

SYNOPSIS

This section contains detailed equipment descriptions for each item of equipment identified in the recommended biomedical and behavioral experiment package. Equipment characteristics data are presented for each item of equipment (e.g., data management characteristics, weight, power, and volume). In addition, development and equipment status information is specified for all equipment identified.

Section 9
EXPERIMENT EQUIPMENT

9.1 BIOMEDICAL EQUIPMENT DESCRIPTION

Equipment specified for the biomedical experiment program is discussed for each item of equipment identified for the three major experiment categories – physiology, microscopy/chemistry, and behavioral. Table 9-1 presents a listing, by experiment, of the major equipment items currently planned for the biomedical experiment equipment package.

The equipment selection for the experiments is the result of a series of carefully planned studies on the definition, specification, and analysis of biomedical and behavioral experiments required for a variety of NASA manned orbital research laboratories presently in the development or conceptual design stage. The specified equipment represents the instrumentation necessary to conduct the biomedical and behavioral experiment program currently under consideration by NASA. It presents an approach to achieve maximum flexibility since it is realized that experiment objectives may change in the light of data received from present and near-future Gemini and early Apollo flight programs. The modular building block approach has therefore been utilized in an attempt to allow for potential experiment modification and the necessity for possible alternate equipment combinations, functions, and requirements.

Equipment characteristics data have been included to provide actual equipment details so that total biomedical program system interface requirements as well as flight-vehicle interface requirements can be initially formulated. In addition, schedules and status are provided to enable future planning for the development of biomedical and behavioral equipment and systems.

Equipment characteristics and considerations discussed in this section are as follows:

- Weight
- Power
- Volume
- Data management characteristics
- Development schedule
- Suggested manufacturer

9.2 PHYSIOLOGY EXPERIMENT EQUIPMENT DESCRIPTION

Equipment required to support the conduct of the physiological experiments has undergone a series of extensive studies, e.g., the prior Biolabs study on AES (AAP), as described in Ref. 9-1. During the analysis, several conceptual designs have been proposed and modified as more definitive spacecraft constraints and capabilities became available. Several equipment items are currently available as prototype hardware for Gemini and/or are being flight-qualified for Apollo. However, many equipment items do not exist or are in conceptual or breadboard stages of development.

This section has been prepared to provide a brief summary (detailed when available) and illustrations (where possible) for each item of equipment required to support the experiments.

The bioinstrumentation system is shown in Fig. 9-1. It consists of the following major components:

- Cardio kit
- Pulmonary kit
- Biometric station console (physiological display/control panel)

The left-hand side of Fig. 9-1 shows the physiological data sensors. The sensed information is signal-conditioned by the appropriate amplifiers and raised to the 0 to 5-v level before being routed to the biometric console. In addition to its data handling

[illegible]

(a) Integrated experiment, including Experiments 0103, 0106, 0107, 0108
(b) Integrated experiment, including Experiments 0104, 0109, and 0110

Table 9-1 AAP Biomedical and Behavioral Experiment/Equipment Summary

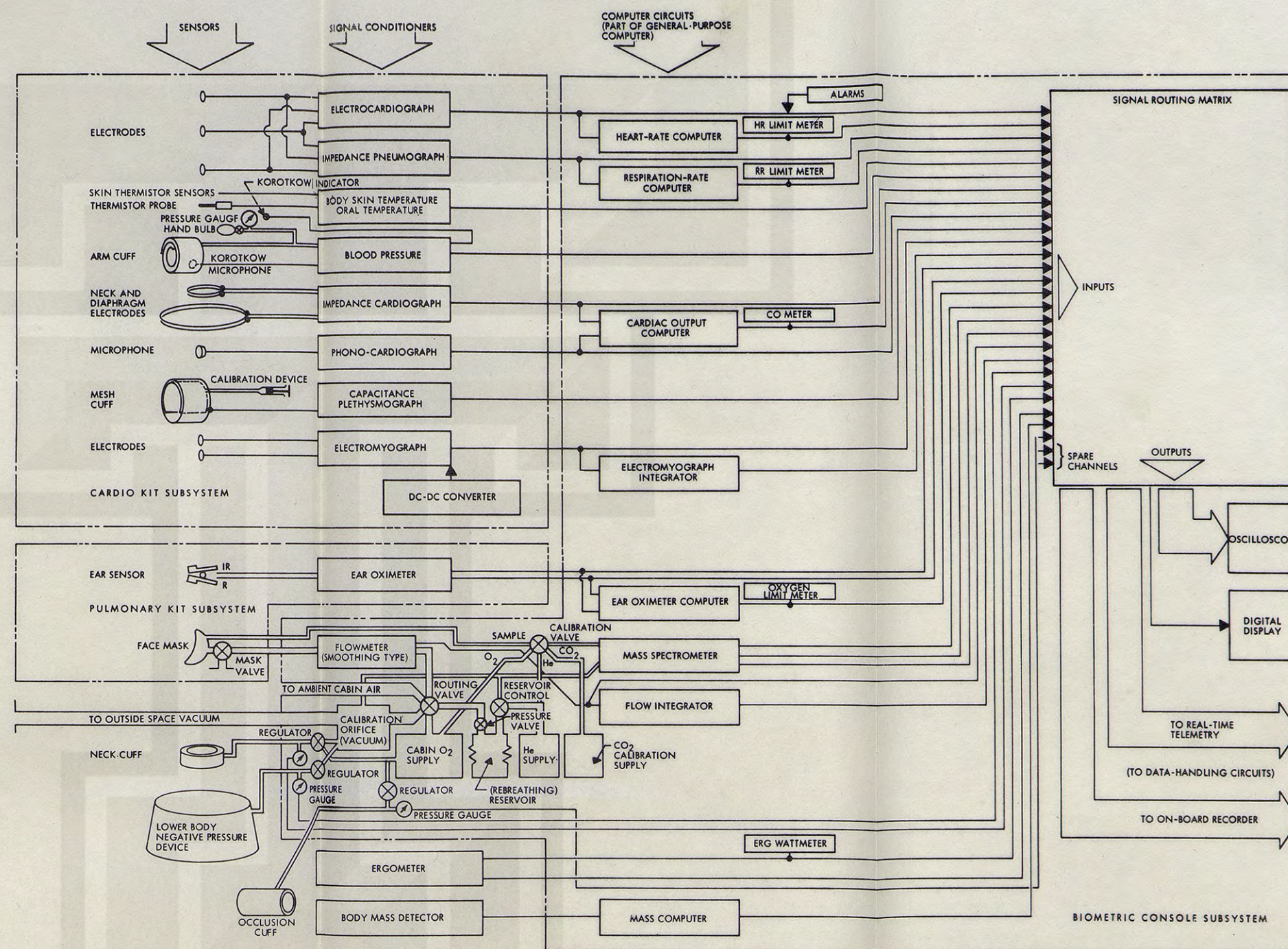


Fig. 9-1 Suggested Physiology Bio-instrumentation System

and display capability, the biometric station also contains the respiratory analyzer subsystem. The physiological panel (an integral element of the biometric station console) and associated physiological sensors, instruments, and equipment comprise the hardware discussed in the following paragraphs.

9.2.1 Physiology Panel

The physiology panel of the biometric station console shown in Fig. 9-2 illustrates the general display/control equipment configuration recommended for use in the study. The panel, an integral element of the biometric station, is located in the right side of the biometric station console and is adjacent to the biomedical stowage compartment. The physiological display/control system consists of two panels – the main display and control panel, and the pulmonary control/input panel.

The pulmonary control/input panel (Fig. 9-3) should be located near the experiment area of the LEM Laboratory if at all possible. The umbilical cables, hoses, and gas sample tubes are plugged into the panel. Since it is necessary for certain of the respiratory analysis equipment (i.e., the flowmeter), to be located near the hose input, some of the respiratory analyzer controls are placed on this panel.

The integral equipment components of the physiology station panel are discussed in the following paragraphs.

Oscilloscope. The proposed oscilloscope has a rectangular single-beam tube which, by chopping and gating, displays up to 8 channels simultaneously. Since the sweep speeds for physiological display are slow, this may be easily accomplished. The following sweep speeds are available by manual selection:

- | | |
|------------------------|---------------------------|
| ● Respiration Displays | ● Cardiovascular Displays |
| 2.5 mm/sec | 25 mm/sec |
| 5 mm/sec | 50 mm/sec |
| 10 mm/sec | 100 mm/sec |

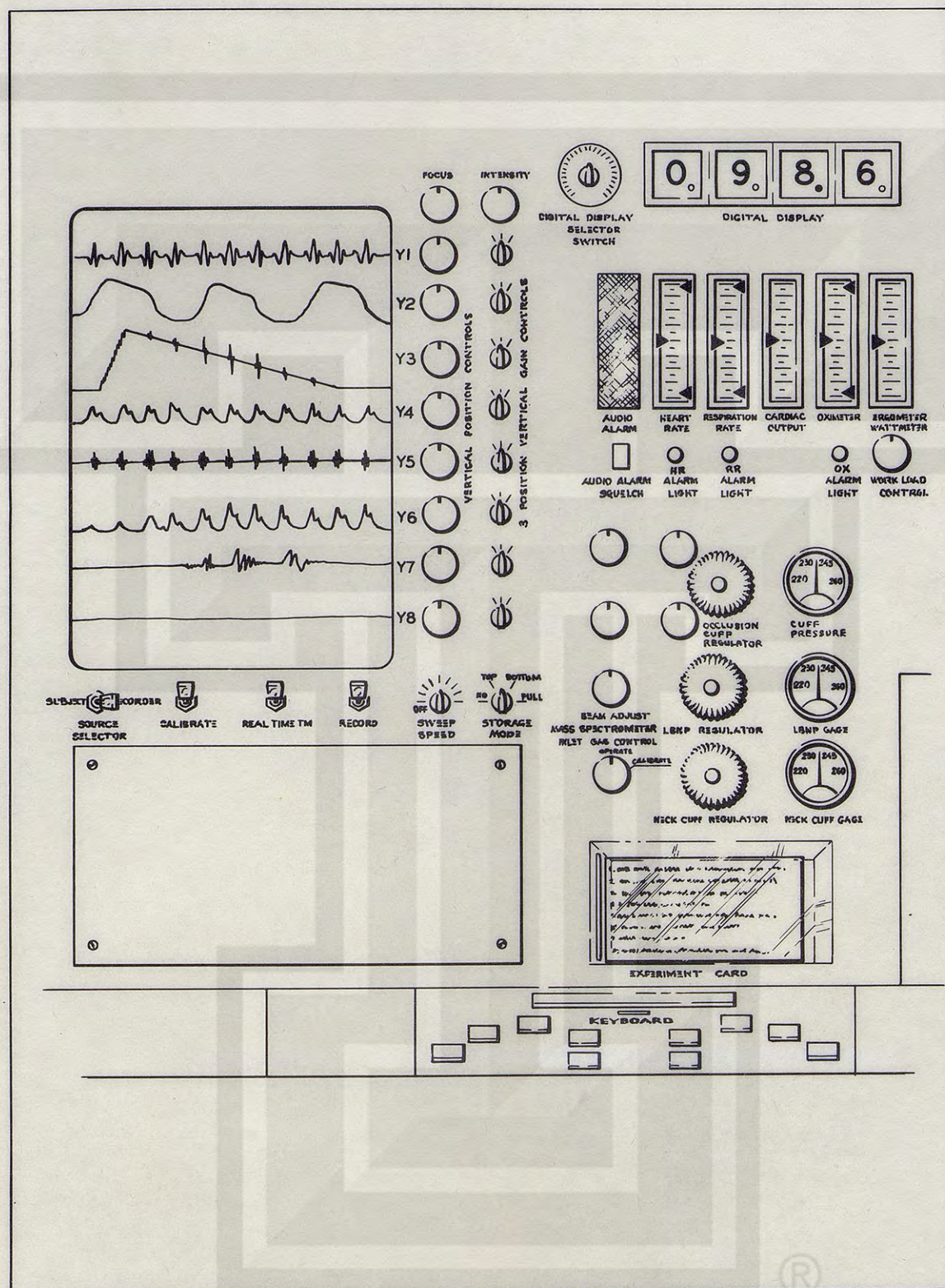


Fig. 9-2 Physiology Display/Control Panel

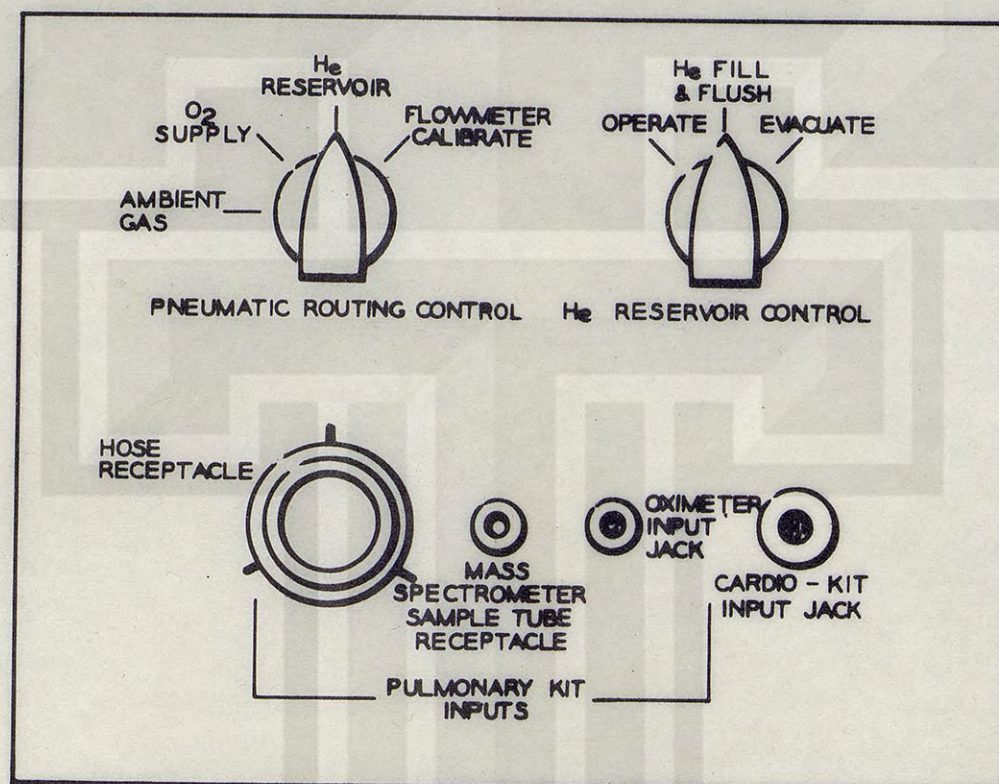


Fig. 9-3 Pulmonary Control/Input Panel

Several storage modes are also available on this oscilloscope. These choices are (1) storage on top half of face, (2) storage on bottom half of face, and (3) full face storage.

An additional proposed feature is an X-axis input. This will enable the operator to display the velocity-volume (V-V) loop of Bartlett (Ref. 9-2).

Oscilloscope controls at the biometric display panel include the following:

- Focus
- Contrast/brightness
- Eight vertical-position switches
- Eight, three-position, vertical-gain controls
- A sweep speed selector with an OFF and X-INPUT position
- Storage mode control

The oscilloscope is not primarily intended for on-board quantified data display. It's main use is to provide feedback to the experimenter to enable him to see if all instruments are attached and operating properly. It can also be used to edit material on the magnetic tape and to indicate when all systems are operating properly and real-time data transmission can take place. In this way, the telemetry links will not be cluttered with unusable data.

Digital Readout Display. A single digital display is proposed for the readout of static, or slowly changing, parameters. A rotary switch is used for manual selection of the parameters desired for display. The following is a list of measurements which will appear as scaled analog d-c voltages to the digital display:

- Heart rate
- Respiration rate
- Oral temperature
- Cabin temperature
- Cardiac output

- Lower body negative pressure (LBNP)
- Neck cuff pressure
- Ergometer - tachometer output
- Body mass
- Gas flow (for calibrating flowmeter)
- Gas volume (for calibrating integrator)
- pO_2 (for calibrating mass spectrometer)
- pCO_2 (for calibrating mass spectrometer)
- pHe (for calibrating mass spectrometer)
- Arterial O_2 saturation (from ear oximeter)

In keeping with the philosophy of making the system flexible, several spare channels will also be available to the digital readout.

Analog Meters. Cardiac output and the ergometer wattmeter are displayed on simple space-qualified analog meters.

Analog Limit Meters. Limit meters are proposed for the display of heart rate, respiration rate, and possibly arterial O_2 saturation (oximeter). Several experiment procedures require that the astronaut-subject exercise until he experiences a particular heart rate or respiration rate. By employing limit meters to monitor these functions, the operator is not required to observe the meters continuously since an alarm will automatically be sounded when a limit is exceeded.

Alarm System. When a limit is exceeded, a small light will flash next to the limit meter by which it has been triggered. Simultaneously, an audio alarm will be sounded. A manual audio alarm squelch will be provided which the operator can operate by depressing a push button. The alarm lights will remain energized, however, until the measured parameters return within the safe range.

Pressure Gages and Regulators. The LBNP device and the neck cuff are controlled at the biometric console by manually operated pressure regulators. Pressure gages on

the physiology panel indicate the internal pressures in the neck cuff and LBNP. In addition to the gages, pressure transducers send analog signals to the on-board recorder. The LBNP is connected to the outside space vacuum through one pressure regulator. The neck cuff and occlusion are connected through the other regulator, either to the outside vacuum for low pressure, or to the ECS air supply for high pressure.

Data Routing. As indicated in Fig. 9-1, a technique is required to route input circuits, containing the acquired physiological data, to the proper output circuits, which include display, recording, telemetry, and other on-board data-handling circuits. Table 9-2 shows the signal routing and control matrix for the proposed system. Inputs are listed at the column on the left, and outputs and control functions are listed horizontally at the top. In addition to routing the data to the various channels of the oscilloscope, telemetry system, and recorder, certain other controls are also shown.

Two data-routing techniques available in the proposed system are (1) manual control using a vector-board approach, and (2) automatic control using coded magnetic cards.

The manual system is located behind a removable panel on the front of the biometric console. Behind that panel is a control patchboard similar in layout to the signal routing and control matrix shown in Table 9-2. Manual signal routing is used only to facilitate a change in the experiment programming while the laboratory is in flight. All other experiments which had been preplanned (most often the case) are routed automatically by the insertion of a coded magnetic "experiment card."

Once the data routing has been programmed, whether it be manual or automatic, the proper circuits are activated by four toggle switches located on the biometric console. The first switch (Source Selector) determines whether the display equipment is sampling data from the test subject or the on-board recorder. (It will, at times, be desirable to monitor recorded information, for the purpose of editing, before dumping the tape on a telemetry down-link.) The second toggle switch is thrown into the Calibrate position when electrical calibration of all circuits is desired. The third switch, when in the Real-Time TM position, directs the programmed information to a telemetry down-link.

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The fourth switch is placed in the Record position when on-board recording of physiological data is desired.

Experiment Card. The experiment card is used for automatic data routing as previously described. In addition to magnetic coding, this card also contains the experiment procedure in written abbreviated form. When the experiment card is placed in the plastic viewer on the biometric console, it provides for programming the data routing and supplying written directions to the experimenter performing the experiment.

Since the automatic experiment programming function and the laboratory procedure are both contained on a single card, it is impossible to confuse a given experiment plan with another experiment data routing program.

Time Code Generator and Digital Time Display. The time-code generator may be either a separate device located in the biometric console or part of the main spacecraft time-control system. In either case, a display of time is required on or near the biometric console.

9.2.2 Personal Data Acquisition Equipment

The equipment worn by the astronaut-subject is shown in Fig. 9-4. The following approaches were considered for signal-conditioning data acquired by the sensors:

- Locating the signal-conditioning equipment in the biometric console with long leads connecting the sensors to the signal conditioners.
- Signal conditioners attached to the subject with high level, low impedance signals then conducted to the biometric console by an umbilical cable.

The second approach was selected for the proposed design. Since most of the physiology experiments (0103 through 0111 and 0115) must be conducted at some distance from the biometric console (in and about various exercising equipment) the signal-conducting leads from the test subject to the biometric console will have to be relatively long.

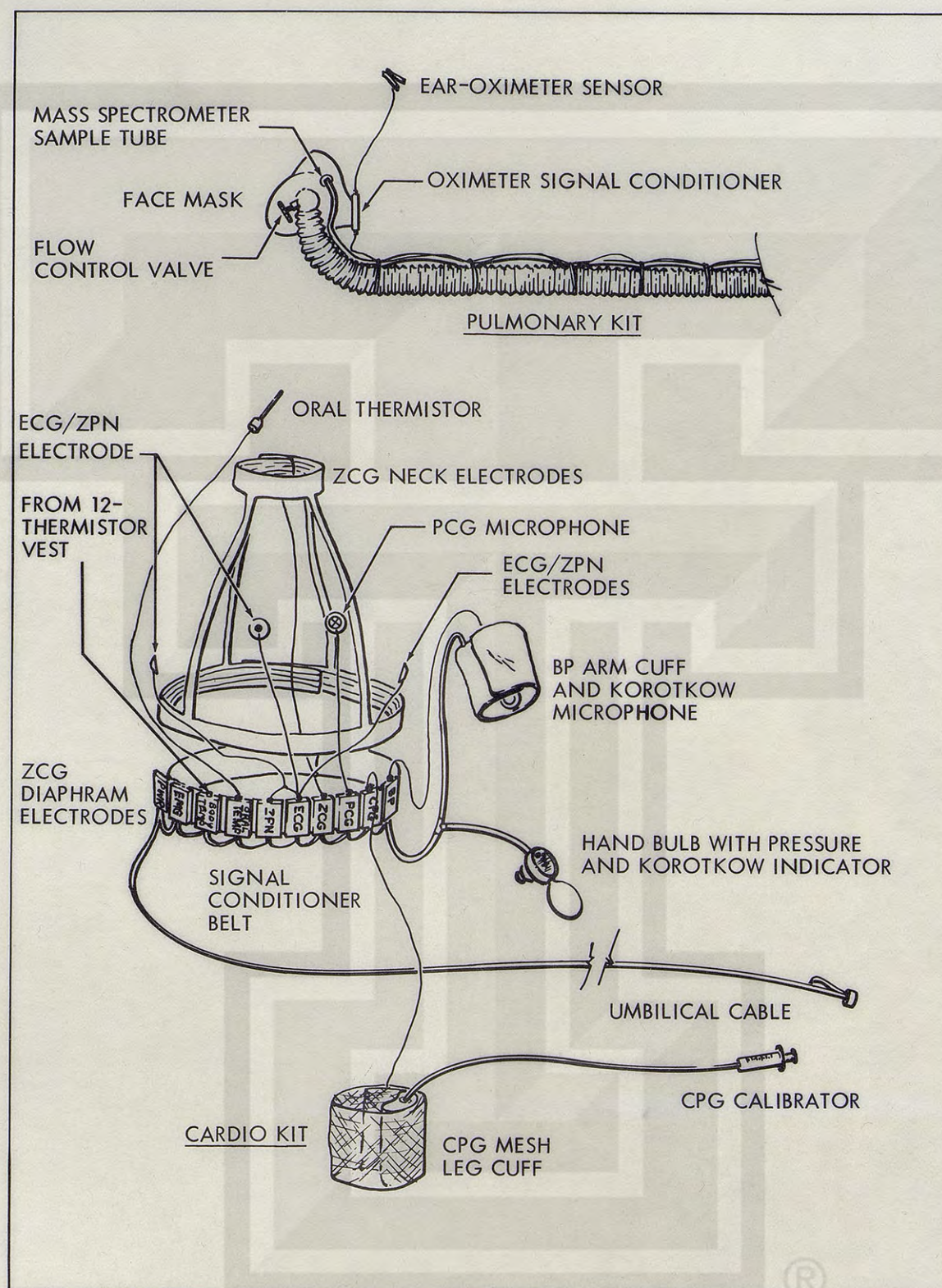


Fig. 9-4 Personal Data Acquisition Equipment

With the signal conditioners attached to the test subject, however, the low level, high impedance, signals from the sensors to the signal conditioners can be conducted by short leads while high level, low impedance, signals are conducted over the long umbilical to the biometric console. Advantages of the second approach are as follows:

- The low level, high impedance, sensor leads are kept short.
- The sensor leads are strain-relieved by the body-attached signal-conditioner belt.
- Signals in the rather long and often flexed umbilical cable are kept at a high level and low impedance by the signal conditioners.
- The system is less sensitive to external electrical noise.
- The system is less influenced by motion of the subject.

