific gravity relative to water = $\frac{\rho}{\rho_w}$
⊕	Location of center of mass

<u>Subscripts</u>

a	Apparent
e	Earth
h	Hydrodynamic
ℓ	Local
s	Subject in zero or partial g being simulated
u	Underwater test subject
w	Water

A.1.2 EQUATIONS OF MOTION UNDERWATER

The forces and moments acting upon a submerged body experiencing translation and rotation consist of the buoyancy force, weight, hydrodynamic lift, drag, static moment, rotational damping moment and the external applied forces, and moments such as those exerted by an astronaut attempting to move the body.

The following equations apply:

$$M_a = M_u + M_h \tag{4}$$

$$M_u = \rho_w \sigma_u V_u \tag{5}$$

$$M_h = \rho_w V_u K \left(\frac{v}{V_u}\right) \tag{6}$$

$$I_a = I_u + I_h \tag{7}$$

Depicted in Figure 4.1-1 are the forces and moments experienced by a body in motion in a fluid medium. The equations of motion for a submerged body, as derived from that figure, are shown below. Note that the center of buoyancy has been placed at the center of mass in order to ensure that the body does not have a preferred static orientation.

$$\ddot{X}_u + \frac{C_D A}{M_a} q \cos(\theta-\alpha) + \frac{C_L A}{M_a} q \sin(\theta-\alpha) - \frac{F \cos \beta_u}{M_a} = 0 \tag{8}$$

$$\ddot{Y}_u - \frac{C_L A}{M_a} q \cos(\theta-\alpha) + \frac{C_D A}{M_a} q \sin(\theta-\alpha) + \left(\frac{V_u \rho_w g_e}{M_a}\right) (\sigma_u - 1) - \frac{F \sin \beta_u}{M_a} = 0 \tag{9}$$

$$\ddot{\theta}_u - \frac{C_m AL}{I_a} q - \frac{K_\theta AL^3}{2 I_a} \rho_w \dot{\theta}^2 - \frac{T_u}{I_a} = 0 \tag{10}$$

The fourth term in Equation 9 represents the ratio of the negative buoyancy to the apparent mass. Rotational damping is a function of body shape, size, θ, α, $\dot{\theta}$, and U. The damping term shown in Equation 10 is a simplified form valid for very small ratio of $U/\dot{\theta}L$.

A.1.3 DYNAMIC SIMULATION REQUIREMENTS

Ideally, exact dynamic simulation is desired, but obviously cannot be achieved. Exact real-time, dynamic simulation would be achieved when:

a. The force and moment history impressed on the model or underwater test subject is identical to that impressed on the space subject:

F_s time history $\equiv$ F_u time history

T_s time history $\equiv$ T_u time history

b. The initial velocity and displacement of the model is identical to that of the space subject.

c. The resulting acceleration history of the underwater model is identical to that of the actual equipment in space:

$\ddot{X}_s$ time history $\equiv$ $\ddot{X}_u$ time history

$\ddot{Y}_s$ time history $\equiv$ $\ddot{Y}_u$ time history

$\ddot{\theta}_s$ time history $\equiv$ $\ddot{\theta}_u$ time history

It should be noted that, if conditions b and c are satisfied, then it follows that the velocity and displacement histories will also be identical.

A.1.4 SCALING LAWS

In order to satisfy the above conditions, the coefficients of the $\ddot{X}$, $\dot{X}^2$, $\dot{Y}^2$ and F terms in Equation 1 must equal those in Equation 8; the coefficients of the $\ddot{Y}$, $\dot{Y}^2$, $\dot{X}^2$ and F terms in Equation 2 must equal those of Equation 9; and the coefficients of the $\ddot{\theta}$, $\dot{\theta}^2$, $\dot{X}^2$, $\dot{Y}^2$ and T terms in Equation 3 must equal those in Equation 10. The following relationships are then obtained for the model characteristics. These seven equations constitute the scaling laws.

$$M_u + M_h = M_s = M_a \tag{11}$$

$$I_u + I_h = I_s = I_a \tag{12}$$

$$q\left(\frac{C_D A}{M_u + M_h}\right) = 0 \qquad (13)$$

$$q\left(\frac{C_L A}{M_u + M_h}\right) = 0 \qquad (14)$$

$$q\left(\frac{C_m AL}{I_u + I_h}\right) = 0 \qquad (15)$$

$$\frac{\dot{\theta}^2}{2}\ \rho_w \left(\frac{K_\theta AL^3}{I_u + I_h}\right) = 0 \qquad (16)$$

$$\frac{V_u \rho_w g_e}{M_a}\ (\sigma_u - 1) = g_\ell \qquad (17)$$

Equations 11 and 12 state that the apparent mass and moment of inertia of the underwater test subject must equal the mass and moment of inertia of the space object being simulated. Equations 13 through 16 state that the ratio of the hydrodynamic force characteristic to mass and the ratio of hydrodynamic moment characteristic to moment of inertia should be minimized or, preferably, reduced to zero. Equation 17 states that the weight of the underwater test subject, less the buoyant force, should equal the effective gravitational attraction acting on the subject being simulated. The above scaling laws, in addition to confirming what may have been intuitively evident, form a basis for generating some very useful model sizing relationships and a criterion for measuring the relative fidelity of underwater simulations.

A.2 MODEL DESIGN

A high-fidelity simulation must employ a model which incorporates as many of the previously stated scaling laws as possible. As will be shown, mass simulation is achieved by including hydrodynamic mass in the design and hydrodynamic drag; lift and moment can be reduced to near-zero values. Equations 13, 14, and 15 include a coefficient, q, indicating that velocities should be low for the simulations to be valid. It has been observed that the translation velocities of underwater test subjects seldom exceed 1 foot per second, when working at a natural pace.

The model design technique which has been studied and tested by General Electric is one which employs a closed center body surrounded by an open frame, as shown in Figure A. 2-1. The center body is sized such that its apparent mass, plus that of the frame, equals that of the body being simulated. The open frame duplicates the outline of the module being simulated, providing the astronaut with visual cues as to size and shape. The center body shape selected is a sphere, which was chosen in preference to a streamlined form because spheres have a large hydrodynamic mass that is independent of the direction of motion, and because they do not generate hydrodynamic lift or moments. The center body is generally of sufficient size to house instrumentation and to contain provisions for ballast to provide neutral buoyancy and moment of inertia adjustments. The frame is fabricated from thin structural members in order to reduce its contribution to both drag and hydrodynamic mass and moment. The model must also provide handholds or other attachment points in the same relation to the center of gravity as in the space equipment. In addition, the center of buoyancy and center of pressure must coincide with the center of gravity.

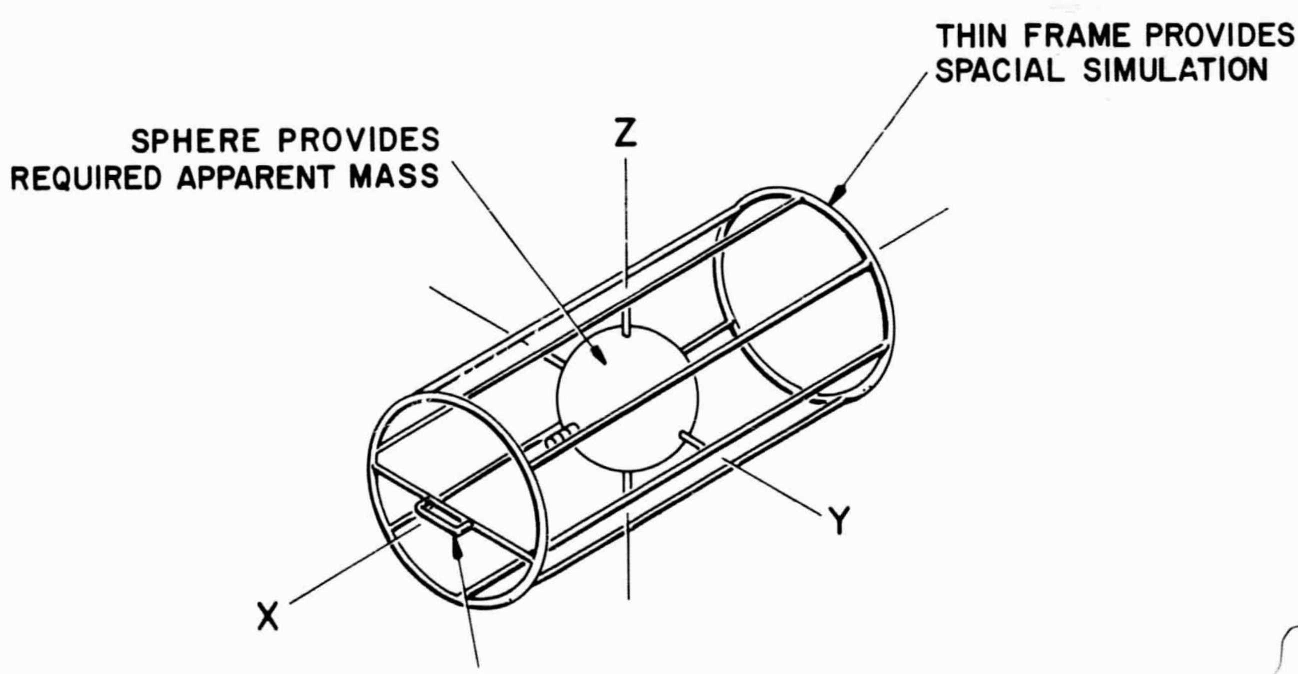


Figure A. 2-1. Typical Underwater Model of Cylindrical Module

Several useful equations for determining the required specific gravity and size of the model have been developed. By substituting Equations 5 and 6 for M_u and M_h, respectively, into Equation 17, simplifying and solving for σ_u obtain:

$$\sigma_u = \frac{K\,(v/V_u)\,(g_\ell/g_e) + 1}{1 - g_\ell/g_e} \qquad (18)$$

This expression, plotted in Figure A. 2-2 for the case $v/V_u = 1$, gives the required specific gravity of the underwater model in order to simulate a given gravitational acceleration.

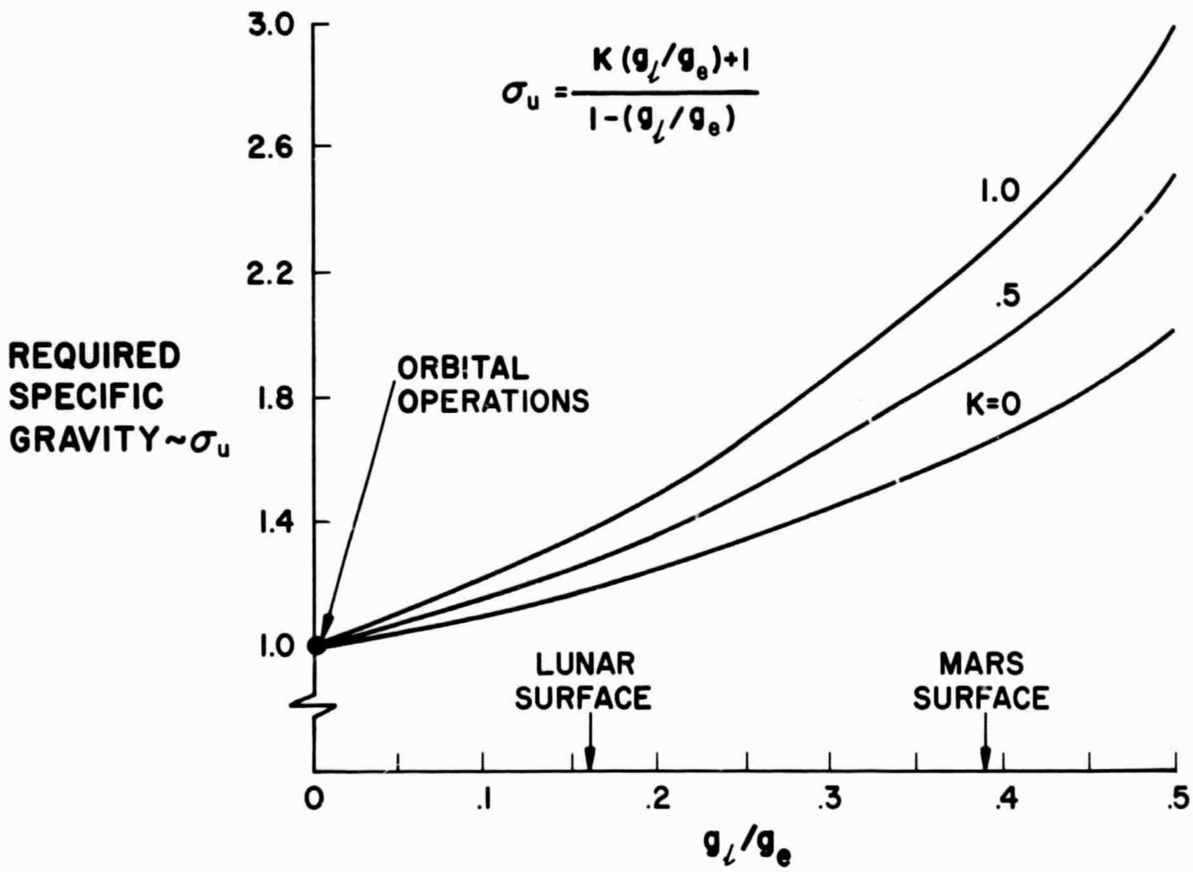


Figure A. 2-2. Model Specific Gravity Requirements

A useful expression for the model displaced volume, V_u can be generated by substituting Equations 5, 6 and 18 into Equation 11 and solve for V_u.

$$V_u = \frac{M_s}{\rho_w} \left[\frac{1 - g_\ell / g_e}{1 + K (v/V_u)} \right] \tag{19}$$

Equation 19 is a general expression for sizing any shaped center body and is valid for zero-g or partial-g simulation. For the special case where the center body is a sphere, $K (v/V_u) = 0.5$, and the center body sphere diameter, in feet, is found to be,

$$D = \left[\frac{4}{\pi} \frac{M_s}{\rho_w} (1 - g_\ell / g_e) \right]^{1/3} \tag{20}$$

Equation 20 is plotted in Figure A.2-3 for convenience in sizing spherical center bodies. It should be noted that no allowance has been made in these estimates for the apparent mass of the frame.

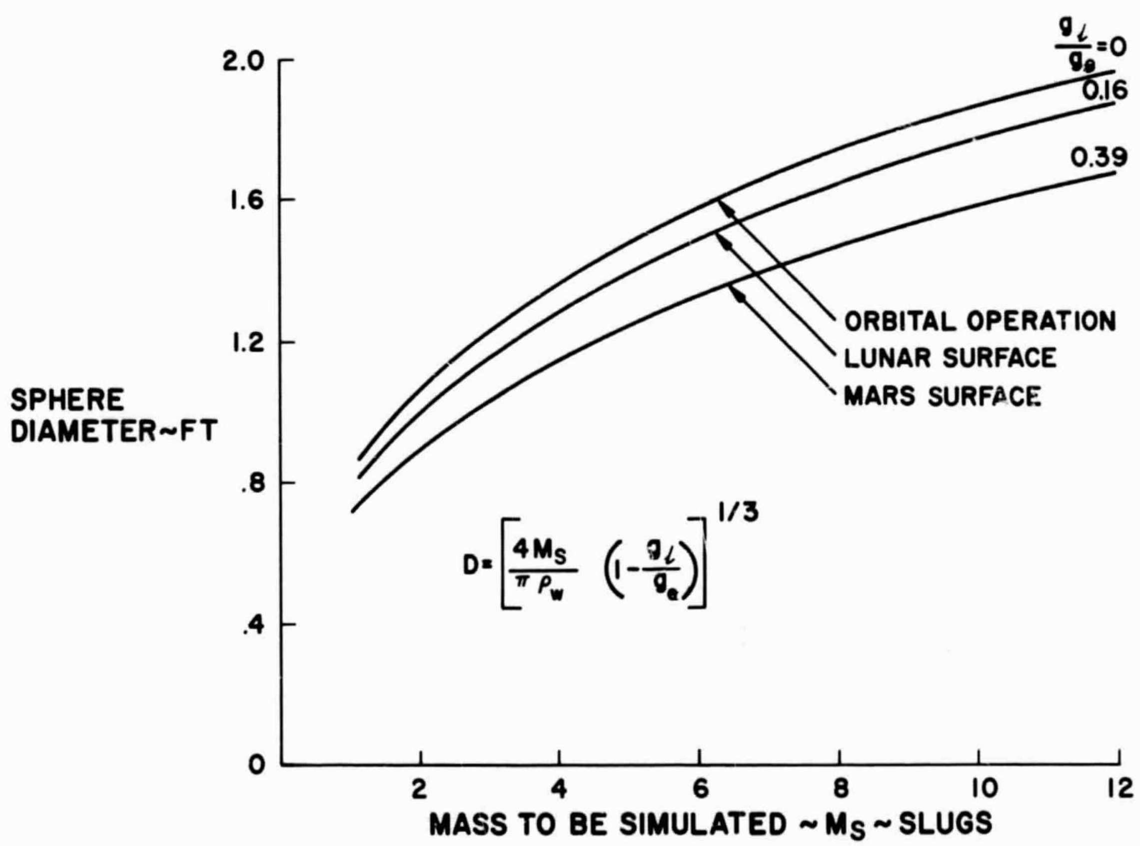


Figure A.2-3. Center Body Size for Mass Simulation

A.3 EXPERIMENTAL VERIFICATION

Tests were performed to verify the scaling laws and the model design technique. The test procedure simply consisted of drawing a sphere and a sphere-frame combination through the water with a constant-known force. The displacement versus time history of the model was recorded during the acceleration and constant velocity portions of the motion. The apparent mass was derived by obtaining the second derivative of the displacement with respect to time or the acceleration. The drag characteristics were determined by measuring the steady-state velocity of the model when the applied force balanced the drag force. Figure A.3-1 illustrates the equipment setup used in these tests. The accelerating force was applied through a cable, one end of which was attached to the test object. The other end suspended a dead weight. A magnetic pickup on one of the guiding pulleys provided pulse data relative to the position of the object.

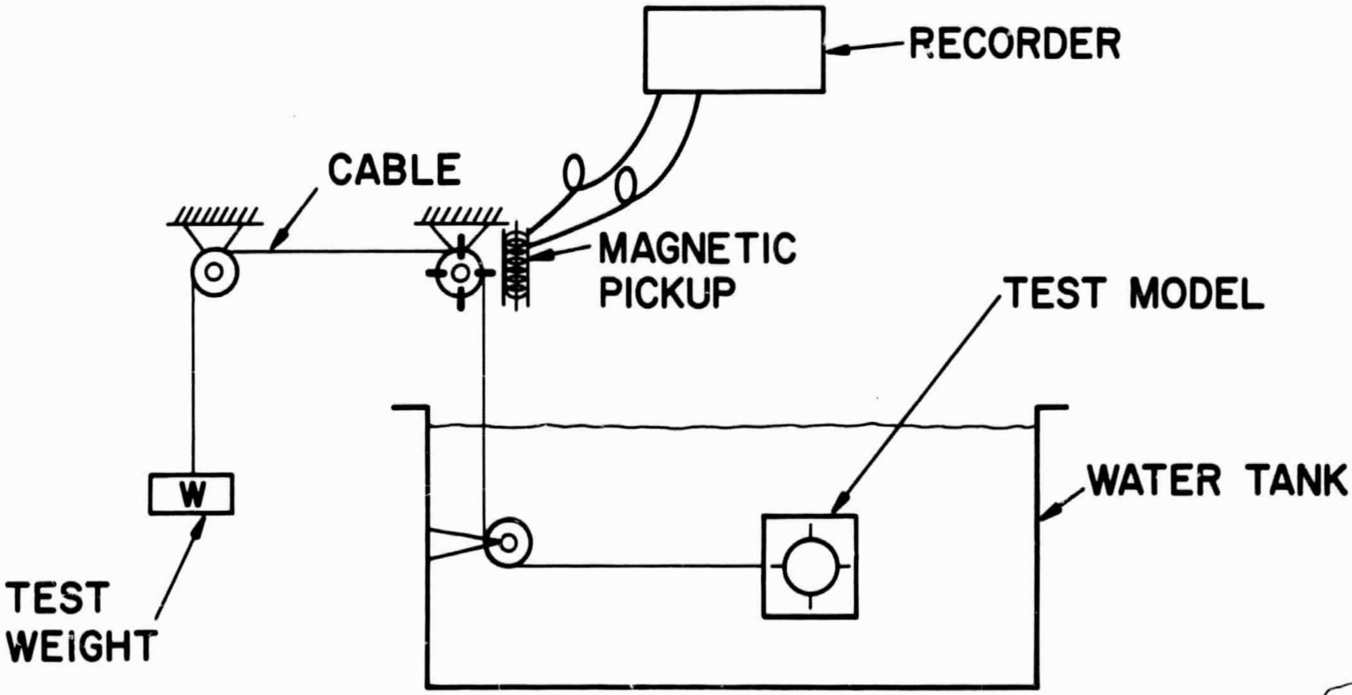


Figure A.3-1. Test Equipment Arrangement

An example of the experimental results obtained by testing a sphere 13.75 inches in diameter is shown in Figure A.3-2. The weight or accelerating force used in this test was 1 pound. The experimental results correspond very closely with predicted results, at velocities up to approximately 13 inches per second. The motion in space corresponding to a 1-pound force accelerating a 2.3 slug mass is shown for comparison purposes. The deviation between the two curves during the constant velocity period, when the acceleration of the body is zero, can be accounted for in part by the difference between the estimated drag coefficient (0.50) and the experimental value (0.45). The test showed that the body had an apparent mass of 2.3 slugs, or 75 pounds. It is interesting to note that if hydrodynamic mass is disregarded and the 2.3 slugs were simulated by a neutrally buoyant sphere that displaces 75 pounds of water, the apparent mass of the sphere would be 3.5 slugs. Thus, the hydrodynamic mass in this case accounts for 33 percent of the total apparent mass.

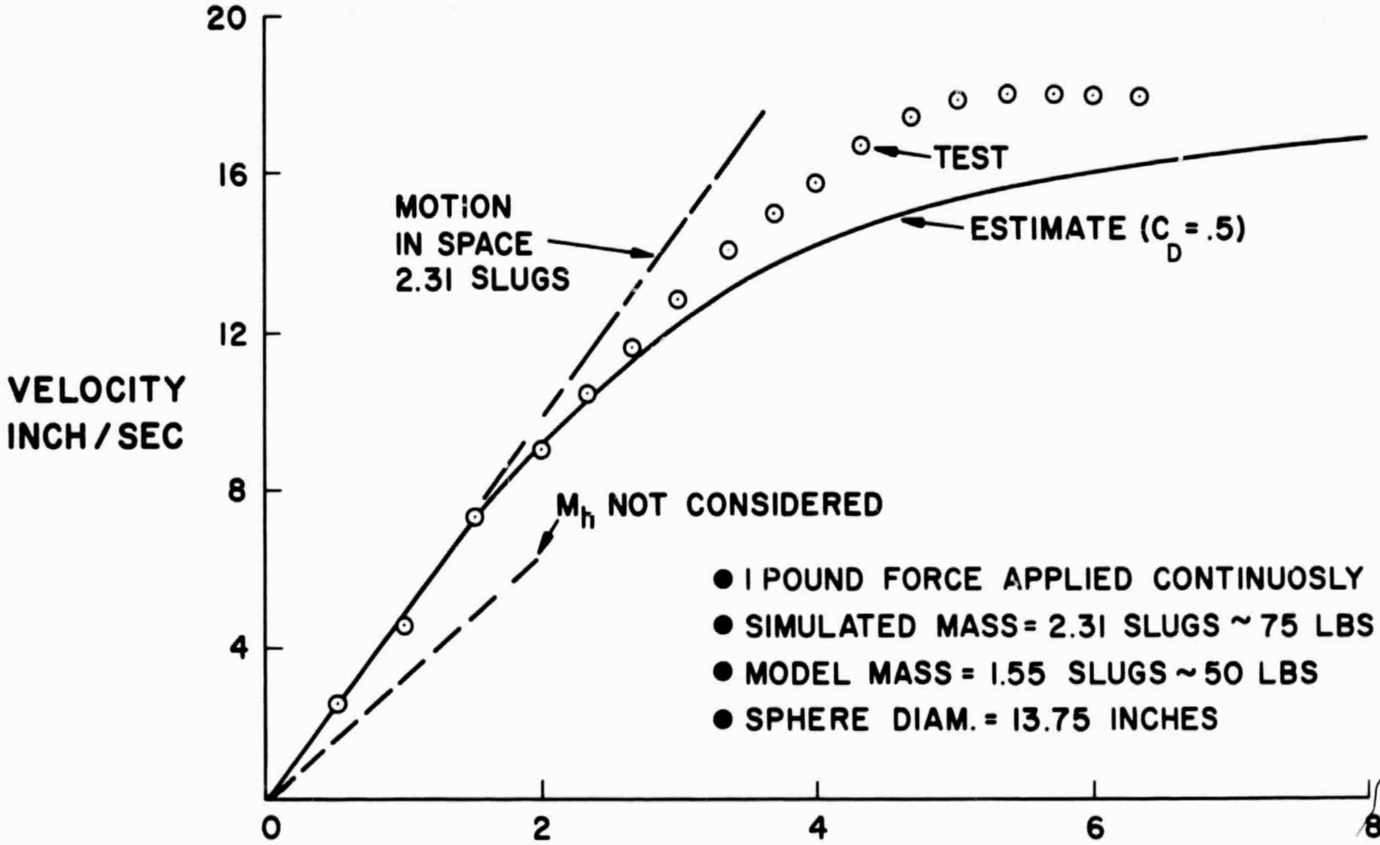


Figure A.3-2. Example of Verification Test Results

A set of tests similar to the one described above was conducted to determine the hydrodynamic characteristics of man with and without a pressurized spacesuit. In these an Apollo state-of-the-art spacesuit was used with the subject's hands held in the "mobility aids position." In this position, both hands are extended in front of the subject, as though he were propelling himself by means of a rigid hand rail. The frontal area of the man and SCUBA tank was estimated to be 2.3 and 5.8 ft^2 in the prone and erect positions, respectively. The frontal area of the backpack in the prone position was 1.42 ft^2.

Figure A.3-3 presents the hydrodynamic drag characteristics of human subjects in the several configurations of interest. Table A.3-1 shows a comparison of the actual mass of the man and his apparent mass underwater. The value of 14.6 slugs corresponding to the apparent mass of the man, spacesuit, and ballast weight, for neutral buoyancy, is 59 percent higher than the physical mass in the underwater configuration, and 168 percent higher than the mass of the man in the spacesuit, in zero-g condition. Since the majority of the tests in underwater simulation involves the mobility of man while he is performing various simulated tasks, the effects of this larger apparent mass become an important factor in the design of the experiment or test, and in the interpretation of the results.

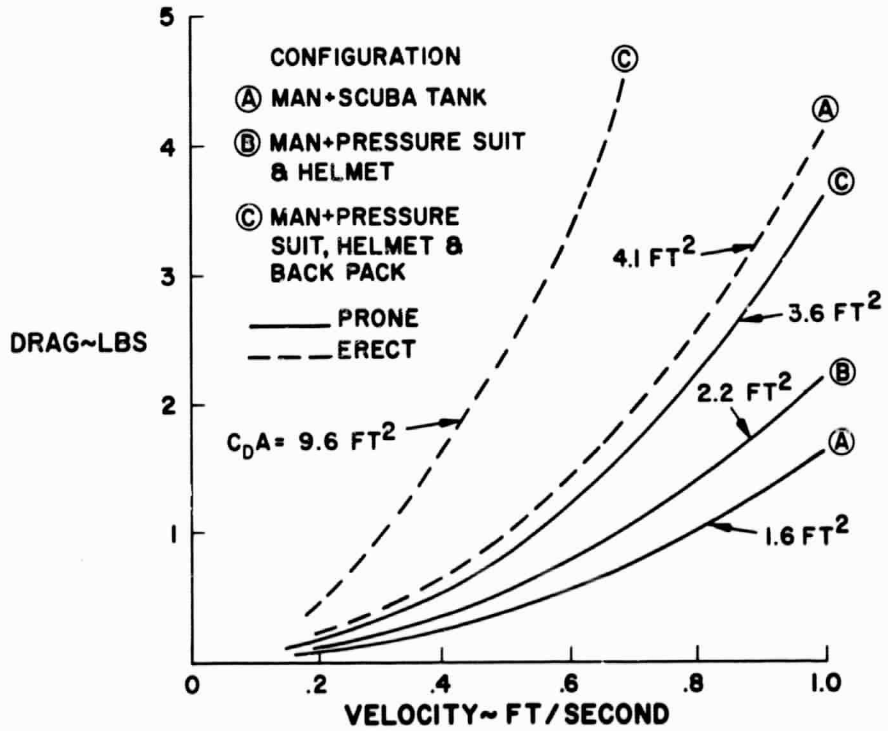


Figure A.3-3. Hydrodynamic Drag of Human Subjects

Table A.3-1. Comparison of Mass of Human Subjects in Space and Under Water

Subject to be Simulated	Mass in Space ~Slugs	Under Water	
		Physical Mass ~Slugs (2) M_u	Apparent Mass ~Slugs (1) M_a
Man (150 lbs)	4.65	4.65	7.4
Man and Pressurized Space Suit (175 lbs) (Apollo State-of-the-Art Suit)	5.45	5.45 3.75 (3) 9.20	14.6

(1) Apparent mass of man in prone position and hands in mobility aid position

(2) Neutrally buoyant

(3) Mass due to water trapped in space suit, or ballast weight for neutral buoyancy

Models of objects having complex external shapes (for proper visual cues and volumetric simulation) must be tested in the manner described above to determine the apparent mass and drag characteristics. This is necessary due to the large errors that are inherent in calculating the hydrodynamic mass and drag coefficient of discontinuous external structures. As an example, consider the design of a passive underwater model for an experimental astronaut maneuvering unit. The basic hydrodynamic design would consist of one or more spherical cores arranged for proper apparent mass and moment of inertia. The external envelope of the maneuvering unit is simulated by means of a lightweight framework. The main sources of discrepancy between calculated and actual hydrodynamic characteristics would be due to (1) inaccuracies in the determination of the drag coefficient of the composite framework, (2) inaccuracies in the determination of the hydrodynamic masses of the framework from different aspect angles, and (3) hydrodynamic interaction effects between the spherical cores, between frame and cores, and between the model and the test subject.

