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DEVELOPMENT OF AN INTERACTIVE COMPUTER PROGRAM TO PRODUCE BODY DESCRIPTION DATA

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NOTICES

TECHNICAL REVIEW AND APPROVAL

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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This report documents program GEBOD (GEnerator of BODy data) an interactive computer program which produces the body description portion of the ATB (Articulated Total Body) Model input deck. The ATB Model simulates the motion and dynamic properties of the human body during events such as aircraft flight seat ejection and automobile crashes. This simulation requires the mass, center of gravity location, contact surface dimensions, joint locations, principal moments

SUMMARY

Program GEBOD was developed in order to automate production of the body description portion of the ATB Model input deck. The ATB Model simulates the motion of the human body during dynamic events such as automobile crashes and aircraft cockpit ejections. It requires mass, center of gravity location, contact surface dimensions, principal moments of inertia and their associated directions for each of 15 body segments. Additionally, the ATB Model requires data locating the 14 joints that connect the body segments for body description.

The starting point for program GEBOD was a program written by Calspan Corporation named program GOOD, which was also designed to produce body description data for crash simulation models. A series of modifications and improvements to program GOOD resulted in program GEBOD. This report details those modifications and improvements.

PREFACE

Work described in this report was performed by the University of Dayton Research Institute (UDRI) under Contract No. F33615-81-C-0513. Principal investigator for UDRI was Mr. L. Douglas Baughman. Sponsor of the contract was the Modeling and Analysis Branch of the Air Force Aerospace Medical Research Laboratory (AFAMRL/BBM). Dr. Ints Kaleps (Chief, AFAMRL/BBM) acted as technical advisor for the work described in this report. The author would like to thank Mrs. Charlene Dunson of UDRI for her careful typing of this report.

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GLOSSARY OF TERMS

Anthropometry: The study of human body dimensions.

Axilla: The arm pit.

Iliocristale: The most superior point on the rim of the pelvic bone.

Inertial Properties: The mass, center of gravity location, principal moments of inertia and associated directions of a body.

Numerical Integration: Approximating the value of an integral by arithmetic computations.

Tenth Rib: The lowest palapable rib in the mid-axillary line.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AFAMRL/BBM - Modeling and Analysis Branch of the Air Force Aerospace Research Laboratory.

ATB Model - Articulated Total Body Model.

CVS - Crash Victim Simulator.

DD_i - The i^{th} measurement of the set of 32 body measurements used by both program GEBOD and program.

GOOD - Generator Of Occupant Data.

GEBOD - Generator Of Body Data.

ROS - Revised Occupant Simulator.

UDRI - University of Dayton Research Institute.

SECTION 1
INTRODUCTION

The development of mathematical/computer models capable of predicting the motion of the human body in a dynamic environment has created a need for extensive data describing human geometry and inertial properties. These models have been used to predict body motion during events such as automobile crashes and aircraft cockpit ejections and are capable of pointing out potentially hazardous designs for these two environments. Various methods have been utilized to obtain the required body description data: predominantly the use of cadavers (eg., Chandler, et al., 1975 and Walker et al., 1973) and mathematically constructing geometric models of the human body (eg., Hanavan, 1964).

Calspan Corporation developed Program GOOD (Generator Of Occupant Data, Bartz and Gianotti, 1973) in order to automate the production of input data sets for the Crash Victim Simulator (CVS) Program (Bartz, 1971, also Fleck et al., 1975), and the Revised Occupant Simulator (ROS) Model (Segal, 1971). Both of these are computer programs developed by Calspan for the simulation of occupant dynamics during automobile crashes, the ROS Model in two dimensions, and the CVS Program in three-dimensions. The Articulated Total Body (ATB) Model (Fleck and Butler, 1975, also Butler and Fleck, 1980) was developed from the CVS Program, by incorporating modifications to provide the additional capabilities needed to simulate the various aspects of aircraft cockpit ejections. These modifications were performed by Calspan Corporation under the sponsorship of the Modeling and Analysis Branch of the Air Force Aerospace Medical Research Laboratory (AFAMRL/BBM), and were incorporated into the previous CVS Program as user available options.

The ATB Model performs simulations by viewing the human body as a series of connected rigid bodies, each referred to as a body segment. The ATB Model is flexible as to how many segments are used in modeling the human body. The standard configuration, presently being used, consists of 15 segments, which is illustrated in Figure 1. For each of these body segments the ATB Model requires segment mass, principal moments of inertia, and semiaxes of an ellipsoid approximating the shape of the body segment. Also required are the locations of joints connecting the body segments.

The subject of this report is the development of an interactive computer program which will produce data sets for the ATB Model corresponding to specific types and sizes of human beings. This program has been named GEBOD (Generator of Body Data) and is an extensively modified version of Calspan's Program GOOD, with modifications being done by the University of Dayton Research Institute (UDRI). The changes made to Program GOOD in the development of GEBOD include the following:

1. an interactive format for the input of parameters describing the subject for which body description data is to be produced

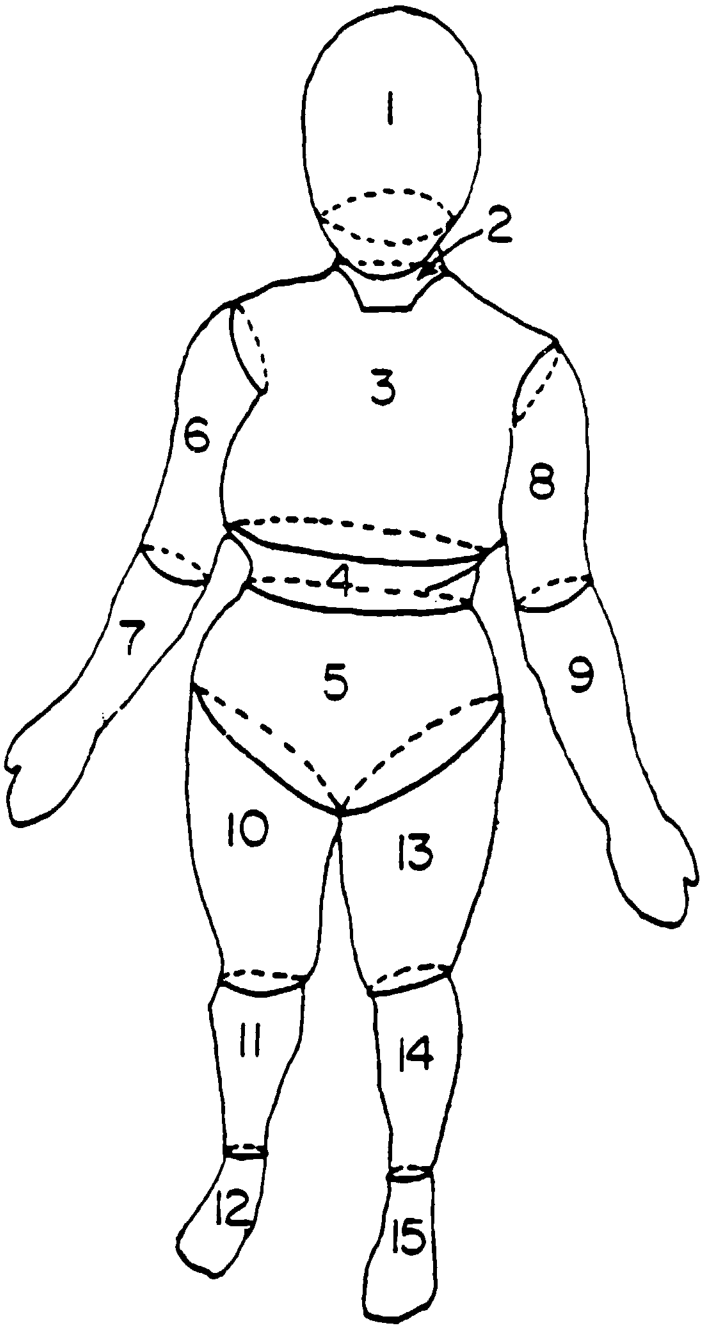
2. body dimensions are obtained from regression equations instead of using a fixed percentile (see Appendix C)

3. restructuring the torso segments (thorax, abdomen, and pelvis)

4. development of a new technique for determinign inertial properties of the torso and the feet segments

5. the units used for handling of data within the program were changed and allowance was made for results to be output in either metric or English units

6. format changes of the output making it compatible with the most recent version of the ATB Model.



1. Head
2. Neck
3. Thorax
4. Abdomen
5. Pelvis
6. Right Upper Arm
7. Right Lower Arm
8. Left Upper Arm
9. Left Lower Arm
10. Right Thigh
11. Right Calf
12. Right Foot
13. Left Thigh
14. Left Calf
15. Left Foot

Figure 1. Fifteen Segment Configuration Commonly Used With Articulated Total Body (ATB) Model.

SECTION 2
BODY DIMENSION SET

All the computations performed by Program GOOD are based on a set of 32 body measurements. These are used to determine sizes of body segments and the location of joints connecting them. GEBOD also uses this set of body measurements, which is listed in Table 1. Through the remainder of this report references to the i^{th} body measurement will be made as DD_i.

GEBOD has two ways of obtaining values for the required 32 body measurements. These measurements can either be read in from a disk file placed on the computer system by a user of GEBOD, or they can be generated by GEBOD using regression equations. There are three groups of regression equations stored within GEBOD. These groups correspond to possible subject types: adult male, adult female, or child. Within each group there are regression equations for each of the 32 body measurements. Both the adult male and the adult female groups contain three regression equations for each body measurement: one against height, one against weight, and the third a stepwise multiple regression equation against both height and weight. The child group contains four regression equations per body measurement: one against height, one against weight, one against age, and the fourth a stepwise multiple regression against height, weight and age. These different regression equations were developed to provide the user a flexible means for generating data sets.

All of the regression equations stored in GEBOD were computed from data in the AFAMRL Anthropometric Data Bank. A survey containing data on 2,420 male flying personnel of the U.S. Air Force (Grunhofer and Kroh, 1975) was used in the development of the adult male regression equations. For the adult female regressions a survey consisting of data on 1,905 women in the U.S. Air Force (Clauser, et al., 1972) was utilized. The child regression equations were computed from survey consisting of data on 3,782 children aged two to twenty years,

TABLE 1

CORRESPONDENCE BETWEEN 32 BODY DIMENSION USED AND THEIR SOURCES

i	DIMENSION NAME	CHILDREN'S POPULATION	ADULT FEMALE POPULATION	ADULT MALE POPULATION
-1	Age	L_{101}	--	--
0	Weight	L_1	L_2	L_2
1	Standing Height	L_2	L_7	L_{13}
2	Shoulder Height	L_{61}	L_{10}	L_{15}
3	Armpit Height	L_{62}	$L_{10} - L_{53}/\pi$	$L_{15} - L_{103}/\pi$
4	Waist Height	L_{69}	L_{13}	L_{21}
5	Seated Height	L_9	L_{23}	L_{32}
6	Head Length	L_{20}	L_{96}	L_{150}
7	Head Breadth	L_{19}	L_{97}	L_{156}
8	Head to Chin Height	L_{25}	L_{104}	L_{179}
9	Neck Circumference	L_{32}	L_{36}	L_{66}
10	Shoulder Breadth	L_{36}	L_{63}	L_{50}
11	Chest Depth	SEMI(L_{64}, L_{63})	L_{74}	L_{62}
12	Chest Breadth	L_{64}	L_{65}	L_{52}
13	Waist Depth	SEMI(L_{67}, L_{66})	L_{75}	L_{63}
14	Waist Breadth	L_{67}	L_{67}	L_{53}
15	Buttock Depth	SEMI(L_{72}, L_{71})	L_{77}	L_{64}
16	Hip Breadth, Standing	L_{72}	L_{68}	L_{55}
17	Shoulder to Elbow Length	L_{37}	L_{31}	L_{42}
18	Forearm-Hand Length	L_{41}	$L_{32} + L_{91}$	$L_{44} + L_{17} - L_{18}$
19	Biceps Circumference	L_{39}	L_{55}	$(L_{104} + L_{105} + L_{106} + L_{107})/4$
20	Elbow Circumference	L_{43}	L_{59}	L_{109}
21	Forearm Circumference	L_{43}	L_{60}	L_{110}
22	Wrist Circumference	L_{45}	L_{62}	L_{112}
23	Knee Height, Seated	L_{15}	$L_{18} + L_{46}/(2\pi)$	L_{37}
24	Thigh Circumference	L_{77}	L_{45}	L_{96}
25	Upper Leg Circumference	$(L_{77} + L_{81})/2$	$(L_{45} + L_{46})/2$	L_{98}
26	Knee Circumference	$(L_{77} + L_{81})/2$	L_{46}	L_{99}
27	Calf Circumference	L_{81}	L_{47}	L_{100}
28	Ankle Circumference	L_{83}	L_{49}	L_{102}
29	Ankle Height, Outside	L_{85}	L_{21}	L_{31}
30	Foot Breadth	L_{87}	L_{95}	L_{127}
31	Foot Length	L_{86}	L_{94}	L_{125}

NOTE:

1) L_i refers to the i^{th} dimension of the appropriate anthropometric survey.

2) SEMI(a, b) is a function returning one axis length of an ellipse where b is the circumference of the ellipse, and a is its other axis length.

from throughout the United States (Synder, et al., 1977). In the case of the child regression equations, some of the regressions were based on data pertaining to only a subset of the total population.

None of the three anthropometric surveys used included all of the measurements needed. In those cases where a needed measurement was missing from a survey it was approximated from available measurements. Table 1 lists the measurements actually used from each survey and indicates any approximations made. Appendix D gives a complete listing of the regression equations computed.

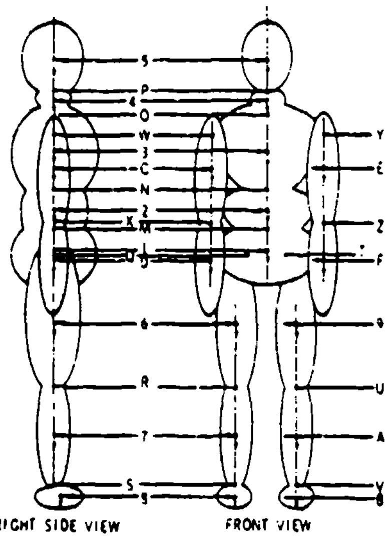
SECTION 3
BODY GEOMETRY

The structure and appearance of the human model as depicted by the ATB Model is determined from contact ellipsoid semiaxes and joint locations. A contact ellipsoid is associated with each body segment, giving the segment shape and providing an interaction surface between the segment and its environment. The joints connect segments and serve as pivot points about which rotational motion is allowed.

A joint is located relative to the two segments it connects (see Table 2). For example, the elbow joint is located by two sets of three-dimensional coordinates: one set relative to the local reference system of the upper arm; the other relative to the local reference system of the forearm. Local reference systems (also referred to as segment geometric axis systems) are located at each segment's center of mass with an arbitrary orientation. The orientation of each of these axis systems, relative to the geometry of its segment, may be chosen so as to provide maximum convenience in inputting data items to the ATB Model.

Each local reference axis system is fixed within its segment, and thus changes orientation as the orientation of its segment is changed. For use with GEBOD the local reference axis systems have been chosen so that they all have a common orientation when the model is an erect standing position, arms extended downward, and toes pointed straight down. When the segments are positioned as described the X axis of each local reference system points forward, each Y to the right, and each Z downward, all relative to the model (see Figure 2).

GEBOD computes joint locations by use of the expressions listed in Table 2. These expressions were developed by using the geometric center of each segment (the geometric center of a segment is the center of that segment's contact ellipsoid) as an approximation for its



LEGEND:

LOCAL REFERENCE SYSTEM ORIGINS		JOINTS	
1 - PELVIS	9 - LEFT THIGH	M - ABDOMEN-PELVIS	T - LEFT HIP
2 - ABDOMEN	A - LEFT CALF	N - THORAX-ABDOMEN	U - LEFT KNEE
3 - THORAX	B - LEFT FOOT	O - NECK-THORAX	V - LEFT ANKLE
4 - NECK	C - RIGHT UPPER ARM	P - HEAD-NECK	W - RIGHT SHOULDER
5 - HEAD	D - RIGHT FORE ARM	Q - RIGHT HIP	X - RIGHT ELBOW
6 - RIGHT THIGH	E - LEFT UPPER ARM	R - RIGHT KNEE	Y - LEFT SHOULDER
7 - RIGHT CALF	F - LEFT FORE ARM	S - RIGHT ANKLE	Z - LEFT ELBOW
8 - RIGHT FOOT			

NOTES:

1. EXCEPT IN THE CASE OF THE FEET THE LOCAL REFERENCE AXES ARE LABELED AS FOLLOWS:
   A. ALL VERTICAL AXES ARE Z AXES
   B. ALL HORIZONTAL AXES IN THE FRONT VIEW ARE Y AXES
   C. ALL HORIZONTAL AXES IN THE RIGHT SIDE VIEW ARE X AXES
2. IN THE CASE OF THE FEET THE LOCAL REFERENCE AXES ARE LABELED AS FOLLOWS:
   A. ALL VERTICAL AXES ARE X AXES
   B. BOTH HORIZONTAL AXES IN THE FRONT VIEW ARE Y AXES
   C. THE HORIZONTAL AXIS IN THE RIGHT SIDE VIEW IS THE Z AXIS
3. IN THE RIGHT SIDE VIEW ONLY LIMB SEGMENTS ON THE RIGHT SIDE OF THE BODY ARE SHOWN

Figure 2. Local Reference Axis Systems and Joint Locations Used By GEBOD to Prepare Input Data for the ATB Model.

center of gravity. Joint coordinates computed using these expressions, then, are not actually relative to segment local reference systems, but to a parallel set of axes located at the geometric center. Once GEBOD has computed the true location of the segment centers of gravity, the appropriate translation is applied to convert to the true local reference systems.

Relative to the segment axis systems described it has been possible to make certain assumptions, simplifying the development of the expressions for joint locations listed in Table 2. First, the X coordinate of all joints relative to appropriate local reference systems, with the exception of the ankles relative to the feet, are zero. Secondly, it is assumed that the only joints with non-zero Y local reference coordinates are the shoulders relative to the thorax and the hips relative to the pelvis (see Figure 2).

Using all the assumptions mentioned the expressions for joint locations as functions of body dimensions were developed, and are listed in Table 2. Similarly, expressions for contact ellipsoid semi-axes are listed in Table 3. Many of these expressions are very straightforward and in many cases have been taken directly from Program GOOD. Others, however, are more complicated and require further explanation.

3.1 DETERMINING EXPRESSIONS FOR JOINT LOCATIONS AND SEMIAXES OF TORSO SEGMENTS

The way in which the torso is divided into three segments is somewhat arbitrary and has varied over the time that the CVS Program and the ATB Model have been in existence. Program GOOD produces data describing an upper torso that only extends down to the axilla area, with the mid torso then extending from the axilla down to the waist. Present usage of the ATB model defines the mid torso or abdomen as extending from the tenth rib landmark to the iliocristale landmark, with the thorax being all of the torso above, and the pelvis being all of the torso below. Because of this change in the definition of torso segments, joint locations and semiaxes lengths were changed from those given by Program GOOD for the torso.

TABLE 2

JOINT LOCATIONS RELATIVE TO LOCAL REFERENCE AXIS SYSTEMS

JOINT	RELATIVE TO	LOCATION X	LOCATION Y	LOCATION Z
Abdomen pelvis	pelvis	0.0	0.0	$(DD_1-DD_5-DD_4+0.1(DD_2-DD_4))/2$
	abdomen	0.0	0.0	$(DD_2-DD_4)/10$
Thorax-abdomen	abdomen	0.0	0.0	$-(DD_2-DD_4)/10$
	thorax	0.0	0.0	$9(DD_2-DD_4)/20$
Neck-thorax	thorax	0.0	0.0	$-9(DD_2-DD_4)/20$
	neck	0.0	0.0	$(DD_1-DD_8-DD_2-\frac{DD_9}{2\pi})/2$
Head-neck	neck	0.0	0.0	$-(DD_1-DD_8-DD_2-\frac{DD_9}{2\pi})/2$
	head	0.0	0.0	$(DD_8+\frac{DD_9}{2\pi})/2$
Right hip	pelvis	0.0	$(DD_{16}-\frac{DD_{24}}{\pi})/2$	$(DD_4-(DD_2-DD_4)/10-DD_1+DD_5-\frac{DD_{24}}{\pi})/2$
	right thigh	0.0	0.0	$-(DD_1-DD_5-DD_{23}+\frac{DD_{26}}{\pi})/2$
Right knee	right thigh	0.0	0.0	$(DD_1-DD_5-DD_{23}+\frac{DD_{24}}{\pi})/2$
	right calf	0.0	0.0	$-(DD_{23}-DD_{29}+\frac{DD_{28}}{2\pi}-\frac{DD_{26}}{\pi})/2$
Right ankle	right calf	0.0	0.0	$(DD_{23}-DD_{29}-\frac{DD_{28}}{2\pi})/2$
	right foot	$\frac{DD_{29}}{2}$	0.0	$-(DD_{31}-\frac{DD_{28}}{\pi})/2$
Left hip	pelvis	0.0	$-(DD_{16}-\frac{DD_{24}}{\pi})/2$	$(DD_4-(DD_2-DD_4)/10-DD_1+DD_5-\frac{DD_{24}}{\pi})/2$
	left thigh	0.0	0.0	$-(DD_1-DD_5-DD_{23}+\frac{DD_{26}}{\pi})/2$
Left knee	left thigh	0.0	0.0	$(DD_1-DD_5-DD_{23}+\frac{DD_{24}}{\pi})/2$
	left calf	0.0	0.0	$-(DD_{23}-DD_{29}+\frac{DD_{28}}{2\pi}-\frac{DD_{26}}{\pi})/2$
Left ankle	left calf	0.0	0.0	$(DD_{23}-DD_{29}-\frac{DD_{28}}{2\pi})/2$
	left foot	$\frac{DD_{29}}{2}$	0.0	$-(DD_{31}-\frac{DD_{28}}{\pi})/2$
Right shoulder	thorax	0.0	$(DD_{10}-\frac{DD_{19}}{\pi})/2$	$-(DD_2-DD_3-\frac{DD_{19}}{2\pi})$
	right upper arm	0.0	0.0	$-(DD_{17}-\frac{DD_{19}}{\pi})/2$
Right elbow	right upper arm	0.0	0.0	$(DD_{17}-\frac{DD_{20}}{\pi})/2$
	right forearm	0.0	0.0	$-(DD_{18}-\frac{DD_{20}}{\pi})/2$

TABLE 2 (Continued)

Left shoulder	thorax	0.0	$-(DD_{10} - \frac{DD_{19}}{\pi})/2$	$-(DD_2 - DD_3 - \frac{DD_{19}}{2\pi})$
	left upper arm	0.0	0.0	$-(DD_{17} - \frac{DD_{19}}{\pi})/2$
Left elbow	left upper arm	0.0	0.0	$(DD_{17} - \frac{DD_{20}}{\pi})/2$
	left forearm	0.0	0.0	$-(DD_{18} - \frac{DD_{20}}{\pi})/2$

TABLE 3

CONTACT ELLIPSOID SEMIAXES

SEGMENT	X SEMIAXIS	Y SEMIAXIS	Z SEMIAXIS
Pelvis	$\frac{DD_{15}}{2}$	$\frac{DD_{16}}{2}$	$(DD_4+DD_5-DD_1-0.1(DD_2-DD_4))/2$
Abdomen	$\frac{DD_{13}}{2}$	$\frac{DD_{14}}{2}$	$(DD_2-DD_4)/10+\frac{DD_9}{\pi}$
Thorax	$\frac{DD_{11}}{2}$	$\frac{DD_{12}}{2}$	$.45(DD_2-DD_4)$
Neck	$\frac{DD_9}{2\pi}$	$\frac{DD_9}{2\pi}$	$(DD_1-DD_8-DD_2+\frac{DD_9}{2\pi})/2$
Head	$\frac{DD_6}{2}$	$\frac{DD_7}{2}$	$(DD_8+\frac{DD_9}{2\pi})/2$
Right and Left Thigh	$\frac{DD_{24}+DD_{25}}{4\pi}$	$\frac{DD_{24}+DD_{25}}{4\pi}$	$(DD_1-DD_5-DD_{23}+\frac{DD_{24}+DD_{26}}{\pi})/2$
Right and Left Calf	$\frac{DD_{27}}{2\pi}$	$\frac{DD_{27}}{2\pi}$	$(DD_{23}-DD_{29}+\frac{DD_{28}}{2\pi})/2$
Right and Left Foot	$\frac{DD_{29}}{2}$	$\frac{DD_{30}}{2}$	$\frac{DD_{31}}{2}$
Right and Left Upper Arm	$\frac{DD_{19}}{2\pi}$	$\frac{DD_{19}}{2\pi}$	$\frac{DD_{17}}{2}$
Right and Left Forearm	$\frac{DD_{21}}{2\pi}$	$\frac{DD_{21}}{2\pi}$	$\frac{DD_{18}}{2}$

Since none of the 32 body measurements being used give tenth rib height, the landmarks located in the two stereophotometric studies (Baughman, 1981 and McConville et al., 1980) were examined. It was found that the ratio of thorax height (vertical distance between suprasternale and tenth rib midspine) to abdomen height (vertical distance between tenth rib midspine and right iliocristale) averages about 4:1. Using this result the distance between the thorax-abdomen joint and the abdomen-pelvis height was set to be one-fifth of the difference between shoulder height and waist height $[(DD_2 - DD_4)/5]$.