The equipment interfacing with the test subject is packed into two convenient kits designed to facilitate the ease with which instruments can be donned for a particular group of experiments. Since the first equipment package is required primarily for cardiovascular measurements, the term "cardio kit" was given to that set of instruments. The second equipment group, used primarily for pulmonary measurements, was designated as the "pulmonary kit."

9.2.3 Signal Conditioners

All body-worn signal conditioners have the physical characteristics of the standard NASA Gemini/Apollo units. The maximum dimensions of these units, except for the ECG Signal Conditioner, are 2.3 in. $\times$ 1.5 in. $\times$ 0.415 in. These modules are of rugged, all-welded, and potted construction. The circuits are solid-state, stable, and nonsusceptible to external electrical noise. Figures 9-5 and 9-6 illustrate typical Gemini/Apollo signal conditioners.

9.2.4 Cardio Kit

The equipment contained in the cardio kit is listed in Table 9-3. The sub-system consists of sensors, signal conditioners, attachment devices such as a signal-conditioner



Fig. 9-5 Gemini Oral Temperature Signal Conditioner

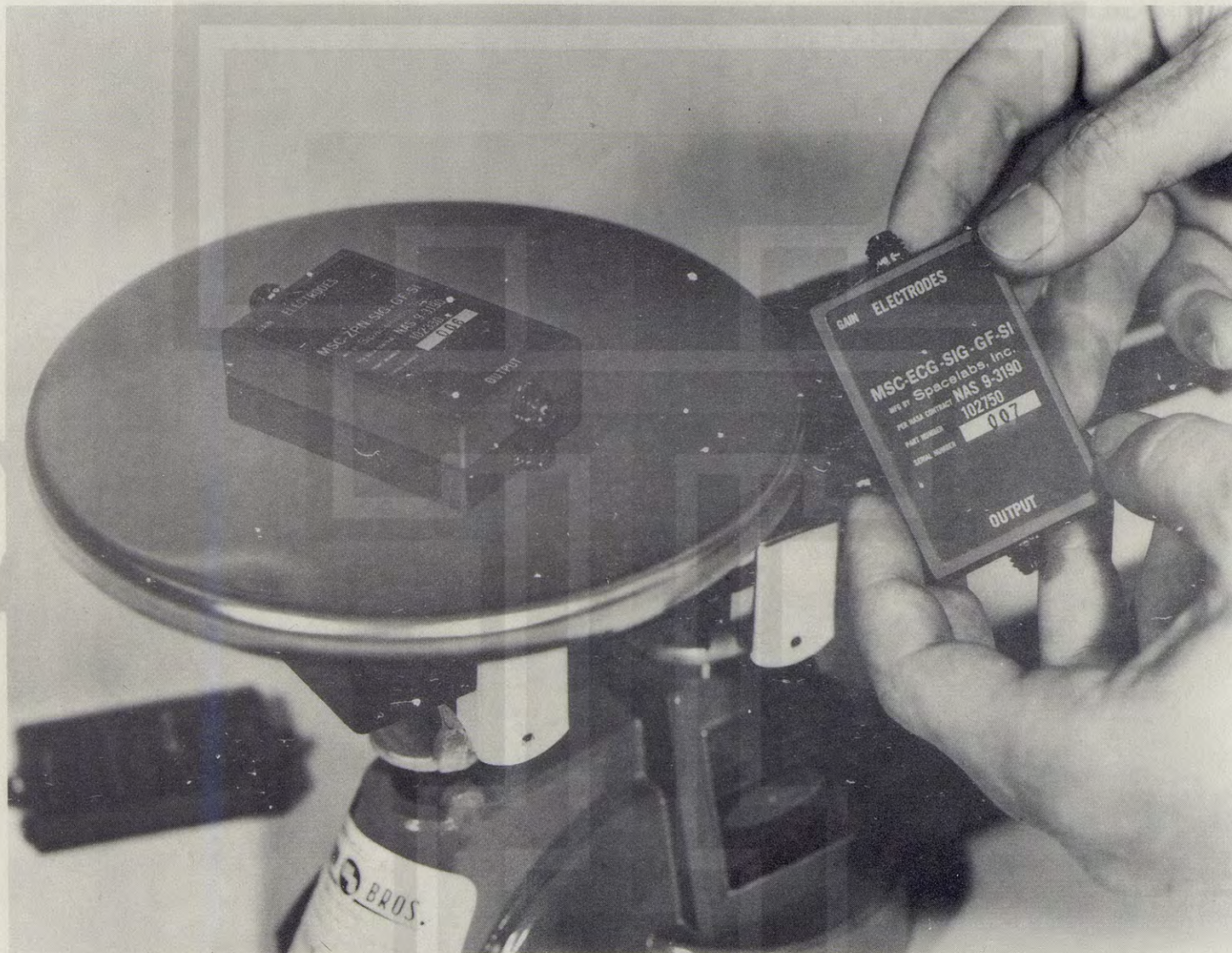


Fig. 9-6 Typical Gemini/Apollo Signal Conditioners

Table 9-3
CARDIO-KIT EQUIPMENT

Parameter	Sensors		Signal Conditioners		Auxiliary Equipment	Notes
	Type	Attachment Devices	Type	Attachment Devices		
Electrocardiogram (and Heart Rate)	Three electrodes (Modified lead I)	Stomoseals and electrode paste	Apollo ECG amplifier	Belt/harness with umbilical cable	—	Internal calibration
Impedance Pneumogram (and Respiration Rate)	Shares two of above electrodes	Same as above	Apollo ZPn		—	
Oral Temperature	Thermistor	None required	Gemini oral temperature		—	Calibration control at console
Body Skin Temperature	12-Thermistor probes	Thermistor vest	Apollo body skin temperature signal conditioner		—	Calibration control at console
Blood Pressure	Microphone and cuff (manually inflated)	Porous surgical tape and arm cuff	Gemini blood pressure		Cuff Inflator (squeeze bulb) pressure gage and Korotkow sound indicator	
Impedance Cardiogram Phonocardiogram (and Cardiac Output)	ZCG-band electrodes and PCG microphone	Electrode harness, Stomoseal, and surgical tape	Apollo ZCG and Apollo PCG		—	
Capacitance Plethysmogram	Mesh cuff	None required	CPG		Calibration system	Mesh cuff stored in separate kit (signal conditioner is integrated) with Cardio-Kit
Electromyogram	Electrodes	Stomoseals and electrode paste	EMG		—	EMG is used in Experiment 0111 but signal conditioner is integrated with Cardio-Kit

belt, and the subject-to-console umbilical cable. All of this equipment folds into a small package which is stowed when the instruments are not in use for the experiments.

Electrodes and Packaging Kit. The electrode system is currently being developed for the Apollo bioinstrumentation development program. Figure 9-7 shows a single electrode. It consists of a molded, thin-flanged, flexible housing containing a silver - silver-chloride electrode which is stabilized relative to the skin by a rigid spacer. Electrode paste is introduced into the assembly from a standard 5-oz tube or in metered quantities by the use of single-application paste ampules. The electrodes are attached to the skin by Stomaseals which are thin, washer-shaped disks with an adhesive on both sides. The Stomaseals are packed in tubes from which they can easily be dispensed. The NASA Manned Space Center is currently working on a packaging scheme for stowage of the electrodes which provides individual packaging of each electrode so that the electrodes can be used on an as-needed basis. Underlying this study was the assumption that the described means of electrode stowage and dispensation would be appropriate for the AAP missions.

Electrode Skin Preparing Apparatus. Figure 9-8 is an illustration of the skin-preparing apparatus. This device is designed to dispense a fluid which will clean the skin surface area in preparation for electrode application. The fluid applied through the dispenser is envisioned as similar to acetone or ether-acetone mixtures of the type currently used for laboratory skin preparation. It must be noted, however, that the solution chosen must be safe and compatible with the atmospheric environment of the spacecraft.

ECG/ZPn Equipment. The ECG/ZPn consists of two transthoracic electrodes, one sternal ground electrode, and the connecting electrode leads used in common with an ECG and a ZPn signal conditioner. The use of common electrodes for the sensing of two different parameters provides the following advantages:

- Fewer devices need be applied to the test subject.
- Fewer components, less weight, and less storage space are required.
- A simpler wiring harness is required.

This equipment is currently being planned for use on the Apollo project.

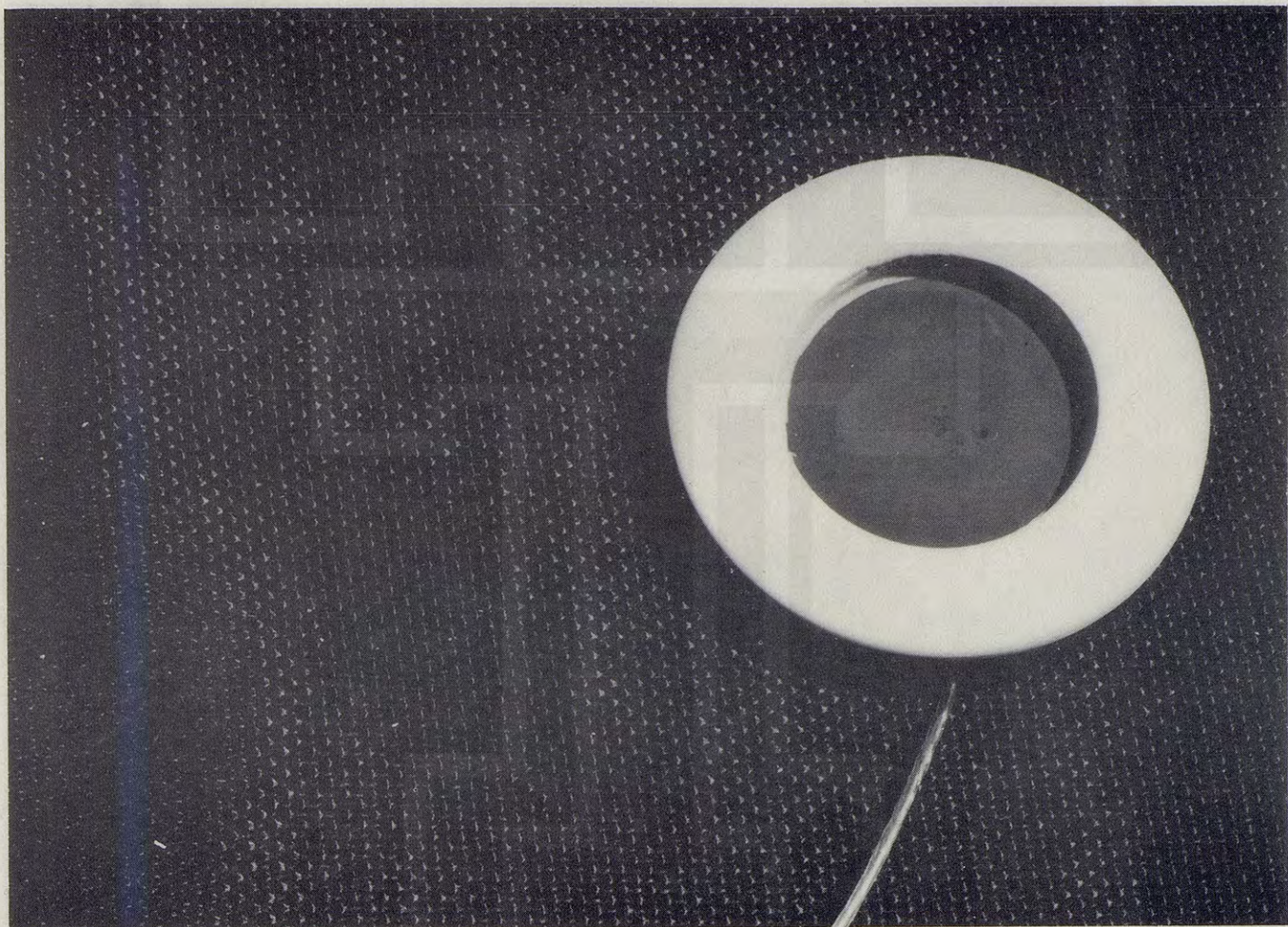


Fig. 9-7 Apollo Electrode (2.5 ×)

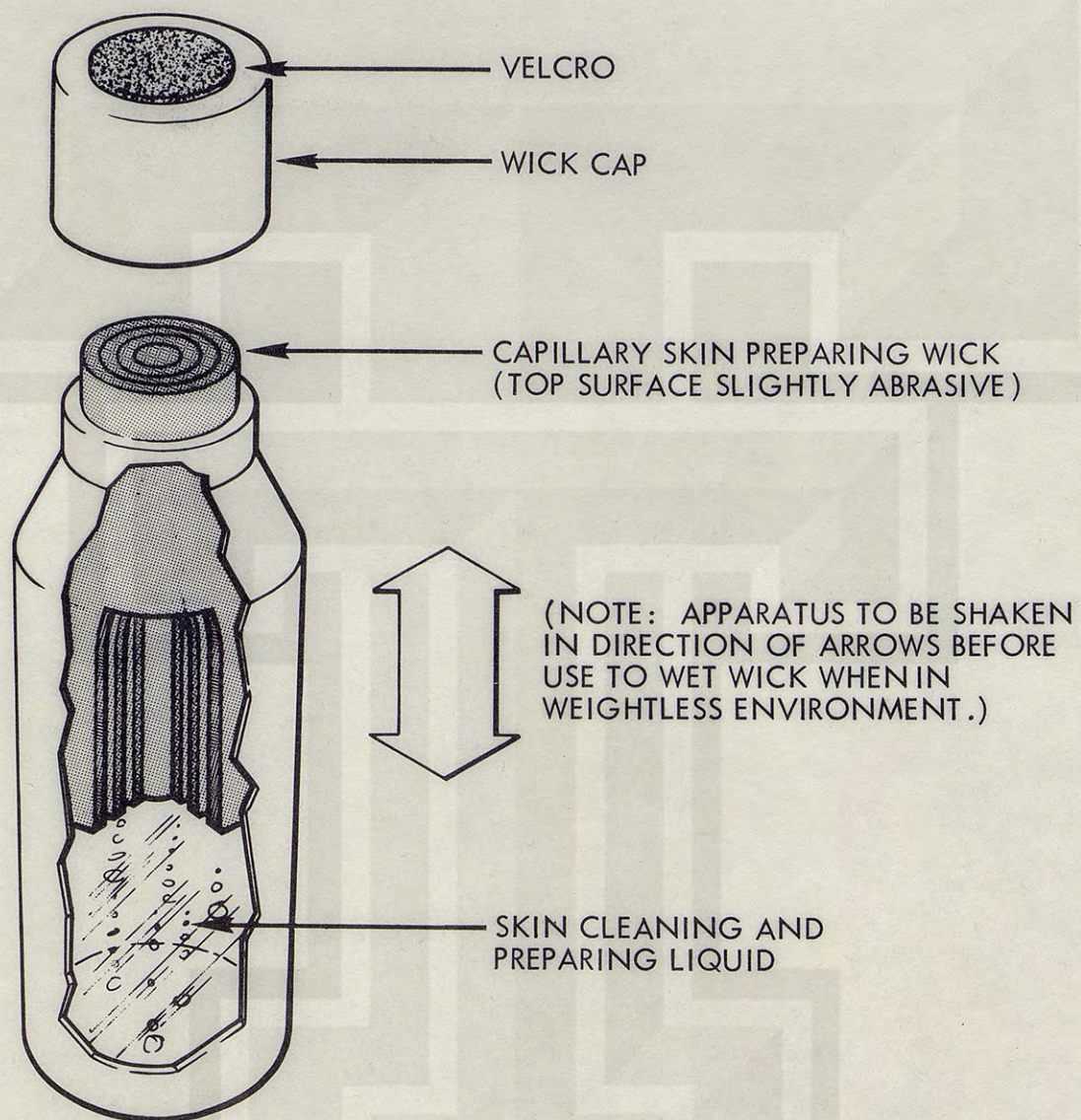


Fig. 9-8 Electrode Skin Preparing Apparatus

ECG Signal Conditioner. The Electrocardiograph (ECG) signal conditioner described here is the same unit currently being developed for the NASA Apollo Program. The Apollo unit is scheduled to complete flight-qualification tests by mid-January 1966. Figure 9-9 illustrates this signal conditioner.

Performance features of the equipment can be summarized as follows: The input circuit affords true differential operation with differential input impedance exceeding 40 meg in the frequency band between 0.2 and 100 cps. The match of input impedance with respect to signal common is better than 1 percent and is determined by precision resistors at the input of the preamplifier. This impedance is virtually independent of amplifier characteristics. The input to the preamplifier is dc-coupled through 100-ohm series resistors which serve to suppress the effects of radiated rf interference by minimizing detection at the input base-emitter junctions. High dc-input impedance assures that dc-current due to a ± 1 v offset at the input will not exceed $0.5 \mu\text{a}$. All the foregoing performance requirements, and those to be listed presently, are met with source impedances as high as 100,000 ohms in either input lead, and with dc voltages as large as ± 1 v peak-to-peak between 10 and 90 kc causes no degradation in performance, and hence the circuit is capable of operating with the impedance pneumograph from a common pair of electrodes.

The output of the signal conditioner is biased at $+2.5 \pm 0.25$ vdc with respect to signal common. The output circuit source impedance is less than 200 ohm. Harmonic distortion is less than 0.25 percent over the band of 0.2 to 100 cps. The response of the ECG within the same bandwidth is flat within ± 3 db, and at 100 cps the roll-off rate is 10 db per octave minimum. Recovery time is less than 2 sec for transient overloads of any nature or duration up to 10 v of either polarity, dc or peak-to-peak ac.

The signal conditioner has a 110-db common-mode rejection for all frequencies within the band of 0.2 to 100 cps, even with differentially applied dc voltages up to ± 1 vdc in series with either input. The common mode signal amplitude can be as great as 10 v peak-to-peak. Common mode rejection can be measured with the input terminal shorted, and a common mode source of any impedance can be applied between input and signal common.



Fig. 9-9 Apollo ECG Signal Conditioner

Noise over all conditions is less than $7\mu\text{v}$ peak-to-peak at the input within the band of 0.2 to 100 cps. The gain is continuously variable from 1,000 to 4,500. The unit meets all specifications operating from a +10 v, -10 v, ± 1 percent dc supply with a current drain less than 4 ma from each half of the supply. The weight is less than 55 gms.

The signal conditioner also features a manually operated calibration switch which inserts an equivalent 1-mv signal referenced to the input. The momentary, actuated, large-diameter pushbutton switch can easily be operated with a gloved hand.

ZPn Signal Conditioner. The impedance pneumograph (ZPn) signal conditioner described in the following paragraphs is the same unit currently undergoing qualification tests for the Apollo Program. Principal features of this equipment are as follows. The electrode excitation is supplied at a nominal frequency of 50 kc and at a current level of 0.5 ma with stability of current and frequency better than 2 percent. The excitation circuit can accommodate electrode base impedance within the range between 100 and 5,000 ohms without compromise to other performance specifications. The circuit presents to the electrodes a source impedance greater than 250 k ohms at 50 kc and greater than 4 meg in the band between 0 and 100 cps. The drive circuit symmetry with respect to signal common gives the electrode circuit a true differential input character.

The output signal swings through 5 v peak-to-peak maximum with a zero signal bias of $+2.5 \pm 0.2$ vdc. The output impedance is nominally 100 ohms. The gain can be adjusted to produce maximum signal swing for changes in electrode impedance between 0.5 ohms at maximum gain and 20 ohms at minimum. The stability of this gain through the range of base impedances and environmental temperature is better than 5 percent.

The frequency response of the circuit at the low end of the data bandwidth corresponds to a time constant between 5 and 10 sec. At the upper end, the response is down 3 db at 10 ± 1 cps and reaches an attenuation rate of 6 db per octave. Recovery is symmetrical from either polarity of transient disturbance and the time does not exceed 15 sec. Response at the output to step-changes in input power of ± 1 percent of the supply voltage does not exceed the equivalent of an impedance change of 0.5 ohm. Other noise effects

do not contribute more than the equivalent of 0.1 ohm impedance change. The current drawn from the power converter does not exceed 7 ma from either side. The maximum unit weight is 55 gms.

Oral Temperature. The oral temperature signal conditioner recommended for AAP is the unit currently being flown on NASA Gemini Program. This signal conditioner, when operating with the proper thermistor probe, is designed to amplify with precision the output of the thermistor bridge. The oral temp system measures temperatures in the range from 95° to 105° F. Its output is 0 to 5 v single-ended with ± 1 percent stability. The signal frequency response is 0 to 1 cps; to reduce sensitivity to external electrical noise, the output is filtered at 18 db/octave above 4 cps. The output impedance is less than 1,000 ohms and its recovery time is 3 ms maximum for 1-v transient inputs of 100 ms or less. The signal conditioner operates from +9.9 to +10.1 v and -9.9 to -10.1 vdc. It draws no more than 5 ma from either side of the power converter. The unit weighs less than 45 gms.

Thermistor Probe. The oral temperature probe (Fig. 9-10) consists of a Yellow Spring Instrument thermistor (Type 44111X) molded in a finger-formable probe which is placed, in turn, in a hermetically sealed handle and cable connector assembly. Bonded to the handle is a Velcro patch by which the thermistor probe may be temporarily attached to the cardio-kit belt when not in use for temperature measurement. The pliability of the probe is advantageous in that it will readily conform to the oral characteristics of a given individual test subject.

12-Lead Thermistor Harness. The 12 thermistors used in the vest suggested for Experiment 0115 will be commutated to a single-channel, body-temperature, signal-conditioner located on the cardio-kit belt. The output of the body skin-temperature signal conditioner may be time-shared with the oral-temperature signal conditioner output if data channels are to be conserved. The thermistor skin sensors and the body-temperature signal conditioner will be identical to those units now being flight-qualified for use on the NASA Apollo Program.

