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**OPERATOR'S MANUAL FOR VARIABLE WEIGHT,
VARIABLE C.G. HELMET SIMULATOR
(Reprint)**

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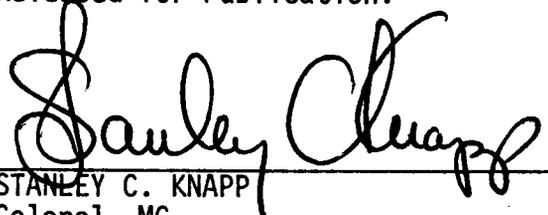
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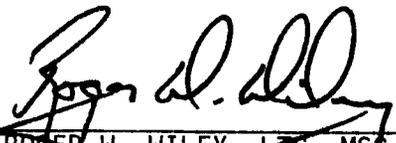


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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A variable weight, variable CG helmet simulator has been designed to measure the effect of US Army headgear on muscle loading and fatigue. The helmet simulator consists of two weight concealment boxes attached to opposite sides of a supporting head which in turn is mounted on the wearer's head by a suspension system taken from an SPH-4 helmet. The weight and CG can be altered by positioning variable weights within the concealment boxes.		

FORWARD

The helmet simulator was developed under a subcontract of U. S. Army Contract DAMD-17-80-C-0089 awarded to Wright State University, Dayton, Ohio. The subcontractor was Simula, Inc., Tempe, Arizona.

Mr. Craig M. Svoboda, project engineer, and Mr. James C. Warrick, project manager, Simula, Inc., did the developmental work and prepared this report. The U. S. Army Aeromedical Research Laboratory (USAARL) requested and received permission from Simula, Inc., to reprint and distribute the report.

CPT John C. Johnson,* Biodynamics Research Division, USAARL, served as the contracting officer's technical representative for the project.

Copies of this report have been requested by other government agencies; therefore, it is being reprinted to insure wider distribution. The contract efforts support the U. S. Army Aeromedical Research Laboratory's ongoing biodynamic research projects.

*CPT John C. Johnson is presently assigned to the Letterman Army Institute of Research, Persidio of San Francisco, California.

**OPERATOR'S MANUAL
FOR
VARIABLE WEIGHT,
VARIABLE C.G.
HELMET SIMULATOR**

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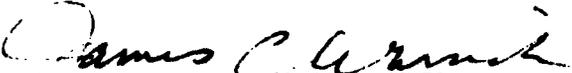
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OPERATOR'S MANUAL
FOR
VARIABLE WEIGHT, VARIABLE C.G.
HELMET SIMULATOR

1.0 DESCRIPTION

The helmet simulator consists of two weight concealment boxes attached to opposite sides of a support ring (headring) which in turn is supported upon the wearer's head by a suspension system taken from an SPH-4 helmet. The weight and c.g. can be altered by positioning variable weights within the concealment boxes. Fabric covers over the boxes prevent the test subjects from obtaining visual clues as to the c.g. location.

The minimum weight of the helmet simulator, without any variable weights in the boxes, is 2.5 lb, slightly less than the weight of most quality crash helmets made by reputable manufacturers. The addition of variable weights to the boxes can alter the center of gravity to simulate the effect of equipment attached to the outside of a helmet. The helmet simulator has been calibrated for weights of 3.2, 4.0, 5.0, 7.0, and 9.0 lb for each of the c.g. locations shown in Table 1. Figure 1 illustrates the range of c.g. variations together with definition of the coordinate axes by which the c.g. locations are measured.

As shown in Figure 1, a point midway between the left and right ear canals has been chosen as the origin of the coordinate axes. The helmet simulator has been provided with adjustment to ensure that an index point on it can be aligned with the ear canals, and also with independent adjustment to permit the suspension system to be made comfortable.

TABLE 1. SPECIFIC C.G. LOCATIONS FOR WHICH THE HELMET SIMULATOR IS CALIBRATED

C.G. Location Description*	Displacement (cm)**		
	X	Y	Z
<u>Central</u>			
Maximum Height	0	0	8.0
Medium Height	0	0	4.0
Low Height	0	0	0
<u>Forward</u>			
Maximum Height	5.0	0	8.0
Medium Height	5.0	0	4.0
Low Height	5.0	0	0
<u>Aftward</u>			
Maximum Height	-2.5	0	8.0
Medium Height	-2.5	0	4.0
Low Height	-2.5	0	0
<u>Central</u>			
Left, Maximum Height	0	2.5	8.0
Left, Medium Height	0	2.5	4.0
Left, Low Height	0	2.5	0
<u>Central</u>			
Right, Maximum Height	0	-2.5	8.0
Right, Medium Height	0	-2.5	4.0
Right, Low Height	0	-2.5	0
<u>Forward</u>			
Left, Maximum Height	4.3	1.8	8.0
Left, Medium Height	4.3	1.8	4.0
Left, Low Height	4.3	1.8	0
<u>Forward</u>			
Right, Maximum Height	4.3	-1.8	8.0
Right, Medium Height	4.3	-1.8	4.0
Right, Low Height	4.3	-1.8	0

