NASA Contractor Report 185679

Astronaut Candidate Strength Measurement Using the Cybex II and the LIDO Multi-Joint II Dynamometers

Amy E. Carroll and Robert P. Wilmington

Contract NAS9-17900

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Lockheed Engineering and Sciences Company
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ASTRONAUT CANDIDATE STRENGTH MEASUREMENT USING THE CYBEX II AND LIDO MULTI-JOINT II DYNAMOMETERS

EXECUTIVE SUMMARY

The Anthropometry and Biomechanics Laboratory in the Man-Systems Division at NASA's Johnson Space Center has as one of its responsibilities the anthropometry and strength measurement data collection of astronaut candidates. The anthropometry data is used to ensure that the astronaut candidates are within the height restrictions for space vehicle and space suit design requirements, for example. The strength data is used to help detect abnormalities or isolate injuries to muscle groups that could jeopardize the astronauts safety.

The Cybex II Dynamometer has been used for strength measurements from 1985 through 1991. The Cybex II was one of the first instruments of its kind to measure strength and similarity of muscle groups by isolating the specific joint of interest. In November 1991, a LIDO Multi-Joint II Dynamometer was purchased to upgrade the strength measurement data collection capability of the Anthropometry and Biomechanics Laboratory. The LIDO Multi-Joint II Dynamometer design offers several advantages over the Cybex II Dynamometer including a more sophisticated method of joint isolation and a more accurate and efficient computer based data collection system.

This document addresses the systems used in astronaut candidate strength measurement. A brief description of the types of measurements taken and the procedures used for both the Cybex II and the LIDO Multi-Joint II Dynamometers is presented. Following these descriptions will be a summary section which highlights the advantages of upgrading the strength measurement instrumentation within the Anthropometry and Biomechanics Laboratory.

1.0 Introduction

Since 1985, the Anthropometry and Biomechanics Laboratory (ABL) of the NASA Johnson Space Center (JSC) has been collecting strength data on astronaut candidates. During this time the Cybex II Dynamometer was used to obtain this data. The information received was used to detect abnormalities or isolate injury to a specific muscle group. In November of 1991 the ABL purchased the LIDO Multi-Joint II Dynamometer. It was procured to replace the Cybex II before the next candidate class is selected.

Both machines work on a similar principle. A serro-controlled actuator rotates an extendable arm. This arm can be attached to a part of a person's body such that the center of rotation is centered about a joint to be tested. The motor generates a constant angular velocity while the subject produces as much force about that joint as he/she can. The machine measures the torque that the subject produces in that joint. This is a measure of strength.

One of the fundamental differences in the strength testing methodologies between the dynamometers is Cybex II assumes that the axis of rotation passes through a fixed joint center. However, anatomical features of the human body are such that the joint center also moves around during joint motion. This results in variable moment arm distance during dynamic strength testing. The LIDO system overcomes this problem by adjusting the moment arm with a sensing line (figure 7a & b) throughout the motion, thereby ensuring that the force is applied at a fixed distance.

The LIDO system is now used by the Exercise Physiology Laboratory in Building 37 at JSC for pre and post shuttle flight strength measurements on the astronauts. The use of the LIDO Multi-Joint II Dynamometer in the ABL on astronaut candidates will allow for consistant data collection methodology for the comparison of data between laboratories.

2.0 CYBEX II

The Cybex II Dynamometer was one of the first instruments of its kind to measure strength and similarity of muscle groups by isolating specific joints (figure 1). A strip chart operating at 5mm/sec is used to record the raw data. These curves show position and torque. Force values are computed by hand or by computer from the torque and the fixed limb length data. The moment arm is measured with a measuring tape from the center of rotation of the shaft to the center of the point of application of the force. It is then written onto the strip chart for each exercise. Before every candidate class comes into the lab to be tested, the Cybex has to be calibrated. Since its torque scale is 360ft-lbs, it is calibrated to 30, 180, and 360ft-lbs.

Three exercises are used for data collection: the back, legs, and arms. With each subject, the order in which they are performed changes. The first sequence is: the back, left knee, left arm, right knee, right arm. These measurements are described in the following 5 subsections. When the next candidate is tested, the sequence starts with the right arm and continues in the opposite direction. This methodology is used to minimize laboratory setup time. Three maximum efforts for each exercise, at 60 degrees/second, are recorded onto the strip chart (Appendix B). Each curve represents torque and is found with a graphing table. These torques are written beside the curve on the chart. Force is then calculated from the torque values.

ORIGINAL PAGE
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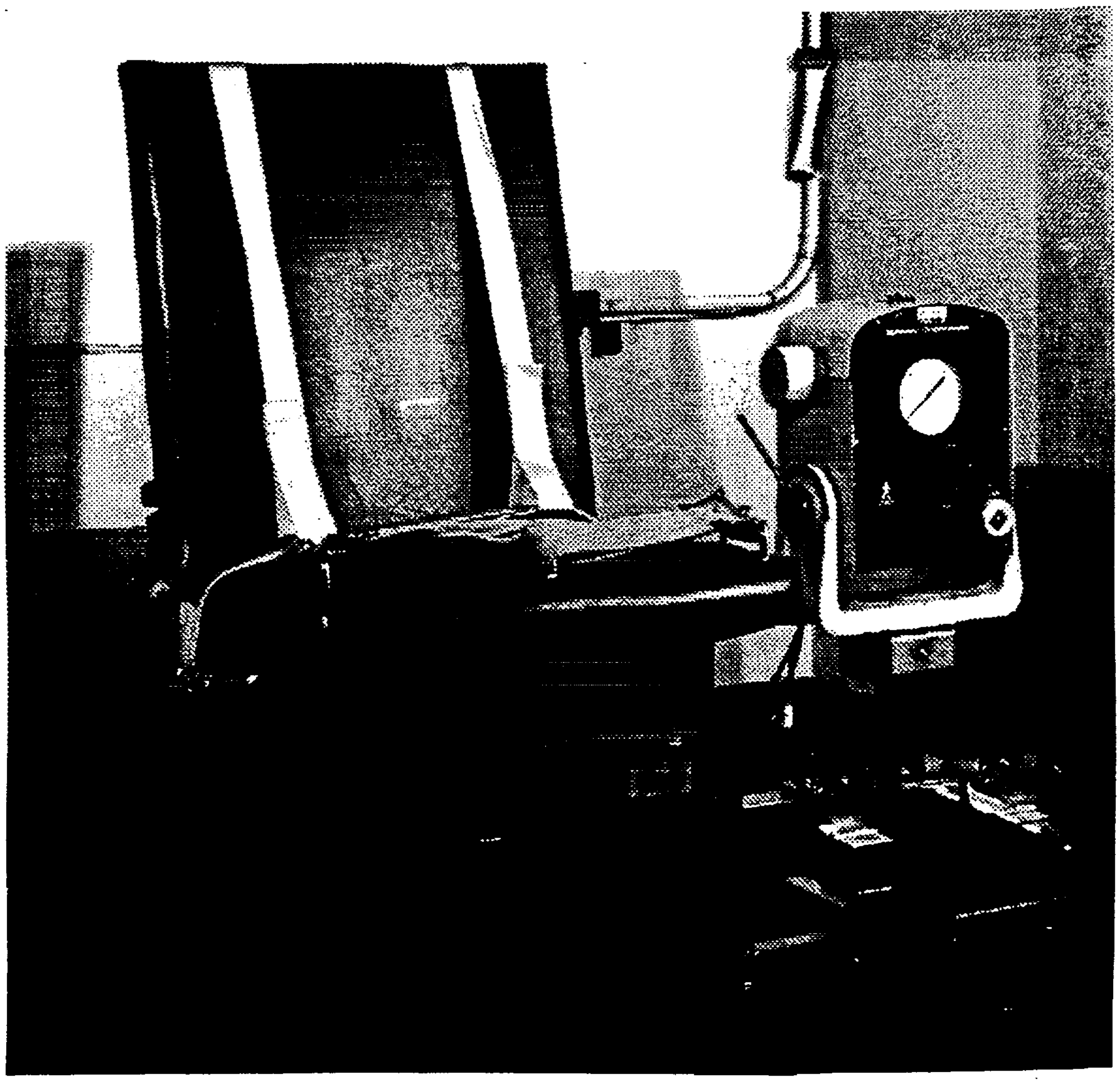