Drag coefficient and hydrodynamic mass can be expected to vary, to a certain extent, with velocity due primarily to changes in Reynolds Number (R.N.). Most of the tests to date have been conducted at velocities in the vicinity of 1 foot per second. For a 1-foot diameter sphere this corresponds to a R.N. of approximately 90,000. This is well below the transition R.N. of blunt bodies and is in the vicinity of a drag coefficient plateau where the slight variations in C_D with R.N. can be neglected. The drag might possibly be reduced by incorporating a boundary layer trip; however, the investigations to date have not explored this possibility.

A.4 FIDELITY INDEX

Underwater simulations are best applied to motions where accelerations predominate, and should not be applied where prolonged coast periods are required. The sections on scaling laws have shown that mass simulation, and therefore acceleration simulation, can best be achieved by employing hydrodynamic mass to help simulate physical mass. They have also shown that drag and rotational damping degrade the simulation, particularly during the coast periods. If the ratio M/C_DA is kept high, then the degradation due to prolonged coast periods is diminished. Note that this parameter is analogous to the ballistic parameter, W/C_DA, used in re-entry technology to determine trajectories. The criterion shown in Figure A.4-1 for comparing the relative degree of fidelity of translation simulations was used. This is taken as the percent of the original velocity remaining after coasting 1 foot. The curve is derived by integrating the theoretical equation of motion of a body acted upon by drag forces only, and solving for the ratio X/X_o, after coasting for a distance of 1 foot.

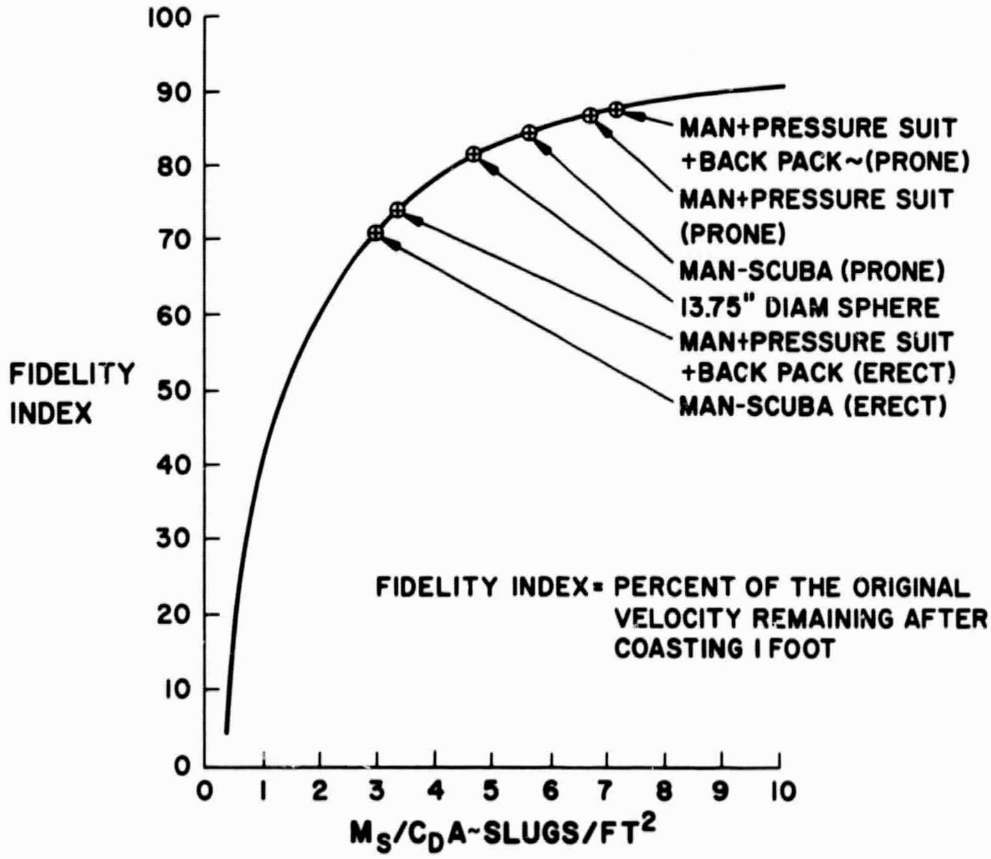


Figure A.4-1. Fidelity Index

For the simplified case of coast motion of a submerged object parallel to the X_u axis, $F = 0$, $C_L = 0$, and Equation 8 reduces to:

$$\ddot{X} + G\dot{X}^2 = 0$$

where (21)

$$G = \frac{C_D A}{2 M_S} \rho_w$$

Solving for the velocity $\dot{X}$ and the distance X after initiation of the coast period:

$$\dot{X} = \frac{\dot{X}_o}{\dot{X}_o Gt + 1} \qquad (22)$$

and,

$$X = X_o + \frac{\ln(\dot{X}_o Gt + 1)}{G} \qquad (23)$$

Let X = 1 foot and X_o = 0 in Equation 23 and solve for the time it takes to coast one foot, t_c:

$$t_c = \frac{e^G - 1}{\dot{X}_o G} \qquad (24)$$

Substitute (24) into (22) and solve for,

$$\dot{X}/\dot{X}_o = \frac{1}{e^G} \qquad (25)$$

Then, by definition:

$$\text{Fidelity Index} = \frac{100}{e^G} \qquad (26)$$

This index is useful only when comparing the relative merit of two different simulations; Figure A.4-2 can be used with Figure A.4-1 in estimating the fidelity of a given simulation. The defining equation, derived from Equation 20 is:

$$\frac{M_s}{C_D A} = \frac{8\, M_s^{1/3}}{4^{2/3}\pi^{1/3}} \left(\frac{\rho_w}{1 - \frac{g_\ell}{g_e}} \right)^{2/3} \approx \frac{3.76\, M_s^{1/3}}{\left(1 - \frac{g_\ell}{g_e}\right)^{2/3}} \qquad (27)$$

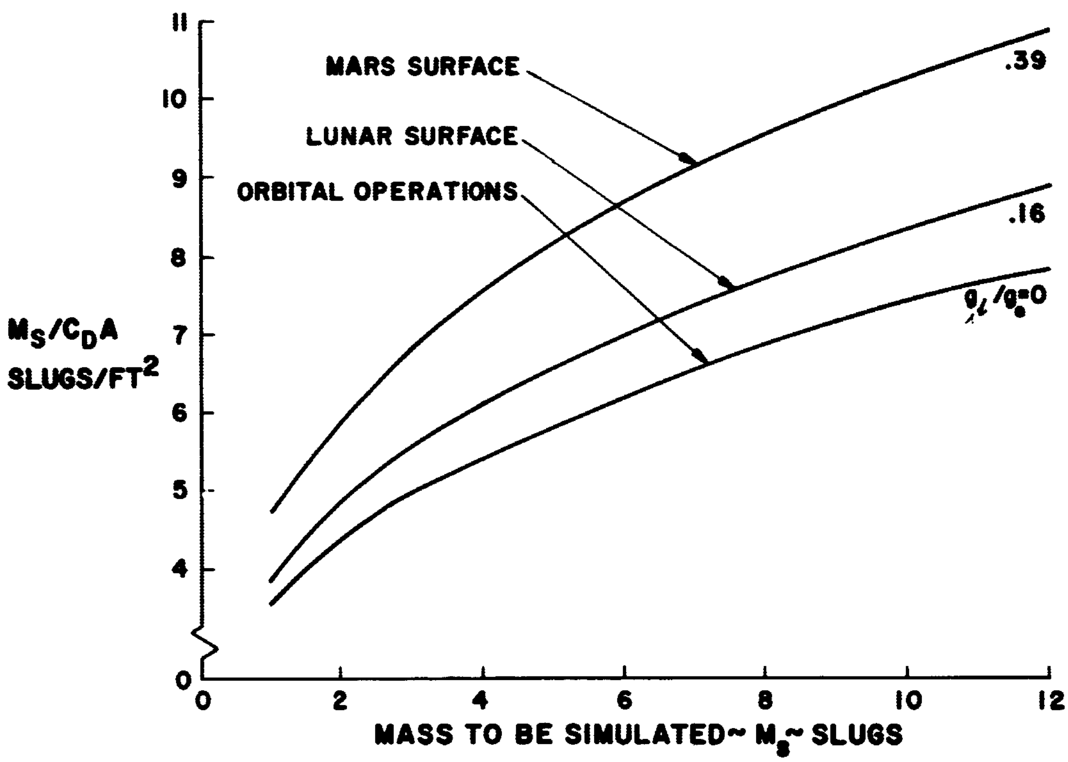


Figure A.4-2. Ratio of Mass to Drag Parameter for Spherical Centerbodies

Note that the larger the mass of the module being simulated, the more faithful is the simulation. This, of course, assumes that the additional drag and apparent mass of the frame is small compared to that of the spherical centerbody. Also, note that partial-g simulations are inherently more faithful than zero-g simulations. A similar index can be generated for rotation.

A. 5 ANALYTICAL ADJUSTMENTS

Successful simulations are those which simulate the most important conditions and to which analytical or empirical corrections can be applied to account for the conditions not properly simulated. As an example, wind tunnel tests, which are in essence simulations, are planned to simulate either Reynolds Number or Mach Number, depending on the relative importance in the flight regime being studied. Adjustments are then applied to the data to account for the parameter not being simulated correctly. In the case of underwater simulations, the requirements for 6 degrees of freedom, mass simulation, and gravitational attraction simulation can be provided. Hydrodynamic lift, drag, and moment are undesirable by-products. When these can be reduced to acceptable levels or when the results can be analytically corrected to compensate for these effects, useful simulations can be conducted.

APPENDIX B
EXPERIMENT 84A APPARATUS

The underwater experiment assembly, Figure B-1, consisted of a force receiver that converted the forces applied by the subject into electrical output signals, a framework to support the force receiver and provide the proper restraints to the test subject, and a panel to display to the test subject the desired force direction and type. In addition to this equipment, a panel was provided to enable the test director to give instruction to the test subject in the water. This appendix includes descriptions of this equipment and points out some of the problems that had to be solved during the equipment assembly and operation phase of the experiment.

B.1 FORCE RECEIVER

The force receiver assembly, shown in Figure B-2, is a cylindrical transducer system capable of measuring bidirectional forces applied along its axis and perpendicular to its axis along the vertical and horizontal planes. Figure 6.4-3 shows a cross-sectional view of this apparatus. The forces are applied through a handle 1.25 inches in diameter, with an effective length of 5.75 inches. These dimensions were chosen to be compatible with the pressurized-gloved hand. The axial (or push-pull) forces are transmitted through a calibrated spring resulting in axial deflections of 2 mils (0.002 in.) per pound. These deflections are sensed by means of a differential transformer (Compu-Tran Model No. 70-3104) mounted to the force receiver's cylindrical housing.

The vertical and horizontal forces applied to the handle result in bending deflections, due to bending of the cantilevered shaft. These deflections are in the order of 2.4 mils (0.0024 in.) per pound and are detected by means of two differential transformers mounted to the hollow shaft that supports the deflecting cantilevered shaft. In addition to the provisions for fixing the force receiver in various positions along the horizontal plane of the force receiver axis, provisions are made for fixing the handle so that its axial centerline is in a horizontal or vertical position, as required by the experimental variables.

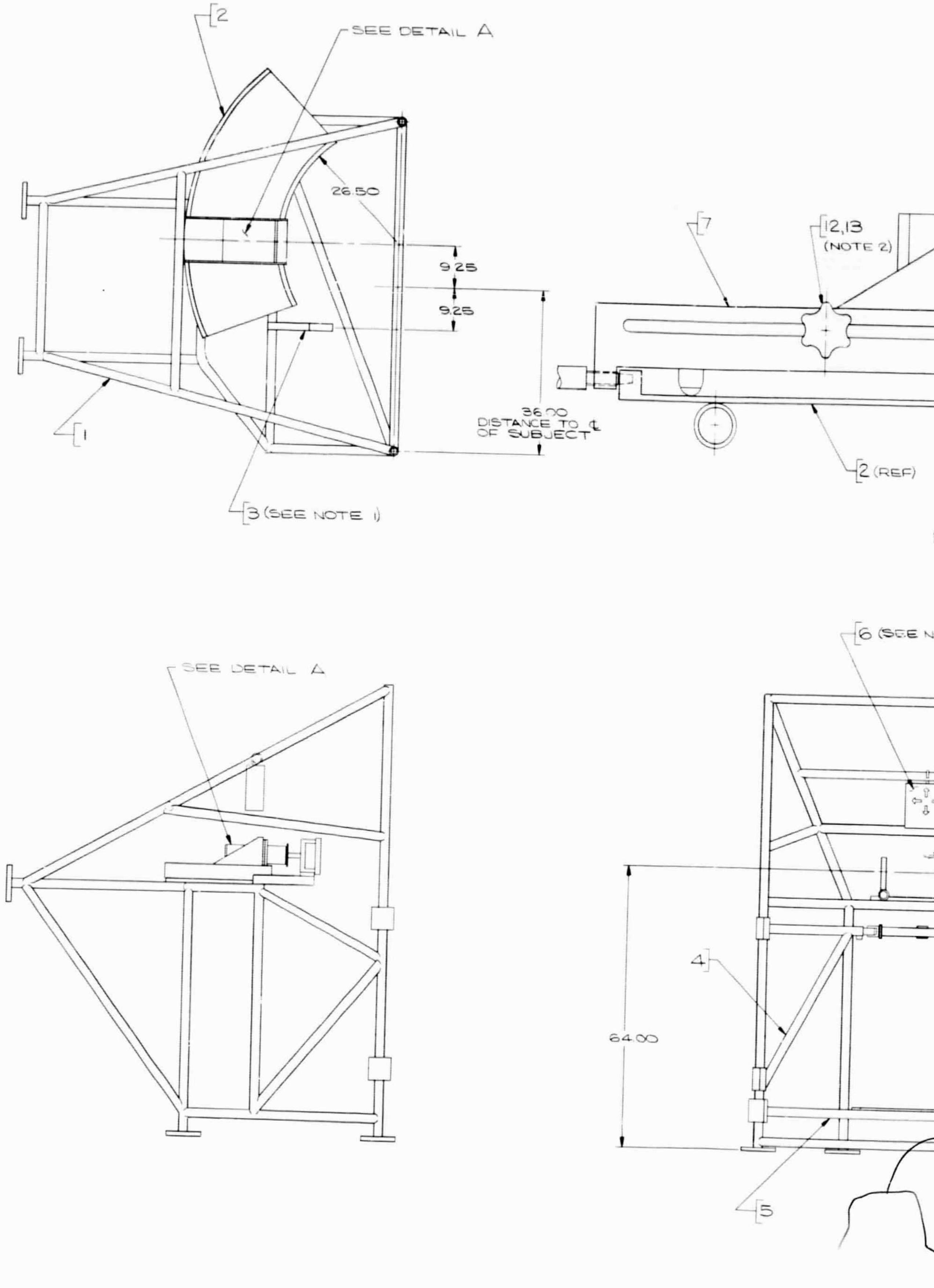
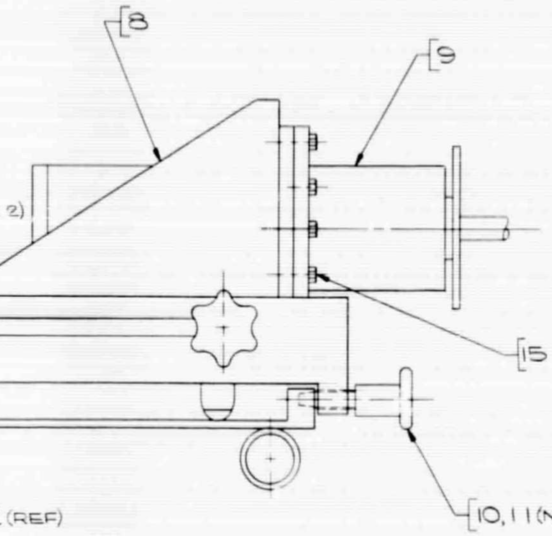
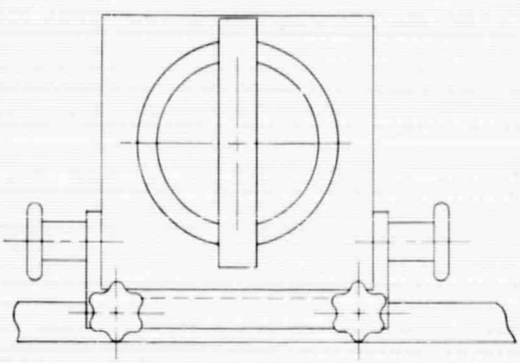


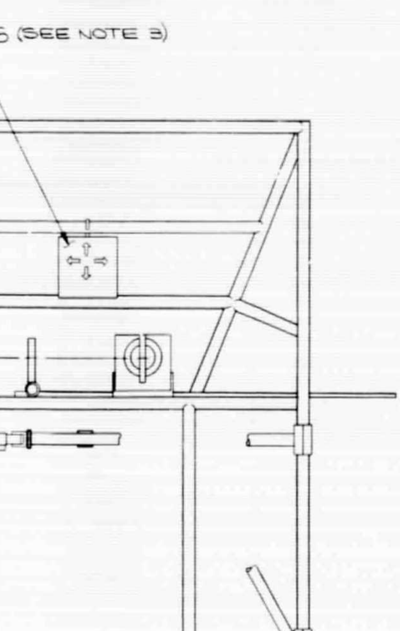
Fig. B-1. A

FOLDOUT FRAME





DETAIL A
SCALE 1/2



NOTES
1. SEE SK56161-701 FOR BASIC HANDLE DIMENSIONS. LOCATE & WELD AS SHOWN.
2. STAKE KNOB THREADS.
3. MOUNTING DETAILS ARE NOT SUPPLIED FOR ITEM 6.
4. ITEMS 11 & 13 MAY BE OBTAINED FROM NORTH-WESTERN TOOLS INC., DAYTON, OHIO. PART NO.'S AHK-7 & AHK-8 RESPECTIVELY.

PART NO	IDENTIFICATION NO.	DESCRIPTION	MATERIAL	QTY
15		SCREW, HEX HD 1/4-20UNC x 1.75 LG	CRES	6
14				
13	SEE NOTE 4	KNOB, HEX TYPE 1/2-13 THD	ALUM	4
12		STUD, 1/2-13UNC-2B x 2.38	CRES	4
11	SEE NOTE 4	KNOB, HEX TYPE, 5/8-11 THD	ALUM	4
10	SK56161-734	TAPERED STUD		4
9	SK56161-700	FORCE RECEIVER ASSY		1
8	SK56161-735	CARRIAGE ADAPTER		1
7	SK56161-733	CARRIAGE		1
6	SK56161-718	SUBJECT PANEL		1
5	SK56161-737	PLATFORM ASSY		1
4	SK56161-724	TETHER ASSY		1
3	SEE NOTE 1	HANDLE RESTRAINT		1
2	SK56161-732	MOUNTING PLATE		1
1	SK56161-711	STRUCTURE ASSY		1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES— TOLERANCES ON: 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ± FRACTIONS ± ALL SURF. ✓ MATERIAL—

SIGNATURES: DRAWN R. JONES 1 3 67

GENERAL ELECTRIC ARPO DEPT LOC PHILA, PA

EXPERIMENT 84 ASSY

SIZE E CODE IDENT NO. SK56161-736

SCALE 1/10 SHEET 1 OF 1

Figure B-1. Experiment 84 Assembly

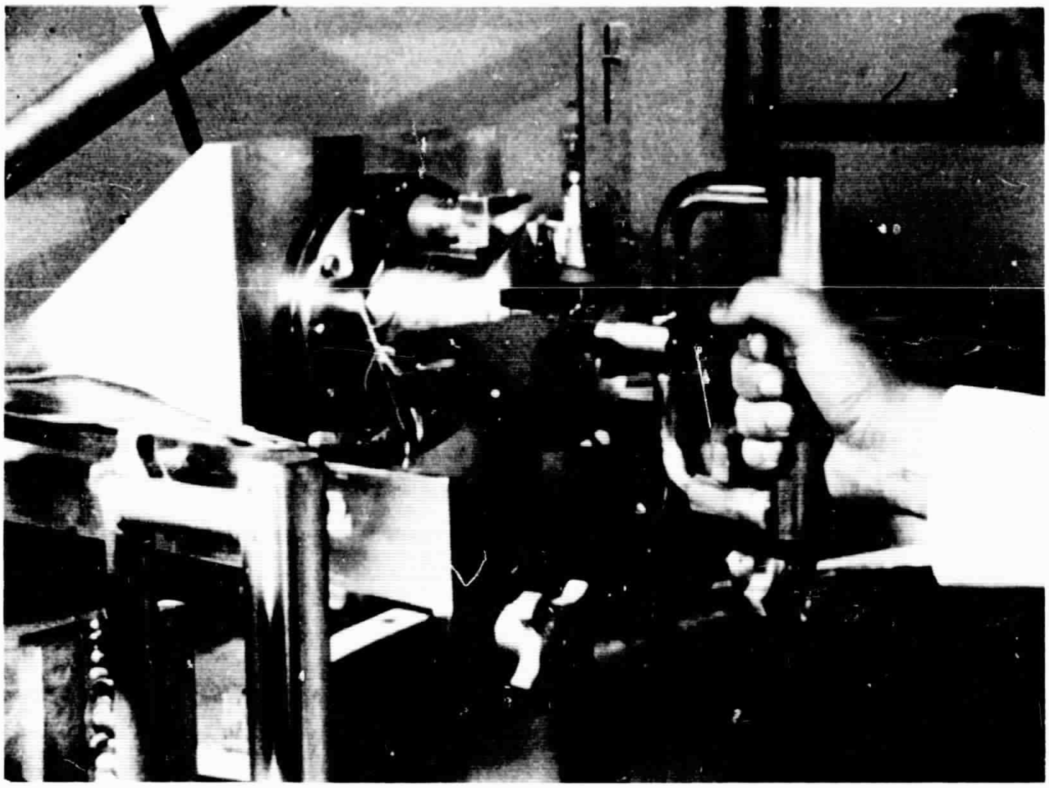


Figure B-2. Force Receiver

Several manufacturing and developmental problems associated with the apparatus were encountered and solved during the pretest period. Excessive friction between the ball-bushings and the bearing surfaces was evidenced during initial calibration. Upon disassembly, it was found that the bearing surfaces were scored and indented by the balls in the bushings. This was caused by improper clearances between the balls and the riding surfaces and unhardened stainless steel bearing surfaces. The bearing surfaces were ground down, chrome plated, and precision-ground for best-fit, after which no frictional or scoring problems were encountered. Another problem was the calibrated spring that provided for axial deflections, due to forces along the X-axis. The spring constant and linearity were within specifications; however, during assembly, it was found that the two circular ends of the spring were grossly out of parallelism and concentricity. Special retainer cups were machined which, in combination with the proper spacers, produced the proper spacing and concentricity for the spring.

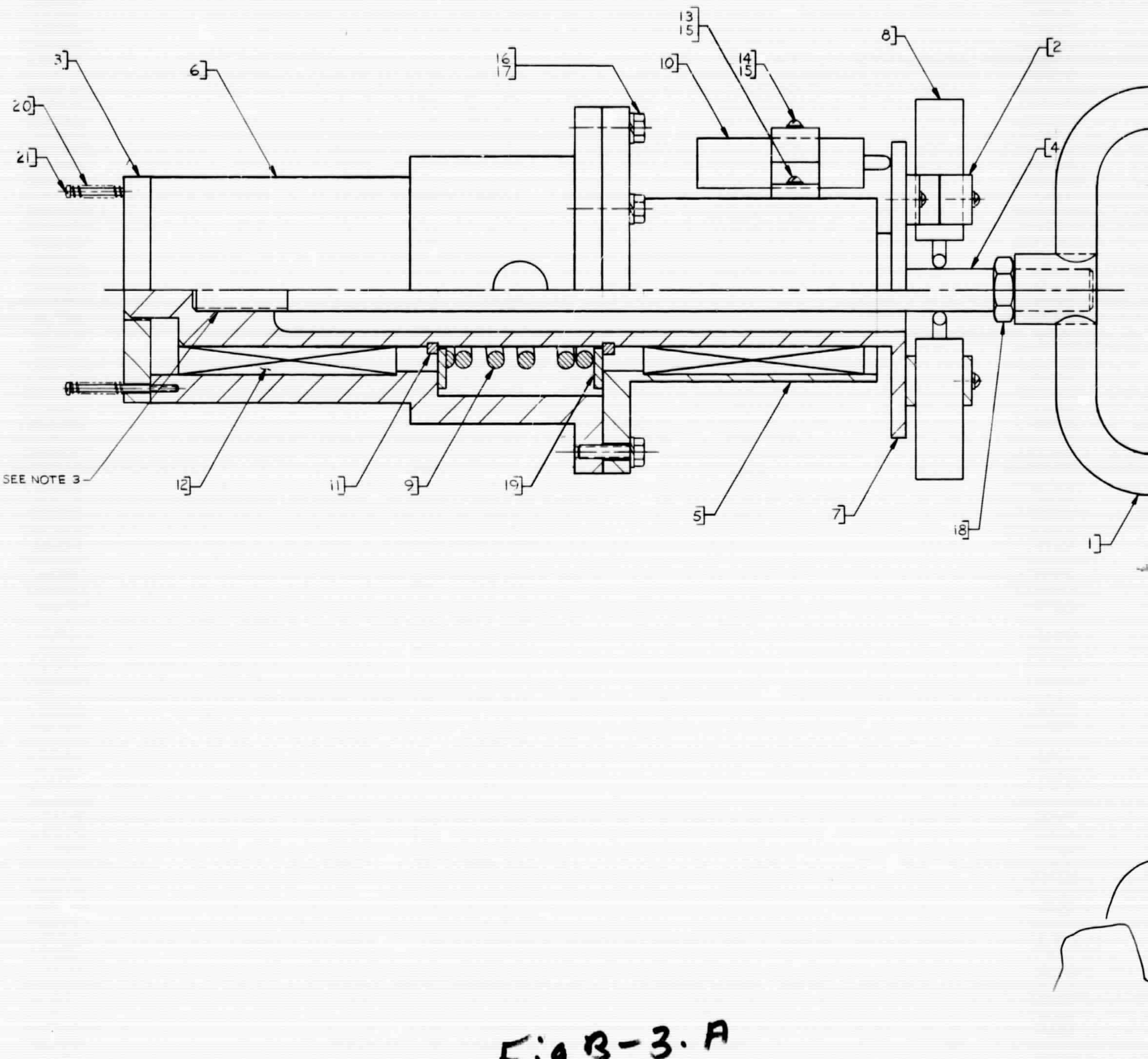
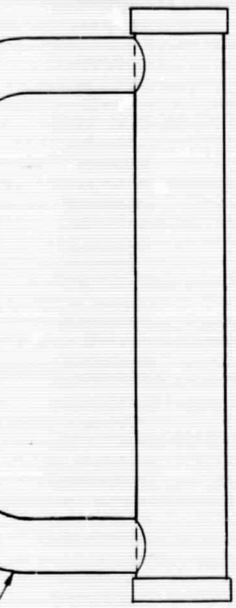


Fig B-3. A



NOTES:
1. PRESS BUSHING, ITEM 12, PER MANUFACTURER'S INSTRUCTIONS.
2. ALIGN HANDLE WITH SLOT ON REAR OF SLIDING SHAFT, ITEM 7 PRIOR TO TIGHTENING JAM NUT.
3. APPLY LOC-TITE TO THREADS PRIOR TO ASSEMBLY.