*C.G. locations for total weights of less than 4 lb may differ from values shown in this table. See Tables 2 through 8 for exact locations.

**Displacement from head and neck c.g. (axis directions as defined in Figure 1).

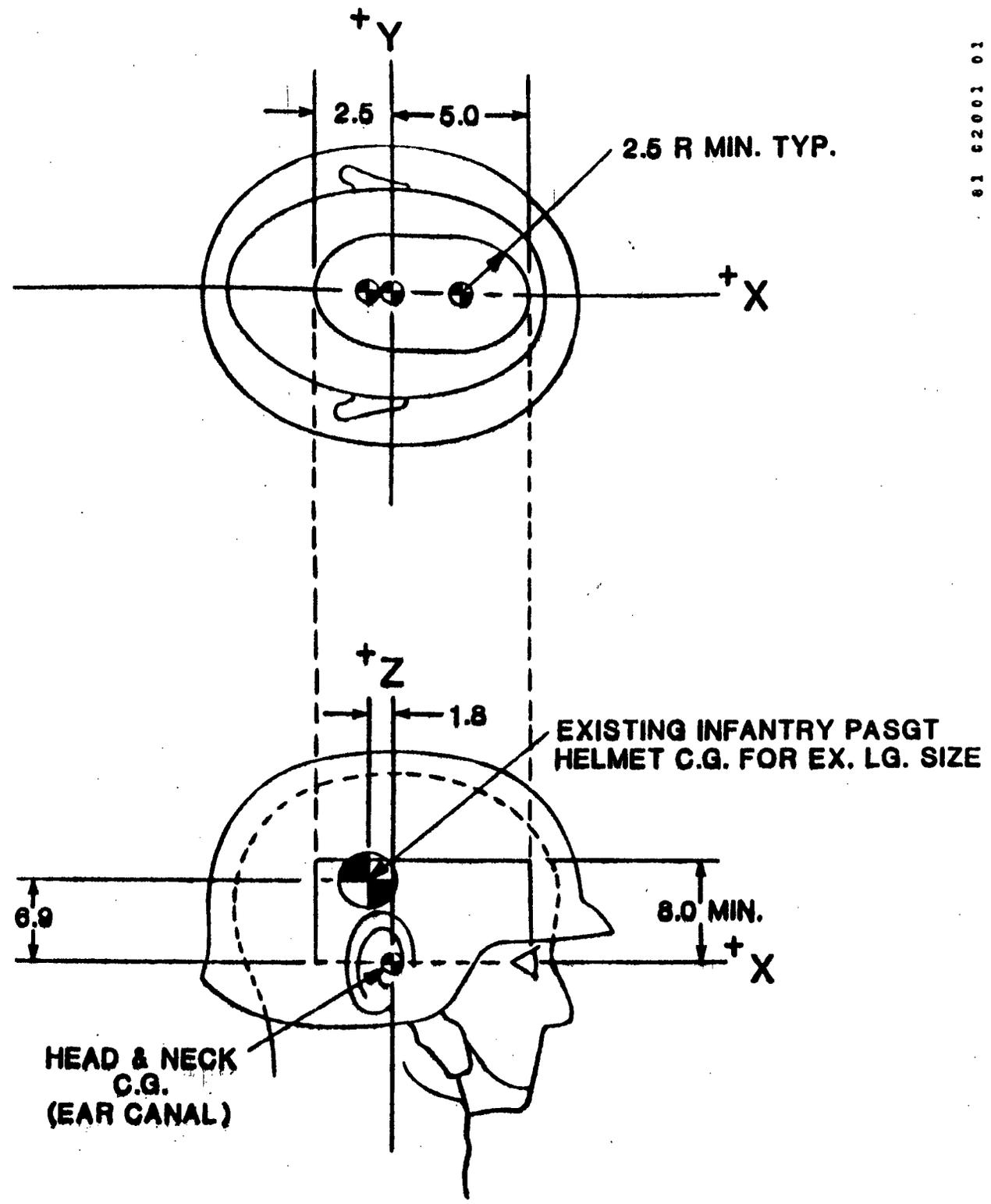


Figure 1. C.G. variation required for test helmet(s)
(all dimensions in centimeters).