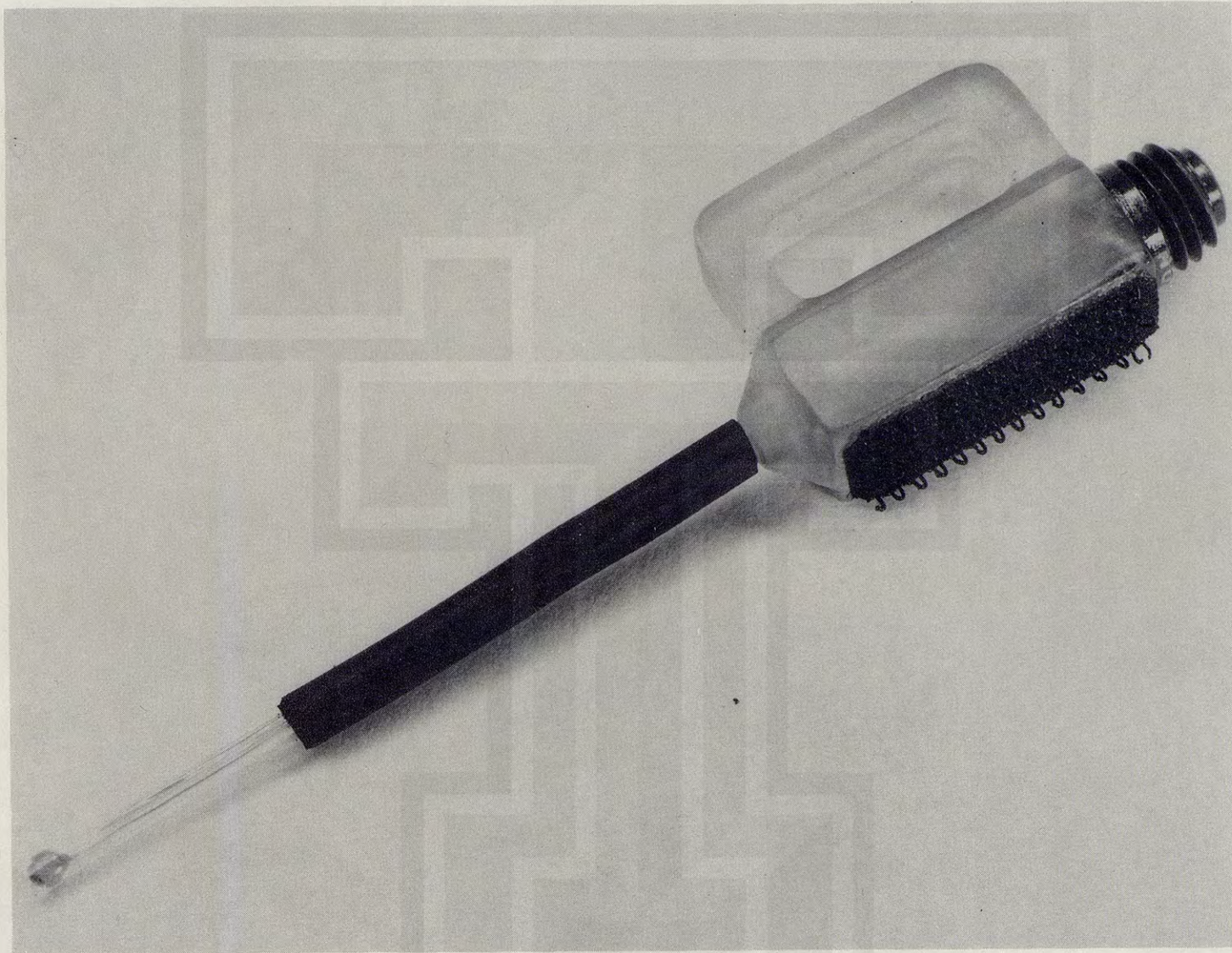


Fig. 9-10 Oral Temperature Thermistor Probe (2.5X)

The performance features of the system can be summarized as follows. The thermistor probes and signal conditioner operating together produce output voltages in the range between 0 and 5 vdc for probe temperatures between 80° and 115° F. The voltage versus sensed temperature characteristic is linear within + 1 percent (or $\pm 0.35^\circ$ F) and the accuracy of repeated measurement with all other effects considered, such as zero shift, gain change, and environmental influences, is within $\pm 0.3^\circ$ F. The output circuit presents a source impedance of 50 ohms and will permit two like unpowered signal conditioners to be paralleled at the output with no compromise to measurement accuracy. The system will respond to a step-temperature change of 5° F by indicating 99 percent of the resulting change in output voltage within 5 sec. The signal conditioner alone has a frequency response which is flat within 3 db between 0 and 1 cps and which, at 4 cps, falls off at 18 db/octave. No response to external fields or voltages above 10 cps is measurable due to internal filtering and common mode rejection. The current drawn from the power converter does not exceed 4.5 ma on either side.

Blood Pressure Equipment. The blood pressure equipment consists of an arm cuff in which is positioned a microphone sensitive to Korotkow sounds, a hand-bulb pressure gage and Korotkow indicator, a signal conditioner, and intraconnecting cables and pneumatic tubes. The auscultatory blood-pressure technique with manual actuation of the brachial arm cuff is currently being employed on the Gemini Program. The system proposed here has an additional feature in that the Korotkow sounds are indicated by flashes from a small lamp located on the hand-held pressure gage. This allows the astrophysician to make rough on-board determinations of the astronaut subject's blood pressure. A more precise indication of blood pressure is recorded and/or telemetered to ground from the analog output of the signal conditioner.

Blood Pressure Cuff, Microphone, and Actuating Device. The blood pressure cuff and microphone currently being used on the Gemini Program are also recommended for the experiments proposed for AAP. It is recommended, however, that the actuating device, or hand bulb, be changed to one which also houses a cuff pressure gage and a Korotkow pulse indicator. Figure 9-11 illustrates the proposed device which will enable the astrophysician to make a rough determination of blood pressure on board the vehicle.

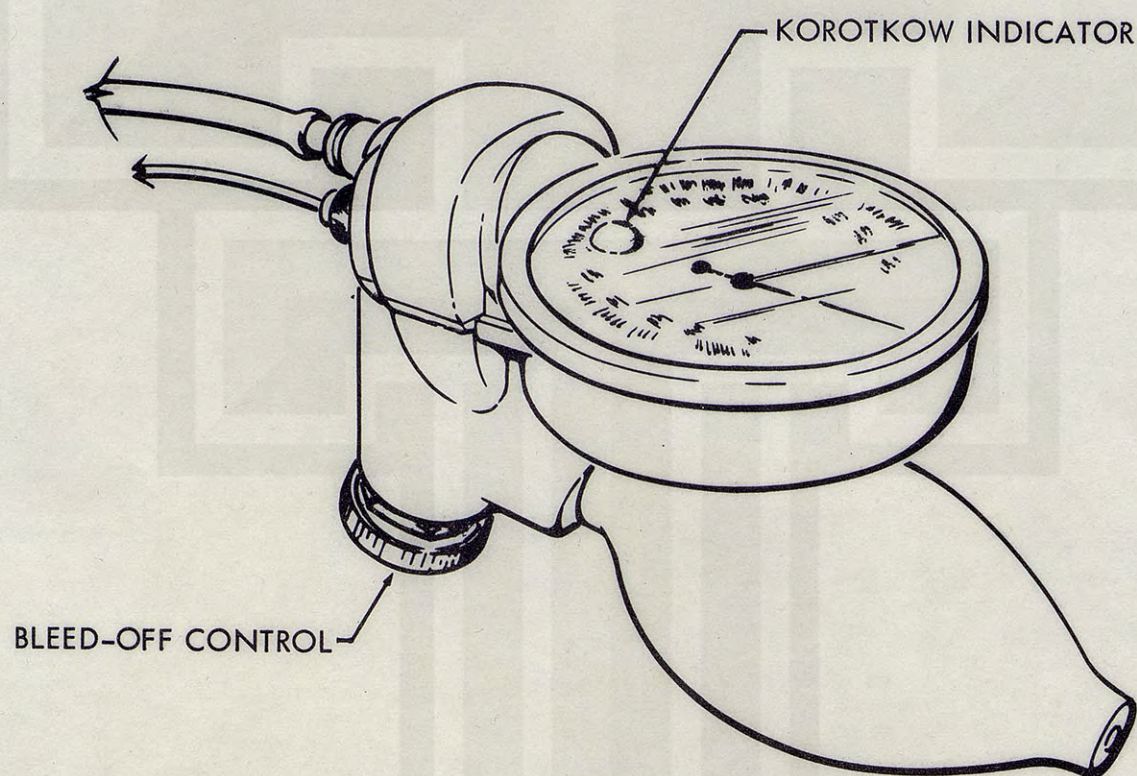


Fig. 9-11 Hand Bulb With Pressure and Korotkow Indicator

Alternately, blood pressure could be measured by reading the analog representation of it on the display oscilloscope or the astrophysician could listen to Korotkow sounds with a conventional stethoscope while observing the arm cuff pressure gage.

Blood Pressure Signal Conditioner. The blood pressure (BP) signal conditioner described below is a modified unit of the type currently flown in the Gemini Program. Its main differences from the current model are as follows:

- The output will be 0 to 5 v instead of the 20-mv output now used on Gemini. The high level output will make it compatible with the rest of the bioinstrumentation system.
- Provision will be made to power a Korotkow pulse indicator located on the arm cuff pressure gage.

The output signal will be an analog of the cuff pressure bleed-off curve on which will be superimposed the Korotkow pulses. Systolic blood pressure will be indicated by the first Korotkow pulse; diastolic pressure will be indicated by the last Korotkow pulse on the bleed-off curve.

Cardiac Output Equipment. Two techniques considered for the measurement of cardiac output are (1) the measurement of thoracic impedance to obtain pulmonary stroke volume, and (2) the indirect Fick method, using CO₂ rebreathing technique.

The former method (impedance cardiographic-ZCG technique) is recommended as the primary method because of the following reasons:

- If cardiac output is the only parameter desired, the ZCG instrumentation occupies less volume, is lighter in weight, and requires less power to operate.
- The experiments requiring the measurement of cardiac output (0103, 0104, 0106, 0107 and 0108) do not require the simultaneous measurement of pulmonary functions for which a mask and other respiratory apparatus will also be required.
- The ZCG technique in no way obstructs the facial area with cumbersome masks and associated tubing.
- The impedance cardiographic technique has been suggested by NASA.

It must be noted that if respiratory measurement is required in the same experiment as that measuring cardiac output, the indirect Fick CO₂ rebreathing technique is recommended since it requires very little additional equipment in the respiratory analyzer. It is therefore suggested that the indirect Fick CO₂ rebreathing technique be used as a secondary or backup method for the following reasons:

- Modification required for the respiratory analyzer is slight since very little apparatus will have to be added to the subsystem.
- It provides a backup should the ZCG instrumentation fail.
- It could provide parallel cardiac output information which could be correlated with the ZCG to determine its validity.

The alternate cardiac output instrumentation will be covered in a later subsection on the respiratory analyzer subsystem.

Two separate physiological parameters are measured by the thoracic impedance cardiac output method. In addition to the acquisition of thoracic impedance information, it is also necessary to sense the phonocardiogram. The cardiac output section thus contains a ZCG electrode harness assembly consisting of neck and diaphragm band electrodes, a PCG microphone, and ZCG and PCG signal conditioners.

The technique for deriving cardiac output using the instrumentation described here was developed by Dr. W. G. Kubicek of the University of Minnesota. His impedance cardiographic technique is designed to first measure the stroke volume into the pulmonary circulation. From geometrical considerations of the thoracic volume, Kubicek has derived the following theoretical relationship:

$$\begin{aligned}\Delta V &= \text{stroke volume into the pulmonary circulation (cm}^3\text{)} \\ \rho &= \text{volume resistivity of blood (150 ohm-cm)} \\ L &= \text{mean distance between the impedance pickup electrodes (cm)} \\ Z &= \text{static impedance between the pickup electrodes (ohm)} \\ \Delta Z &= \text{extrapolated impedance change per stroke (ohm)}\end{aligned}$$

Assuming that changes in the heart do not directly influence the measured impedance waveform, the ΔV calculated with each heart beat can be taken as cardiac stroke volume, and the product ΔVHR as an estimate of the cardiac output. Figure 9-12 shows the intrathoracic impedance waveform and extrapolation, of which measurement is necessary to determine stroke volume as is shown in the foregoing equation.

The Minnesota-developed thoracic impedance technique begins with placing four band electrodes on the subject - two on the neck, one on the lower thorax approximately 2 cm below the xiphisternal joint, and one on the abdomen between the subcostal and intertubercular planes.

The two outer electrodes are excited by a 100-kcps constant current source and the thoracic impedance changes are monitored between the two inner electrodes. According to the investigators, a four-electrode system is preferred over a combination two-electrode arrangement because it reduces the effects of skin resistance on the measurement.

The static value of thoracic impedance is approximately 25 ohms. The peak impedance change is about 0.1 ohm with the impedance decreasing initially during the systolic period. As indicated by Fig. 9-12, the measurement of ΔZ , or the extrapolated impedance change, requires measurement of the duration of systole. The duration of systole is generally defined by the appearance of the first and second heart sounds which indicate the opening and closing of the pulmonary valves. This measurement must therefore take place on the independent phonocardiogram channel.

The analog outputs from the ZCG signal conditioner (to be defined in the signal conditioner description) and the analog phonocardiogram output from the PCG signal conditioner are then fed into the biometric console where further data reduction and display of cardiac output takes place.

ZCG Band Electrodes. Figure 9-13 illustrates the prototype for the band electrode harness developed for thoracic impedance measurement on Apollo. The primary design criteria were as follows:

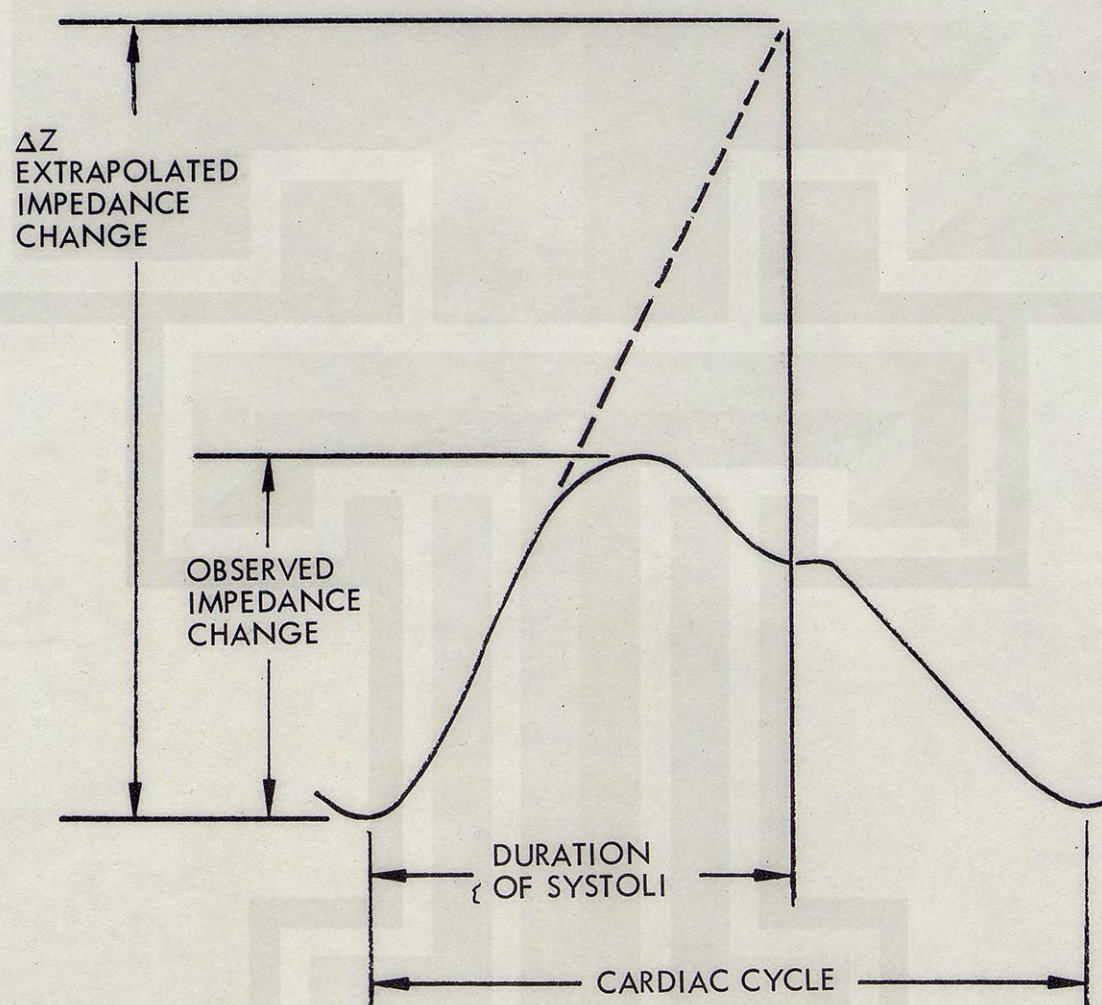


Fig. 9-12 Intrathoracic Impedance Waveform and Its Extrapolation



Fig. 9-13 Prototype Impedance Cardiograph Electrode Harness

- Low weight and comfort
- Adjustability
- Adherence to body contours
- Compensation for breathing movements
- Flexible, low-resistance, electrode material

The harness is fabricated from two horizontal elastic bands. Two metallic cloth electrodes are mounted on each band. The stretchable bands are fastened by Velcro cloth, and the lower band electrodes are broken at the small of the back (normally a non-contact point) to provide strain relief in breathing. Thin cloth strips connect the neck and chest elastic bands and these perform the important functions of maintaining a set electrode distance L for consecutive measurements. Details of the metallic cloth electrode bands are shown in Fig. 9-14. The material used in the prototype was Foylon, a foil-fabric combination manufactured by Archer Aluminum. Foylon is produced by pressure bonding thin aluminum sheet to cloth backing. The resultant product is strong, porous, and completely flexible, and has a satisfactory low resistance (about 0.02 ohms/in. in 0.5-in. strips). This low resistance means that the use of noncontinuous bands (there is a small break where the adjustable elastic bands overlap) and one lead attachment point per band has a negligible effect on the high frequency field produced in the thorax. This electrode system has performed consistently well without the use of electrode paste, a great advantage in spaceflight experimentation. The electrode harness to be delivered to NASA with the flight-qualified Apollo system will also employ either rigid electrode separation bands or crotch straps to maintain the very critical distance between the neck and diaphragm electrodes.

ZCG Signal Conditioner. The impedance cardiograph (ZCG) signal conditioner will contain the circuit presently being developed for Project Apollo. This circuit, however, will be repackaged into a welded construction potted module of the same dimensions as the other signal conditioners in the cardio kit.

The characteristics of the signal conditioner are as follows: Excitation electrodes are supplied from a 100-kc constant current source. A 100-kc voltage proportional to



Fig. 9-14 Detail of Dual-Band Impedance Cardiograph Electrodes

the transthoracic impedance appears across the thorax and is sensed by the sense electrodes. This voltage, which is a measure of transthoracic impedance, is amplified and detected to supply output voltages ranging from 0 to +5 v. The output is available in three different forms, defined as follows:

- $|\bar{Z}|$ = average (base) impedance
- $\Delta|Z|$ = impedance, minus dc component
- $|\dot{Z}| = \frac{d|Z|}{dt}$ = rate of change of impedance

The dynamic range of $|\bar{Z}|$ is 10 to 40 ohms. The accuracy to which it can be measured over the full environment is ± 3 percent maximum. The dynamic range of $\Delta|Z|$ is ± 0.25 ohms and the accuracy to which it can be measured is ± 3 percent maximum also. The dynamic range of $|\dot{Z}|$ is +3 to -7 ohms/sec and the accuracy to which it can be measured is ± 4 percent maximum. The ZCG signal conditioner is sharply tuned to eliminate interference in the 50-kc region which might be picked up from the impedance pneumograph. The system is thus designed to allow simultaneous operation of both the impedance pneumograph and the impedance cardiograph. All output voltages are in the 0 to 5-v range with symmetrical operation on both sides of the 2.5-v point. Output impedances will not exceed 200 ohms within the bandpasses of interest. The signal conditioner will operate from a +10, -10v ± 1 percent vdc power source. It will consume no more than 7 ma from both the positive and negative sides of the supply.

PCG Microphone. The PCG microphone is a modified version of one developed by NASA/MSD for use on the Gemini Program. This microphone utilizes a bimorph-type crystal slab mounted in a modified ECG electrode housing. The design of this unit is unique in that it is small, light in weight, and can be affixed to the astronaut's body using Stomaseal disks in the same way as for the ECG electrodes. The design incorporates a thin epoxy spray coating on the face of the crystal which is placed against the astronaut's body. In addition, a V-groove has been provided at the point where the microphone cable enters the microphone housing so that an epoxy potting material can be added after final assembly to prevent moisture from entering the

housing either at the microphone cable entrance or around the crystal face. The back face of the microphone is completely encapsulated with an epoxy resin. The curie point of the crystal is 300° F which will prevent trouble from developing due to high storage temperatures. Figure 9-15 illustrates this microphone.

PCG Signal Conditioner. The phonocardiograph (PCG) signal conditioner is the same unit currently undergoing qualification tests for the Apollo Program. It is basically a modified Apollo ECG signal conditioner. The modifications consist of removal of the calibrate switch and changing filtering characteristics to permit the proper frequency response for PCG measurement.

Capacitance Plethysmograph. The capacitance plethysmograph (CPG) consists of a spiral electrocapacitance screen, or mesh cuff, and a signal conditioner containing an oscillator, an amplifier, and a phase discriminator. Auxiliary equipment includes a calibration device.

The insulated copper screen, or mesh cuff, is placed around an extremity and forms one plate of a condenser. The other insulated shield screen, along with the skin, forms the other grounded plate. Changes in volume move the skin towards the fixed screen to change capacitance. This modifies the frequency and alters the output of the phase discriminator in direct proportion to the volume change.

Calibration is accomplished by injecting a known volume of saline solution between the cuff and the skin. The calibration volume directly affects the capacitance, yielding an accurate reproducible change in the output. This direct end-to-end calibration provides a certain and absolute evaluation of the entire apparatus.

Although space-qualified hardware has not yet been developed for the CPG measurement, laboratory equipment is being built (see Fig. 9-16). Figure 9-17 illustrates the mockup used in the study.

