

ANTHROPOMETRICS

Presented
28 Aug 74

S.L. Symposium

MAN'S BODY, BOTH AS A SPECIES AND AS AN INDIVIDUAL, HAS BEEN SHAPED BY CONTINUOUS EXPOSURE TO GRAVITY AND A MAJOR PORTION OF IT IS DEDICATED TO MORE OR LESS CONTINUOUSLY OPPOSING GRAVITATIONAL FORCES. ONE COULD CONFIDENTLY PREDICT THAT PLACING THE HUMAN BODY IN WIEGHTLESSNESS WOULD PRODUCE CHANGES IN SIZE, SHAPE, AND COMPOSITION. MANY OF THESE CHANGES AND THEIR EFFECTS WERE DESCRIBED BY ASTRONAUTS FROM THE EARLIEST DAYS OF SPACEFLIGHT. PUFFY FACES, STUFFY NOSES, ENGORGED HEAD VEINS, LOW BACK DISCOMFORT, AND 'BIRD LEGS' OF SPACE FOR EXAMPLE.

IN AMERICAN SPACE PROGRAMS PRIOR TO SKYLAB THE ANTHROPOMETRIC STUDIES DONE WERE:

PRE- AND POST-FLIGHT LEG VOLUMES ON THE LATTER APOLLO FLIGHTS.

(STEREOPHOTOGRAMMETRY)

ANTHROPOMETRICS -2

STEREOPHOTOGRAMMETRY OF THE CREW PRE- AND
POST-FLIGHT ON APOLLO 16.

ON SKYLAB ONLY LEG VOLUMES AND STEREOGRAMMETRY
PRE- AND POST-FLIGHT AND MAXIMUM CALF GIRTHS IN FLIGHT
WERE ORIGINALLY SCHEDULED.

IN AN EFFORT TO OBTAIN THE MOST COMPREHENSIVE AND
COHORENT PICTURE OF CHANGES UNDER WIEGHTLESSNESS, WE
INITIATED A SET OF MEASUREMENTS ON SKYLAB 2 AND, AT EVERY
OPPORTUNITY, ADDITIONAL STUDIES WERE ADDED. ALL PERTINENT
INFORMATION FROM ANCILLARY SOURCES EVEN NEWS PHOTOS
WAS GLEANED AND COLLATED.

ON SKYLAB 2, THE INITIAL ANTHROPOMETRIC STUDIES WERE
SCHEDULED IN CONJUNCTION WITH THE MUSCLE STUDY PRESENTED
THIS MORNING AND CONSISTED OF DIRECT MEASUREMENT FOR LIMB

(VOLUMES)

ANTHROPOMETRICS - 3

VOLUMES AND TRUNK GIRTHS. A SINGLE SET OF FACIAL PHOTOS WAS MADE IN FLIGHT. THESE MEASUREMENTS WERE CONTINUED ON SKYLAB 3, WITH ADDITIONAL PHOTOS AND TRUNCAL AND LIMB GIRTH MEASUREMENTS IN FLIGHT.

PRIOR TO SKYLAB 4, A FEW OF US FELT THERE WAS CONSIDERABLE EVIDENCE FOR LARGE AND RAPID FLUID SHIFTS, SO A SERIES OF IN-FLIGHT VOLUME AND CENTER OF MASS MEASUREMENTS AND INFRARED PHOTOS WERE SCHEDULED AS EARLY AS POSSIBLE IN THE MISSION.

A NUMBER OF CHANGES WERE PROPERLY DOCUMENTED FOR THE FIRST TIME, MOST IMPORTANT OF WHICH WERE THE FLUID SHIFTS. THE FOLLOWING DESCRIPTION OF SKYLAB ANTHROPOMETRICS WILL BE PRIMARILY WORK DONE ON SKYLAB 4.

(THE SERIES OF)

ANTHROPOMETRICS - 4

SLIDE 4-1

THE SERIES OF ANTHROPOMETRIC MEASUREMENTS SHOWN
HERE WERE MADE PRE-FLIGHT AND POST-FLIGHT ON ALL MISSIONS,
AND MISSIONS IN-FLIGHT ON SKYLAB 4. LEG AND ARM GIRTH
MEASUREMENTS WERE MADE EVERY 3 cm BY MEANS OF A
CALIBRATED TAPE JIG ATTACHED TO THE LIMB TO INSURE
ACCURATE LOCATION. DRS. HOFFLER AND JOHNSON MADE
SUCH LEG MEASUREMENTS ON APOLLO AND SKYLAB PRE- AND
POST-FLIGHT, AND, TO AVOID REPETITION OF MEASUREMENTS,
DATA FROM THIS MEASUREMENT WAS *shared*-
WE EXTENDED THEIR TECHNIQUE TO THE ARMS. THE
IN-FLIGHT LIMB MEASUREMENTS ON SKYLAB 4 WERE MADE
WITH A SINGLE TAPE AND A CALIBRATED LONGITUDINAL TAPE.
PRE-FLIGHT AND POST-FLIGHT, A SERIES OF FRONT,
SIDE, AND BACK PHOTOGRAPHS WERE MADE WITH THE
(CREWMEN)

ANTHROPOMETRICS - 5

CREWMEN IN STANDARD ANATOMICAL POSITION FOR GENERAL DOCUMENTATION. IN FLIGHT, A SECOND SERIES OF PHOTOGRAPHS WAS MADE WITH THE CREWMAN COMPLETELY RELAXED AND FREE-FLOATING TO NOTE POSTURAL CHANGES.

IN AN ATTEMPT TO DOCUMENT THE VENOUS BLOOD DISTRIBUTION, AN INFRARED SENSITIVE COLOR FILM WAS USED FOR THESE PHOTOGRAPHS.

THE INFRARED FILM HAD POOR RESOLUTION AND AT THE LAST MINUTE, 35mm WAS SUBSTITUTED FOR 70 mm FILM FURTHER REDUCING RESOLUTION. QUALITY OF THE IN-FLIGHT ANATOMICAL AND POSTURAL FILM SUFFERED. HOWEVER, WITH DILIGENCE, A GOOD DEAL OF VASCULAR DETAIL COULD BE DETERMINED THAT WOULD NOT HAVE BEEN AVAILABLE ON ORDINARY FILM.