2.0 ADJUSTMENT TO FIT WEARER'S HEAD

Fitting of the helmet simulator to the subject's head should be as follows:

- 2.1 Remove all weights, weight support tubes, and fabric covers from the concealment boxes.
- 2.2 Place the device on the subject's head.
- 2.3 Adjust the headband suspension buckle.
- 2.4 While applying downward pressure upon the helmet handle to compress the hair, adjust the crown strap buckles (3 places) to permit comfortable vertical positioning of the earcups on the wearer's ears.
- 2.5 Snap and adjust chin strap, also adjust rear earcup retainer strap buckle.
- 2.6 With helmet sitting squarely upon subject's head, readjust all straps.
- 2.7 Determine if ear canals are aligned with holes in concealment boxes. If not, loosen the screw attaching one of the weight boxes to the head ring, slide the box to the correct position, then retighten the screw. Repeat for the other box.
- 2.8 Repeat the preceding steps, if necessary, to obtain snug and comfortable fit.

3.0 ADJUSTMENT OF VARIABLE WEIGHTS

Weights can be installed in the concealment boxes, either with the helmet in place on the subject's head, or with the helmet removed and placed upon a table out of view of the subject.

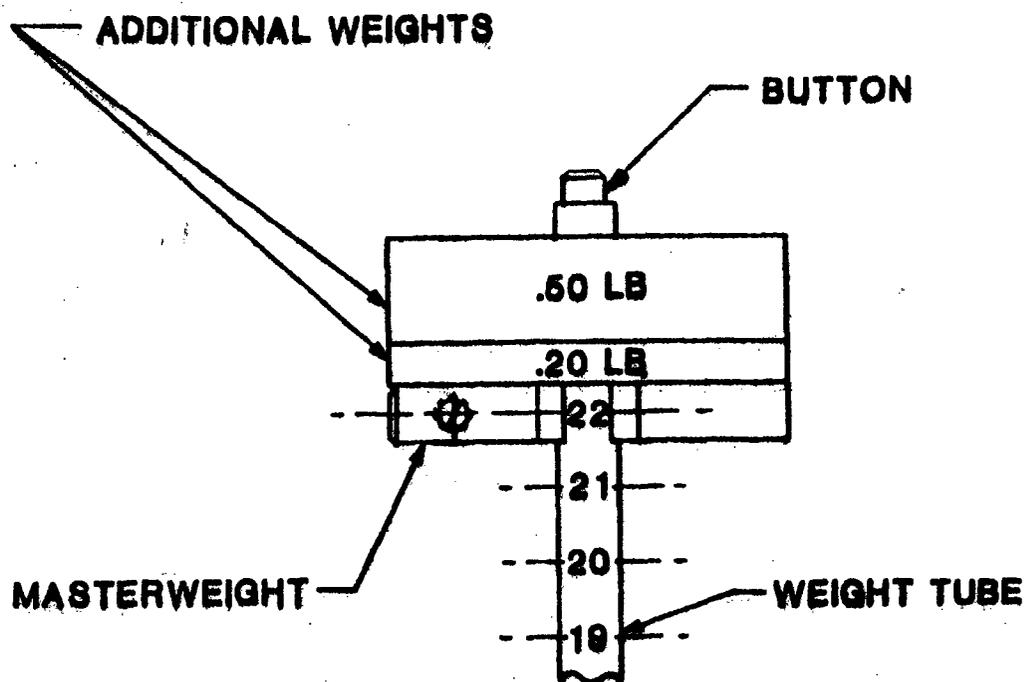
Tables 2 through 8 identify, for chosen combinations of weights and c.g. locations, the quantity of variable weights which must be added to each concealment box and the location of the weights within each box.

The installation of weights can best be understood by studying the following example:

EXAMPLE: Suppose that it has been chosen to test a c.g. location that is forward, to the left, and high. This condition is found in Table 7. Now suppose the total desired weight is 4.0 lb. This condition is found in row two of that table.

Remove the weight tube from the left-hand weight box (if this has not already been done) by pressing on the button and swinging the top of the tube out of the box. Pull the lock pin in the master weight out of engagement with the tube but not completely out of the master weight. Reposition the master weight on the tube so that graduation 22 appears in the window formed by the notch in the master weight as shown in Figure 2, and re-engage the lock pin with the tube. Additional weights, one each 0.2 lb and 0.5 lb, should then be assembled to that side of the master weight which has higher numbered tube graduations.