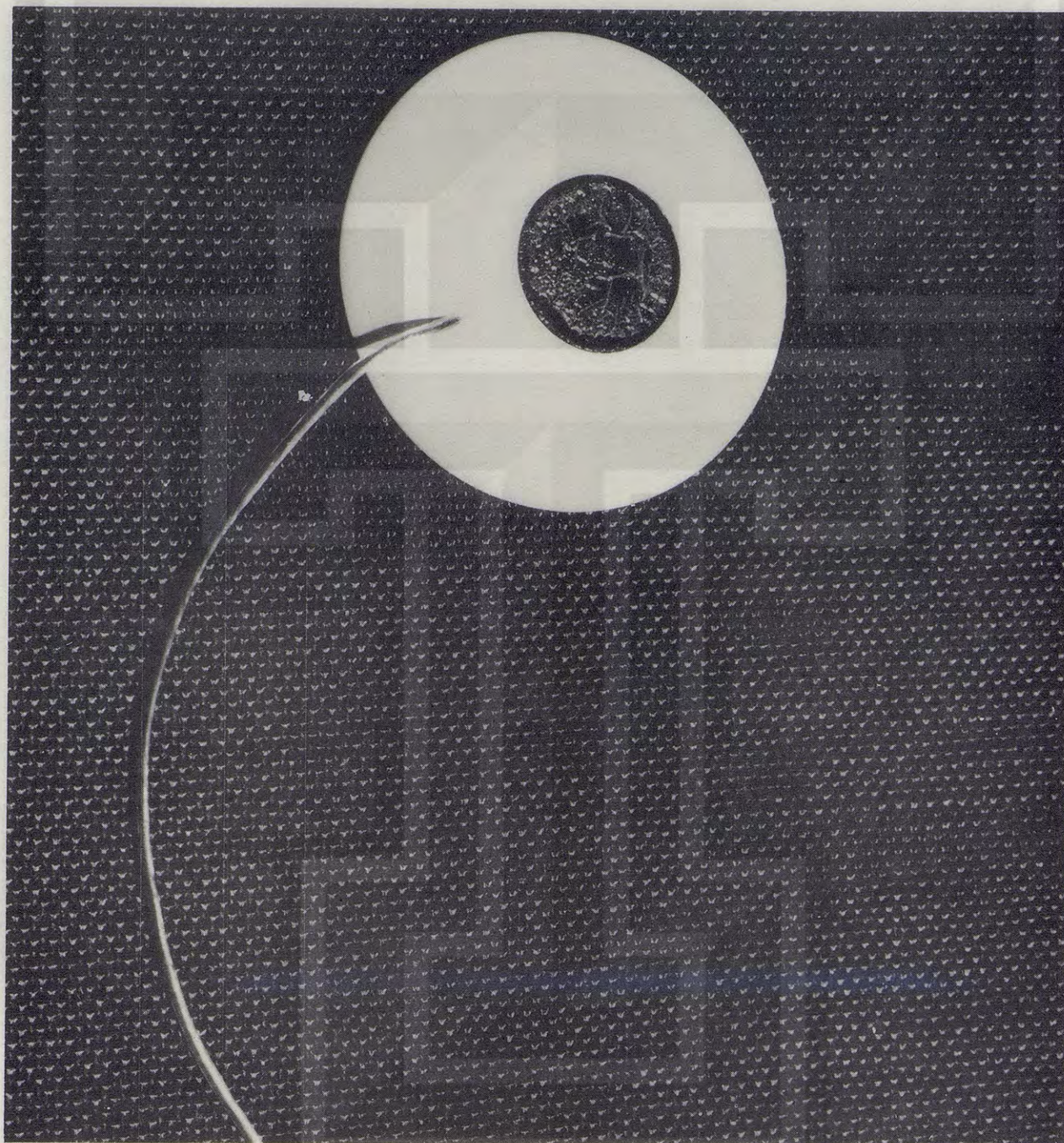


Fig. 9-15 PCG Microphone (2.5 x)

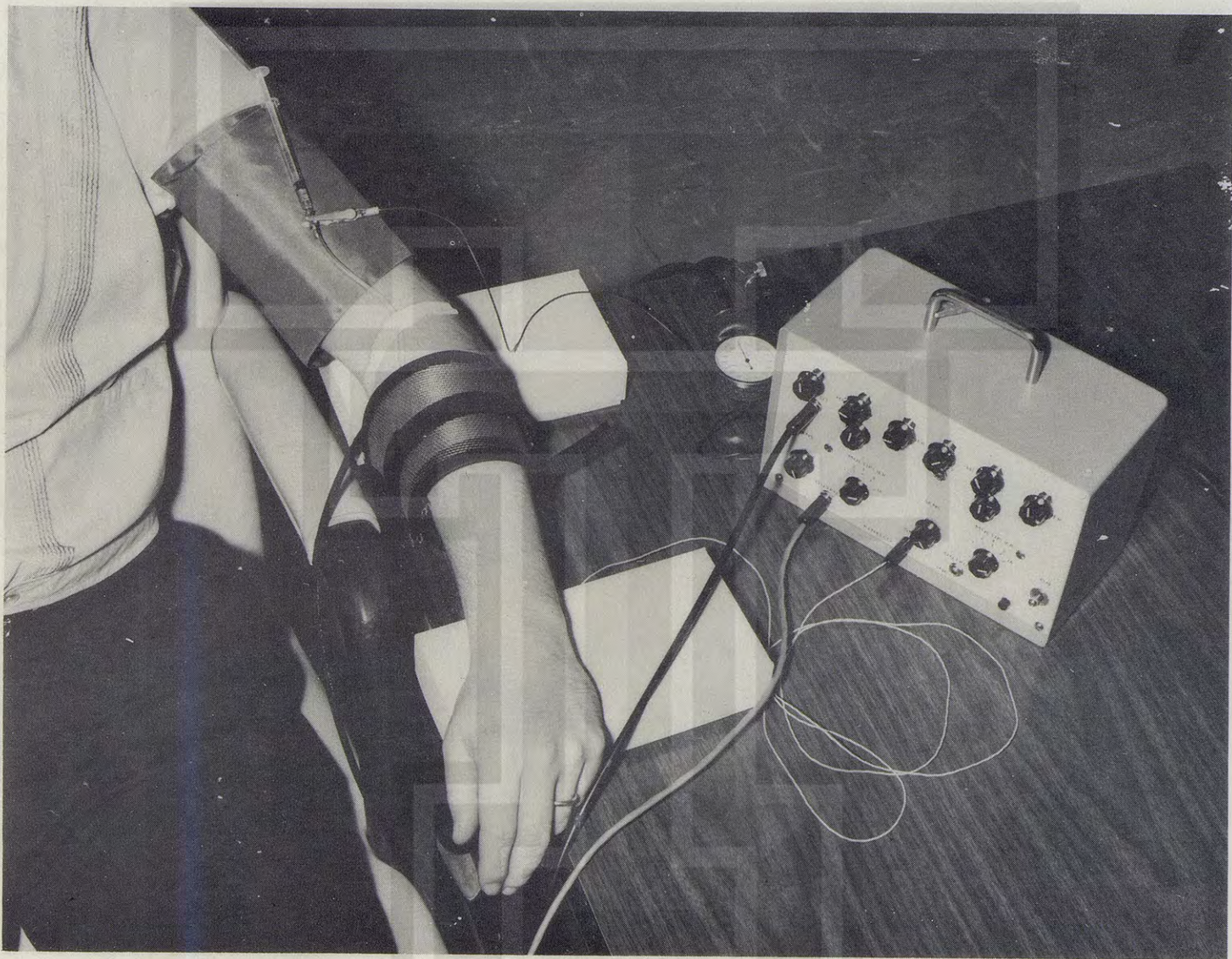


Fig. 9-16 Typical Laboratory CPG Apparatus

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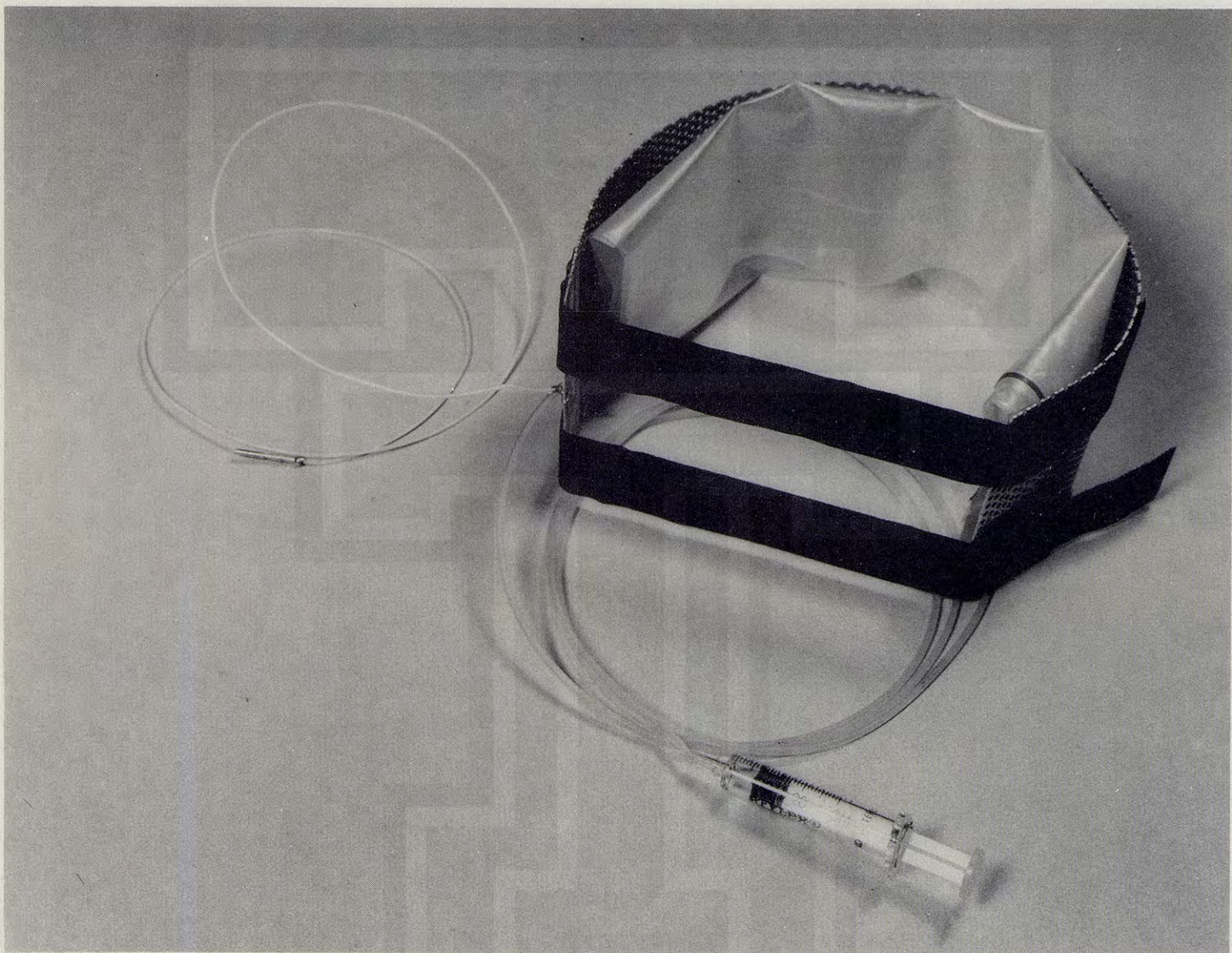


Fig. 9-17 Mockup of Capacitance Plethysmograph Used in Study

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The calibration device proposed for the system is simply a polyethylene bag attached to a tube which, in turn, is attached to a device resembling a syringe. During calibration, the saline solution in the bag, which has been placed between the mesh cuff and the skin, is adjusted by the position of the syringe-like plunger. Thus an end-to-end calibration is seen at the output which is directly proportional to the volumetric change of saline in the bag.

A CPG signal conditioner will have to be designed and developed since there is no flight-qualified hardware available at present. The unit required for the AAP will use basically the same circuitry now employed in clinical CPG units, but the packaging will have to be much smaller as it must fit in a module conforming in size and weight to the other signal conditioners in the cardio kit. The signal conditioner will contain the necessary oscillators and excitation sources for the mesh leg cuff. The capacitance variation due to volumetric changes under the cuff will modulate the carrier signal at the excitation bridge. The modulated carrier will then be amplified and detected to provide a 0 to 5-v analog of the volume change at the signal conditioner output.

Electromyograph. The electromyograph (EMG) signal conditioner will also be a modified Apollo type ECG signal conditioner. The main change in the ECG circuit will be to increase its frequency response to accommodate EMG signals. Since EMG biopotentials are roughly the same amplitude as ECG biopotentials, no other changes should be necessary in the circuit.

DC-DC Converter. The power converter provides isolated dc power to the signal conditioners on the cardio-kit belt in the same fashion that the dc-dc converter now supplies isolated power to the signal conditioners presently being developed for the Apollo Program.

Performance features of the power converter currently undergoing development for Apollo, as shown in Fig. 9-18, are as follows. The unit delivers an isolated, balanced, +10 and -10-v output constant within ± 0.05 v over the entire specified range of



Fig. 9-18 Apollo DC-DC Converter

load currents and over a range of input voltage from 12.8 to 20.8 vdc. Power input voltage transients of 1-ms duration and 40-v amplitude, and a sustained input voltage reversal will not damage the unit. Further, a current limiting feature is incorporated which will limit short-circuit current to a specified maximum. This protection acts independently for each output, and continuous short circuits will not damage the supply. Regulated output is recovered quickly upon removal of the short. The output impedance of the converter is approximately 3 ohms and the ripple in the output voltage is less than 1 mv peak-to-peak. The two output voltages have a common return; otherwise, they function in a totally independent manner. Input, output and case are mutually isolated by a minimum of 10,000 meg. The output voltage and current limits are factory set, and no external adjustment is required or provided. The converter is hermetically sealed in an envelope of specified standard dimensions and its weight is less than 55 gms.

Sensor Harnesses, Signal Conditioner Belt and Umbilical Cable. The wiring harnesses for the cardio-kit subsystem consist of several assemblies which serve to interconnect the signal conditioners, the power converter, the electrodes, and the temperature probe, and to provide electrical interfaces to the biometric console. Among the critical requirements considered in the design of harnesses are reliability, mechanical flexibility, weight and size, temperature effects, and materials. The main harness consists of flexible, multiconductor, flat tape molded from translucent silicone rubber and containing an array of conductors of which some are shielded. To strengthen the tape which emerges from strain-relief blocks, stainless-steel stranded conductor is molded into the tape along each edge. These steel braces terminate in the potting behind the connectors which couple to signal-conditioner modules and to the main umbilical plug. Other harness assemblies provide the interconnections between the signal conditioners and the data acquisition sensors. Figure 9-19 shows a similar harness assembly currently being produced for the Apollo Program.

The signal conditioner belt is basically a two-inch strip of Velcro-backed cloth which is wrapped around the waist of the test subject just below the ZCG diaphragm electrode band. The signal conditioners then have patches of mating Velcro bonded to them and can be attached to the belt by the Velcro material. As an alternate the signal conditioners

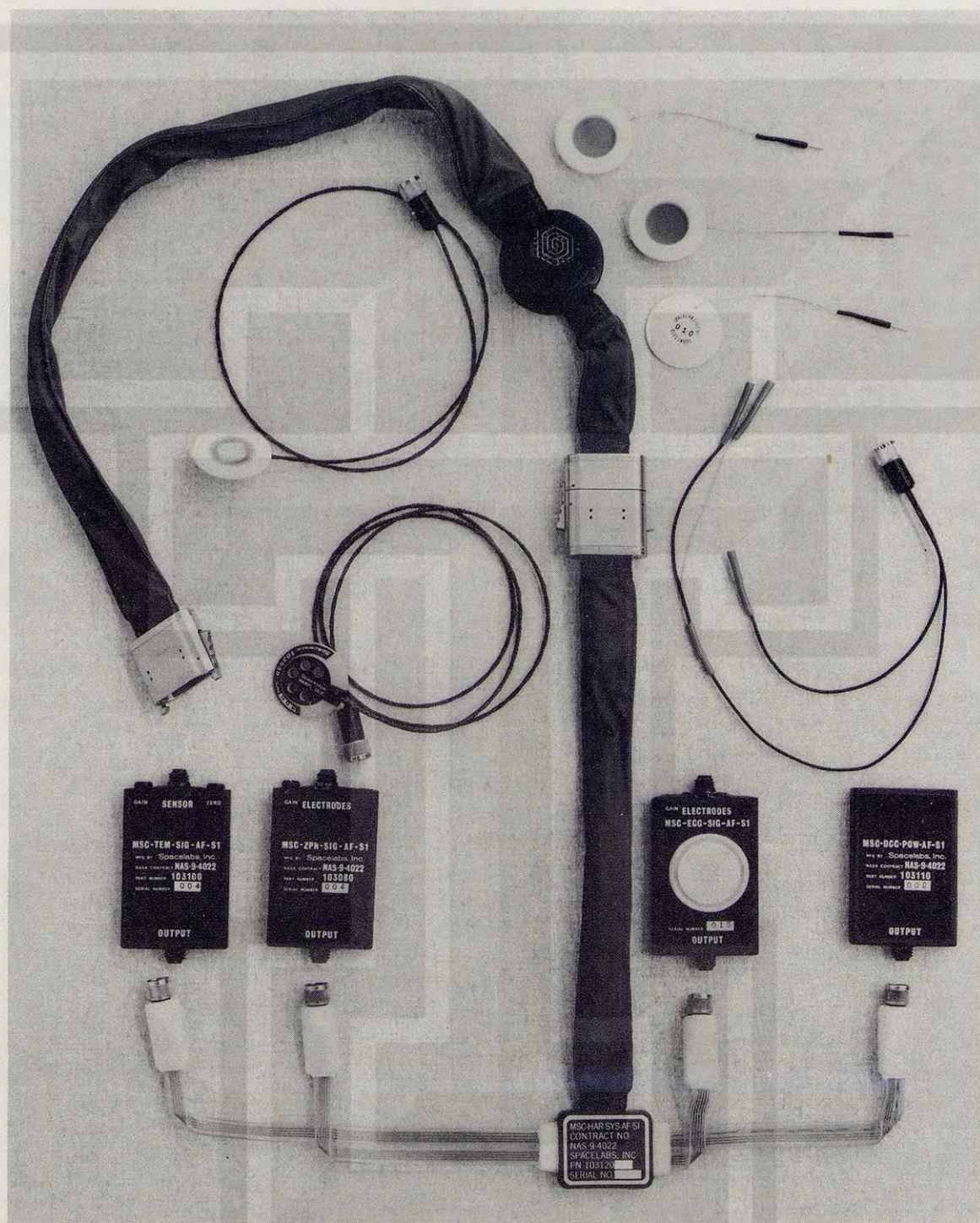


Fig. 9-19 Apollo Bioinstrumentation Assembly

could be semipermanently attached to the belt by cloth straps or individual pockets. Figure 9-20 shows the signal-conditioner belt mockup.

9.2.5 Pulmonary Kit

The pulmonary kit consists of the equipment listed in Table 9-4. The major piece is a face mask with its associated tubes and valves. Attached to the face mask is an ear-oximeter signal conditioner to which the ear sensor is connected. This signal conditioner may be attached either by insertion in a pocket on the face mask or by some other means, such as Velcro material. The pulmonary kit folds into a rather small package which is stowed when not in use.

The face mask portion of the pulmonary kit is a part of the larger respiratory analyzer subsystem. The main components of the respiratory analyzer are located in the biometric console.

Face Mask, Tubes, and Valves. The proposed face mask is of the strap-on type designed to cover the nose and mouth. For the purposes of this study, a single tube mask was suggested. A three-position, manually operated control on the flapper valve enables the test subject to inspire only, expire only, or rebreath into the connecting tube, depending on the measurement to be made. An alternate mask system using two tubes, one for inspiration and one for expiration, is proposed if cardiac output is to be obtained by a CO₂ rebreathing technique.

Ear Oximeter. The proposed ear oximeter is one similar to that being developed at NASA/Ames. The sensor shown in Fig. 9-21 detects the amount of light being transmitted from a light source through the blood in the ear. The associated electronics signal conditions the analog quantities detected by means of a red (0.64 millimicrons) and an infrared (0.79 millimicrons) filtered photocell. According to the engineers at Ames, with proper signal conditioning and data handling, a calibrated output of blood oxygen saturation (possible accuracy to within 5 percent) is obtained. The blood pulse wave is also available but is not normally calibrated.

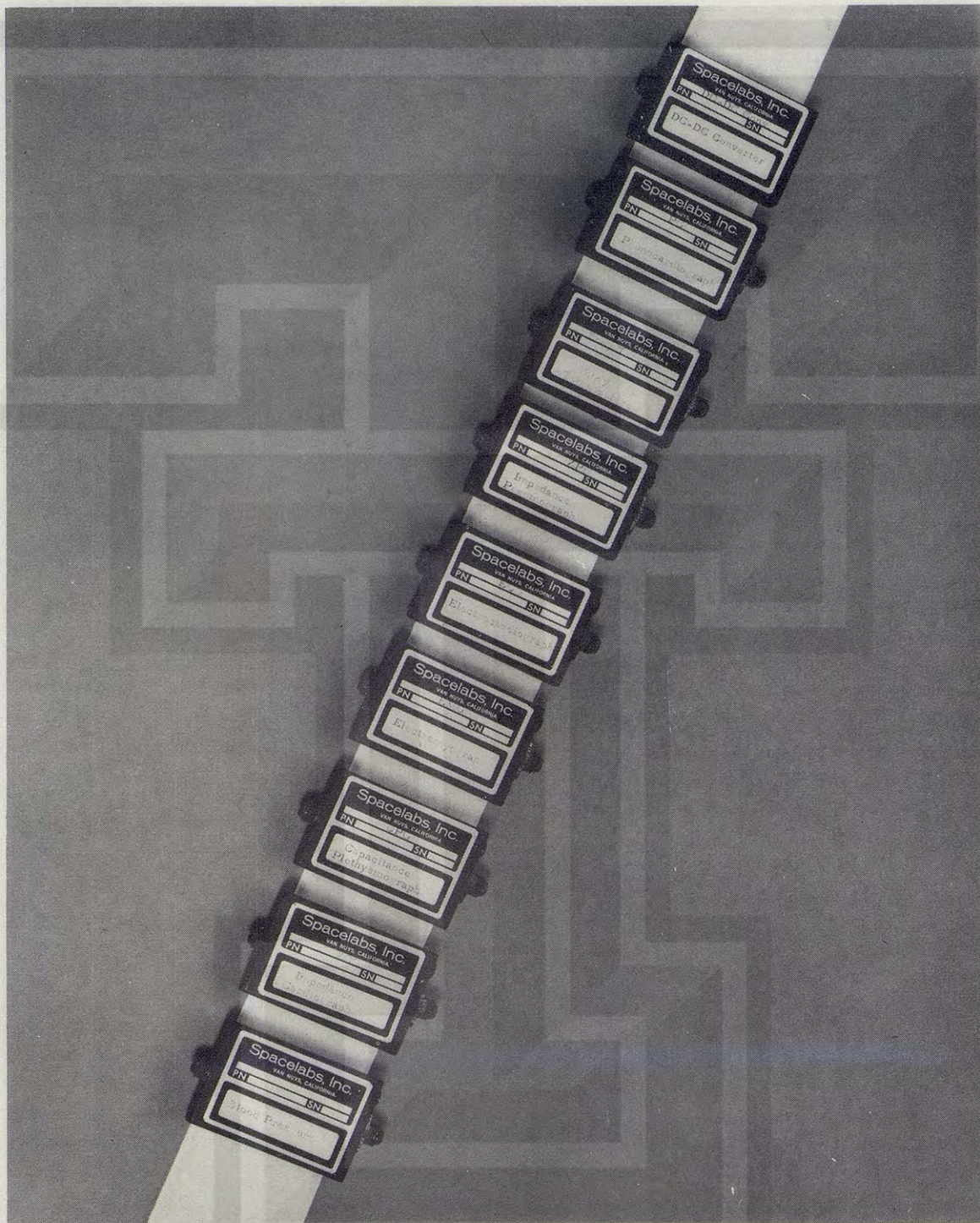


Fig. 9-20 Mockup of Signal Conditioner Belt Used in Study

Table 9-4
PULMONARY KIT EQUIPMENT

Parameter	Sensors		Signal Conditioners		Auxiliary Equipment	Notes
	Type	Attachment Devices	Type	Attachment Devices		
Lung Volumes and Gas Flow Rates	Flowmeter	—	Flowmeter signal conditioner		Mouthpiece and hoses	Flowmeter and volume integrator in console
He, O ₂ , and CO ₂ Concentrations	Gas sample tube (fed to mass spectrometer)	Face mask assembly	None required			Mass spectrometer in console
Arteriolar Hemoglobin Saturation by O ₂	Ear oximeter	Ear clip	Oximeter signal conditioner	Face mask assembly or related harness	Calibration system (squeeze bulb and filters)	

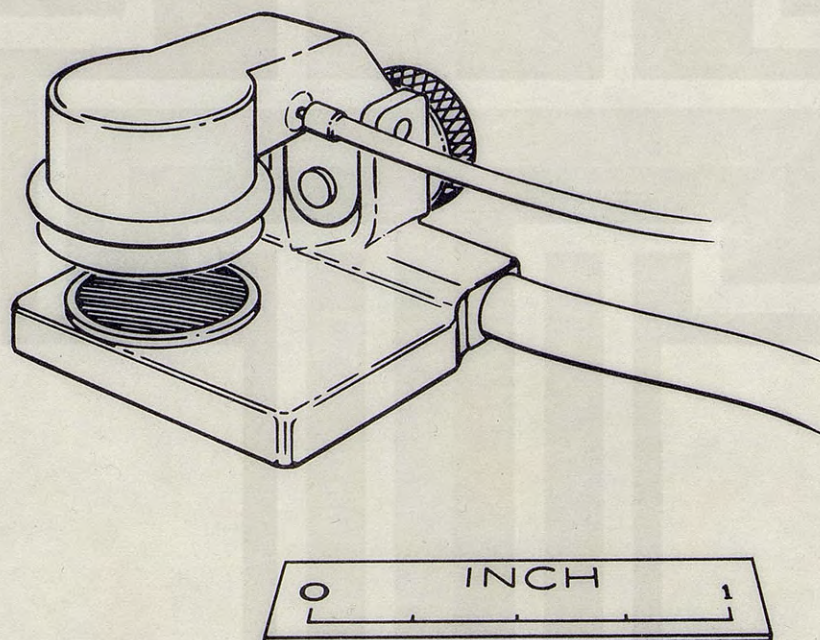


Fig. 9-21 Ear Oximeter

Respiratory Analyzer Subsystem. The respiratory analyzer includes the following:

- Pulmonary kit
- Mass spectrometer (gas analyzer)
- Flowmeter (or volume meter)
- Rebreathing reservoir and pneumatic plumbing
- Sharing of the special purpose computer

The block diagram (Fig. 9-1) shows the respiratory analyzer about which the time-line study procedures were written. The face mask has a manually operated control which allows the following three modes of operation:

- Breathing tube connected only during inhalation half of cycle.
- Breathing tube connected only during exhalation half of cycle.
- Breathing tube connected during entire respiration cycle for rebreathing maneuvers.