(IN AN EFFORT)

SLIDE 4-4

IN AN EFFORT TO DEVISE A SIMPLE INDICATION OF FLUID SHIFTS, CENTER OF MASS AND CENTER OF GRAVITY MEASUREMENTS WERE MADE. ON EARTH, A TEETER BOARD WAS USED.

IN FLIGHT IT WAS POSSIBLE TO OBTAIN C/M DIRECTLY -- BY THE TYING OF A CORD AROUND THE SUBJECT AND THEN PULLING AT RIGHT ANGLES TO THE SUBJECT. IF THE CORD WAS ANYWHERE OFF THE C/M THE CREWMEN WOULD TILT. THE CREW CLAIMED THIS SCHEME WAS ACCURATE TO A FEW mm.

BODY MASS WAS AVAILABLE TO REASONABLE ACCURACY AS REPORTED THIS MORNING.

SOME COMPOSITION AND FLUID VOLUME MEASUREMENTS WERE AVAILABLE FROM ISOTOPIC STUDIES ON OTHER EXPERIMENTS.

LET'S LOOK FIRST AT THE POSTURAL CHANGES THAT OCCUR.

HERE IS A PRE-FLIGHT AND POST-FLIGHT FRONT VIEW OF A

SLIDE 4-4 SKYLAB 4 CREWMAN -- ALTHOUGH THIS IS THIRD-GENERATION

(COPY,)

ANTHROPOMETRICS - 7

COPY, YOU SHOULD BE ABLE TO CLEARLY SEE ARM VENOUS
PATTERN.

SLIDE 4-5 THE COMMANDER OF SKYLAB 3 IS SHOWN IN FLIGHT HERE. IN
ONE OF THE ANATOMICAL FILMS, I THOUGHT THAT HE HAD DONE A
MILITARY BRACE IN SPITE OF HIS DENIALS, FOR HE ISN'T THAT
TRIM AND ERECT UNDER 1-G. NOTE THE ABDOMEN AND RAM ROD
SPINE. ALSO NOTE, IF YOU CAN SEE THEM IN THIS PROJECTION,
THE JUGULAR FULL TO THE ANGLE OF THE JAW AND OTHER HEAD
VEINS.

SLIDE 4-6 AND HERE IS AN IN-FLIGHT PICTURE FREE-FLOATING AND
(GIBSON)
RELAXED. RELAXED POSTURAL CHANGES VARY SOMEWHAT

SLIDE 4-7 THROUGHOUT THE FLIGHT AND FROM INDIVIDUAL TO INDIVIDUAL,
AND 4-8
BUT THESE TRACINGS FROM IN-FLIGHT PHOTOGRAPHS OF THE
SCIENCE PILOT OF SKYLAB 4 ARE TYPICAL OF CHANGES SEEN.

(THE SPINAL COLUMN)

THE SPINAL COLUMN WAS FLEXED WITH LOSS OF THE
THORACO-LUMBAR CURVE BUT WITH RETENTION OF THE
CERVICAL CURVATURE, SUCH THAT THE HEAD IS THRUST
FORWARD. BOTH UPPER AND LOWER LIMBS HAVE MOVED TOWARD
A QUADRIPEDE POSITION. POST-FLIGHT, THERE WAS SURPRISINGLY
LITTLE CHANGE FROM PRE-FLIGHT.

NEXT LOOK AT WHAT GRAVITATIONAL UNLOADING DOES TO
TRUNCAL SIZE. THESE ARE PLOTS OF SOME CHANGES THROUGHOUT
SKYLAB 4.

SLIDE 4-9
AND 4-10

THE PILOT HAD THE LARGEST CHANGES WITH GAIN OF SOME
TWO INCHES IN HEIGHT AND LOSS OF 4 INCHES OF ABDOMINAL
GIRTH. CHEST GIRTH WAS ALSO INITIALLY REDUCED IN BOTH
INSPIRATION AND EXPIRATION, BUT TRENDED TOWARD
"NORMAL" IN FLIGHT. POST-FLIGHT, WHICH IS POORLY SHOWN

(HERE,)

HERE, THERE WAS A MORE OR LESS RAPID TREND TOWARD
PRE-FLIGHT VALUES. IT SEEMS THAT MOST OF THE INCREASE
IN HEIGHT WAS CAUSED BY EXPANSION OF THE INTER-VERTEBRAL
DISCS WHICH WERE UNLOADED. THIS STRETCHED THE TORSO
AND PROBABLY AIDED IN REDUCTION OF ABDOMINAL GIRTH.
ABDOMINAL VISCERA MAY BE CONSIDERED SEMI-LIQUID, AND
WHEN THEIR WEIGHT WAS REMOVED. THE NORMAL TONE OF
ABDOMINAL MUSCLES MOVED THEM IN AND UPWARD. CHANGES
IN CHEST GIRTH ARE NOT SO EASILY EXPLAINED, BUT IF THE
SPINAL COLUMN MOVED UPWARD WITHOUT A SIMILAR ANTERIOR
ELEVATION OF THE STERNUM, THEN THE RIB ANGLE IS INCREASED,
EFFECTIVELY REDUCING THORACIC GIRTH. THE COMMANDER'S
CHANGES WERE VIRTUALLY THE SAME AS THE SCIENCE PILOT'S.

NEXT, LET'S LOOK AT IN-FLIGHT LIMB VOLUMES -- ALTHOUGH
THERE WAS CONSIDERABLE EVIDENCE FOR LARGE AND RAPID

(SHIFTS IN FLUID)

ANTHROPOMETRICS - 10

SHIFTS IN FLUID FROM LOWER TO UPPER BODY PRIOR TO SKYLAB 4
INDEED, NO SUBJECT HAS BEEN DISCUSSED MORE IN SPACE
PHYSIOLOGY. IN SPITE OF THIS, VIRTUALLY NO ONE WAS WILLING
TO ACCEPT IT. SUCH LARGE AND RAPID SHIFTS SEEMED TO BE
CONTRADICTED BY THE RELATIVELY SMALL GAINS IN POST-FLIGHT
LEG VOLUME WHICH OBVIOUSLY CONTAINED TISSUE INCREASES.
SINGLE MID-CALF GIRTH MEASUREMENTS ON SKYLAB 2 AND 3, IN FLIGHT
WERE ALSO MISLEADING FOR THEY INDICATED MUCH SMALLER AND
SLOWER CHANGES CONSISTENT WITH A PREDOMINANT COMPONENT OF
MUSCLE ATROPHY.