PART NO.	IDENTIFICATION NO.	DESCRIPTION	MATERIAL	QTY
21		SCREW 4-40 NC-2 X 2.00 LG, .112 DIA, .50 MAX THD	CRES	2
20		SPRING, 1.5 TO 2.0 LBS PER IN., 1.00 FREE LG.	CRES	2
19		WASHER, 2.75 O.D. - 2.00 I.D. - .12 THK	CRES	2
18		NUT, JAM 3/4-16 NF-3	CRES	1
17		WASHER, SPLIT LOCK 1/4	CRES	6
16		SCREW, 1/4-20 UNC-2 X 1.00 LG	CRES	6
15		WASHER, SPLIT LOCK #4	CRES	20
14		SCREW, 4-40 NC-2 X 1.00 LG	CRES	10
13		SCREW, 4-40 NC-2 X .50 LG	CRES	10
12	A-324864-55	BUSHING, BALL (THOMSON IND. INC. OR EQUIV)		2
11	XSC 160	RING (NATIONAL LOCK WASHER CO. OR EQUIV)		2
10	SK56161-710	TRANSFORMER, MODIFIED		1
9	SK56161-709	SPRING		1
8	SK56161-708	TRANSFORMER, MODIFIED		4
7	SK56161-707	SLIDING, SHAFT		1
6	SK56161-706	REAR HOUSING		1
5	SK56161-705	FRONT HOUSING		1
4	SK56161-704	SHAFT		1
3	SK56161-703	PLATE		1
2	SK56161-702	CLAMP		5
1	SK56161-701	HANDLE		1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2-PLACE DECIMALS ±
3-PLACE DECIMALS ±.003 ALL SURF. ✓
ANGLES ±
FRACTIONS ±
MATERIAL—

SIGNATURES	DAY	MO	YR
DRAWN R. Jones	28	11	66
CHECKED [illegible]	5	12	66
ISSUED			
ENGRG V.R. Abrarate	2	12	66
MFG			
MATLS			

GENERAL ELECTRIC
ARPO DEPT LOC PHILA., PA

FORCE RECEIVER ASSEMBLY

SIZE E | CODE IDENT NO. | SK56161-700

SCALE 1/1 | SHEET 1 OF 1

Figure B-3.B Force Receiver Assembly

FOLDOUT FRAME

B.2 FRAMEWORK

The force receiver was mounted on a carriage which provided the capability to vary both the distance from the subject and the horizontal (side-to-side) locations. The carriage was mounted to the rigid frame, shown in Figure B-4, which also provided the attachment points for the subject to the various restraints. Figure 6.3-1 shows the framework assembly and details of the subject restraints. During the experiment the test subject was attached in one of the eight restraint combinations, and the appropriate experiment conditions were set up by a technician who remained underwater with the test subject.

B.2.1 RESTRAINTS

In the design of the restraints it was necessary to account for the different sizes of the subjects and to assure that changes in experimental conditions could easily be accomplished underwater by one support technician. Safety was also an important consideration for the following reasons:

a. The test subject had to be easily and rapidly removed from the experimental apparatus in the event of an emergency.

b. The support personnel had to operate the experiment easily and without possibility of injury.

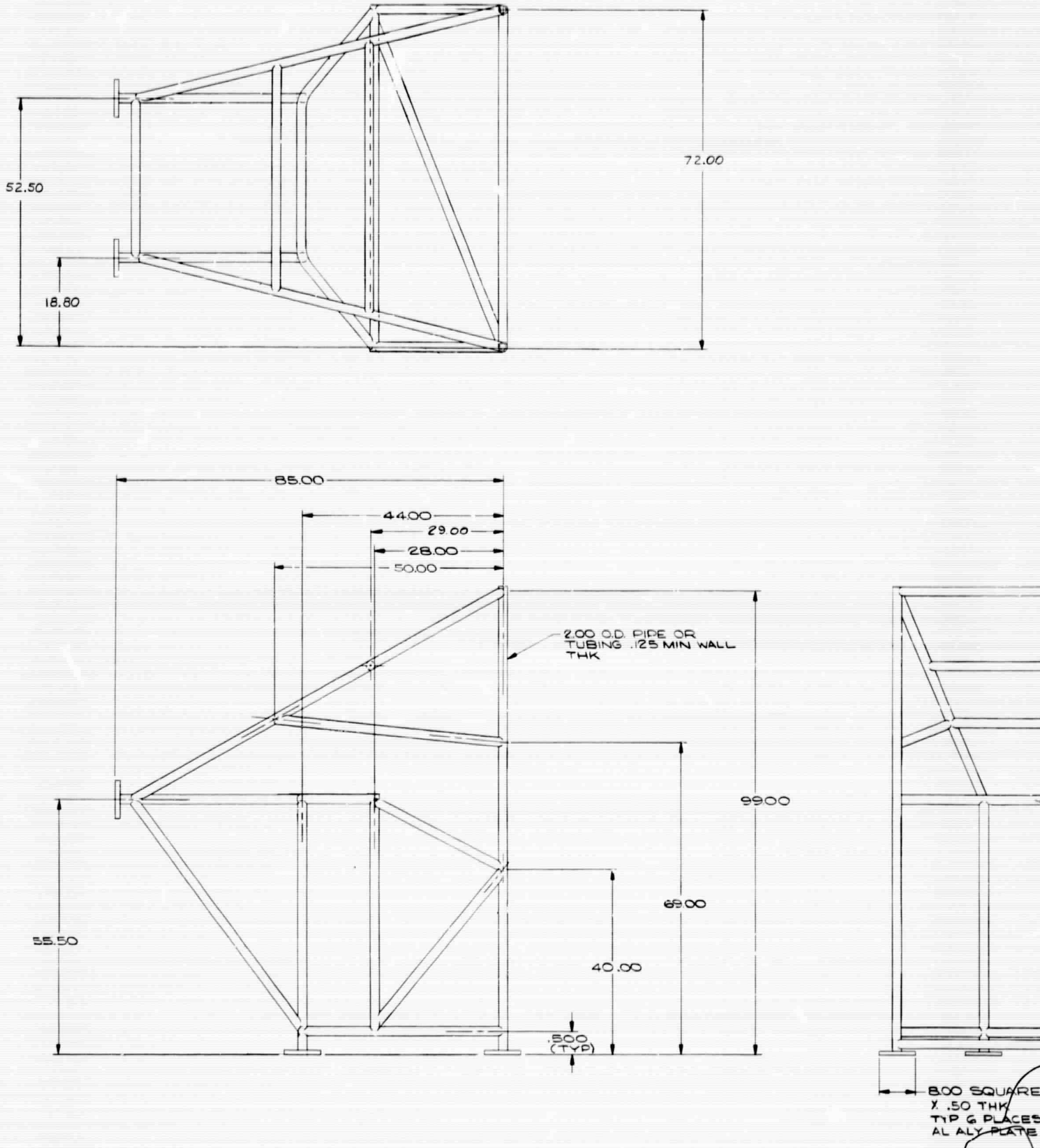
c. Contact between the subject and the support structure had to be minimized in order to prevent damage to the pressure suit.

B.2.1.1 Handhold

The handhold consisted of a fixed handle 1.25 inches in diameter and 5.75 inches long, oriented in a vertical position. See Figure B-5.

B.2.1.2 Waist Restraint

The waist restraint, Figure B-6, consisted of a wide fabric belt (auto seat belt) attached to metal bars extending from the sides of the support structure. These telescoping bars terminated in slotted swivel plates through which the fabric belt was laced for attachment to the subject. The fabric belt had a quick release fastener to permit immediate removal



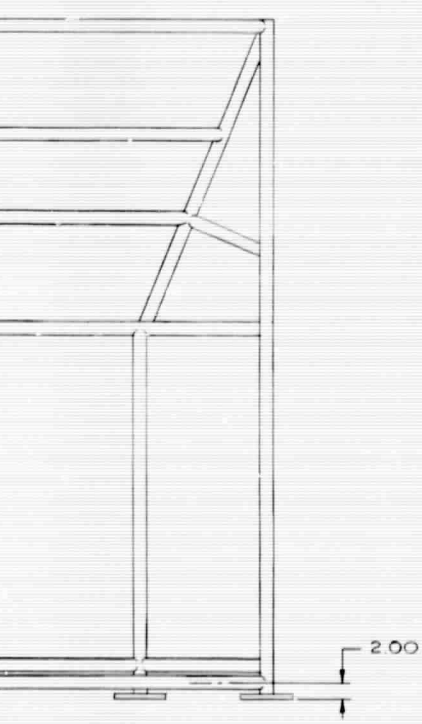
B-11

Fig. B-4A

FOLDOUT FRAME

NOTES

1. WELDED CONSTRUCTION THROUGHOUT



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2-PLACE DECIMALS ±
3-PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF. ✓
MATERIAL—
AL ALY TUBING

SIGNATURES	DAY	MO	YR
DRAWN R. Jones	2	12	66
CHECKED	5	12	66
ISSUED			
ENGR			
APPD			
MATLS			

GENERAL ELECTRIC
ARPO DEPT LOC PHILA PA VFSTC

STRUCTURE ASSY

SIZE E | CODE IDENT NO. | SK 56161-711

SCALE 1/10 | SHEET 1 OF 1

Figure B-4. Structure Assembly

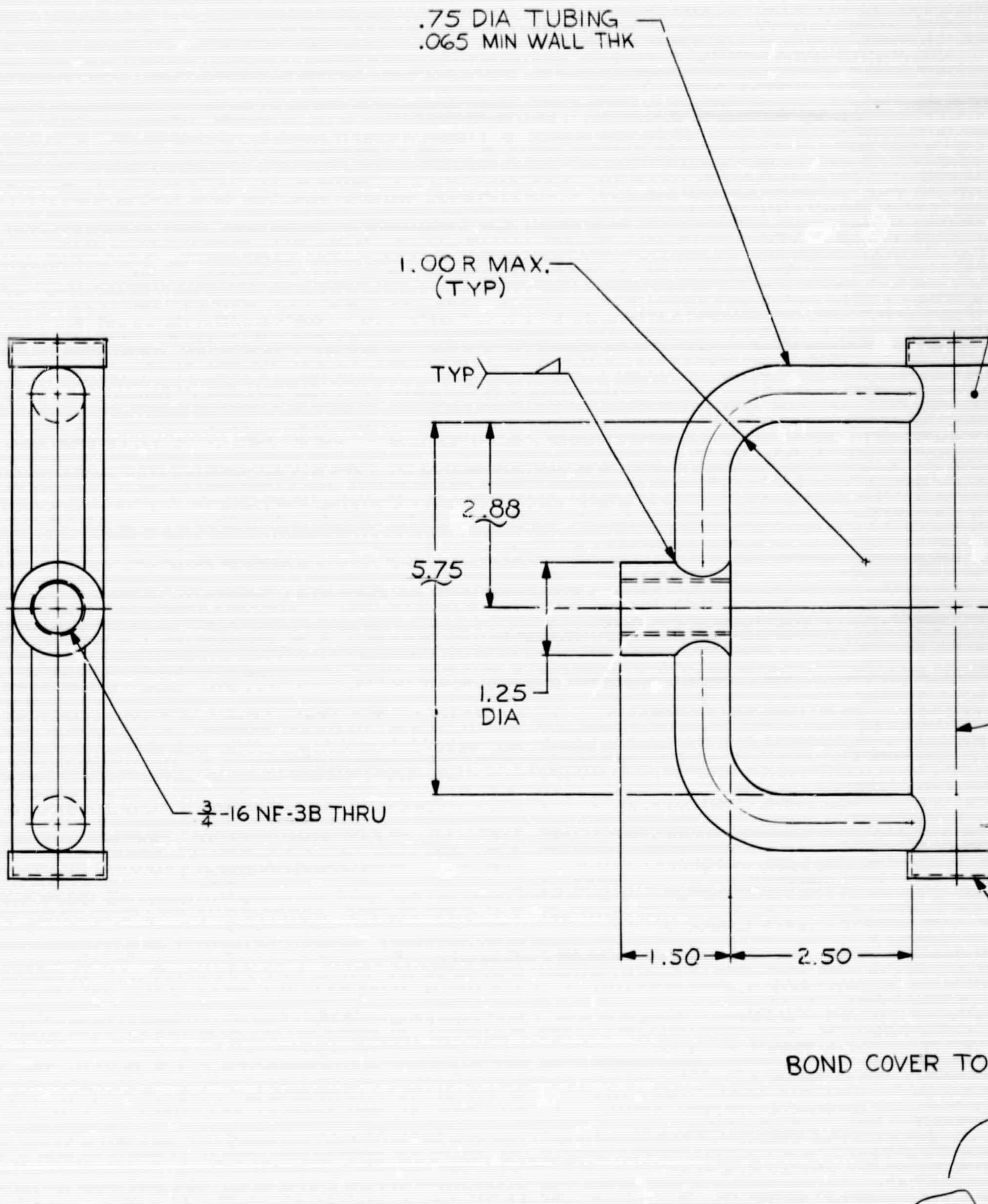
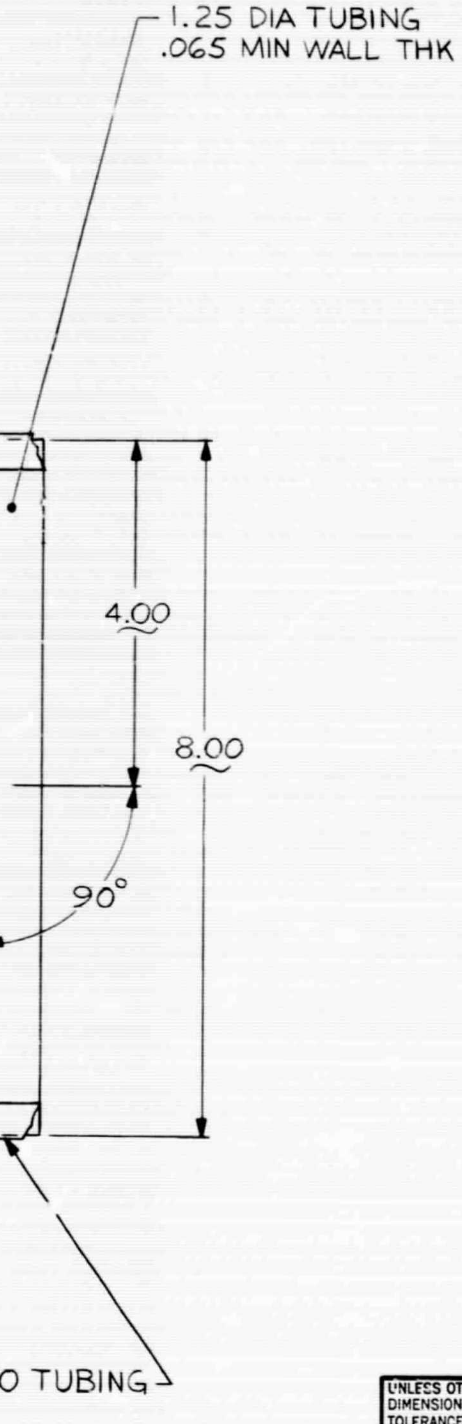

.75 DIA TUBING
.065 MIN WALL THK
1.00 R MAX.
(TYP)
TYP
2.88
5.75
1.25
DIA
$\frac{3}{4}$-16 NF-3B THRU
1.50
2.50
BOND COVER TO

Fig. B-5.A



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2-PLACE DECIMALS ± .02
3-PLACE DECIMALS ±
ANGLES ± 1°
FRACTIONS ±
ALL SURF. ✓
MATERIAL—
STAINLESS STEEL-
PASSIVATE

SIGNATURES		DAY	MO	YR
DRAWN	M. Wagner	23	11	66
CHECKED	[signature]	5	12	66
ISSUED				
ENGRG	W.R. Alvarado	2	12	66
MFG				
MATLS				

ARPO — GENERAL ELECTRIC — DEPT LOC PHILA., PA

HANDLE

SIZE D | CODE IDENT NO. | SK56161-701

SCALE 1/1 | SHEET 1 OF FIN

Figure B-5. Handle

of the subject from the restraint (See Figure 6.3-1). Vertical positioning of the waist restraint was provided by the clamping blocks located on the side frame. The adjustments were designed to be operated by the experiment technician, by hand. However, sufficient tightness could be achieved only with the use of pliers or a similar tool. When not in use the waist restraints were swung aside.

B.2.1.3 GEMINI DUTCH SHOES

The Gemini Dutch Shoes, Figure B-7, were mounted on a flat plate positioned between the side frame members. Vertical positioning was provided by clamping blocks on the side frames, as in the waist restraints, and similarily, when not in use this platform was swung aside.

B.3 CONTROL PANEL AND CUE PANEL

The instructions as to force type and direction were programmed by the test director through his control panel (Figures B-8 and B-9). When the "Start Sequence" switch is closed, the particular force type and direction lights are illuminated on the test subject's underwater cue panel (Figure B-10) for a 2-second cue period prior to the force application command ("go"). The type of force to be applied is denoted by illumination of either the "I" (impulse) or "S" (sustained) lights, while the direction of force application is commanded by illumination of the appropriate arrow (left, right, up or down), or the appropriate legend ("push" or "pull"). At the end of the cue interval, the "go" light is illuminated for a period of 4 seconds if the instruction is sustained , or 1 second if the instruction is impulse.

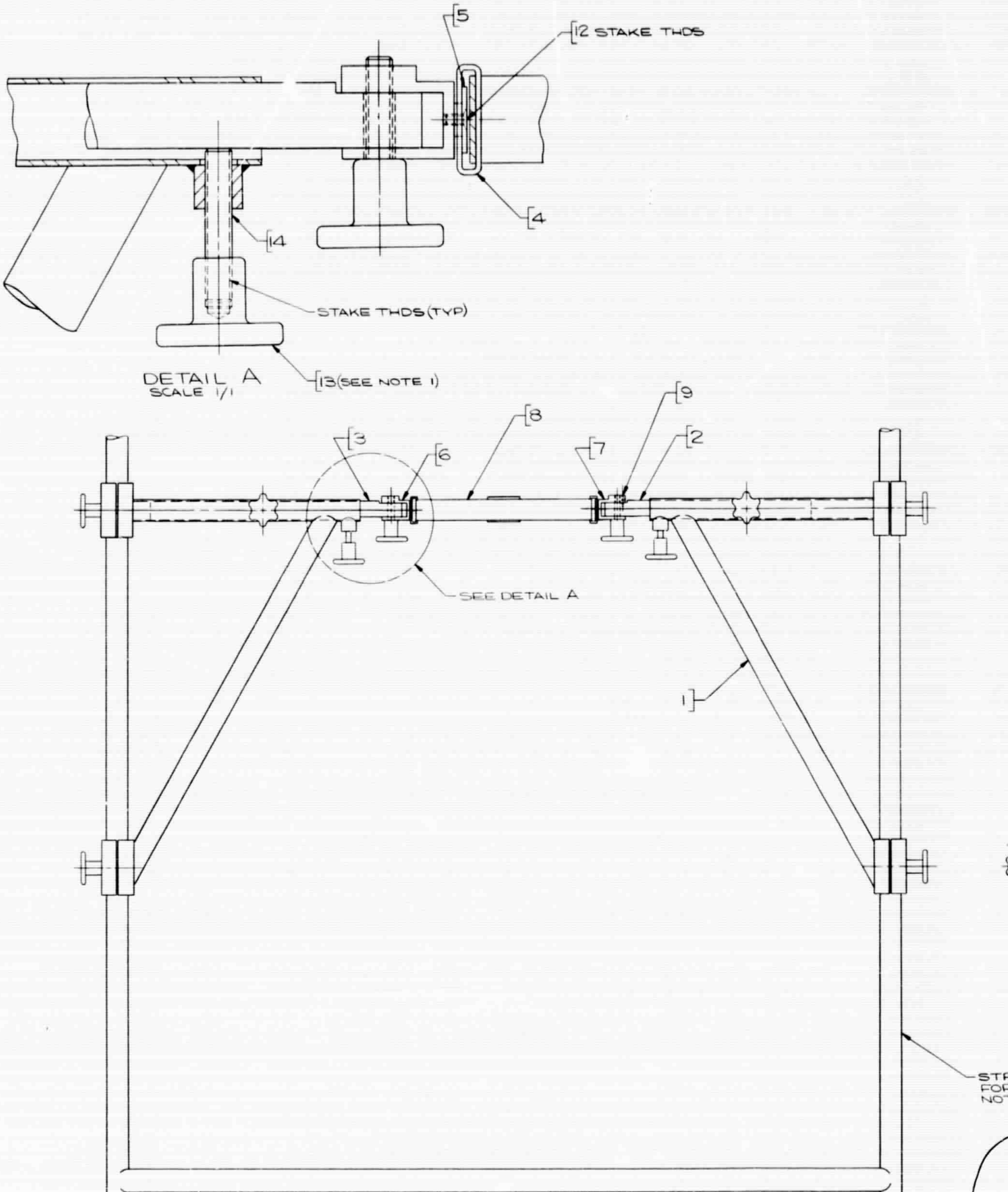

5
12 STAKE THDS
4
14
STAKE THDS (TYP)
13 (SEE NOTE 1)
DETAIL A
SCALE 1/1
8
9
3
6
7
2
SEE DETAIL A
1
FRONT VIEW OF STRUCTURE

Fig. B-6.A

1

NOTES

1. ITEM 13 MAY BE OBTAINED FROM NORTHWESTERN TOOLS INC., DAYTON, OHIO. PART NO AHK-8T.
2. STAKE THDS AFTER FINAL ADJUSTMENT.

PART NO.	IDENTIFICATION NO.	DESCRIPTION	MATERIAL	QTY
14		STUD, 5/8-11NC-3A × 3.50 LG	CRES	10
13	SEE NOTE 1	KNOB, HEX TYPE, 5/8-11 THD	ALUM	10
12		SCREW, 100° CSK, 1/4-20UNC-×.50 LG	CRES	2
11		WASHER, FLAT (.640 I.D)	CRES	4
10		BOLT, HEX HD, 5/8-11NC-3A × 2.5 LG	CRES	4
9		PIN SPRING (.125 O.D. × 1.125 LG	CRES	1
8		SAFETY BELT (METAL TO METAL)		1
7	SK 56161-731P1	SWIVEL		1
6	SK 56161-731P2	SWIVEL		1
5	SK 56161-720	RETAINER PLATE		2
4	SK 56161-719	BELT LOOP		2
3	SK 56161-722P2	TETHER EXTENSION		1
2	SK 56161-722P1	TETHER EXTENSION		1
1	SK 56161-721	TETHER SUPPORT		2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF. √
MATERIAL— SEE TABLE

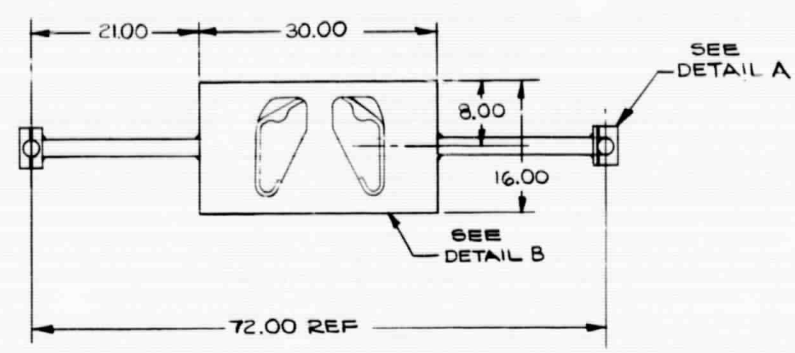
SIGNATURES: R. JONES 7 22 67

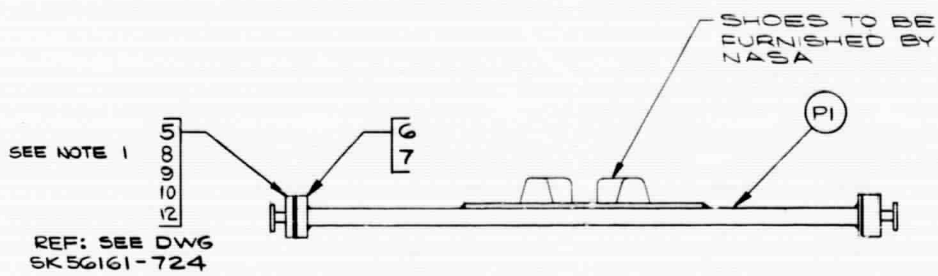
GENERAL ELECTRIC
ARPO DEPT LOC PHILA., PA

TETHER ASSEMBLY

SIZE E CODE IDENT NO. SK 56161-724
SCALE 1/4 SHEET 1 OF 1

Figure B-6. Tether Assembly





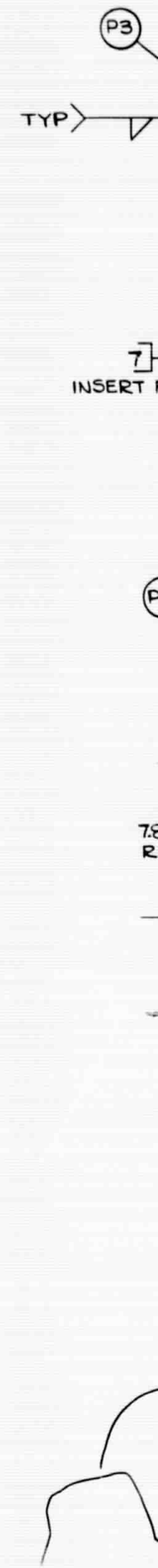
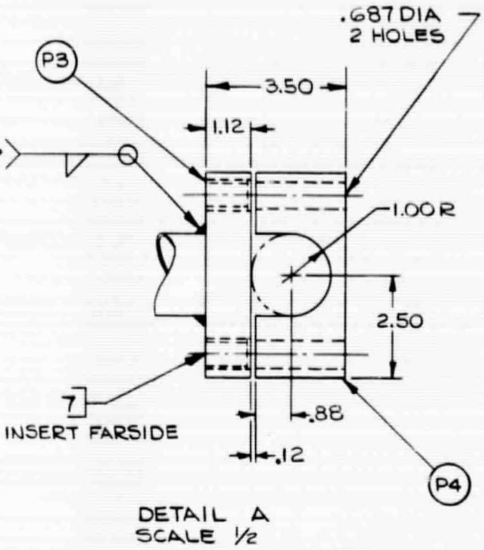
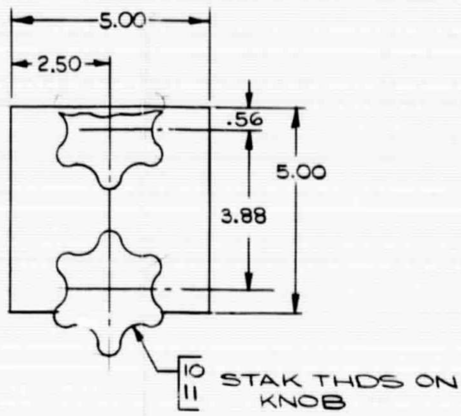


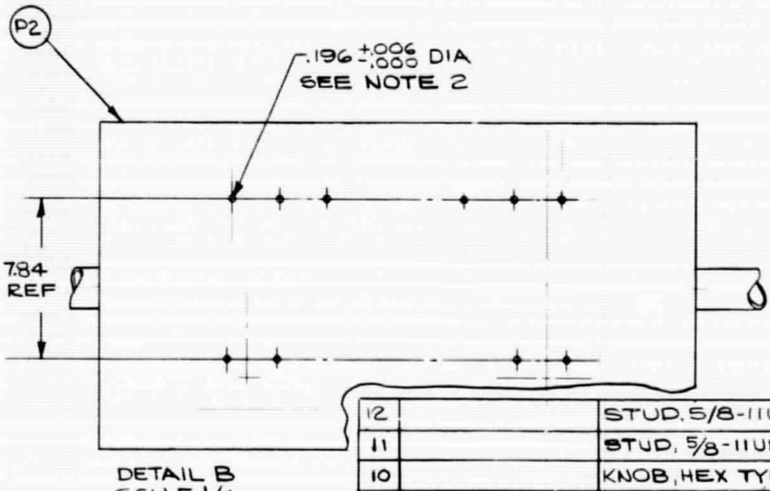
Fig B-7.A

FOLDOUT FRAME





NOTES:
1. STAKE THDS ON ITEM 8 AFTER FINAL ADJUSTMENT.
2. MATCH HOLE PATTERN & LOCATION WITH FOOT RESTRAINT-EVA & AMU. REF McDONNELL DWG NO. 52-87926 EO# 182690, SEQ 1.