After loading the left-hand tube with the correct weights, install it by inserting the 3/16-in. diameter end of the tube into hole V in the bottom of the left-hand box. Depress the button at the top of the tube and swing the top of the tube into the box, allowing the button to engage with that hole which is in line with the bottom of the tube.



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Figure 2. Appearance of weights loaded onto weight tube.

Verify correctness of weight location and quantity. Notice that both the left-hand weight tube and weight concealment box are color coded yellow.

Attach fabric cover, using velcro patches.

Follow similar procedure for the right-hand box: position the master weight at graduation 22; add one each weights of 0.1 and 0.2 lb; and position tube in right-hand box at hole U. Verify correctness, noting that both right-hand weight tube and right-hand box are color coded white. It is NOT necessary for left-hand and right-hand weights to be positioned at identical graduations.

4.0 RECALIBRATION OF HELMET SIMULATOR

Refer to Appendix A for information concerning recalibration if it becomes necessary to perform tests with weight and c.g. combinations other than those for which the helmet simulator has already been calibrated.

TABLE 2. CENTRAL X, CENTRAL Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code)					Right-hand (R.H.) Box						
				Left-hand (L.H.) Box				Position of L.H. Tube in L.H. Box	Right-hand (R.H.) Box				Position of R.H. Tube in R.H. Box		
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of Master Weight on R.H. Tube	Additional Weights (lb)					
X	Y	Z	0.1		0.2	0.5	1.0	0.1		0.2	0.5	1.0			
				Quantity					Quantity						
0	0	6.8	3.2	23	1	-	-	-	H	23	1	-	-	-	H
0	0	8	4	22	-	-	1	-	J	22	-	-	1	-	J
		High	5	19	-	-	-	1	J	19	-	-	-	1	J
			7	16	-	-	-	2	K	16	-	-	-	2	K
			9	14	-	-	-	3	K	14	-	-	-	3	K
			4	3.2	9	1	-	-	-	H	9	1	-	-	-
		Med	4	11	-	-	1	-	J	11	-	-	1	-	J
			5	10	-	-	-	1	J	10	-	-	-	1	J
			7	10	-	-	-	2	K	10	-	-	-	2	K
			9	8	-	-	-	3	K	8	-	-	-	3	K
		2.6	3.2	2	1	-	-	-	H	2	1	-	-	-	H
		1	4	2	-	-	1	-	J	2	-	-	1	-	J
		0	5	2	-	-	-	1	J	2	-	-	-	1	J
		0	7	3	-	-	-	2	K	3	-	-	-	2	K
		0	9	3	-	-	-	3	K	3	-	-	-	3	K

TABLE 3. FORWARD X, CENTRAL Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code) Left-hand (L.H.) Box					Right-hand (R.H.) Box						
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
					0.1	0.2	0.5	1.0			0.1	0.2	0.5	1.0	
X	Y	Z		Quantity					Quantity						
4	0	6.8	3.2	23	1	-	-	-	Z	23	1	-	-	-	Z
5	0	8	4	22	-	-	1	-	X	22	-	-	1	-	X
		High	5	19	-	-	-	1	T	19	-	-	-	1	T
			7	16	-	-	-	2	R	16	-	-	-	2	R
			9	14	-	-	-	3	R	14	-	-	-	3	R
4	0		4	3.2	9	1	-	-	-	Z	9	1	-	-	-
5	0	4	4	11	-	-	1	-	X	11	-	-	1	-	X
		Med	5	10	-	-	-	1	T	10	-	-	-	1	T
			7	10	-	-	-	2	R	10	-	-	-	2	R
			9	8	-	-	-	3	R	8	-	-	-	3	R
4	0	2.6	3.2	2	1	-	-	-	Z	2	1	-	-	-	Z
5	0	1	4	2	-	-	1	-	X	2	-	-	1	-	X
		0	5	2	-	-	-	1	T	2	-	-	-	1	T
		0	7	3	-	-	-	2	R	3	-	-	-	2	R
		0	9	3	-	-	-	3	R	3	-	-	-	3	R