THERE WAS OBVIOUSLY NO WAY TO PROVE THE POINT WITH OUT
DATA AND TO DO THIS DURING ACTIVATION OF AN ALREADY
OVERSCHEDULED MISSION WAS THE TOUGHEST JOB I TACKLED.
THANKS TO DICK JOHNSON, KENNY KLEINKNECHT AND OTHERS,
AND ABOVE ALL, THE CREW, THIS DATA WAS GATHERED -- NOT

(AS MUCH AS)

ANTHROPOMETRICS - 11

AS MUCH AS DESIRED BUT TO GATHER FROM THE PAPERS TODAY,
APPARENTLY ENOUGH TO CONVINCE ALL CONCERNED.

LEG AND ARM VOLUMES WERE CALCULATED BY TREATING
EACH 3cm SEGMENT WHOSE GIRTH WAS MEASURED AS A TAPERED
CYLINDER AND SUMMATING THESE VOLUMES.

MD-3 WAS THE EARLIEST POSSIBLE THAT WE COULD SCHEDULE
THIS MEASUREMENT WHICH SHOULD HAVE STARTED WITHIN HOURS
OF ORBITAL INSERTION AND ONLY TWO CREWMEN PERFORMED
IT THEN. THERE IS A RAPID LOSS IN LEG VOLUME -- THESE CURVES
ARE ONLY ESTIMATES, AND I SUSPECT THE SHIFT WAS ESSENTIALLY
OVER BY THE FIRST DAY. REMEMBER THESE ARE CHANGES IN
ONE LEG SUCH THAT ON MD-8 TOTAL CHANGE WAS APPROXIMATELY
2 LITERS AND 13 PERCENT OF TOTAL LEG VOLUME FOR EACH
CREWMAN.

(AS YOU CAN SEE,)

ANTHROPOMETRICS - 12

AS YOU CAN SEE, THE MAJORITY OF THE INCREASE IN LEG VOLUME ON RECOVERY WAS COMPLETE BY THE TIME OF FIRST MEASUREMENT AT R + 0, OR WITHIN A MATTER OF HOURS AFTER RE-EXPOSURE TO 1-G.

I WOULD AGREE WITH MIKE WHITTLE THAT THESE SLOW POST-FLIGHT TRENDS HAVE TISSUE REPLACEMENT IN THEM. SOMEWHAT TO MY SURPRISE, THE ARMS SHOWED NO EVIDENCE OF FLUID SHIFT AND THE CHANGES SEEN ARE SMALL AND PROBABLY RELATED TO METABOLISM.

WHERE DID THIS FLUID GO? THERE IS NO WEIGHT LOSS IN TWO OF THE CREWMEN COMPATIBLE WITH LOSING THIS AMOUNT OF FLUID.

CENTER OF MASS MEASUREMENTS WERE SCHEDULED ON THIS FLIGHT PRIMARILY TO FOLLOW THE TIME COURSE OF

(SHIFTS,)

SHIFTS, SINCE ONLY MINUTES WERE REQUIRED FOR THE
MEASUREMENT. UNFORTUNATELY, SCHEDULES WERE CHANGED
SUCH THAT THE POINTS OF REAL INTEREST WERE OVER BEFORE

SLIDE 4-11 THE FIRST MEASUREMENT. THIS IS A PLOT OF CENTER OF MASS,
THE UPPER CURVE, WHICH WAS COMPLICATED BY THE INCREASE
IN HEIGHT LOWER CURVE. CENTER OF MASS SHIFTED CEPHALAD
MORE THAN COULD BE ACCOUNTED FOR BY THE HEIGHT INCREASE
WHICH IS ANOTHER SMALL CONFIRMATION OF FLUID SHIFT. WE HAVE
LONG HAD ASTRONAUT DESCRIPTIONS OF PUFFY FACES, HEAD
FULLNESS AND OTHER SYMPTOMS OF INCREASED FLUID IN THE
HEAD.

FINALLY, THERE ARE THE PHOTOGRAPHS. WHILE THESE
DO NOT ALLOW QUANTITATION, THEY PROVIDED POWERFUL
EVIDENCE FOR INCREASED FLUID IN THE HEAD AND NECK REGION.

(THIS PHOTOGRAPH)

SLIDES
4-11

THIS PHOTOGRAPH, AS THE FIRST TAKEN FOR THIS PURPOSE, AND MADE ON SKYLAB 2, AND ALTHOUGH SLIGHTLY DISTORTED, STILL DEMONSTRATES THE PUFFY FACES -- NOTE THE THICKENED EYELIDS. THESE PHOTOGRAPHS WERE NEAR THE END OF THE MISSION AND DEMONSTRATE THAT THIS EDEMA AND VENOUS CONGESTION STILL REMAINED.

SLIDE
4-12

NEXT IS A PICTURE OF SKYLAB 3 WITH A PRE-FLIGHT PICTURE -- THE BLACK AND WHITE ONE -- AND AN IN-FLIGHT PHOTOGRAPH AGAIN NEAR THE END OF THE MISSION. ALTHOUGH ANGLE AND LIGHTING DIFFER, I BELIEVE THE DIFFERENCE IN FACIES ARE APPARENT.

FINALLY, WE HAVE THE L. R. PHOTOGRAPHS TO ASSESS. IT WAS ORIGINALLY PLANNED TO MACHINE ANALYZE THE SUPERFICIAL VENOUS PATTERN, BUT THE QUALITY WAS TOO VARIABLE AND ONLY A QUALITATIVE ASSESSMENT WAS MADE.