When developing the expressions for torso joint locations, these locations were first laid out in a global setting, with axes origin on the floor (that is vertical distance from the floor). The top of the thorax was determined by shoulder height (DD_2), and the distance from the floor to the bottom of the pelvis was taken as the difference between standing height and seated height ($DD_1 - DD_5$). The center of the abdomen was then located by waist height (DD_4). The abdomen-pelvis joint and the thorax-abdomen joint were located so that the center of the abdomen is mid-way between these two joints (recall that the distance between these two joints is $[(DD_2 - DD_4)/5]$). The center of the thorax was then placed mid-way between the thorax abdomen joint and top of the torso, and the center of the pelvis was placed mid-way between the bottom of the pelvis and the abdomen-pelvis joint. From these global locations the expressions for local reference system coordinates of torso joints were determined.

The Z semiaxis of the pelvis contact ellipsoid is set to the distance from center of the pelvis to the abdomen-pelvis joint. This causes the pelvis contact ellipsoid to cover the pelvis vertically from the abdomen-pelvis joint to the bottom of the pelvis ($DD_1 - DD_5$), since the pelvis center is mid-way between these points. Similarly, the Z semiaxis of the thorax contact ellipsoid is set to the distance from center of the thorax to the thorax-abdomen joint, which results in the contact ellipsoid covering the thorax from the top of the thorax (DD_2) to the thorax-abdomen joint. For the resulting model to have a proper appearance there must be some overlap between adjacent contact ellipsoids. Since this overlap is primarily for appearance, the extent of overlap utilized is the neck radius ($DD_{29}/2\pi$). This is the amount that the abdomen contact ellipsoid overlaps both the thorax contact ellipsoid and the pelvis contact ellipsoid.

3.2 DETERMINING EXPRESSIONS FOR JOINT LOCATIONS AND SEMIAXES OF THE HEAD AND NECK

As in the torso, segment centers and joint locations involving the head and neck were first laid out globally. First, the top of the head was placed at standing height (DD_1), and the neck-thorax joint was placed at shoulder height (DD_2). In order to provide overlap the Z semiaxis of the head is set to one half the quantity head height plus neck radius

$$[(DD_8 + \frac{DD_9}{2\pi})/2].$$

The center of the head is then determined by standing height minus the Z semiaxis of the head, and the head-neck joint is located by standing height minus twice the Z semiaxis of the head. The center of the neck is located mid-way between the head-neck joint and the neck-thorax joint. The top of the neck contact ellipsoid is desired to be at standing height minus head height ($DD_1 - DD_8$), so the Z semiaxis of the neck contact ellipsoid is set to the distance between this location and the center of the neck.

3.3 DETERMINING EXPRESSIONS FOR ANKLE LOCATIONS RELATIVE TO THE FEET

As with other limb segments, the Z reference axis of either foot runs the length of the segment (from heel to toe, see Figure 2). For simplicity in developing expresssion for joint locations, the foot is viewed in a normal position for a standing model. This rotates the foot reference system 90° from the reference system of other systems, i.e. Z forward, X upward, and Y to the right. The ankle joint is then a vertical distance of ankle height (DD_{29}) from the bottom of the foot, or one half this distance from the center of the foot. In the Z-horizontal direction the ankle joint is located as being ankle radius ($DD_{29}/2\pi$) in front of the back of the foot, and the center of the foot is located at one-half foot length ($DD_{31}/2$) from the back of the foot in this direction.

3.4 DETERMINING EXPRESSIONS FOR JOINT LOCATIONS AND SEMIAXES OF LIMB SEGMENTS

The remainder of the joint and semiaxis expressions were taken directly from Program GOOD. A concept used in developing expressions for many of these semiaxes and joint locations is that of spherical joints. The usage of this concept is illustrated in Figure 3.

3.5 CONCLUSION

Using the criteria discussed, the expressions in Table 2 for joint locations and the expressions in Table 3 for contact ellipsoid semiaxes have been developed. When used with a set of the 32 body dimensions corresponding to a subject of a specific type and size, these expressions provide values necessary to determine the structure and appearance of the human model utilized by the ATB Model.

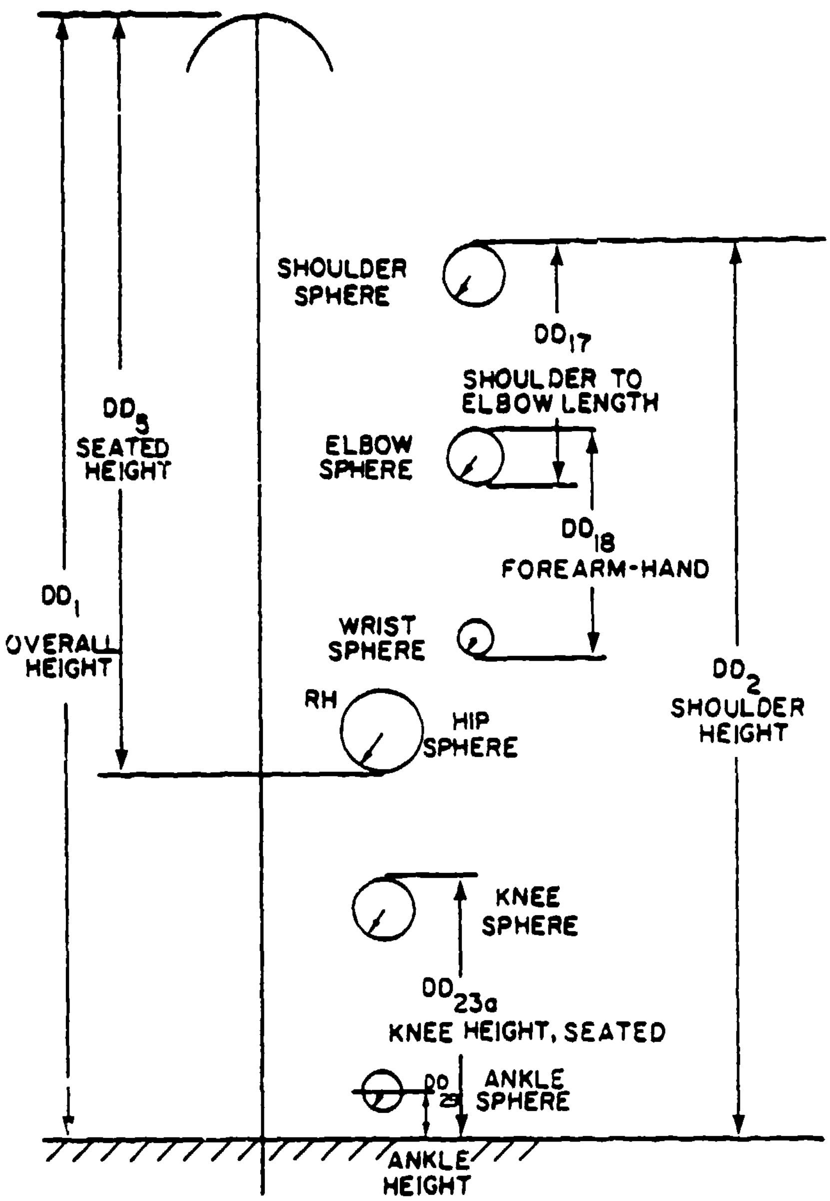


Figure 3. Spherical Joint Concept Developed for Program GOOD and Used to Determine Joint Locations Relative to Limb Segments.

Radii of these spheres are as follows:

Shoulder Sphere	$DD_{19}/(2\pi)$
Elbow Sphere	$DD_{20}/(2\pi)$
Wrist Sphere	$DD_{22}/(2\pi)$
Hip Sphere	$DD_{24}/(2\pi)$
Knee Sphere	$DD_{26}/(2\pi)$
Ankle Sphere	$DD_{28}/(2\pi)$

SECTION 4
INERTIAL PROPERTIES OF BODY SEGMENTS

The inertial properties of a body refer to its mass, principal moments of inertia and associated directions, and the location of its center of gravity. The ATB Model requires direct input of the mass and principal moments of inertia of each segment, as well as the directions of the principal moments, relative to the local reference axes. Use of local reference axis systems, which are located with respect to segment centers of gravity, to specify joint locations indirectly locate the segment centers of gravity. Thus, direct input of center of gravity locations to the ATB Model is not necessary.

The distribution of mass within the human body greatly affects the inertial properties. For simplicity it is assumed that the human body is homogeneous, and thus, each individual body segment is homogeneous and has the same density as does all the other body segments.

Program GOOD determines inertial properties of a segment by calculating the inertial properties of that segment's contact ellipsoid (see Appendix E). These inertial properties are then taken as approximations to the inertial properties of the segment. The density used in these computations is determined by first computing the volume of all the contact ellipsoids combined. From this total a density may be determined such that the mass of all the segments combined will equal the desired total mass of the body (DD_0).

Program GEBOD also uses this technique for computation of inertial properties of the head, neck, upper and forearms, and thighs and calves. For the torso segments and the feet GEBOD uses a technique similar to that developed by Leet (1978). This involves modeling a segment by a right elliptical solid that satisfies two criteria:

1) each horizontal cross section (parallel to the local reference XY plane) is an ellipse,
2) the center of each of these elliptical cross sections lies on the Z local reference axis.

The inertial properties of this model are then calculated and taken as approximations to the inertial properties of the segment.

The right elliptical solid used for the torso segments is illustrated in Figure 4a. It consists of four pieces. The top is a semi-ellipsoid. Below this are two elliptical frustrums. The bottom of the model consists of another semi-ellipsoid. The right and left feet use identical models which are elliptical frustrums. The dimensions of the frustrums and ellipsoids used in these models are determined from the body dimension data as indicated in Figures 4a and 4b.

Numerical integration is used to compute interial properties of the right elliptical solids. Successive approximations are made to the model by stacks of elliptical cylinders. Within each approximation all cylinders are of the same height. Each successive approximation uses more cylinders of a lesser height than the previous. After each approximation the combined volume of all cylinders within the stack is compared back to the combined volume of the previous stack. When the difference between these two volumes drops below a specified tolerance level, the inertial properties of the combined stack of cylinders (see Appendix E) are taken as the inertial properties of the right elliptical solid. These inertial properties are then used as approximations to the inertial properties of the segment in question.

Program GEBOD determines the density to be used in computation of inertial properties in much the same way as does Program GOOD. The combined volume of all models used to determine inertial properties (both ellipsoids and right elliptical solids) is computed and a density is determined so that the total mass of these models will equal the desired total body mass (DD_0). The ratic of this density to the density of water (which approximates average human body density) is listed with other results of Program GEBOD as a weight correction factor.

The center of gravity of the models used to approximate segment inertial properties are taken by GEBOD as the true locations of segment centers of gravity. In developing expressions for joint

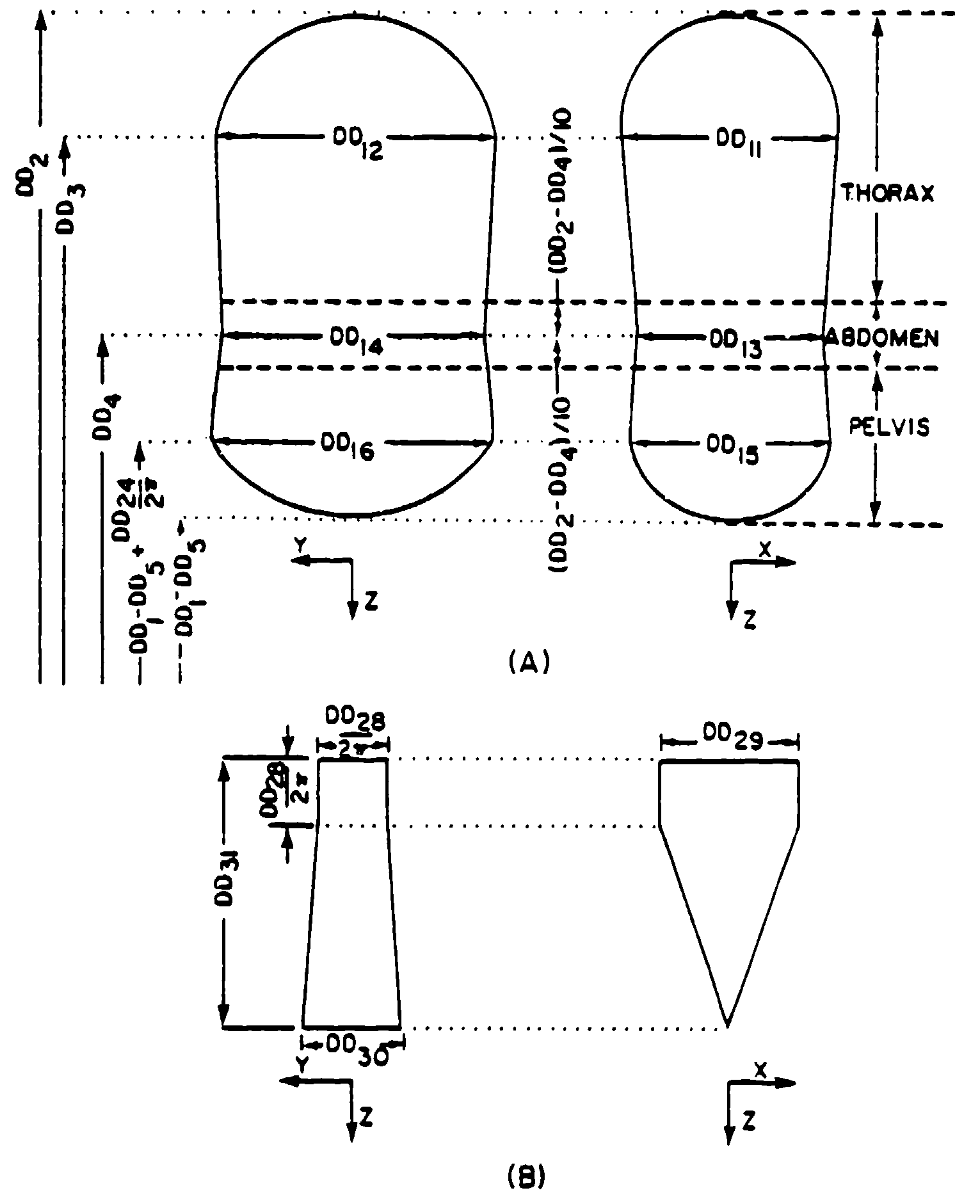


Figure 4. Cross Sections of Right Elliptical Solids Used to Approximate Segment Inertial Properties.

(a) Solid used with thorax segments.
(b) Solid used with feet segments.

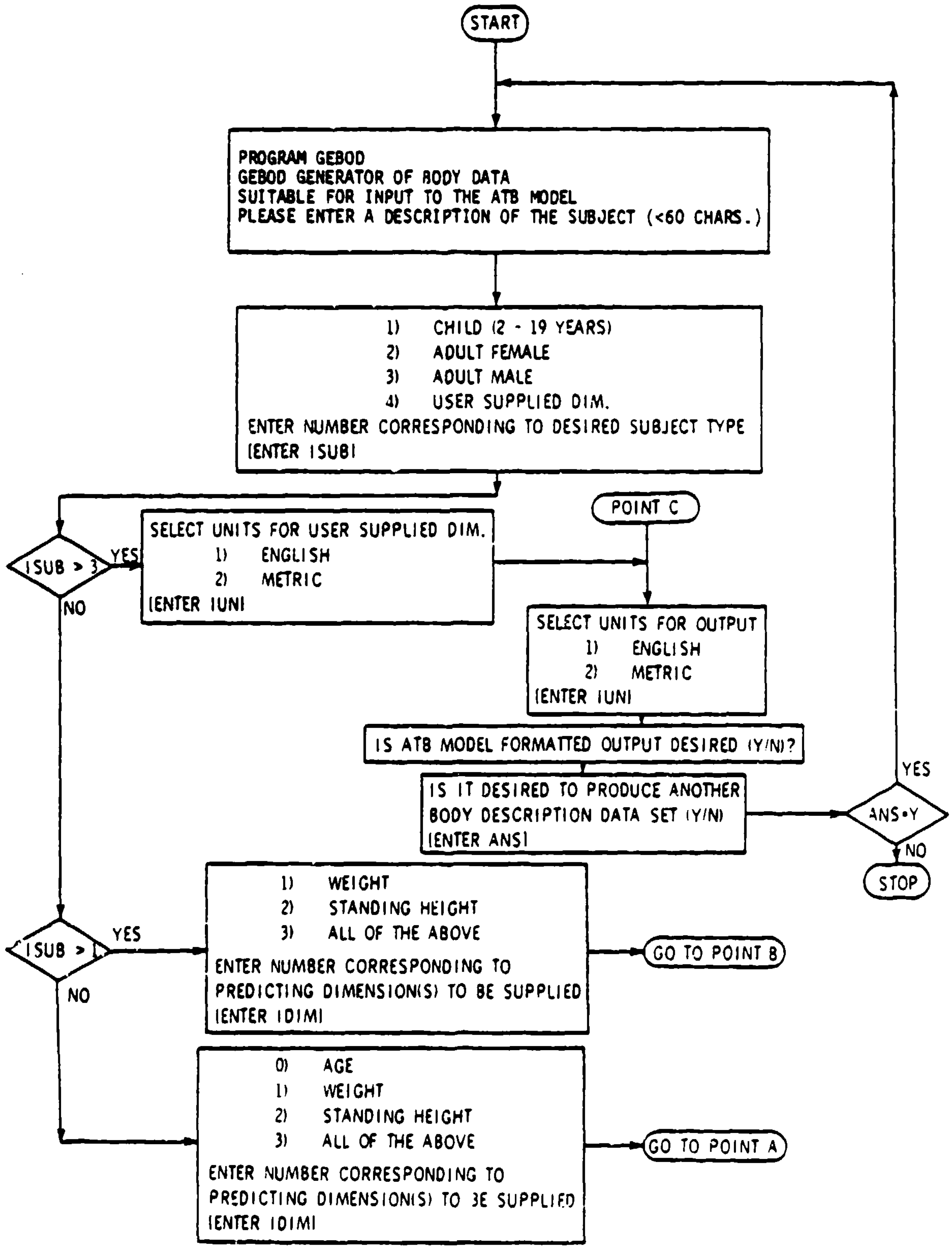
locations (see Section 3), the origins of local reference systems (i.e., segment centers of gravity) were approximated by contact ellipsoid centers. Once GEBOD has developed the models for inertial properties joint location coordinates must be converted, corresponding in each case to a translation of axes from a contact ellipsoid center to the center of gravity of the model used to compute inertial properties. Since an ellipsoid is completely symmetrical, its center of gravity is located at its center, which agrees with the assumed location of the local reference systems. The right elliptical solids, however, are only symmetric about the Z axis. So, in general, the location of the center of gravity of this model does not correspond with its center in the Z direction. The torso segments and feet segments, which use this type model in computation of their inertial properties, are the only segments in which the center of gravity does not coincide with the center of the contact ellipsoid. Because this moves the location of the local reference system of these segments in the Z direction, the Z coordinates of joints located relative to these segments are adjusted for this change, after computation of inertial properties. This adjustment of joint Z coordinates completes the computations performed by GEBOD in order to determine body description data.

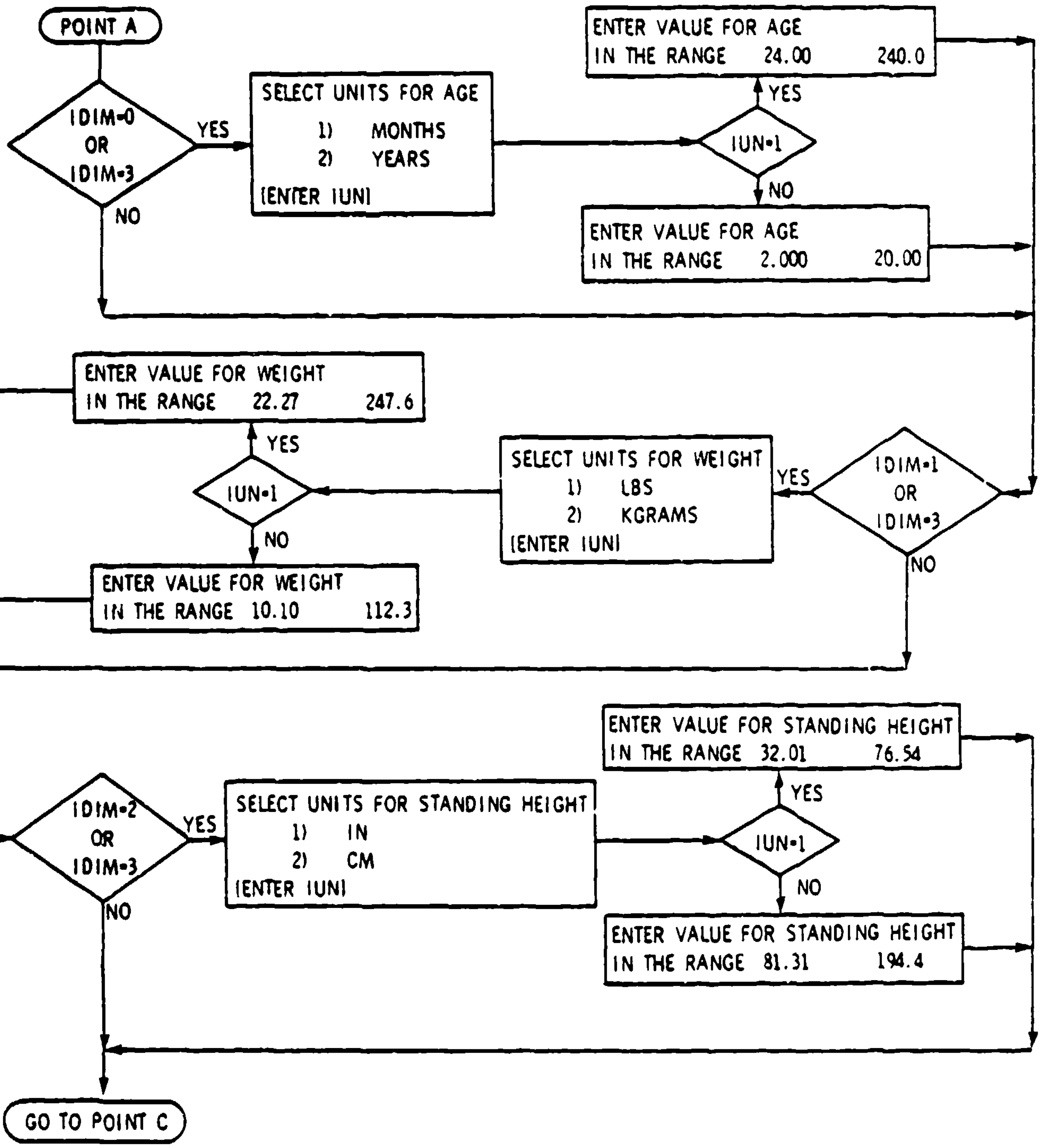
APPENDIX A
USER'S GUIDE

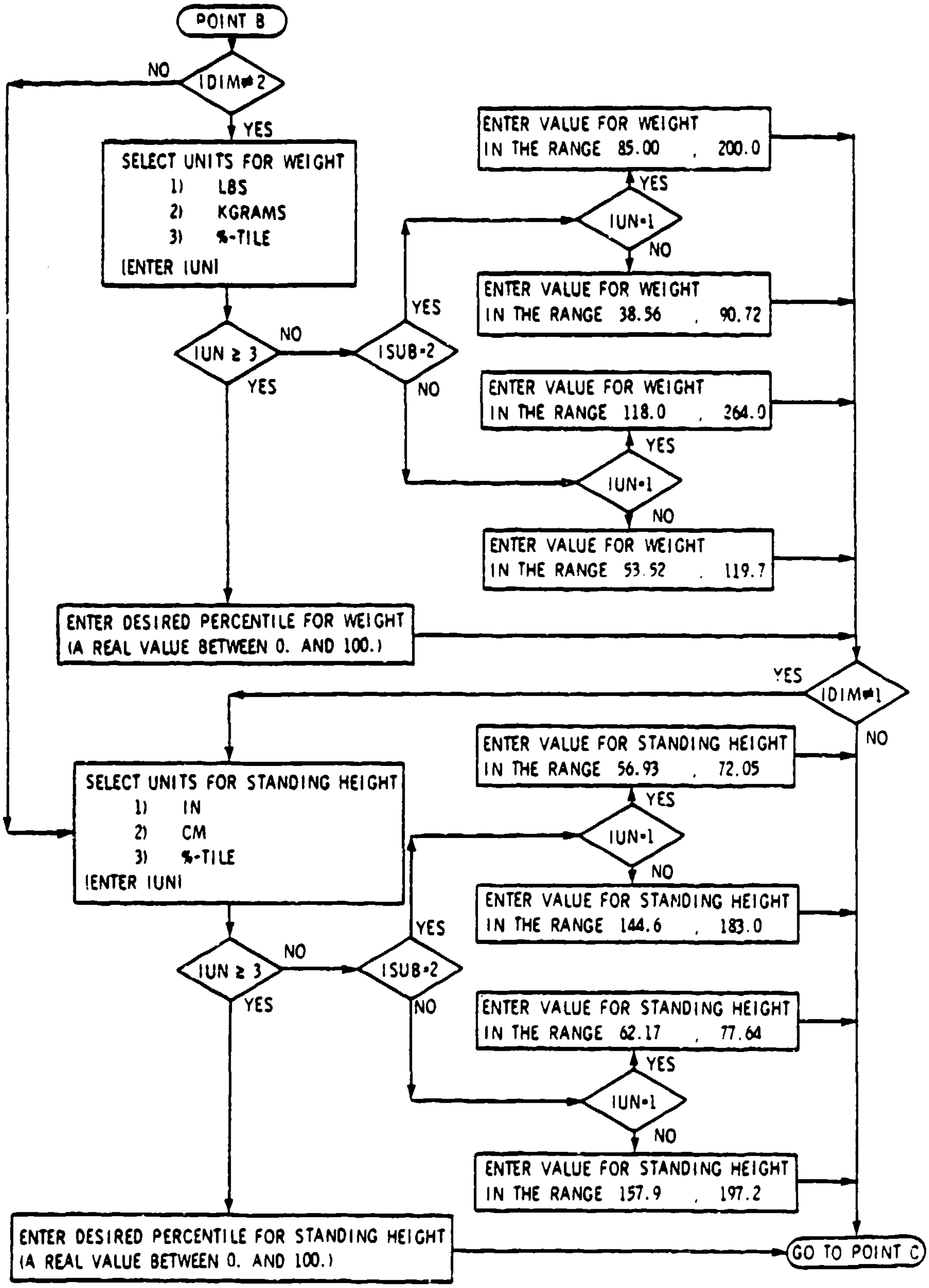
The computer program GEBOD was written in Perkin-Elmer Fortran VII and was developed and tested on the Perkin-Elmer 3240 located at Building 441, Wright-Patterson Air Force Base; Dayton, Ohio. This version of the Fortran VII programming language meets the ANSI '77 standard for Fortran, and thus, GEBOD should be portable to any system supporting an ANSI '77 standard Fortran.