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TABLE 4. AFTWARD X, CENTRAL Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code) Left-hand (L.H.) Box					Right-hand (R.H.) Box						
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
					0.1	0.2	0.5	1.0			Quantity	0.1	0.2	0.5	
X	Y	Z													
-1.4	0	6.8	3.2	23	1	-	-	-	A	23	1	-	-	-	A
-2.5	0	8	4	22	-	-	1	-	C	22	-	-	1	-	C
		High	5	19	-	-	-	1	E	19	-	-	-	1	E
			7	16	-	-	-	2	F	16	-	-	-	2	F
			9	14	-	-	-	3	G	14	-	-	-	3	G
-1.4	0	4	3.2	9	1	-	-	-	A	9	1	-	-	-	A
-2.5	0	4	4	11	-	-	1	-	C	11	-	-	1	-	C
		Med	5	11	-	-	-	1	E	11	-	-	-	1	E
			7	10	-	-	-	2	F	10	-	-	-	2	F
			9	8	-	-	-	3	G	8	-	-	-	3	G
-1.4	0	2.6	3.2	2	1	-	-	-	A	2	1	-	-	-	A
-2.5	0	1	4	2	-	-	1	-	C	2	-	-	1	-	C
		0	5	2	-	-	-	1	E	2	-	-	-	1	E
		0	7	3	-	-	-	2	F	3	-	-	-	2	F
		0	9	3	-	-	-	3	G	3	-	-	-	3	G

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TABLE 5. CENTRAL X, LEFT Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code) Left-hand (L.H.) Box					Right-hand (R.H.) Box						
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
X	Y	Z	0.1		0.2	0.5	1.0	0.1			0.2	0.5	1.0		
				Quantity					Quantity						
0	1.3	6.8	3.2	23	-	1	-	-	H	23	-	-	-	-	H
0	2.5	8	4	22	1	1	1	-	J	21	-	1	-	-	J
		High	5	19	1	1	-	1	J	18	-	1	1	-	J
			7	16	-	-	1	2	J	16	-	-	1	1	J
			9	14	1	-	1	3	J	14	-	2	-	2	J
0	1.3		4	3.2	9	2	-	-	-	H	9	-	-	-	-
0	2.5	4	4	11	1	1	1	-	J	10	-	1	-	-	J
		Med	5	11	1	1	-	1	J	10	-	1	1	-	J
			7	9	-	-	1	2	J	9	-	-	1	1	J
			9	8	1	-	1	3	J	8	-	2	-	2	J
0	1.3	2.6	3.2	2	-	1	-	-	H	2	-	-	-	-	H
0	2.5	1	4	2	1	1	1	-	J	2	-	1	-	-	J
		0	5	2	1	1	-	1	J	2	-	1	1	-	J
		0	7	3	-	-	1	2	J	3	-	-	1	1	J
		0	9	3	1	-	1	3	J	3	-	2	-	2	J

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TABLE 6. CENTRAL X, RIGHT Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code) Left-hand (L.H.) Box				Right-hand (R.H.) Box							
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
					0.1	0.2	0.5	1.0			0.1	0.2	0.5	1.0	
X	Y	Z		Quantity					Quantity						
0	-1.3	5.8	3.2	23	-	-	-	-	H	23	-	1	-	-	H
0	-2.5	8	4	21	-	1	-	-	J	22	1	1	1	1	J
		High	5	18	-	1	1	-	J	19	1	1	-	1	J
			7	16	-	-	1	1	J	16	-	-	1	2	J
			9	14	-	2	-	2	J	14	1	-	1	3	J
0	-1.3	4	3.2	9	-	-	-	-	H	9	-	1	-	-	H
0	-2.5	4	4	10	-	1	-	-	J	11	1	1	1	-	J
		Med	5	10	-	1	1	-	J	11	1	1	-	1	J
			7	9	-	-	1	1	J	9	-	-	1	2	J
			9	8	-	2	-	2	J	8	1	-	1	3	J
0	-1.3	2.6	3.2	2	-	-	-	-	H	2	-	1	-	-	H
0	-2.5	1	4	2	-	1	-	-	J	2	1	1	1	-	J
		0	5	2	-	1	1	-	J	2	1	1	-	1	J
		0	7	3	-	-	1	1	J	3	-	-	1	2	J
		0	9	3	-	2	-	2	J	3	1	-	1	3	J