It is important that the breathing tube be kept as short as possible. Particularly, for the rebreathing experiments. A flowmeter in the breathing line detects velocity of gas flow. The flowmeter output is directed to the general purpose computer for integration of the flow rates (volume measurements).

Figure 9-3 shows the pulmonary control panel. The Pneumatic Routing Control directs the gas flowing through the face mask and flowmeter, to and from various chambers. In the Flowmeter Calibrate position the flowmeter is routed through a precision calibrated orifice to a vacuum chamber which is vented to the outside space vacuum. It is proposed that the calibration orifice be of a size which will allow gas to pass through the flowmeter at a rate equal to the expected mean gas flow. The routing control is also used to select the source of inspired gas. Either pure oxygen from the ECS supply or ambient gas may be inhaled.

A helium rebreathing reservoir is used to measure total lung volume. To operate, the Helium Reservoir Control switch is first turned to the Evacuate position. The helium

reservoir is then vented to the outside vacuum to remove all air from the previous experiments. Next, the reservoir control is turned to the Helium Fill and Flush position. This allows a 10-percent helium - 90-percent oxygen mixture in a high pressure supply to bleed into the rebreathing reservoir. When the pressure in the reservoir has built up to a predetermined level, a pressure pop valve in the breathing line opens, thus flushing out the flowmeter and breathing line with the helium mixture. During this operation, the Pneumatic Routing Control should be in the Helium Reservoir position. The Helium Reservoir Control is then switched to the Operate position which routes the face mask to the reservoir. In the Operate position, the reservoir pressure valve is opened. The face mask control is placed in the Rebreathing position when determining total lung volume. A small capillary tube from the face mask to the mass spectrometer samples respiratory gases.

An alternate mask and flowmeter hookup must be used if the measurement of cardiac output by the CO_2 rebreathing technique is desired. (Since so little additional equipment is required for the measurement of cardiac output, it is recommended that this alternate be used in addition to the impedance cardiographic technique previously described.) This arrangement is shown in Fig. 9-22.

Consideration should also be given to an indirect measurement of cardiac output by an oxygen measurement technique currently being developed by Dr. H. Rahn of the State University of New York at Buffalo.

Mass Spectrometer (Gas Analyzer). The recommended gas analyzer is the mass spectrometer which will allow breath-by-breath continuous recording of gas concentrations. This instrument is recommended for the following reasons:

- The only practical way to measure residual lung volume (and, therefore, total lung capacity) is to utilize the helium closed-circuit technique. This method is quite versatile since it also yields indexes for gas distribution in the lungs and volume of alveolar ventilation (Ref. 9-3). The mass spectrometer is essential in order to measure helium concentration continuously.

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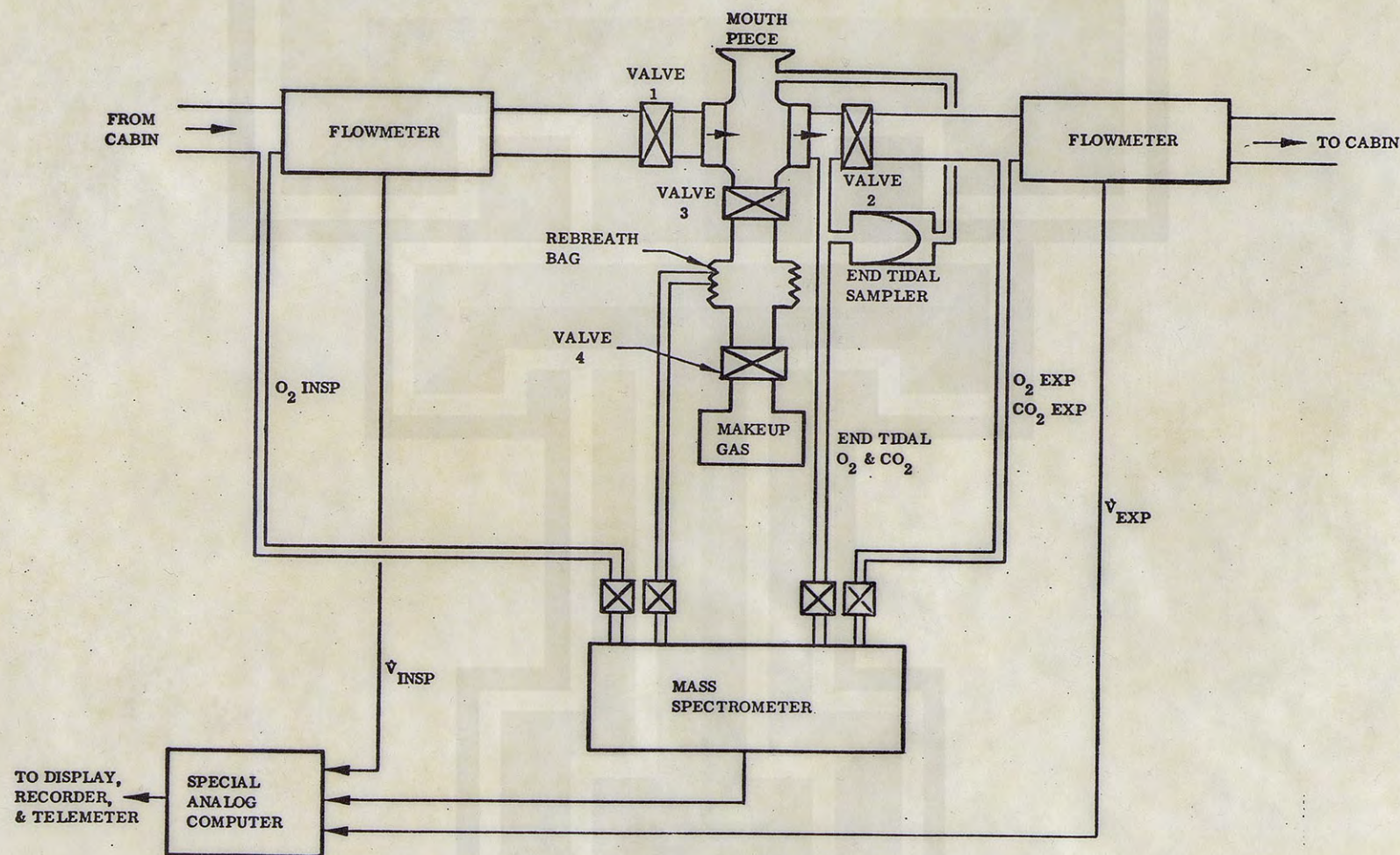


Fig. 9-22 Alternate System for Measurement of Cardio Output

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- Because of the nature of the oxygen dissociation curve, an ear oximeter is rather useless in detecting oxyhemoglobin saturation when the subject is breathing 100-percent ambient oxygen at a total pressure of 260 mm Hg. It is unlikely that an oximeter would detect any changes in arterial O_2 saturation until the arterial O_2 tension has dropped below 80 mm Hg. Assuming a 5-mm alveolar/capillary gradient, this means an end-tidal or alveolar pO_2 of 85 mm Hg or an ambient O_2 tension of about 170 mm Hg (Ref. 9-4). This is about 90 mm Hg lower than the actual cabin pressure of 260 mm Hg and would only exist in an emergency situation.

The mass spectrometer is able to record pO_2 values during the entire breath. Substituting arterial for end-tidal pO_2 , oxyhemoglobin saturation can be obtained from the oxygen dissociation curve with greater accuracy and reliability than with an ear oximeter. Only severe airway obstruction or ventilation/perfusion disturbances will limit the use of this method.

- Integrated breath-by-breath analysis of pO_2 and pCO_2 with the mass spectrometer allows for real-time computed values for O_2 consumption and CO_2 production during exercise, reflecting changes in mechanical efficiency and physical fitness.
- The mass spectrometer also can serve another purpose, namely the detection of air contaminants.

Mass spectrometers designed for use in space are currently being designed and fabricated. A system has been built for the NASA Flight Research Center at Edwards Air Force Base, California, and prototype units are currently being built for similar Air Force programs. There is a high probability that a mass spectrometer suitable for AAP will be in the flight-qualified stage by the planned launch date. However, if the mass spectrometer cannot be made ready by the time, certain other types of gas

analyzers must be considered. They are as follows:

- Infrared CO₂ analyzers
- Infrared-ultraviolet CO₂/O₂ sensors
- High speed, long-life, polagraphic sensors

The mass spectrometer has two controls at the biometric console. One control adjusts the mass spectrometer beam and the other selects the inlet gas. When the inlet gas control is in the Operate position, gas is accepted from the pulmonary kit face mask. When the control is in the Calibrate position, known concentrations of O₂, He and CO₂ are supplied to the mass spectrometer.

It should be noted that no vacuum pump is necessary since the outside space vacuum is sufficient to depressurize the mass spectrometer chambers.

Flowmeter (or Volume Meter). The proposed flowmeter is a pneumotachometer similar to the Fleisch clinical device but modified for flight qualification. The velocity output of the flowmeter would then be integrated in the special-purpose computer for volumetric measurements. An alternate to this device is the dry gas volume meter currently under development by NASA. The dry-gas device may have to be modified to handle the necessary breath volume capacities, but it too can probably be flight-qualified by the planned launch date for AAP.

9.2.6 Special Purpose Computer

A special-purpose computer is required to provide the following computations on-board the spacecraft:

- Heart rate
- Respiration rate
- Cardiac output
- Electromyograph integration
- Ear oximetry (IR/R ratio)
- Gas flow integration (gas volume)
- Body mass

These computations may be made either by small analog computation circuits within the biometric console or they may be computed by the major on-board computer system.

9.2.7 Conditioning, Monitoring, and Support Equipment

Several items of equipment which also support the physiological experiment series but do not lend themselves to the experiment packages discussed in Subsections 9.2.2 through 9.2.5 are presented in the following paragraphs.

Urine Collection System. The suggested urine collection system (Figs. 9-23 and 9-24) consists of a transparent plastic flask, a motor-driven centrifuge, a transfer syringe, and a urine freezer. The flask, which has a capacity of 2 to 2.5 liters, is restrained by the centrifuge structure and rotated by an electric motor ($1/40$ to $1/20$ hp at 100 to 200 rpm). The flask stopper has two tubes passing through it, the input funnel, and the vacuum tube. When the stopper is inserted into the neck of the spinning flask, the flask rotation is stopped, although the motor may continue to run until turned off. There is a valve above the stopper which closes both the funnel and vacuum tubes simultaneously. The unit is designed to prevent electric power from entering any structure leading to the funnel, valve, vacuum line etc. Requirements for hand-powering of the centrifuge should be provided.

The transfer syringe is essentially a hypodermic syringe modified for greater capacity. Its barrel will be fabricated of clear plastic, and equipped with a valve at one end to prevent spillage. This location of the valve will permit the deposit of minute quantities upon a specimen slide. The quality of the manufacture of this syringe should be similar to that required for gas transfer syringes. The capacity of the syringe will be 150 cc. Overall dimensions are a length of 12 in. and a diameter of 2.5 in.

The urine collection system includes a cryogenic refrigerator. The body and door of the unit will have a network of tubing incorporated into their structure. This cooling

COLLECTION PROCEDURE

1. START MOTOR
2. VOID INTO FUNNEL
3. CLOSE VALVE
4. CLOSE STOPPER
5. TURN OFF MOTOR
6. DETACH UNIT FROM WASTE SYSTEM
7. AT END OF 24 HR PERIOD, NOTE VOLUME COLLECTED BETWEEN OPERATIONS 2 AND 3

SPECIMEN WITHDRAWAL

1. AFTER FINAL VOIDING IN THE 24-HR PERIOD, INSERT TRANSFER SYRINGE BETWEEN THE STOPPER AND FLASK.
2. WITHDRAW 50 TO 150 CC URINE

EMPTYING AND STERILIZATION

1. TURN OFF MOTOR, LEAVING VACUUM ON
2. WHEN FLASK IS CLEAR, CLOSE STOPPER
3. ADD STERILIZING AGENT TO FUNNEL
4. ALLOW VACUUM TO RUN UNTIL FLASK IS REASONABLY DRY
5. SWAB WITH CLEANING TISSUE

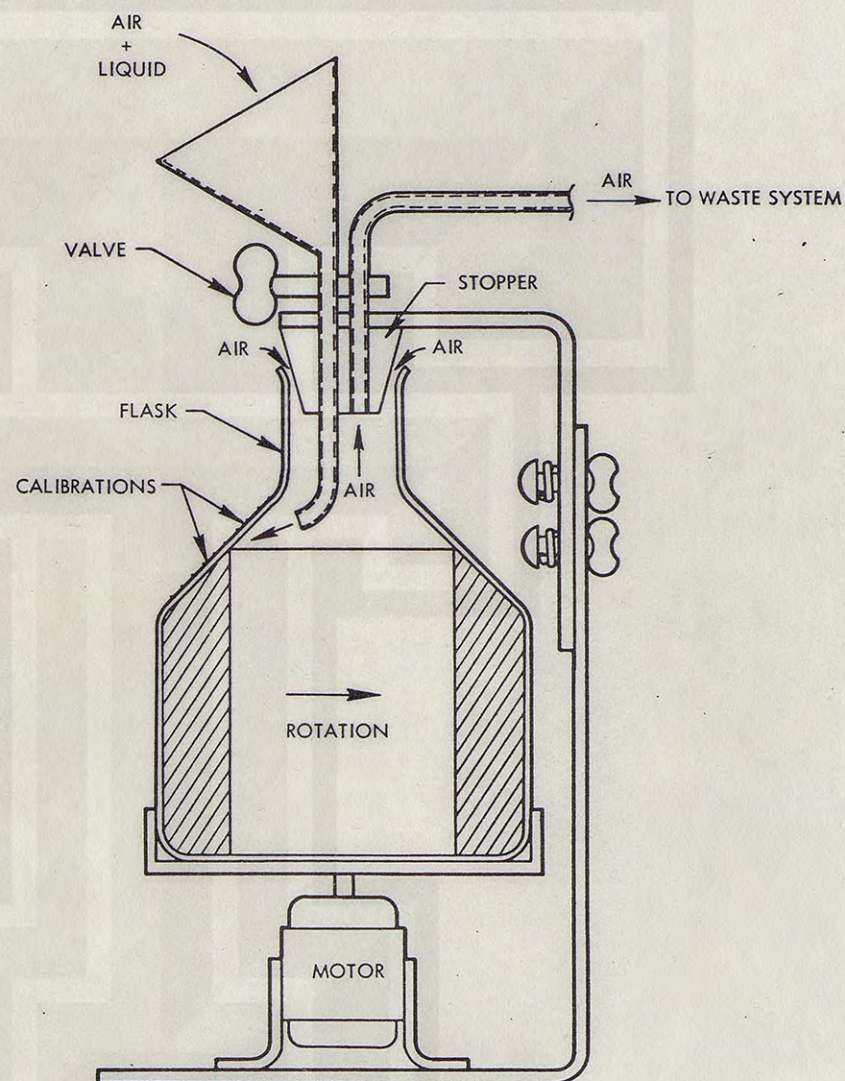


Fig. 9-23 Urine-Collection Process Using Transparent Plastic Flask and Motor-Driven Centrifuge

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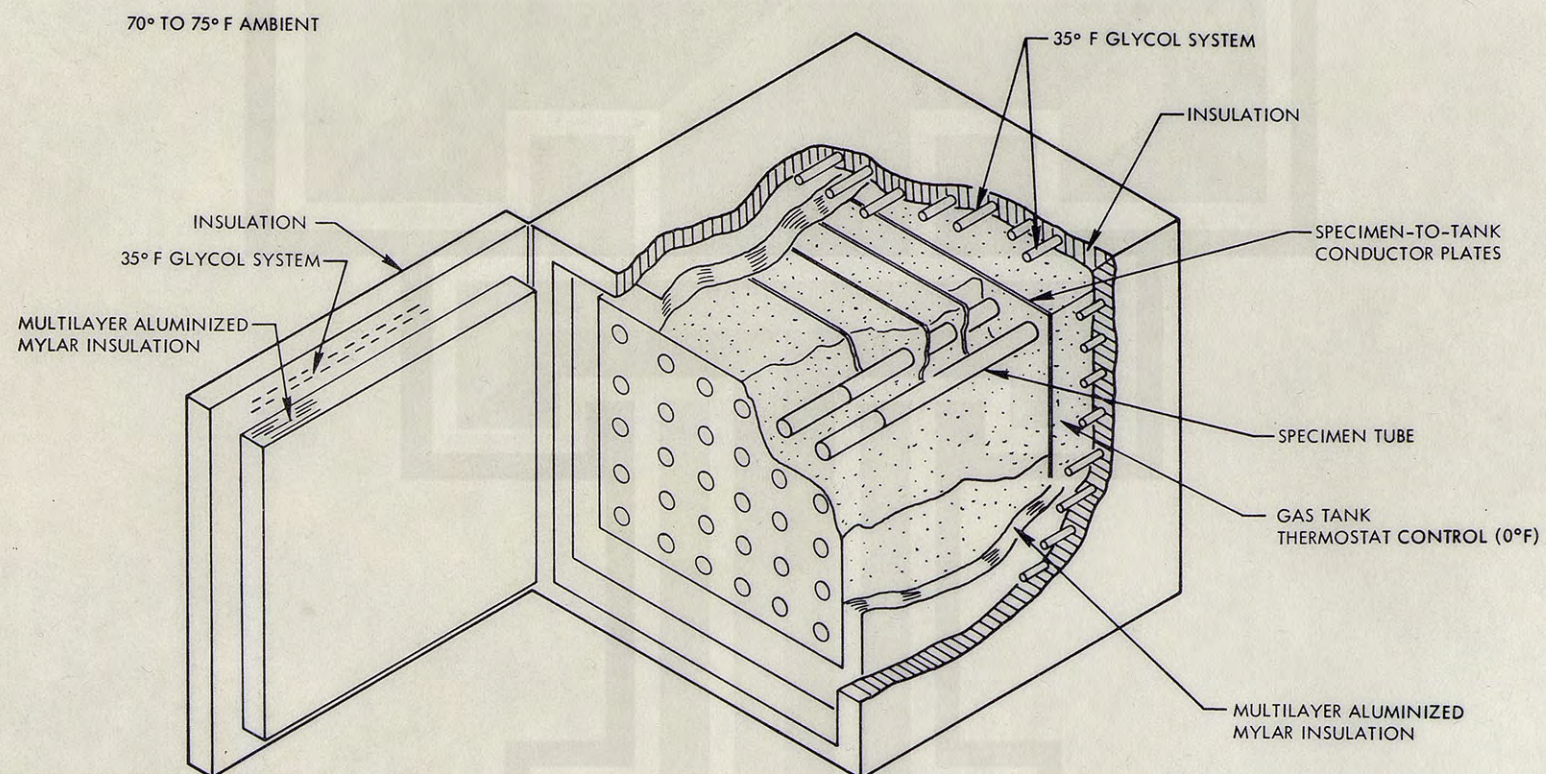


Fig. 9-24 Urine-Freezing Unit - Cryogenic Refrigerator Containing Solid Mixture of Ethanol and Water

system is connected to a 35° F, Cooland-25, cooling system. The outside of this structure will be lightly insulated to avoid any significant effect upon the temperature balance within the Apollo command module. The primary insulation barrier consists of approximately 2 in. of multilayered aluminized mylar applied to the inside of the structure. The specimen tubes are supported by a structure which also is a gas container. The gas/solid contained is a mixture of ethanol and water which vaporizes at 0° F. As a result, the pressure rises, and when the temperature rises to 0° F, the solid material changes directly into gas. When the pressure is relieved by a thermostatically controlled valve, the temperature is lowered. The unit must be charged on the ground and installed up to 24 hr before lift-off.

The contents of the transfer syringe will be inserted into the specimen storage unit. This can be done during the flask-evacuation or drying cycles. After opening the door, the transfer syringe is inserted through the plug in one of the specimen tubes, and the specimen is deposited for freezing. The transfer syringe will then be sterilized by filling with the same solution used in the collection system. The contents are then disposed of in the waste system and the syringe exposed to ultraviolet light.

Photo-Anthropometric Technique (PAT). The on-board TV camera is used to take a video picture of the astronaut's body to provide the earth monitors with a picture of the physiognomy of the astronaut. Target plates are used to locate the astronaut's body members in the proper position for TV viewing.

Thermal Suit. The Apollo spacesuit concept now employs an inner undergarment (water-cooled with tubing) which will be used for the thermal suit. This garment, in combination with the Apollo backpack which contains the necessary pumping/cooling mechanisms, comprises the system. Longer hosing is required for this experiment so that the subject can wear the undergarment without wearing the spacesuit itself or the backpack.