(SEVERAL FEATURES)

SEVERAL FEATURES WERE OBVIOUS HOWEVER. FROM FIRST TO LAST IN FLIGHT THE FOLLOWING WAS OBSERVED IN ALL CREWMEN: OBVIOUSLY ONLY SUPERFICIAL VEINS WERE VISUALIZED -- FOOT VEINS WERE NOT DISTENDED AS IN STANDING UNDER 1-G, HOWEVER, THEY WERE NOT EMPTY FOR THE DORSAL ARCADE OF THE FOOT AND DIGITAL BRANCHES WERE EASILY SEEN WITH THE INFRARED FILM. CALF VEINS WERE NOT DISTENDED BUT STILL VISIBLE. SEVERAL SUPERIOR BRANCHES IN THE ANTERIOR THIGH WERE MODERATELY FULL. LITTLE DIFFERENCE COULD BE SEEN BETWEEN PRE- AND IN-FLIGHT PATTERNS OF THE TRUNK AND UPPER ARMS. HAND AND FOREARM VEINS WERE WELL FILLED AND DISTENDED IN FLIGHT. THIS SURPRISED ME SINCE SUPERFICIAL ARM VEINS, LIKE THOSE OF THE LEG HAVE INCREASING AMOUNTS OF WALL MUSCLE AS THEY BECOME (MORE DISTAL.)

MORE DISTAL. JUGULARS WERE ALWAYS COMPLETELY FULL AND DISTENDED AS WERE VEINS OF TEMPLE AND FOREHEAD. POST-FLIGHT, THERE WAS A PROMPT REVERSION TO PRE-FLIGHT PATTERN, HOWEVER, FOOT AND LOWER LEG FILLING APPEARED TO BE LESS IN THE EARLY RECOVERY PERIOD.

CHANGES IN MASS HAVE ALREADY BEEN DISCUSSED AND ARE OBVIOUSLY RELATED TO THE CHANGES SEEN HERE.

IT WAS NOT POSSIBLE TO DOCUMENT BODY COMPOSITION CHANGES WITH SPECIFIC GRAVITY AND OTHER MEASUREMENTS. OBSERVATION OF ALL CREWS, AND ESPECIALLY SKYLAB 2 AND 3, LEFT THE IMPRESSION THAT LOSS OF FAT HAD OCCURRED, EXCEPT FOR THE COMMANDER OF SKYLAB 4.

RADIOISOTOPIC STUDIES BY DRS. JOHNSON AND LEACH CONFIRMED AN INCREASED LOSS OF FAT BY ALL CREWMEN EXCEPT THE COMMANDER OF SKYLAB 4.

(WHAT IS THE IMPORTANCE)

WHAT IS THE IMPORTANCE OF THESE CHANGES UNDER WEIGHTLESSNESS? LET'S REVIEW THE MAJOR ONES: CHANGE IN HEIGHT IS AS MUCH A CONVERSATION PIECE AS ANYTHING ELSE. ONE CREWMAN FOR EXAMPLE, IS SHORTER THAN HIS WIFE AND WAS ELATED TO FIND IN FLIGHT THAT HE WAS FINALLY TALLER. POST-FLIGHT THERE WAS AN UNDERSHOOT, AND HE CAME HOME ON R + 3 SHORTER THAN EVER.

SUCH CHANGES PROVIDE NEW DATA POINTS FOR THOSE STUDYING THE HUMAN SKELETON AND HOPEFULLY WILL ADD TO THE KNOWLEDGE OF IT. IN FUTURE FLIGHT, ALLOWANCES MAY HAVE TO BE MADE IN CUSTOM FITTED GEAR. FOR EXAMPLE, SMALL HEIGHT INCREASES GREATLY INCREASE THE DIFFICULTY OF ENTERING PRESSURE SUITS AND MAY SHOW UP IN TIME AND MOTION STUDIES ON SKYLAB.

(REDUCTION)

REDUCTION IN WAIST GIRTH WITH ELEVATION OF ABDOMINAL VISCERA PROBABLY ALTERS MAXIMUM LUNG VOLUMES BUT TO NO GREAT EXTENT. VITAL CAPACITY IS REDUCED BY LYING DOWN IN 1-G AND THE EFFECTS ARE SOMEWHAT ANALAGOUS. APPARENTLY IT DID ALTER SOME INTERNAL RELATIONSHIPS FOR AT LEAST ONE CREWMAN FELT THAT RUNNING AND JUMPING ON THE TREADMILL PRODUCED UNPLEASANT JOUNCING OF GASTRIC CONTENTS. ONE COULD SPECULATE ON EFFECTS THAT SUCH SHIFTS WOULD HAVE ON BOWEL PATHOLOGICAL PROCESSES -- SAY HIATUS HERNIA OR A PERFORATION. IT IS HARDLY NECESSARY TO COMMENT ON THE CHANGES IN CHEST GIRTH WHICH WERE SMALL.

POSTURAL CHANGES HAVE TWO SIGNIFICANT CONSIDERATIONS. HUMAN ENGINEERING SHOULD ALLOW FOR THE MOST EFFICIENT WORK POSITIONS IN THE FUTURE. FOR EXAMPLE, A 1-G CHAIR
(WHICH SUPPORTS)

WHICH SUPPORTS THE WEIGHT OF LEGS AND TORSO, IS NOT SHAPED TO PROVIDE GOOD PASSIVE SUPPORT IN WEIGHTLESSNESS. THE BODY HAD TO BE FORCED INTO SUCH A POSITION BY A TIGHT WAIST RESTRAINT. SECONDLY, THESE CHANGES UNDER WEIGHTLESSNESS SHOULD BE OF INTEREST TO THOSE MAKING THEORETICAL STUDIES OF POSTURAL MECHANISMS AND THE LIKE AND PROVIDE THEM WITH NEW DATA POINTS.