Figure 1. Cybex II Dynamometer

2.1 Back

To use the Cybex for back measurements the candidate is seated in the chair. Velcro straps secure the legs by strapping through a metal loop between the knees. When facing the chair, the Cybex is on the left side. A short input adaptor attaches to the shaft of the Cybex. Attaching to the short input adaptor is a homemade padded long stabilizing handle, which is held in front of the chest at the level of the nipple. Once an acceptable level is found, the moment arm is measured and written onto the strip chart.

To properly position for this test, the arms must cross over the bar and hold it tightly. After a few warm-up motions, the Cybex is stabilized, the chart recorder is lined properly, and data is taken. The first motion is flexion (bending towards legs).

2.2 Left Knee

Moving the Cybex to the right side of the table allows the left leg to be tested. This exercise does not require rotating the dynamometer actuator. A long input adaptor attaches to the shaft and an adjustable arm with push button connects to the adaptor. The Cybex is lowered so that the shaft is at the center of rotation of the knee. Lengthening or shortening the moment arm allows the ankle cuff to wrap comfortably just above the ankle. The moment arm is then measured and written down on the chart.

The thighs and hips are secured with the velcro straps. Two separate velcro stabilizing straps cross over the subject's shoulders and attach at the hip to prevent the chest from movement. Hands rest in the lap. The candidate warms up the leg muscles by moving through the motion a few times. The Cybex is stabilized, the data recorder is lined properly and the test begins. Extension, or straightening of the leg, is the first motion measured.

2.3 Left Arm

The stabilizing straps and Cybex remain in the same position for the left arm evaluation. With the arm straight and holding the handle of the arm attachment, the arm is held level with the floor. The moment arm is measured and recorded on the strip chart.

With the elbow bent and touching the back pad, the arm is pushed out as far as possible and then pulled back to the starting point. Once the candidate is comfortable with this movement, the Cybex is stabilized, the recorders' line positioned and data taken.

Since the ABL's Cybex II chair is not designed to lie flat, this exercise is performed in the sitting position. This test is used for arm strength because the back and shoulder are somewhat stabilized. The axis of rotation of the shaft is not level with the shoulder as it should be. Therefore, this test setup does not isolate the particular muscle group needed, as is desired for proper evaluation.

2.4 Right Knee

The Cybex is moved to the left side of the table to test the right leg. Its entire stand turns 180 degrees to face the candidate. The same procedure as the left leg test is used.

2.5 Right Arm

Remaining on the left side of the table, the same procedure as the left arm is performed.

3.0 LIDO Multi-Joint II

The LIDO Multi-Joint II has two main system components. First, the *Actuator* (figure 2) is the controlling component. The actuator shaft is the attachment point for the joint testing tools. All the exercise modes and motions occur through this unit. A hand crank located on the side of the pedestal allows the actuator to be raised or lowered. Flexibility in the types of exercises the LIDO can perform occurs because of the wide range of rotation the pedestal allows. It can rotate the actuator 360 degrees in either direction or to 16 different angles in 22.5 degree increments. The transition from one test to the next is fast and easy because of the pedestal tracks (figure 3). These tracks allow the actuator and pedestal to be positioned on either side of the seat cushion. The second LIDO component is the *Controller*. An on-board computer controls the rotation of the actuator shaft. Torque and position measurements are read directly into the computer, resulting in a more accurate and controlled movement. The Controller is seen in figure 4.