TABLE 7. FORWARD X, LEFT Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code)					Right-hand (R.H.) Box						
				Left-hand (L.H.) Box				Position of L.H. Tube in L.H. Box	Right-hand (R.H.) Box				Position of R.H. Tube in R.H. Box		
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of Master Weight on R.H. Tube	Additional Weights (lb)					
X	Y	Z	0.1		0.2	0.5	1.0	Quantity		0.1	0.2	0.5	1.0	Quantity	
4.0	1.3	6.8	3.2	23	-	1	-	-	Z	23	-	-	-	-	Z
4.3	1.8	8	4	22	-	1	1	-	V	22	1	1	-	-	U
		High	5	19	-	1	-	1	S	19	1	1	1	-	S
			7	16	1	1	-	2	R	16	-	1	1	1	Q
			9	14	-	2	-	3	Q	14	1	-	1	2	P
4.0	1.3	4	3.2	9	-	1	-	-	Z	9	-	-	-	-	Z
4.3	1.8	Med	4	10	-	1	1	-	V	11	1	1	-	-	U
			5	10	-	1	-	1	S	10	1	1	1	-	S
			7	9	1	1	-	2	R	10	-	1	1	1	Q
			9	8	-	2	-	3	Q	8	1	-	1	2	P
4.0	1.3	2.6	3.2	2	-	1	-	-	Z	2	-	-	-	-	Z
4.3	1.8	1	4	2	-	1	1	-	V	2	1	1	-	-	U
		0	5	2	-	1	-	1	S	2	1	1	1	-	S
		0	7	4	1	1	-	2	R	3	-	1	1	1	Q
		0	9	3	-	2	-	3	Q	3	1	-	1	2	P

TABLE 8. FORWARD X, RIGHT Y, VARIABLE Z, AND WEIGHT

C.G. Location (cm)			Total Weight (lb)	(Yellow color code) Left-hand (L.H.) Box				Right-hand (R.H.) Box							
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
					0.1	0.2	0.5	1.0			0.1	0.2	0.5	1.0	
X	Y	Z		Quantity					Quantity						
4.0	-1.3	6.8	3.2	23	-	-	-	-	Z	23	-	1	-	-	Z
4.3	-1.8	8	4	22	1	1	-	-	U	22	-	1	1	-	V
		High	5	19	1	1	1	-	S	19	-	1	-	1	S
			7	16	-	1	1	1	Q	16	1	1	-	2	R
			9	14	1	-	1	2	P	14	-	2	-	3	Q
4.0	-1.3		4	3.2	9	-	-	-	-	Z	9	-	1	-	-
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			7	10	-	1	1	1	Q	9	1	1	-	2	R
			9	8	1	-	1	2	P	8	-	2	-	3	Q
4.0	-1.3	2.6	3.2	2	-	-	-	-	Z	2	-	1	-	-	Z
4.3	-1.8	1	4	2	1	1	-	-	U	2	-	1	1	-	V
		0	5	2	1	1	1	-	S	2	-	1	-	1	S
		0	7	3	-	1	1	1	Q	4	1	1	-	2	R
		0	9	3	1	-	1	2	P	3	-	2	-	3	Q

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APPENDIX A

RECALIBRATION

1. Place helmet on scale and add variable weights to provide the desired total weight.
2. Assemble the balsa wood calibration brackets to the helmet and drill into each bracket a hole which is in line with the desired c.g. (see Figure A-1).
3. Hang the helmet from a string or cable passing through the new hole in one bracket, and shift the weights to level the helmet. (A bubble level attached to the helmet may facilitate this.) See Figure A-2.
4. Repeat for the hole in the other bracket (See Figure A-3).
5. Record the weight quantity and location on a copy of data sheet (Figure A-4).