GEBOD utilizes five logical units. Prompts for the user are written to logical unit 5. User input is received through unit 7. Body description data produced by GEBOD is written to both units 3 and 9. Data written to unit 3 is ready for insertion into the ATB Model input deck, whereas the data written to unit 9 (see Appendix B), is a tabular presentation of the data. If the user chooses to supply a specific set of the 32 body dimensions (see Table 1), this data is received through unit 1. The data must be supplied in four 80 character records, each record containing values for 8 of the body measurements. The values for the body measurements are listed in sequential order on these records with each record using an (8F10.3) format.

The remainder of this appendix is a flowchart describing options available to the user of GEBOD.


START
PROGRAM GEBOD
GEBOD GENERATOR OF BODY DATA
SUITABLE FOR INPUT TO THE ATB MODEL
PLEASE ENTER A DESCRIPTION OF THE SUBJECT (<60 CHARS.)
1) CHILD (2 - 19 YEARS)
2) ADULT FEMALE
3) ADULT MALE
4) USER SUPPLIED DIM.
ENTER NUMBER CORRESPONDING TO DESIRED SUBJECT TYPE
(ENTER ISUB)
ISUB > 3
YES
NO
SELECT UNITS FOR USER SUPPLIED DIM.
1) ENGLISH
2) METRIC
(ENTER IUN)
POINT C
SELECT UNITS FOR OUTPUT
1) ENGLISH
2) METRIC
(ENTER IUN)
IS ATB MODEL FORMATTED OUTPUT DESIRED (Y/N)?
IS IT DESIRED TO PRODUCE ANOTHER BODY DESCRIPTION DATA SET (Y/N)
(ENTER ANS)
ANS•Y
YES
NO
STOP
ISUB > 1
YES
NO
1) WEIGHT
2) STANDING HEIGHT
3) ALL OF THE ABOVE
ENTER NUMBER CORRESPONDING TO PREDICTING DIMENSION(S) TO BE SUPPLIED
(ENTER IDIM)
GO TO POINT B
0) AGE
1) WEIGHT
2) STANDING HEIGHT
3) ALL OF THE ABOVE
ENTER NUMBER CORRESPONDING TO PREDICTING DIMENSION(S) TO BE SUPPLIED
(ENTER IDIM)
GO TO POINT A


POINT A
IDIM=0 OR IDIM=3
YES
NO
SELECT UNITS FOR AGE
1) MONTHS
2) YEARS
(ENTER IUN)
IUN=1
YES
NO
ENTER VALUE FOR AGE
IN THE RANGE 24.00 240.0
ENTER VALUE FOR AGE
IN THE RANGE 2.000 20.00
IDIM=1 OR IDIM=3
SELECT UNITS FOR WEIGHT
1) LBS
2) KGRAMS
(ENTER IUN)
ENTER VALUE FOR WEIGHT
IN THE RANGE 22.27 247.6
ENTER VALUE FOR WEIGHT
IN THE RANGE 10.10 112.3
IDIM=2 OR IDIM=3
SELECT UNITS FOR STANDING HEIGHT
1) IN
2) CM
(ENTER IUN)
ENTER VALUE FOR STANDING HEIGHT
IN THE RANGE 32.01 76.54
ENTER VALUE FOR STANDING HEIGHT
IN THE RANGE 81.31 194.4
GO TO POINT C


POINT B
IDIM≠2
NO
YES
SELECT UNITS FOR WEIGHT
1) LBS
2) KGRAMS
3) %-TILE
(ENTER IUN)
IUN ≥ 3
NO
YES
ISUB=2
YES
NO
IUN=1
YES
NO
ENTER VALUE FOR WEIGHT IN THE RANGE 85.00 , 200.0
ENTER VALUE FOR WEIGHT IN THE RANGE 38.56 , 90.72
ENTER VALUE FOR WEIGHT IN THE RANGE 118.0 , 264.0
ENTER VALUE FOR WEIGHT IN THE RANGE 53.52 , 119.7
ENTER DESIRED PERCENTILE FOR WEIGHT (A REAL VALUE BETWEEN 0. AND 100.)
IDIM≠1
SELECT UNITS FOR STANDING HEIGHT
1) IN
2) CM
3) %-TILE
(ENTER IUN)
ENTER VALUE FOR STANDING HEIGHT IN THE RANGE 56.93 , 72.05
ENTER VALUE FOR STANDING HEIGHT IN THE RANGE 144.6 , 183.0
ENTER VALUE FOR STANDING HEIGHT IN THE RANGE 62.17 , 77.64
ENTER VALUE FOR STANDING HEIGHT IN THE RANGE 157.9 , 197.2
ENTER DESIRED PERCENTILE FOR STANDING HEIGHT (A REAL VALUE BETWEEN 0. AND 100.)
GO TO POINT C

APPENDIX B

SAMPLE OUTPUT FROM PROGRAM GEBOD

TEST OF 5'10" MALE WEIGHING 150LB.

ADULT MALE

SELECTED BODY DIMENSIONS

	WEIGHT	150.0	LBS
	STANDING HEIGHT	70.00	IN

COMPUTED BODY DIMENSIONS

0	WEIGHT	68.04	KGRAMS
1	STANDING HEIGHT	177.8	CM
2	SHOULDER HEIGHT	145.1	CM
3	ARMPIT HEIGHT	130.4	CM
4	WAIST HEIGHT	107.2	CM
5	SEATED HEIGHT	93.12	CM
6	HEAD LENGTH	19.74	CM
7	HEAD BREADTH	15.42	CM
8	HEAD TO CHIN HEIGHT	22.79	CM
9	NECK CIRCUMFERENCE	36.63	CM
10	SHOULDER BREADTH	40.01	CM
11	CHEST DEPTH	22.58	CM
12	CHEST BREADTH	30.80	CM
13	WAIST DEPTH	20.03	CM
14	WAIST BREADTH	28.39	CM
15	BUTTOCK DEPTH	21.75	CM
16	HIP BREADTH, STANDING	33.59	CM
17	SHOULDER TO ELBOW LENGTH	36.05	CM
18	FOREARM-HAND LENGTH	49.41	CM
19	BICEPS CIRCUMFERENCE	29.01	CM
20	ELBOW CIRCUMFERENCE	30.19	CM
21	FOREARM CIRCUMFERENCE	26.74	CM
22	WRIST CIRCUMFERENCE	17.03	CM
23	KNEE HEIGHT, SEATED	55.61	CM
24	THIGH CIRCUMFERENCE	53.79	CM
25	UPPER LEG CIRCUMFERENCE	36.74	CM
26	KNEE CIRCUMFERENCE	37.30	CM
27	CALF CIRCUMFERENCE	34.92	CM
28	ANKLE CIRCUMFERENCE	21.41	CM
29	ANKLE HEIGHT, OUTSIDE	13.83	CM
30	FOOT BREADTH	9.601	CM
31	FOOT LENGTH	26.88	CM

WEIGHT CORRECTION FACTOR = 1.110

TEST OF 5'10" MALE WEIGHING 150LB.

CRASH VICTIM PARAMETERS (3-D)

SEGMENT NO.	SYM	PLOT	MASS (KG.)	SEGMENT MOMENT OF INERTIA (KG-M**2) X	Y	Z	SEGMENT CONTACT ELLIPSOID SEMIAXIS (CM) X	Y	Z	CENTER (CM) X	Y	Z
1	LT	1	11.389	0.10929	0.06578	0.10943	10.88	16.79	9.37	0.00	0.00	-0.28
2	CT	2	3.856	0.02210	0.01184	0.03018	10.01	14.20	9.62	0.00	0.00	-0.02
3	UT	3	16.787	0.21751	0.17534	0.13616	11.29	15.40	17.04	0.00	0.00	-1.78
4	N	4	1.244	0.00241	0.00241	0.00170	5.83	5.83	7.88	0.00	0.00	0.00
5	H	5	5.062	0.02696	0.03084	0.01601	9.87	7.71	14.31	0.00	0.00	0.00
6	RUL	6	7.004	0.12632	0.12632	0.01465	7.20	7.20	29.03	0.00	0.00	0.00
7	RLL	7	3.243	0.03539	0.03539	0.00404	5.56	5.56	22.59	0.00	0.00	0.00
8	RF	8	0.737	0.00337	0.00326	0.00040	6.91	4.80	13.44	0.00	0.00	3.46
9	LUL	9	7.004	0.12632	0.12632	0.01465	7.20	7.20	29.03	0.00	0.00	0.00
10	LLL	A	3.243	0.03539	0.03539	0.00404	5.56	5.56	22.59	0.00	0.00	0.00
11	LF	B	0.737	0.00337	0.00326	0.00040	6.91	4.80	13.44	0.00	0.00	3.46
12	RUA	C	1.785	0.01246	0.01246	0.00153	4.62	4.62	18.03	0.00	0.00	0.00
13	RLA	D	2.080	0.02634	0.02634	0.00152	4.26	4.26	24.71	0.00	0.00	0.00
14	LUA	E	1.785	0.01246	0.01246	0.00153	4.62	4.62	18.03	0.00	0.00	0.00
15	LLA	F	2.080	0.02634	0.02634	0.00152	4.26	4.26	24.71	0.00	0.00	0.00

JOINT J	SYM	PLOT	JNT	PIN	LOCATION(CM) - SEG(JNT) X	Y	Z	LOCATION(CM) - SEG(J+1) X	Y	Z	PRIN. AXIS(DEG) - SEG(JNT) YAW	PITCH	ROLL	PRIN. AXIS(DEG) - SEG(J+1) YAW	PITCH	ROLL
1	P	M	1	0	0.00	0.00	-9.65	0.00	0.00	3.76	0.00	30.00	0.00	0.00	0.00	0.00
2	N	N	2	0	0.00	0.00	-3.81	0.00	0.00	15.26	0.00	0.00	0.00	0.00	0.00	0.00
3	NP	O	3	0	0.00	0.00	-18.83	0.00	0.00	2.05	0.00	0.00	0.00	0.00	0.00	0.00
4	HP	P	4	0	0.00	0.00	-2.05	0.00	0.00	14.31	0.00	30.00	0.00	0.00	0.00	0.00
5	RH	Q	1	0	0.00	8.23	0.53	0.00	0.00	-20.47	0.00	0.00	0.00	0.00	-90.00	0.00
6	RK	R	6	1	0.00	0.00	23.10	0.00	0.00	-16.66	0.00	90.00	0.00	0.00	-45.00	0.00
7	RA	S	7	0	0.00	0.00	19.19	6.91	0.00	-6.57	0.00	45.00	0.00	0.00	-90.00	0.00
8	LH	T	1	0	0.00	-8.23	0.53	0.00	0.00	-20.47	0.00	0.00	0.00	0.00	-90.00	0.00
9	LK	U	9	1	0.00	0.00	23.10	0.00	0.00	-16.66	0.00	90.00	0.00	0.00	-45.00	0.00
10	LA	V	10	0	0.00	0.00	19.19	6.91	0.00	-6.57	0.00	45.00	0.00	0.00	-90.00	0.00
11	RS	W	3	0	0.00	15.39	-11.81	0.00	0.00	-13.41	0.00	0.00	0.00	0.00	15.00	0.00
12	RE	X	12	1	0.00	0.00	13.22	0.00	0.00	-19.90	0.00	60.00	0.00	0.00	0.00	0.00
13	LS	Y	3	0	0.00	-15.39	-11.81	0.00	0.00	-13.41	0.00	0.00	0.00	0.00	15.00	0.00
14	LE	Z	14	1	0.00	0.00	13.22	0.00	0.00	-19.90	0.00	60.00	0.00	0.00	0.00	0.00

APPENDIX C

COMPARISON OF REGRESSION TO PERCENTILE BASIS FOR BODY DIMENSIONS

Program GOOD computes values of body dimensions for a particular subject by using two fixed percentiles. The user selects a percentile for stature, and dimensions 23 through 31 (see Table 1) are computed to be the same percentile. The user also selects a percentile for sitting height, and dimensions 2 through 22 and 32 and 33 are computed to be this percentile. The percentile values are computed by use of a mean value and standard deviation for each body dimension, along with the assumption that each of the body dimension measurements are normally distributed.

The problem with this approach is that when component dimensions are all set to a fixed percentile, the resulting whole is of a different percentile. This can be illustrated by considering three populations A, B, and C. Each of these populations consists of n measurements, referred to as a_i, b_i, c_i $(i = 1, n)$, and for each i $(i = 1, n)$ $a_i + b_i = c_i$. The mean of the A, B, and C populations are $\bar{a}$, $\bar{b}$, and $\bar{c}$, respectively, and s_a, s_b, s_c are the respective standard deviations of the three populations. Assuming a normal distribution for each of the populations, a specific percentile point may be computed as being a certain number of standard deviations away from the mean. Thus if a_m, b_m, and c_m are the m^{th} percentile points of their respective populations, there exists an α such that $a_m = \bar{a} + \alpha s_a$, $b_m = \bar{b} + \alpha s_b$, and $c_m = \bar{c} + \alpha s_c$. Ideally $a_m + b_m = c_m$, however, in general this is not the case, as is shown in the following:

$$\begin{aligned} c_m &= \bar{c} + \alpha s_c \\ &= \frac{1}{n} \Sigma\, c_i + \frac{\alpha}{n-1} \left[\Sigma\left(c_i - \frac{\Sigma c_i}{n}\right)^2\right] \\ &= \frac{1}{n} \Sigma(a_i + b_i) + \frac{\alpha}{n-1}\left[\Sigma\left(a_i + b_i - \frac{\Sigma(a_i + b_i)}{n}\right)^2\right] \\ &= \bar{a} + \bar{b} + \frac{\alpha}{n-1} [\Sigma((a_i - \bar{a}) + (b_i - \bar{b}))^2] \end{aligned}$$

$$= \bar{a} + \bar{b} + \frac{\alpha}{n-1}\left[\Sigma(a_i - \bar{a})^2 + \Sigma(b_i - \bar{b})^2 + 2\Sigma(a_i - \bar{a})(b_i - \bar{b})\right]$$

$$= a + \alpha S_a + \bar{b} + \alpha S_b + \frac{2\alpha}{n-1}\left[\Sigma(a_i - \bar{a})(b_i - \bar{b})\right]$$

$$= a_m + b_m + \frac{2\alpha}{n-1}\left[\Sigma(a_i - \bar{a})(b_i - \bar{b})\right]$$

where the usual definitions of mean and standard deviation ($a = \frac{1}{n}\Sigma a_i$, $s_a = \frac{1}{n-1}\Sigma(a_i - a)^2$, etc.) have been used.

The method used by GEBOD, to determine body dimension values corresponding to a particular subject, is to regress each body dimension against age (for children only), height, and/or weight (see Appendix D). Using the A, B, and C populations to illustrate this method also, least squares linear regressions equations would be developed expressing values from the A and B populations as functions of values from the C populations. That is, the coefficients p_a, q_a, p_b, and q_b would be computed such $a_o = p_a c_o + q_a$ and $b_o = p_b c_o + q_b$, where a_o is the least squares value from the A population corresponding to c_o (a value from the C population), and b_o is the least squares value from the B population corresponding to c_o. Using standard least squares techniques the values of these parameters are computed as follows:

$$p_a = \frac{\Sigma(a_i - \bar{a})(c_i - \bar{c})}{\Sigma(c_i - \bar{c})^2}, \qquad q_a = \bar{a} - p_a \bar{c}$$

$$p_b = \frac{\Sigma(b_i - \bar{b})(c_i - \bar{c})}{\Sigma(c_i - \bar{c})^2}, \qquad q_b = \bar{b} - p_b \bar{c} .$$

The additivity that does not occur with the percentile method can be shown to exist for this regression technique. The first step in showing this is to establish the result $p_a + p_b = 1$:

$$p_a + p_b = \frac{\Sigma(a_i - \bar{a})(c_i - \bar{c})}{\Sigma(c_i - \bar{c})^2} + \frac{\Sigma(b_i - \bar{b})(c_i - \bar{c})}{\Sigma(c_i - \bar{c})^2}$$

$$= \frac{\Sigma[(c_i - \bar{c})((a_i - \bar{a}) + (b_i - \bar{b}))]}{\Sigma(c_i - \bar{c})^2}$$

$$= \frac{\Sigma[(c_i - \bar{c})(a_i + b_i - (\bar{a} + \bar{b}))]}{\Sigma(c_i - \bar{c})^2}$$

$$= \frac{\Sigma[(c_i - \bar{c})^2]}{\Sigma(c_i - \bar{c})^2}$$

$$= 1 .$$

Using this result it can be shown that values from the A and B populations, a_o, and b_o, respectively, both corresponding to the same value of the C population, c_o, sum to that value of the C population:

$$a_o + b_o = p_a c_o + q_a + p_b c_o + q_b$$

$$= c_o(p_a + p_b) + (q_a + q_b)$$

$$= c_o + (\bar{a} - p_a\bar{c} + \bar{b} - p_b\bar{c})$$

$$= c_o + (\bar{a} + \bar{b}) - \bar{c}(p_a + p_b)$$

$$= c_o + \bar{c} - \bar{c}$$

$$= c_o.$$

It is for this reason of additivity, that a regression approach was felt to be more correct than the percentile approach of program GOOD as a method of determining body dimensions corresponding to a particular subject, and was therefore used in program GEBOD.