PART NO.	IDENT NO.	DESCRIPTION	MATL	QTY
12		STUD, 5/8-11UNC-3A x 3.50 LG	CRES	1
11		STUD, 5/8-11UNC-3A X 4.50 LG	CRES	2
10		KNOB, HEX TYPE 5/8-11 THD	ALUM	3
9		WASHER FLAT (.640 ID)	CRES	1
8		BOLT, HEX HD 5/8-11UNC-2A x 2.50 LG	CRES	1
7	ROSAN # SR621	INSERT	CRES	4
6	SK56161-721 P4	BLOCK	AL ALY	1
5	SK56161-721 P3	BLOCK	AL ALY	1
4	SK56161-737 P4	BLOCK	AL ALY	1
3	SK56161-737 P3	BLOCK	AL ALY	1
2	SK56161-737 P2	PLATE, .50 THK	AL ALY	1
1	SK56161-737 P1	TUBE, 2.00 OD X .12 MIN WALL	AL ALY	1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES— TOLERANCES ON: 2-PLACE DECIMALS ±.02 3-PLACE DECIMALS ±.010 ANGLES ± FRACTIONS ± ALL SURF. ✓	SIGNATURES DAY MO YR — DRAWN R. MESBICK 1 3 67; CHECKED; ISSUED; ENGRG; MFG; MATLS	GENERAL ELECTRIC ARPO DEPT LOC PHILA., PA
MATERIAL— SEE TABLE		PLATFORM ASSEMBLY
		SIZE D; CODE IDENT NO.; SK56161-737
		SCALE 1/10; SHEET 1 OF 1

Figure B-7. Platform Assembly

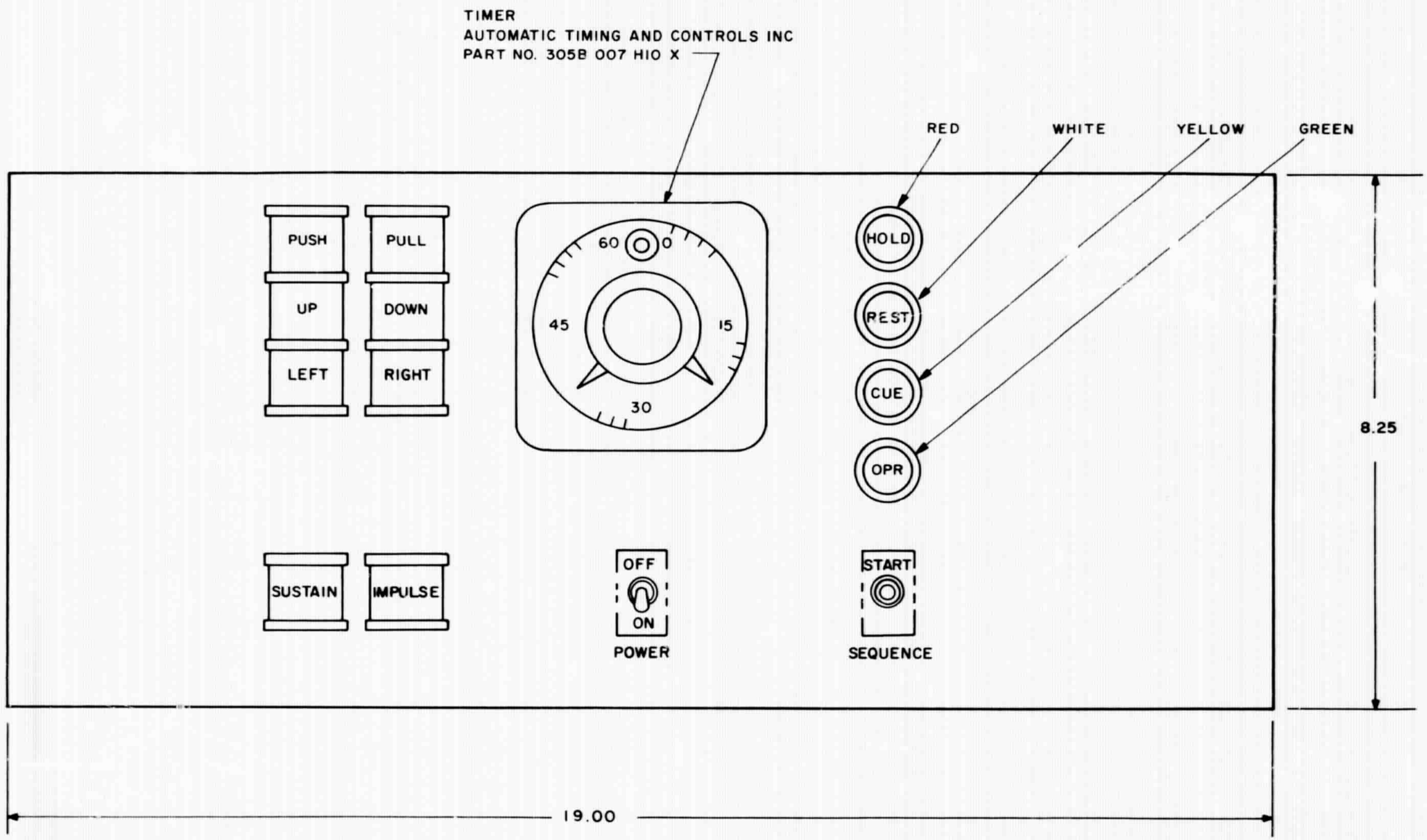


Figure B-8. Test Director's Control Panel

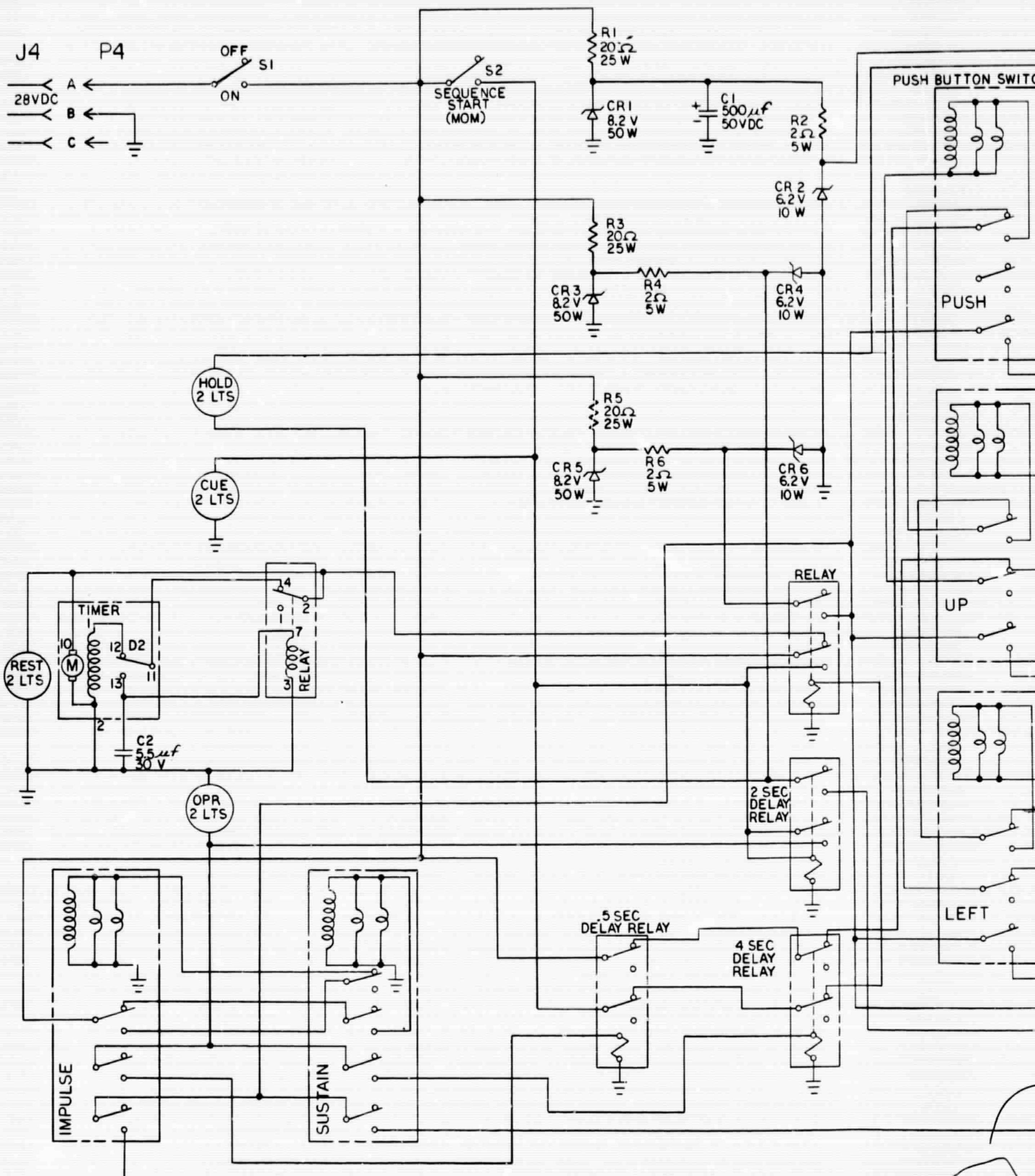


Fig. B-9A

FOLDOUT FRAME

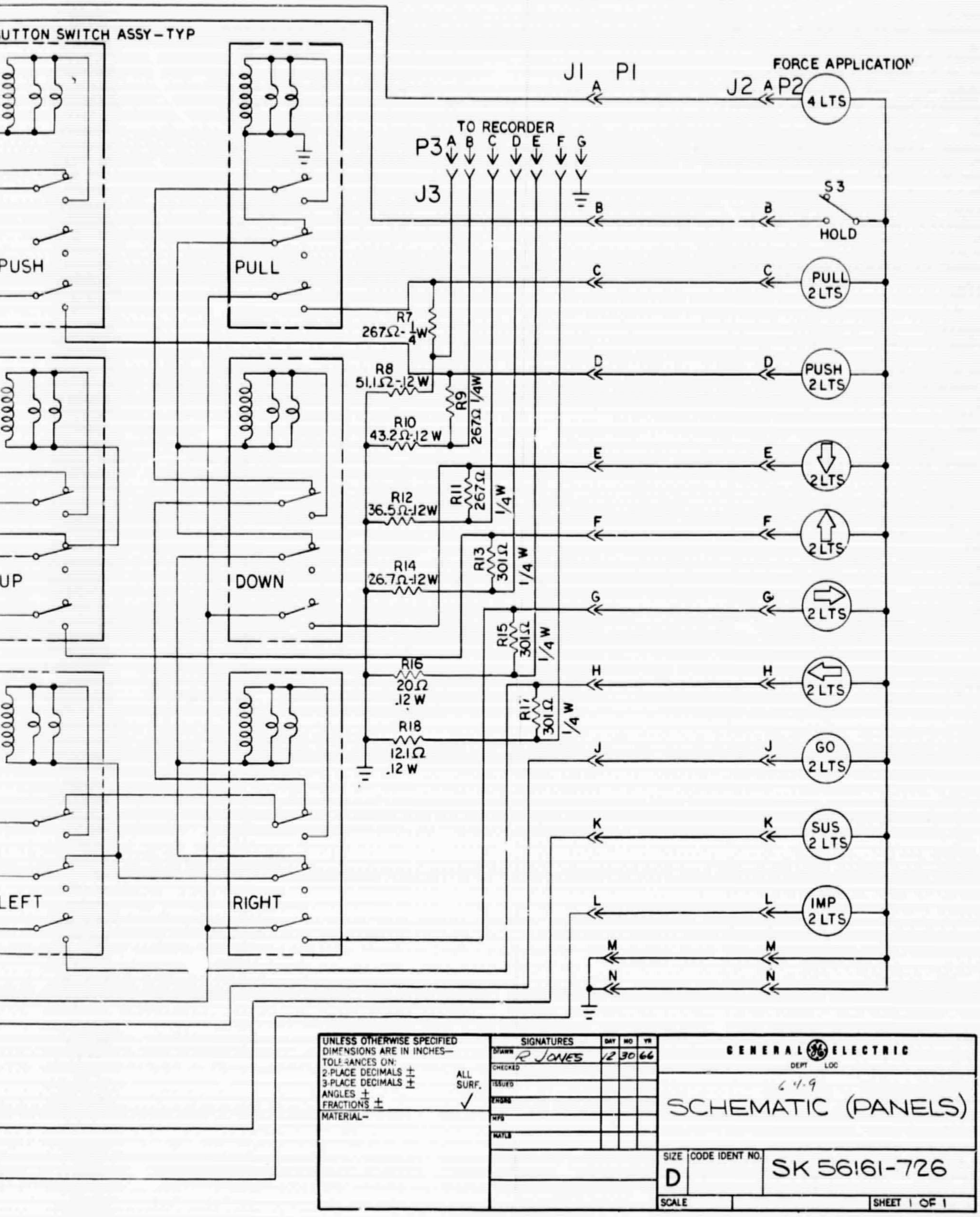
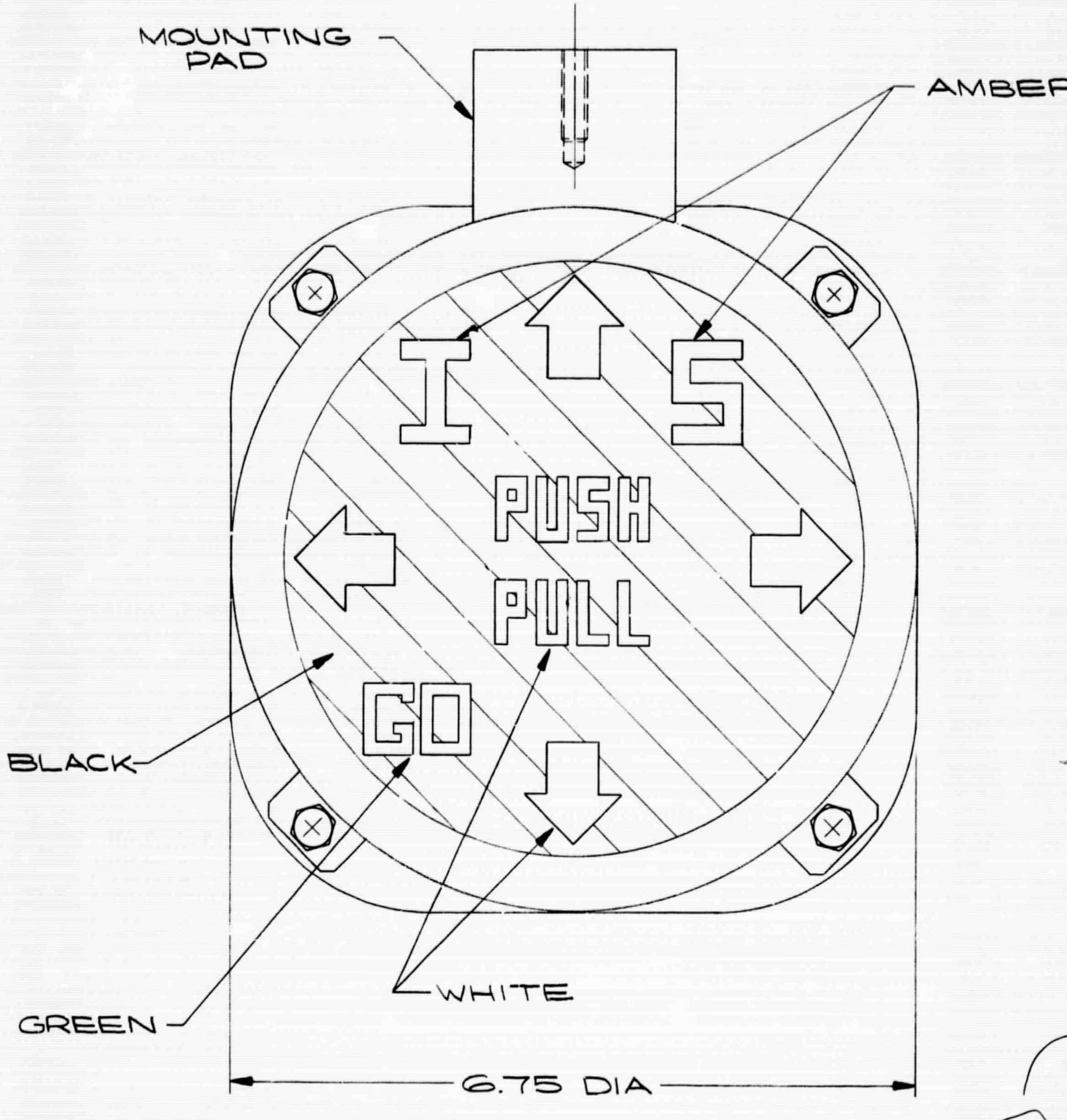


Figure B-9. Schematic (Panels)

FOLDOUT FRAME



B-25
Fig. B10A

FOLDOUT FRAME

SER

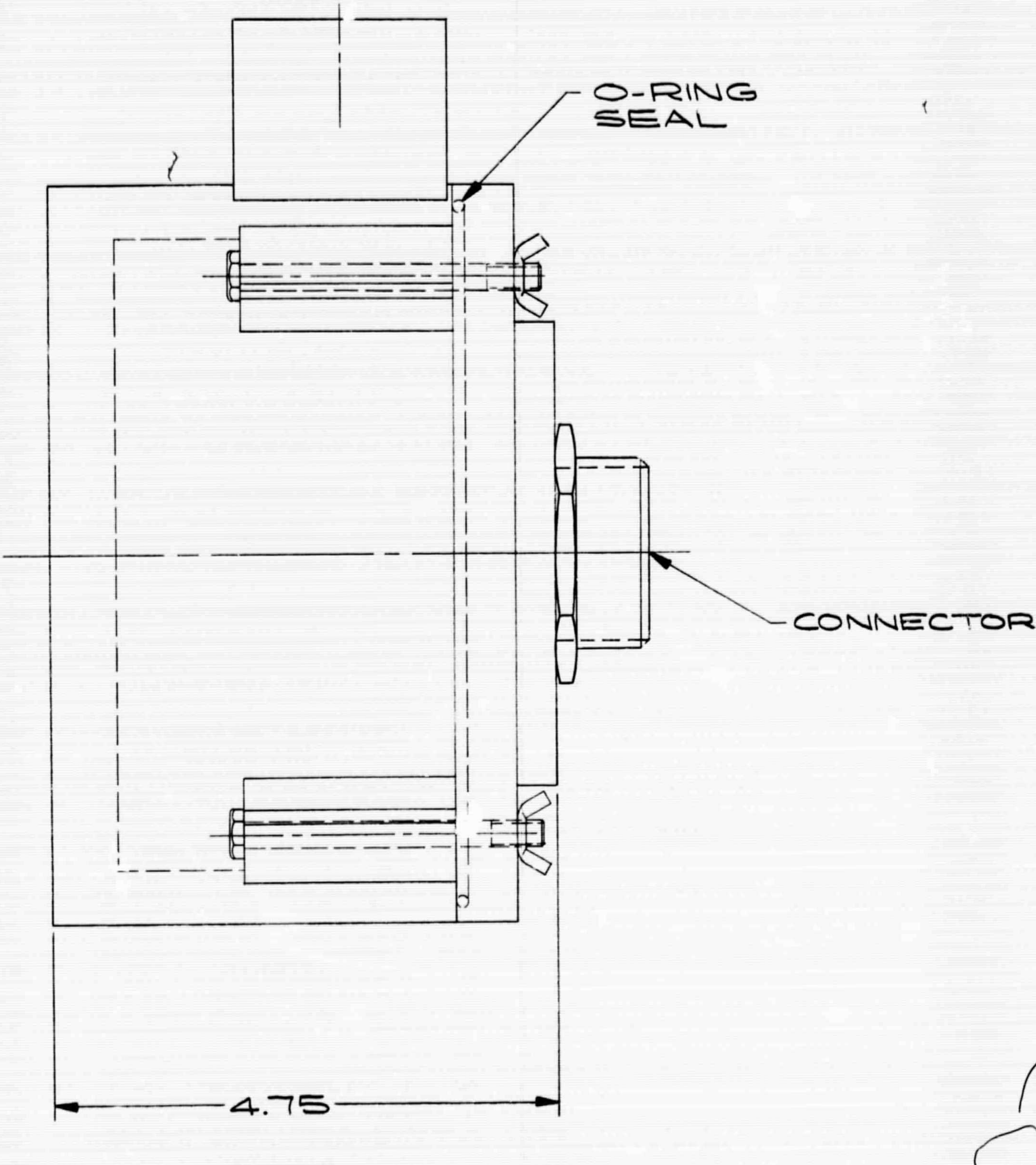


Figure B-10 Test Subject's Cue Panel

APPENDIX C

TABULATION OF OUTPUTS OF EXPERIMENT 84A PROGRAM

In this Appendix are tabulated the outputs of the Experiment 84A Computerized Averaging Program. As stated in Section 6.7.1 of Volume II of this report, the program provided the capability to average various combinations of experimental conditions. These included, either separately or in combination, the following variables on test conditions:

a. Subject

b. Pressurization method

c. Receiver angle

d. Receiver distance

e. Receiver orientation

f. Restraint

Data for various combinations of these variables are presented in Tables C-1 through C-167. A detailed description of the format and the definition of terms is contained in Section 6.7.1. A matrix of the combination of variables making up these 167 tables is presented in Figure C-1.

	Table No. →	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18
Subject No	All	X					X	X	X	X	X	X	X	X	X	X	X	X	X
	1		X																
	2			X															
	3				X														
	4					X													
Pressurization Method	Both	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
	Air						X												
	Water							X											
Receiver Angle	All	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	-15^o								X										
	0^o									X									
	45^o										X								
Receiver Distance	All	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X
	Near											X							
	Medium												X						
	Far													X					
Receiver Orientation	Both	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
	Horizontal														X				
	Vertical															X			
Restraint	All	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	None																X		
	Hand																	X	
	Waist and Shoes																		X
	Waist																		
	Shoes																		
	Hand, Waist, & Shoes																		
	Hand and Waist																		
	Hand and Shoes																		

	Table No. →	C-91	C-92	C-93	C-94	C-95	C-96	C-97	C-98	C-99	C-100	C-101	C-102	C-103	C-104	C-105	C-10
Subject No.	All	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	1																
	2																
	3																
	4																
Pressurization Method	Both	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Air																
	Water																
Receiver Angle	All																
	-15^o																
	0^o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	45^o																
Receiver Distance	All																
	Near																
	Medium	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Far														X	X	X
Receiver Orientation	Both																
	Horizontal	X	X	X	X	X									X	X	X
	Vertical						X	X	X	X	X	X	X	X			
Restraint	All																
	None						X								X		
	Hand							X								X	
	Waist and Shoes								X								X
	Waist	X								X							
	Shoes		X								X						
	Hand, Waist, & Shoes			X								X					
	Hand and Waist				X								X				
	Hand and Shoes					X								X			

Fig C-1A
C-3.A

FOLDOUT FRAME

16	C-17	C-18	C-19	C-20	C-21	C-22	C-23	C-24	C-25	C-26	C-27	C-28	C-29	C-30	C-31	C-32	C-33	C-34	C-35	C-36	C-37	C-38	C-39	C-40	C
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

-104	C-105	C-106	C-107	C-108	C-109	C-110	C-111	C-1[illegible]	113	C-114	C-115	C-116	C-117	C-118	C-119	C-120	C-121	C-122	C-123	C-124	C-12
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	[illegible]	[illegible]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	[illegible]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Fig C-1B

C-38	C-39	C-40	C-41	C-42	C-43	C-44	C-45	C-46	C-47	C-48	C-49	C-50	C-51	C-52	C-53	C-54	C-55	C-56	C-57	C-58	C-59	C-60	C-61	C-62
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

C-123	C-124	C-125	C-126	C-127	C-128	C-129	C-130	C-131	C-132	C-133	C-134	C-135	C-136	C-137	C-138	C-139	C-140	C-141	C-142	C-143
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Fig. C-1.c

FOLDOUT FRAME

	C-59	C-60	C-61	C-62	C-63	C-64	C-65	C-66	C-67	C-68	C-69	C-70	C-71	C-72	C-73	C-74	C-75	C-76	C-77	C-78	C-79	C-80	C-81	C-82	C-83
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	C-141	C-142	C-143	C-144	C-145	C-146	C-147	C-148	C-149	C-150	C-151	C-152	C-153	C-154	C-155	C-156	C-157	C-158	C-159	C-160	C-161
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Figur

T

FOLDOUT FRAME

-84	C-85	C-86	C-87	C-88	C-89	C-90
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X

C-162	C-163	C-164	C-165	C-166	C-167
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X

C-1.D Matrix of Information in
ables C-1 Through C-167

Table C-1

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	Sustained Minimum Mean	Sustained Minimum Range		Sustained Maximum Mean	Sustained Maximum Range			Impulse Maximum Mean	Impulse Maximum Range		
PUSH	19.68	0.00	102.67	41.56	0.02	109.51	(***)	51.53	1.29	106.89	(***)
PULL	20.80	0.00	101.37	42.41	1.56	114.85	(***)	51.24	5.96	116.67	(***)
UP	12.42	0.00	61.83	23.93	0.21	80.90	(***)	25.21	8.11	82.62	(***)
DOWN	15.55	0.00	65.02	24.41	0.22	72.25	(***)	28.69	4.12	82.67	(***)
RIGHT	11.69	0.00	58.83	22.03	0.63	76.00	(***)	23.42	1.50	83.11	(***)
LEFT	13.68	0.00	58.82	25.08	0.93	79.00	(***)	26.31	1.01	93.60	(***)

Table C-2

SUBJECT 1
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	Sustained Minimum Mean	Sustained Minimum Range		Sustained Maximum Mean	Sustained Maximum Range			Impulse Maximum Mean	Impulse Maximum Range		
PUSH	17.98	0.00	80.40	39.28	0.02	99.37	(315)	50.93	2.70	99.81	(318)
PULL	24.36	0.00	101.37	47.46	1.85	114.85	(311)	57.93	2.99	114.85	(314)
UP	11.78	0.00	40.05	24.54	4.45	56.77	(314)	25.75	0.08	56.56	(316)
DOWN	10.97	0.00	37.82	20.64	0.82	59.70	(308)	25.33	0.71	49.37	(309)
RIGHT	9.35	0.00	38.56	19.86	0.72	54.73	(315)	20.32	3.16	52.94	(311)
LEFT	11.08	0.00	37.25	22.45	3.35	59.82	(314)	22.84	1.36	51.60	(315)

Table C-3

SUBJECT 2
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	23.81	0.00	93.89	43.03	1.16	103.71	(328)	50.88	11.15	102.90	(330)
PULL	23.92	0.00	87.04	43.08	1.88	102.62	(3[illegible])	49.26	4.63	116.67	(332)
UP	14.85	0.00	61.83	24.35	0.21	80.90	(319)	25.76	0.21	82.62	(320)
DOWN	17.86	0.00	65.02	25.65	1.84	72.25	(328)	29.10	3.48	82.67	(331)
RIGHT	14.30	0.00	58.83	23.59	1.86	76.70	(334)	24.73	1.50	83.11	(332)
LEFT	15.67	0.00	58.82	25.24	1.54	79.00	(330)	27.44	1.13	93.60	(333)

Table C-4

SUBJECT 3
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	20.67	0.00	85.56	45.08	1.67	103.49	(350)	59.37	1.29	103.49	(348)
PULL	17.65	0.00	77.15	40.75	1.56	102.23	(348)	53.53	5.96	94.98	(347)
UP	12.80	0.00	44.67	25.47	0.54	58.69	(339)	27.31	8.11	60.39	(347)
DOWN	20.83	0.00	60.11	29.47	0.22	64.19	(350)	35.82	0.10	64.73	(352)
RIGHT	13.44	0.00	45.36	25.85	1.28	63.58	(354)	28.72	2.07	61.13	(353)
LEFT	16.39	0.00	52.85	30.47	2.05	65.18	(349)	31.52	2.56	63.96	(349)

Table C-5

SUBJECT 4
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	16.19	0.00	102.67	38.59	3.82	109.51	(335)	44.53	5.85	106.89	(333)
PULL	17.70	0.00	79.28	38.76	9.49	104.15	(333)	44.52	5.39	111.95	(334)
UP	10.24	0.00	30.71	20.79	0.27	48.16	(322)	21.82	1.44	46.22	(318)
DOWN	11.95	0.00	43.36	21.37	4.07	54.07	(334)	23.83	4.12	60.35	(331)
RIGHT	9.43	0.00	45.37	18.45	0.63	57.23	(333)	19.15	5.57	47.11	(330)
LEFT	11.32	0.00	36.91	21.73	0.93	50.70	(331)	22.99	1.01	48.12	(330)

Table C-6

SUBJECT *
PRESSURIZATION METHOD AIR
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	19.77	0.00	102.67	42.35	0.02	109.51	(573)	51.79	3.77	106.89	(576)
PULL	21.71	0.00	80.90	44.41	1.85	104.15	(565)	53.03	5.96	116.67	(568)
UP	12.66	0.00	57.85	24.16	0.36	80.90	(554)	24.91	0.08	82.62	(555)
DOWN	15.20	0.00	55.02	24.07	0.81	72.25	(550)	27.46	4.12	82.67	(551)
RIGHT	11.91	0.00	58.83	22.53	0.63	76.00	(549)	23.38	1.50	83.11	(539)
LEFT	14.22	0.00	58.82	26.13	1.54	79.00	(541)	26.96	1.13	93.00	(542)

Table C-7

SUBJECT *
PRESSURIZATION METHOD WATER
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	19.61	0.00	90.02	40.96	1.16	100.21	(755)	51.32	1.29	99.81	(753)
PULL	20.13	0.00	101.37	40.92	1.56	114.85	(757)	49.89	0.05	114.85	(759)
UP	12.24	0.00	61.83	23.75	0.21	71.09	(740)	25.43	8.11	64.97	(746)
DOWN	15.80	0.00	54.71	24.66	0.22	63.28	(770)	29.57	3.48	82.54	(772)
RIGHT	11.54	0.00	45.37	21.68	0.72	60.72	(787)	23.45	0.02	63.56	(787)
LEFT	13.31	0.00	48.30	24.36	0.93	63.68	(783)	25.87	1.01	61.50	(785)

Table C-8

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	18.11	0.00	69.91	39.81	0.02	97.88	(446)	49.37	5.85	97.13	(444)
PULL	20.30	0.00	77.11	42.02	1.85	102.23	(448)	51.16	2.91	116.67	(443)
UP	13.04	0.00	57.85	25.50	0.36	80.90	(428)	26.43	0.84	82.62	(437)
DOWN	17.21	0.00	65.02	26.85	1.81	72.25	(440)	31.23	2.87	82.67	(444)
RIGHT	12.63	0.00	58.83	23.74	1.86	76.00	(442)	25.08	1.50	83.11	(444)
LEFT	14.69	0.00	52.85	27.00	5.23	79.00	(446)	28.22	7.19	78.38	(445)