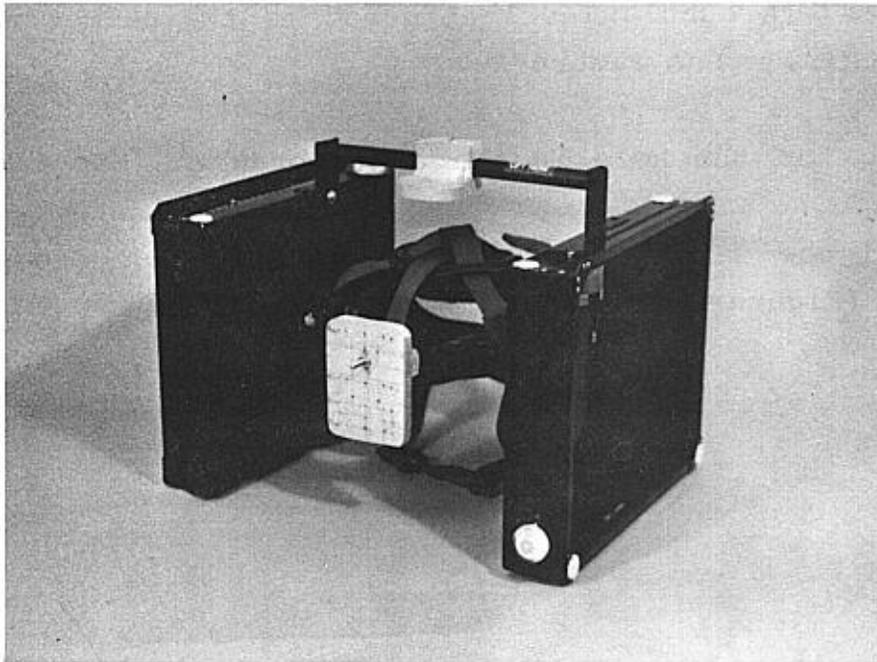
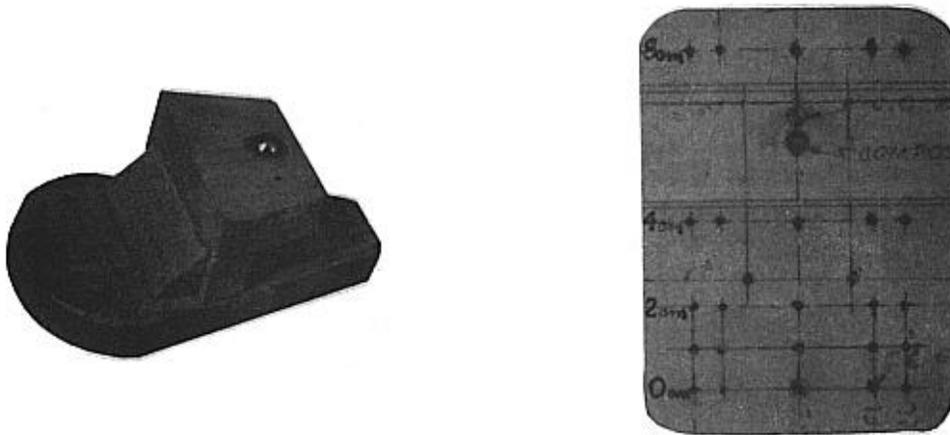


Figure A-1. Balsa wood calibration brackets and assembly on helmet.

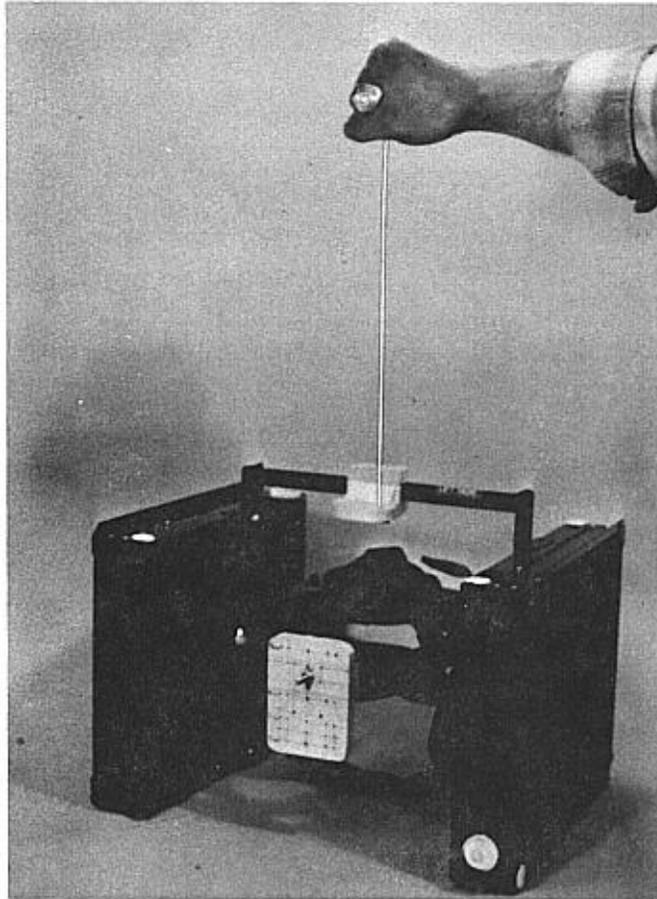


Figure A-2. Suspend helmet by cable attached to proper hole in top bracket. Shift weights between left-hand and right-hand boxes to balance laterally, and shift weight tubes from hole-to-hole to balance in the fore-and-aft direction.