APPENDIX D

BODY DIMENSION REGRESSION EQUATIONS DEVELOPED FOR GEBOD

This appendix contains a complete listing of the regression equations developed for use by GEBOD. For the adult male and female sets heights and weight are used as predicting variables. The child set uses age along with height and weight. At the top of each set of regression equations is listed the range of values, mean, and standard deviation of the predicting variables within that subject type. For each body dimension a separate regression equation is given against each of the predicting variables. The last regression equation given for each body dimension is a step-wise multiple regression against all of the predicting variables. Since this is a step-wise regression, only those predicting variables that would make a significant contribution to the regression appear in the final form of the regression equation. With each regression equation the square of the correlation coefficient (R**2) and the number of subjects the regression equation is based on (NSUB) are given.

```
REGRESSION EQUATIONS FOR ADULT FEMALES

PREDICTING VARIABLES
WEIGHT                  RANGE:   85.00      200.0      MEAN:   127.3      S.D.:   16.59
STANDING HEIGHT         RANGE:   56.93      72.05      MEAN:   63.82      S.D.:   2.364

REGRESSION EQUATIONS FOR WEIGHT
WEIGHT           : 1.000     *WEIGHT   +.4547E-12                                      R**2 :  1.0000    NSUB : 1905
WEIGHT           : 3.737     *STANDING -111.2                                          R**2 :   .2836    NSUB : 1905
WEIGHT           : 1.000     *WEIGHT   +.4547E-12                                      R**2 :  1.0000    NSUB : 1905

REGRESSION EQUATIONS FOR STANDING HEIGHT
STANDING HEIGHT  : .7589E-01*WEIGHT   +54.16                                           R**2 :   .2836    NSUB : 1905
STANDING HEIGHT  : 1.000     *STANDING +.2274E-12                                      R**2 :  1.0000    NSUB : 1905
STANDING HEIGHT  : 1.000     *STANDING +.2274E-12                                      R**2 :  1.0000    NSUB : 1905

REGRESSION EQUATIONS FOR SHOULDER HEIGHT
SHOULDER HEIGHT  : .7182E-01*WEIGHT   +42.77                                           R**2 :   .3049    NSUB : 1905
SHOULDER HEIGHT  : .8751     *STANDING -3.936                                          R**2 :   .9194    NSUB : 1905
SHOULDER HEIGHT  : .7555E-02*WEIGHT   +.8469    *STANDING -3.096                       R**2 :   .9218    NSUB : 1905

REGRESSION EQUATIONS FOR ARMPIT HEIGHT
ARMPIT HEIGHT    : .5840E-01*WEIGHT   +39.83                                           R**2 :   .2217    NSUB : 1905
ARMPIT HEIGHT    : .8309     *STANDING -5.762                                          R**2 :   .9115    NSUB : 1905
ARMPIT HEIGHT    :-.6495E-02*WEIGHT   +.8551    *STANDING -6.484                       R**2 :   .9135    NSUB : 1905

REGRESSION EQUATIONS FOR WAIST HEIGHT
WAIST HEIGHT     : .5302E-01*WEIGHT   +32.73                                           R**2 :   .2465    NSUB : 1905
WAIST HEIGHT     : .6845     *STANDING -4.206                                          R**2 :   .8346    NSUB : 1905
WAIST HEIGHT     : .6845     *STANDING -4.206                                          R**2 :   .8346    NSUB : 1905

REGRESSION EQUATIONS FOR SEATED HEIGHT
SEATED HEIGHT    : .3620E-01*WEIGHT   +29.09                                           R**2 :   .2317    NSUB : 1905
SEATED HEIGHT    : .4225     *STANDING +6.734                                          R**2 :   .6409    NSUB : 1905
SEATED HEIGHT    : .5773E-02*WEIGHT   +.4010    *STANDING +7.376                       R**2 :   .6451    NSUB : 1905

REGRESSION EQUATIONS FOR HEAD LENGTH
HEAD LENGTH      : .4897E-02*WEIGHT   +6.625                                           R**2 :   .0923    NSUB : 1905
HEAD LENGTH      : .3600E-01*STANDING +4.950                                           R**2 :   .1014    NSUB : 1905
HEAD LENGTH      : .3021E-02*WEIGHT   +.2471E-01*STANDING +5.286                       R**2 :   .1265    NSUB : 1905

REGRESSION EQUATIONS FOR HEAD BREADTH
HEAD BREADTH     : .4089E-02*WEIGHT   +5.194                                           R**2 :   .0839    NSUB : 1905
HEAD BREADTH     : .1347E-01*STANDING +4.855                                           R**2 :   .0183    NSUB : 1905
HEAD BREADTH     : .4089E-02*WEIGHT   +5.194                                           R**2 :   .0839    NSUB : 1905
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REGRESSION EQUATIONS FOR HEAD TO CHIN HEIGHT
HEAD TO CHIN HEIGH : .7362E-02*WEIGHT   +7.688                             R**2 :   .0741    NSUB : 1905
HEAD TO CHIN HEIGH : .6816E-01*STANDING +4.275                             R**2 :   .1290    NSUB : 1905
HEAD TO CHIN HEIGH : .3057E-02*WEIGHT   +.5674E-01*STANDING +4.615         R**2 :   .1382    NSUB : 1905

REGRESSION EQUATIONS FOR NECK CIRCUMFERENCE
NECK CIRCUMFERENCE : .2316E-01*WEIGHT   +10.34                             R**2 :   .3387    NSUB : 1905
NECK CIRCUMFERENCE : .8900E-01*STANDING +7.607                             R**2 :   .1016    NSUB : 1905
NECK CIRCUMFERENCE : .2316E-01*WEIGHT   +10.34                             R**2 :   .3387    NSUB : 1905

REGRESSION EQUATIONS FOR SHOULDER BREADTH
SHOULDER BREADTH   : .1927E-01*WEIGHT   +11.66                             R**2 :   .2451    NSUB : 1905
SHOULDER BREADTH   : .1246    *STANDING +6.160                             R**2 :   .2082    NSUB : 1305
SHOULDER BREADTH   : .1369E-01*WEIGHT   +.7344E-01*STANDING +7.682         R**2 :   .2969    NSUB : 1905

REGRESSION EQUATIONS FOR CHEST DEPTH
CHEST DEPTH        : .3412E-01*WEIGHT   +4.965                             R**2 :   .5535    NSUB : 1905
CHEST DEPTH        : .7300E-01*STANDING +4.650                             R**2 :   .0515    NSUB : 1905
CHEST DEPTH        : .3989E-01*WEIGHT   -.7607E-01*STANDING +9.086         R**2 :   .5936    NSUB : 1905

REGRESSION EQUATIONS FOR CHEST BREADTH
CHEST BREADTH      : .3185E-01*WEIGHT   +6.968                             R**2 :   .4912    NSUB : 1905
CHEST BREADTH      : .8875E-01*STANDING +5.357                             R**2 :   .0775    NSUB : 1905
CHEST BREADTH      : .3505E-01*WEIGHT   -.4222E-01*STANDING +9.255         R**2 :   .5037    NSUB : 1905

REGRESSION EQUATIONS FOR WAIST DEPTH
WAIST DEPTH        : .2922E-01*WEIGHT   +2.979                             R**2 :   .5422    NSUB : 1905
WAIST DEPTH        : .5358E-01*STANDING +3.279                             R**2 :   .0370    NSUB : 1905
WAIST DEPTH        : .3511E-01*WEIGHT   -.7761E-01*STANDING +7.183         R**2 :   .5979    NSUB : 1905

REGRESSION EQUATIONS FOR WAIST BREADTH
WAIST BREADTH      : .3527E-01*WEIGHT   +5.010                             R**2 :   .5892    NSUB : 1905
WAIST BREADTH      : .1060    *STANDING +2.734                             R**2 :   .1081    NSUB : 1905
WAIST BREADTH      : .3800E-01*WEIGHT   -.3598E-01*STANDING +6.959         R**2 :   .5981    NSUB : 1905

REGRESSION EQUATIONS FOR BUTTOCK DEPTH
BUTTOCK DEPTH      : .3419E-01*WEIGHT   +3.976                             R**2 :   .6477    NSUB : 1905
BUTTOCK DEPTH      : .7090E-01*STANDING +3.803                             R**2 :   .0566    NSUB : 1905
BUTTOCK DEPTH      : .4021E-01*WEIGHT   -.7937E-01*STANDING +6.275         R**2 :   .6985    NSUB : 1905

REGRESSION EQUATIONS FOR HIP BREADTH,STANDING
HIP BREADTH,STANDI : .4052E-01*WEIGHT   +8.610                             R**2 :   .5935    NSUB : 1905
HIP BREADTH,STANDI : .1295    *STANDING +5.563                             R**2 :   .1213    NSUB : 1905
HIP BREADTH,STANDI : .4294E-01*WEIGHT   -.3192E-01*STANDING +10.34         R**2 :   .5988    NSUB : 1905
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REGRESSION EQUATIONS FOR SHOULDER TO ELBOW LENGTH
SHOULDER TO ELBOW  : .1702E-01*WEIGHT   +10.04                                        R**2 :   .1946    NSUB : 1905
SHOULDER TO ELBOW  : .1962     *STANDING -.3163                                       P**2 :   .5252    NSUB : 1905
SHOULDER TO ELBOW  : .2976E-02*WEIGHT   +.1851    *STANDING +.1459E-01                R**2 :   .5295    NSUB : 1905

REGRESSION EQUATIONS FOR FOREARM-HAND LENGTH
FOREARM-HAND LENGT : .2092E-01*WEIGHT   +13.78                                        R**2 :   .1941    NSUB : 1905
FOREARM-HAND LENGT : .2478     *STANDING +.6324                                       R**2 :   .5526    NSUB : 1905
FOREARM-HAND LENGT : .2960E-02*WEIGHT   +.2367    *STANDING +.9615                    R**2 :   .5554    NSUB : 1905

REGRESSION EQUATIONS FOR BICEPS CIRCUMFERENCE
BICEPS CIRCUMFEREN : .4369E-01*WEIGHT   +4.522                                        R**2 :   .6442    NSUB : 1905
BICEPS CIRCUMFEREN : .5386E-01*STANDING +6.646                                        R**2 :   .0199    NSUB : 1905
BICEPS CIRCUMFEREN : .5528E-01*WEIGHT   -.1527    *STANDING +12.79                    R**2 :   .7587    NSUB : 1905

REGRESSION EQUATIONS FOR ELBOW CIRCUMFERENCE
ELBOW CIRCUMFERENC : .2421E-01*WEIGHT   +7.539                                        R**2 :   .3274    NSUB : 1905
ELBOW CIRCUMFERENC : .1221     *STANDING +2.826                                       R**2 :   .1692    NSUB : 1905
ELBOW CIRCUMFERENC : .2086E-01*WEIGHT   +.4420E-01*STANDING +5.145                    R**2 :   .3433    NSUB : 1905

REGRESSION EQUATIONS FOR FOREARM CIRCUMFERENCE
FOREARM CIRCUMFERE : .2643E-01*WEIGHT   +5.879                                        R**2 :   .6524    NSUB : 1905
FOREARM CIRCUMFERE : .7088E-01*STANDING +4.719                                        R**2 :   .0953    NSUB : 1905
FOREARM CIRCUMFERE : .2938E-01*WEIGHT   -.3890E-01*STANDING +7.986                    R**2 :   .6730    NSUB : 1905

REGRESSION EQUATIONS FOR WRIST CIRCUMFERENCE
WRIST CIRCUMFERENC : .1090E-01*WEIGHT   +4.503                                        R**2 :   .4168    NSUB : 1905
WRIST CIRCUMFERENC : .5371E-01*STANDING +2.463                                        R**2 :   .2054    NSUB : 1905
WRIST CIRCUMFERENC : .9530E-02*WEIGHT   +.1810E-01*STANDING +3.523                    R**2 :   .4335    NSUB : 1905

REGRESSION EQUATIONS FOR KNEE HEIGHT,SEATED
KNEE HEIGHT,SEATED : .3002E-01*WEIGHT   +14.98                                        R**2 :   .2549    NSUB : 1905
KNEE HEIGHT,SEATED : .3345     *STANDING -2.547                                       R**2 :   .6428    NSUB : 1905
KNEE HEIGHT,SEATED : .6469E-02*WEIGHT   +.3104    *STANDING -1.828                    R**2 :   .6512    NSUB : 1905

REGRESSION EQUATIONS FOR THIGH CIRCUMFERENCE
THIGH CIRCUMFERENC : .8417E-01*WEIGHT   +11.13                                        R**2 :   .7063    NSUB : 1905
THIGH CIRCUMFERENC : .1869     *STANDING +9.912                                       R**2 :   .0707    NSUB : 1905
THIGH CIRCUMFERENC : .9769E-01*WEIGHT   -.1781    *STANDING +20.77                    R**2 :   .7523    NSUB : 1905

REGRESSION EQUATIONS FOR UPPER LEG CIRCUMFERENCE
UPPER LEG CIRCUMFE : .6412E-01*WEIGHT   +9.905                                        R**2 :   .7710    NSUB : 1905
UPPER LEG CIRCUMFE : .1664     *STANDING +7.448                                       R**2 :   .1054    NSUB : 1905
UPPER LEG CIRCUMFE : .7187E-01*WEIGHT   -.1022    *STANDING +15.44                    R**2 :   .7995    NSUB : 1905
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REGRESSION EQUATIONS FOR KNEE CIRCUMFERENCE
KNEE CIRCUMFERENCE = .4406E-01*WEIGHT   +8.684                                          R**2 =   .6714    NSUB = 1905
KNEE CIRCUMFERENCE = .1458    *STANDING +4.985                                          R**2 =   .1494    NSUB = 1905
KNEE CIRCUMFERENCE = .4605E-01*WEIGHT   -.2626E-01*STANDING \10.11                      R**2 =   .6749    NSUB = 1905

REGRESSION EQUATIONS FOR CALF CIRCUMFERENCE
CALF CIRCUMFERENCE = .4012E-01*WEIGHT   +8.335                                          R**2 =   .5661    NSUB = 1905
CALF CIRCUMFERENCE = .1106    *STANDING +6.386                                          R**2 =   .0873    NSUB = 1905
CALF CIRCUMFERENCE = .4429E-01*WEIGHT   -.5493E-01*STANDING +11.31                      R**2 =   .5816    NSUB = 1905

REGRESSION EQUATIONS FOR ANKLE CIRCUMFERENCE
ANKLE CIRCUMFERENC = .1809E-01*WEIGHT   +5.999                                          R**2 =   .3496    NSUB = 1905
ANKLE CIRCUMFERENC = .7603E-01*STANDING +3.449                                          R**2 =   .1254    NSUB = 1905
ANKLE CIRCUMFERENC = .1720E-01*WEIGHT   +.1177E-01*STANDING +5.361                      R**2 =   .3517    NSUB = 1905

REGRESSION EQUATIONS FOR ANKLE HEIGHT.OUTSIDE
ANKLE HEIGHT.OUTSI = .3434E-02*WEIGHT   +2.230                                          R**2 =   .0607    NSUB = 1905
ANKLE HEIGHT.OUTSI = .4163E-01*STANDING +.9788E-02                                      R**2 =   .1813    NSUB = 1905
ANKLE HEIGHT.OUTSI = .4163E-01*STANDING +.9788E-02                                      R**2 =   .1813    NSUB = 1905

REGRESSION EQUATIONS FOR FOOT BREADTH
FOOT BREADTH       = .4638E-02*WEIGHT   +2.901                                          R**2 =   .1541    NSUB = 1905
FOOT BREADTH       = .2947E-01*STANDING +1.611                                          R**2 =   .1263    NSUB = 1905
FOOT BREADTH       = .3353E-02*WEIGHT   +.1694E-01*STANDING +1.984                      R**2 =   .1840    NSUB = 1905

REGRESSION EQUATIONS FOR FOOT LENGTH
FOOT LENGTH        = .1365E-01*WEIGHT   +7.738                                          R**2 =   .2601    NSUB = 1905
FOOT LENGTH        = .1299    *STANDING +1.186                                          R**2 =   .4783    NSUB = 1905
FOOT LENGTH        = .5296E-02*WEIGHT   +.1101     *STANDING +1.775                      R**2 =   .5063    NSUB = 1905
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REGRESSION EQUATIONS FOR ADULT MALES

PREDICTING VARIABLES
WEIGHT                   RANGE:   118.0      264.0       MEAN:   173.6       S.D.:   21.44
STANDING HEIGHT          RANGE:   62.17      77.64       MEAN:   69.82       S.D.:   2.437

REGRESSION EQUATIONS FOR WEIGHT
WEIGHT ,          : 1.000     *WEIGHT   +.9095E-12                                  R**2 :  1.0000    NSUB : 2420
WEIGHT            : 4.530     *STANDING -142.7                                      R**2 :   .2650    NSUB : 2420
WEIGHT            : 1.000     *WEIGHT   +.9095E-12                                  R**2 :  1.0000    NSUB : 2420

REGRESSION EQUATIONS FOR STANDING HEIGHT
STANDING HEIGHT   : .5850E-01*WEIGHT   +59.66                                       R**2 :   .2650    NSUB : 2420
STANDING HEIGHT   : 1.000     *STANDING +.4547E-12                                  R**2 :  1.0000    NSUB : 2420
STANDING HEIGHT   : 1.000     *STANDING +.4547E-12                                  R**2 :  1.0000    NSUB : 2420

REGRESSION EQUATIONS FOR SHOULDER HEIGHT
SHOULDER HEIGHT   : .5844E-01*WEIGHT   +47.02                                       R**2 :   .3058    NSUB : 2420
SHOULDER HEIGHT   : .8911     *STANDING -5.049                                      R**2 :   .9183    NSUB : 2420
SHOULDER HEIGHT   : .8583E-02*WEIGHT   +.8522     *STANDING -3.824                  R**2 :   .9231    NSUB : 2420

REGRESSION EQUATIONS FOR ARMPIT HEIGHT
ARMPIT HEIGHT     : .4637E-01*WEIGHT   +43.06                                       R**2 :   .2125    NSUB : 2420
ARMPIT HEIGHT     : .8398     *STANDING -7.529                                      R**2 :   .9001    NSUB : 2420
ARMPIT HEIGHT     :-.3761E-02*WEIGHT   +.8569     *STANDING -8.066                  R**2 :   .9011    NSUB : 2420

REGRESSION EQUATIONS FOR WAIST HEIGHT
WAIST HEIGHT      : .3642E-01*WEIGHT   +35.59                                       R**2 :   .1764    NSUB : 2420
WAIST HEIGHT      : .7043     *STANDING -7.256                                      R**2 :   .8519    NSUB : 2420
WAIST HEIGHT      :-.6506E-02*WEIGHT   +.7330     *STANDING -8.185                  R**2 :   .8560    NSUB : 2420

REGRESSION EQUATIONS FOR SEATED HEIGHT
SEATED HEIGHT     : .2664E-01*WEIGHT   +32.06                                       R**2 :   .2086    NSUB : 2420
SEATED HEIGHT     : .4043     *STANDING +8.460                                      R**2 :   .6205    NSUB : 2420
SEATED HEIGHT     : .4060E-02*WEIGHT   +.3859     *STANDING +9.039                  R**2 :   .6241    NSUB : 2420

REGRESSION EQUATIONS FOR HEAD LENGTH
HEAD LENGTH       : .3209E-02*WEIGHT   +7.266                                       R**2 :   .0673    NSUB : 2420
HEAD LENGTH       : .2680E-01*STANDING +5.952                                       R**2 :   .0606    NSUB : 2420
HEAD LENGTH       : .2233E-02*WEIGHT   +.1668E-01*STANDING +6.271                   R**2 :   .0846    NSUB : 2420

REGRESSION EQUATIONS FOR HEAD BREADTH
HEAD BREADTH      : .3060E-02*WEIGHT   +5.611                                       R**2 :   .0943    NSUB : 2420
HEAD BREADTH      : .1174E-01*STANDING +5.322                                       R**2 :   .0179    NSUB : 2420
HEAD BREADTH      : .3060E-02*WEIGHT   +5.611                                       R**2 :   .0943    NSUB : 2420
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REGRESSION EQUATIONS FOR HEAD TO CHIN HEIGHT
HEAD TO CHIN HEIGH : .3143E-02*WEIGHT   +8.420                        R**2 :   .0281    NSUB : 2420
HEAD TO CHIN HEIGH : .4659E-01*STANDING +5.712                        R**2 :   .0796    NSUB : 2420
HEAD TO CHIN HEIGH : .4659E-01*STANDING +5.712                        R**2 :   .0796    NSUB : 2420

REGRESSION EQUATIONS FOR NECK CIRCUMFERENCE
NECK CIRCUMFERENCE : .2444E-01*WEIGHT   +10.85                        R**2 :   .4865    NSUB : 2420
NECK CIRCUMFERENCE : .5527E-01*STANDING +10.54                        R**2 :   .0448    NSUB : 2420
NECK CIRCUMFERENCE : .2806E-01*WEIGHT   -.6185E-01*STANDING +14.54    R**2 :   .5160    NSUB : 2420

REGRESSION EQUATIONS FOR SHOULDER BREADTH
SHOULDER BREADTH   : .1612E-01*WEIGHT   +13.24                        R**2 :   .2043    NSUB : 2420
SHOULDER BREADTH   : .1181     *STANDING +7.790                       R**2 :   .1416    NSUB : 2420
SHOULDER BREADTH   : .1253E-01*WEIGHT   +.6133E-01*STANDING +9.578    R**2 :   .2323    NSUB : 2420

REGRESSION EQUATIONS FOR CHEST DEPTH
CHEST DEPTH        : .2690E-01*WEIGHT   +4.984                        R**2 :   .5767    NSUB : 2420
CHEST DEPTH        : .5114E-01*STANDING +5.386                        R**2 :   .0385    NSUB : 2420
CHEST DEPTH        : .3174E-01*WEIGHT   -.8265E-01*STANDING +9.915    R**2 :   .6284    NSUB : 2420

REGRESSION EQUATIONS FOR CHEST BREADTH
CHEST BREADTH      : .2911E-01*WEIGHT   +7.854                        R**2 :   .5608    NSUB : 2420
CHEST BREADTH      : .8877E-01*STANDING +6.709                        R**2 :   .0673    NSUB : 2420
CHEST BREADTH      : .3254E-01*WEIGHT   -.5866E-01*STANDING +11.35    R**2 :   .5824    NSUB : 2420

REGRESSION EQUATIONS FOR WAIST DEPTH
WAIST DEPTH        : .3026E-01*WEIGHT   +3.528                        R**2 :   .5712    NSUB : 2420
WAIST DEPTH        : .5167E-01*STANDING +5.174                        R**2 :   .0215    NSUB : 2420
WAIST DEPTH        : .3706E-01*WEIGHT   -.1162     *STANDING +10.46   R**2 :   .6512    NSUB : 2420

REGRESSION EQUATIONS FOR WAIST BREADTH
WAIST BREADTH      : .3741E-01*WEIGHT   +5.694                        R**2 :   .7269    NSUB : 2420
WAIST BREADTH      : .1105     *STANDING +4.473                       R**2 :   .0819    NSUB : 2420
WAIST BREADTH      : .4211E-01*WEIGHT   -.8025E-01*STANDING +10.48    R**2 :   .7586    NSUB : 2420

REGRESSION EQUATIONS FOR BUTTOCK DEPTH
BUTTOCK DEPTH      : .3077E-01*WEIGHT   +4.095                        R**2 :   .6664    NSUB : 2420
BUTTOCK DEPTH      : .6978E-01*STANDING +4.566                        R**2 :   .0442    NSUB : 2420
BUTTOCK DEPTH      : .3632E-01*WEIGHT   -.9475E-01*STANDING +9.749    R**2 :   .7263    NSUB : 2420

REGRESSION EQUATIONS FOR HIP BREADTH,STANDING
HIP BREADTH,STANDI : .2803E-01*WEIGHT   +9.019                        R**2 :   .6556    NSUB : 2420
HIP BREADTH,STANDI : .,258     *STANDING +5.100                       R**2 :   .1706    NSUB : 2420
HIP BREADTH,STANDI : .2803E-01*WEIGHT   +9.019                        R**2 :   .6556    NSUB : 2420
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REGRESSION EQUATIONS FOR SHOULDER TO ELBOW LENGTH
SHOULDER TO ELBOW  : .1256E-01*WEIGHT   +11.97                                    R**2 :   .1595    NSUB : 2420
SHOULDER TO ELBOW  : .2087    *STANDING -.4158                                    R**2 :   .5683    NSUB : 2420
SHOULDER TO ELBOW  : .2087    *STANDING -.4158                                    R**2 :   .5683    NSUB : 2420

REGRESSION EQUATIONS FOR FOREARM-HAND LENGTH
FOREARM-HAND LENGT : .1671E-01*WEIGHT   +16.54                                    R**2 :   .1621    NSUB : 2420
FOREARM-HAND LENGT : .2646    *STANDING +.9735                                    R**2 :   .5245    NSUB : 2420
FOREARM-HAND LENGT : .1677E-02*WEIGHT   +.2570    *STANDING +1.213                R**2 :   .5258    NSUB : 2420

REGRESSION EQUATIONS FOR BICEPS CIRCUMFERENCE
BICEPS CIRCUMFEREN : .3340E-01*WEIGHT   +6.608                                    R**2 :   .6711    NSUB : 2420
BICEPS CIRCUMFEREN : .5996E-01*STANDING +8.219                                    R**2 :   .0279    NSUB : 2420
BICEPS CIRCUMFEREN : .4067E-01*WEIGHT   -.1243    *STANDING +14.02                R**2 :   .7593    NSUB : 2420

REGRESSION EQUATIONS FOR ELBOW CIRCUMFERENCE
ELBOW CIRCUMFERENC : .1919E-01*WEIGHT   +8.967                                    R**2 :   .3583    NSUB : 2420
ELBOW CIRCUMFERENC : .1061    *STANDING +4.894                                    R**2 :   .1413    NSUB : 2420
ELBOW CIRCUMFERENC : .1767E-01*WEIGHT   +.2601E-01*STANDING +7.416                R**2 :   .3645    NSUB : 2420

REGRESSION EQUATIONS FOR FOREARM CIRCUMFERENCE
FOREARM CIRCUMFERE : .2116E-01*WEIGHT   +7.411                                    R**2 :   .6225    NSUB : 2420
FOREARM CIRCUMFERE : .6760E-01*STANDING +6.359                                    R**2 :   .0822    NSUB : 2420
FOREARM CIRCUMFERE : .2341E-01*WEIGHT   -.3835E-01*STANDING +9.700                R**2 :   .6419    NSUB : 2420

REGRESSION EQUATIONS FOR WRIST CIRCUMFERENCE
WRIST CIRCUMFERENC : .9921E-02*WEIGHT   +5.202                                    R**2 :   .3446    NSUB : 2420
WRIST CIRCUMFERENC : .5166E-01*STANDING +3.317                                    R**2 :   .1207    NSUB : 2420
WRIST CIRCUMFERENC : .9386E-02*WEIGHT   +.9137E-02*STANDING +4.657                R**2 :   .3474    NSUB : 2420

REGRESSION EQUATIONS FOR KNEE HEIGHT,SEATED
KNEE HEIGHT,SEATED : .2467E-01*WEIGHT   +17.67                                    R**2 :   .2900    NSUB : 2420
KNEE HEIGHT,SEATED : .3558    *STANDING -2.889                                    R**2 :   .7789    NSUB : 2420
KNEE HEIGHT,SEATED : .5244E-02*WEIGHT   +.3321    *STANDING -2.141                R**2 :   .7885    NSUB : 2420

REGRESSION EQUATIONS FOR THIGH CIRCUMFERENCE
THIGH CIRCUMFERENC : .6998E-01*WEIGHT   +11.01                                    R**2 :   .7392    NSUB : 2420
THIGH CIRCUMFERENC : .1614    *STANDING +11.89                                    R**2 :   .0508    NSUB : 2420
THIGH CIRCUMFERENC : .8237E-01*WEIGHT   -.2117    *STANDING +23.64                R**2 :   .8034    NSUB : 2420

REGRESSION EQUATIONS FOR UPPER LEG CIRCUMFERENCE
UPPER LEG CIRCUMFE : .3229E-01*WEIGHT   +9.621                                    R**2 :   .7188    NSUB : 2420
UPPER LEG CIRCUMFE : .1412    *STANDING +5.370                                    R**2 :   .1774    NSUB : 2420
UPPER LEG CIRCUMFE : .3229E-01*WEIGHT   +9.621                                    R**2 :   .7188    NSUB : 2420
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REGRESSION EQUATIONS FOR KNEE CIRCUMFERENCE
KNEE CIRCUMFERENCE : .3334E-01*WEIGHT   +9.686                          R**2 :  .7310   NSUB : 2420
KNEE CIRCUMFERENCE : .1512    *STANDING +4.910                          R**2 :  .1941   NSUB : 2420
KNEE CIRCUMFERENCE : .3334E-01*WEIGHT   +9.686                          R**2 :  .7310   NSUB : 2420

REGRESSION EQUATIONS FOR CALF CIRCUMFERENCE
CALF CIRCUMFERENCE : .3250E-01*WEIGHT   +9.002                          R**2 :  .6081   NSUB : 2420
CALF CIRCUMFERENCE : .8842E-01*STANDING +8.469                          R**2 :  .0581   NSUB : 2420
CALF CIRCUMFERENCE : .3718E-01*WEIGHT   -.8000E-01*STANDING +13.77      R**2 :  .6430   NSUB : 2420

REGRESSION EQUATIONS FOR ANKLE CIRCUMFERENCE
ANKLE CIRCUMFERENC : .1610E-01*WEIGHT   +6.028                          R**2 :  .4917   NSUB : 2420
ANKLE CIRCUMFERENC : .6599E-01*STANDING +4.216                          R**2 :  .1045   NSUB : 2420
ANKLE CIRCUMFERENC : .1665E-01*WEIGHT   -.9456E-02*STANDING +6.593      R**2 :  .4832   NSUB : 2420

REGRESSION EQUATIONS FOR ANKLE HEIGHT.OUTSIDE
ANKLE HEIGHT.OUTSI : .4310E-02*WEIGHT   +4.652                          R**2 :  .0419   NSUB : 2420
ANKLE HEIGHT.OUTSI : .8736E-01*STANDING -.6990                          R**2 :  .2223   NSUB : 2420
ANKLE HEIGHT.OUTSI :-.1090E-02*WEIGHT   +.9230E-01*STANDING -.8545      R**2 :  .2242   NSUB : 2420

REGRESSION EQUATIONS FOR FOOT BREADTH
FOOT BREADTH       : .4136E-02*WEIGHT   +3.127                          R**2 :  .2068   NSUB : 2420
FOOT BREADTH       : .3418E-01*STANDING +1.459                          R**2 :  .1824   NSUB : 2420
FOOT BREADTH       : .2907E-02*WEIGHT   +.2101E-01*STANDING +1.873      R**2 :  .2575   NSUB : 2420

REGRESSION EQUATIONS FOR FOOT LENGTH
FOOT LENGTH        : .1028E-01*WEIGHT   +8.858                          R**2 :  .2214   NSUB : 2420
FOOT LENGTH        : .1309    *STANDING +1.502                          R**2 :  .4634   NSUB : 2420
FOOT LENGTH        : .3570E-02*WEIGHT   +.1148    *STANDING +2.012      R**2 :  .4830   NSUB : 2420
```