Table C-9

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	18.71	0.00	75.00	41.07	1.16	98.75	(436)	51.02	1.29	97.37	(439)
PULL	19.35	0.00	68.22	40.19	1.56	91.83	(431)	49.86	3.94	111.95	(442)
UP	12.51	0.00	61.83	23.69	0.96	71.09	(432)	25.18	8.11	64.97	(432)
DOWN	14.91	0.00	54.13	24.06	0.22	59.42	(439)	28.10	4.12	60.35	(437)
RIGHT	12.35	0.00	45.37	23.16	0.63	60.72	(446)	24.40	0.02	63.56	(439)
LEFT	14.03	0.00	58.82	25.88	1.72	76.46	(440)	27.11	1.36	93.60	(439)

Table C-10

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	22.20	0.00	102.67	43.79	1.99	109.51	(446)	54.17	6.36	106.89	(446)
PULL	22.72	0.00	101.37	44.97	1.87	114.85	(443)	52.69	5.96	114.85	(442)
UP	11.72	0.00	42.08	22.61	0.21	56.45	(434)	24.00	0.34	52.00	(432)
DOWN	14.52	0.00	54.71	22.33	0.81	63.28	(441)	26.73	0.10	82.54	(442)
RIGHT	10.11	0.00	43.70	19.22	0.72	59.10	(448)	20.79	2.07	57.67	(443)
LEFT	12.31	0.00	48.30	22.33	0.93	63.68	(438)	23.61	1.01	61.50	(443)

Table C-11

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	22.82	0.00	102.67	43.87	0.02	109.51	(435)	53.22	2.70	106.89	(433)
PULL	16.51	0.00	68.61	36.93	1.85	88.71	(431)	45.65	2.99	90.21	(431)
UP	14.26	0.00	61.83	25.93	0.54	71.09	(425)	26.97	8.11	64.97	(427)
DOWN	16.24	0.00	60.11	25.49	0.81	64.19	(432)	29.23	4.12	64.73	(435)
RIGHT	12.22	0.00	45.36	22.56	2.48	73.54	(440)	24.22	2.38	74.28	(434)
LEFT	14.66	0.00	51.76	26.75	2.05	79.00	(432)	27.95	1.36	78.38	(436)

Table C-12

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	19.70	0.00	90.02	42.58	1.16	103.49	(445)	52.42	1.29	103.49	(449)
PULL	20.73	0.00	74.70	42.35	1.87	96.04	(442)	51.72	4.11	104.12	(446)
UP	11.58	0.00	57.85	23.36	0.21	80.90	(436)	25.02	1.76	82.62	(434)
DOWN	15.51	0.00	65.02	24.36	0.22	72.25	(441)	29.32	0.71	82.67	(438)
RIGHT	11.49	0.00	45.91	22.30	0.72	59.10	(448)	23.82	2.07	57.67	(447)
LEFT	13.39	0.00	58.82	24.97	1.72	76.46	(445)	25.90	3.36	93.60	(445)

Table C-13

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION *
RESTRAINT *

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	16.61	0.00	80.31	38.30	1.99	98.75	(448)	48.99	2.96	99.51	(447)
PULL	25.00	0.00	101.37	47.72	1.56	114.85	(449)	56.11	5.96	116.67	(450)
UP	11.46	0.00	38.64	22.53	0.27	55.79	(433)	23.69	0.08	54.16	(440)
DOWN	14.91	0.00	56.01	23.43	0.82	64.31	(447)	27.56	3.48	60.73	(450)
RIGHT	11.37	0.00	58.83	21.24	0.63	76.00	(448)	22.25	1.50	83.11	(445)
LEFT	13.04	0.00	52.85	23.58	0.93	71.88	(447)	25.13	1.01	75.19	(446)

Table C-14

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT *

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	20.16	0.00	102.67	42.03	0.02	109.51	(664)	52.97	2.70	106.89	(664)
PULL	20.97	0.00	98.70	41.97	1.56	111.89	(662)	50.20	5.96	114.85	(664)
UP	10.55	0.00	61.83	20.15	0.21	71.09	(626)	20.71	8.11	64.97	(636)
DOWN	13.82	0.00	51.43	22.00	0.22	59.70	(658)	26.30	4.12	82.54	(657)
RIGHT	14.69	0.00	58.83	26.80	0.63	76.00	(673)	[illegible]	3.57	83.11	(667)
LEFT	13.76	0.00	52.85	25.48	0.93	79.00	(662)	26.48	1.01	73.38	(666)

Table C-15

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION VERTICAL
RESTRAINT *

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	19.20	0.00	90.02	41.09	1.16	107.04	(664)	50.08	1.29	105.73	(665)
PULL	20.64	0.00	101.37	42.85	1.92	114.85	(660)	52.28	0.05	116.67	(663)
UP	14.17	0.00	57.85	27.47	3.43	80.90	(668)	29.52	0.08	82.62	(665)
DOWN	17.26	0.00	65.02	26.81	1.39	72.25	(662)	31.05	2.87	82.67	(666)
RIGHT	8.64	0.00	27.34	17.19	0.72	44.88	(663)	17.93	1.50	47.11	(659)
LEFT	13.61	0.00	58.82	24.69	1.72	76.46	(662)	26.14	2.72	93.68	(661)

Table C-16

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.01	0.00	1.09	22.74	1.73	55.22	(170)	35.38	1.29	75.11	(172)
PULL	0.18	0.00	6.39	26.36	6.17	60.63	(173)	43.21	5.39	78.66	(171)
UP	0.48	0.00	7.68	15.70	0.27	27.90	(164)	19.27	8.11	49.84	(166)
DOWN	1.56	0.00	21.76	14.52	0.22	48.66	(166)	22.54	0.10	49.43	(168)
RIGHT	0.12	0.00	4.56	12.32	0.63	33.31	(171)	17.52	0.02	42.58	(170)
LEFT	0.02	0.00	3.02	13.31	2.53	30.32	(170)	18.16	2.56	35.08	(168)

Table C-17

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.33	0.00	14.27	22.29	1.16	55.55	(164)	40.86	2.70	85.24	(167)
PULL	2.06	0.00	15.18	24.40	1.87	48.91	(163)	43.22	0.05	82.98	(167)
UP	4.76	0.00	16.77	17.86	1.42	37.37	(157)	21.34	1.89	40.80	(161)
DOWN	8.60	0.00	37.82	18.38	1.39	51.30	(163)	25.79	4.12	60.01	(163)
RIGHT	10.46	0.00	34.96	19.69	3.28	46.84	(169)	22.39	3.34	55.64	(163)
LEFT	16.60	0.00	47.61	27.55	2.05	59.82	(165)	29.03	4.99	56.65	(166)

Table C-18

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	35.49	0.00	102.67	57.37	3.82	109.51	(160)	58.48	5.85	106.89	(157)
PULL	36.54	3.93	87.04	56.61	10.29	104.15	(157)	56.81	3.57	111.95	(156)
UP	17.17	0.00	38.47	27.11	0.95	54.26	(154)	27.56	2.38	52.16	(153)
DOWN	19.28	0.00	51.43	26.47	5.99	57.69	(156)	30.41	10.79	82.54	(158)
RIGHT	13.61	0.00	41.20	22.21	5.01	55.80	(157)	22.84	5.57	58.78	(156)
LEFT	14.75	0.00	34.54	24.97	9.56	50.08	(156)	25.39	8.43	51.78	(158)

Table C-19

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	14.65	0.00	60.02	34.35	5.40	88.26	(160)	43.33	3.77	80.52	(159)
PULL	22.36	0.00	59.17	40.62	9.49	81.03	(160)	46.05	5.96	81.98	(158)
UP	10.39	0.00	25.97	19.95	0.54	41.21	(153)	22.74	0.34	47.53	(155)
DOWN	10.40	0.00	34.12	18.71	3.74	41.88	(157)	22.80	4.76	53.44	(158)
RIGHT	12.32	0.00	41.67	20.94	2.48	54.00	(158)	21.82	3.16	57.36	(160)
LEFT	12.14	0.00	28.77	21.5	2.23	48.01	(156)	22.15	1.36	43.30	(156)

Table C-20

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	4.09	0.00	27.13	25.69	0.02	72.13	(166)	45.75	13.17	83.67	(166)
PULL	4.30	0.00	32.17	27.10	1.56	79.43	(162)	47.55	2.99	116.67	(168)
UP	17.46	0.00	61.83	28.71	0.96	71.09	(160)	27.82	0.21	64.97	(159)
DOWN	20.81	0.00	54.71	29.61	1.84	64.31	(169)	32.74	3.48	60.73	(167)
RIGHT	9.42	0.00	29.53	19.78	3.82	37.60	(168)	22.09	3.55	52.71	(168)
LEFT	8.44	0.00	20.61	19.10	1.72	39.53	(165)	22.97	4.76	51.60	(165)

Table C-21

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	42.52	0.00	93.89	68.04	9.84	103.74	(172)	69.17	9.97	102.98	(172)
PULL	37.56	0.00	101.37	60.78	1.92	114.85	(171)	60.90	20.12	114.85	(169)
UP	17.03	0.00	44.67	28.36	0.21	57.85	(171)	28.78	1.76	59.70	(172)
DOWN	21.58	0.00	60.11	30.20	6.77	64.19	(173)	32.11	9.68	64.73	(171)
RIGHT	16.10	0.00	49.09	27.41	1.86	63.58	(173)	26.93	1.50	61.13	(169)
LEFT	19.33	0.00	52.85	30.89	0.93	65.18	(171)	29.88	1.01	63.96	(172)

Table C-22

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE * DEGREES
RECEIVER DISTANCE *
RECEIVER ORIENTATION *
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	29.25	0.00	65.71	49.85	4.06	89.81	(164)	56.56	13.15	103.49	(164)
PULL	30.62	0.00	77.01	49.08	8.12	92.68	(163)	50.71	4.63	91.18	(166)
UP	13.57	0.00	32.67	22.22	4.88	45.10	(165)	23.28	4.01	44.73	(165)
DOWN	15.79	0.00	48.15	22.43	0.82	53.31	(166)	26.05	3.79	52.51	(168)
RIGHT	15.32	0.00	43.70	24.65	3.11	59.10	(169)	25.44	8.82	57.67	(168)
LEFT	17.41	0.00	36.32	28.03	9.96	52.90	(169)	27.98	8.31	56.60	(170)

Table C-23

SUBJECT	*
PRESSUPIZATION METHOD	*
RECEIVER ANGLE	* DEGREES
RECEIVER DISTANCE	*
RECEIVER ORIENTATION	*
RESTRAINT	HAND AND SHOES

	SUSTAINED MINIMUM MEAN	SUSTAINED MINIMUM RANGE		SUSTAINED MAXIMUM MEAN	SUSTAINED MAXIMUM RANGE			IMPULSE MAXIMUM MEAN	IMPULSE MAXIMUM RANGE		
PUSH	29.67	0.00	67.95	51.48	14.20	103.49	(172)	62.37	17.92	92.06	(172)
PULL	33.01	0.00	68.61	54.08	15.85	88.71	(173)	61.32	3.94	108.14	(172)
UP	18.04	0.00	57.85	30.86	0.36	80.90	(170)	30.64	0.08	82.62	(170)
DOWN	25.60	0.00	65.02	34.12	6.54	72.25	(170)	36.63	0.73	82.67	(170)
RIGHT	16.30	0.00	58.83	29.08	6.11	76.00	(171)	28.15	5.97	83.11	(172)
LEFT	20.56	0.00	58.82	34.70	1.54	79.00	(172)	34.28	1.13	93.60	(172)

Table C-24

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED MINIMUM MEAN	SUSTAINED MINIMUM RANGE		SUSTAINED MAXIMUM MEAN	SUSTAINED MAXIMUM RANGE			IMPULSE MAXIMUM MEAN	IMPULSE MAXIMUM RANGE		
PUSH	0.00	0.00	0.00	19.44	14.30	25.69	(9)	33.89	12.55	55.63	(9)
PULL	0.12	0.00	1.09	22.24	11.57	38.50	(9)	40.60	19.48	63.07	(9)
UP	0.00	0.00	0.00	16.20	12.04	23.08	(7)	17.67	11.67	26.75	(7)
DOWN	2.82	0.00	13.25	12.79	5.88	20.35	(8)	25.28	12.77	35.32	(8)
RIGHT	0.00	0.00	0.00	16.21	6.41	23.04	(9)	24.88	10.71	42.50	(9)
LEFT	0.00	0.00	0.00	17.47	7.[illegible]9	30.32	(9)	22.97	9.90	32.49	(9)

Table C-25

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	5.33	0.00	14.27	20.46	1.67	38.29	(9)	38.76	26.16	55.07	(8)
PULL	1.66	0.00	5.46	22.06	9.83	37.94	(9)	40.54	22.89	64.50	(9)
UP	5.52	0.00	11.02	16.75	10.23	23.67	(8)	15.97	3.42	27.20	(8)
DOWN	6.49	0.00	19.90	15.71	3.83	24.24	(9)	23.42	15.54	47.85	(9)
RIGHT	9.68	2.56	13.56	20.85	15.13	26.69	(9)	26.87	19.82	36.36	(9)
LEFT	15.86	8.78	20.47	23.87	14.45	28.35	(9)	30.11	17.70	37.47	(9)

Table C-26

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	35.75	0.89	59.12	57.38	8.77	90.56	(8)	58.76	10.55	88.96	(8)
PULL	23.51	3.93	36.67	38.78	10.29	56.93	(8)	40.92	8.00	54.69	(8)
UP	13.73	3.26	21.19	24.07	19.79	30.18	(7)	20.70	2.98	29.82	(8)
DOWN	15.20	4.13	37.30	21.60	5.99	43.79	(8)	27.04	10.84	61.65	(8)
RIGHT	14.30	0.00	23.93	28.96	14.91	51.66	(8)	29.39	17.04	47.08	(8)
LEFT	11.81	0.00	23.08	24.05	11.47	36.46	(8)	25.79	12.56	41.23	(8)

Table C-27

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	17.64	2.87	37.19	37.73	18.77	62.55	(9)	46.39	27.10	65.22	(9)
PULL	10.85	1.07	20.94	30.06	9.49	44.70	(9)	35.44	17.83	52.50	(9)
UP	10.92	3.27	19.91	21.74	11.71	36.52	(9)	23.38	13.08	46.54	(9)
DOWN	6.34	0.00	15.49	16.33	7.51	26.77	(9)	20.18	6.28	30.80	(9)
RIGHT	19.14	0.00	41.67	27.98	6.47	48.97	(9)	27.60	9.87	52.07	(9)
LEFT	15.67	9.10	28.77	23.45	14.95	37.38	(9)	24.88	15.21	36.86	(9)

Table C-28

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.61	0.00	7.50	22.46	0.02	51.04	(8)	44.26	23.34	61.38	(8)
PULL	2.27	0.00	10.49	21.04	1.85	66.11	(8)	38.18	2.99	65.78	(8)
UP	14.00	0.00	25.38	23.51	18.92	28.91	(7)	20.04	1.56	30.28	(8)
DOWN	14.28	1.22	41.42	25.23	11.04	49.56	(8)	28.19	11.56	55.55	(8)
RIGHT	9.36	0.00	18.27	19.80	12.66	33.25	(8)	23.14	7.31	44.69	(8)
LEFT	9.66	0.00	16.97	23.14	18.19	33.79	(8)	26.17	16.33	42.99	(8)

Table C-29

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	48.01	28.55	69.76	70.28	52.89	91.74	(9)	69.13	56.65	81.13	(9)
PULL	26.83	13.27	46.00	51.89	33.08	71.18	(9)	51.72	32.38	68.67	(9)
UP	12.30	0.00	22.60	26.55	8.36	52.40	(9)	27.48	9.18	59.78	(9)
DOWN	29.41	12.09	43.19	37.46	23.73	56.79	(9)	40.73	24.33	60.27	(9)
RIGHT	27.58	13.93	45.36	42.19	25.82	63.58	(9)	41.71	24.98	61.13	(9)
LEFT	21.18	0.30	51.76	37.27	6.68	65.18	(9)	35.34	12.61	57.11	(9)

Table C-30

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

								IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	31.49	13.96	49.62	51.39	20.60	83.00	(11)	56.64	38.97	81.88	(11)
PULL	22.98	8.22	33.22	40.85	16.84	57.14	(11)	45.45	21.93	57.38	(11)
UP	14.65	7.71	28.53	22.76	14.87	45.10	(11)	21.91	16.62	29.83	(11)
DOWN	16.02	7.16	27.96	22.08	13.17	37.74	(11)	24.88	15.96	34.15	(11)
RIGHT	22.60	3.52	37.62	36.04	24.39	50.95	(11)	36.85	26.21	50.38	(11)
LEFT	17.06	0.12	30.25	30.81	17.48	52.07	(11)	30.76	19.83	40.82	(11)

Table C-31

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	38.15	25.42	65.61	56.24	45.19	81.66	(8)	62.45	33.35	91.86	(9)
PULL	37.70	26.30	52.92	56.36	42.06	71.68	(9)	61.76	40.53	79.88	(9)
UP	14.87	0.27	40.29	27.61	3.05	50.21	(9)	27.26	13.10	45.50	(9)
DOWN	24.88	8.62	38.73	33.74	22.59	42.63	(9)	35.93	23.59	45.08	(9)
RIGHT	23.55	10.23	44.04	38.20	24.85	73.54	(9)	38.25	21.43	74.28	(9)
LEFT	26.29	17.14	49.32	42.77	26.71	79.00	(9)	42.15	23.90	78.38	(9)

Table C-32

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	16.92	5.95	27.75	(8)	30.92	7.44	45.22	(8)
PULL	0.00	0.00	0.00	29.76	9.64	59.38	(8)	44.26	5.39	70.81	(8)
UP	0.00	0.00	0.00	15.19	3.43	26.77	(8)	19.90	13.13	33.92	(8)
DOWN	2.04	0.00	6.67	23.08	12.08	39.19	(7)	31.82	14.92	44.38	(8)
RIGHT	0.00	0.00	0.00	13.03	6.51	20.67	(8)	15.94	10.23	24.79	(8)
LEFT	0.13	0.00	1.07	16.37	7.16	22.66	(8)	25.14	16.59	35.08	(8)

Table C-33

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	4.79	0.00	11.02	29.01	10.45	43.89	(8)	43.61	31.24	74.17	(8)
PULL	0.30	0.00	2.41	20.39	8.67	30.67	(8)	40.89	23.62	71.84	(7)
UP	3.73	0.00	13.16	18.23	11.23	27.92	(6)	25.34	17.70	35.89	(8)
DOWN	9.15	0.00	17.78	22.00	9.36	28.87	(8)	25.48	13.01	32.16	(8)
RIGHT	9.99	3.75	15.92	15.90	8.77	22.03	(8)	15.99	3.54	21.69	(8)
LEFT	13.57	0.00	24.85	27.67	18.22	45.76	(8)	25.93	20.08	40.23	(8)

Table C-34

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	36.54	0.64	55.64	53.90	3.82	88.76	(9)	52.95	5.85	76.65	(8)
PULL	28.31	6.89	51.14	45.49	13.08	62.79	(9)	47.19	18.68	59.18	(9)
UP	25.43	6.07	35.14	36.44	11.27	51.36	(8)	35.36	4.21	50.13	(10)
DOWN	21.64	8.56	29.72	29.85	17.16	55.93	(9)	34.45	10.84	50.33	(9)
RIGHT	10.38	4.42	15.10	18.13	13.56	23.70	(9)	17.09	14.43	23.59	(9)
LEFT	13.82	0.82	22.25	25.74	11.82	49.42	(9)	27.05	9.75	51.78	(9)

Table C-35

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	7.44	0.00	20.20	31.61	16.36	49.38	(9)	39.17	26.49	48.15	(8)
PULL	9.81	0.97	18.19	27.68	22.92	40.88	(9)	36.09	25.00	49.09	(9)
UP	13.30	2.20	23.15	23.87	12.26	37.00	(9)	31.35	14.13	45.56	(9)
DOWN	10.60	3.05	20.05	22.57	12.05	30.35	(9)	26.56	10.22	34.49	(9)
RIGHT	13.12	9.01	18.76	19.66	13.12	26.90	(9)	20.83	10.79	26.36	(9)
LEFT	11.25	0.00	18.41	23.81	13.78	31.03	(9)	24.35	15.80	34.57	(9)

Table C-36

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	1.42	0.00	9.03	21.30	2.04	33.83	(12)	41.42	24.49	57.91	(12)
PULL	0.99	0.00	8.16	20.64	3.00	40.08	(12)	45.97	16.68	72.02	(12)
UP	26.58	12.03	41.37	41.85	20.52	58.69	(12)	43.32	25.77	60.39	(11)
DOWN	23.79	1.39	54.35	36.24	14.47	59.66	(12)	34.56	2.87	56.48	(12)
RIGHT	8.35	1.75	14.32	18.04	12.08	21.34	(12)	17.95	12.91	25.56	(12)
LEFT	8.74	3.35	13.04	20.65	8.51	32.11	(11)	24.59	15.96	35.79	(12)

Table C-37

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	39.42	0.00	56.60	57.13	14.50	79.18	(9)	63.08	26.07	82.47	(9)
PULL	30.92	22.06	39.57	52.00	33.74	79.70	(9)	48.38	32.24	69.09	(8)
UP	25.86	14.08	39.96	39.09	23.53	57.66	(9)	39.34	18.44	56.64	(9)
DOWN	32.83	5.96	60.11	40.72	17.04	64.19	(9)	40.70	16.39	64.73	(9)
RIGHT	15.06	7.80	23.45	25.61	14.82	33.69	(8)	23.61	14.39	30.98	(8)
LEFT	29.34	12.63	50.00	40.40	20.10	60.81	(9)	40.16	23.34	63.96	(9)

Table C-38

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.24	0.00	59.86	55.22	35.96	74.03	(8)	54.85	13.82	79.20	(8)
PULL	26.06	15.64	40.65	45.85	28.08	60.31	(8)	44.96	29.58	62.25	(8)
UP	18.01	2.02	29.14	30.56	20.75	41.92	(8)	32.88	24.05	44.73	(8)
DOWN	21.47	11.35	36.29	29.76	16.93	40.02	(8)	31.53	16.93	44.25	(8)
RIGHT	17.35	13.16	27.34	25.83	21.30	36.83	(8)	26.73	22.67	32.42	(8)
LEFT	22.12	11.77	36.32	35.56	23.06	52.90	(8)	32.65	16.84	46.22	(8)

Table C-39

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	34.39	19.82	56.44	52.76	30.07	73.83	(10)	59.46	29.40	87.68	(10)
PULL	32.73	0.00	68.61	58.80	42.59	85.86	(10)	64.53	43.57	90.21	(10)
UP	23.93	8.29	37.37	41.04	22.71	53.14	(10)	39.75	30.20	46.06	(10)
DOWN	27.87	5.45	59.13	39.22	17.77	62.35	(10)	37.74	23.28	55.92	(10)
RIGHT	13.51	1.80	18.00	27.11	18.01	44.88	(10)	22.06	14.92	27.16	(10)
LEFT	25.87	9.69	47.39	41.80	13.71	62.98	(10)	39.25	17.37	58.79	(10)

Table C-40

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	18.90	6.45	27.16	(11)	37.56	21.04	71.66	(11)
PULL	0.27	0.00	2.97	23.85	6.71	44.08	(11)	43.45	17.83	73.83	(11)
UP	0.87	0.00	5.03	17.01	12.63	25.28	(10)	19.06	13.97	24.18	(10)
DOWN	0.40	0.00	3.41	10.96	3.66	19.19	(10)	21.49	14.83	28.83	(10)
RIGHT	0.00	0.00	0.00	16.48	7.82	30.39	(11)	27.21	10.78	41.93	(11)
LEFT	0.00	0.00	0.00	13.82	5.27	23.90	(11)	18.89	7.19	32.72	(11)

Table C-41

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	3.15	0.00	11.46	28.03	11.23	43.94	(10)	43.01	28.14	62.08	(10)
PULL	0.94	0.00	9.15	22.93	12.15	38.73	(10)	41.31	20.84	61.92	(10)
UP	5.92	0.00	10.24	16.52	8.69	22.41	(8)	17.44	11.52	22.58	(9)
DOWN	11.90	3.37	31.82	20.51	7.95	45.04	(10)	30.50	16.17	60.01	(10)
RIGHT	11.94	7.73	15.68	22.02	15.04	31.61	(10)	30.07	16.76	39.00	(10)
LEFT	17.40	7.24	29.58	31.28	25.95	47.73	(10)	32.52	25.34	52.63	(10)

Table C-42

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	36.24	16.01	57.10	57.82	26.13	85.71	(10)	57.86	31.75	81.00	(10)
PULL	33.10	16.14	53.29	52.00	35.81	63.48	(10)	48.67	20.16	67.41	(10)
UP	9.58	0.00	21.43	18.32	2.19	29.91	(10)	18.81	2.38	29.91	(10)
DOWN	21.22	5.91	41.97	27.57	6.84	51.50	(10)	28.86	15.54	56.50	(10)
RIGHT	18.84	0.64	33.46	31.60	13.78	41.76	(10)	35.86	19.47	57.28	(10)
LEFT	15.24	0.00	26.88	25.95	10.38	36.18	(10)	26.44	11.89	40.25	(10)

Table C-43

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	6.48	0.00	16.14	28.53	18.98	36.40	(8)	43.36	28.83	52.38	(8)
PULL	18.01	0.13	29.25	37.39	27.98	46.15	(8)	48.66	39.87	62.26	(8)
UP	6.22	0.00	17.22	14.65	2.08	26.99	(7)	17.90	6.73	30.17	(7)
DOWN	9.12	0.00	27.09	18.49	7.31	29.69	(7)	23.73	11.04	45.07	(7)
RIGHT	11.37	0.00	25.32	24.62	8.53	37.06	(8)	29.61	10.76	44.70	(8)
LEFT	14.69	8.62	26.18	24.22	17.75	33.65	(8)	25.71	18.05	35.93	(8)

Table C-44

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.63	0.00	4.13	23.31	5.37	50.05	(8)	50.82	26.94	83.67	(8)
PULL	3.26	0.00	12.46	23.92	11.93	56.97	(8)	52.40	24.16	104.12	(8)
UP	10.18	0.00	17.91	19.86	8.20	30.42	(8)	18.68	7.33	26.16	(8)
DOWN	13.93	0.00	39.00	24.84	11.16	44.97	(8)	30.96	12.85	57.44	(8)
RIGHT	9.37	0.00	13.22	24.10	14.54	35.48	(8)	27.49	17.58	42.63	(8)
LEFT	7.87	0.95	14.65	21.55	15.70	30.39	(8)	23.08	15.09	32.02	(8)

Table C-45

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	38.[illegible]9	10.35	69.91	68.76	52.13	90.46	(11)	70.45	53.06	89.63	(11)
PULL	40.20	0.00	66.73	65.23	44.12	91.28	(11)	60.14	41.47	80.42	(10)
UP	16.70	8.25	25.21	25.11	19.05	36.74	(11)	25.48	21.18	35.19	(11)
DOWN	20.97	13.84	28.82	28.62	16.28	43.17	(11)	32.58	23.07	48.75	(11)
RIGHT	28.86	14.73	45.91	44.32	27.36	56.38	(11)	40.57	23.53	56.05	(11)
LEFT	17.91	0.00	31.86	33.31	22.67	44.21	(11)	31.18	17.71	41.48	(11)

Table C-46

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.69	15.05	38.78	47.67	34.89	65.09	(9)	58.00	40.06	79.14	(9)
PULL	31.26	16.84	43.70	49.98	24.33	59.37	(9)	53.33	30.83	84.89	(9)
UP	10.23	2.15	14.44	18.09	13.25	24.34	(9)	18.55	13.42	28.61	(9)
DOWN	15.48	5.13	21.43	23.45	15.09	31.54	(9)	27.97	18.13	36.99	(9)
RIGHT	24.50	6.43	38.35	36.51	18.69	51.69	(9)	36.44	18.17	54.06	(9)
LEFT	21.78	6.36	33.67	32.54	23.64	47.32	(9)	33.01	22.47	46.11	(9)

Table C-47

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	33.08	10.62	60.25	56.81	31.10	80.32	(9)	66.45	48.68	91.36	(9)
PULL	35.16	2.59	56.13	56.34	39.64	78.04	(9)	68.35	42.69	90.08	(9)
UP	12.94	0.00	22.50	24.11	0.36	35.58	(9)	23.11	1.83	38.09	(9)
DOWN	28.30	15.38	37.02	36.28	25.30	45.80	(9)	37.25	30.62	50.09	(9)
RIGHT	20.83	12.43	30.46	34.79	25.20	54.64	(9)	33.36	23.23	47.19	(9)
LEFT	22.31	17.30	27.26	37.72	25.79	50.97	(9)	35.82	28.38	49.72	(9)

Table C-48

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	17.52	8.34	22.09	(10)	32.51	11.54	66.92	(11)
PULL	0.43	0.00	2.77	20.54	6.84	39.61	(12)	40.17	17.97	65.78	(11)
UP	0.13	0.00	1.41	14.98	8.65	26.41	(11)	21.31	4.05	33.66	(11)
DOWN	1.22	0.00	5.19	14.99	6.81	25.88	(11)	25.78	10.60	42.80	(11)
RIGHT	0.00	0.00	0.00	11.96	6.37	16.64	(11)	14.51	7.52	20.92	(11)
LEFT	0.00	0.00	0.00	13.35	6.39	22.82	(11)	19.77	10.15	30.26	(11)