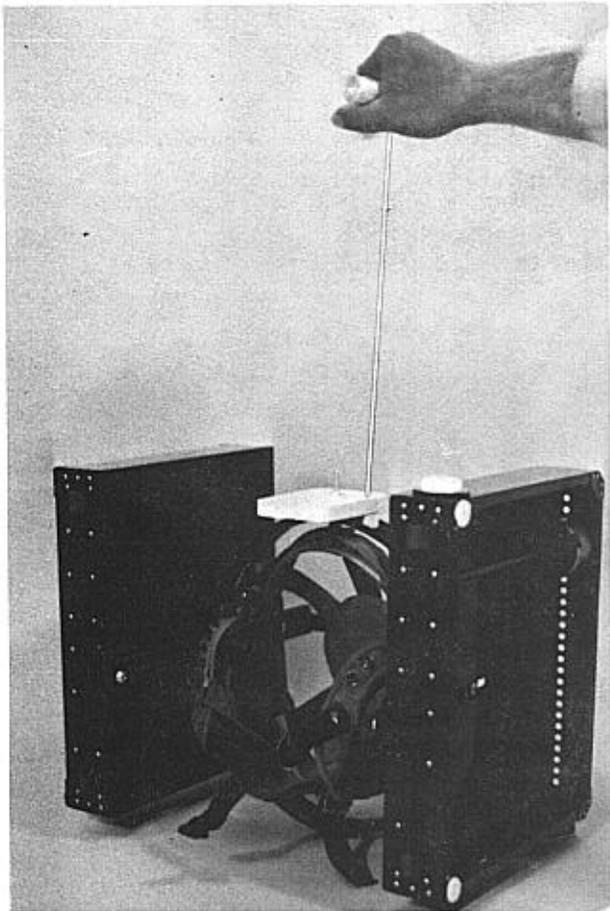
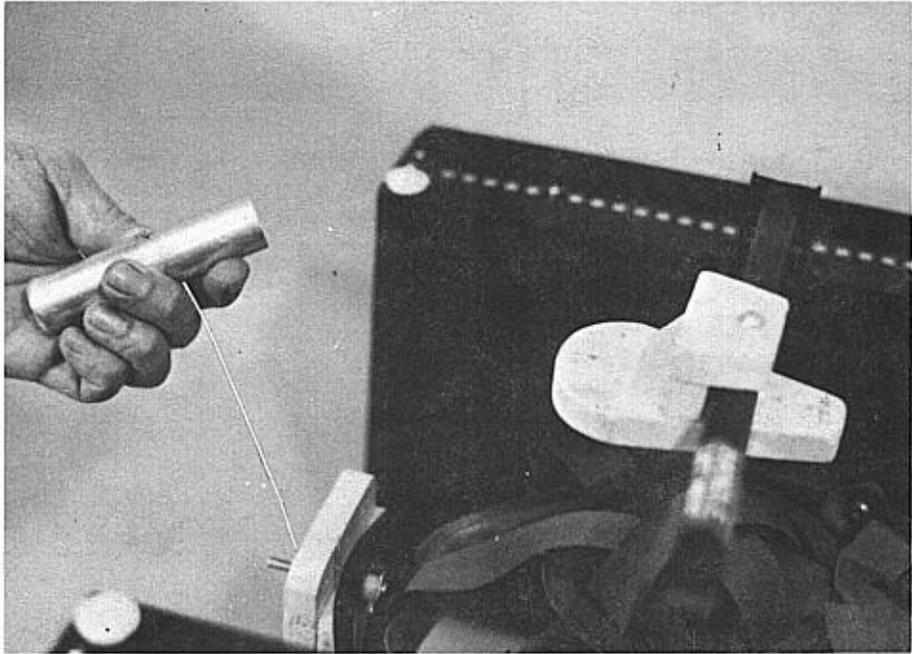


Figure A-3. Relocate cable to proper hole in front bracket, hang helmet and adjust position of weights on each weight tube to balance helmet with aid of bubble level.

A-5

C.G. Location (cm)			Total Weight (lb)	Left-hand (L.H.) Box				Right-hand (R.H.) Box							
				Position of Master Weight on L.H. Tube	Additional Weights (lb)				Position of L.H. Tube in L.H. Box	Position of Master Weight on R.H. Tube	Additional Weights (lb)				Position of R.H. Tube in R.H. Box
X	Y	Z			0.1	0.2	0.5	1.0			0.1	0.2	0.5	1.0	
				Quantity					Quantity						
			High	4											
				5											
				7											
				9											
			Med	4											
				5											
				7											
				9											
			Low	4											
				5											
				7											
				9											

Figure A-4. Sample data sheet.