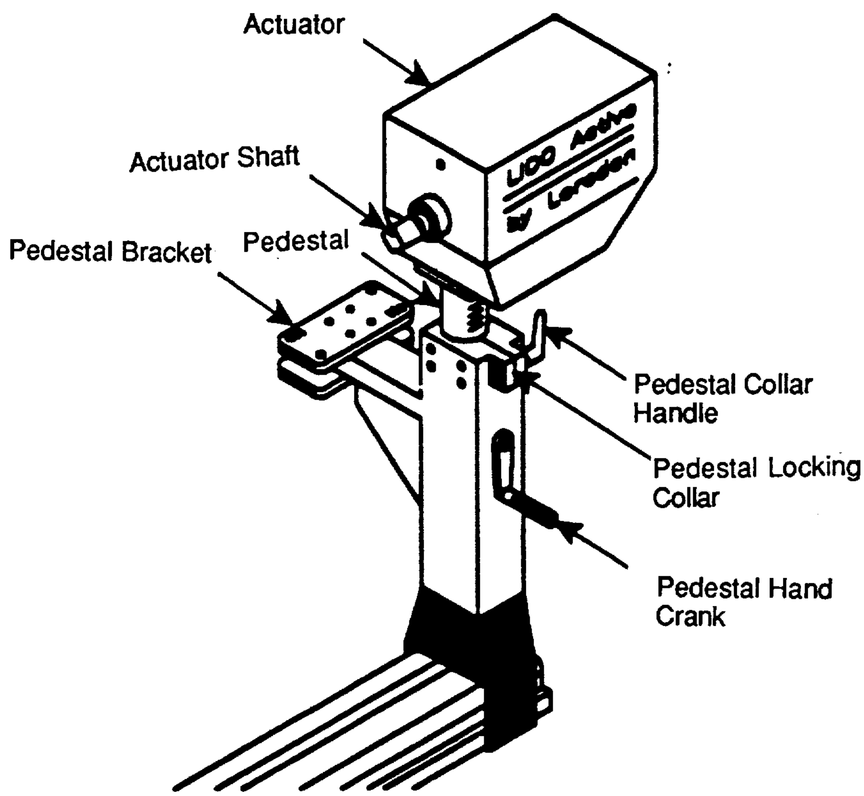


Figure 2. Actuator & Pedestal

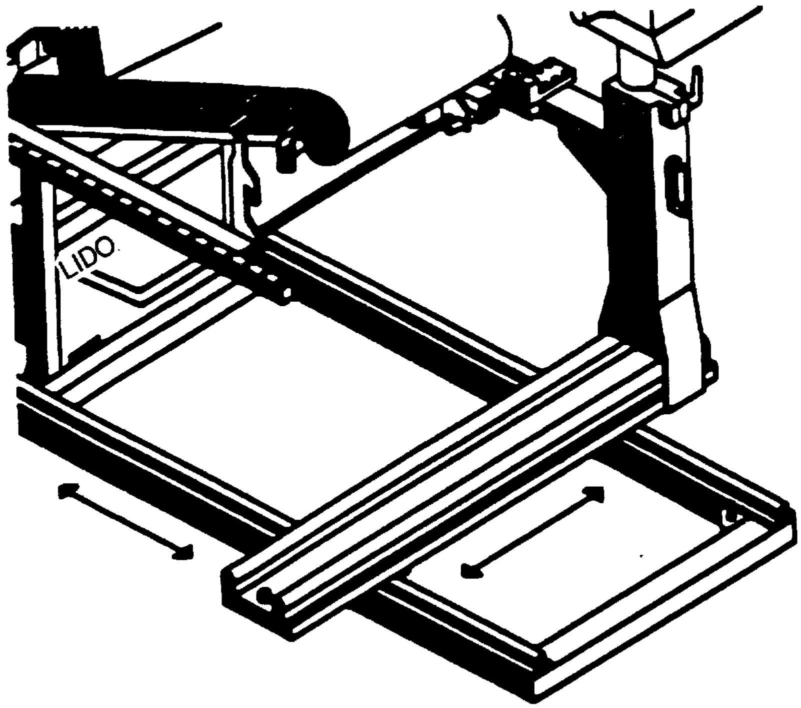


Figure 3. Pedestal Tracks

Four exercise modes have been selected to collect the strength data on the candidates. Each of these modes are performed on both the right and left sides. The order of the testing procedure is: back, right shoulder, left shoulder, left elbow, right elbow, left leg, and right leg. This order has been evaluated by the ABL and ensures the simplest and fastest maneuvering of the equipment. See figure 4 for the entire system.

Each candidate moves through the exercise a few times to warm the muscles. After the initial warm-up for the particular mode, the data collection begins. Three maximum repetitions at 60 degrees/second are performed for each exercise. The average peak torque is calculated on the computer using the three measurements.

Studies have shown that optimal quantification of strength of many joints is at 60 degrees/sec. Joint velocites lower than this can make performing tasks very difficult. Joint velocities higher than 60 degrees/second reduce the strength dramatically; hence, such velocities may not reflect the realistic (dynamic) situations.

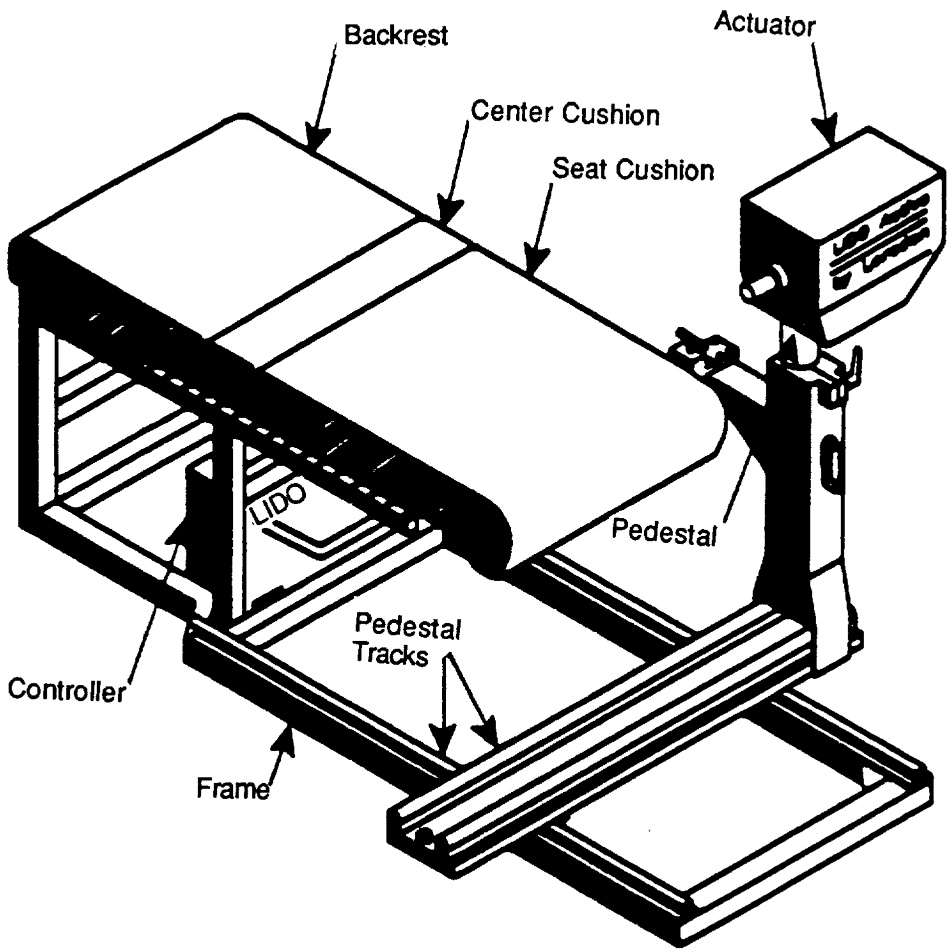


Figure 4. LIDO Multi-Joint II

3.1 Back

The back attachment contains several parts for the extension and flexion exercise of the back (figure 5). The frame attaches to the actuator shaft and holds the back pad. A vertical support, vertical support bearing and large side rail lock attach to the other side of the back attachment and LIDO table. The subject is secured with the back and chest pad located on the frame.