FLUID SHIFTS ARE OF MORE IMPORTANCE. ALTHOUGH TISSUE FLUID AND BLOOD SHIFTS ARE SO CLOSELY INTERRELATED AS TO BE DIFFICULT TO SEPARATE, I FEEL SOMETHING IS GAINED BY TREATING THEM SEPARATELY. BLOOD SHIFTS OCCUR RAPIDLY -- THEY BEGIN IN SECONDS AFTER CHANGES IN FORCES BUT THEIR LONG TERM EFFECTS MAY OCCUPY MONTHS.

UPRIGHT UNDER 1-G VEINS AND ARTERIES BELOW THE HEART HAVE INCREASING HYDROSTATIC PRESSURE AS ONE MOVES TOWARD
(THE FEET)

THE FEET WHERE THE FORCE MAY BE 80 TO 100 mm Hg. SHORTLY ABOVE THE HEART THE VENOUS PRESSURE BECOMES ZERO AND THE VESSELS ARE VIRTUALLY EMPTY AND AT LEAST PARTIALLY COLLAPSED. WITHOUT THIS SUPERIMPOSED HYDROSTATIC PRESSURE UNDER WEIGHTLESSNESS, VENOUS PRESSURE, EXCEPT FOR NEGLEGIBLE FLOW, PRESSURES ARE THE SAME THROUGHOUT THE BODY. VOLUMES ARE NOW SHIFTED ONLY IN RESPONSE TO THE COMPLIANCES, THE TENSION IF YOU WILL, OF THE VARIOUS AREAS OF THE VENOUS SYSTEMS. THE RESULT IS THAT WE HAVE ESSENTIALLY CENTRAL VENOUS OR RIGHT ATRIAL PRESSURE THROUGHOUT THE ENTIRE VENOUS SYSTEM. VEINS SUCH AS HEAD AND NECK WHICH ARE NORMALLY EMPTY FILL, UNTIL THEIR BACK PRESSURE IS EQUAL TO THAT OF THE PRESSURE IN SAY A FOOT VEIN, WHICH DEVELOPS THE SAME PRESSURE AT A MUCH LOWER VOLUME. WHEN ONE STANDS FROM A LYING POSITION UNDER 1-G,

(A NOMINAL)

A NOMINAL 700 ml. OF BLOOD GOES INTO THE LEGS AND PROBABLY THE SAME ORDER OF VOLUME IS SHIFTED CENTRALLY HERE. MOST OF THIS MOVES TO THAT UNDEFINED CENTRAL VOLUME AND PRODUCES A SMALL INCREASE IN PRESSURE. I BELIEVE THAT ONE EFFECT OF THIS IS TO INCREASE CARDIAC OUTPUT BUT WILL NOT TRY TO DEFEND IT HERE.

A SECOND RESULT OF THIS SHIFT PRODUCES BETTER DOCUMENTED RESULTS. THIS IS SENSED AS AN ABNORMALLY LARGE VOLUME AND PLASMA IS REDUCED, LEAVING ABNORMALLY HIGH Hgb AND HEMATOCRITS. AND UNKNOWN SENSOR DETECTS THIS AND REDUCES RBC PRODUCTION SUCH THAT RCM BECOMES APPROPRIATE TO THE NEW VOLUME OVER A MATTER OF WEEKS. SUCH RE-ADJUSTMENTS TO ALTERED VOLUMES, AND WE HAVE AN EFFECTIVELY REDUCED VOLUME HERE, ARE SEEN UNDER 1-G. FOR EXAMPLE,

(INDIVIDUALS WITH LEG)

INDIVIDUALS WITH LEG VARICOSITIES HAVE INCREASED BLOOD VOLUMES. I FEEL THAT THE REDUCED LOSS OF RCM IN THE SKYLAB 4 COMMANDER IS FURTHER EVIDENCE FOR REDUCED LEG VENOUS VOLUME.

SLIDE

ON RETURN TO 1-G, A REVERSE PROCESS ENSUES. AFTER THE FIRST DAY WE SEE AN ANEMIA WHICH IS SLOWLY REPLACED.

TISSUE FLUID SHIFTS ARE GREATER IN VOLUME THAN BLOOD BUT SOMEWHAT SLOWER. FOR SENTIMENTAL PURPOSES -- I MUST SHOW MY OLD CAMPAIGN SLIDE, POOR AS IT IS. WHEN STANDING UNDER 1-G THERE IS A HYDROSTATIC COLUMN OF UP TO 80 TO 100 ml PRESSURE -- ILLUSTRATED BY THE INTERNAL ARROWS -- ON ARTERIES, VEINS, AND CAPILLARIES IN THE FOOT. THIS IS OPPOSED BY TISSUE PRESSURES -- AFTER A PERIOD OF EXTRAVASATION THEY EQUALIZE. UNDER 0-G, THE REVERSE OCCURS WITH
(RESORPTION)

RESORPTION OF FLUID TISSUE UNTIL TRANSMURAL PRESSURES ARE AGAIN BALANCED. IN UPPER AREAS AND PARTICULARLY THE HEAD, WE HAVE THE OPPOSITE EFFECT FROM INCREASED TRANSMURAL PRESSURE WHICH PRODUCES THESE PROCESSES ARE SIMULTANEOUS.

WHETHER THIS SHIFT OF FLUID PRODUCES AN INCREASE IN INTRAVASCULAR VOLUME OR NOT DEPENDS UPON HOW RAPIDLY FLUID IS REGAINED FROM SOME AREAS AND LOST TO OTHERS. IT IS AT LEAST THEORETICALLY POSSIBLE THAT THAT FLUID IS LOST MORE RAPIDLY THAN IT IS GAINED FROM OTHERS WITH A REDUCTION OF INTRAVASCULAR VOLUME. I DO NOT THINK THIS HAPPENS AND EXPECT THERE MAY BE A VERY SLIGHT EXPANSION OF VOLUME WHICH, COUPLED WITH THE BLOOD FROM LEG VEINS, MAY RESULT IN A SMALL FLUID LOSS VIA THE GAUER-HENRY SCHEME
(OR SOME OTHER)

OR SOME OTHER MECHANISM. HOWEVER, REMEMBER THAT
TISSUE FLUID SHIFTS OCCUR UNDER 1-G WITHOUT UNDUE DIURESIS. .
LEGS ARE SMALLER IN THE MORNING AND EYES ARE PUFFY, AND
A SHAVE LASTS LONGER IF MADE AN HOUR OR SO AFTER ARISING.