Table C-49

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.62	0.00	5.61	26.18	15.15	43.19	(9)	41.31	28.70	59.31	(9)
PULL	0.66	0.00	4.43	25.89	13.89	44.88	(9)	42.60	18.62	69.03	(9)
UP	6.74	0.00	16.77	22.53	11.74	36.88	(9)	27.26	15.12	40.80	(9)
DOWN	13.90	0.00	34.61	23.63	10.44	40.25	(9)	31.06	15.33	53.25	(9)
RIGHT	9.39	0.00	16.25	16.47	6.51	24.75	(9)	17.60	3.34	24.07	(9)
LEFT	18.48	8.37	28.03	27.74	17.96	39.92	(9)	29.41	21.00	39.92	(9)

Table C-50

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	31.30	15.69	47.93	48.21	29.37	73.09	(9)	49.95	28.47	68.28	(9)
PULL	35.01	20.46	53.57	53.36	27.83	70.70	(9)	55.88	42.11	76.80	(8)
UP	19.39	9.10	33.36	35.74	17.17	48.16	(9)	34.15	20.96	52.16	(9)
DOWN	20.83	2.25	34.59	29.71	19.09	38.66	(8)	36.53	23.76	50.90	(9)
RIGHT	11.68	6.65	15.59	18.89	17.11	20.28	(8)	20.18	15.25	26.76	(9)
LEFT	12.71	6.61	18.14	21.12	11.82	28.13	(9)	23.38	15.56	31.11	(9)

Table C-51

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST

	SUSTAINED MINIMUM MEAN	SUSTAINED MINIMUM RANGE		SUSTAINED MAXIMUM MEAN	SUSTAINED MAXIMUM RANGE			IMPULSE MAXIMUM MEAN	IMPULSE MAXIMUM RANGE		
PUSH	9.30	0.00	21.12	32.58	18.75	41.42	(9)	40.25	23.80	63.24	(9)
PULL	23.17	1.25	44.70	41.17	32.03	57.90	(9)	47.77	35.95	66.13	(9)
UP	7.83	0.00	20.12	19.58	11.36	35.17	(9)	25.99	15.24	40.35	(9)
DOWN	11.35	0.00	29.94	21.59	14.71	36.23	(9)	28.84	23.42	37.69	(9)
RIGHT	11.20	6.43	18.44	19.91	13.51	27.11	(8)	18.73	8.39	25.40	(8)
LEFT	16.57	6.63	24.18	25.90	11.09	35.49	(8)	26.72	16.74	38.58	(8)

Table C-52

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	SHOES

	SUSTAINED MINIMUM MEAN	SUSTAINED MINIMUM RANGE		SUSTAINED MAXIMUM MEAN	SUSTAINED MAXIMUM RANGE			IMPULSE MAXIMUM MEAN	IMPULSE MAXIMUM RANGE		
PUSH	0.90	0.00	3.57	27.14	12.15	72.13	(9)	47.66	27.80	62.97	(9)
PULL	0.54	0.00	2.74	26.35	18.48	39.08	(9)	56.48	28.83	86.12	(9)
UP	21.64	6.60	40.05	38.45	17.46	58.17	(9)	34.16	16.88	47.76	(9)
DOWN	28.32	9.09	50.40	36.22	14.32	57.10	(9)	41.63	27.06	57.86	(9)
RIGHT	7.09	0.90	13.04	16.83	7.86	20.36	(9)	16.97	6.48	24.04	(9)
LEFT	10.81	5.73	19.37	22.07	17.11	26.01	(9)	27.00	17.51	43.53	(9)

Table C-53

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	35.29	18.45	57.69	62.22	37.11	88.93	(11)	61.35	46.15	75.25	(11)
PULL	27.54	0.00	44.62	52.46	33.61	88.35	(11)	53.42	36.13	69.65	(11)
UP	19.15	2.37	36.67	34.13	19.78	54.06	(11)	33.54	21.82	42.99	(11)
DOWN	23.99	0.36	36.40	38.59	25.76	60.17	(11)	39.31	25.27	56.57	(10)
RIGHT	7.60	0.00	12.29	19.07	12.24	24.40	(11)	19.82	12.05	26.09	(11)
LEFT	22.30	0.00	40.37	36.39	20.37	50.67	(11)	36.56	21.72	50.10	(10)

Table C-54

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	32.10	6.54	50.19	52.27	26.81	72.16	(9)	56.93	43.96	75.22	(9)
PULL	28.84	11.72	40.66	52.57	35.46	67.30	(9)	57.58	44.67	74.79	(9)
UP	16.76	5.22	23.15	27.74	19.62	33.92	(9)	28.95	16.40	39.99	(9)
DOWN	22.33	14.18	37.88	28.10	20.92	40.60	(8)	33.17	24.37	43.32	(9)
RIGHT	13.88	4.78	21.00	22.64	14.11	27.34	(9)	23.55	15.71	31.07	(9)
LEFT	17.36	4.71	29.03	30.15	16.77	46.41	(9)	28.84	17.49	45.24	(9)

Table C-55

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	32.50	0.00	56.88	54.63	40.08	76.01	(10)	63.35	51.04	74.82	(10)
PULL	41.47	24.42	58.64	60.00	30.43	82.67	(10)	67.22	35.02	82.41	(10)
UP	25.60	0.00	57.85	46.85	29.03	80.90	(10)	48.79	27.95	82.62	(10)
DOWN	37.14	8.20	65.02	45.22	21.79	72.25	(9)	48.63	31.40	82.67	(10)
RIGHT	13.00	0.00	25.54	24.90	16.64	39.53	(10)	21.46	16.37	27.67	(10)
LEFT	25.19	16.50	33.24	38.84	22.98	55.25	(10)	37.02	21.19	49.08	(10)

Table C-56

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	19.51	10.10	38.53	(9)	33.34	11.83	75.11	(9)
PULL	0.00	0.00	0.00	25.82	9.34	42.56	(9)	40.30	18.55	57.76	(9)
UP	1.10	0.00	7.68	13.86	3.59	25.04	(7)	15.42	0.84	24.67	(8)
DOWN	5.10	0.00	15.02	17.04	1.81	31.28	(8)	22.93	6.76	41.64	(9)
RIGHT	0.00	0.00	0.00	13.61	2.13	24.61	(9)	18.92	7.31	31.43	(9)
LEFT	0.00	0.00	0.00	15.21	5.67	22.36	(9)	19.98	9.78	26.28	(9)

Table C-57

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.74	0.00	6.82	22.69	8.[illegible]8	35.03	(8)	45.38	22.33	62.03	(8)
PULL	3.19	0.00	11.41	21.33	5.75	31.64	(8)	35.80	2.91	59.66	(8)
UP	7.55	4.49	9.94	13.55	10.05	17.70	(5)	13.12	1.89	20.24	(6)
DOWN	14.64	0.00	36.33	23.24	8.20	51.30	(8)	32.68	16.63	59.39	(8)
RIGHT	12.75	6.45	18.87	22.92	18.13	33.07	(8)	28.71	19.51	39.62	(8)
LEFT	18.62	9.53	25.49	26.74	17.03	35.37	(8)	29.14	23.11	45.29	(8)

Table C-58

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	20.23	0.00	50.43	48.26	23.44	72.44	(9)	47.80	29.13	82.28	(9)
PULL	40.41	11.81	66.33	60.62	20.03	82.41	(9)	58.89	20.03	84.24	(9)
UP	10.33	6.33	14.19	18.58	12.39	25.22	(8)	18.57	11.99	25.39	(8)
DOWN	17.24	0.26	50.58	24.84	11.41	52.42	(9)	25.57	13.90	49.35	(9)
RIGHT	18.06	8.89	29.62	27.84	16.17	38.33	(9)	26.80	12.32	50.22	(9)
LEFT	11.19	0.00	21.74	21.70	10.94	32.53	(9)	23.25	12.58	32.61	(9)

Table C-59

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED MINIMUM MEAN	RANGE		SUSTAINED MAXIMUM MEAN	RANGE			IMPULSE MAXIMUM MEAN	RANGE		
PUSH	8.40	0.00	17.64	23.67	12.79	35.59	(8)	32.56	20.43	45.25	(8)
PULL	30.89	9.92	51.79	45.23	21.79	71.38	(8)	54.06	28.85	80.75	(8)
UP	9.69	3.39	15.08	17.09	12.25	24.67	(8)	18.56	13.08	29.19	(8)
DOWN	7.65	0.62	18.46	14.01	7.93	27.38	(8)	17.75	10.52	29.58	(8)
RIGHT	15.67	0.00	38.32	23.97	11.66	45.36	(8)	25.92	9.76	51.06	(8)
LEFT	14.73	8.07	25.04	21.71	14.19	31.99	(8)	23.76	13.86	36.73	(8)

Table C-60

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED MINIMUM MEAN	RANGE		SUSTAINED MAXIMUM MEAN	RANGE			IMPULSE MAXIMUM MEAN	RANGE		
PUSH	1.08	0.00	4.98	25.84	14.42	42.93	(10)	40.43	26.34	65.82	(10)
PULL	1.95	0.00	5.86	23.59	18.05	40.95	(9)	42.85	13.37	64.48	(10)
UP	14.20	8.71	26.05	25.81	17.12	40.90	(9)	21.82	17.48	25.52	(9)
DOWN	17.41	0.96	38.86	26.47	9.49	47.65	(10)	28.91	13.58	53.13	(10)
RIGHT	8.79	0.00	22.72	24.16	16.49	37.60	(10)	28.85	9.43	52.71	(10)
LEFT	6.97	0.00	14.13	21.00	10.44	28.35	(10)	24.53	12.74	32.61	(10)

Table C-61

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	36.99	17.03	64.82	64.33	26.87	97.88	(9)	62.44	25.14	97.13	(9)
PULL	42.03	18.73	77.11	64.90	39.34	102.23	(9)	62.43	43.60	85.33	(9)
UP	14.72	0.00	29.44	23.96	16.95	39.16	(9)	25.00	17.20	35.56	(9)
DOWN	19.34	4.28	37.40	26.97	12.30	46.38	(9)	27.45	11.82	46.97	(9)
RIGHT	22.97	6.61	49.09	40.76	20.19	58.87	(8)	38.79	20.60	58.63	(9)
LEFT	16.87	0.00	52.85	30.60	8.02	60.56	(9)	27.94	11.22	57.02	(8)

Table C-62

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	24.14	0.00	44.81	40.97	4.06	65.67	(10)	54.67	16.48	86.13	(10)
PULL	35.29	16.12	49.16	58.80	43.87	76.58	(10)	52.52	5.68	71.13	(10)
UP	8.41	0.00	12.85	15.10	8.29	20.14	(9)	17.37	13.21	23.02	(10)
DOWN	14.44	1.60	48.15	20.76	2.19	53.31	(10)	22.49	8.27	47.31	(10)
RIGHT	19.08	7.86	26.96	29.91	18.78	42.35	(10)	29.25	20.33	37.99	(10)
LEFT	16.18	1.30	29.75	26.49	9.96	36.69	(10)	25.54	8.31	36.46	(10)

Table C-63

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM RANGE			MAXIMUM RANGE				MAXIMUM RANGE		
	MEAN			MEAN				MEAN			
PUSH	27.89	2.71	46.88	50.97	25.17	68.41	(10)	65.27	48.80	77.94	(9)
PULL	36.88	17.72	57.01	61.28	40.91	86.58	(10)	70.04	45.26	89.63	(9)
UP	16.70	2.40	29.37	24.86	6.07	36.90	(9)	23.18	1.44	39.29	(10)
DOWN	27.03	18.64	36.56	33.63	24.97	44.60	(10)	39.16	31.28	48.75	(10)
RIGHT	25.76	0.00	58.83	39.42	22.05	76.00	(10)	38.25	20.75	83.11	(10)
LEFT	22.34	6.88	47.24	39.53	31.14	71.88	(10)	39.72	30.48	75.19	(10)

Table C-64

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM RANGE			MAXIMUM RANGE				MAXIMUM RANGE		
	MEAN			MEAN				MEAN			
PUSH	0.00	0.00	0.00	22.67	11.52	55.22	(10)	29.63	14.41	45.27	(10)
PULL	0.35	0.00	3.55	29.82	12.57	60.63	(10)	44.82	20.51	78.66	(10)
UP	0.00	0.00	0.00	18.09	10.15	27.90	(10)	21.27	11.29	36.20	(10)
DOWN	1.77	0.00	8.40	16.68	9.45	24.54	(10)	25.77	12.25	42.25	(10)
RIGHT	0.00	0.00	0.00	9.33	5.39	13.62	(10)	12.59	6.43	18.83	(10)
LEFT	0.30	0.00	3.02	14.57	5.23	26.60	(10)	18.04	7.45	24.57	(10)

Table C-65

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	24.65	8.22	37.21	(8)	40.49	23.38	56.35	(8)
PULL	2.58	0.00	11.27	27.28	11.62	39.20	(8)	46.11	33.79	66.65	(8)
UP	6.94	0.00	13.41	23.51	9.49	37.37	(7)	27.86	16.00	39.82	(8)
DOWN	12.96	3.24	28.60	25.79	9.45	40.12	(8)	30.56	15.70	53.12	(8)
RIGHT	8.68	4.23	14.82	16.55	9.72	22.92	(8)	20.75	16.81	23.64	(7)
LEFT	17.66	7.45	24.61	28.92	19.08	38.63	(8)	30.21	19.91	49.37	(8)

Table C-66

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	25.08	3.07	47.79	43.26	18.94	59.32	(11)	46.52	18.81	81.18	(11)
PULL	42.32	21.40	76.10	63.52	31.38	85.84	(11)	61.59	29.99	91.08	(11)
UP	19.82	3.58	37.51	31.44	17.34	47.08	(11)	28.82	16.92	47.76	(11)
DOWN	19.50	10.04	34.01	28.47	17.77	40.92	(11)	30.78	17.74	43.50	(11)
RIGHT	8.33	0.00	13.22	15.67	9.19	21.60	(10)	15.67	8.56	22.01	(11)
LEFT	13.39	5.99	20.51	22.29	16.32	27.56	(11)	24.18	15.46	32.43	(11)

Table C-67

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	8.38	0.00	23.41	28.57	10.66	46.59	(9)	31.38	17.85	58.73	(9)
PULL	33.49	14.54	49.86	50.86	39.87	73.65	(9)	53.96	40.71	71.24	(9)
UP	9.22	0.00	18.61	19.91	11.86	29.93	(9)	24.43	16.42	31.27	(9)
DOWN	12.15	2.55	25.74	20.59	6.55	31.90	(9)	26.30	10.67	36.29	(9)
RIGHT	10.75	4.04	14.14	17.51	12.31	21.47	(9)	18.30	10.79	23.85	(9)
LEFT	12.54	2.80	28.33	19.67	8.44	36.81	(9)	20.70	9.32	35.41	(9)

Table C-68

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE -15 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	1.40	0.00	5.57	22.26	11.31	42.98	(9)	41.28	20.09	70.62	(9)
PULL	2.14	0.00	6.81	26.90	17.08	38.57	(9)	53.97	26.10	116.67	(9)
UP	17.07	9.11	31.59	30.06	14.32	51.52	(9)	33.29	19.54	54.16	(9)
DOWN	25.27	12.33	52.12	38.23	19.79	64.31	(9)	40.46	19.24	60.04	(9)
RIGHT	6.64	0.00	10.94	14.68	3.82	23.05	(9)	16.65	6.23	22.43	(9)
LEFT	11.08	0.00	18.26	20.11	10.88	33.66	(9)	23.29	10.56	36.27	(9)

Table C-69

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	33.84	9.59	52.94	59.55	39.76	78.16	(11)	64.82	39.06	96.83	(11)
PULL	42.68	26.06	74.05	70.73	50.71	94.24	(11)	72.11	47.21	92.06	(11)
UP	21.25	4.16	34.93	37.07	24.73	51.52	(11)	39.73	25.20	53.87	(11)
DOWN	26.45	1.99	52.83	38.31	23.90	58.34	(11)	43.27	23.92	55.57	(11)
RIGHT	10.56	0.00	17.37	19.91	1.86	25.88	(11)	18.89	1.50	25.88	(11)
LEFT	19.77	5.43	33.48	33.23	22.25	44.87	(11)	32.85	21.34	41.90	(11)

Table C-70

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	15.89	0.00	40.83	42.06	18.54	71.04	(9)	45.91	18.54	62.53	(9)
PULL	37.95	23.23	62.72	58.60	41.22	79.12	(9)	63.99	52.35	78.07	(9)
UP	13.80	5.60	21.69	22.98	10.21	34.45	(9)	27.01	15.43	37.05	(9)
DOWN	15.10	7.10	24.40	24.88	10.58	37.38	(9)	29.43	19.11	39.77	(9)
RIGHT	13.93	7.03	20.82	20.48	9.73	24.72	(8)	20.02	12.27	26.50	(9)
LEFT	17.18	10.59	29.29	24.22	16.30	38.93	(9)	23.16	16.30	33.53	(9)

Table C-71

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	-15 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	32.31	17.95	50.39	50.39	27.98	65.27	(10)	59.93	39.57	83.83	(10)
PULL	32.46	5.82	56.01	60.01	39.79	76.73	(10)	66.47	4.08	108.14	(10)
UP	20.79	0.00	38.64	39.62	23.39	54.49	(10)	35.18	27.79	46.06	(10)
DOWN	31.32	16.98	56.01	39.55	18.78	59.63	(10)	40.29	25.45	55.42	(10)
RIGHT	12.13	4.10	15.90	22.37	17.17	37.48	(10)	20.91	16.91	26.05	(9)
LEFT	23.33	8.81	41.98	35.84	13.18	64.44	(10)	34.32	18.34	54.56	(10)

Table C-72

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.02	0.00	0.18	21.63	1.73	50.69	(8)	27.93	19.52	47.17	(8)
PULL	0.80	0.00	6.39	19.46	6.17	36.03	(8)	30.43	11.42	46.55	(8)
UP	0.53	0.00	3.21	15.30	8.26	21.08	(7)	14.13	8.11	22.18	(8)
DOWN	2.80	0.00	21.76	16.10	8.14	35.42	(8)	19.10	3.40	45.79	(8)
RIGHT	0.25	0.00	1.97	13.60	10.05	18.03	(8)	22.00	10.05	36.48	(8)
LEFT	0.00	0.00	0.00	14.59	8.01	24.69	(8)	17.43	4.41	23.86	(8)

Table C-73

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.19	0.00	3.55	24.66	14.47	41.11	(8)	43.91	2.70	85.24	(8)
PULL	0.74	0.00	4.45	25.23	12.32	39.02	(6)	47.12	31.92	60.73	(8)
UP	6.47	2.70	12.66	15.34	9.81	19.98	(6)	20.23	4.27	35.19	(7)
DOWN	7.20	0.00	18.03	17.15	4.55	23.17	(6)	21.78	4.12	33.70	(6)
RIGHT	14.98	5.74	30.01	25.74	12.52	39.25	(8)	27.95	17.20	49.64	(8)
LEFT	19.75	9.76	28.96	30.67	20.01	45.70	(8)	34.77	26.32	48.68	(8)

Table C-74

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	42.06	17.08	75.00	62.02	36.52	88.51	(10)	62.47	39.99	92.80	(10)
PULL	25.57	12.83	44.80	40.13	29.89	51.70	(10)	38.35	29.75	58.87	(10)
UP	16.90	10.57	25.95	23.80	12.45	32.48	(10)	24.76	14.83	37.72	(10)
DOWN	15.99	4.82	29.52	22.88	11.97	36.69	(10)	25.42	10.79	34.27	(10)
RIGHT	20.56	7.57	41.20	31.17	16.85	55.80	(10)	33.92	14.55	58.78	(10)
LEFT	18.28	11.09	30.93	26.91	17.37	40.41	(10)	28.68	16.20	43.60	(10)

Table C-75

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	17.44	0.00	32.14	36.95	25.65	50.69	(12)	47.97	19.94	66.01	(12)
PULL	12.20	3.93	26.67	27.30	13.51	39.16	(12)	36.95	18.68	49.32	(10)
UP	12.08	0.00	19.56	20.20	3.15	28.23	(11)	22.92	6.67	30.46	(11)
DOWN	8.49	0.00	18.24	17.18	8.80	32.72	(12)	22.56	13.58	39.31	(12)
RIGHT	17.33	4.69	36.99	28.49	15.83	45.76	(12)	28.95	13.87	48.49	(12)
LEFT	11.78	0.60	27.57	22.85	10.67	35.48	(11)	21.34	1.36	43.38	(12)

Table C-76

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	4.57	0.00	14.38	25.55	12.58	36.19	(9)	49.95	24.85	75.86	(10)
PULL	2.39	0.00	8.93	23.63	2.79	48.73	(9)	48.41	12.18	77.07	(10)
UP	20.61	0.00	61.83	29.66	2.87	71.09	(10)	28.54	7.55	64.97	(10)
DOWN	13.51	0.00	31.75	24.18	4.64	36.81	(10)	24.98	3.85	39.13	(10)
RIGHT	11.41	1.13	21.57	23.23	14.28	35.61	(10)	28.70	17.95	44.86	(10)
LEFT	9.43	5.12	19.16	20.02	13.65	28.64	(10)	24.14	8.62	34.32	(10)

Table C-77

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	50.37	31.96	64.43	75.97	39.58	92.40	(10)	76.09	50.12	90.58	(10)
PULL	28.85	0.00	48.33	48.70	30.85	81.58	(10)	51.58	22.67	66.93	(10)
UP	17.11	6.89	24.95	25.66	9.11	46.87	(9)	24.60	9.36	42.59	(9)
DOWN	18.86	7.37	31.39	27.54	11.54	40.89	(10)	26.76	10.94	39.35	(9)
RIGHT	20.59	3.85	38.58	36.17	24.28	49.87	(11)	36.76	25.51	46.78	(9)
LEFT	16.09	1.38	29.33	32.83	20.97	45.45	(9)	28.91	12.30	47.12	(10)

Table C-78

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	39.64	20.22	56.09	57.40	36.75	72.80	(6)	68.00	50.17	87.40	(7)
PULL	22.26	0.00	41.06	39.62	8.12	56.77	(8)	42.33	17.47	61.91	(8)
UP	16.04	2.04	24.52	23.86	4.88	36.05	(9)	22.80	8.55	32.62	(9)
DOWN	16.95	4.49	30.95	22.47	9.06	31.70	(9)	27.29	11.97	48.32	(9)
RIGHT	20.45	11.17	27.17	30.59	18.12	45.16	(8)	32.10	17.63	43.04	(8)
LEFT	22.20	13.82	34.87	33.53	22.82	51.93	(8)	35.85	27.16	51.08	(8)

Table C-79

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.48	0.00	45.93	56.51	39.68	74.77	(10)	66.29	46.45	75.80	(10)
PULL	30.40	0.00	46.17	56.69	32.96	88.43	(10)	52.99	3.94	88.86	(10)
UP	17.04	6.58	36.38	26.72	11.68	44.74	(9)	26.10	12.34	42.27	(9)
DOWN	20.72	0.00	38.21	32.17	17.22	43.45	(9)	33.37	13.67	46.87	(9)
RIGHT	21.18	7.79	44.12	35.44	14.04	59.00	(10)	34.25	19.87	55.30	(10)
LEFT	20.71	2.66	40.94	36.36	19.50	55.32	(10)	36.79	22.79	54.02	(10)

Table C-80

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.12	0.00	1.09	22.34	8.64	36.12	(9)	31.49	13.75	64.36	(9)
PULL	0.00	0.00	0.00	22.85	13.07	44.20	(9)	40.44	24.42	57.06	(9)
UP	0.13	0.00	1.20	16.27	12.42	20.43	(9)	18.98	13.96	23.24	(9)
DOWN	0.82	0.00	2.25	14.02	7.68	19.89	(8)	20.14	10.62	35.89	(9)
RIGHT	0.05	0.00	0.49	10.89	2.50	14.35	(9)	14.79	11.70	22.30	(8)
LEFT	0.00	0.00	0.00	13.72	7.46	19.55	(9)	17.76	12.00	25.39	(9)

Table C-81

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.32	0.00	1.70	28.19	10.27	53.41	(9)	49.99	21.51	82.54	(9)
PULL	0.29	0.00	2.59	22.91	5.40	44.45	(9)	42.85	17.91	77.05	(9)
UP	3.26	0.00	8.72	15.87	4.45	26.91	(9)	22.31	14.04	31.08	(9)
DOWN	10.39	0.32	23.03	22.34	13.80	35.31	(9)	31.27	20.15	48.50	(9)
RIGHT	12.36	6.29	17.71	19.76	11.16	29.39	(9)	21.62	13.25	31.29	(9)
LEFT	15.29	8.09	22.64	27.87	12.78	54.42	(8)	28.79	14.40	52.28	(9)

Table C-82

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	39.30	21.44	57.45	57.52	27.62	79.87	(8)	63.72	39.97	87.26	(8)
PULL	26.47	13.03	48.98	45.59	29.34	60.27	(8)	47.36	35.74	59.65	(8)
UP	26.21	19.01	34.98	36.27	26.46	54.26	(8)	37.59	31.29	48.50	(8)
DOWN	28.46	20.60	37.45	34.78	26.06	44.37	(8)	37.46	28.41	41.89	(8)
RIGHT	9.12	0.00	17.75	17.59	12.57	25.85	(8)	16.50	5.57	24.37	(8)
LEFT	18.06	9.93	23.96	28.08	14.14	50.08	(8)	30.67	13.72	46.71	(8)

Table C-83

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	20.89	9.51	34.84	40.86	35.08	47.82	(10)	46.98	30.91	60.54	(10)
PULL	14.21	0.98	19.29	33.51	23.93	45.81	(10)	38.25	28.52	54.84	(10)
UP	12.81	0.48	25.97	24.89	15.13	39.07	(10)	30.93	20.31	42.73	(10)
DOWN	13.16	0.00	21.06	23.58	19.17	30.52	(10)	26.78	12.81	33.73	(10)
RIGHT	9.89	1.92	15.76	17.03	11.93	20.64	(10)	18.34	11.52	22.58	(10)
LEFT	12.31	0.00	24.33	27.59	7.02	48.01	(10)	26.84	5.74	38.97	(10)

Table C-84

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	2.61	0.00	20.43	23.03	16.09	30.40	(10)	44.38	29.37	60.82	(10)
PULL	1.73	0.00	8.36	22.04	10.85	27.08	(8)	52.16	18.98	79.49	(10)
UP	21.63	4.08	35.68	34.21	22.36	50.38	(10)	32.43	23.09	52.35	(8)
DOWN	18.89	4.24	40.67	30.14	16.98	43.03	(11)	36.45	18.52	48.81	(10)
RIGHT	8.95	0.00	17.76	18.28	10.25	25.81	(10)	19.75	11.29	26.40	(10)
LEFT	10.36	0.00	15.64	19.15	3.07	30.31	(10)	20.23	6.44	33.99	(10)

Table C-85

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND, WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	34.99	0.58	48.54	54.23	9.84	72.99	(8)	54.50	9.97	73.16	(8)
PULL	24.79	1.76	38.95	42.96	23.31	58.20	(8)	44.57	27.45	59.08	(9)
UP	22.22	1.54	44.67	34.11	10.51	57.85	(9)	34.51	15.07	57.62	(10)
DOWN	27.61	10.78	42.60	34.06	18.38	46.06	(9)	34.75	15.76	53.64	(8)
RIGHT	11.13	0.00	18.55	19.65	12.70	26.78	(9)	19.43	7.60	27.87	(8)
LEFT	21.38	1.36	38.98	33.78	12.48	58.44	(9)	33.20	14.01	57.42	(8)

Table C-86

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	33.34	2.79	56.23	50.38	10.94	64.63	(9)	56.08	13.15	76.40	(9)
PULL	18.91	0.00	49.87	34.64	8.40	58.82	(9)	35.93	11.47	57.28	(8)
UP	18.97	1.64	32.67	27.23	6.54	43.39	(10)	28.47	7.64	41.75	(10)
DOWN	18.77	10.36	35.30	25.42	11.46	37.25	(9)	32.10	10.95	42.29	(10)
RIGHT	12.97	3.27	22.83	21.09	13.90	29.22	(11)	21.29	11.1[illegible]	33.78	(11)
LEFT	18.55	8.90	26.80	29.24	14.00	43.90	(10)	27.95	17.[illegible]2	41.53	(11)

Table C-87

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE NEAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	31.35	17.65	40.15	56.15	43.14	79.09	(8)	63.61	38.72	89.84	(8)
PULL	42.67	26.05	55.57	58.96	33.79	88.71	(8)	62.06	38.48	81.03	(8)
UP	23.10	3.01	38.05	39.65	18.07	56.77	(8)	39.25	12.16	52.00	(8)
DOWN	29.73	18.26	44.58	37.55	26.22	54.17	(8)	39.08	29.83	50.97	(8)
RIGHT	12.35	6.20	17.80	25.95	13.02	34.03	(7)	23.19	13.53	27.01	(7)
LEFT	18.03	5.45	28.63	33.98	13.67	50.87	(7)	34.52	15.53	47.59	(7)