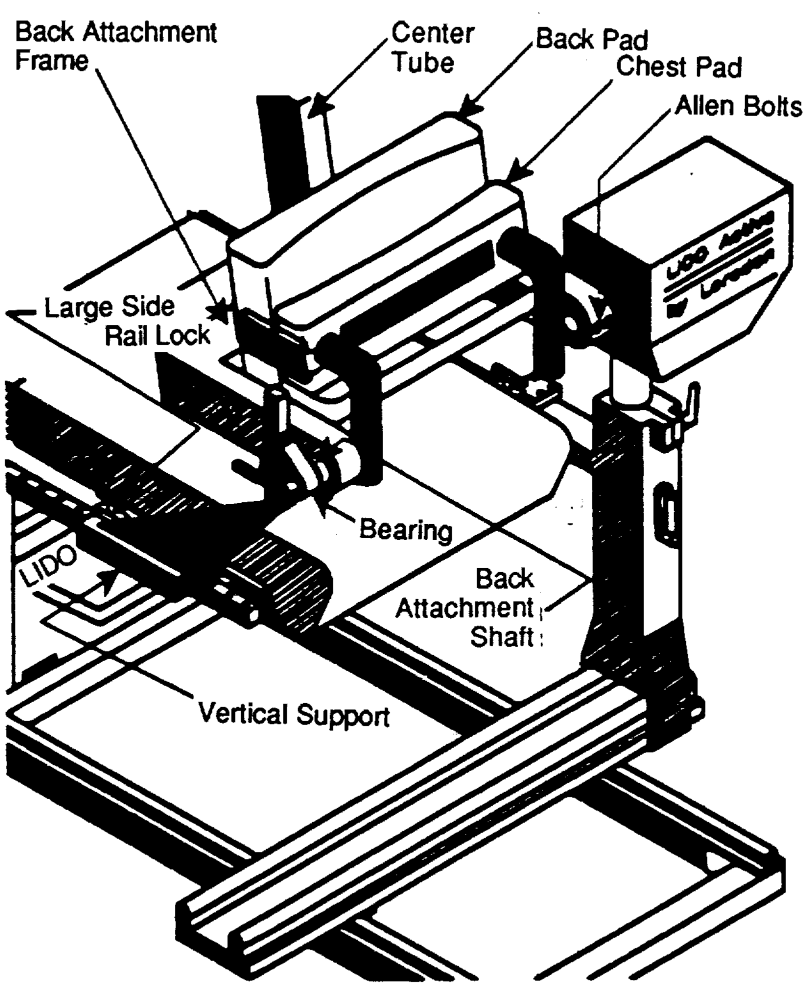


Figure 5. Back Attachment Installation

3.2 Right and Left Shoulder

The actuator shaft is on the right side of the table (looking at the table) ready for the right shoulder. The table is on the upper extremity notch so that the subject can lie comfortably during this exercise. Figure 6 illustrates both upper and lower notches. Three attachments are used for this exercise. An upper extremity hub attaches to the actuator shaft, the upper extremity extension attaches to the hub and the upper extremity arm attaches to the extension (figure 7a&7b). The moment arm is measured by the sensing line connected from the hub to the arm.