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REGRESSION EQUATIONS FOR CHILDREN

PREDICTING VARIABLES
AGE                    RANGE:   24.00      240.0      MEAN:   124.7      S.D.:   53.02
WEIGHT                 RANGE:   22.27      247.6      MEAN:   81.86      S.D.:   39.18
STANDING HEIGHT        RANGE:   32.01      76.54      MEAN:   54.52      S.D.:   9.741

REGRESSION EQUATIONS FOR AGE
AGE                 : 1.000     *AGE      +.4547E-12                                                R**2 :  1.0000    NSUB : 3889
AGE                 : 1.213     *WEIGHT   +25.43                                                    R**2 :   .8036    NSUB : 3889
AGE                 : 5.202     *STANDING -158.9                                                    R**2 :   .9136    NSUB : 3889
AGE                 : 1.000     *AGE      +.4547E-12                                                R**2 :  1.0000    NSUB : 3889

REGRESSION EQUATIONS FOR WEIGHT
WEIGHT              : .6625     *AGE      -.7660                                                    R**2 :   .8036    NSUB : 3889
WEIGHT              : 1.000     *WEIGHT   +.4547E-12                                                R**2 :  1.0000    NSUB : 3889
WEIGHT              : 3.743     *STANDING -122.2                                                    R**2 :   .8659    NSUB : 3889
WEIGHT              : 1.000     *WEIGHT   +.4547E-12                                                R**2 :  1.0000    NSUB : 3889

REGRESSION EQUATIONS FOR STANDING HEIGHT
STANDING HEIGHT     : .1756     *AGE      +32.62                                                    R**2 :   .9136    NSUB : 3889
STANDING HEIGHT     : .2314     *WEIGHT   +35.58                                                    R**2 :   .8659    NSUB : 3889
STANDING HEIGHT     : 1.000     *STANDING +.2274E-12                                                R**2 :  1.0000    NSUB : 3889
STANDING HEIGHT     : 1.000     *STANDING +.2274E-12                                                R**2 :  1.0000    NSUB : 3889

REGRESSION EQUATIONS FOR SHOULDER HEIGHT
SHOULDER HEIGHT     : .1518     *AGE      +24.79                                                    R**2 :   .9078    NSUB : 1237
SHOULDER HEIGHT     : .1994     *WEIGHT   +27.37                                                    R**2 :   .8539    NSUB : 1237
SHOULDER HEIGHT     : .8721     *STANDING -3.898                                                    R**2 :   .9962    NSUB : 1237
SHOULDER HEIGHT     : .8721     *STANDING -3.898                                                    R**2 :   .9962    NSUB : 1237

REGRESSION EQUATIONS FOR ARMPIT HEIGHT
ARMPIT HEIGHT       : .1467     *AGE      +22.53                                                    R**2 :   .9085    NSUB : 1310
ARMPIT HEIGHT       : .1916     *WEIGHT   +25.19                                                    R**2 :   .8475    NSUB : 1310
ARMPIT HEIGHT       : .8315     *STANDING -4.469                                                    R**2 :   .9921    NSUB : 1310
ARMPIT HEIGHT       :-.1217E-01*WEIGHT    +.8770     *STANDING -5.954                               R**2 :   .9926    NSUB : 1310

REGRESSION EQUATIONS FOR WAIST HEIGHT
WAIST HEIGHT        : .1186     *AGE      +17.74                                                    R**2 :   .8929    NSUB : 1239
WAIST HEIGHT        : .1530     *WEIGHT   +19.97                                                    R**2 :   .8146    NSUB : 1239
WAIST HEIGHT        : .6822     *STANDING -4.726                                                    R**2 :   .9826    NSUB : 1239
WAIST HEIGHT        :-.1855E-01*WEIGHT    +.7519     *STANDING -7.012                               R**2 :   .9843    NSUB : 1239

REGRESSION EQUATIONS FOR SEATED HEIGHT
SEATED HEIGHT       : .7804E-01*AGE       +19.17                                                    R**2 :   .8944    NSUB : 3848
SEATED HEIGHT       : .1047     *WEIGHT   +20.34                                                    R**2 :   .8785    NSUB : 3848
SEATED HEIGHT       : .4412     *STANDING +4.849                                                    R**2 :   .9641    NSUB : 3848
SEATED HEIGHT       : .5848E-02*AGE       +.1910E-01*WEIGHT   +.3393    *STANDING +8.114            R**2 :   .9686    NSUB : 3848

REGRESSION EQUATIONS FOR HEAD LENGTH
HEAD LENGTH         : .3642E-02*AGE       +6.881                                                    R**2 :   .3224    NSUB : 1297
HEAD LENGTH         : .5571E-02*WEIGHT    +6.881                                                    R**2 :   .4124    NSUB : 1297
HEAD LENGTH         : .2249E-01*STANDING  +6.110                                                    R**2 :   .4191    NSUB : 1297
HEAD LENGTH         :-.3975E-02*AGE       +.2793E-02*WEIGHT   +.3264E-01*STANDING +5.825            R**2 :   .4631    NSUB : 1297
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REGRESSION EQUATIONS FOR HEAD BREADTH
HEAD BREADTH        : .3642E-02*AGE       +5.220                                                R**2 :   .4591    NSUB : 3782
HEAD BREADTH        : .5337E-02*WEIGHT    +5.237                                                R**2 :   .5367    NSUB : 3782
HEAD BREADTH        : .2096E-01*STANDING +4.532                                                 R**2 :   .5129    NSUB : 3782
HEAD BREADTH        :-.6471E-03*AGE       +.3641E-02*WEIGHT    +.1071E-01*STANDING +4.873      R**2 :   .5468    NSUB : 3782

REGRESSION EQUATIONS FOR HEAD TO CHIN HEIGHT
HEAD TO CHIN HEIGH : .8988E-02*AGE       +6.582                                                 R**2 :   .5869    NSUB : 1262
HEAD TO CHIN HEIGH : .1266E-01*WEIGHT    +6.666                                                 R**2 :   .6370    NSUB : 1262
HEAD TO CHIN HEIGH : .5203E-01*STANDING +4.867                                                  R**2 :   .6674    NSUB : 1262
HEAD TO CHIN HEIGH :-.2157E-02*AGC       +.4550E-02*WEIGHT    +.4621E-01*STANDING +5.080       R**2 :   .6808    NSUB : 1262

REGRESSION EQUATIONS FOR NECK CIRCUMFERENCE
NECK CIRCUMFERENCE : .2281E-01*AGE       +8.421                                                 R**2 :   .7077    NSUB : 1310
NECK CIRCUMFERENCE : .3449E-01*WEIGHT    +8.448                                                 R**2 :   .8070    NSUB : 1310
NECK CIRCUMFERENCE : .1301     *STANDING +4.177                                                 R**2 :   .7824    NSUB : 1310
NECK CIRCUMFERENCE :-.2812E-02*AGE       +.3292E-01*WEIGHT    +.2141E-01*STANDING +7.760       R**2 :   .8082    NSUB : 1310

REGRESSION EQUATIONS FOR SHOULDER BREADTH
SHOULDER BREADTH    : .3595E-01*AGE       +7.530                                                R**2 :   .8727    NSUB : 1239
SHOULDER BREADTH    : .4866E-01*WEIGHT    +8.020                                                R**2 :   .8764    NSUB : 1239
SHOULDER BREADTH    : .2040     *STANDING +.8749                                                R**2 :   .9328    NSUB : 1239
SHOULDER BREADTH    : .4037E-02*AGE       +.1483E-01*WEIGHT    +.1271     *STANDING +3.354     R**2 :   .9460    NSUB : 1239

REGRESSION EQUATIONS FOR CHEST DEPTH
CHEST DEPTH         : .2870E-01*AGE       +5.225                                                R**2 :   .7190    NSUB : 1308
CHEST DEPTH         : .4249E-01*WEIGHT    +5.333                                                R**2 :   .8665    NSUB : 1308
CHEST DEPTH         : .1620     *STANDING -.2418E-01                                            R**2 :   .7786    NSUB : 1308
CHEST DEPTH         : .3764E-01*WEIGHT    +.2091E-01*STANDING +4.589                            R**2 :   .8682    NSUB : 1308

REGRESSION EQUATIONS FOR CHEST BREADTH
CHEST BREADTH       : .2699E-01*AGE       +5.195                                                R**2 :   .7952    NSUB : 1311
CHEST BREADTH       : .3856E-01*WEIGHT    +5.411                                                R**2 :   .8917    NSUB : 1311
CHEST BREADTH       : .1504     *STANDING +.3666                                                R**2 :   .8386    NSUB : 1311
CHEST BREADTH       : .4513E-02*AGE       +.2798E-01*WEIGHT    +.2213E-01*STANDING +4.506      R**2 :   .9034    NSUB : 1311

REGRESSION EQUATIONS FOR WAIST DEPTH
WAIST DEPTH         : .1284E-01*AGE       +5.024                                                R**2 :   .3173    NSUB : 1301
WAIST DEPTH         : .2279E-01*WEIGHT    +4.763                                                R**2 :   .5504    NSUB : 1301
WAIST DEPTH         : .7598E-01*STANDING +2.485                                                 R**2 :   .3781    NSUB : 1301
WAIST DEPTH         :-.8176E-02*AGE       +.3995E-01*WEIGHT    -.3147E-01*STANDING +6.097      R**2 :   .6063    NSUB : 1301

REGRESSION EQUATIONS FOR WAIST BREADTH
WAIST BREADTH       : .2718E-01*AGE       +5.367                                                R**2 :   .7342    NSUB : 1310
WAIST BREADTH       : .3977E-01*WEIGHT    +5.508                                                R**2 :   .8634    NSUB : 1310
WAIST BREADTH       : .1522     *STANDING +.4650                                                R**2 :   .7820    NSUB : 1310
WAIST BREADTH       : .3925E-02*AGE       +.3503E-01*WEIGHT    +5.406                           R**2 :   .8664    NSUB : 1310

REGRESSION EQUATIONS FOR BUTTOCK DEPTH
BUTTOCK DEPTH       : .2730E-01*AGE       +4.812                                                R**2 :   .7191    NSUB : 1224
BUTTOCK DEPTH       : .4032E-01*WEIGHT    +4.910                                                R**2 :   .8631    NSUB : 1224
BUTTOCK DEPTH       : .1528     *STANDING -.1220                                                R**2 :   .7468    NSUB : 1224
BUTTOCK DEPTH       : .4893E-02*AGE       +.3874E-01*WEIGHT    -.1900E-01*STANDING +5.466      R**2 :   .8653    NSUB : 1224
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REGRESSION EQUATIONS FOR HIP BREADTH,STANDING
HIP BREADTH,STANDI = .3552E-01*AGE      +5.542                                              R**2 =   .8640    NSUB = 1234
HIP BREADTH,STANDI = .4957E-01*WEIGHT   +5.905                                              R**2 =   .9229    NSUB = 1234
HIP BREADTH,STANDI = .1960    *STANDING -.7718                                              R**2 =   .8011    NSUB = 1234
HIP BREADTH,STANDI = .1151E-01*AGE      +.3192E-01*WEIGHT   +.1642E-01*STANDING +5.020      R**2 =   .9477    NSUB = 1234

REGRESSION EQUATIONS FOR SHOULDER TO ELBOW LENGTH
SHOULDER TO ELBOW  = .3933E-01*AGE      +6.369                                              R**2 =   .8922    NSUB = 3023
SHOULDER TO ELBOW  = .5175E-01*WEIGHT   +7.038                                              R**2 =   .8440    NSUB = 3023
SHOULDER TO ELBOW  = .2237    *STANDING -.9239                                              R**2 =   .9735    NSUB = 3023
SHOULDER TO ELBOW  = .8433E-03*AGE      +.2193    *STANDING -.7898                          R**2 =   .9736    NSUB = 3023

REGRESSION EQUATIONS FOR FOREARM-HAND LENGTH
FOREARM-HAND LENGT = .4900E-01*AGE      +8.421                                              R**2 =   .8783    NSUB = 3821
FOREARM-HAND LENGT = .6536E-01*WEIGHT   +9.182                                              R**2 =   .8541    NSUB = 3821
FOREARM-HAND LENGT = .2804    *STANDING -.7587                                              R**2 =   .9701    NSUB = 3821
FOREARM-HAND LENGT =-.2689E-02*AGE      +.4490E-02*WEIGHT   +.2776    *STANDING -.6374      R**2 =   .9709    NSUB = 3821

REGRESSION EQUATIONS FOR BICEPS CIRCUMFERENCE
BICEPS CIRCUMFEREN = .2664E-01*AGE      +4.976                                              R**2 =   .6794    NSUB = 3824
BICEPS CIRCUMFEREN = .4173E-01*WEIGHT   +4.878                                              R**2 =   .9115    NSUB = 3824
BICEPS CIRCUMFEREN = .1501    *STANDING +.1143                                              R**2 =   .7281    NSUB = 3824
BICEPS CIRCUMFEREN = .5211E-01*WEIGHT   -.4492E-01*STANDING +6.478                          R**2 =   .9203    NSUB = 3824

REGRESSION EQUATIONS FOR ELBOW CIRCUMFERENCE
ELBOW CIRCUMFERENC = .2267E-01*AGE      +5.152                                              R**2 =   .7400    NSUB = 3822
ELBOW CIRCUMFERENC = .3434E-01*WEIGHT   +5.166                                              R**2 =   .9287    NSUB = 3822
ELBOW CIRCUMFERENC = .1290    *STANDING +.9440                                              R**2 =   .8097    NSUB = 3822
ELBOW CIRCUMFERENC =-.1938E-02*AGE      +.3358E-01*WEIGHT   +.1344E-01*STANDING +4.738      R**2 =   .9293    NSUB = 3822

REGRESSION EQUATIONS FOR FOREARM CIRCUMFERENCE
FOREARM CIRCUMFERE = .2267E-01*AGE      +5.152                                              R**2 =   .7400    NSUB = 3822
FOREARM CIRCUMFERE = .3434E-01*WEIGHT   +5.166                                              R**2 =   .9287    NSUB = 3822
FOREARM CIRCUMFERE = .1290    *STANDING +.9440                                              R**2 =   .8097    NSUB = 3822
FOREARM CIRCUMFERE =-.1938E-02*AGE      +.3358E-01*WEIGHT   +.1344E-01*STANDING +4.738      R**2 =   .9293    NSUB = 3822

REGRESSION EQUATIONS FOR WRIST CIRCUMFERENCE
WRIST CIRCUMFERENC = .1145E-01*AGE      +3.971                                              R**2 =   .6390    NSUB = 1311
WRIST CIRCUMFERENC = .1771E-01*WEIGHT   +3.951                                              R**2 =   .8395    NSUB = 1311
WRIST CIRCUMFERENC = .6620E-01*STANDING +1.791                                              R**2 =   .7273    NSUB = 1311
WRIST CIRCUMFERENC =-.3478E-02*AGE      +.1804E-01*WEIGHT   +.1674E-01*STANDING +3.447      R**2 =   .8446    NSUB = 1311

REGRESSION EQUATIONS FOR KNEE HEIGHT,SEATED
KNEE HEIGHT,SEATED = .5917E-01*AGE      +9.584                                              R**2 =   .8612    NSUB = 3678
KNEE HEIGHT,SEATED = .7857E-01*WEIGHT   +10.55                                              R**2 =   .8222    NSUB = 3678
KNEE HEIGHT,SEATED = .3433    *STANDING -1.746                                              R**2 =   .9693    NSUB = 3678
KNEE HEIGHT,SEATED =-.8480E-02*AGE      -.4527E-02*WEIGHT   +.4045    *STANDING -3.654      R**2 =   .9714    NSUB = 3678

REGRESSION EQUATIONS FOR THIGH CIRCUMFERENCE
THIGH CIRCUMFERENC = .6066E-01*AGE      +9.311                                              R**2 =   .7556    NSUB = 3782
THIGH CIRCUMFERENC = .8944E-01*WEIGHT   +9.551                                              R**2 =   .8992    NSUB = 3782
THIGH CIRCUMFERENC = .3382    *STANDING -1.560                                              R**2 =   .7921    NSUB = 3782
THIGH CIRCUMFERENC = .1018E-01*AGE      +.8338E-01*WEIGHT   -.2709E-01*STANDING +10.25      R**2 =   .9015    NSUB = 3782
```

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REGRESSION EQUATIONS FOR UPPER LEG CIRCUMFERENCE
UPPER LEG CIRCUMFE : .4805E-01*AGE      +7.998                                          R**2 :   .7829    NSUB : 3777
UPPER LEG CIRCUMFE : .7076E-01*WEIGHT   +8.195                                          R**2 :   .9292    NSUB : 3777
UPPER LEG CIRCUMFE : .2691    *STANDING -.6787                                          R**2 :   .8281    NSUB : 3777
UPPER LEG CIRCUMFE : .5930E-02*AGE      +.6358E-01*WEIGHT   +8.043                      R**2 :   .9316    NSUB : 3777

REGRESSION EQUATIONS FOR KNEE CIRCUMFERENCE
KNEE CIRCUMFERENCE : .4805E-01*AGE      +7.998                                          R**2 :   .7829    NSUB : 3777
KNEE CIRCUMFERENCE : .7076E-01*WEIGHT   +8.195                                          R**2 :   .9292    NSUB : 3777
KNEE CIRCUMFERENCE : .2691    *STANDING -.6787                                          R**2 :   .8281    NSUB : 3777
KNEE CIRCUMFERENCE : .5930E-02*AGE      +.6358E-01*WEIGHT   +8.043                      R**2 :   .9316    NSUB : 3777

REGRESSION EQUATIONS FOR CALF CIRCUMFERENCE
CALF CIRCUMFERENCE : .3544E-01*AGE      +6.685                                          R**2 :   .7907    NSUB : 3822
CALF CIRCUMFERENCE : .5209E-01*WEIGHT   +6.839                                          R**2 :   .9342    NSUB : 3822
CALF CIRCUMFERENCE : .1998    *STANDING +.2129                                          R**2 :   .8486    NSUB : 3822
CALF CIRCUMFERENCE : .1539E-02*AGE      +.4370E-01*WEIGHT   +.2825E-01*STANDING +5.794  R**2 :   .9380    NSUB : 3822

REGRESSION EQUATIONS FOR ANKLE CIRCUMFERENCE
ANKLE CIRCUMFERENC : .1770E-01*AGE      +5.116                                          R**2 :   .7028    NSUB : 1314
ANKLE CIRCUMFERENC : .2659E-01*WEIGHT   +5.152                                          R**2 :   .8686    NSUB : 1314
ANKLE CIRCUMFERENC : .1016    *STANDING +1.786                                          R**2 :   .7887    NSUB : 1314
ANKLE CIRCUMFERENC :-.3664E-02*AGE      +.2284E-01*WEIGHT   +.3523E-01*STANDING +3.995  R**2 :   .8741    NSUB : 1314

REGRESSION EQUATIONS FOR ANKLE HEIGHT,OUTSIDE
ANKLE HEIGHT,OUTSI : .6637E-02*AGE      +1.319                                          R**2 :   .5237    NSUB : 1182
ANKLE HEIGHT,OUTSI : .9232E-02*WEIGHT   +1.417                                          R**2 :   .5227    NSUB : 1182
ANKLE HEIGHT,OUTSI : .4015E-01*STANDING -.2052E-01                                      R**2 :   .5974    NSUB : 1182
ANKLE HEIGHT,OUTSI :-.1302E-02*AGE      +.4697E-01*STANDING -.2305                      R**2 :   .5992    NSUB : 1182

REGRESSION EQUATIONS FOR FOOT BREADTH
FOOT BREADTH       : .8742E-02*AGE      +2.193                                          R**2 :   .7581    NSUB : 3826
FOOT BREADTH       : .1221E-01*WEIGHT   +2.283                                          R**2 :   .8088    NSUB : 3826
FOOT BREADTH       : .5052E-01*STANDING +.5281                                          R**2 :   .8544    NSUB : 3826
FOOT BREADTH       :-.1722E-02*AGE      +.4119E-02*WEIGHT   +.4407E-01*STANDING +.7576  R**2 :   .8687    NSUB : 3826

REGRESSION EQUATIONS FOR FOOT LENGTH
FOOT LENGTH        : .2436E-01*AGE      +5.384                                          R**2 :   .8191    NSUB : 3828
FOOT LENGTH        : .3275E-01*WEIGHT   +5.742                                          R**2 :   .8079    NSUB : 3828
FOOT LENGTH        : .1416    *STANDING +.7017                                          R**2 :   .9341    NSUB : 3828
FOOT LENGTH        :-.5757E-02*AGE      +.1715    *STANDING -.2125                      R**2 :   .9380    NSUB : 3828
```

APPENDIX E

INERTIAL PROPERTIES OF ELLIPSOIDS AND RIGHT ELLIPTICAL CYLINDER STACKS

An ellipsoid with a semiaxis length in the x direction of a, in the y direction of b, and in the z direction of c has volume $4/3\ \pi$ abc. If this ellipsoid is homogeneous with density ρ its inertial properties are as follows:

mass $= 4/3\ \pi\ \rho$ abc,

x moment of inertia $= \frac{\text{mass}}{5}\ (b^2 + c^2)$,

y moment of inertia $= \frac{\text{mass}}{5}\ (a^2 + c^2)$,

z moment of inertia $= \frac{\text{mass}}{5}\ (a^2 + b^2)$,

and the center of gravity is located at the center of the ellipsoid.