Thermal Suit Support Equipment. The thermal suit requires certain ancillary equipment to support the required measurements, namely, temperature sensors (body-harness mounted).

Ergometer. The ergometer assembly is designed to provide provocative work loads for evaluating physiological status and providing a method for the astronauts to maintain physical fitness. Such a device, (Fig. 9-25) is currently being built by LMSC for the U.S. Air Force (Aerospace Medical Division) and is presently being flight-qualified. It is basically a rotary-type pedal ergometer consisting of a generator bicycle-type pedal assembly and step-up gear train for generator drive. Associated electronics consist of a tachometer and effort-rate wattmeter, a visual indicator, feedback control amplifier for generator field and power dissipation resistors, and additional alternative leads for external means of power storage and/or recording. The following target specifications are presently being met.

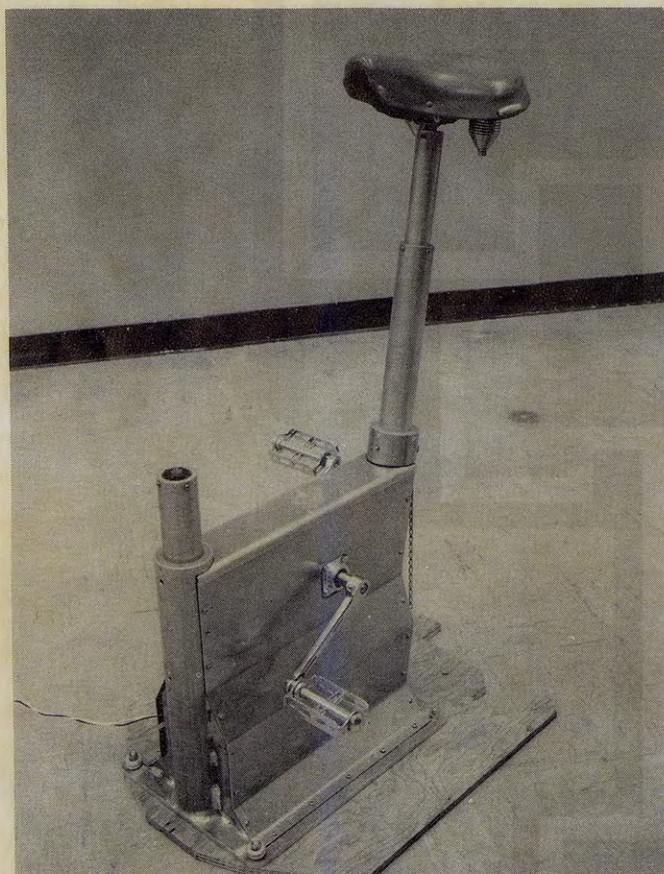
- Rotary type and stowable into a minimum volume
- Capability for either hand or foot operation
- Inclusion of a tachometer and wattmeter – electrical load of 25 to 300 w
- Generator power input controlled to within ± 5 percent, regardless of rotation velocity of the pedal input within the continuous range of 50 to 100 rpm
- Lightest possible materials, oriented toward the space environment, utilized in construction
- Completely self-powered.

Several modifications of the device are necessary to adapt the current ground-qualified prototype to a space-qualified version; however, no particular problems have been identified by the engineering design team.

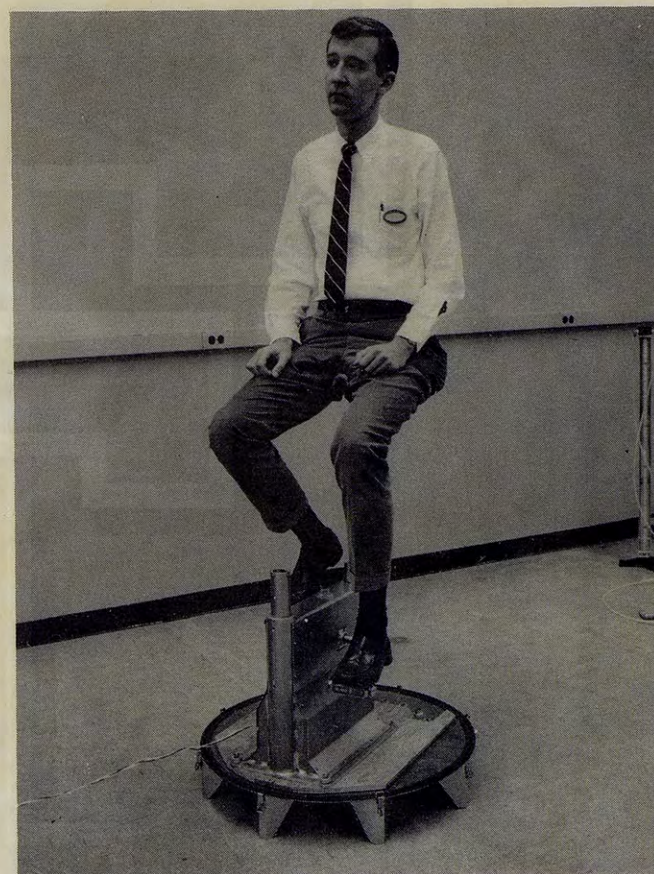
Lower Body Negative Pressure Device (LBNP). Prolonged weightlessness generally eliminates the hydrostatic pressure gradient (which man experiences while on earth) thus leading to numerous physiological effects including pooling of blood, increased pressure in the left atrium, loss in blood volume due to diuresis stimulated by engorgement of the chest veins, etc.

Certain gravitational effects may be simulated by changing the pressure environment of the body in the absence of gravity. If the lower part of the body is placed in an

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(a) Development Model Ergometer



(b) Development Model Ergometer With Subject In Operating Position

Fig. 9-25 Development-Model Ergometer Used in Study

airtight chamber sealed off at the waist, and if a slight vacuum is applied in this chamber, the LBNP can be utilized to perform three distinct functions as follows:

- Cardiovascular Countermeasure. The negative pressure will encourage blood to linger in the lower limbs and abdomen, since these blood vessels will experience an external pressure lower than that in the upper torso area.
- Provocative Testing. A means of performing provocative tests to detect changes in circulatory mechanisms (similar to a tilt table used in hospitals) is provided.
- Reentry Conditioning. Toward the end of the mission, a preparatory series of therapeutic sessions in the LBNP device could prepare the astronauts for the onset of reentry stresses and mitigate orthostatic intolerance upon debarking.

The LBNP device will be similar to the device built by LMSC and associated subcontractors for the U.S. Air Force, Aerospace Medical Division. The device consists of a solid base plate at the lower end (Fig. 9-26) and a similar plate at the upper end except for an oval seal at the body cutout opening. The body cutout opening incorporates an airtight seal which fits the crewman's waist (Fig. 9-27). The cylindrical portion between the end plates is constructed of fabric in order to permit the device to collapse like an accordion bellows for compact stowage (Fig. 9-28). The fabric cylinder is prevented for collapsing when under negative pressure by a series of internal hoops and external straps (attached to the floor and overhead).

A small vacuum pump of the type which will not contaminate the cabin atmosphere with lubricants is used to lower the pressure inside the LBNP chamber. The desired negative pressure level (e.g., -40 mm Hg below ambient) is maintained by a pressure regulator which allows just enough leakage into the chamber to keep the pressure at the present value. This deliberate leakage also provides ventilation to prevent the crewman's lower body from overheating and excessive perspiration.

In order to obtain periodic cycling of the LBNP chamber pressure from ambient to the desired negative value, an electric timer turns the pump motor off and opens a solenoid



Fig. 9-26 Lower Body Negative Pressure (LBNP) Device Base Plate

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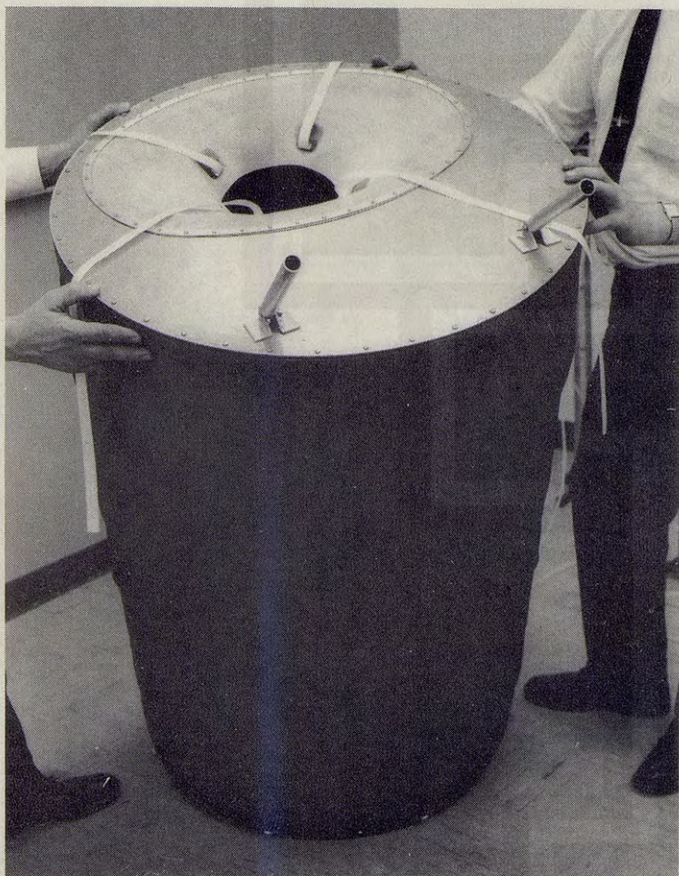


Fig. 9-27 LBNP Device Body Seal

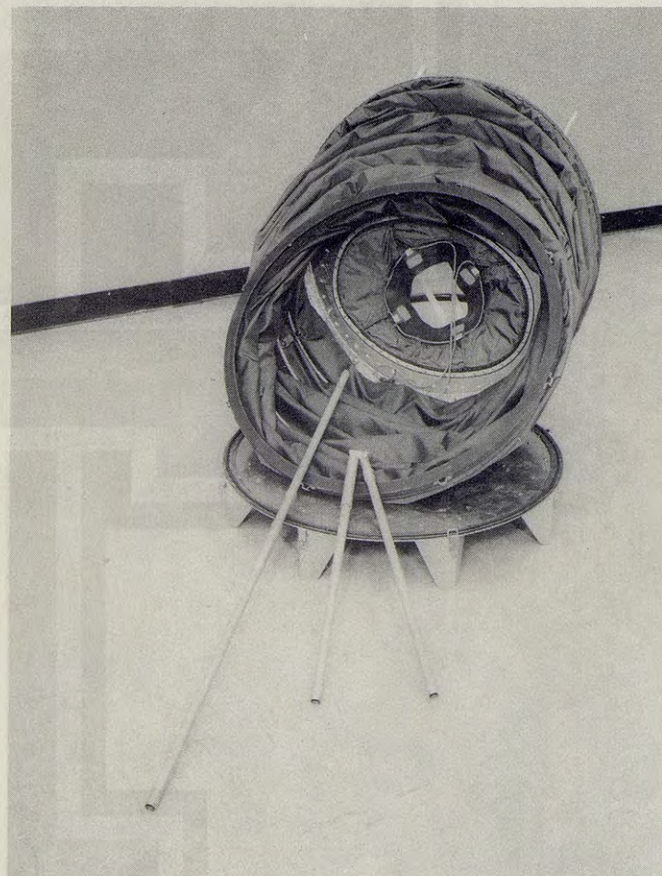


Fig. 9-28 LBNP Device in Collapsed Mode

valve for a preselected period, after which the valve is again closed and the pump restarted. The pressure cycling can be continued for any prescribed duration.

Figures 9-29 and 9-30 illustrate a subject in a fully bioinstrumented mode positioned in the LBNP device. Figure 9-25B illustrates the method of positioning the ergometer on the LBNP base plate within the chamber if desired for cardiovascular conditioning experimentation.

Neck Cuff Device. The carotid baroreceptor pressure device consists of a molded or fitted neck cuff allowing for positive and negative pressure in the cervical region. This approach has been proposed as a potential countermeasure device. The response of the carotid arteriolar response will be determined. Positive pressure up to 3 psi will be required. The pressure regulation system employed with the LBNP and the occluding cuffs system will be utilized. A pressure gage provides direct readout at the physiology panel, and a pressure transducer converts the cuff pressure reading to a 0 to 5-v analog signal which is routed to the data handling system. The pneumatic control operates in conjunction with the pressure supply used in the occlusion cuff. Figure 9-31 illustrates the neck cuff mockup device used in the study.

Occlusion Cuff. Simple constricting pressurized cuffs, placed at or near limb-trunk junctions, offer a means for exercising or stimulating peripheral vascular mechanisms; for example, the application of light cuff pressure (5 to 30 mm Hg) causes venous pooling with subsequent limb engorgement. Relief of the constriction restores normal blood circulation. The use of occluding cuff pressures up to systolic blood pressure should be considered, although it is doubtful if pressures above the required for venous occlusion (70 mm Hg) will prove beneficial. In using this technique, subject comfort as well as effects on general vascular tone should be considered.

A program of periodic on-off cycling of the cuff, possibly combined with active exercise, may provide a beneficial effect on the vascular system. The cuffs placed on the upper thighs probably offer the most promise because their use may stimulate circulatory reactions similar to those provided by orthostatic changes in body position under the normal earth-gravity state.

9-66



Fig. 9-29 Fully Bioinstrumented Subject
In LBNP Device

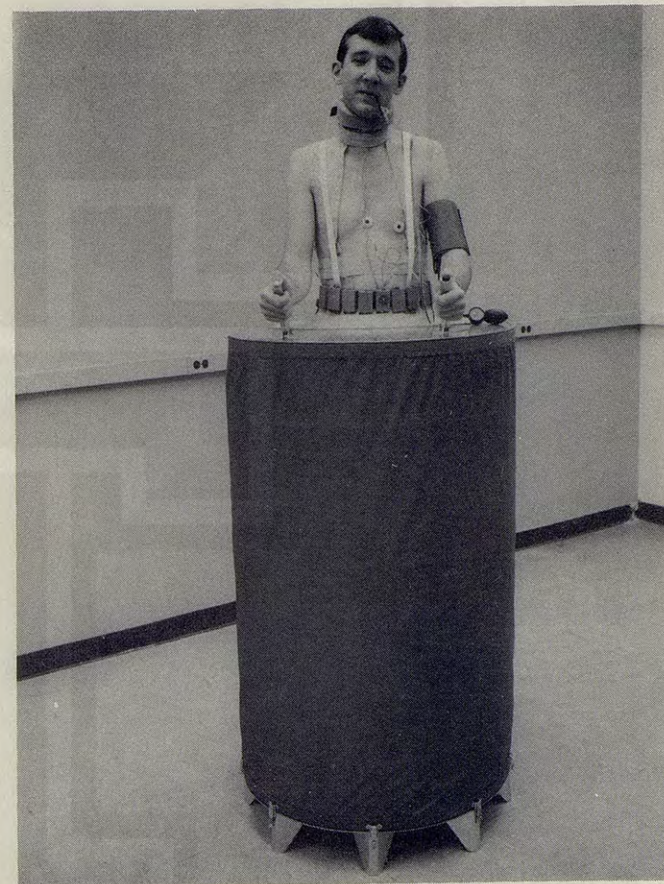


Fig. 9-30 Over-all view of Bioinstrumented Subject
in LBNP During Study Test Mode



Fig. 9-31 Neck Cuff Device Mockup Used in Study

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The occlusion cuff suggested for Experiment 0108 is controlled at the biometric console by a pressure regulator. A pressure gage provides direct readout at the panel and a pressure transducer converts the cuff pressure reading to a 0 to 5-v analog signal which is routed to the data-handling system. The pneumatic control operates in conjunction with the pressure supply used for the neck cuff.

Motion Chair. The motion chair is an adaptation of the Graybiel/Miller Litter Chair and the LMSC-developed mass measurement device. The chair illustrated in the Graybiel/Miller configuration (Fig. 9-32), is designed to provide linear and rotary acceleration while operating in a zero-g environment. The motion chair utilizes a rigid pallet platform, a single square bearing, and spring alignment centered at both ends of the platform. The design permits replacement of the servomotor-driven winch at one end of the platform (used during linear acceleration measurements) with fore and aft springs used during the linear harmonic motion in order to determine mass by the oscillating-spring method. Conversion equipment required to convert the device to the rotary acceleration mode consists of an attachment fitting housing a rotational bearing, the same servo motor, a braking device, and acceleration sensors. The incorporation of the Graybiel/Miller Litter Chair and the LMSC-developed mass measurement device into one equipment item reduces considerably the number of equipment items, and the required weight and volume of the equipment needed to conduct Experiments 0101, 0102, and 0111.

Strength Measurement Device. The strength measurement device is required to determine and quantify any deleterious effects on the muscular system. A preselected pattern of exercise motions (nonconditioning in application) are performed on the device to evaluate strength characteristics of major muscle groups. The device will be used in combination with the electromyogram. The strength measurement device is a single load cell attached to an adjustable isometric exercise strap. The load cell is calibrated before and after the flight to assure minimum reading drift. The astronaut will conduct a specified series of basic muscle engagement exercises although none are intended (duration and energy) to condition the muscle regime.

9-69

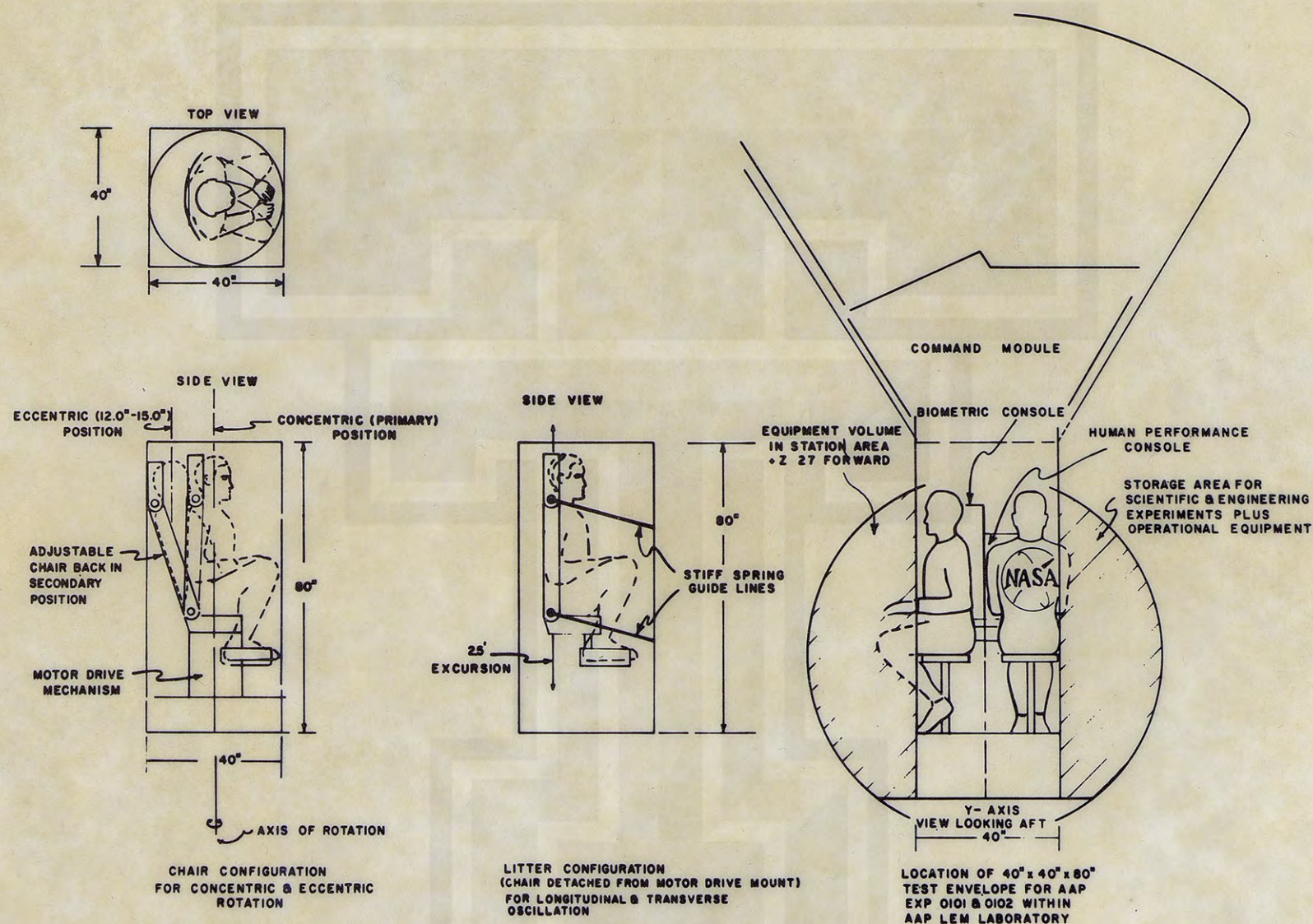


Fig. 9-32 Motion Chair in Graybiel/Miller Litter-Chair Configuration Within LEM Laboratory

Endoradiosonde Pill and Equipment. The endoradiosonde equipment is used for measuring phenomena in the gastrointestinal tract. It consists of a pill that is swallowed and of related external equipment. The pill contains one or more sensors, signal conditioners, and a minute telemetry transmitter. The external equipment consists of a telemetry receiver, demodulation circuitry, and a readout display. Typical parameters that have been measured with endoradiosondes include pressure, temperature, motility, and pH. These are continuously monitored and telemetered as the pill travels through the gastrointestinal tract until it is excreted in the feces. Current plans are under consideration to develop a pill that can monitor all four parameters simultaneously. At present, however, the pill has been developed to monitor only one parameter at a time.

Goggles, Fiber Optics Bundle, and Targets. The equipment required to monitor eye movements, horizon location, and oculogravic and oculogyric illusions is composed of test goggles, bite-board, and a fiber-optics bundle. The special test goggles are designed so that a fiber-optics bundle can be attached to the goggle and the bundle connected at the other end to the ciné camera. The goggles are primarily held in place by the bite-board. The goggles, when connected to the ciné camera through the fiber-optics bundle, provide the sensor for determining egocentric visual location of the horizon, and oculogravic and oculogyric illusions. The apparatus measures the eyeball rotation from 0 to 10 deg with an accuracy of ± 1 deg in the subject's x-axis with respect to the head. The apparatus is also required to measure a 0 to 90 deg tilt of illuminated horizon with ± 1 deg accuracy with respect to the vehicle. (The head orientation to the vehicle is known prior to the determination.) The left or right eye cover extension of the goggles is designed for easy removal in order to conduct lateral, vertical, and cyclophoric measurements. A set of special target plates will be provided for use in the visual testing phase. The targets will be small circular discs mounted on the cabin wall bulkhead (with Velcro) during the testing sequence.