Table C-88

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	21.06	9.73	33.97	(11)	35.26	21.19	47.68	(11)
PULL	0.00	0.00	0.00	25.10	6.45	43.76	(11)	39.63	16.08	70.83	(11)
UP	0.88	0.00	3.46	15.29	10.33	22.17	(11)	23.42	14.65	49.84	(11)
DOWN	0.00	0.00	0.00	8.69	0.22	15.59	(11)	20.10	10.40	28.34	(11)
RIGHT	0.00	0.00	0.00	15.94	4.32	33.31	(11)	24.31	12.52	40.39	(10)
LEFT	0.00	0.00	0.00	13.76	5.59	26.34	(10)	19.70	10.75	31.32	(11)

Table C-89

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.31	0.00	5.25	22.61	11.78	37.07	(8)	44.87	21.66	80.36	(9)
PULL	0.26	0.00	2.31	23.23	11.94	40.27	(9)	41.04	23.80	62.21	(9)
UP	7.22	0.00	15.62	19.30	8.53	30.65	(8)	22.40	7.84	34.64	(9)
DOWN	4.47	0.00	14.23	13.39	2.27	23.56	(9)	19.77	6.39	31.27	(9)
RIGHT	14.50	5.47	34.96	23.52	11.04	40.02	(9)	27.75	14.56	52.79	(9)
LEFT	17.78	8.28	22.95	30.80	14.67	48.25	(9)	31.75	19.78	39.45	(9)

Table C-90

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	39.98	0.00	67.61	66.52	32.56	88.70	(9)	65.96	34.85	87.40	(9)
PULL	34.19	20.70	54.27	54.37	36.83	68.91	(9)	53.32	31.14	74.77	(9)
UP	15.05	8.53	22.14	22.29	12.10	32.42	(9)	22.60	10.31	29.30	(8)
DOWN	15.39	0.00	29.00	24.84	12.20	35.22	(9)	29.01	23.09	34.87	(8)
RIGHT	21.23	9.14	29.61	32.24	14.90	48.65	(9)	30.54	18.73	46.71	(8)
LEFT	17.37	8.22	29.22	27.07	21.55	38.90	(9)	25.29	10.81	38.06	(9)

Table C-91

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	15.49	5.85	28.88	31.13	16.01	47.69	(9)	39.97	25.93	60.27	(9)
PULL	20.48	9.49	32.29	33.18	19.28	53.37	(9)	40.50	29.44	55.89	(9)
UP	9.42	1.60	14.99	16.44	5.78	21.05	(9)	18.59	5.95	25.44	(9)
DOWN	6.56	0.00	11.01	14.75	8.91	22.95	(8)	18.76	12.14	27.28	(8)
RIGHT	16.90	5.54	25.56	29.45	11.95	45.33	(8)	26.95	18.10	40.95	(10)
LEFT	10.06	0.00	26.30	20.59	13.48	32.67	(9)	19.43	12.88	32.49	(9)

Table C-92

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	4.39	0.00	16.69	26.03	11.45	48.05	(9)	47.75	21.29	70.27	(9)
PULL	1.40	0.00	6.28	23.64	3.06	34.96	(9)	44.88	25.13	74.94	(9)
UP	7.58	0.00	17.71	12.82	0.96	25.42	(8)	11.89	1.80	29.54	(8)
DOWN	22.95	5.34	44.36	28.48	7.46	49.38	(9)	32.19	6.58	53.97	(9)
RIGHT	8.70	1.10	18.17	22.35	10.53	35.99	(9)	26.94	15.24	38.97	(9)
LEFT	9.42	1.41	15.27	17.66	8.62	30.12	(9)	22.29	8.46	35.55	(9)

Table C-93

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND, WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	38.24	0.31	57.74	66.78	48.69	92.54	(10)	72.70	65.53	91.98	(10)
PULL	34.59	1.76	52.49	58.64	43.07	85.37	(9)	55.02	20.12	76.27	(10)
UP	14.67	2.79	25.61	24.36	9.02	35.64	(11)	24.45	9.45	34.28	(11)
DOWN	16.81	1.36	28.13	27.91	14.95	40.81	(11)	27.88	15.29	40.79	(11)
RIGHT	19.70	0.10	33.13	35.39	19.65	52.30	(11)	32.68	16.96	54.58	(11)
LEFT	18.94	1.47	36.56	28.50	11.62	49.39	(11)	27.29	11.37	41.02	(11)

Table C-94

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	27.65	9.81	42.55	44.62	24.05	61.84	(10)	50.35	25.66	65.58	(10)
PULL	26.52	10.65	45.29	41.59	26.23	65.51	(9)	45.42	31.32	61.55	(9)
UP	13.89	9.36	19.10	20.62	12.26	25.50	(9)	23.65	15.82	32.15	(8)
DOWN	17.57	7.97	36.05	22.95	14.50	37.92	(10)	27.81	16.43	47.37	(10)
RIGHT	18.56	1.13	30.90	29.27	17.18	44.30	(10)	31.17	17.03	48.47	(10)
LEFT	17.01	0.00	32.16	31.69	20.72	51.17	(10)	32.77	20.23	56.68	(10)

Table C-95

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	29.07	0.83	46.01	53.06	35.33	78.73	(10)	64.70	47.97	77.38	(10)
PULL	36.14	24.54	52.40	54.67	32.82	83.02	(10)	59.26	33.37	88.71	(10)
UP	16.00	9.15	30.57	25.90	16.99	36.57	(9)	26.89	16.31	36.20	(9)
DOWN	21.34	0.00	38.87	27.48	13.19	49.43	(9)	25.38	0.73	46.95	(9)
RIGHT	18.81	9.72	35.67	37.35	24.15	54.73	(10)	34.18	20.11	52.94	(10)
LEFT	18.32	0.00	26.97	34.94	20.77	49.87	(10)	30.50	10.96	43.70	(10)

Table C-96

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	0.00	0.00	0.00	21.65	2.60	45.16	(9)	28.30	1.29	44.47	(9)
PULL	1.16	0.00	6.39	27.33	13.98	38.23	(9)	44.12	24.39	74.09	(9)
UP	0.65	0.00	5.84	17.08	6.40	26.10	(9)	22.59	10.98	31.96	(9)
DOWN	0.40	0.00	1.78	15.21	4.47	26.92	(9)	23.29	4.42	37.66	(8)
RIGHT	0.18	0.00	1.59	11.42	6.66	13.87	(9)	15.42	11.20	22.70	(9)
LEFT	0.00	0.00	0.00	10.64	2.81	22.57	(8)	16.27	8.15	26.67	(9)

Table C-97

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	24.76	1.16	42.33	(9)	45.11	19.46	78.19	(10)
PULL	0.59	0.00	4.69	23.90	6.16	43.63	(8)	48.51	21.82	74.15	(11)
UP	3.59	0.00	8.30	18.25	11.24	27.74	(10)	22.65	12.19	39.08	(9)
DOWN	11.16	0.00	25.02	19.87	5.39	30.91	(9)	31.53	12.71	53.10	(9)
RIGHT	8.93	0.00	17.13	18.22	8.92	27.49	(11)	20.85	10.74	28.65	(9)
LEFT	14.44	2.08	26.21	32.75	14.02	57.50	(10)	33.73	15.47	56.65	(10)

Table C-98

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	36.48	16.79	58.73	56.95	34.13	78.28	(8)	57.69	34.85	78.18	(8)
PULL	35.72	7.46	46.97	55.04	39.61	60.85	(8)	54.00	35.58	73.85	(8)
UP	20.80	0.86	33.98	33.53	22.56	47.43	(8)	33.99	23.79	45.48	(8)
DOWN	25.72	11.52	43.27	32.43	22.95	54.33	(8)	38.40	29.06	54.33	(8)
RIGHT	10.34	0.14	15.56	17.25	6.41	23.05	(8)	17.73	10.68	24.58	(8)
LEFT	11.31	0.00	17.01	27.09	18.39	43.25	(7)	30.09	20.04	38.48	(7)

Table C-99

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	11.54	4.13	20.28	33.21	20.69	45.85	(10)	37.65	3.77	56.42	(10)
PULL	18.47	8.72	41.29	36.38	18.57	51.65	(10)	45.12	26.51	60.35	(10)
UP	7.30	0.00	14.65	18.76	10.75	25.60	(10)	21.72	11.17	29.14	(10)
DOWN	10.61	1.48	24.69	18.42	10.58	32.93	(10)	23.49	12.14	38.85	(10)
RIGHT	10.19	0.25	21.78	16.56	3.93	27.33	(10)	17.24	3.16	29.09	(10)
LEFT	12.13	0.00	24.64	20.35	3.23	37.23	(10)	20.93	3.57	36.50	(9)

Table C-100

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.87	0.00	18.24	22.97	11.17	32.87	(10)	39.35	20.13	54.25	(10)
PULL	2.74	0.00	7.51	30.48	13.18	52.67	(9)	51.44	19.87	79.35	(10)
UP	18.67	6.45	31.75	32.25	19.84	49.97	(10)	34.61	21.02	49.28	(10)
DOWN	19.63	0.00	32.97	32.01	17.15	49.11	(10)	33.42	19.21	45.44	(9)
RIGHT	7.91	2.56	18.68	16.50	10.51	21.45	(10)	17.51	8.63	25.14	(10)
LEFT	9.98	0.00	17.77	19.22	1.72	30.90	(10)	21.72	5.50	33.01	(10)

Table C-101

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	41.33	28.76	54.69	69.09	48.65	92.26	(8)	63.79	48.09	74.84	(8)
PULL	27.93	13.25	44.88	57.50	36.15	91.83	(8)	56.88	34.60	84.95	(8)
UP	18.98	5.74	38.82	35.93	15.49	54.82	(8)	36.43	18.56	52.22	(8)
DOWN	25.18	10.61	43.51	32.73	19.02	51.18	(8)	31.80	19.40	47.64	(8)
RIGHT	10.83	0.00	18.02	21.84	11.02	27.78	(8)	22.48	19.77	25.09	(7)
LEFT	19.15	4.38	36.96	32.53	12.66	48.43	(8)	33.12	13.33	47.10	(8)

Table C-102

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	32.43	1.42	54.65	51.80	21.76	67.46	(9)	57.88	21.00	68.12	(8)
PULL	37.06	21.92	51.32	53.09	43.25	65.25	(7)	48.82	29.49	66.78	(8)
UP	17.55	9.34	27.48	27.38	17.92	35.90	(8)	29.91	22.63	37.42	(8)
DOWN	16.33	8.34	30.42	23.61	9.31	31.27	(8)	30.05	15.67	42.47	(8)
RIGHT	14.19	8.32	27.09	20.42	13.82	30.43	(8)	20.83	13.60	33.52	(8)
LEFT	16.87	4.31	23.76	24.09	14.00	30.98	(8)	24.98	13.17	34.84	(8)

Table C-103

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	28.86	2.65	48.98	54.92	36.92	79.56	(8)	62.63	37.89	82.98	(8)
PULL	31.53	1.25	59.15	53.25	29.92	80.54	(8)	67.85	32.27	94.98	(8)
UP	15.95	0.00	30.03	35.76	25.61	46.70	(9)	34.38	21.93	44.48	(8)
DOWN	24.31	0.00	54.13	38.29	26.61	58.49	(9)	38.95	28.45	54.51	(9)
RIGHT	9.62	2.25	17.23	22.77	11.16	34.66	(8)	21.46	5.97	40.09	(11)
LEFT	22.38	0.00	58.82	37.04	13.00	76.46	(9)	35.56	13.84	93.68	(8)

Table C-104

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	24.35	8.64	33.92	(9)	41.50	22.73	70.60	(10)
PULL	0.00	0.00	0.00	24.74	6.8[illegible]	38.[illegible]	(10)	43.16	20.40	63.30	(10)
UP	0.64	0.00	6.21	14.15	5.73	21.[illegible]	(10)	18.11	10.41	23.58	(10)
DOWN	1.07	0.00	10.74	10.97	2.29	18.93	(10)	17.99	10.30	22.84	(10)
RIGHT	0.00	0.00	0.00	16.24	0.63	26.18	(10)	22.67	10.24	36.88	(10)
LEFT	0.00	0.00	0.00	15.64	5.62	23.69	(10)	18.48	12.30	21.29	(10)

Table C-105

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	0.05	0.00	0.47	23.17	3.88	53.41	(10)	49.45	17.59	81.85	(10)
PULL	1.33	0.00	3.34	24.49	11.83	40.83	(10)	46.47	18.60	74.87	(10)
UP	3.97	0.00	14.23	14.44	2.37	22.85	(10)	17.15	5.78	27.48	(10)
DOWN	7.49	0.00	19.51	19.60	8.18	36.33	(9)	25.74	8.94	39.65	(9)
RIGHT	11.54	0.00	21.74	27.48	13.02	43.42	(10)	29.79	11.68	49.89	(10)
LEFT	21.57	10.43	37.85	32.41	18.51	46.67	(10)	30.91	20.32	43.26	(10)

Table C-106

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	31.07	8.74	60.55	46.42	28.07	81.13	(9)	48.53	33.79	79.18	(8)
PULL	43.16	29.39	59.17	59.27	42.33	79.16	(9)	55.51	37.58	111.95	(9)
UP	13.03	8.85	17.48	24.94	15.00	46.69	(7)	20.91	14.45	23.91	(6)
DOWN	15.27	2.03	37.90	22.53	9.81	41.19	(9)	30.85	11.44	53.97	(9)
RIGHT	21.24	9.58	32.62	31.94	15.16	47.09	(9)	33.66	15.24	50.40	(8)
LEFT	17.59	11.25	23.85	25.78	17.22	37.12	(9)	27.95	21.81	32.56	(8)

Table C-107

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	7.09	0.00	25.36	23.67	5.40	40.92	(9)	38.13	20.73	52.48	(9)
PULL	28.82	6.80	47.10	47.83	20.35	67.16	(9)	52.57	27.05	69.89	(9)
UP	10.80	6.42	16.65	18.68	13.92	24.51	(7)	17.13	1.47	26.39	(8)
DOWN	9.70	0.00	21.62	16.15	10.10	30.47	(8)	18.61	5.21	30.64	(9)
RIGHT	13.82	5.47	21.90	22.38	13.39	37.93	(9)	23.94	14.22	37.51	(9)
LEFT	9.90	0.00	23.21	22.81	14.60	38.19	(8)	21.22	10.67	31.94	(8)

Table C-108

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	4.18	0.00	17.69	30.15	11.64	51.78	(10)	43.19	13.66	61.24	(9)
PULL	3.97	0.00	13.44	22.64	1.56	46.38	(10)	43.97	20.08	61.63	(11)
UP	13.96	0.00	36.15	20.28	1.80	41.30	(10)	19.81	0.21	46.72	(11)
DOWN	17.92	0.00	43.14	23.36	1.84	47.56	(11)	24.10	3.48	48.77	(11)
RIGHT	12.18	0.25	29.53	21.36	12.87	32.09	(11)	22.80	13.50	32.04	(11)
LEFT	10.69	3.74	20.61	19.26	7.65	35.21	(11)	23.44	7.65	43.78	(10)

Table C-109

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	38.78	22.61	45.97	71.67	57.21	98.75	(9)	72.16	53.52	97.37	(9)
PULL	45.83	31.33	66.06	70.59	57.69	82.91	(9)	72.34	59.58	83.06	(9)
UP	13.00	4.24	19.06	20.84	9.02	29.15	(8)	21.39	3.41	32.93	(9)
DOWN	19.92	9.36	43.36	26.21	12.95	54.07	(9)	30.31	13.84	60.35	(9)
RIGHT	25.82	15.17	32.08	37.06	28.35	47.83	(9)	36.50	30.63	45.24	(9)
LEFT	22.98	6.74	34.64	31.41	23.73	41.10	(9)	31.17	10.45	48.12	(9)

Table C-110

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.22	14.57	38.11	44.18	29.84	51.83	(7)	55.56	48.34	68.42	(7)
PULL	40.22	26.63	49.11	58.39	46.51	72.30	(7)	50.64	17.47	68.48	(8)
UP	13.28	9.92	20.24	19.55	13.84	28.28	(8)	20.28	14.94	25.65	(8)
DOWN	9.65	2.01	18.95	15.65	5.40	23.16	(8)	19.93	10.64	29.24	(8)
RIGHT	17.58	10.94	26.14	29.65	23.92	44.06	(8)	27.61	19.98	37.69	(7)
LEFT	22.31	17.36	33.17	31.80	25.61	47.77	(8)	32.29	23.78	49.22	(8)

Table C-111

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	30.77	15.27	42.97	57.13	44.84	76.88	(11)	66.36	44.61	79.72	(11)
PULL	47.08	34.99	64.74	67.75	51.95	79.05	(11)	73.08	59.74	89.43	(11)
UP	14.42	0.00	26.40	24.17	1.70	36.70	(11)	26.05	2.03	35.57	(10)
DOWN	20.96	6.65	39.13	31.76	21.59	45.93	(11)	36.84	25.73	56.11	(11)
RIGHT	24.34	7.65	45.37	40.74	28.52	60.72	(11)	40.78	26.43	63.56	(11)
LEFT	24.72	0.14	39.29	40.63	25.51	51.25	(11)	40.93	30.34	51.15	(12)

Table C-112

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	24.08	4.72	34.14	(11)	36.37	20.49	55.81	(11)
PULL	0.00	0.00	0.00	26.13	11.47	49.57	(11)	46.69	15.81	72.11	(11)
UP	0.59	0.00	6.50	16.12	7.37	20.17	(11)	18.79	10.05	23.82	(11)
DOWN	0.66	0.00	5.70	14.82	7.17	21.80	(11)	22.94	8.68	37.31	(11)
RIGHT	0.01	0.00	0.07	11.23	8.04	16.52	(10)	13.68	0.02	18.23	(11)
LEFT	0.00	0.00	0.00	11.99	3.35	24.81	(11)	19.04	9.85	25.14	(10)

Table C-113

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.02	0.00	0.18	25.49	6.89	55.55	(10)	38.96	2.96	69.09	(10)
PULL	1.03	0.00	3.85	26.11	12.80	40.03	(10)	47.44	27.30	60.79	(10)
UP	6.18	0.00	15.18	20.30	14.39	35.59	(10)	24.80	16.46	35.21	(10)
DOWN	11.27	0.00	22.92	22.02	13.81	34.45	(10)	26.57	11.69	46.70	(10)
RIGHT	11.08	7.59	16.76	17.58	11.41	22.77	(9)	17.97	14.03	23.18	(9)
LEFT	17.40	3.07	26.42	25.90	10.84	41.03	(10)	28.14	13.80	45.97	(10)

Table C-114

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.17	0.00	44.55	53.71	30.69	86.55	(8)	51.80	33.16	70.55	(8)
PULL	46.05	22.93	68.22	64.23	50.27	79.14	(8)	67.12	52.18	81.38	(8)
UP	21.51	16.43	38.47	30.84	23.37	48.32	(8)	32.23	22.34	48.15	(8)
DOWN	23.58	12.50	34.00	29.16	9.99	47.80	(8)	28.76	10.87	48.67	(8)
RIGHT	9.33	4.38	15.72	14.57	3.66	21.28	(8)	15.04	8.81	19.78	(8)
LEFT	14.27	8.86	25.46	20.28	11.59	33.19	(8)	21.05	11.15	35.13	(8)

Table C-115

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	9.35	0.00	19.33	25.76	11.06	33.64	(8)	38.47	16.50	58.61	(8)
PULL	25.16	6.66	39.02	48.90	24.73	62.86	(8)	52.15	30.20	72.89	(8)
UP	8.98	0.00	17.38	16.78	5.09	24.78	(8)	22.40	9.31	27.76	(8)
DOWN	6.22	1.26	12.14	16.69	9.98	21.42	(8)	20.56	14.06	28.21	(8)
RIGHT	10.49	0.00	15.74	17.35	11.87	24.72	(8)	19.08	14.48	26.23	(8)
LEFT	8.14	0.00	18.91	15.59	2.23	25.84	(8)	19.28	3.23	29.18	(7)

Table C-116

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	2.16	0.00	13.01	17.87	9.52	32.05	(8)	36.97	15.75	51.76	(8)
PULL	0.31	0.00	1.87	21.73	2.52	38.12	(8)	46.54	29.77	67.91	(8)
UP	17.94	9.66	27.08	29.99	22.41	38.28	(8)	26.06	20.09	31.78	(8)
DOWN	22.31	10.90	42.06	30.52	22.62	48.81	(8)	32.34	19.75	51.12	(8)
RIGHT	8.45	2.86	15.90	15.05	9.77	18.97	(8)	16.34	8.60	26.01	(8)
LEFT	5.32	0.00	10.86	15.47	2.31	20.49	(8)	18.37	8.90	28.27	(7)

Table C-117

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM					MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	30.28	6.55	65.45	63.22	32.39	97.52	(9)	60.09	42.57	92.13	(9)
PULL	34.31	0.00	53.73	55.31	1.92	86.75	(9)	62.04	44.03	80.39	(9)
UP	15.04	3.86	24.77	27.05	18.28	43.43	(9)	28.47	21.41	39.92	(9)
DOWN	17.54	0.47	30.83	27.54	17.59	35.11	(9)	32.26	21.46	49.57	(9)
RIGHT	9.46	2.88	14.07	16.71	8.85	20.74	(9)	16.92	10.09	21.88	(9)
LEFT	19.54	7.12	32.93	30.57	18.30	48.28	(9)	30.22	18.47	45.23	(9)

Table C-118

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 0 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM					MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	29.48	13.42	52.78	42.73	27.55	68.47	(7)	48.39	15.19	71.66	(8)
PULL	31.00	0.00	53.09	51.10	13.14	88.51	(8)	54.21	4.63	82.19	(8)
UP	10.95	0.00	17.61	21.72	14.11	27.90	(8)	24.20	16.50	31.51	(8)
DOWN	20.31	5.86	34.27	26.50	9.27	36.42	(7)	30.50	21.14	38.82	(8)
RIGHT	8.53	0.00	14.28	19.37	3.11	24.52	(9)	16.28	8.82	27.76	(8)
LEFT	16.49	0.00	30.98	26.89	12.33	37.74	(9)	28.09	14.00	38.23	(9)

Table C-119

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	0 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	27.08	0.00	37.23	48.91	14.20	71.52	(10)	61.81	41.99	86.61	(10)
PULL	34.03	13.75	57.29	57.44	42.79	76.92	(10)	64.59	48.36	76.84	(10)
UP	17.66	1.95	28.47	35.45	22.98	55.79	(9)	34.33	0.08	53.38	(10)
DOWN	26.72	0.00	49.18	40.70	19.29	59.42	(10)	41.89	31.00	56.48	(10)
RIGHT	10.68	0.00	16.22	21.51	16.98	29.10	(9)	20.70	17.45	25.36	(8)
LEFT	16.06	0.00	39.90	36.44	21.28	54.63	(9)	37.49	17.92	73.42	(9)

Table C-120

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	25.75	13.12	53.78	(8)	38.70	27.24	55.62	(8)
PULL	0.00	0.00	0.00	30.88	8.21	55.36	(8)	45.28	26.99	64.77	(8)
UP	0.51	C.00	2.02	15.33	9.63	20.28	(7)	18.51	15.09	24.13	(7)
DOWN	1.99	0.00	15.06	10.45	0.81	34.06	(8)	16.73	0.10	38.00	(8)
RIGHT	1.03	0.00	4.56	13.17	5.58	20.67	(8)	18.55	8.76	32.07	(8)
LEFT	0.00	0.00	0.00	11.56	5.53	27.32	(7)	13.24	2.56	27.28	(7)

Table C-121

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	17.58	3.69	34.71	(10)	36.02	17.16	59.73	(10)
PULL	2.39	0.00	7.20	23.84	18.03	32.44	(10)	42.56	16.60	82.58	(10)
UP	4.27	0.00	14.50	17.57	8.45	21.81	(9)	20.68	8.45	30.42	(9)
DOWN	2.65	0.00	20.61	12.59	1.48	47.49	(9)	21.87	8.01	40.89	(10)
RIGHT	11.55	0.00	20.86	20.35	3.28	36.42	(11)	26.87	15.54	55.64	(9)
LEFT	12.70	0.00	31.63	23.77	2.05	40.58	(10)	28.52	16.75	43.67	(10)

Table C-122

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	49.13	11.71	102.67	75.31	52.08	109.51	(9)	76.88	54.36	106.89	(9)
PULL	27.33	16.62	40.69	53.13	22.58	74.91	(9)	54.14	31.54	70.04	(9)
UP	18.50	12.75	34.27	24.91	17.56	44.76	(9)	25.64	18.54	44.16	(9)
DOWN	16.00	0.00	26.20	24.51	10.90	38.52	(9)	28.03	15.94	34.97	(9)
RIGHT	13.67	3.79	27.90	22.01	11.49	39.69	(9)	25.83	13.24	43.48	(9)
LEFT	17.04	5.08	23.46	30.69	22.09	44.34	(9)	25.73	12.05	35.38	(9)

Table C-123

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	28.50	9.01	60.02	45.21	15.79	88.26	(8)	49.84	6.36	80.52	(8)
PULL	19.65	0.00	43.97	33.78	13.04	59.45	(8)	41.76	25.08	70.99	(8)
UP	10.48	0.00	15.91	18.64	0.54	27.40	(8)	17.90	0.34	27.27	(8)
DOWN	11.51	3.31	27.37	19.62	3.74	41.88	(8)	22.98	4.76	53.44	(8)
RIGHT	16.43	0.52	38.56	27.52	6.71	54.00	(8)	29.68	8.46	57.36	(8)
LEFT	10.31	0.00	26.04	21.05	12.11	33.18	(8)	23.68	12.20	40.58	(8)

Table C-124

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	4.34	0.00	13.59	28.21	17.53	44.07	(8)	42.21	22.17	75.15	(8)
PULL	8.73	0.00	16.19	35.25	19.07	79.43	(8)	42.72	27.01	82.85	(8)
UP	12.44	0.00	34.42	30.61	4.82	56.45	(7)	24.23	2.68	52.00	(7)
DOWN	20.57	0.00	31.83	29.51	23.69	38.46	(8)	33.82	27.18	43.23	(8)
RIGHT	12.84	2.13	23.86	23.23	10.62	36.57	(8)	25.58	12.23	38.68	(8)
LEFT	4.80	0.00	12.26	14.50	6.96	21.65	(7)	19.13	4.76	27.66	(7)

Table C-125

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	54.51	10.95	93.89	73.41	37.33	103.74	(8)	77.91	53.02	102.90	(8)
PULL	30.70	0.99	42.30	46.02	24.37	58.75	(8)	47.77	25.65	57.76	(7)
UP	13.14	3.93	18.87	19.19	7.82	27.90	(8)	19.65	9.20	27.59	(7)
DOWN	12.99	7.28	23.55	15.58	8.55	25.02	(8)	19.66	10.42	28.48	(8)
RIGHT	18.36	7.22	32.09	28.00	11.63	50.36	(8)	29.92	14.33	43.15	(8)
LEFT	20.71	13.77	27.70	28.66	19.87	34.99	(8)	27.68	18.04	42.03	(8)

Table C-126

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	45.78	14.40	63.49	61.71	23.78	82.77	(10)	66.14	18.26	91.46	(10)
PULL	21.69	4.69	39.49	37.31	13.96	57.12	(10)	40.42	13.96	58.36	(10)
UP	12.01	0.90	26.61	21.39	11.06	33.87	(9)	18.38	4.01	32.48	(9)
DOWN	18.34	4.07	36.95	24.74	8.09	41.10	(10)	26.76	7.09	52.51	(10)
RIGHT	16.11	0.00	38.82	26.00	9.71	52.37	(10)	30.25	14.29	51.27	(10)
LEFT	17.90	9.34	31.18	27.73	17.88	40.76	(10)	27.45	13.39	40.33	(10)

Table C-127

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	36.90	21.69	67.95	53.11	34.66	79.97	(9)	66.13	24.62	92.06	(9)
PULL	19.11	0.00	40.73	32.05	15.85	55.43	(9)	43.82	28.47	73.37	(9)
UP	11.01	2.20	18.69	16.22	6.79	24.33	(9)	17.40	6.97	28.72	(9)
DOWN	19.50	4.08	38.68	24.86	6.54	43.18	(9)	30.68	11.12	53.20	(9)
RIGHT	13.75	6.88	30.01	21.84	10.80	40.98	(9)	23.48	9.15	39.58	(9)
LEFT	18.12	0.00	28.99	27.53	19.00	38.83	(9)	30.48	18.39	37.64	(9)

Table C-128

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	28.10	14.92	50.34	(9)	32.00	17.87	46.60	(9)
PULL	0.00	0.00	0.00	29.42	17.91	59.06	(9)	44.63	28.85	68.62	(9)
UP	0.00	0.00	0.00	15.78	7.48	26.08	(9)	20.07	14.64	24.40	(9)
DOWN	1.61	0.00	8.56	21.35	8.96	48.66	(9)	25.61	11.51	49.43	(9)
RIGHT	0.00	0.00	0.00	8.48	2.49	18.79	(9)	11.33	3.20	20.88	(9)
LEFT	0.00	0.00	0.00	10.32	2.53	28.72	(9)	15.89	3.36	30.64	(9)