FLUID SHIFTS SHOULD AT LEAST BE RULED OUT AS A PARTICIPANT
IN THE VESTIBULAR UPSETS THAT HAVE OCCURRED. TIME COURSE
AND OTHER ASPECTS OF THESE VESTIBULAR UPSETS ARE
SUGGESTIVE. I HAVE NO HARD EVIDENCE FOR OR AGAINST THIS.

IN SUMMARY WE HAVE DOCUMENTED FOR THE FIRST TIME
ANTHROPOMETRIC CHANGES AND THE CORRECT MAGNITUDE AND
TIME COURSE OF FLUID SHIFTS UNDER WEIGHTLESSNESS THAT
HAVE IMPLICATIONS FOR FUTURE ENGINEERING AND THAT EXPLAIN
SOME MEDICAL PHENOMENA. MORE IMPORTANTLY THEY PROVIDE
A FUNDAMENTAL POINT OF DEPARTURE FOR FUTURE RESEARCH.

(BED REST)

BED REST STUDIES FOR EXAMPLE HAVE NOT PROPERLY
CONSIDERED SUCH FLUID SHIFTS. WE NOW HAVE BETTER CRITERIA,
FOR EVALUATING THE FIDELITY OF WEIGHTLESS ANALOGS SUCH
AS BED REST AND WATER IMMERSION. MOST IMPORTANTLY WE
AGAIN FIND THE HUMAN BODY CAPABLE OF MAKING STABLE
ADAPTATION TO TWO WIDELY DIFFERING ENVIRONMENTS IN AN
AMAZINGLY SHORT TIME. IN THE COURSE OF THESE EXPERIMENTS,
I FEEL DATA HAS BEEN OFFERED TO JUSTIFY THE TITLE "EARTH
MAN -- SPACE MAN".