TV Camera. A TV camera with an approximate 90-deg tilt adjustment can be mounted in the main cabin area. The field of view includes the head and shoulders of the

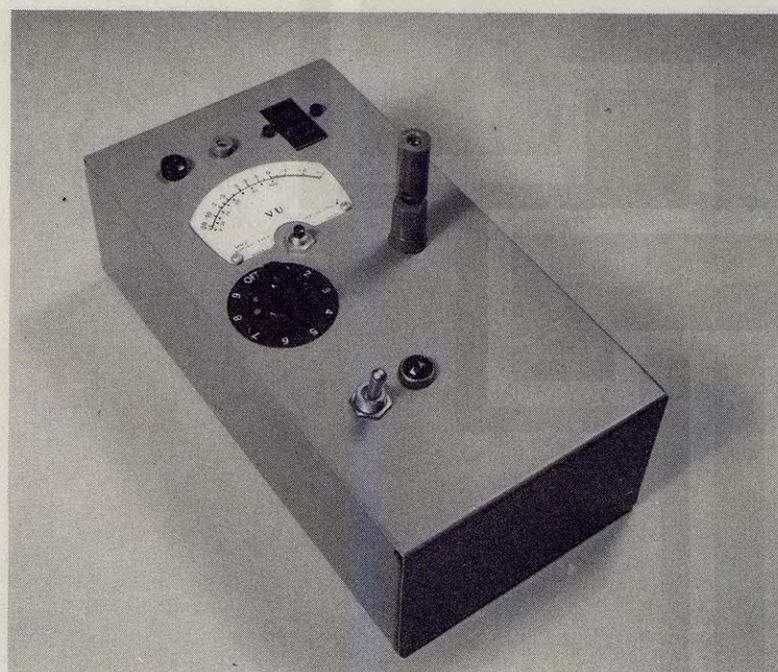
astronaut-subject. Power for the TV camera is provided from on-board power. The monitor should be located in the control panel area of the forward station close to the experiment area. When the camera is used for video recording of muscle size the camera is removed from the quick-disconnect mount and repositioned in the midsection compartment of the LEM Laboratory. The targets are then positioned opposite the camera and the subject assumes the correct position for muscle-size anthropometric picture recording.

The TV camera will provide a black and white picture with 30 frames/sec, 525 scan lines/frame, 500 elements/line, and a 4 to 3 aspect ratio. The video bandwidth is 2.1 Mc.

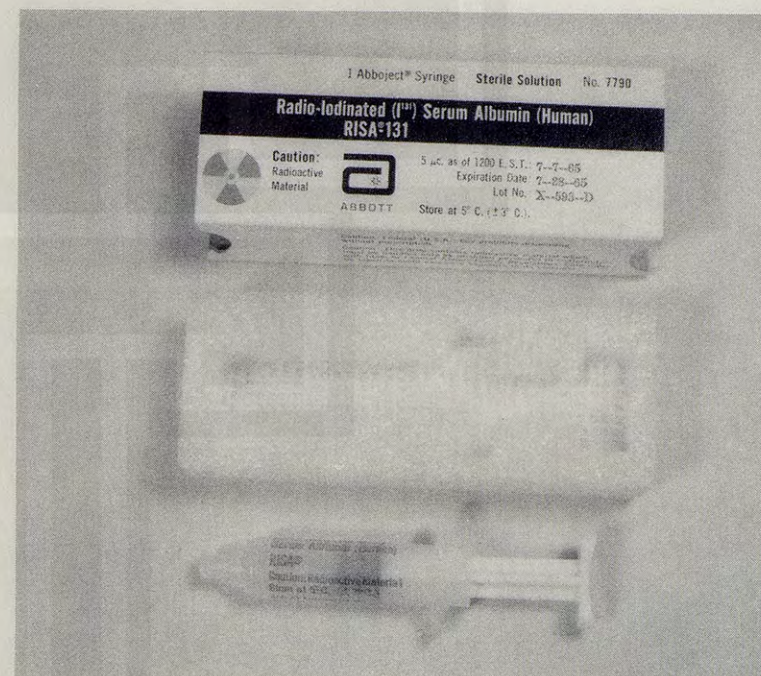
Camera. Two types of film cameras will, in all probability, be standard equipment for all AAP flights. The first is a 35 mm single-lens reflex with a variety of lenses, fast shutter speed, and large lens opening capability. This single lens reflex capability will be required when used in conjunction with the telemicroscope to provide direct viewing for focusing and positioning of subject material. The second camera is a real-type film camera to record events in which subject movement must be recorded. As in the case of the 35 mm camera, additional lenses will be provided, probably in the form of a turret head to minimize lens changing. Film packages can be both color and black and white. It is of particular interest to provide color film for the 35 mm camera when used in conjunction with the microscopy/chemistry experiments concerned with photographing cultures, and hematological samples (mounted on slides and viewed through the telemicroscope).

Scintillation Counter. Scintillation counters are used in radioisotope tracer determinations of body fluid compartments. A well crystal and spectrometer are used to determine equilibrium concentrations of Iodine-125. Iodine-125 tagged human serum albumin (RISA) is used for monitoring blood plasma volume. Figure 9-33 presents an illustration of the scintillation counter and RISA-Kit mockups utilized in the study. Tritium (hydrogen-3) labeled water is used to determine total body water. A urine sample is mixed in a cell which is inserted in the scintillator and the cell output is

9-72



(a)



(b)

Fig. 9-33 Scintillation Counter (a) and RISA Kit (b) Mockups Used in Study

counted, using a pair of photomultiplier tubes. The detector design is based on that of the LMSC proton-electron spectrometer that has been utilized for satellite sensing of space radiation, and which was also used on the Gemini IV mission. An indirect benefit to be gained with the detectors is their use as secondary backup for providing RBC mean lifetime. With the addition of a very small detector, cardiac output can also be measured.

Desired reproducibility during a series of runs is 0.5 percent. It is suggested that a minimum of 4×10^4 counts above background be accumulated for each determination to reduce the 0.95 error to 1. The two modes of counting are as follows:

- Well Crystal Scintillation Detector. Counts 5-ml blood samples for I-125, with expected activity $5 \times 10^{-3} \mu\text{c/ml}$ I-125
- Liquid Scintillation Counter. Counts 20 ml sample of solution urine with expected activity $2 \times 10^{-2} \mu\text{c/ml}$ of urine, or approximately $4 \times 10^{-2} \mu\text{c}$ total sample activity.

The two counting instruments may consist of two separate systems, or of interchangeable combinations of power supply, preamplifier, photomultiplier tube, and scintillator. The most desirable packaging approach will be determined by design analysis, consideration of weight, required set-up time, and reliability. In order to reduce the background counting rate, combinations of material shielding and an anticoincidence mantle will be considered.

Bone Densitometer. The differential X-ray absorption bone densitometer consists of high and low energy radioisotope X-ray sources, a pair of matched X-ray detectors, tapered absorption wedges, and associated electronics and holders. Figure 9-34 illustrates the bone densitometer mockup used in the study.

Two source-shield assemblies are used. The low energy source could be self-excited Pm_2O_3 (38.4 Kev) Iodine-125 (28 Kev), or Tungsten-181 (58 Kev). For the high energy source, Tin-113 (392 Kev), Chromium-51 (320 Kev), Mercury-203 (Kev),

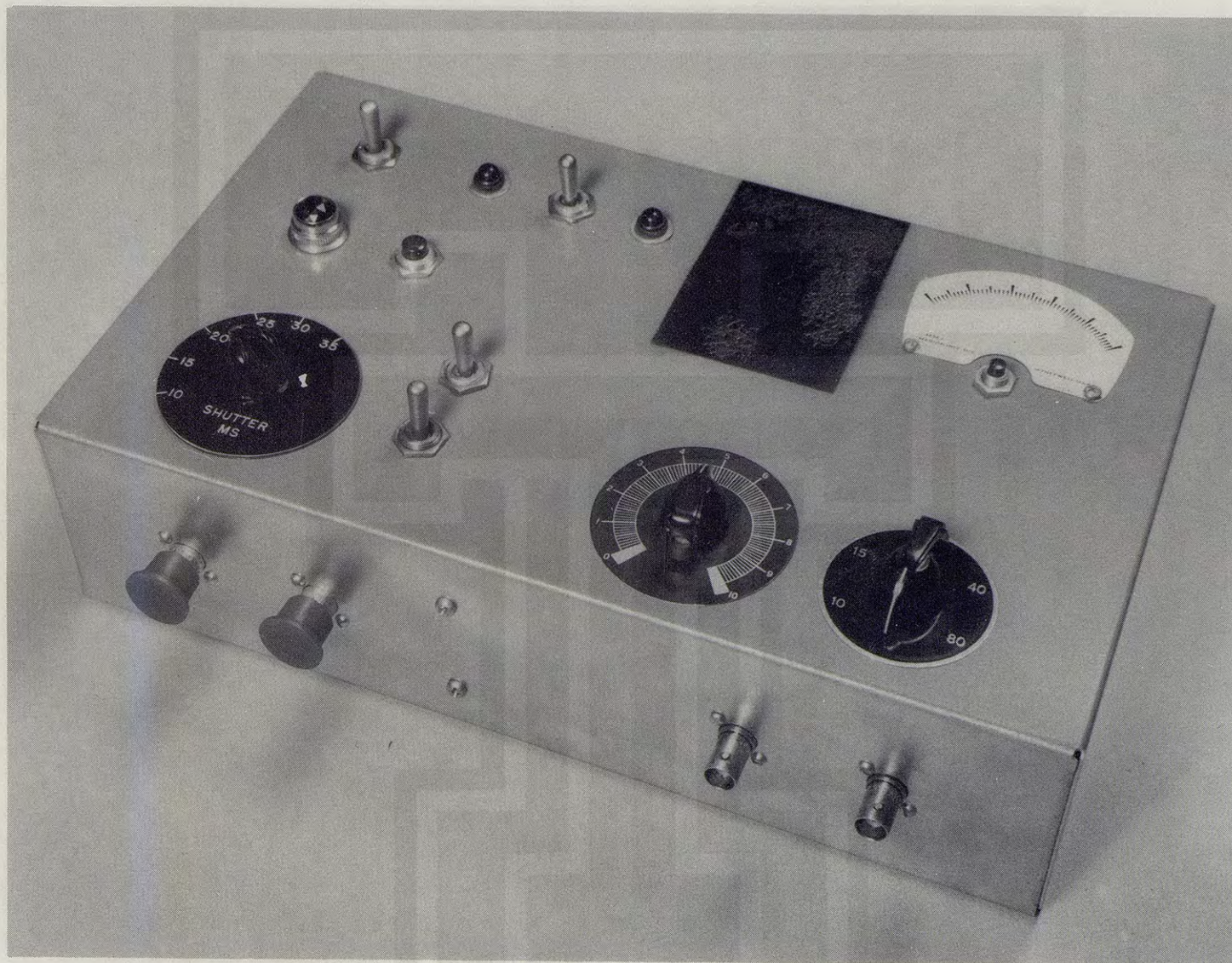


Fig. 9-34 Bone Densitometer Mockup Used in Study

or Cobalt-57 (125 Kev) could be used. The sources are specially prepared to have two opposite surfaces of equal activity. The X-ray detector consists of a thin crystal, photomultiplier tube, and electronics. Two tapered absorption wedges are employed, one representing soft tissue, the other, bone mineral.

The measurement is obtained when the subject places the part of his body being measured (os calcis, distal femur, or distal ulna) between the source and a detector. Simultaneously, one wedge is placed between the other side of the source and the other radiation detector. This wedge is then positioned so that equal counts are observed from the subject and from the wedge. This wedge thickness is related to the absorption of the subject. The second wedge is then substituted and the procedure repeated. The other source is then used and the wedges again positioned to give equal counts. From this set of data, bone mineral density is determined. Precision of the method is expected to be from 1 to 5 percent.

Determination of bone demineralization is performed in the following manner. By analyzing differential absorption of the sample at two X-ray energies, changes in absorption due to a variation in bone mineral {assumed to be $3 [\text{Ca}_3 (\text{PO}_4)_2] \text{CaCO}_3$ } can be separated from changes, due to variations in the soft tissue and fat layer intercepted by the X-rays. A first calculation yields a 5-percent differential absorption change for percentage of the percent change in bone mineral content. For the calculation, bone density was taken as 1.3, and to be 40 without mineral, 60 without collagen. A 3.5-cm-thick bone with a 4.5-cm overlayer of soft tissue was assumed to represent the os calcis region (heel). Other possible body sites for consideration have a higher ratio of bone thickness to tissue thickness and would show greater sensitivity. Two such sites are the distal femur and the distal ulna. The three bones mentioned are calcareous for which calcium metabolism is more rapid than in cortical bone.

9.3 BIOCHEMICAL/CYTOLOGICAL EXPERIMENT EQUIPMENT DESCRIPTION

The adaptation of the biochemical and cytological determinations to the mission and vehicle constraints and the operational requirements of the zero-g environment required design generation of special instrumentation devices to handle liquid and semiliquid samples. To assure the most rapid integration of the experiments into a mission profile, the design was based on the consideration that, for the initial flights, the astronaut will be performing essential manipulations manually to reduce the equipment requirements and to minimize the developmental time required to generate new instrumental techniques for automated chemical analysis.

The state-of-the-art of automated chemical analysis has not progressed in the conventional medical laboratory or in industry to the point that the techniques and instruments are applicable to the space environment. The main problem with the implementation of automated systems for chemical analysis in space is that present systems are not polyfunctional; that is, they require separate monitoring systems for each parameter monitored, they are still cumbersome in design and operation, and they do not therefore lend themselves readily to miniaturization for spaceflight. In addition, the ever-present problems of reliability and space maintenance persist as major design considerations.

The designs for the instruments which had to be generated were as simple and reliable as possible to minimize the incorporation of new and added experimental variables as well as to require minimal time in instruction and training of an astronaut in the use.

All the devices are based on well-known and sound manipulation principles and represent merely the incorporation of simple operational aids in the experimental program. In addition, the design team considered the possible sophistication of automation in the devices provided the mission profile allowed and required it. The concept would allow further development to occur without extensive redesign and development of the instrumental package as well as of operational protocol. The design of these devices was

also totally integrated with the design of the micro-chem station to assure the maximal utility and efficiency of the station and the experimental time.

9.3.1 Description of the Micro-Chem Station Console

Analysis of the operations required for the performance of all manipulations indicated that to assure minimal maneuvers and minimal relocation of devices, the manipulations and the handling would best be performed on the panel itself. The micro-chem station panel (Fig. 7-8) has been color-coded for rapid operator identification and inspection.

The micro-chem station panel was designed in a modular fashion to insure rapid correction of a malfunction that may arise. The modular design also facilitates replacement of malfunctioning instrument and/or replacement of present equipment with new or updated equipment.

Centrifuge. From the analysis of the operations and manipulations required to perform the determinations allotted to the micro-chem station, it was found that the centrifuge serves a convenient common purpose in both the biochemical and cytological determinations, for the handling and manipulation of fluids in a zero-g environment. For this reason, it represents the single most important and commonly useful device for this purpose in the zero-g environment. The procedures as adapted in this study make repeated and unique use of the centrifuge to solve difficult problems associated with the constraints of spaceflight. Boiling, wet digestion, dry ashing, and evaporation (and recovery) of chloroform used for extractions are all performed in the centrifuge. As conceived, the centrifuge chambers will be fitted with heating coils, insulation, temperature sensors and controllers, reagent addition (while spinning) means, control of atmosphere above samples, and automatic boiling-point reaction termination controls. The centrifuge housing will also serve as a fan housing, with the exhaust directed through and absorbent bed (such as charcoal) for fume entrapment. The rotor will serve as a fan by design. Further thought should be given to the possibility of pneumatic drive and/or pneumatic assistance for starting in order to minimize power requirements.

pH and pCl Syringes. The pH-pCl syringe module was designed as a pull-out drawer and color-coded blue. Both syringes are held by padded syringe clamps mounted inside the drawer. The electrode syringes receive power and transmit the signal through a detachable, retractable cable. The data readout for the electrode syringe module is located on the pH-pCl control module in the form of a meter. Operation of the pH-pCl syringe module is discussed further in subsection 9.3.2 regarding special equipment.

pH-pCl Control Module. The pH-pCl control module is used exclusively in conjunction with the pH-pCl electrode syringe module. This module contains the readout meter, four range-selection pushbuttons, and a calibration control for each of the electrode systems.

Lyophilizer. It is anticipated that many samples may be returned to earth for postflight analysis. However, since on-board lyophilization may be desired a small lyophilizer has been shown in the panel layout. Conceptually, the lyophilizer will be vented to space through a back-pressure regulator, and samples contained in tubes or bags of a dialysis membrane would auto-freeze due to rapid evaporation at low pressure. An interlock would prevent opening of the access port while venting to space.

Particle Counter. A space-adapted version of the laboratory particle counter will be required for several procedures. The mechanical ports and electronics could be fitted into the space allotted in the panel layout only if a direct count, with little or no size discrimination, would be sufficient.

The particle counter contains two inlet ports, three manual controls, and four push buttons. The manual controls are used to set limits for the count and to calibrate the counter. The four push buttons are used to select the proper sequence for the operation. At this time, the counter is intended to be exclusively a visual readout although the incorporation of the counter into the data-management system does not appear to present difficulty.

Spectrophotometer. In selecting clinical analytical approaches, one major consideration was that the end determinations be made by a common instrument. Consequently, the vast majority of clinical tests selected employ a spectrophotometric determination. The instrument proposed is actually better classified as a colorimeter, but the use of modern interference filters with 90 percent transmission and a band-pass of about 5 m μ permits specificity comparable to that obtained with clinical spectrophotometers of much simpler design. The instrument could be converted to a fluorimeter by operation of a lever, for example, and by proper adjustment of sensitivity.

The meter on the spectro-fluor module is used for operator information only, since all data is automatically processed. The manually operated controls include a rotary switch, for instrumental system selection, and four push button switches for proper sequence programming of the operation. The color of the module is coded red for operator identification.

Wavelength Module. The wavelength module, at the bottom center of the station, is used in conjunction with the spectrophotometer-fluorometer module and is color-coded brown. Most of the clinical procedures, when utilizing this module, require an individual wavelength. This module is exclusively a wavelength selector. The space behind the wavelength module is used for various electronic and optical components of the spectrophotometer.

Reagent Port Module. The reagent port module, located at the bottom right corner of the panel, contains 24 individual reagent ports. All reagents used in the station, except those found in the kits, are located in this module. The reagents are stored in bottles (as previously discussed) behind the respective port. This module is color-coded brown.

Absorber. The absorber is a replaceable cartridge, located in the upper right corner of the station, which absorbs toxicants from the centrifuge and other modules. To replace the cartridge, the module drawer is pulled out, the contaminated cartridge removed and discarded in solid waste receptacle, and the new cartridge from storage is inserted.

Electronic Hematocrit. The electronic hematocrit design is based upon measurement of the electrolytic conductivity of whole or heparinized blood. This module consists of a sample inlet, a count push button, and a flush push button. The totaled count is taken from the data readout on the particle counter module, thus eliminating the need for an additional meter or digital readout.

Interval-Timing Module. There are seven individually operated timers on the green interval-timing module that may be set with a precision thumbwheel for intervals ranging from 1 min to 12 hr. An alarm will sound when the prescribed interval has elapsed. The timers are designed to be electrically operated. For conservation of power, however, mechanical timers could easily be incorporated into the existing space.

Centrifuge Manifold Module. The centrifuge manifold module controls the gaseous reagents to be used in conjunction with samples that are being centrifuged. There is a four-position rotary switch for the proper selection of nitrogen, oxygen, and water. The fourth switch position is the off position. A retractable hose, with a male syringe fitting, is inserted into the centrifuge induction port, when one of these reagents is needed, and the rotary switch is then turned to the correct additive. The volume and pressure of the reagent is preset.

FM Receiver Module. The FM receiver module has one push button which is depressed when reception is initiated or discontinued. This module is used with the gastrointestinal determinations. The signal transmitted by the swallowed sensor is received by this module and then recorded or relayed to ground control.

Liquid Waste Module. The blue liquid-waste module has two ports, with female syringe connectors, into which all liquid waste is deposited. The two ports are connected to individual containers with check valves to prevent back-flow.

Solid Waste Module. The solid-waste disposal module is located directly below the liquid waste on the left side and is also color-coded blue. All solid waste is disposed of by pushing the waste through the rubber diaphragm into the waste receptacle.

Sonic Mixer. Mixing is required frequently in the biochemical determinations included in this program. Due to the constraints imposed by a closed system in a zero-g environment, a sonic mixer was included in the panel design to attain satisfactory mixing. The sonic mixer, which is color-coded red, has three syringe ports which are activated by the insertion of a syringe.

Centrifuge Control Panel. Since more than one temperature is required simultaneously, five arms of the centrifuge were designed with individual temperature controls. The yellow panel includes a centrifuge brake, interval timer and five temperature controls. The interval timer activates the centrifuge when set and stops the centrifuge motor when the interval timer returns to zero. The temperature controls must be set manually to the desired temperature but are returned to zero automatically when the centrifuge stops.

Temporary Syringe Storage. Several biochemical procedures require incubation at ambient temperature when a number of syringes are being employed. Four syringe storage ports were integrated into the station.

Temperature Block Modules A and B. Since most of the procedures at the micro-chem station required an incubation period at elevated temperatures, two temperature blocks were included in the panel. Each temperature block has six syringe incubating ports and two temperature controls, each controlling three ports. The yellow color-coded temperature blocks are designed for rapid temperature equilibration to eliminate a prolonged waiting period as much as possible.

Keypunch. The keypunch, required for all micro-chem station procedures, is installed in the drawer at the bottom of the station panel. The keypunch board is designed with enlarged keys to facilitate punching while wearing gloves. The board keys include three letters (for experiment code), ten numbers, and a spacing key.

Panel Illumination. Panel illumination (if required) is provided by a 15-w fluorescent light located in the drawer at the bottom of the station panel. The light illuminates the complete panel but is shielded from the astronaut's eyes.

Procedural Display. The procedural display, located in the drawer, is an electrically or mechanically operated revolving cylinder. The unit is driven by an electrical motor, but may be stopped and rotated manually in either direction, if necessary.

Malfunction Indicators. There are 28 malfunction indicators designed to pinpoint any subsystems malfunction that may occur throughout the station panel. A test switch is provided on the malfunction panel which, when energized, illuminates all indicators. Critical subsystems requiring malfunction indicator circuitry have been limited to the readout sensors and associated components.

9.3.2 Description of Micro-Chem Manipulation Devices

The manipulation devices which were generated during the analysis of the operational requirements are discussed in the following paragraphs.

Biochemical Determinations. Devices for performing these determinations are described in the following paragraphs.

- pH Electrode Syringe. The pH electrode syringe (Fig. 9-35) has a standard barrel with the pH electrode, the reference electrode, and the temperature compensator incorporated into the plunger. A sonic mixer attached to the cable is clamped to the exterior wall of the syringe barrel. The electrodes and temperature compensator are incorporated into the syringe plunger to ensure contact between the electrodes and the sample, regardless of the sample volume. The mixer is included in the syringe design thus permitting simultaneous mixing of reagents.