The other geometric model utilized by GEBOD for the determination of inertial properties is a stack of right elliptical cylinders.

The cylinders in the stack are numbered from 1 to n (where there are n cylinders in the stack) sequentially from one end of the stack to the other. In order to locate the center of gravity of this figure an axis system must be defined. The origin of this axis system is located at the center of the elliptical end surface of cylinder 1 most distant from the center of the stack. The x, y, and z axes are parallel to the directions of the local reference system of the segment being modeled (see Section 3). The end of the stack is chosen for the origin (and to begin numbering with) so that the positive z axis passes through all the cylinders.

The cylinders are stacked so that the positive z axis passes through the center of both elliptical end surfaces of each cylinder. The cylinders are oriented so that one semiaxis (referred to as the x semiaxis) is parallel to the x axis, and the other (referred to as the y semiaxis) is parallel to the y axis. The length of the x semiaxis of cylinder i is referred to as a_i, and the length of the y semiaxis is referred to as b_i. Each cylinder has the same height, called h. By assumption, each cylinder is also homogeneous with density ρ, giving the i^{th} cylinder the following geometric and inertial properties:

volume $= v_i = \pi a_i b_i h$,

mass $= m_i = \rho v_i$,

x moment of inertia $= Ixx_i = \frac{m_i}{12}(3b_i^2 + h^2)$,

y moment of inertia $= Iyy_i = \frac{m_i}{12}(3a_i^2 + h^2)$

z moment of inertia $= Izz_i = \frac{m_i}{4}(a_i^2 + b_i^2)$,

x center of mass coordinate $= cgx_i = 0.0$

y center of mass coordinate $= cgy_i = 0.0$

z center of mass coordinate $= cgz_i = (i - \frac{1}{2})h$,

where the x, y, and z moments of inertia are about axes parallel to the x, y, and z reference axes, respectively, but through the center (both geometric center and center of gravity) of the cylinder.

To compute the mass or volume of the entire stack the individual masses or volumes are summed. The center of mass of the stack is located as follows:

x center of mass coordinate $= cgx = \frac{\Sigma m_i cgx_i}{\Sigma m_i} = 0.0$,

y center of mass coordinate $= cgy = \frac{\Sigma m_i cgy_i}{\Sigma m_i} = 0.0$,

z center of mass coordinate $= cgz = \frac{\Sigma m_i cgz_i}{\Sigma m_i}$.

Moments of inertia may be combined by simple summing, as long as they have all been computed relative to the same set of axes. Since different x and y axes have been used in the computation of each cylinder's moments of inertia, a single set of axes must be defined, the individual moments of inertia recomputed relative to that set of axes, and then summed. It is standard to express moments of inertia relative to axes at the center of gravity of a body, and this is assumed by the ATB Model. For this reason a new axis system is defined at the center of mass of the stack and parallel to the old reference system. Since the x and y coordinates of the center of mass, relative to the old system, are both zero, the new and old systems share a common z axis, which is also the z axis relative to which the Izz_i (i = 1, n) were computed. Thus, the moment of inertia of the stack relative to this new z axis is simply the sum of the individual Izz_i. Since the x axes relative to which the Ixx_i (i = 1, n) were computed are all parallel to the x axis of the new system, the parallel axis theorem may be used to recompute the moments of inertia of each cylinder relative to the new system's x axis, and these values may then be summed. The same procedure is then applied to the moments of inertia about y. These computations which determine the moments of inertia of the entire stack are summarized as follows:

$$\text{x moment of inertia} = Ixx = \sum_{i=1}^{n} [Ixx_i + m_i(cgz - cgz_i)^2],$$

$$\text{y moment of inertia} = Iyy = \sum_{i=1}^{n} [Iyy_i = m_i(cgz - cgz_i)^2],$$