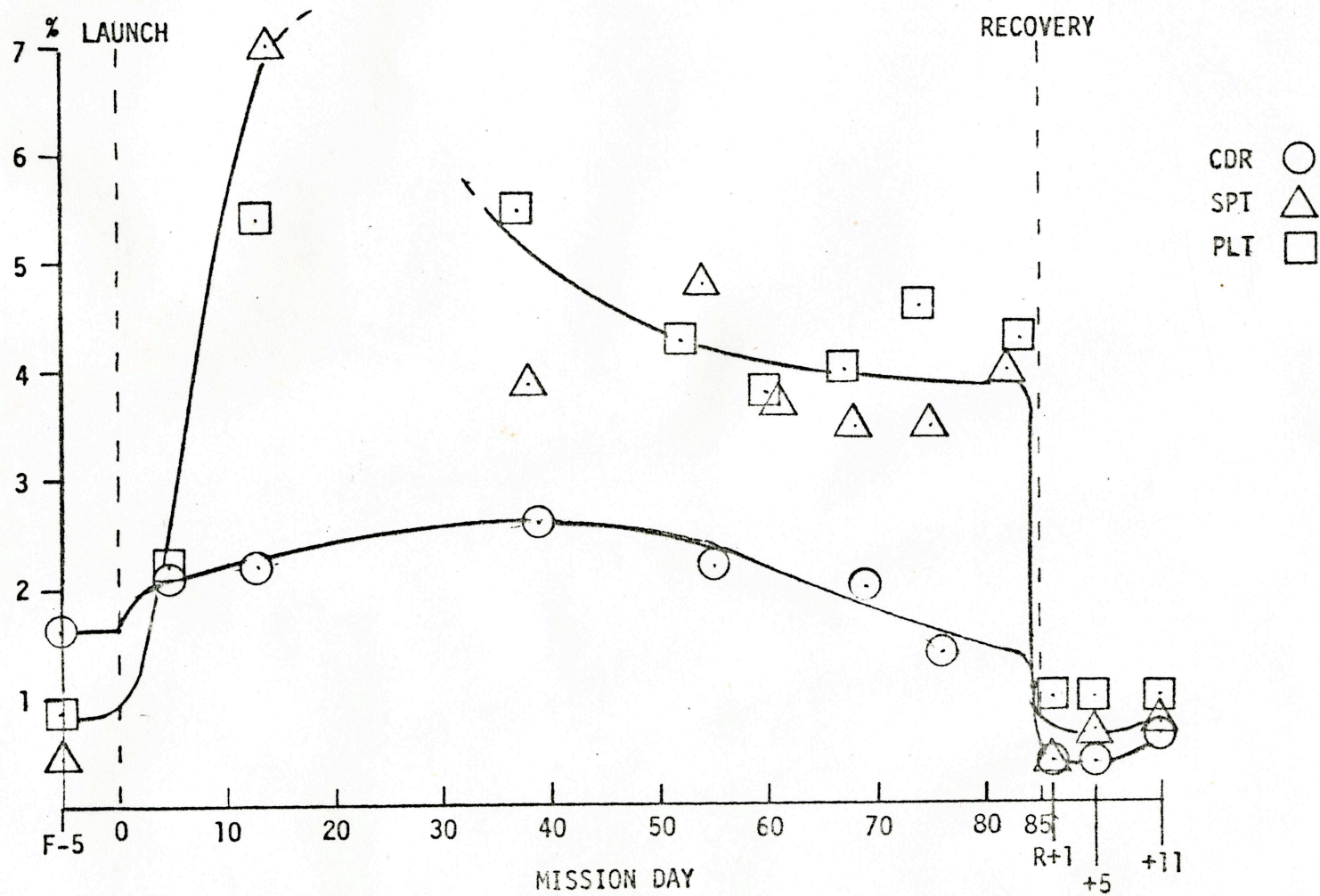
ACKNOWLEDGE

SKYLAB 4 CREW
SCHNEIDER
JOHNSTON

VASCULAR COMPLIANCE, LEFT LEG

SL-4 CREW - $\Delta P = 30\text{mm Hg}$

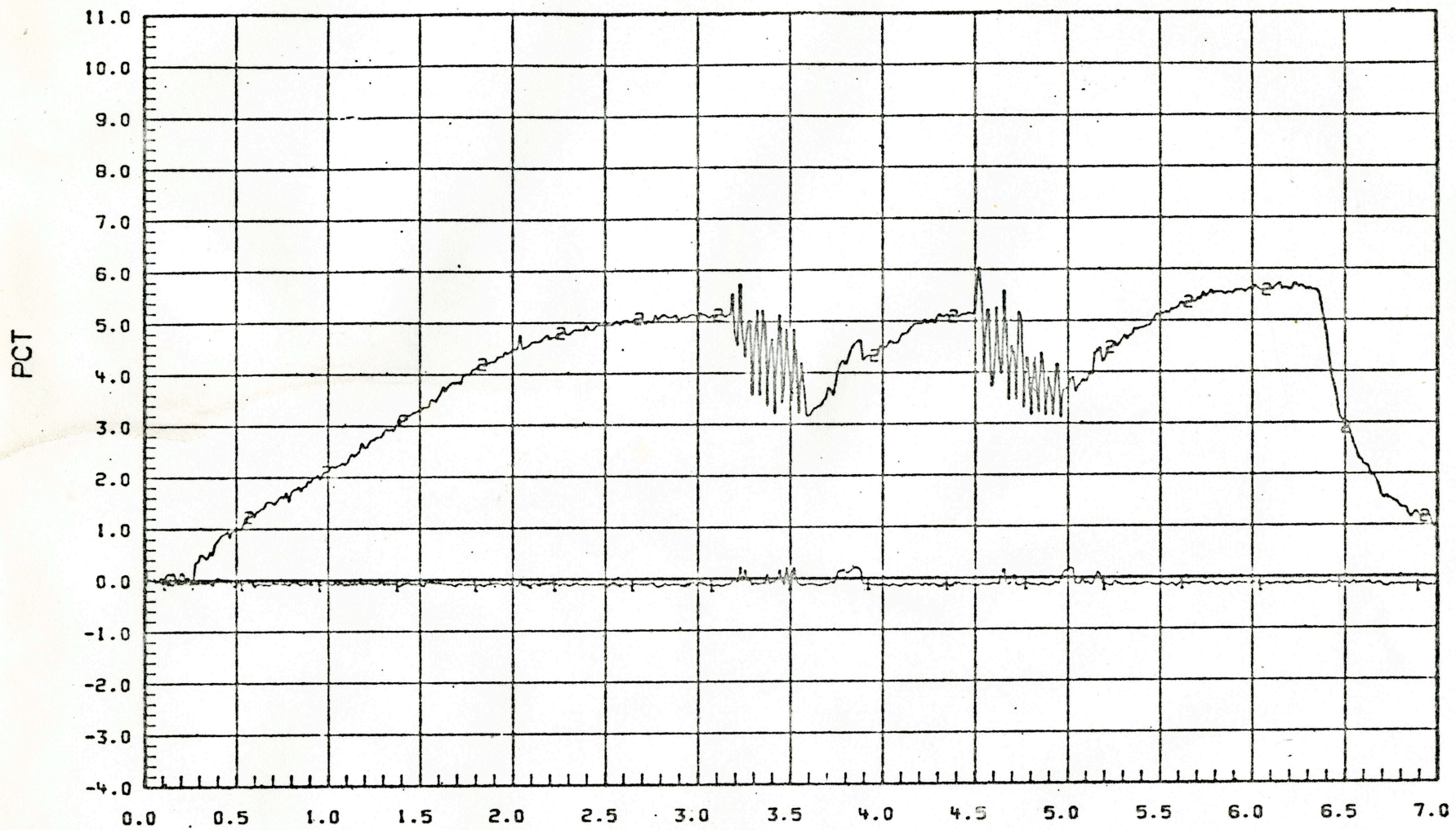
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MUSCLE PUMP DATA