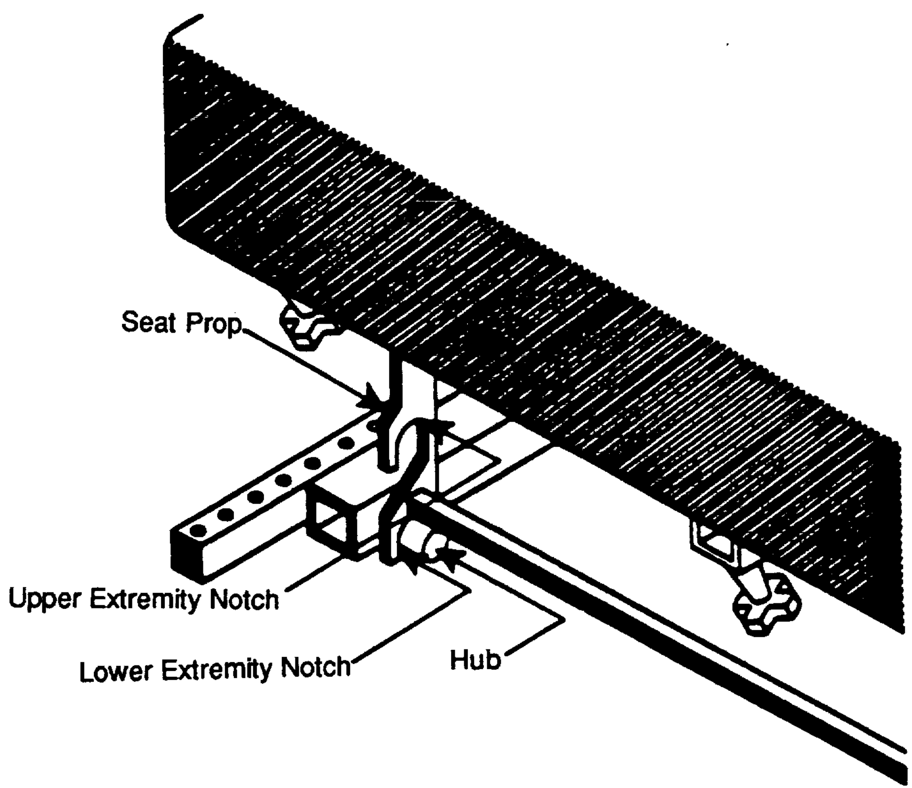


Figure 6. Upper & Lower Extremity Notches

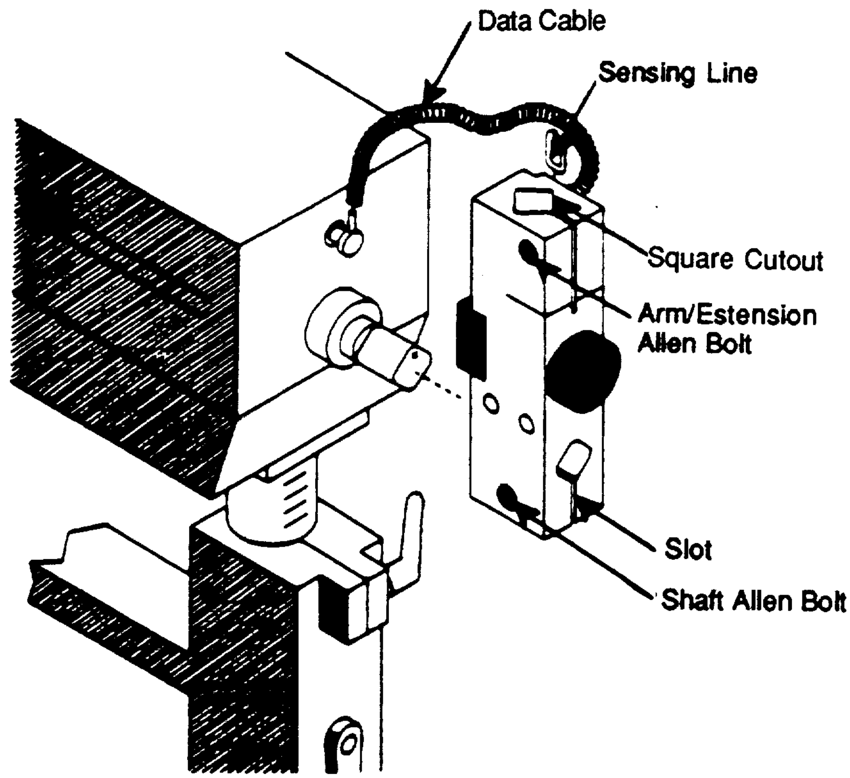


Figure 7a. Upper Extremity Hub

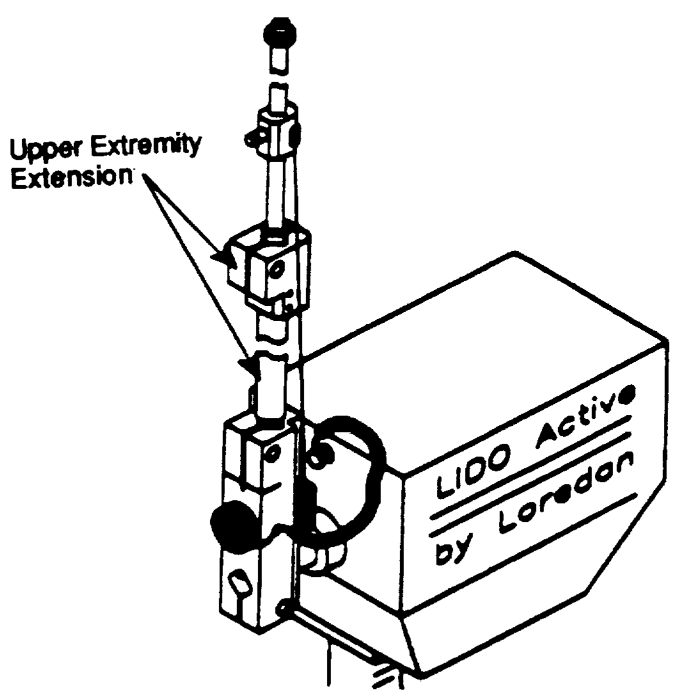


Figure 7b. Upper Extremity Extension & Arm

Lying on the table supine, or face up, the candidate's head rests on the installed headrest. The center of rotation for the shoulder is determined by palpatations of the anatomical landmarks. Raise or lower the actuator so that the center of its shaft is at that level. Arms are rested at the side and the opposite leg is flexed at the hip and knee. One stabilization strap is used across the hips at the iliac crest and one strap is used diagonally from the opposite shoulder to the hip on the testing side. The first movement is flexion (moving towards head).

The actuator is moved to the left side of the table to test the left shoulder. The same procedure as above is used.

3.3 Left and Right Elbow

For the elbow exercise, the arrangement of the table and actuator remains in the same position as for the shoulder exercise. Requiring change is the upper arm extremity and the swivel handle. An elbow cup is installed on the hub for the candidate's elbow to rest (figure 8). Attachment of the side bar extension to the pedestal and side rail allows a sufficient amount of room for the subject to lay on the table and perform this exercise. The height of the actuator shaft is adjusted to the level of the center of rotation for the elbow and the angle is 22.5 degrees away from the table.

Subject is in the same position as for the shoulder measurement. Elbow is placed in the elbow cup with the hand grasping the handle. A stabilization strap fastens across the hips at the iliac crest. The first movement is flexion.

With subject in the same position, the pedestal is moved to the right side of the table and the actuator is rotated 180 degrees to face the table. The actuator is then rotated 22.5 degrees out from the subject. The candidate and the table are now in position for the right elbow.

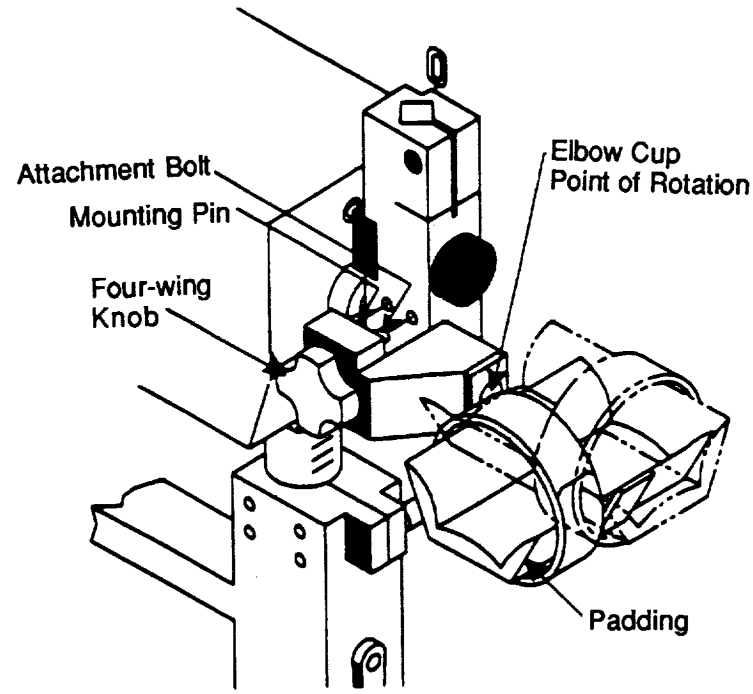


Figure 8. Elbow Cup

3.4 Left and Right Leg

The table is converted into the LIDO Multi-Joint II chair and placed in the lower extremity notch for the leg exercise (see figure 6). A lower extremity arm attachment (figure 9a) connects to the actuator shaft for the lower body exercises.