$$\text{z moment of inertia} = Izz = \sum_{i=1}^{n} Izz_i.$$

APPENDIX F

SOURCE LISTING OF PROGRAM GEBOD

```
C--PROGRAM GEBOD------(PERKIN-ELMER  FTN VII)--------------------------------C
C     GEBOD GENERATES BODY DESCRIPTION DATA SETS FOR USE IN THE ARTICULATED  C
C     TOTAL BODY (ATB) MODEL.  USER HAS CHOICE OF PRODUCING A DATA SET       C
C     CORRESPONDING TO ADULT MALE, ADULT FEMALE, OR A CHILD SUBJECT.         C
C     THE BASIC GEOMETRY OF THE MODEL USED TO CALCULATE THE BODY DESCRIPTION C
C     DATA IS AN EXTENSIVELY MODIFIED VERSION OF THE MODEL USED BY           C
C     PROGRAM GOOD (GENERATOR OF OCCUPANT DATA) WRITTEN BY CALSPAN           C
C     CORP.  THE MODIFICATIONS TO THE MODEL AND THIS THE RESULTING           C
C     PROGRAM, WERE WRITTEN BY THE UNIVERSITY OF DAYTON RESEARCH             C
C     INSTITUTE UNDER CONTRACT F33615-81-C-0513                              C
C                                                                            C
C     FILES:                                                                 C
C        UNIT1--USER SUPPLIED DIMENSIONAL DATA.                              C
C        UNIT3--RESULTS READY FOR INSERTION INTO AN ATB MODEL INPUT DECK.    C
C        UNIT5 (CRT OUTPUT)--INPUT PROMPTS ARE WRITTEN TO THIS UNIT.         C
C        UNIT7 (CRT INPUT)--SUBJECT DESCRIPTION IS ENTERED TO THIS UNIT.     C
C        UNIT9 (PRINTER)--TABLE FORM OF RESULTS.                             C
C                                                                            C
C     ROUTINES (IN ORDER OF APPEARANCE):                                     C
C        PROGRAM GEBOD                                                       C
C        BLOCK DATA                                                          C
C        SUBROUTINE DIALOG                                                   C
C        SUBROUTINE ASKUN                                                    C
C        SUBROUTINE PTILE                                                    C
C        SUBROUTINE CONTAC                                                   C
C        SUBROUTINE SEGMAS                                                   C
C        SUBROUTINE SGINER                                                   C
C        SUBROUTINE ELLIP                                                    C
C        ENTRY ELLPMI                                                        C
C        SUBROUTINE TORSO                                                    C
C        SUBROUTINE FEET                                                     C
C        SUBROUTINE RESULTS                                                  C
C        SUBROUTINE CNVRT                                                    C
C----------------------------------------------------------------------------C

      PROGRAM GEBOD
      COMMON /DIMS/ DD(-1:31),REGEQ(24,-1:31),PRED(0:2)
      COMMON /FLOAT/ PI,PI2,PI4

      CALL CARCON (9,1)
      PI = ACOS(-1.)
      PI2 = PI + PI
      PI4 = PI2 + PI2


10    CALL DIALOG (IPTR,ICNT,ISTRT)
      IF (IPTR.LT.25) THEN
         DO 100 I = ISTRT,31
            DD(I) = REGEQ(IPTR+ICNT,I)
            DO 100 J = 0,ICNT -1
100            DD(I) = DD(I) + PRED(J)*REGEQ(IPTR+J,I)
      ENDIF

      CALL CONTAC
      CALL SEGMAS
      CALL SGINER
      CALL RESULTS (ISTRT)
      GOTO 10
      END
C--BLOCK DATA-----------------------------------------------------------------C
C     DATA IN COMMON AREAS                                                   C
C     /SGMNTS/--SEGMENT DATA                                                 C
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C        ABCN--X,Y, AND Z CONTACT ELLIPSOID SEMIAXES FOR EACH SEGMENT         C
C        RMN--MASS OF EACH SEGMENT                                            C
C        PHI--SEGMENT MOMENTS OF INERTIA                                      C
C        XYZCG--LOCAL REFERENCE COORDINATES OF CENTER OF SEGMENT              C
C           CONTACT ELLIPSOIDS                                                C
C                                                                             C
C     /JNTS/--JOINT DATA                                                      C
C        RNJ--LOCAL REFERENCE SYSTEM COORDINATES OF EACH JOINT.  THIRD        C
C           SUBSCRIPT EQUAL TO 2 SPECIFIES LOCAL REFERENCE SYSTEM OF SEGMENT  C
C           J+1. A VALUE OF 1 IN THIS POSITION SPECIFIES LOCAL REFERENCE      C
C           SYSTEM OF SEGMENT JNT(J), WHERE IN BOTH CASES J IS THE VALUE OF   C
C           THE FIRST SUBSCRIPT.                                              C
C        JNT--POINTER ARRAY FOR ASSOCIATING JOINTS WITH SEGMENTS              C
C        YPRLL--YAW, PITCH, AND ROLL ANGLES OF JOINT AXES RELATIVE TO LOCAL   C
C           REFERENCE AXES                                                    C
C        IPIN--SPECIFIES JOINT TYPE                                           C
C                                                                             C
C     /DIMS/--BODY DIMENSION DATA                                             C
C        DD--BODY DIMENSIONS                                                  C
C        REGEQ--REGRESSION EQUATIONS USED TO COMPUTE BODY DIMENSIONS          C
C        PRED--VALUES OF PREDICTING VARIABLES TO BE USED WITH REGEQ           C
C        RANGE--ACCEPTIBLE RANGE FOR PREDICTING VARIABLES                     C
C        CONV--CONSTANTS FOR CONVERTING BODY DIMENSIONS FROM METRIC TO        C
C           ENGLISH UNITS                                                     C
C                                                                             C
C     /NAMES/--CHARACTER STRINGS FOR VARIOUS LABLES                           C
C        SUBTYP--DESCRIPTION TO USER OF 4 SOURCES OF BODY DIMENSION DATA      C
C        SEGLAB--SEGMENT LABLES                                               C
C        JNTLAB--JOINT LABLES                                                 C
C        PLTSYM--PLOTTING SYMBOL FOR SEGMENTS AND JOINTS                      C
C        DIMLAB--NAMES OF THE BODY DIMENSIONS                                 C
C        TITLE--RUN TITLE SUPPLIED BY THE USER                                C
C        UNITS--UNITS FOR USER TO CHOOSE BETWEEN                              C
C                                                                             C
C     /FLOAT/--VARIOUS CONSTANTS                                              C
C        PI--THE CONSTANT PI                                                  C
C        PI2--PI**2                                                           C
C        PI4--PI**4                                                           C
C        DENS--DENSITY USED FOR COMPUTATION OF SEGMENT INERTIAL PROPERTIES    C
C        GRAV--ACCELERATION OF GRAVITY                                        C
C                                                                             C
C     /CYL/--DATA USED IN RIGHT ELLIPTICAL CYLINDER MODELLING OF SEGMENTS     C
C        FOR COMPUTATION OF INERTIAL PROPERTIES                               C
C        ZESS--CONTAINS Z CORDINATE GIVING VERTICAL EXTENT OF CYLINDERS       C
C        ZH--HEIGHT OF EACH CYLINDER IN THE NUMERICAL INTEGRATION             C
C        NSEG--NUMBER OF CYLINDERS IN THE NUMERICAL INTEGRATION               C
C        CGZ--Z COORDINATE OF CENTER OF GRAVITY OF MODEL                      C
C        WTCOR--EIGHT COORECTION FACTOR USED TO ADJUST DENS                   C
C                                                                             C
C     ALL DATA WILL BE CALCULATED AND STORED IN ENGLISH UNITS                 C
C        DD(-1)--MONTHS                                                       C
C        DD(0)--POUNDS                                                        C
C        DD(1)-DD(31)--INCHES                                                 C
C        DENS--SLUG/IN**3                                                     C
C        GRAV--IN/SEC**2                                                      C
C        RMN--SLUGS                                                           C
C        PHI--SLUG*IN**2                                                      C
C        ALL REMAINING LINEAR MEASUREMENTS ARE IN INCHES                      C
C     THESE UNITS ARE UTILIZED UNTIL JUST PRIOR TO WRITTING OUT OF RE-        C
C     SULTS.  VALUES ARE THEN CONVERTED, IN PLACE, TO APPROPRIATE UNITS.      C
C     THE VALUE STORED IN GRAV IS USED FOR CONVERSION FROM SLUGS TO           C
C     POUNDS.                                                                 C
C-----------------------------------------------------------------------------C
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      BLOCK DATA
      COMMON /SGMNTS/ ABCN(15,3),RMN(15),PHI(3,15),XYZCG(15,3)
      COMMON /JNTS/ RNJ(3,28),JNT(14),YPRLL(14,6),IPIN(14)
      COMMON /DIMS/ DD(-1:31),REGEQ(24,-1:31),PRED(3),
     &              RANGE(2,-1:1,3),CONV(-1:1)
      COMMON /NAMES/ SUBTYP(4),SEGLAB(15),JNTLAB(14),PLTSYM(29),
     &              DIMLAB(-1:31),TITLE,UNITS(3,-1:2)
      COMMON /FLOAT/ PI,PI2,PI4,DENS,GRAV
      COMMON /CYL/ ZEES(0:15),ZH(15),NSEG(15),CGZ(15),WTCCR
      CHARACTER SUBTYP*20,SEGLAB*3,JNTLAB*2,PLTSYM*1,DIMLAB*24,TITLE*60
      CHARACTER UNITS*6

      DATA SEGLAB/'LT ','CT ','UT ','N  ','H  ','RUL','RLL',
     &'RF ','LUL','LLL','LF ','RUA','RLA','LUA','LLA'/
      DATA JNTLAB/'P ','W ','NP','HP','RH','RK','RA',
     &'LH','LK','LA','RS','RE','LS','LE '/
      DATA PLTSYM/'1','2','3','4','5','6','7','8','9','A','B','C','D',
     &'E','F','M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z'/
      DATA JNT/1,2,3,4,1,6,7,1,9,10,3,12,3,14/
      DATA SUBTYP /'CHILD (2 - 19 YEARS)','ADULT FEMALE',
     &             'ADULT MALE', 'USER SUPPLIED DIM.'/
      DATA UNITS /'MONTHS','YEARS',' ','LBS','KGRAMS','%-TILE',
     &             'IN','CM','%-TILE','ENGLSH','METRIC',' '/
      DATA CONV /12.,2.2046,.39370/,DENS,GRAV/1.12287E-3,32.17405/
C
C DIMENSIONAL DATA LABELS
      DATA DIMLAB /
     &     'AGE                     ','WEIGHT                  ',
     &     'STANDING HEIGHT         ','SHOULDER HEIGHT         ',
     &     'ARMPIT HEIGHT           ','WAIST HEIGHT            ',
     &     'SEATED HEIGHT           ','HEAD LENGTH             ',
     &     'HEAD BREADTH            ','HEAD TO CHIN HEIGHT     ',
     &     'NECK CIRCUMFERENCE      ','SHOULDER BREADTH        ',
     &     'CHEST DEPTH             ','CHEST BREADTH           ',
     &     'WAIST DEPTH             ','WAIST BREADTH           ',
     &     'BUTTOCK DEPTH           ','HIP BREADTH,STANDING    ',
     &     'SHOULDER TO ELBOW LENGTH','FOREARM-HAND LENGTH     ',
     &     'BICEPS CIRCUMFERENCE    ','ELBOW CIRCUMFERENCE     ',
     &     'FOREARM CIRCUMFERENCE   ','WRIST CIRCUMFERENCE     ',
     &     'KNEE HEIGHT,SEATED      ','THIGH CIRCUMFERENCE     ',
     &     'UPPER LEG CIRCUMFERENCE ','KNEE CIRCUMFERENCE      ',
     &     'CALF CIRCUMFERENCE      ','ANKLE CIRCUMFERENCE     ',
     &     'ANKLE HEIGHT,OUTSIDE    ','FOOT BREADTH            ',
     &     'FOOT LENGTH             '/
      DATA RANGE /
     & 24.00    , 240.0    , 22.27    , 247.6    , 32.01    , 76.54    ,
     & 18.50    , 56.50    , 85.00    , 200.0    , 56.93    , 72.05    ,
     & 21.50    , 50.50    , 118.0    , 264.0    , 62.17    , 77.64    /
      DATA (REGEQ(J,-1), J=1,24) /
     & 1.000    , .4547E-12, 1.213    , 25.43    , 5.202    ,-158.9    ,
     & 1.000    ,0.        ,0.        , .4547E-12,0.        ,0.        ,
     &0.        ,0.        ,0.        ,0.        ,0.        ,0.        ,
     &0.        ,0.        ,0.        ,0.        ,0.        ,0.        /
      DATA (REGEQ(J, 0), J=1,24) /
     & .6625    ,-.7660    , 1.000    , .4547E-12, 3.743    ,-122.2    ,
     &0.        , 1.000    ,0.        , .4547E-12, 1.000    , .4547E-12,
     & 3.737    ,-111.2    , 1.000    ,0.        , .4547E-12, 1.000    ,
     & .9095E-12, 4.530    ,-142.7    , 1.000    ,0.        , .9095E-12/
      DATA (REGEQ(J, 1), J=1,24) /
     & .1756    , 32.62    , .2314    , 35.58    , 1.000    , .2274E-12,
     &0.        ,0.        , 1.000    , .2274E-12, .7589E-01, 54.16    ,
     & 1.000    , .2274E-12,0.        , 1.000    , .2274E-12, .5850E-01,
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& 59.56    , 1.000    , .4547E-12,0.         , 1.000    , .4547E-12/
 DATA (REGEG(J, 2), J=1,24) /
& .1518    , 24.79    , .1994    , 27.37    , .8721    ,-3.398    ,
&0.        ,0.        , .8721    ,-3.898    , .7182E-01, 42.77    ,
& .8751    ,-3.936    , .7555E-02, .3469    ,-3.096    , .5844E-01,
& 47.02    , .8911    ,-5.049    , .8583E-02, .8522    ,-3.824    /
 DATA (REGEG(J, 3), J=1,24) /
& .1467    , 22.53    , .1916    , 25.19    , .8315    ,-4.469    ,
&0.        ,-.1217E-01, .8770    ,-5.954    , .5840E-01, 39.83    ,
& .8309    ,-5.762    ,-.6495E-02, .8551    ,-6.484    , .4637E-01,
& 43.06    , .8398    ,-7.529    ,-.3761E-02, .8569    ,-8.066    /
 DATA (REGEQ(J, 4), J=1,24) /
& .1186    , 17.74    , .1530    , 19.97    , .6922    ,-4.726    ,
&0.        ,-.1855E-01, .7519    ,-7.012    , .5302E-01, 32.73    ,
& .6845    ,-4.206    ,0.        , .6845    ,-4.206    , .3642E-01,
& 35.39    , .7043    ,-7.256    ,-.6506E-02, .7338    ,-8.185    /
 DATA (REGEQ(J, 5), J=1,24) /
& .7804E-01, 19.17    , .1047    , 20.34    , .4412    , 4.849    ,
& .5848E-02, .1910E-01, .3393    , 8.114    , .3620E-01, 29.09    ,
& .4225    , 6.734    , .5773E-02, .4010    , 7.376    , .2664E-01,
& 32.06    , .4043    , 8.460    , .4060E-02, .3859    , 9.039    /
 DATA (REGEQ(J, 6), J=1,24) /
& .3642E-02, 6.831    , .5571E-02, 6.881    , .2249E-01, 6.110    ,
&-.3975E-02, .2793E-02, .3264E-01, 5.825    , .4897E-02, 6.625    ,
& .3600E-01, 4.950    , .3021E-02, .2471E-01, 5.286    , .3209E-02,
& 7.266    , .2680E-01, 5.952    , .2233E-02, .1668E-01, 6.271    /
 DATA (REGEQ(J, 7), J=1,24) /
& .3642E-02, 5.220    , .5337E-02, 5.237    , .2096E-01, 4.532    ,
&-.6471E-03, .3641E-02, .1071E-01, 4.873    , .4089E-02, 5.194    ,
& .1347E-01, 4.855    , .4089E-02,0.         , 5.194    , .3060E-02,
& 5.611    , .1174E-01, 5.322    , .3060E-02,0.         , 5.611    /
 DATA (REGEQ(J, 8), J=1,24) /
& .8988E-02, 6.582    , .1266E-01, 6.666    , .5203E-01, 4.867    ,
&-.2157E-02, .4550E-02, .4621E-01, 5.080    , .7362E-02, 7.688    ,
& .6816E-01, 4.275    , .3057E-02, .5674E-01, 4.615    , .3143E-02,
& 8.420    , .4659E-01, 5.712    ,0.        , .4659E-01, 5.712    /
 DATA (REGEQ(J, 9), J=1,24) /
& .2281E-01, 8.421    , .3449E-01, 8.448    , .1301    , 4.177    ,
&-.2812E-02, .3292E-01, .2141E-01, 7.760    , .2316E-01, 10.34    ,
& .8900E-01, 7.607    , .2316E-01,0.         , 10.34    , .2444E-01,
& 10.85    , .6527E-01, 10.54    , .2806E-01,-.6185E-01, 14.54    /
 DATA (PEGEQ(J,10), J=1,24) /
& .3595E-01, 7.530    , .4866E-01, 8.020    , .2040    , .8749    ,
& .4037E-02, .1483E-01, .1271    , 3.354    , .1927E-01, 11.66    ,
& .1246    , 6.160    , .1369E-01, .7344E-01, 7.682    , .1612E-01,
& 13.24    , .1181    , 7.790    , .1253E-01, .6133E-01, 9.578    /
 DATA (REGEQ(J,11), J=1,24) /
& .2870E-01, 5.225    , .4249E-01, 5.333    , .1620    ,-.2418E-01,
&0.        , .3764E-01, .2091E-01, 4.539    , .3412E-01, 4.965    ,
& .7300E-01, 4.650    , .3989E-01,-.7607E-01, 9.086    , .2690E-01,
& 4.984    , .6114E-01, 5.386    , .3174E-01,-.8265E-01, 9.915    /
 DATA (REGEQ(J,12), J=1,24) /
& .2699E-01, 5.195    , .3856E-01, 5.411    , .1504    , .3666    ,
& .4513E-02, .2798E-01, .2213E-01, 4.506    , .3185E-01, 6.968    ,
& .8875E-01, 5.357    , .3505E-01,-.4222E-01, 9.255    , .2911E-01,
& 7.854    , .8877E-01, 6.709    , .3254E-01,-.5866E-01, 11.35    /
 DATA (REGEQ(J,13), J=1,24) /
& .1284E-01, 5.026    , .2279E-01, 4.763    , .7598E-01, 2.485    ,
&-.8176E-02, .3995E-01,-.3147E-01, 6.097    , .2922E-01, 2.979    ,
& .5358E-01, 3.279    , .3511E-01,-.7761E-01, 7.183    , .3026E-01,
& 3.528    , .5167E-01, 5.174    , .3706E-01,-.1162    , 10.46    /
 DATA (REGEQ(J,14), J=1,24) /
& .2718E-01, 5.367    , .3977E-01, 5.508    , .1522    , .4650    ,
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& .3925E-02, .3503E-01,0.        , 5.406     , .3527E-01, 5.010     ,
& .1060     , 2.734     , .3800E-01,-.3598E-01, 6.959     , .3741E-01,
& 5.694     , .1105     , 4.473     , .4211E-01,-.8025E-01, 10.48     /
 DATA (REGEQ(J,15), J=1,24) /
& .2730E-01, 4.812     , .4032E-01, 4.910     , .1525     ,-.1220     ,
& .4893E-02, .3874E-01,-.1900E-01, 5.466     , .3419E-01, 3.976     ,
& .7090E-01, 3.803     , .4021E-01,-.7937E-01, 8.275     , .3077E-01,
& 4.095     , .6978E-01, 4.566     , .3632E-01,-.9475E-01, 9.749     /
 DATA (REGEQ(J,16), J=1,24) /
& .3552E-01, 5.542     , .4957E-01, 5.905     , .1968     ,-.7718     ,
& .1151E-01, .3192E-01, .1642E-01, 5.020     , .4052E-01, 8.610     ,
& .1285     , 5.563     , .4294E-01,-.3192E-01, 10.34     , .2803E-01,
& 9.019     , .1258     , 5.100     , .2803E-01,0.        , 9.019     /
 DATA (REGEQ(J,17), J=1,24) /
& .3933E-01, 6.369     , .5175E-01, 7.038     , .2237     ,-.9239     ,
& .8433E-03,0.        , .2193     ,-.7898     , .1702E-01, 10.04     ,
& .1962     ,-.3163     , .2976E-02, .1851     , .1459E-01, .1256E-01,
& 11.97     , .2087     ,-.4158     ,0.        , .2087     ,-.4158     /
 DATA (REGEQ(J,18), J=1,24) /
& .4900E-01, 8.421     , .6536E-01, 9.182     , .2804     ,-.7587     ,
&-.2689E-02, .4490E-02, .2776     ,-.6374     , .2092E-01, 13.78     ,
& .2478     , .6324     , .2960E-02, .2367     , .9615     , .1671E-01,
& 16.54     , .2646     , .9735     , .1677E-02, .2570     , 1.213     /
 DATA (REGEQ(J,19), J=1,24) /
& .2664E-01, 4.976     , .4173E-01, 4.878     , .1501     , .1143     ,
&0.        , .5211E-01,-.4492E-01, 6.478     , .4369E-01, 4.522     ,
& .5386E-01, 6.646     , .5528E-01,-.1527     , 12.79     , .3340E-01,
& 6.608     , .5996E-01, 8.219     , .4067E-01,-.1243     , 14.02     /
 DATA (REGEQ(J,20), J=1,24) /
& .2267E-01, 5.152     , .3434E-01, 5.166     , .1290     , .9440     ,
&-.1938E-02, .3358E-01, .1344E-01, 4.738     , .2421E-01, 7.539     ,
& .1221     , 2.826     , .2086E-01, .4420E-01, 5.145     , .1919E-01,
& 8.967     , .1061     , 4.894     , .1767E-01, .2601E-01, 7.416     /
 DATA (REGEQ(J,21), J=1,24) /
& .2267E-01, 5.152     , .3434E-01, 5.166     , .1290     , .9440     ,
&-.1938E-02, .3358E-01, .1344E-01, 4.738     , .2643E-01, 5.879     ,
& .7088E-01, 4.719     , .2938E-01,-.3890E-01, 7.986     , .2116E-01,
& 7.411     , .6768E-01, 6.359     , .2341E-01,-.3835E-01, 9.700     /
 DATA (REGEQ(J,22), J=1,24) /
& .1143E-01, 3.971     , .1771E-01, 3.951     , .6620E-01, 1.791     ,
&-.3478E-02, .1804E-01, .1674E-01, 3.447     , .1090E-01, 4.503     ,
& .5371E-01, 2.463     , .9530E-02, .1810E-01, 3.523     , .9921E-02,
& 5.202     , .5166E-01, 3.317     , .9386E-02, .9137E-02, 4.657     /
 DATA (REGEQ(J,23), J=1,24) /
& .5917E-01, 9.584     , .7857E-01, 10.55     , .3433     ,-1.746     ,
&-.8480E-02,-.4527E-02, .4045     ,-3.654     , .3002E-01, 14.98     ,
& .3345     ,-2.547     , .6469E-02, .3104     ,-1.829     , .2467E-01,
& 17.67     , .3558     ,-2.389     , .5244E-02, .3321     ,-2.141     /
 DATA (REGEQ(J,24), J=1,24) /
& .6066E-01, 9.311     , .8944E-01, 9.551     , .3382     ,-1.560     ,
& .1018E-01, .8338E-01,-.2709E-01, 10.25     , .8417E-01, 11.13     ,
& .1869     , 9.912     , .9769E-01,-.1781     , 20.77     , .6998E-01,
& 11.01     , .1614     , 11.89     , .8237E-01,-.2117     , 23.64     /
 DATA (REGEQ(J,25), J=1,24) /
& .4805E-01, 7.998     , .7076E-01, 8.195     , .2691     ,-.6787     ,
& .5930E-02, .6358E-01,0.        , 8.043     , .6412E-01, 9.905     ,
& .1664     , 7.448     , .7187E-01,-.1022     , 15.44     , .3229E-01,
& 9.621     , .1412     , 5.370     , .3229E-01,0.        , 9.621     /
 DATA (REGEQ(J,26), J=1,24) /
& .4805E-01, 7.998     , .7076E-01, 8.195     , .2691     ,-.6787     ,
& .5930E-02, .6358E-01,0.        , 8.043     , .4406E-01, 8.694     ,
& .1458     , 4.985     , .4605E-01,-.2626E-01, 10.11     , .3334E-01,
& 9.686     , .1512     , 4.916     , .3334E-01,0.        , 9.686     /
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      DATA (REGEQ(J,27), J=1,24) /
     $ .3544E-01, 6.685    , .5209E-01, 6.639    , .1998    , .2129    ,
     $ .1539E-02, .4370E-01, .2325E-01, 5.794    , .4012E-01, 8.335    ,
     & .1106    , 6.386    , .4429E-01,-.5493E-01, 11.31    , .3250E-01,
     $ 9.002    , .8942E-01, 8.469    , .3718E-01,-.8000E-01, 13.77    /
      DATA (REGEQ(J,28), J=1,24) /
     & .1770E-01, 5.116    , .2659E-01, 5.152    , .1016    , 1.786    ,
     $-.3664E-02, .2284E-01, .3523E-01, 3.995    , .1809E-01, 5.999    ,
     & .7603E-01, 3.449    , .1720E-01, .1177E-01, 5.361    , .1610E-01,
     & 6.028    , .6599E-01, 4.216    , .1665E-01,-.9456E-02, 6.593    /
      DATA (REGEQ(J,29), J=1,24) /
     $ .6837E-02, 1.319    , .9232E-02, 1.417    , .4015E-01,-.2052E-01,
     $-.1302E-02,0.        , .4697E-01,-.2305    , .3434E-02, 2.230    ,
     $ .4163E-01, .9788E-02,0.        , .4163E-01, .9788E-02, .4310E-02,
     $ 4.652    , .8736E-01,-.6990    ,-.1090E-02, .9230E-01,-.8545    /
      DATA (REGEQ(J,30), J=1,24) /
     & .8742E-02, 2.193    , .1221E-01, 2.283    , .5052E-01, .5281    ,
     &-.1722E-02, .4119E-02, .4407E-01, .7576    , .4638E-02, 2.901    ,
     $ .2947E-01, 1.611    , .3353E-02, .1694E-01, 1.984    , .4136E-02,
     $ 3.127    , .3418E-01, 1.459    , .2907E-02, .2101E-01, 1.873    /
      DATA (REGEQ(J,31), J=1,24) /
     & .2436E-01, 5.384    , .3275E-01, 5.742    , .1416    , .7017    ,
     &-.5737E-02,0.        , .1715    ,-.2125    , .1365E-01, 7.738    ,
     & .1299    , 1.186    , .5296E-02, .1101    , 1.775    , .1028E-01,
     $ 8.858    , .1309    , 1.502    , .3570E-02, .1148    , 2.012    /
C
C YAW,PITCH AND ROLL
      DATA YPRLL/
     $   14*0.,30.,0.,0.,30.,0.,90.,45.,0.,90.,45.,0.,60.,0.,60.,
     &   32*0.,-90.,-45.,-90.,-90.,-45.,-90.,15.,0.,15.,15*0./
      DATA IPIN/0,0,0,0,0,1,0,0,1,0,0,1,0,1/
      END
C--SUBROUTINE DIALOG-------------------------------------------------------C
C     DIALOG WRITES PROMPTS TO THE CRT AND ACCEPTS INPUT FROM THE CRT     C
C     DESCRIBING THE SUBJECT FOR WHICH BODY DESCRIPTION DATA IS TO BE     C
C     PRODUCED.  THE PARAMETERS, IPTR, ICNT, AND ISTRT, ARE RETURNED TO THE C
C     MAIN ROUTINE SPECIFYING THE CHOICES MADE BY THE USER                C
C        IPTR--SPECIFIES ROW OF REGEQ CONTAINING FIRST REGRESSION EQUATION C
C           COEFFICIENT TO BE USED.  IPTR IS SET TO 25 FOR USER SUPPLIED  C
C           DIMENSIONAL DATA.                                             C
C        ICNT--NUMBER OF COEFFICIENTS IN THE REGRESSION EQUATION TO BE USED. C
C        ISTRT--FIRST BODY DIMENSION TO BE GENERATED:                     C
C           ISTRT =-1 (AGE) FOR CHILD SUBJECTS                            C
C           ISTRT =0 (WEIGHT) FOR ADULT SUBJECTS OR USER SUPPLIED DATA    C
C     VALUES ARE ALSO READ INTO PRED FOR THE PREDICTING VARIABLES         C
C-------------------------------------------------------------------------C

      SUBROUTINE DIALOG (IPTR,ICNT,ISTRT)
      COMMON /DIMS/ DD(-1:31),REGEQ(24,-1:31),PRED(-1:1),
     $              RANGE(2,-1:1,3),CONV(-1:1)
      COMMON /NAMES/ SUBTYP(4),SEGLAB(15),JNTLAB(14),PLTSYM(29),
     $               DIMNM(-1:31),TITLE,UNITS(3,-1:2)
      CHARACTER SUBTYP*20,SEGLAB*3,JNTLAB*2,PLTSYM*1,ANS*1,DIMNM*24
      CHARACTER TITLE*60,UNITS*6,CLR(7)*4
      INTEGER IPTMAT(-1:2,3),IPT2(13)
      EQUIVALENCE (IPTMAT,IPT2)
      DATA IPT2 /1,3,5,7,11,11,13,15,18,18,20,22,25/
      DATA CLR /Z1B5B3F32,Z6C1B4818,Z4A1B3C0C,Z00194800,3*Z0/

      WRITE (5,11) CLR
      WRITE (5,22)
      READ (7,333) TITLE
      WRITE (5,11) CLR
```

```
      WRITE (5,333) ' '//TITLE
      WRITE (9,333) '1'//TITLE

10    WRITE (5,33) (I,SUBTYP(I),I=1,4)
      WRITE (5,44)
      READ (7,222) ISUB
      IF (ISUB.GT.4 .OR. ISUB.LT.1)  GOTO 10
      WRITE (9,333) '0'//SUBTYP(ISUB)
      ISTRT = -1
      IF (ISUB.GT.1)  ISTRT = 0
      IF (ISUB.GT.3)  GOTO 100

      WRITE (5,11) CLR
      WRITE (5,333) ' '//TITLE
20    WRITE (5,33) (I+1,DIMNM(I),I=ISTRT,1),3,'ALL OF THE ABOVE'
      WRITE (5,55)
      READ (7,222) IDIM
      IDIM = IDIM -1
      IF (IDIM.LT.ISTRT .OR. IDIM.GT.2)  GOTO 20
      IF (IDIM.GE.2)  THEN
         LPSTRT = ISTRT
         LPEND = 1
      ELSE
         LPSTRT = IDIM
         LPEND = LPSTRT
      ENDIF

      WRITE (5,11) CLR
      WRITE (5,333) ' '//TITLE
      WRITE (9,555)
      DO 50 I = LPSTRT,LPEND
         CALL ASKUN (DIMNM(I),UNITS(1,I),ICHOS,ISTRT+3)
         IF (ICHOS.GE.3) THEN
            CALL PTILE (ISUB,I,PRED(I))
         ELSE
            TCONV = 1.
            IF (ICHOS.GE.2)  TCONV = CONV(I)
40          WRITE (5,77) DIMNM(I),(RANGE(J,I,ISUB)/TCONV,J=1,2)
            READ (5,444)  PRED(I)
            WRITE (9,666) DIMNM(I),PRED(I),UNITS(ICHOS,I)
            PRED(I) = PRED(I)*TCONV
            IF ((PRED(I)-RANGE(1,I,ISUB))*(PRED(I)-RANGE(2,I,ISUB))
     &          .GT. 0.)   GOTO 40
         ENDIF
50       CONTINUE

      IF (IDIM.LT.2)  THEN
         PRED(-1) = PRED(IDIM)
      ELSE
         IF (ISUB.GT.1)  THEN
            DO 60 I=-1,0
60             PRED(I) = PRED(I+1)
         ENDIF
      ENDIF
      IPTR = IPTMAT(IDIM,ISUB)
      ICNT = IPTMAT(IDIM+1,ISUB) - IPTR - 1
      WRITE (5,11) CLR
      WRITE (5,333) ' '//TITLE
      RETURN

100   WRITE (5,88)
      READ (7,333) ANS
      IF (ANS.EQ.'N')  STOP 'FROM DIALOG'
```

```
      IF (ANS.NE.'Y')  GOTO 100
      READ (1,99) (DD(I),I=0,31)
      IPTR = 25
      CALL ASKUN(SUBTYP(4),UNITS(1,2),ICHOS,2)
      IF (ICHOS.GE.2)  THEN
         DD(0) = DD(0)*CONV(0)
         DO 120 I=1,31
120         DD(I) = DD(I)*CONV(1)
      ENDIF
      RETURN

11    FORMAT (7A4)
22    FORMAT (' PROGRAM GEBOD'/' GEBOD GENERATES BODY DESCRIPTION',
     &        ' DATA'/' SUITABLE FOR INPUT TO THE ATB MODEL'/
     &        ' PLEASE ENTER A DESCRIPTION OF THE SUBJECT' ,
     &        ' (<60 CHARS.)')
33    FORMAT (//(I12,')',3X,A/))
44    FORMAT (' ENTER NUMBER CORRESPONDING TO DESIRED SUBJECT TYPE')
55    FORMAT (' ENTER NUMBER CORRESPONDING TO '/' PREDICTING',
     &        ' DIMENSION(S) TO BE SUPPLIED')
77    FORMAT (' ENTER VALUE FOR ',A24/' IN THE RANGE ',G10.4,',',G10.4)
88    FORMAT (' TO UTILIZE EXTERNAL DIMENSIONAL DATA, THE DATA MUST BE'
     &        /' IN THE PROPER FORMAT AND IN A FILE ASSIGNED TO UNIT 1'/
     &        ' HAS THE ABOVE BEEN SATISFIED (Y/N) ?')
99    FORMAT (8F10.0)
222   FORMAT (BN,I60)
333   FORMAT (A)
444   FORMAT (G60.0)
555   FORMAT ('0SELECTED BODY DIMENSIONS'/)
666   FORMAT (A40,G15.4,A6)
      END
C--SUBROUTINE ASKUN-----------------------------------------------------C
C     ASKUN ASKS USER CHOICE OF UNITS TO BE USED WITH SOME INPUT VARIABLE C
C     OR THE OUTPUT OF RESULTS.  THE PARAMETERS ARE THE FOLLOWING:        C
C        VARB--CHARACTER STRING DESCRIBING WHAT UNITS ARE TO BE SELECTED FOR C
C        UNITS--UNITS AVAILABLE TO CHOOSE FROM                             C
C        ICHOS--RETURNS WHICH OF THE UNITS WAS CHOSEN                      C
C        ICNT--NUMBER OF DIFFERENT UNITS AVAILABLE TO CHOOSE FROM          C
C-----------------------------------------------------------------------C

      SUBROUTINE ASKUN (VARB,UNITS,ICHOS,ICNT)
      CHARACTER VARB*(*),UNITS(ICNT)*6,UNITIN*6

30    WRITE (5,66) VARB
      WRITE (5,55) (I,UNITS(I),I=1,ICNT)
      READ (7,44) ICHOS
      IF ( (ICHOS-1)*(ICHOS-ICNT) .GT. 0)   GOTO 30

      RETURN
44    FORMAT (BN,I60)
55    FORMAT (I10,')',5X,A)
66    FORMAT (' SELECT UNITS FOR ',A)
      END
C--SUBROUTINE PTILE-----------------------------------------------------C
C     PTILE COMPUTES A PERCENTILE POINT, SPECIFIED BY THE USER, OF A BODY C
C     DIMENSION USED AS A PREDICTOR, BY ASSUMING THE DIMENSION IS         C
C     NORMALLY DISTRIBUTED.  THE PARAMETERS ARE THE FOLLOWING:            C
C        ISUB--SPECIFIES SUBJECT TYPE, AND THUS WHICH POSITION OF THE     C
C            MEAN AND STANDARD ARRAYS TO USE.                             C
C        IDIM--THE DIMENSION A PERCENTILE POINT IS TO BE COMPUTED FOR     C
C        PRED--RETURNS THE COMPUTED PERCENTILE POINT                      C
C     NOTE:  THIS ROUTINE REQUIRES USE OF IMSL ROUTINE MDNRIS             C
C-----------------------------------------------------------------------C
```

```
      SUBROUTINE PTILE (ISUB,IDIM,PRED)
      COMMON /NAMES/ SUBTYP(4),SEGLAB(15),JNTLAB(14),PLTSYM(29),
     &               DIMNM(-1:31),TITLE,UNITS(3,-1:1)
      REAL MEAN(0:1,2:3), STDEV(0:1,2:3)
      CHARACTER SUBTYP*20,SEGLAB*3,JNTLAB*2,PLTSYM*1,DIMNM*24
      CHARACTER TITLE*60,UNITS*6
      DATA MEAN,STDEV/127.24,63.82,173.54,69.82,16.57,2.36,21.42,2.44/

10    WRITE (5,111) DIMNM(IDIM)
      READ (7,99) PCENT
      IF ( (PCENT-1.)*(PCENT-100.)  .GE. 0.)  GOTO 10
      WRITE (9,222) DIMNM(IDIM),PCENT
      PCENT = PCENT/100.

      CALL NOTRI (PCENT,X,D,IER)
      PRED = MEAN(IDIM,ISUB) + X*STDEV(IDIM,ISUB)

      RETURN
99    FORMAT (F40.0)
111   FORMAT (' ENTER DESIRED PERCENTILE FOR ',A/
     &        ' (A REAL VALUE BETWEEN 0. AND 100.)')
222   FORMAT (A40,G15.4,'%-TILE')
      END
C--SUBROUTINE NOTRI---------------------------------------------------C
C     NOTRI COMPUTES X (THE OUTPUT ARGUMENT SUCH THAT P=Y=THE          C
C     PROBABILITY THAT U, THE RANDOM VARIABLE, IS LESS THAN OR EQUAL   C
C     TO X.), D (THE OUTPUT DENSITY,F(X).), AND IER (THE OUTPUT        C
C     ERROR CODE.) USING P (THE INPUT PROBABILITY.).                   C
C--------------------------------------------------------------------C

      SUBROUTINE NOTRI(P,X,D,IE)
C
      IE=0
      X=.99999E+74
      D=X
      IF(P)1,4,2
1     IE=-1
      GO TO 12
2     IF (P-1.0)7,5,1
4     X=-.999999E+74
5     D=0.0
      GO TO 12
C
7     D=P
      IF(D-0.5)9,9,8
8     D=1.0-D
9     T2=ALOG(1.0/(D*D))
      T=SQRT(T2)
      X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2
     & +0.001308*T*T2)
      IF(P-0.5)10,10,11
10    X=-X
11    D=0.3989423*EXP(-X*X/2.0)
12    RETURN
      END
C--SUBROUTINE CONTAC--------------------------------------------------C
C     CONTAC COMPUTES JOINT LOCATIONS AND CONTACT ELLIPSOID SEMIAXES.  C
C--------------------------------------------------------------------C

      SUBROUTINE CONTAC
      COMMON /FLOAT/ PI,PI2,PI4
      COMMON /SGMNTS/ AN(15),BN(15),CN(15),RMN(15),PHI(3,15),XYZCG(15,3)
```

```
      COMMON /JNTS/ RNJ(3,28)
      COMMON /DIMS/ DD(-1:31)

C    THE CENTERS OF GRAVITY AND JOINT X,Y COORDINATES ARE ALL SET TO ZERO.
      DO 10 J=1,3
      DO 10 I=1,15
   10 XYZCG(I,J)=0.0
      DO 20 J=1,2
      DO 20 I=1,28
   20 RNJ(J,I)=0.0

C     NON-ZERO X,Y JOINT COORDINATES ARE COMPUTED.
      RNJ(1,21)=DD(29)*0.5
      RNJ(1,24)=RNJ(1,21)
      RNJ(2,5)=0.5*(DD(16)-DD(24)/PI)
      RNJ(2,8)=-RNJ(2,5)
      RNJ(2,11)=0.5*(DD(10)-DD(19)/PI)
      RNJ(2,13)=-RNJ(2,11)

C     SMW IS ONE HALF THE HEIGHT OF THE ABDOMEN SEGMENT.
C     OLAP IS USED AS AN OVERLAP AMOUNT BETWEEN CERTAIN CONTACT ELLIPSOIDS.
      SMW = (DD(2) - DD(4))/10.
      OLAP = DD(9)/PI

C     Z COORDINATES OF JOINTS ARE COMPUTED RELATIVE TO SEGMENT JNT(J),
C     WHERE J IS THE SECOND SUBSCRIPT OF RNJ
      RNJ(3,1) = (DD(1) - DD(5) - DD(4) + SMW)/2.
      RNJ(3,2) = -SMW
      RNJ(3,3) = -9.*SMW/2.
      RNJ(3,4) = (DD(8) + DD(2) - DD(1) + OLAP/2.)/2.
      RNJ(3,5) = (DD(4) - SMW - DD(1) + DD(5) - DD(24)/PI)/2.
      RNJ(3,6)=0.5*(DD(1)-DD(5)-DD(23)+DD(24)/PI)
      RNJ(3,7)=0.5*(DD(23)-DD(29)-DD(28)/PI2)
      RNJ(3,8) = RNJ(3,5)
      RNJ(3,9)=RNJ(3,6)
      RNJ(3,10)=RNJ(3,7)
      RNJ(3,11)=-DD(2)+DD(3)+DD(19)/PI2
      RNJ(3,12)=0.5*(DD(17)-DD(20)/PI)
      RNJ(3,13)=RNJ(3,11)
      RNJ(3,14)=RNJ(3,12)

C     Z COORDINATES OF JOINTS ARE COMPUTED RELATIVE TO SEGMENT J-13,
C     WHERE J IS THE SECOND SUBSCRIPT OF RNJ
      RNJ(3,15) = SMW
      RNJ(3,16) = -RNJ(3,3)
      RNJ(3,17) = (DD(1) - DD(8) - DD(2) - OLAP/2.)/2.
      RNJ(3,18) = DD(8) /2. + OLAP/4.
      RNJ(3,19)=0.5*(-DD(1)+DD(5)+DD(23)-DD(26)/PI)
      RNJ(3,20) = (DD(29) - DD(23) - DD(28)/PI2 + DD(26)/PI)/2.
      RNJ(3,21) = DD(29)/PI2 - DD(31)/2.
      RNJ(3,22)=RNJ(3,19)
      RNJ(3,23)=RNJ(3,20)
      RNJ(3,24)=RNJ(3,21)
      RNJ(3,25)=0.5*(DD(19)/PI-DD(17))
      RNJ(3,26)=0.5*(DD(20)/PI-DD(18))
      RNJ(3,27)=RNJ(3,25)
      RNJ(3,28)=RNJ(3,26)

C     SEGMENT CONTACT ELLIPSOID X SEMIAXES ARE COMPUTED.
      AN(5)=DD(6)*0.5
      AN(4)=DD(9)/PI2
      AN(3)=DD(11)*0.5
      AN(2)=DD(13)*0.5
```

```
      AN(1)=DD(15)*0.5
      AN(6)=(DD(24)+DD(25))/PI4
      AN(7)=DD(27)/PI2
      AN(8)=DD(29)*0.5
      AN(9)=AN(6)
      AN(10)=AN(7)
      AN(11)=AN(8)
      AN(12)=DD(19)/PI2
      AN(13)=DD(21)/PI2
      AN(14)=AN(12)
      AN(15)=AN(13)

C     SEGMENT CONTACT ELLIPSOID Y SEMIAXES ARE COMPUTED.
      BN(5)=DD(7)*0.5
      BN(4)=AN(4)
      BN(3)=DD(12)*0.5
      BN(2)=DD(14)*0.5
      BN(1)=DD(16)*0.5
      BN(6)=AN(6)
      BN(7)=AN(7)
      BN(8)=DD(30)*0.5
      BN(9)=AN(9)
      BN(10)=AN(10)
      BN(11)=BN(8)
      BN(12)=AN(12)
      BN(13)=AN(13)
      BN(14)=AN(14)
      BN(15)=AN(15)

C     SEGMENT CONTACT ELLIPSOID Z SEMIAXES ARE COMPUTED.
      CN(5) = (DD(8) + OLAP/2.)/2.
      CN(4) = (DD(1) - DD(8) - DD(2) + OLAP/2.)/2.
      CN(3) = 9.*SMW/2.
      CN(2) = SMW + OLAP/2.
      CN(1) = (DD(4)+DD(5)-DD(1) - SMW)*0.5
      CN(6)=(DD(1)-DD(5)-DD(23)+DD(24)/PI+DD(26)/PI)*0.5
      CN(7)=(DD(23)-DD(29)+DD(28)/PI2)*0.5
      CN(8)=DD(31)*0.5
      CN(9)=CN(6)
      CN(10)=CN(7)
      CN(11)=CN(8)
      CN(12)=DD(17)*0.5
      CN(13)=DD(18)*0.5
      CN(14)=CN(12)
      CN(15)=CN(13)

C     THE GLOBAL LOCATION OF SEGMENT CENTERS IS PLACED IN XYZCG FOR
C        SEGMENTS THAT WILL USE ELLIP IN COMPUTATION OF MASS AND
C        MOMENTS OF INERTIA.
      XYZCG(1,3) = (DD(4) - SMW + DD(1) - DD(5))/2.
      XYZCG(2,3) = DD(4)
      XYZCG(3,3) = DD(2) - 9.*SMW/2.
      XYZCG(8,3) = DD(29) - DD(31)/2. + DD(28)/PI2
      XYZCG(11,3) = XYZCG(8,3)

      RETURN
      END
C--SUBROUTINE SEGMAS---------------------------------------------------C
C     SEGMAS COMPUTES APPROXIMATE SEGMENT MASSES.  WTCOR IS THEN COMPUTED    C
C      TO ADJUST BODY DENSITY, DENS, SO THAT TOTAL BODY MASS AGREES          C
C     WITH DD(0).  SEGMENT MASSES ARE THEN RECOMPUTED USING WTCOR.          C
C----------------------------------------------------------------------C
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```
      SUBROUTINE SEGMAS
      EXTERNAL TORSO, FEET
      COMMON /FLOAT/ PI,PI2,PI4,DENS,GRAV
      COMMON /CYL/ ZEES(0:15),ZH(15),NSEG(15),CGZ(15),WTCOR
      COMMON /JNTS/ RNJ(3,29)
      COMMON /SGMNTS/ ABCN(15,3),RMN(15),PHI(45),XYCG(30),ZCG(15)
      COMMON /DIMS/ DD(-1:31)
      REAL AN(15),BN(15),CN(15)
      EQUIVALENCE (AN,ABCN),(BN,ABCN(1,2)),(CN,ABCN(1,3))
      SUMM=0.0

C     POSITIONS 0 THRU 3 OF ZEES DEFINE THE VERTICAL LIMITS OF TORSO
C        SEGMENTS.  10 THRU 11 DEFINE THE LIMITS OF THE FEET.
      SMW = (DD(2) - DD(4))/10.
      ZEES(0) = DD(1) - DD(5)
      ZEES(1) = DD(4) - SMW
      ZEES(2) = DD(4) + SMW
      ZEES(3) = DD(2)
      ZEES(11) = DD(29) + DD(28)/PI2
      ZEES(10) = ZEES(11) - DD(31)
      DO 5 I = 1,3
         CALL ELLIP (I,TORSO,RMN(I))
         ZCG(I) = CGZ(I) - ZCG(I)
5        SUMM = SUMM + RMN(I)
      CALL ELLIP (11,FEET,RMN(11))
      SUMM = SUMM + 2.*RMN(11)
      RMN(8) = RMN(11)
      ZCG(11) = CGZ(11) - ZCG(11)
      ZCG(8) = ZCG(11)
      DO 7 I = 1,3
7        RNJ(3,I) = RNJ(3,I) + ZCG(I)
      RNJ(3,15) = ZCG(2) + RNJ(3,15)
      RNJ(3,16) = ZCG(3) + RNJ(3,16)
      RNJ(3,5) = ZCG(1) + RNJ(3,5)
      RNJ(3,8) = ZCG(1) + RNJ(3,8)
      RNJ(3,11) = RNJ(3,11) + ZCG(3)
      RNJ(3,13) = RNJ(3,13) + ZCG(3)
      RNJ(3,21) = RNJ(3,21) + ZCG(8)
      RNJ(3,24) = RNJ(3,24) + ZCG(11)
      DO 10 I = 4,7
      RMN(I) = 4.0/3.0*PI*AN(I)*BN(I)*CN(I)*DENS
      SUMM = SUMM+RMN(I)
      IF (I.GT.5)  THEN
         SUMM = SUMM + RMN(I)
         RMN(I+3) = RMN(I)
      ENDIF
   10 CONTINUE
      DO 15 I = 12,13
      RMN(I) = 4.0/3.0*PI*AN(I)*BN(I)*CN(I)*DENS
      SUMM = SUMM+2.*RMN(I)
   15 RMN(I+2) = RMN(I)
C
C     THE FOLLOWING ADJUSTS SEGMENT MASSES TO TOTAL BODY WEIGHT
C
      WTCOR = DD(0)/SUMM/GRAV
      DO 20 I=1,15
      RMN(I)=RMN(I)*WTCOR
   20 CONTINUE
      RETURN
      END
C--SUBROUTINE SGINER----------------------------------------------------C
C     SGINER COMPUTES SEGMENT MOMENTS OF INERTIA.                       C
C----------------------------------------------------------------------C
```

```
      SUBROUTINE SGINER
      EXTERNAL TORSO, FEET
      COMMON /FLOAT/ PI,PI2,PI4
      COMMON /SGMNTS/ AN(15),BN(15),CN(15),RMN(15),PHI(3,15)

      DO 5 I=1,3
5        CALL ELLPMI (I,TORSO,PHI(1,I))
      DO 10 I=4,7
      TEMP=RMN(I)/5.0
      A2=AN(I)*AN(I)
      B2=BN(I)*BN(I)
      C2=CN(I)*CN(I)
      PHI(1,I)=TEMP*(B2+C2)
      PHI(2,I)=TEMP*(A2+C2)
      PHI(3,I)=TEMP*(A2+B2)
      IF (I.GT.5) THEN
         DO 7 J = 1,3
7           PHI(J,I+3) = PHI(J,I)
      ENDIF
   10 CONTINUE
      DO 20 I=12,13
      TEMP=RMN(I)/5.0
      A2=AN(I)*AN(I)
      B2=BN(I)*BN(I)
      C2=CN(I)*CN(I)
      PHI(1,I)=TEMP*(B2+C2)
      PHI(2,I)=TEMP*(A2+C2)
      PHI(3,I)=TEMP*(A2+B2)
      DO 15 J = 1,3
15       PHI(J,I+2) = PHI(J,I)
   20 CONTINUE
      CALL ELLPMI (11,FEET,PHI(1,11))
      DO 25 J=1,3
25       PHI(J,8) = PHI(J,11)
      RETURN
      END
C--SUBROUTINE ELLIP-----------------------------------------------------C
C     ELLIP COMPUTES MASS AND CENTER OF GRAVITY LOCATION OF A RIGHT      C
C     ELLIPTICAL SOLID.  THE PARAMETERS ARE:                             C
C        ISEG--SPECIFIES SEGMENT BEING MODELLED BY RIGHT ELLIPTICAL SOLID C
C        ABEVAL--SPECIFIES SUBOUTINE TO BE USED TO COMPUTE SEMIAXES OF THE C
C           THE SOLID AT SPECIFIC Z HEIGHTS.                             C
C        TMASS--RETURNS THE MASS COMPUTED FOR THE SOLID.                 C
C-----------------------------------------------------------------------C

      SUBROUTINE ELLIP (ISEG,ABEVAL,TMASS)
      COMMON /CYL/ ZEES(0:15),ZH(15),NSEG(15),CGZ(15),WTCOR
      COMMON /FLOAT/ PI,PI2,PI4,DENS,GRAV
      REAL IXX,IXXP,IYY,IYYP,IZZ,IZZP
      REAL MASS
      REAL MI(3)
      TMASSO=0.0
      Z0 = ZEES(ISEG-1)
      Z1 = ZEES(ISEG)
      NSEG(ISEG)=0.0
10    NSEG(ISEG)=NSEG(ISEG)+10
      TCGN=0.0
      TMASS=0.0
      ZH(ISEG)=(Z1-Z0)/FLOAT(NSEG(ISEG))
        DO 100 I=1,NSEG(ISEG)
        Z = Z0 + (FLOAT(I-1)+.5)*ZH(ISEG)
        CALL ABEVAL(Z,A,B)
```

```
        MASS=PI*A*3*ZH(ISEG)*DENS
        CG=Z
        CGN=CG*MASS
        TMASS=TMASS+MASS
100     TCGN=TCGN+CGN
      TMASSN=TMASS
      IF (ABS(TMASSN-TMASSO)/TMASSN.GT.5.E-5)  THEN
        TMASSO = TMASSN
        GOTO10
      ENDIF
      CGZ(ISEG)=TCGN/TMASS
      RETURN

C  ENTRY ELLPMI
C     ELLPMI COMPUTES MOMENTS OF INERTIA OF A RIGHT ELLIPTICAL SOLID, BASED
C     ON THE NUMERICAL INTEGRATION DETERMINED BY ELLIP.  THE FIRST TWO
C     PARAMETERS ARE THE SAME AS THOSE USED BY ELLIP.  THE THIRD, MI,
C     RETURNS THE MOMENTS OF INERTIA OF THE SOLID.

      ENTRY EL PMI (ISEG,ABEVAL,MI)
        DO 5 I=1,3
5       MI(I)-0.0
        ZO = ZEES(ISEG-1)
        DO 200 I=1,NSEG(ISEG)
        Z = ZO + (FLOAT(I-1)+.5)*ZH(ISEG)
        CALL ABEVAL(Z,A,B)
        MASS=PI*A*B*ZH(ISEG)*DENS*WTCOR
        IXX=(MASS/12)*(3.0*B**2+ZH(ISEG)**2)
        IYY=(MASS/12)*(3.0*A**2+ZH(ISEG)**2)
        IZZ=(MASS/4.0)*(A**2+B**2)
        DIST=Z-CGZ(ISEG)
        IXXP=IXX+MASS*DIST**2
        IYYP=IYY+MASS*DIST**2
        IZZP=IZZ
        MI(1)=MI(1)+IXXP
        MI(2)=MI(2)+IYYP
        MI(3)=MI(3)+IZZP
200     Z=Z+ZH(ISEG)
      RETURN
      END
C--SUBROUTINE TORSO-----------------------------------------------------C
C     TORSO COMPUTES SEMIAXIS VALUES FOR THE RIGHT ELLIPTICAL MODEL OF THE    C
C     THREE TORSO SEGMENTS.  THE PARAMETERS ARE THE FOLLOWING:              C
C        Z--VERTICAL LOCATION AT WHICH THE SEMIAXES ARE TO BE COMPUTED      C
C        X--RETURNS X SEMIAXIS                                              C
C        Y--RETURNS Y SEMIAXIS                                              C
C-----------------------------------------------------------------------C

      SUBROUTINE TORSO (Z,X,Y)
      COMMON /DIMS/ D(-1:31)
      COMMON /FLOAT/ PI,PI2
      REAL H2,H3,H4,H5,H6

C     H2--TOP OF SOLID
C     H3--BREAK BETWEEN TOP SEMI-ELLIPSOID AND TOP FRUSTRUM
C     H4--BREAK BETWEEN TWO FRUSTRUM
C     H5--BREAK BETWEEN BOTTOM FRUSTUM AND BOTTOM SEMI-ELLIPSOID
C     H6--BOTTOM OF SOLID

      H2=D(2)
      H3=D(3)
      H4=D(4)
      H5=(D(1)-D(5))+D(24)/PI2
```

```
      H6=(D(1)-D(5))
      IF (Z.LT.H4)THEN
         IF (Z.LT.H5)THEN
            IF (Z.LT.H6)STOP 'Z IS LESS THAN MIN.'
           Y= SQRT(1. - ((Z - H5)/D(24)/PI2)**2)
           X = D(15)/2.*Y
           Y = D(16)/2.*Y
         ELSE
            Y=(Z-D(4))/(H5-D(4))
            X = (Y*(D(15)-D(13))  +D(13))/2.
            Y = (Y*(D(16)-D(14))  +D(14))/2.
         END IF
      ELSE
         IF(Z.LT.H3)THEN
            Y=(Z-D(3))/(D(4)-D(3))
            X= (Y*(D(13)-D(11))+D(11))/2.
            Y= (Y*(D(14)-D(12))+D(12))/2.
         ELSE
            IF (Z.GT.H2)   STOP 'Z IS GREATER THAN MAX.'
            Y=SQRT(1. - ( (Z - D(3))/(D(2) - D(3)) )**2)
            X= Y*D(11)/2.
            Y= Y*D(12)/2.
         END IF
      END IF
      END
C--SUBROUTINE FEET-----------------------------------------------------C
C     FEET COMPUTES SEMIAXIS VALUES FOR THE RIGHT ELLIPTICAL MODEL OF THE     C
C     FEET.  THE PARAMETERS ARE THE FOLLOWING:                                C
C        Z--Z LOCATION (TOE TO HEEL) AT WHICH SEMIAXES ARE TO BE COMPUTED     C
C        X--RETURNS X SEMIAXIS                                                C
C        Y--RETURNS Y SEMIAXIS                                                C
C----------------------------------------------------------------------C

      SUBROUTINE FEET (Z,X,Y)
      COMMON /CYL/ ZEES(0:15),ZH(15),NSEG(15),CGZ(15),WTCOR
      COMMON /DIMS/ DD(-1:31)
      COMMON /FLOAT/ PI,PI2

C     H2--TOP OF SOLID
C     H1--BREAK BETWEEN ELLIPTICAL CYLINDER AND FRUSTRUM
C     H0--BOTTOM OF SOLID

      ANKR = DD(23)/PI2
      H2 = DD(29) + ANKR
      H1 = DD(29) - ANKR
      H0 = H2 - DD(31)

      IF (Z.GT.H1)  THEN
         IF (Z.GT.H2)  STOP  'Z VALUE TOO LARGE IN FEET'
         X = ANKR
         Y = ANKR
      ELSE
         IF (Z.LT.H0)  STOP 'Z VALUE TOO SMALL IN FEET'
         X = ANKR/(DD(31) - 2.*ANKR)*(Z - DD(29) + DD(31) - ANKR)
         Y = (ANKR - DD(30)/2.)/(DD(31) - 2.*ANKR)
         Y = Y*(Z - DD(29) + ANKR) + ANKR
      ENDIF

      RETURN
      END
C--SUBROUTINE RESULTS--------------------------------------------------C
C     RESULTS WRITES OUT THE COMPUTED BODY DESCRIPTION DATA.                  C
C----------------------------------------------------------------------C
```

```
      SUBROUTINE RESULTS (ISTRT)
      COMMON /SGMNTS/ A(15),B(15),C(15),RMN(15),PHI(3,15),
     &                XCG(15),YCG(15),ZCG(15)
      COMMON /JNTS/ RNJ(3,14,2),JNT(14),YPRLL(14,6),IPIN(14)
      COMMON /DIMS/ DD(-1:31)
      COMMON /NAMES/ SUBTYP(4),SEGLAB(15),JNTLAB(14),PLTSYM(29),
     &               DIMLAB(-1:31),TITLE,UNITS(3,-1:2)
      COMMON /CYL/ ZEES(0:15),ZH(15),NSEG(15),CGZ(15),WTCOR
      CHARACTER SUBTYP*20,SEGLAB*3,JNTLAB*2,PLTSYM*1,DIMLAB*24,TITLE*60
      CHARACTER ANS*1,UNITS*6,LABL1(2)*6,LABL2(2)*12,LABL3(2)*2,
     &          LABL4(2)*4 ,VARB*6
      DATA LABL1,LABL2,LABL3,LABL4 /'WEIGHT','MASS','LB-SEC**2-IN',
     &     'KG-M**2','IN','CM','LBS.','KG.'/,VARB/'OUTPUT'/
      DATA IBET/201000000/, IA/240000000/

      WRITE (9,11)
      CALL ASKUN (VARB,UNITS(1,2),IUN,2)
      CALL CNVRT (IUN)
      IF (ISTRT.LT.0) WRITE (9,22) -1,DIMLAB(-1),DD(-1),UNITS(1,-1)
      WRITE (9,22) 0,DIMLAB(0),DD(0),UNITS(IUN,0)
      WRITE (9,22) (I,DIMLAB(I),DD(I),UNITS(IUN,1),I=1,31)
      WRITE (9,66) WTCOR

      WRITE (9,44)  '1'//TITLE
      WRITE(9,1170) LABL1(IUN),LABL2(IUN),LABL3(IUN),LABL3(IUN),
     &              LABL4(IUN)
      WRITE(9,1180) (I,SEGLAB(I),PLTSYM(I),RMN(I),(PHI(J,I),J=1,3),
     &        A(I),B(I),C(I),XCG(I),YCG(I),ZCG(I),I=1,15)
      WRITE(9,1190) LABL3(IUN),LABL3(IUN)
      WRITE(9,1200) (I,JNTLAB(I),PLTSYM(I+15),JNT(I),IPIN(I),
     &   ((RNJ(J,I,K),J=1,3),K=1,2),(YPRLL(I,J),J=1,6),I=1,14)

10    WRITE (5,33)
      READ (7,44) ANS
      IF (ANS.EQ.'Y')  THEN
         WRITE (3,77) TITLE(1:52)
         WRITE(3,1300) (SEGLAB(I),PLTSYM(I),RMN(I),(PHI(J,I),J=1,3),
     &         A(I),B(I),C(I),XCG(I),YCG(I),ZCG(I),IA+I*IBET,I=1,15)
C
         WRITE(3,1320) (JNTLAB(I),PLTSYM(I+15),JNT(I),IPIN(I),
     &         ((RNJ(J,I,K),J=1,3),K=1,2),IA+I*IBET,
     &         (YPRLL(I,J),J=1,6),I=1,14)
      ELSE
         IF (ANS.NE.'N')  GOTO 10
      ENDIF

20    WRITE (5,55)
      READ (7,44) ANS
      IF (ANS.EQ.'N')  STOP 'FROM RESULTS'
      IF (ANS.NE.'Y')  GOTO 20
      RETURN

11    FORMAT ('-COMPUTED BODY DIMENSIONS'/)
22    FORMAT (I10,A30,G15.4,A6)
33    FORMAT (' IS ATB MODEL FORMATTED OUTPUT DESIRED (Y/N) ?')
44    FORMAT (A)
55    FORMAT (' IS IT DESIRED TO PRODUCE ANOTHER BODY DESCRIPTION ',
     &        'DATA SET (Y/N) ?')
66    FORMAT ('0WEIGHT CORRECTION FACTOR =',F10.3)
77    FORMAT (4X,'15',4X,'14',8X,A52,'CARD B.1')
 1170 FORMAT(           1H0,"CRASH VICTIM PARAMETERS (3-D)"/1H0,33X,
     1 25HSEGMENT MOMENT OF INERTIA,
     2 19X,25HSEGMENT CONTACT ELLIPSOID/5X,7HSEGMENT,7X,A6
```

```
     3,15X,'(',A12,')',17X,10HSEMIAXIS (,A2,')',14X,'CENTER (',
     4,A2,')'/3X,12HNO. SYM PLOT,4X,'(',A4,')',10X,1HX,10X,1HY,10X,
     51HZ,12X,1HX,6X,1HY,6X,1HZ,12X,1HX,7X,1HY,6X,1HZ/1H )
 1180 FORMAT ((3X,I2,2X,A4,A2,6X,F6.3,3X,3(4X,F7.5),5X,3(2X,F5.2),5X,3
     1(3X,F5.2)))
 1190 FORMAT(1H0,///3X,5HJOINT,16X,'LOCATION(',A2,') - SEG(JNT)',5X,
     1 'LOCATION(',A2,') - SEG(J+1)',2X,'PRIN. AXIS(DEG) - SEG(JNT)',
     2 ' PRIN. AXIS(DEG) - SEG(J+1)'/2X,'J SYM PLOT JNT PIN',
     3 4X,2(1X,'X',8X,'Y',8X,'Z',8X),2('YAW',5X,'PITCH',5X,'ROLL',6X)/)
 1200 FORMAT ((I3,A4,A3,2X,2I3,4(3F9.2,1X)))
 1300 FORMAT(A4,A2,F6.3,3F6.4,6F6.3,6X,'CARD 8.2.',A1)
 1320 FORMAT(A4,1X,A1,2I4,6F6.2,22X,'CARD 9.3.',A1/14X,6F6.2)
      END
C--SUBROUTINE CNVRT-----------------------------------------------------C
C     CNVRT CONVERTS ALL OUTPUT DATA TO THE UNITS SELECTED BY THE USER   C
C----------------------------------------------------------------------C

      SUBROUTINE CNVRT (IUN)
      COMMON /SGMNTS/ ABC(15,3),RMN(15),PHI(3,15),XYZCG(15,3)
      COMMON /JNTS/ RNJ(3,28)
      COMMON /DIMS/ DD(-1:31)
      REAL CONV(2,3)
      DATA CONV /1.,2.54,32.17405,14.5939,12.,105.4034/

      DO 100 I = 1,15
         DO 10 J = 1,3
            ABC(I,J) = ABC(I,J)*CONV(IUN,1)
            XYZCG(I,J) = XYZCG(I,J)*CONV(IUN,1)
10          PHI(J,I) = PHI(J,I)/CONV(IUN,3)
100      RMN(I) = RMN(I)*CONV(IUN,2)

      DO 200 I = 1,28
      DO 200 J = 1,3
200      RNJ(J,I) = RNJ(J,I)*CONV(IUN,1)

      IF (IUN.GT.1)   THEN
         DD(0) = DD(0)/CONV(1,2)*CONV(2,2)
         DO 300 I=1,31
300         DD(I) = DD(I)*CONV(2,1)
      ENDIF

      RETURN
      END
```