Table C-129

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	16.92	3.20	31.43	(9)	36.19	12.94	48.59	(9)
PULL	3.52	0.00	13.93	26.80	10.04	41.72	(9)	45.69	23.08	82.98	(9)
UP	3.98	0.00	7.62	18.23	14.37	21.61	(9)	23.72	19.37	27.24	(9)
DOWN	6.90	0.00	15.99	16.95	10.56	26.13	(9)	26.22	13.86	41.92	(9)
RIGHT	6.95	0.00	11.39	14.88	6.94	20.84	(9)	16.08	11.10	19.90	(9)
LEFT	18.92	2.60	47.61	27.61	13.88	56.04	(9)	28.38	21.89	55.69	(9)

Table C-130

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	41.40	8.19	62.68	64.30	17.32	107.04	(10)	74.55	56.72	105.73	(8)
PULL	31.98	18.35	56.05	52.36	33.98	64.95	(7)	59.50	46.99	76.51	(8)
UP	17.67	3.96	28.41	[illegible]	13.33	40.88	(9)	34.25	24.60	41.71	(8)
DOWN	23.23	6.26	44.16	34.11	18.32	48.56	(8)	33.82	11.61	51.93	(9)
RIGHT	8.95	0.67	18.61	15.46	7.27	27.21	(8)	16.34	7.12	26.03	(8)
LEFT	19.11	1.72	34.54	30.19	17.43	46.49	(8)	30.12	18.63	43.22	(8)

Table C-131

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	23.36	9.25	38.30	45.75	27.59	75.64	(8)	52.21	17.13	72.63	(8)
PULL	22.84	0.00	49.54	40.74	20.55	69.63	(8)	42.62	20.83	69.63	(8)
UP	11.98	0.00	25.24	24.57	10.43	41.21	(8)	28.23	16.01	47.53	(8)
DOWN	18.21	8.07	29.70	25.07	18.72	40.16	(8)	29.77	13.45	49.37	(8)
RIGHT	6.22	0.00	14.81	12.55	2.48	22.05	(8)	13.19	4.00	20.15	(8)
LEFT	12.57	0.00	21.79	21.32	11.48	33.05	(8)	23.19	9.31	36.34	(8)

Table C-132

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	8.06	0.00	25.77	30.32	19.54	46.41	(10)	50.51	25.63	71.68	(10)
PULL	6.43	0.00	17.11	34.85	23.38	62.66	(10)	41.83	22.54	76.25	(10)
UP	21.37	11.47	36.23	35.17	21.48	52.34	(10)	34.08	21.14	45.87	(10)
DOWN	25.25	12.68	54.71	31.49	18.49	63.28	(10)	34.47	22.98	60.14	(10)
RIGHT	6.39	0.00	20.88	15.90	10.70	27.68	(10)	19.00	12.60	30.59	(10)
LEFT	9.13	0.00	18.54	20.10	7.75	39.53	(10)	26.71	11.22	51.60	(10)

Table C-133

SUBJECT	*
PRESSURIZATION M[illegible]	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND,WAIST [illegible]ND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	53.29	8.75	85.56	76.17	19.10	101.77	(12)	70.21	30.39	95.86	(12)
PULL	30.52	0.00	60.75	53.14	27.59	79.[illegible]0	(12)	51.74	23.29	75.01	(11)
UP	21.82	4.45	30.40	35.38	23.20	[illegible].12	(12)	36.03	19.83	43.11	(12)
DOWN	22.83	6.55	43.66	32.30	19.71	46.68	(11)	33.52	18.47	46.18	(12)
RIGHT	8.70	0.00	12.76	16.78	10.15	22.76	(12)	18.51	2.38	28.70	(12)
LEFT	19.89	8.38	31.97	29.42	14.69	40.35	(12)	28.13	14.76	37.91	(12)

Table C-134

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	37.37	22.08	55.70	58.81	38.01	85.83	(9)	64.23	47.80	84.90	(9)
PULL	27.23	4.62	38.26	43.70	17.60	55.60	(9)	47.89	18.1[illegible]	60.12	(9)
UP	17.37	5.94	28.78	26.55	17.07	35.38	(9)	30.09	20.70	40.05	(9)
DOWN	15.34	5.02	28.09	22.59	11.41	33.65	(9)	25.71	14.86	37.11	(9)
RIGHT	8.06	3.93	13.96	16.08	11.11	22.75	(9)	18.65	13.00	[illegible]7.11	(9)
LEFT	16.70	7.71	27.97	29.38	18.80	41.85	(9)	30.05	17.61	42.64	(9)

Table C-135

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	NEAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	31.75	19.09	52.40	50.91	35.59	72.87	(10)	63.57	37.21	75.78	(10)
PULL	25.92	7.69	39.87	45.98	23.10	59.70	(10)	54.69	29.46	79.09	(10)
UP	25.30	15.76	42.08	38.01	26.57	53.70	(10)	36.50	23.42	49.96	(10)
DOWN	30.37	5.35	51.91	36.07	14.59	54.11	(10)	39.62	24.16	51.99	(10)
RIGHT	13.19	7.07	22.22	24.90	15.18	41.14	(10)	24.61	12.40	37.77	(10)
LEFT	23.06	12.70	48.30	36.93	15.05	63.68	(10)	35.41	18.17	61.50	(10)

Table C-136

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	28.04	15.48	49.46	(11)	41.97	30.83	58.81	(11)
PULL	0.08	0.00	0.90	33.01	8.63	53.95	(11)	47.91	36.90	76.59	(11)
UP	0.47	0.00	3.95	14.78	7.89	21.84	(10)	17.20	7.01	25.10	(10)
DOWN	1.41	0.00	15.49	15.16	4.79	36.51	(11)	22.65	12.40	46.06	(10)
RIGHT	0.25	0.00	2.77	13.55	4.00	22.77	(11)	20.46	6.63	33.15	(11)
LEFT	0.00	0.00	0.00	13.29	5.36	22.72	(11)	16.20	3.36	26.24	(11)

Table C-137

SUB. T *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.42	0.00	12.75	16.06	9.32	25.67	(9)	38.60	8.46	68.13	(9)
PULL	2.79	0.00	10.91	22.90	1.87	34.07	(9)	41.49	21.90	62.58	(9)
UP	3.19	0.00	7.60	16.42	1.42	26.09	(9)	17.71	11.08	25.58	(9)
DOWN	9.62	0.00	37.82	18.32	7.76	40.30	(9)	23.24	0.71	46.29	(9)
RIGHT	11.31	0.20	21.86	19.54	11.29	28.86	(9)	22.85	12.54	33.61	(9)
LEFT	15.28	0.00	26.14	25.03	16.57	34.37	(8)	23.64	10.79	31.43	(8)

Table C-138

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	46.32	28.91	89.87	69.07	37.71	101.52	(8)	69.42	42.94	95.82	(8)
PULL	40.33	27.33	70.46	63.33	48.71	82.93	(7)	54.89	38.54	69.60	(6)
UP	14.46	0.00	19.27	20.23	0.95	30.02	(7)	22.84	3.12	30.70	(8)
DOWN	16.65	2.67	32.00	23.28	18.00	36.78	(6)	35.80	24.50	82.54	(7)
RIGHT	18.26	10.11	33.44	26.04	18.17	40.05	(8)	27.08	15.03	44.26	(7)
LEFT	14.55	11.61	21.75	25.30	15.24	43.48	(7)	21.82	11.11	30.97	(8)

Table C-139

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	21.99	8.97	36.38	40.65	25.30	63.28	(9)	53.07	33.85	75.91	(9)
PULL	29.93	11.88	53.20	47.86	27.78	75.60	(9)	53.78	34.80	81.98	(9)
UP	9.64	5.56	14.57	19.04	8.42	29.29	(7)	17.37	4.10	26.33	(8)
DOWN	10.86	1.08	26.29	19.59	8.59	39.96	(9)	23.01	10.67	48.83	(9)
RIGHT	14.00	3.72	30.58	24.98	9.15	50.23	(9)	26.08	11.91	56.92	(9)
LEFT	12.20	6.72	21.62	20.84	13.69	29.47	(9)	21.05	11.16	33.88	(9)

Table C-140

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	8.94	0.00	17.62	31.81	11.14	48.63	(9)	46.68	16.89	72.00	(9)
PULL	11.53	0.00	26.46	34.26	19.71	48.05	(9)	48.06	4.11	75.79	(,)
UP	13.56	4.11	24.36	22.00	7.92	35.53	(7)	23.86	13.21	34.13	(7)
DOWN	26.40	8.45	48.14	31.82	18.30	55.31	(9)	34.28	21.19	57.34	(9)
RIGHT	13.52	5.31	18.82	25.36	18.57	32.68	(9)	30.61	17.45	39.11	(9)
LEFT	7.95	0.00	12.21	20.87	12.34	31.43	(9)	22.63	15.18	36.02	(9)

Table C-141

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND, WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	50.82	11.69	87.83	76.63	37.92	99.37	(10)	74.08	38.64	99.81	(10)
PULL	52.30	38.58	74.70	73.79	59.01	96.04	(10)	73.99	54.53	91.61	(10)
UP	11.76	0.00	18.46	19.26	0.21	25.87	(10)	19.92	1.76	29.13	(10)
DOWN	16.94	0.00	38.74	28.15	10.16	59.70	(10)	28.25	10.98	58.12	(10)
RIGHT	19.03	4.04	36.92	30.85	15.10	50.66	(10)	29.68	14.70	46.19	(10)
LEFT	16.79	0.00	28.92	27.29	17.09	42.36	(10)	28.57	17.96	39.35	(10)

Table C-142

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	28.18	0.00	65.71	54.32	27.60	89.81	(9)	62.70	28.58	103.49	(9)
PULL	29.34	1.10	60.64	48.24	29.31	77.02	(8)	51.35	35.05	76.45	(10)
UP	7.40	1.21	15.83	15.40	7.73	21.69	(8)	14.67	8.06	20.03	(8)
DOWN	13.57	1.85	31.42	21.79	12.81	38.68	(10)	24.15	8.73	45.77	(8)
RIGHT	13.03	0.00	43.70	24.25	12.94	59.10	(9)	25.30	14.19	57.87	(9)
LEFT	14.26	4.28	20.52	25.10	16.77	33.23	(9)	24.50	12.13	33.48	(9)

Table C-143

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM					MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	28.61	17.52	37.71	50.65	28.93	103.49	(8)	52.01	38.32	75.90	(8)
PULL	27.02	2.67	43.80	45.23	28.18	54.46	(8)	56.26	40.00	93.62	(8)
UP	12.67	3.58	17.71	18.55	10.67	23.22	(8)	18.24	9.51	24.53	(8)
DOWN	18.70	11.94	30.65	26.09	18.19	42.49	(7)	28.95	20.41	44.47	(7)
RIGHT	15.38	0.00	30.80	28.35	15.77	42.97	(8)	28.16	13.25	40.19	(8)
LEFT	15.74	7.25	26.12	26.56	15.92	38.14	(8)	26.97	9.67	38.14	(8)

Table C-144

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM					MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	26.32	11.46	42.87	(10)	36.03	17.16	63.48	(10)
PULL	0.00	0.00	0.00	29.76	22.39	43.90	(10)	45.00	21.72	69.76	(10)
UP	0.00	0.00	0.00	17.11	9.33	25.42	(10)	19.37	11.81	30.39	(10)
DOWN	2.18	0.00	8.69	13.70	7.44	30.68	(10)	21.39	13.71	34.39	(10)
RIGHT	0.00	0.00	0.00	6.89	0.72	12.90	(10)	9.96	6.81	14.59	(10)
LEFT	0.00	0.00	0.00	12.15	4.39	22.22	(10)	16.78	4.47	24.80	(10)

Table C-145

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.95	0.00	9.51	18.86	8.37	36.00	(10)	39.41	24.06	57.78	(11)
PULL	5.56	0.00	13.80	28.55	2.30	46.81	(11)	45.40	23.55	75.06	(11)
UP	2.22	0.00	8.37	18.24	7.36	26.05	(11)	23.64	14.46	31.30	(11)
DOWN	7.34	1.25	11.80	15.51	5.77	27.76	(11)	24.47	12.41	44.40	(11)
RIGHT	6.50	0.00	18.07	16.22	7.11	26.16	(11)	17.40	10.93	27.34	(11)
LEFT	16.63	3.59	29.94	27.23	11.18	54.00	(11)	25.75	4.99	42.70	(11)

Table C-146

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM				MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	48.99	16.33	90.02	72.61	49.23	100.21	(7)	65.83	42.52	95.82	(8)
PULL	45.95	30.87	73.61	65.31	41.99	85.19	(8)	74.28	61.26	87.91	(8)
UP	20.59	15.01	32.96	29.97	18.63	43.72	(8)	35.12	24.61	46.39	(7)
DOWN	20.68	12.96	36.57	25.92	17.13	44.03	(8)	31.19	18.42	47.40	(8)
RIGHT	8.29	3.97	12.81	14.62	8.10	17.22	(8)	14.66	9.34	20.48	(8)
LEFT	14.97	5.96	22.68	22.71	10.73	34.03	(8)	22.74	8.43	30.92	(8)

Table C-147

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	19.85	6.71	32.85	41.18	15.11	56.45	(8)	54.73	21.27	77.13	(8)
PULL	28.89	0.41	45.35	47.90	33.66	59.39	(8)	49.92	20.79	68.62	(8)
UP	13.64	6.59	24.02	21.43	12.72	34.15	(8)	24.66	15.86	35.54	(8)
DOWN	13.33	3.57	20.41	18.00	7.32	27.84	(8)	20.21	10.72	31.72	(8)
RIGHT	5.48	0.15	12.39	11.69	5.81	19.72	(8)	12.19	5.10	21.67	(8)
LEFT	10.90	1.76	19.39	17.46	6.62	25.55	(8)	17.52	6.45	25.90	(8)

Table C-148

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	MEDIUM
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	11.08	0.00	27.13	34.79	19.63	62.89	(8)	57.06	34.54	81.92	(8)
PULL	8.23	0.00	20.51	31.93	5.85	66.88	(8)	43.38	30.75	63.08	(8)
UP	20.20	12.61	28.23	29.44	21.85	37.50	(8)	33.06	26.71	44.01	(8)
DOWN	23.93	11.83	39.76	29.77	16.03	42.97	(8)	32.35	17.17	45.85	(8)
RIGHT	10.42	1.94	21.66	16.61	5.14	29.12	(8)	17.75	3.59	29.98	(8)
LEFT	4.87	0.00	18.54	13.19	4.47	25.88	(8)	19.06	9.67	38.25	(8)

Table C-149

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED MINIMUM MEAN	RANGE		MAXIMUM MEAN	RANGE			IMPULSE MAXIMUM MEAN	RANGE		
PUSH	45.86	0.00	85.56	74.47	53.16	94.87	(9)	77.95	57.77	93.91	(9)
PULL	41.94	4.11	64.10	62.90	37.59	77.21	(9)	64.57	34.53	87.61	(9)
UP	18.27	0.00	27.51	31.32	20.09	39.38	(9)	29.42	3.38	40.59	(9)
DOWN	21.31	7.29	47.94	29.89	13.80	50.62	(9)	32.04	15.12	45.76	(9)
RIGHT	7.96	0.00	14.14	14.92	3.51	22.94	(9)	16.79	2.07	24.49	(8)
LEFT	14.75	1.72	27.47	24.70	12.52	37.80	(9)	25.38	13.38	40.76	(9)

Table C-150

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED MINIMUM MEAN	RANGE		MAXIMUM MEAN	RANGE			IMPULSE MAXIMUM MEAN	RANGE		
PUSH	28.66	0.00	61.74	56.41	20.33	81.34	(11)	62.09	31.09	86.15	(11)
PULL	35.32	0.00	66.77	53.12	17.75	81.81	(11)	53.56	19.50	78.50	(11)
UP	14.39	4.69	24.27	23.00	10.71	34.56	(11)	24.25	6.83	32.43	(11)
DOWN	13.47	3.91	22.00	19.03	6.70	31.01	(11)	22.19	9.67	32.76	(11)
RIGHT	11.58	4.68	23.72	17.98	7.89	29.17	(11)	17.53	8.86	34.01	(11)
LEFT	14.93	8.26	28.89	22.29	13.06	38.44	(11)	23.42	11.70	42.92	(11)

Table C-151

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE MEDIUM
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	20.84	0.00	31.97	44.79	22.38	62.28	(10)	54.73	17.92	71.62	(10)
PULL	28.21	1.40	46.66	45.66	23.10	61.08	(10)	56.48	28.13	87.95	(10)
UP	22.03	13.29	32.17	33.03	21.84	46.40	(10)	35.60	27.24	44.32	(9)
DOWN	23.48	4.01	51.57	31.28	11.94	53.69	(10)	36.35	17.60	55.64	(10)
RIGHT	11.95	3.73	23.38	21.73	6.11	40.46	(10)	21.53	11.96	42.30	(10)
LEFT	15.10	1.69	28.94	27.91	10.27	58.13	(10)	27.39	16.38	39.45	(10)

Table C-152

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	0.00	0.00	0.00	32.02	16.23	46.96	(8)	47.42	26.67	67.73	(8)
PULL	0.02	0.00	0.17	25.36	7.12	49.96	(8)	48.81	19.98	68.44	(7)
UP	1.69	0.00	5.48	12.80	0.27	25.27	(9)	16.43	4.56	24.67	(8)
DOWN	2.06	0.00	12.08	14.07	4.93	38.18	(7)	20.71	7.28	37.33	(8)
RIGHT	0.51	0.00	3.14	11.98	4.60	19.12	(8)	16.45	3.57	32.07	(8)
LEFT	0.00	0.00	0.00	12.65	4.45	24.21	(8)	14.47	6.24	23.69	(7)

Table C-153

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.13	0.00	12.46	18.67	2.36	34.84	(11)	33.51	16.33	72.64	(11)
PULL	3.67	0.00	15.18	24.71	7.07	39.35	(11)	42.77	22.88	78.40	(11)
UP	5.16	0.00	14.42	18.97	12.73	33.58	(10)	20.12	9.61	32.88	(11)
DOWN	3.56	0.00	12.52	10.50	3.22	22.31	(11)	19.05	6.92	36.12	(10)
RIGHT	12.16	3.33	28.28	20.53	9.78	46.84	(11)	19.37	4.22	37.23	(11)
LEFT	13.30	0.00	21.10	21.28	3.86	33.97	(10)	24.78	16.57	38.57	(10)

Table C-154

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	26.42	0.00	64.27	52.93	27.90	86.16	(9)	52.44	19.26	87.15	(9)
PULL	42.37	17.36	76.95	73.28	56.19	104.15	(9)	63.92	3.57	85.78	(9)
UP	10.96	0.00	22.57	19.62	4.54	34.27	(9)	20.22	3.32	30.57	(8)
DOWN	17.75	8.81	51.43	22.88	13.47	57.69	(9)	25.94	15.57	60.30	(9)
RIGHT	12.02	2.38	24.41	18.55	10.65	31.96	(9)	19.83	10.98	36.93	(9)
LEFT	11.87	0.00	25.85	24.67	14.88	42.60	(9)	22.51	14.41	35.87	(10)

Table C-155

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	10.90	0.61	20.33	35.05	14.97	67.90	(8)	43.82	24.46	68.30	(8)
PULL	29.65	5.52	59.17	52.93	34.20	81.03	(8)	46.84	5.96	77.50	(8)
UP	7.74	0.00	12.80	18.36	12.40	27.89	(7)	19.78	13.93	28.80	(7)
DOWN	9.18	3.63	34.12	14.90	5.90	37.69	(8)	18.17	6.56	47.92	(8)
RIGHT	12.03	3.50	21.95	20.10	10.49	36.56	(8)	20.22	9.62	30.84	(8)
LEFT	13.72	7.58	27.62	21.91	13.86	35.59	(7)	19.96	10.64	30.77	(8)

Table C-156

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	6.14	0.00	17.20	23.62	8.77	39.29	(10)	51.87	13.17	81.47	(10)
PULL	9.14	0.00	32.17	35.59	15.47	67.02	(10)	53.66	26.71	81.28	(10)
UP	15.08	1.36	32.56	21.85	7.34	49.09	(9)	22.10	8.18	41.47	(9)
DOWN	17.47	2.89	41.45	25.96	12.36	49.59	(10)	31.14	17.45	60.73	(10)
RIGHT	10.24	2.98	19.08	21.22	12.28	33.00	(10)	22.62	13.20	36.55	(10)
LEFT	6.77	0.00	10.53	16.50	9.57	23.99	(9)	22.07	11.95	32.21	(10)

Table C-157

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	43.69	15.26	69.73	61.42	25.45	92.69	(10)	76.46	38.73	99.51	(10)
PULL	53.04	24.89	98.70	79.81	42.11	111.89	(10)	80.89	46.34	114.85	(10)
UP	13.23	1.90	19.78	20.18	12.00	25.34	(9)	21.44	13.87	30.51	(9)
DOWN	15.90	3.88	41.45	22.09	6.77	56.86	(10)	25.86	11.70	59.08	(10)
RIGHT	18.46	0.37	36.49	30.21	12.84	55.65	(10)	26.16	12.91	48.08	(10)
LEFT	16.27	0.30	32.13	23.58	0.93	38.23	(10)	23.86	1.01	40.89	(10)

Table C-158

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	HORIZONTAL
RESTRAINT	HAND AND WAIST

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	16.57	3.55	30.69	37.48	16.93	57.63	(11)	42.47	26.99	60.87	(10)
PULL	42.37	23.97	64.06	57.51	35.14	83.57	(11)	58.89	35.70	78.26	(11)
UP	8.45	0.00	14.04	15.34	8.95	19.58	(11)	15.38	7.54	21.03	(11)
DOWN	8.92	0.00	15.94	15.43	0.82	25.26	(10)	17.34	3.79	27.69	(11)
RIGHT	14.65	1.85	26.39	24.09	10.58	39.14	(11)	25.39	12.15	48.45	(11)
LEFT	14.44	0.54	30.99	24.95	10.51	43.22	(11)	22.98	10.62	38.83	(11)

Table C-159

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION HORIZONTAL
RESTRAINT HAND AND SHOES

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	19.51	9.71	32.93	37.49	24.31	53.01	(11)	58.06	24.77	81.71	(11)
PULL	31.94	6.33	42.35	52.14	37.21	65.54	(11)	58.88	42.31	81.39	(11)
UP	15.06	0.00	35.85	23.67	8.30	46.78	(11)	24.06	7.43	45.02	(12)
DOWN	21.82	2.04	37.01	26.21	11.71	38.44	(11)	29.74	17.32	46.64	(10)
RIGHT	17.89	6.92	28.79	32.70	13.42	45.79	(11)	35.07	14.26	49.31	(11)
LEFT	12.44	0.00	28.27	20.94	1.54	34.36	(11)	23.70	1.13	44.01	(11)

Table C-160

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT NONE

	SUSTAINED							IMPULSE			
	MINIMUM			MAXIMUM				MAXIMUM			
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	0.00	0.00	0.00	19.79	14.71	28.39	(10)	40.32	14.24	63.79	(10)
PULL	0.00	0.00	0.00	28.88	9.23	53.72	(10)	47.12	28.72	60.38	(10)
UP	0.45	0.00	3.14	16.61	10.42	24.94	(9)	21.54	12.98	30.39	(10)
DOWN	1.30	0.00	4.21	14.42	7.44	29.89	(10)	22.34	11.83	34.27	(10)
RIGHT	0.15	0.00	1.47	7.31	1.28	16.07	(10)	11.11	4.11	17.92	(10)
LEFT	0.00	0.00	0.00	9.09	4.39	18.92	(11)	15.27	7.09	27.99	(9)

Table C-161

SUBJECT	-
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	1.45	0.00	13.03	15.14	3.84	28.35	(9)	30.04	17.79	51.12	(10)
PULL	4.09	0.00	12.31	25.53	8.34	48.91	(9)	36.67	0.05	71.61	(9)
UP	3.34	0.00	14.91	16.15	8.78	23.38	(11)	19.32	11.54	29.38	(10)
DOWN	5.55	0.00	16.81	15.04	1.39	37.12	(10)	20.31	11.80	37.12	(10)
RIGHT	5.44	0.00	17.38	16.19	9.45	39.17	(10)	14.92	5.08	30.15	(9)
LEFT	14.73	4.48	28.00	24.64	7.51	59.82	(10)	26.43	12.56	52.94	(10)

Table C-162

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	30.91	0.00	72.45	52.60	19.97	89.87	(9)	53.62	25.35	91.43	(9)
PULL	55.57	36.91	87.04	79.05	57.89	102.62	(9)	78.40	65.39	100.78	(9)
UP	15.47	0.00	22.46	26.96	19.42	34.71	(9)	28.53	19.53	36.15	(9)
DOWN	14.36	7.85	22.99	19.22	11.42	25.65	(9)	22.31	11.01	32.58	(9)
RIGHT	7.50	0.21	16.50	13.28	5.01	21.82	(9)	13.13	9.24	16.51	(9)
LEFT	12.13	3.55	31.53	20.21	9.56	43.48	(8)	21.75	14.63	42.62	(9)

Table C-163

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	WAIST

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	18.88	0.00	32.01	35.17	12.82	59.79	(9)	43.43	10.10	56.13	(9)
PULL	32.68	14.34	52.06	56.67	30.14	71.25	(9)	55.93	27.97	68.85	(9)
UP	13.46	0.17	23.45	21.81	8.01	30.94	(9)	22.01	9.27	32.60	(9)
DOWN	12.06	4.27	18.92	18.09	9.53	27.59	(9)	20.59	11.30	28.53	(9)
RIGHT	6.04	1.21	11.34	13.40	3.06	21.17	(9)	13.12	4.92	21.86	(9)
LEFT	9.62	0.00	17.30	16.37	9.49	23.60	(9)	17.75	8.34	25.56	(9)

Table C-164

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	9.09	0.00	24.00	26.86	1.99	52.02	(9)	49.27	18.85	65.80	(9)
PULL	9.97	0.00	24.73	29.49	15.89	39.89	(9)	48.25	27.54	84.25	(9)
UP	19.17	9.01	30.40	29.03	19.16	43.18	(9)	31.15	21.26	42.08	(9)
DOWN	22.94	0.22	46.82	27.50	3.47	55.64	(9)	36.54	18.98	59.63	(9)
RIGHT	9.43	0.00	20.83	18.42	11.12	28.25	(9)	19.71	10.36	31.29	(9)
LEFT	5.66	0.00	13.67	17.10	4.56	32.25	(9)	22.28	7.59	45.69	(9)

Table C-165

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND,WAIST AND SHOES

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	51.30	0.00	80.31	77.83	51.26	97.66	(9)	76.21	57.10	86.61	(9)
PULL	58.33	19.13	101.37	82.53	41.09	114.85	(9)	81.13	41.53	114.26	(9)
UP	14.81	0.00	23.76	27.28	20.18	36.02	(9)	26.09	21.47	32.33	(9)
DOWN	19.68	8.61	34.26	25.73	12.10	44.92	(9)	28.00	9.68	47.77	(9)
RIGHT	7.89	0.00	15.83	13.57	6.64	26.06	(9)	14.23	7.47	21.74	(9)
LEFT	12.85	0.05	17.50	18.66	4.71	23.90	(7)	18.18	2.72	30.21	(10)

Table C-166

SUBJECT *
PRESSURIZATION METHOD *
RECEIVER ANGLE 45 DEGREES
RECEIVER DISTANCE FAR
RECEIVER ORIENTATION VERTICAL
RESTRAINT HAND AND WAIST

	SUSTAINED							IMPULSE			
	MEAN	MINIMUM RANGE		MEAN	MAXIMUM RANGE			MEAN	MAXIMUM RANGE		
PUSH	28.62	1.47	61.60	49.33	15.91	72.22	(10)	58.58	25.44	77.69	(10)
PULL	36.74	0.00	77.01	58.45	13.22	92.68	(10)	60.96	20.52	91.18	(10)
UP	12.27	3.10	20.75	21.80	9.37	34.46	(10)	22.85	9.95	32.94	(10)
DOWN	13.39	5.74	25.10	18.22	11.67	28.68	(10)	19.53	8.51	31.85	(10)
RIGHT	9.27	0.00	19.45	17.39	9.39	26.36	(10)	17.83	10.58	29.98	(10)
LEFT	13.35	4.22	27.56	21.26	10.57	33.83	(10)	22.79	13.68	34.83	(10)

Table C-167

SUBJECT	*
PRESSURIZATION METHOD	*
RECEIVER ANGLE	45 DEGREES
RECEIVER DISTANCE	FAR
RECEIVER ORIENTATION	VERTICAL
RESTRAINT	HAND AND SHOES

	SUSTAINED							IMPULSE			
		MINIMUM			MAXIMUM				MAXIMUM		
	MEAN	RANGE		MEAN	RANGE			MEAN	RANGE		
PUSH	28.20	14.95	38.73	45.23	29.51	61.17	(10)	57.22	46.46	73.13	(10)
PULL	22.14	0.00	39.38	46.91	32.43	63.45	(10)	54.78	32.28	77.29	(10)
UP	18.06	7.82	29.67	31.93	17.32	45.25	(10)	34.03	22.07	44.42	(10)
DOWN	25.88	8.59	47.03	33.24	14.18	48.94	(10)	35.83	16.20	57.01	(10)
RIGHT	12.21	5.98	23.74	19.49	13.07	29.29	(10)	20.97	12.66	27.69	(10)
LEFT	19.00	2.02	31.49	28.48	9.57	49.14	(10)	28.43	12.61	40.57	(10)