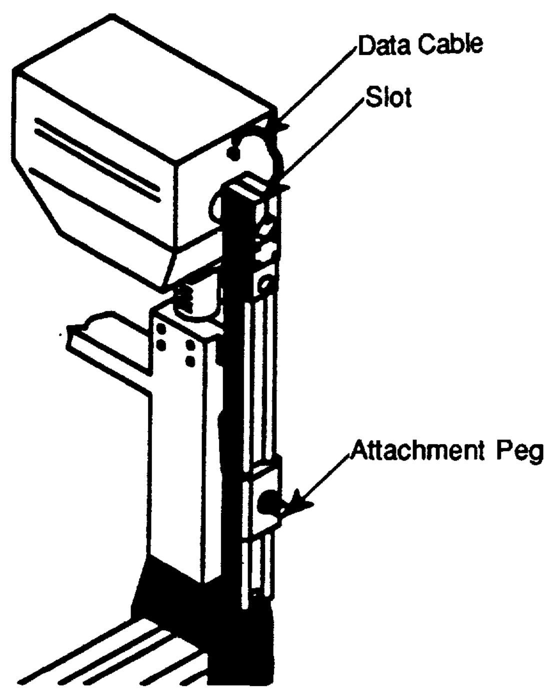


Figure 9a. Lower Extremity Attachment

Subject is positioned on the chair, and the back rest adjusts to fit comfortably against the back. The pedestal is raised so that the actuator shaft is level with the center of rotation of the knee. The extension bar is removed from the side rail and the pedestal is positioned forward or backward according to the knee position. Attachment of the ankle cuff (figure 9b) around the testing leg and of the velcro strap around the opposing ankle, isolates and secures the legs. A separate strap is placed around the hips for stabilization. A thigh bolster (figure 9c) holds the testing side thigh down to isolate the knee joint completely. While the subject holds the hand grips, the first movement is extension of the leg.

The subject is kept in the same position while the pedestal is moved to the left side of the table. The right leg is then tested.

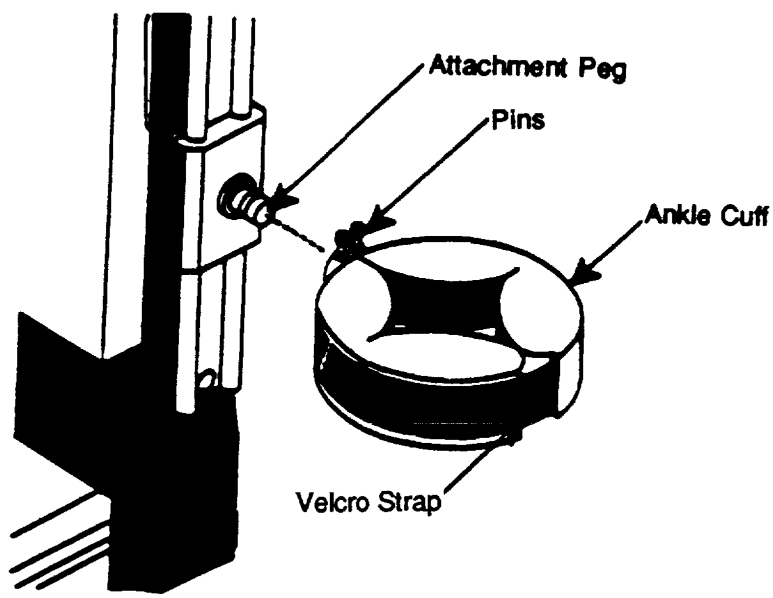


Figure 9b. Ankle Cuff

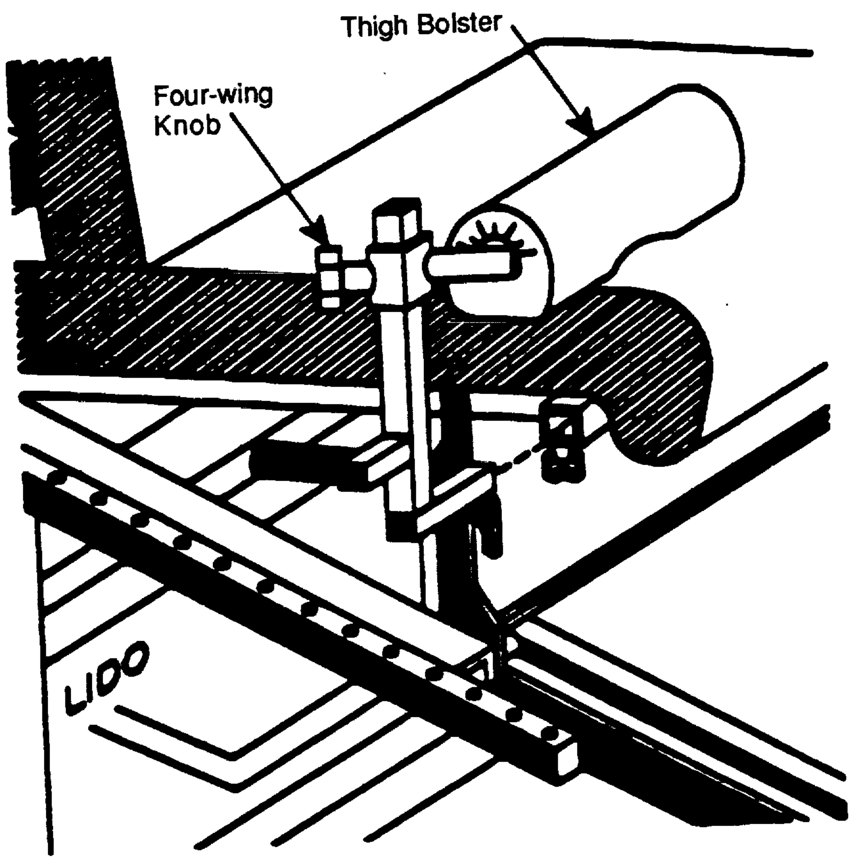


Figure 9c. Thigh Bolster

4.0 Summary

The upgrade of the Cybex II Dynamometer with the LIDO Multi-Joint II Dynamometer offers several advantages, but the LIDO does require changes in strength measurement techniques,which are presented in the previous sections. The disadvantage in changing from the Cybex II to the LIDO Multi-Joint II system is that the data collected from 1985 to 1991 will not be directly comparable to the new strength data. The advantages the upgrade will offer are the following:

a. Capability to collect isolated joint data in a more controlled manner
b. Ability for data comparison with other NASA laboratories
c. Capability for sitting as well as supine position strength measurement
d. Greater accuracy in data collection
e. Easier techniques for setup and adjustments
f. Time reduction in data collection and analysis
g. Capability of continual torque arm length measurement compensation
h. Capability of gravity compensation