1. P7036M092 .

2. P7004M092

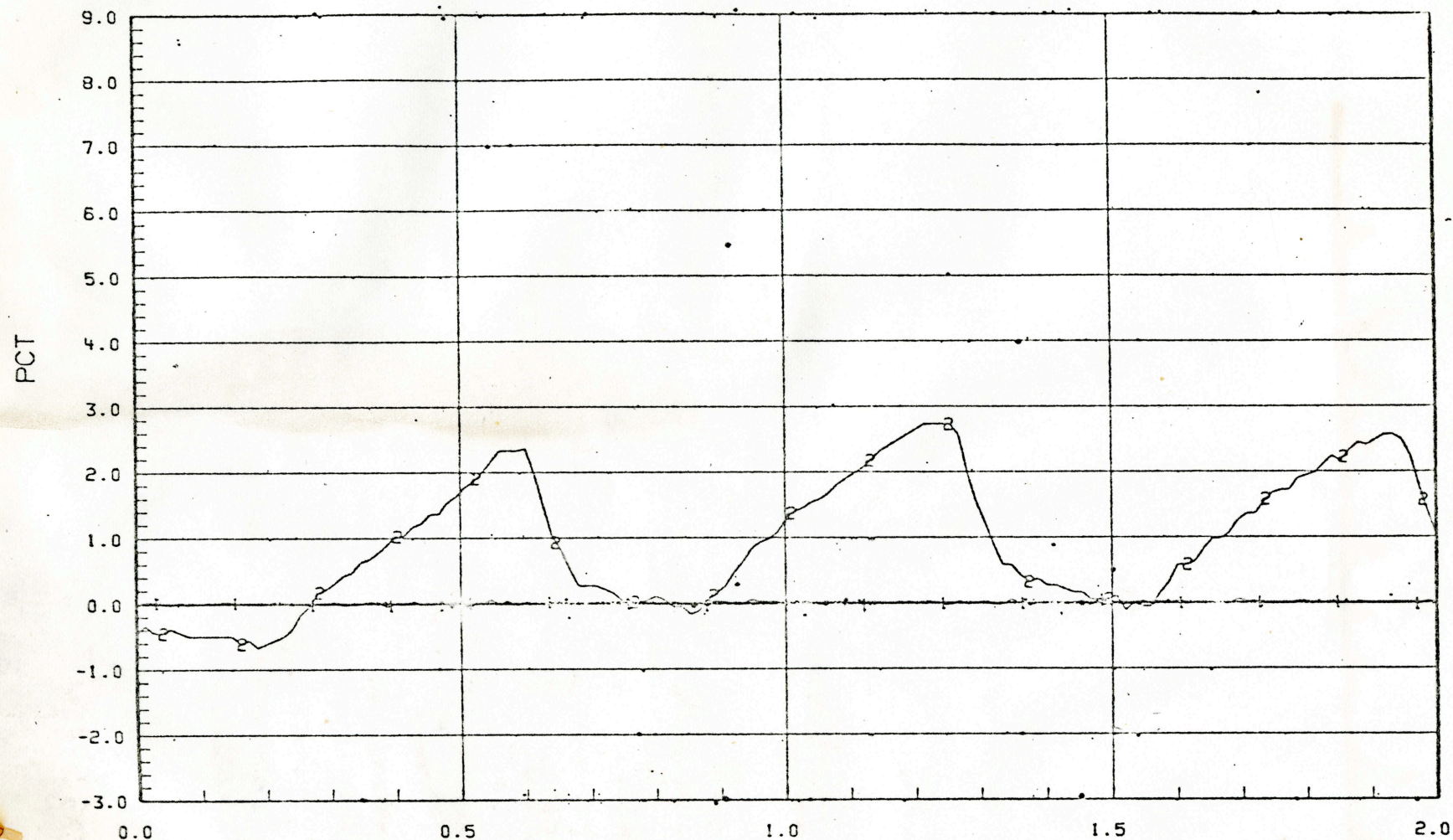


TIME IN MINS STARTING FROM 21 DAYS, 14 HRS, 9 MIN, 30.000 SEC

LEG BLOOD FLOW DATA (A)

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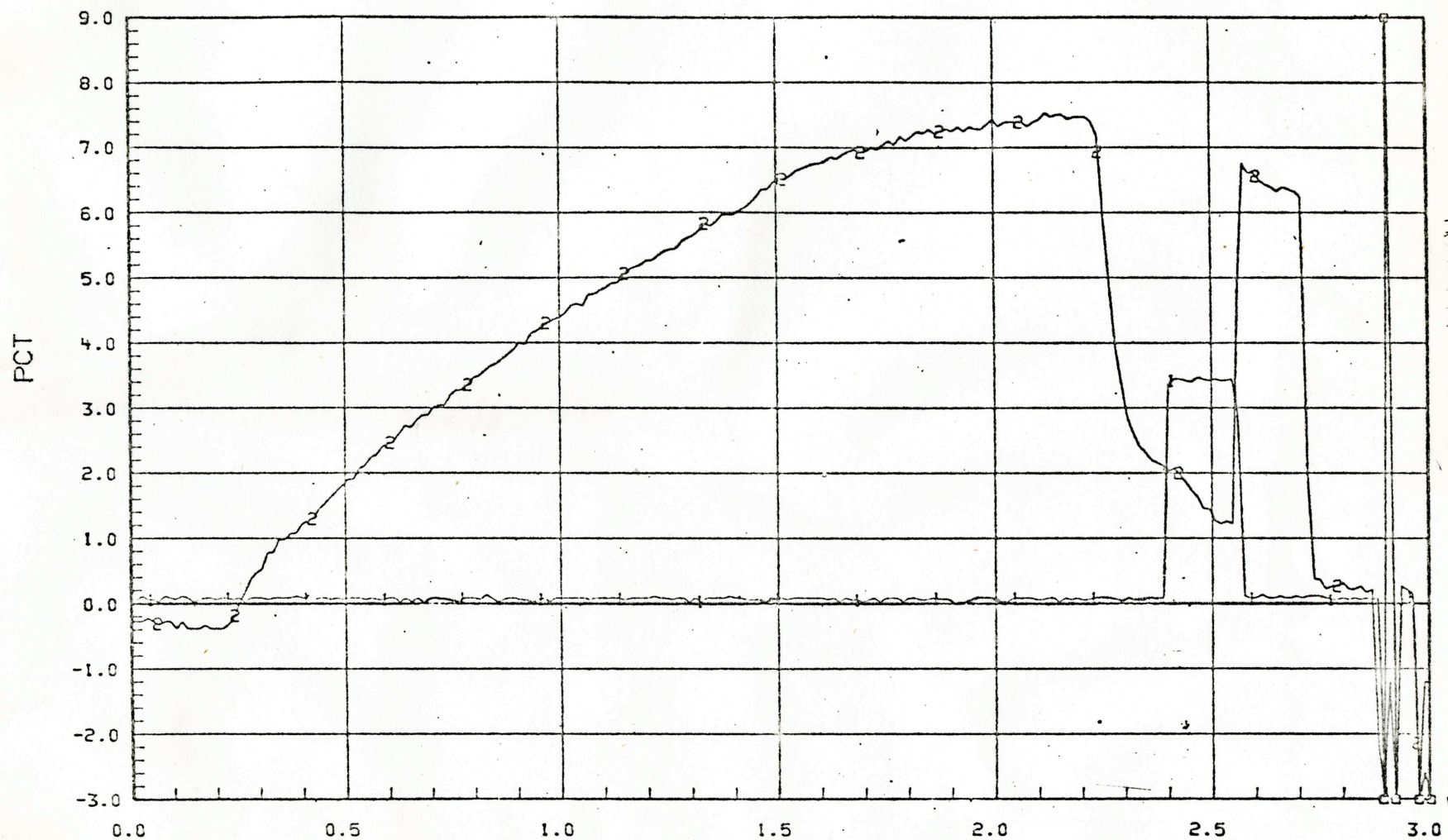
2. P7004M092



LEG BLOOD FLOW DATA (B)

1. P7036M092

2. P7004M092



TIME IN MINS STARTING FROM 333 DAYS, 22 HRS, 48 MIN, 20.000 SEC