REFERENCES

Bartz, John A., July 1971, "A Three-Dimensional Computer Simulation of a Motor Vehicle Crash Victim, Phase I - Development of the Computer Program," VJ-2979-V-1, Calspan Corporation, Buffalo, New York.

Bartz, John A. and Charles R. Gianotti, January 1973, "A Computer Program to Generate Input Data Sets for Crash Victim Simulations," ZQ-5167-V-1, Calspan Corporation, Buffalo, New York.

Baughman, L. Douglas, April 1982, "Segmentation and Analysis of Stereophotometric Body Surface Data," AFAMRL-TR-81-96, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Butler, F. E. and J. T. Fleck, May 1980, "Advanced Restraint System Modeling," AFAMRL-TR-80-14, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Chandler, R. F., C. E. Clauser, J. T. McConville, H. M. Reynolds, and J. W. Young, 1975, "Investigation of Inertial Properties of the Human Body," AMRL-TR-74-137, AD A-016485, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Clauser, Charles E., Pearl E. Tucker, John T. McConville, Edmund Churchill, Lloyd L. Laubach, Joan A. Reardon, April 1972, "Anthropometry of Air Force Women," AMRL-TR-70-5, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Fleck, J. T. and F. E. Butler, July 1975, "Development of an Improved Computer Model of the Human Body and Extremity Dynamics," AMRL-TR-75-14, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Fleck, J. T., F. E. Butler, and S. L. Vogel, April 1975, "An Improved Three-Dimensional Computer Simulation of Crash Victims," DOT-HS-801-507 through 510, National Technical Information Service, Springfield, Virginia.

Grunhofer, H. J. and G. Kroh, 1975, "A Review of Anthropometric Data of German Air Force and United States Air Force Personnel 1967-1968," AGARD-AG-205, Advisory Group for Aerospace Research and Development, 7 Rue Ancelle 92200, Neuilly Sur Seine, France.

Hanavan, Ernest P., October 1964, "A Mathematical Model of the Human Body," AMRL-TR-64-102, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Leet, Duane G., September 1978, "MISEC2: An Interactive Fortran Program that Computes the Inertial Properties of a Homogeneous Right Elliptical Solid," UDR-TR-78-26, University of Dayton Research Institute, Dayton, Ohio.

McConville, John T., Thomas D. Churchill, Ints Kaleps, Charles E. Clauser, Jamie Cuzzi, December 1980, "Anthropometric Relationships of Body and Body Segment Moments of Inertia," AFAMRL-TR-80-119, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Segal, D. J., January 1971, "Revised Computer Simulation of the Automobile Crash Victim," VJ-2759-V-2, Calspan Corporation, Buffalo, New York.

Snyder, Richard G., Lawrence W. Schneider, Clyde L. Owings, Herbert M. Reynolds, D. Henry Golomb, M. Anthony Sckork, May 1977, "Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design," UM-HSRI-77-17, Consumer Product Safety Commission, Bethesda, Maryland.

Walker, L. B., Jr., E. H. Harris, V. R. Pontius, 1973, "Mass, Volume, Center of Mass and Mass Moment of Inertia of Head and Neck of the Human Body," AD 762 581, Final Report, Department of the Navy, Office of Naval Research, Washington, D.C.

U.S. Government Printing Office 1983 659 005 705