APPENDIX A

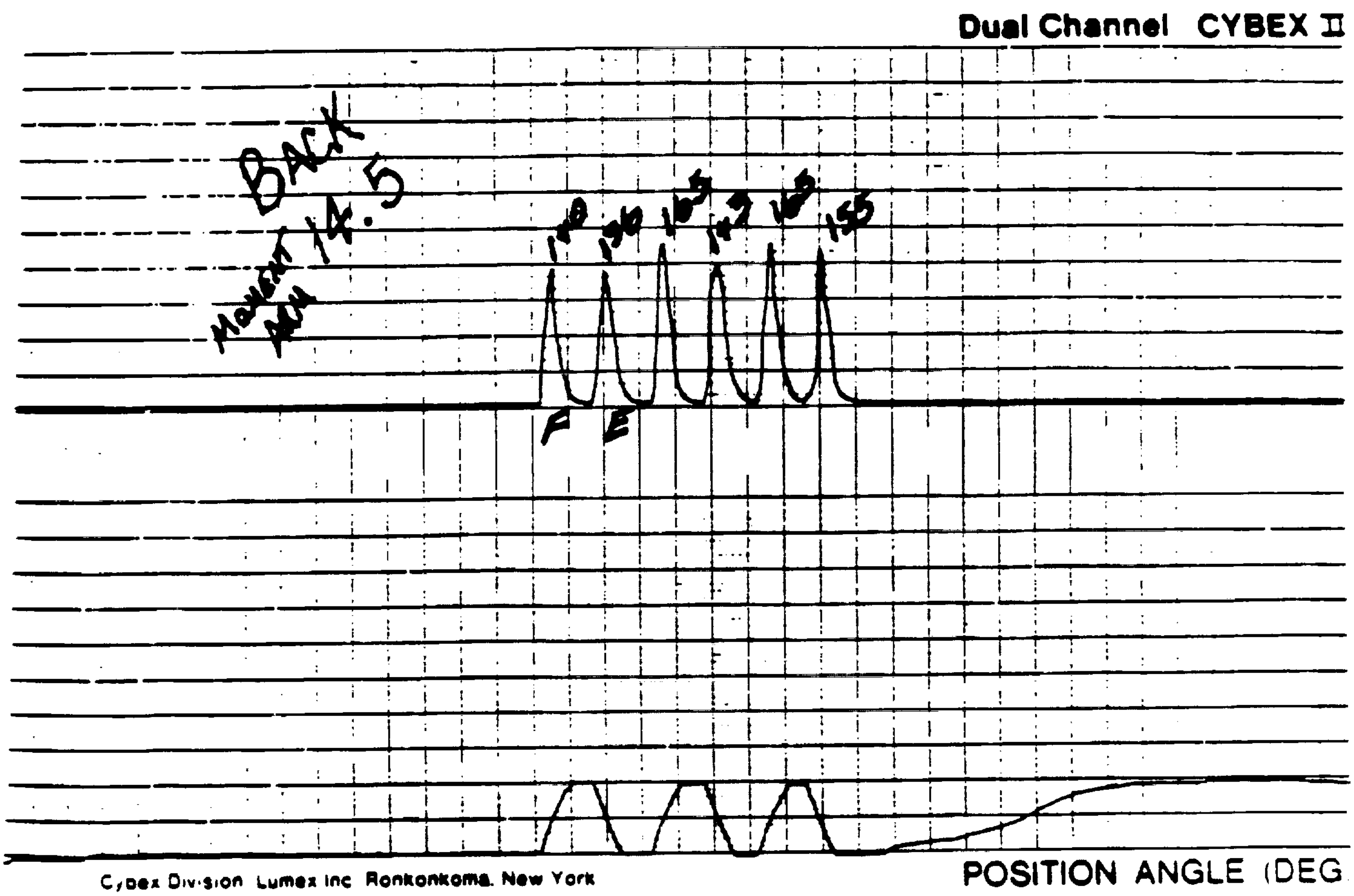
LIDO File Names & Range of Motions

The LIDO Multi-Joint II Dynamometer enables each of the testing modes to be saved into Configuration Defaults or files (#8 on the main menu). The *default* file that is shown when the system is turned on is the back exercise. Each of the exercises are in the order of performance and are shown with their file name and range of motion (ROM).

FILE NAME	EXERCISE NAME	FLEXION	EXTENSION
Default	back flexion/extension sitting	50	0
Shoulder	shoulder flex/ext supine	10	70
Elbow	elbow flex/ext supine	20	60
Leg	knee ext/flex sitting	0	60

APPENDIX B

Cybex II Data Format



LIDO Text Data Format

LIDO ACTIVE TEST REPORT

ABL - Man Systems Division
NASA Johnson Space Center
Houston, Tx 77058 (713) 483-4898

Patient:
Address:

Gender:
Date of Birth:
Body Weight: 0 (lb)
Body Height: 0 (in)

Test Date: 04-06-92
System: LIDO ACTIVE

Insurance Carrier:
Referring Physician:
Pathology:
Clinician:
Diagnosis:

Joint:	SHOULDER	Involved Side:	
Motion:	flex/ext	Dominant Side:	
Velocity:	60/60 deg/sec	Mode:	Con/Con
Position:	(supine)	Gravity Compensation:	Yes

	RIGHT
Peak torque flex	15.0 ft-lbs
Avg P torque flex	14.0 ft-lbs
Avg angle at P torque flex	-47.0 deg
Peak torque ext	20.0 ft-lbs
Avg P torque ext	18.0 ft-lbs
Avg angle at P torque ext	-20.0 deg
Avg work flex	15.0 ft-lbs
Avg work ext	21.3 ft-lbs
Avg explosive work flex	0.1 ft-lbs
Avg explosive work ext	0.5 ft-lbs
Avg power flex	7.7 ft-lbs/sec
Avg power ext	12.5 ft-lbs/sec
Avg P torque flex/Wt	0.0 ft-lbs/(lb)
Avg P torque ext/Wt	0.0 ft-lbs/(lb)
Avg P torque ext/flex	128.6 %
Avg work flex/Wt	0.0 ft-lbs/(lb)
Avg work ext/Wt	0.0 ft-lbs/(lb)
Avg work ext/flex	142.2 %
Avg power flex/Wt	0.0 ft-lbs/sec/(lb)
Avg power ext/Wt	0.0 ft-lbs/sec/(lb)
Avg power ext/flex	162.8 %
Decline P torque flex	0.0 ft-lbs/sec
Decline P torque ext	-0.4 ft-lbs/sec
Conformability flex	10.1 %
Conformability ext	86.1 %
Extreme ROM flex	-1.0 deg
Extreme ROM ext	-80.0 deg

LIDO Graphical Data Format

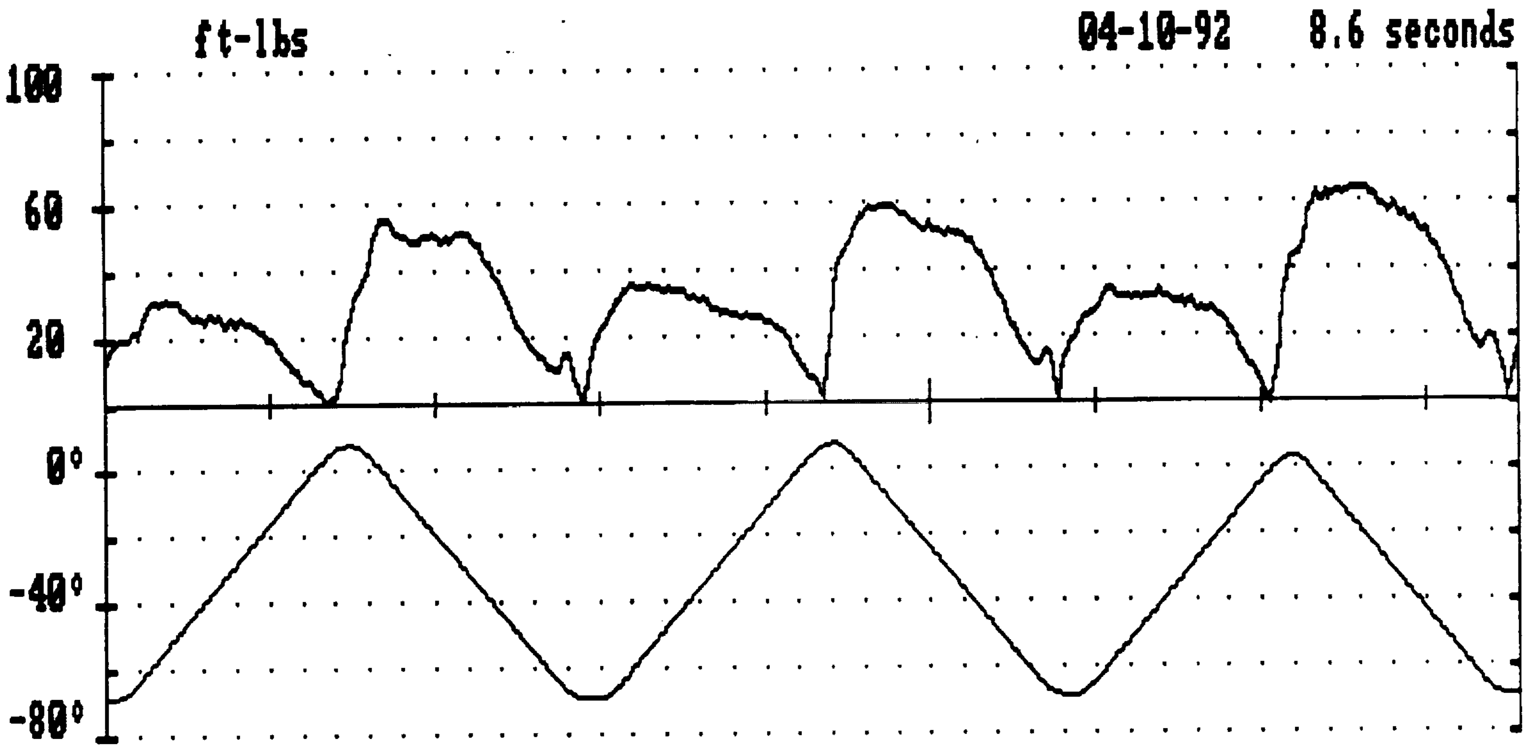
ABL - Man Systems Division
NASA Johnson Space Center
Houston, Tx 77058 (713) 483-4898

DATE: 04-10-92 LIDO TEST RESULTS TIME: 10:05:45

SHOULDER

NAME:
ID#1: ID#2:
PHYSICIAN:
CLINICIAN:
PATHOLOGY:
DIAG/SURG:
COMMENTS:

WEIGHT (lb): 192
HEIGHT (in): 73
AGE:
DOM SIDE:
INV SIDE:
GENDER:



rep # 1 to 3

SHOULDER - right (supine)	flex	ext
average peak torque (ft-lbs)	34	59
Peak torque (ft-lbs)	36	64
average joint angle at peak torque	-58°	-6°
average range of motion	75°	75°
fatigue index (%)	108%	119%
total work done (ft-lbs)	94	167

Con/Con
Velocity 60/60

Extreme ROM
-69° to 8°

LOREDAN
Sac., Calif.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Contractor Report - Final

4. TITLE AND SUBTITLE
ASTRONAUT CANDIDATE STRENGTH MEASUREMENT USING THE CYBEX II AND LIDO MULTI-JOINT II DYNAMOMETERS

5. FUNDING NUMBERS
NAS 9-17900

6. AUTHOR(S)
A. E. Carroll LESC
R. P. Wilmington LESC

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lockheed Engineering & Sciences Company (LESC)
2400 NASA ROAD 1, C95
Houston, TX 77058

8. PERFORMING ORGANIZATION REPORT NUMBER
LESC 30277

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Anthropometry and Biomechanics Laboratory
Lyndon B. Johnson Space Center
Houston, TX 77058

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Technical Monitor - G. Klute/SP34

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unlimited/unclassified

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS
STRENGTH MEASUREMENT, DYNAMOMETERS, CYBEX, LIDO

15. NUMBER OF PAGES
27

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	unlimited