The pH-pCl module is activated by a microswitch in the pH-pCl drawer. The microswitch is released when the pH syringe is removed from the drawer. The pH syringe is then removed, the liquid dispersed into the liquid waste, and the buffer or standard is drawn up into the syringe. The pH calibration knob is then turned until the meter needle corresponds to the red line on the

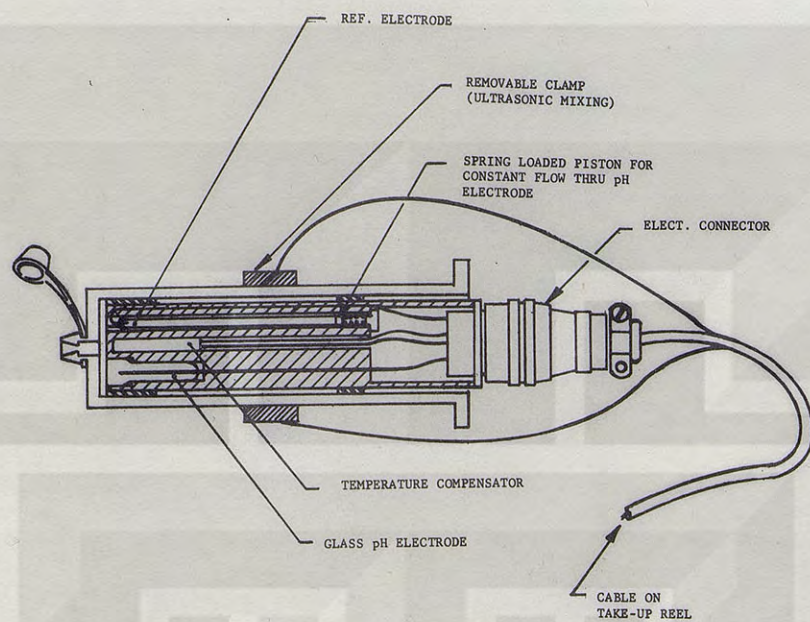


Fig. 9-35 Design of pH and pCl Electrode Syringe

meter, thus completing calibration of the pH meter. The buffer is then dispersed into the liquid waste, the sample introduced into the syringe, and the reading is taken off of the pH-pCl module meter. The syringe is then emptied into liquid waste, filled with water from the reagent port, and returned to the drawer.

- pCl Electrode Syringe. The chloride electrode (pCl) syringe has a standard barrel with the chloride electrode, the reference electrode, and the temperature compensator incorporated into the plunger (Fig. 9-35). A sonic mixer, attached to the cable, is clamped to the exterior wall of the syringe barrel. The electrodes and temperature compensator are incorporated into the syringe plunger to ensure contact between the electrodes and the sample, regardless of the volume.

The pH-pCl module is activated by a microswitch in the pH-pCl drawer. The microswitch is released when the pCl syringe is removed from the drawer. The pCl syringe is removed and the liquid retained for calibration of the pCl meter. After the meter has been calibrated to the red line on the meter with the pCl calibration knob, the liquid is emptied into the liquid waste, and the sample is introduced into the syringe. The reading is then taken from the meter, the sample emptied into the liquid waste, the syringe rinsed with water and filled to the 1.0 cc mark with pCl standard, and the syringe returned to the drawer.

- Type B Micro-Sampler. The Type B liquid sampler (Fig. 9-36) is a four-port rotary chromatograph type sampler with a sample input port (female syringe connector), a water input port (male syringe connector), a sample output port (female syringe connector), and a waste output port (male syringe connector). The Type B micro-sample design was developed in response to the need for transferring microvolumes accurately, and the micro-sampler

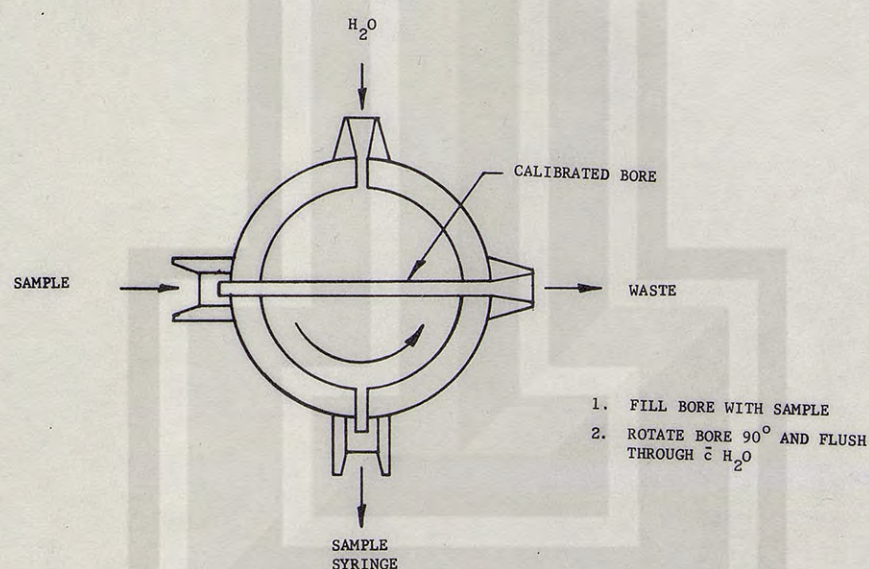


Fig. 9-36 Type B Micro-Sampler

removes from the astronaut the responsibility of measuring minute samples in a syringe. A syringe containing a liquid is connected to the sample input port, and the rotating center is rotated to line up with the sample input and waste output. The sample is injected with the overflow going to waste. The rotary center is then rotated 90 deg to line up with the water input and the sample output. A syringe is connected to the sample output port, and the sample is flushed into it for analysis.

- Type A Micro-Sampler. The Type A micro-sampler incorporates a lancet on one end and a female syringe connector on the other. The bore and the length are calibrated to permit sampling of a very small known volume of whole blood from a pricked fingertip. The micro-sampler can then be transferred to a syringe and the sample drawn in for analysis. After use, the micro-sampler is discarded into the solid waste container.
- Adsorption Column. The adsorption column (Fig. 9-37) was designed to achieve a chromatographic fractionation, in a zero-g environment of various

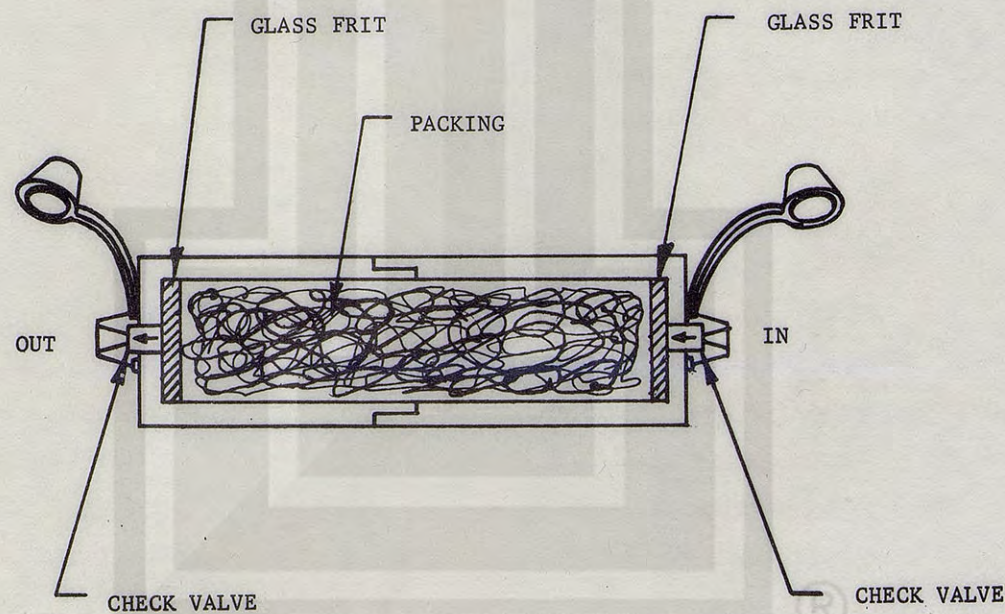


Fig. 9-37 Adsorption Column

compounds in urine. Both ends of the column are equipped with female syringe fittings to accept syringes, and a detachable coupling enabling the column to be inserted into the waste and/or the reagent ports. The column is packed with either a granular or powdered solid absorbent material. Check valves are incorporated at each end to allow only one-way flow through the column. Glass frits are used at each end to keep the packing from fouling the inlet and outlet ports of the column. A sample is transferred from one syringe through the column to another syringe. During this procedure, specific compounds are adsorbed from the sample as it passed through the absorbent material. After elution with appropriate solvent, the column is returned to the kit from which it originated and not used again.

- Syringes. Four types of syringes, as shown in Figs. 9-38 through 9-41, were used.

- (1) Type A. The Type A syringe (Fig. 9-38) was designed to maintain the separation of two liquids until mixing is required. The Type A syringe contains two reagent chambers separated by the piston or plunger. The chambers are interconnected by one-way check valves leading from the rear reagent chamber to the front of the piston. A check valve in the needle hub prevents the introduction of air into the front chamber when the plunger is being pulled to the rear, accomplishing the mixing of the two liquids.
- (2) Type B. The Type B syringe (Fig. 9-39) is a standard type of syringe with a standard barrel and piston. The piston is modified to displace the dead volume of the needle hub. The plunger is threaded to permit micro-manipulation and provides a position-lock for centrifugation.
- (3) Type C. The Type C syringe (Fig. 9-40) was designed to permit retention of the precipitate while discharging the supernatant liquid. This syringe is identical to Type B, except for the concave piston head, which is designed to retain the precipitate as the liquid is being discharged.

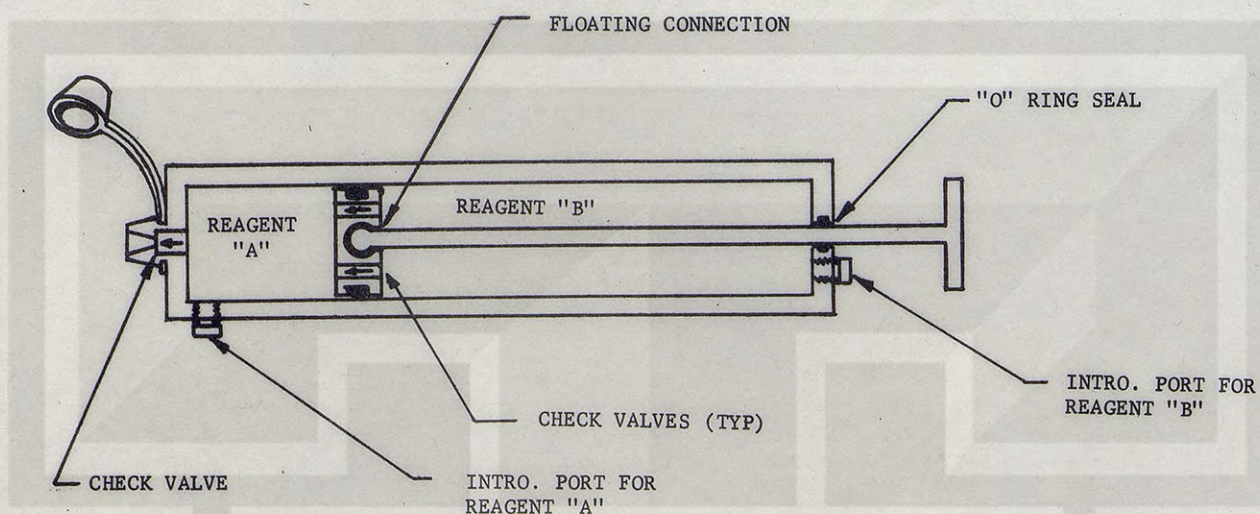


Fig. 9-38 Type A Syringe

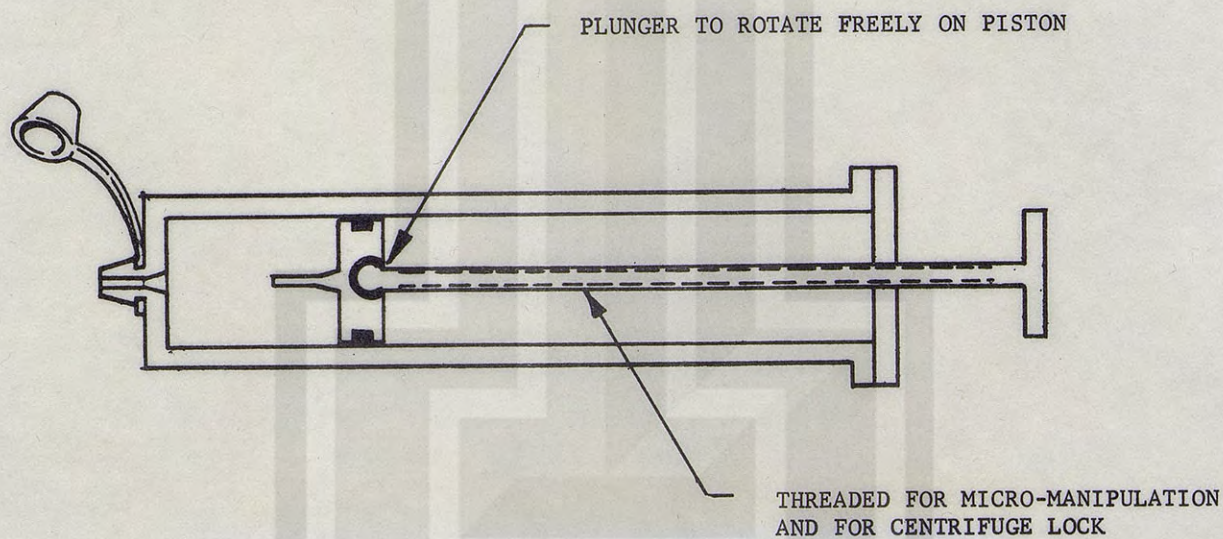


Fig. 9-39 Type B Syringe

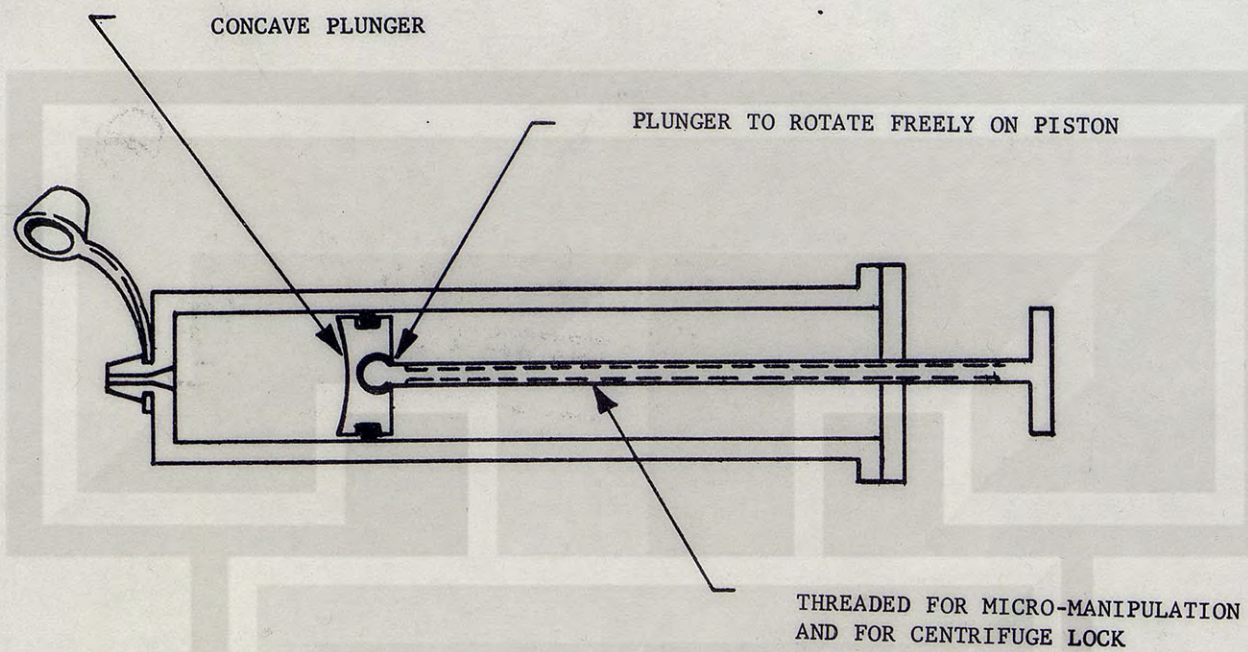


Fig. 9-40 Type C Syringe

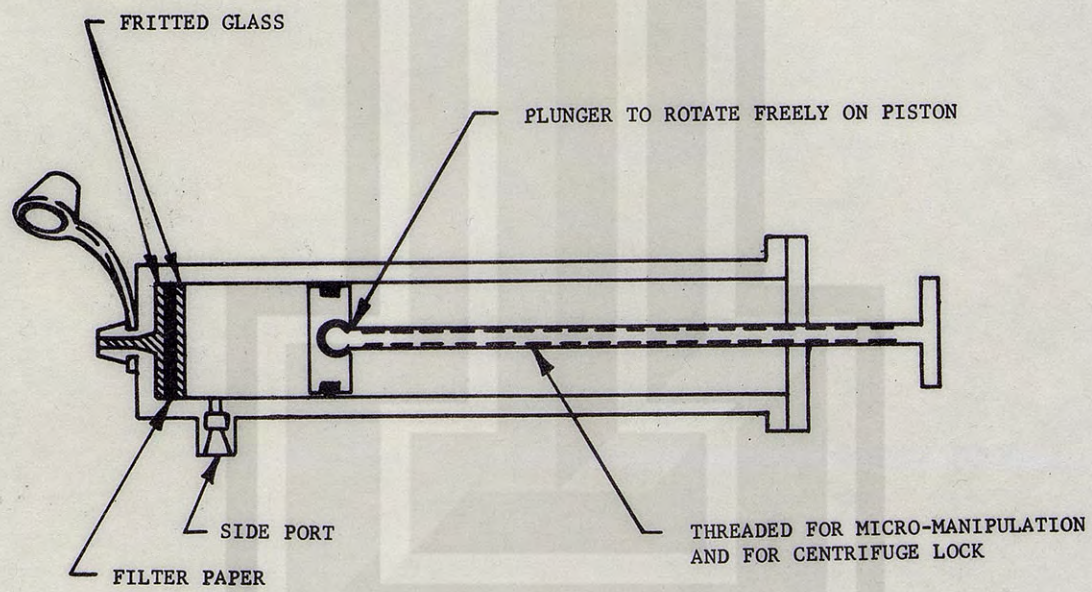


Fig. 9-41 Type D Syringe

- (4) The Type D syringe (Fig. 9-41) was designed to filter unwanted particulate matter from a liquid sample as it is discharged from the syringe. The syringe is equipped with a side sample induction port, with a check valve that allows flow into the syringe only. The head of the syringe contains a filtering wafer composed of a filter paper pad sandwiched between two glass frits. The head of the piston is flat to match the surface of the filtering wafer.
- Reagent Bottles. The reagent bottles (Fig. 9-42) contain the reagents required to perform the determinations. The bottles will be hooked up to the reagent panel behind the reagent ports on the station panel. They will vary in size, depending upon the amount required for the particular determinations programmed for the mission. Each bottle contains a bladder which is filled with reagent. The bottle and the bladder may be pressurized by either gas or a piston driven by a spring.
 - Reagent Ports. The reagent ports (Fig. 9-43) are located on the station panel. Each port is a female syringe connector with a check valve that allows only one-way flow through the port to the outside. A syringe, when inserted into the port, activates the valve, allowing the reagent to be dispensed from the reagent bottle through the reagent port.
 - Gaseous Reagent Addition Device. The addition of very small amounts of reagents and the solubilization of gases into the reaction mixture can be readily accomplished by the gaseous reagent addition device illustrated in Fig. 9-44. It was specifically designed for the addition of a measured volume of gas into the reaction vessel and for performing this step quantitatively in weightlessness. The gas is stored in a vial surrounded by a Teflon envelope with the tip of the vial protruding into a rotating piston with a bore. Rotation of piston breaks the tip of the vial, and the bore opens the passage to the syringe coupling. A check valve prevents the backflow into the envelope. For return to storage, the rotating piston is returned to the closed position.

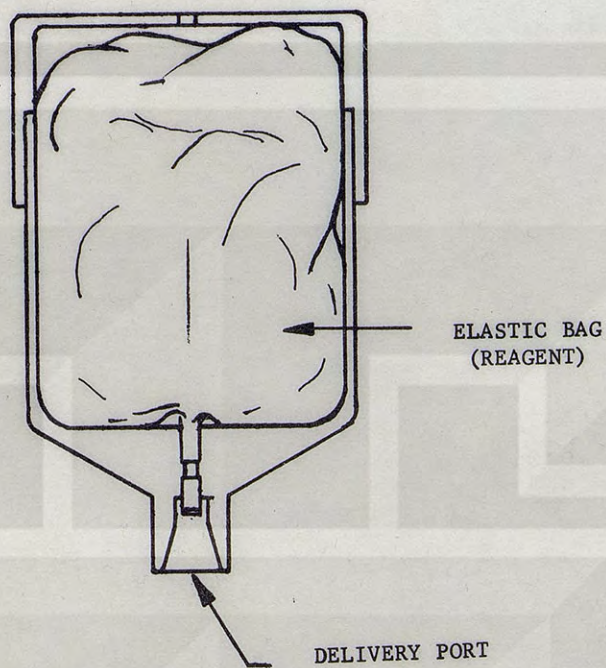


Fig. 9-42 Reagent Bottle

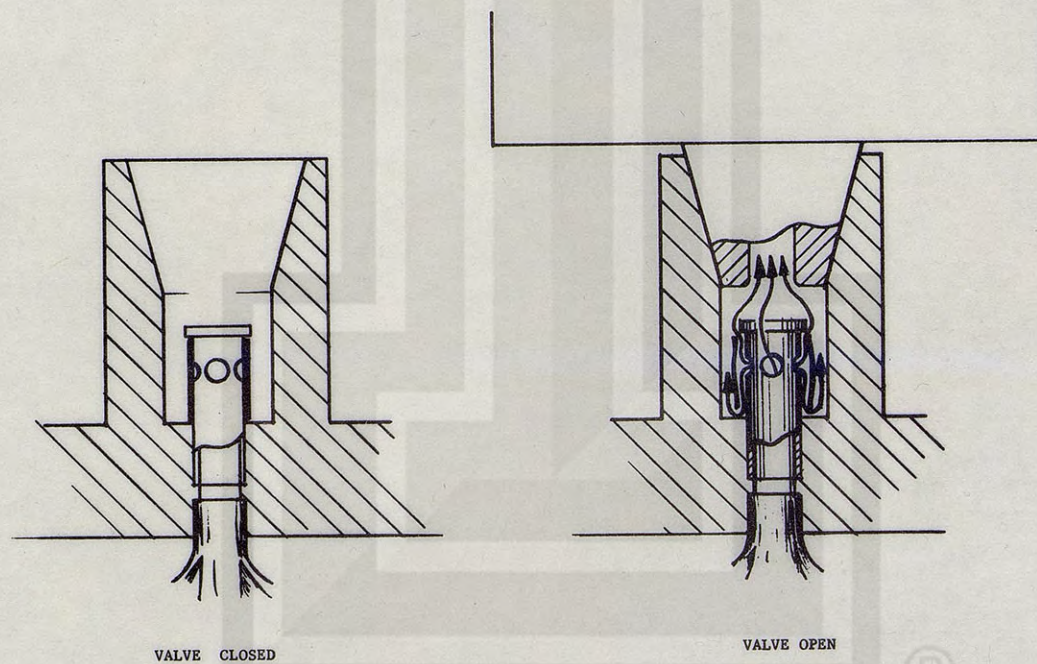


Fig. 9-43 Reagent Port

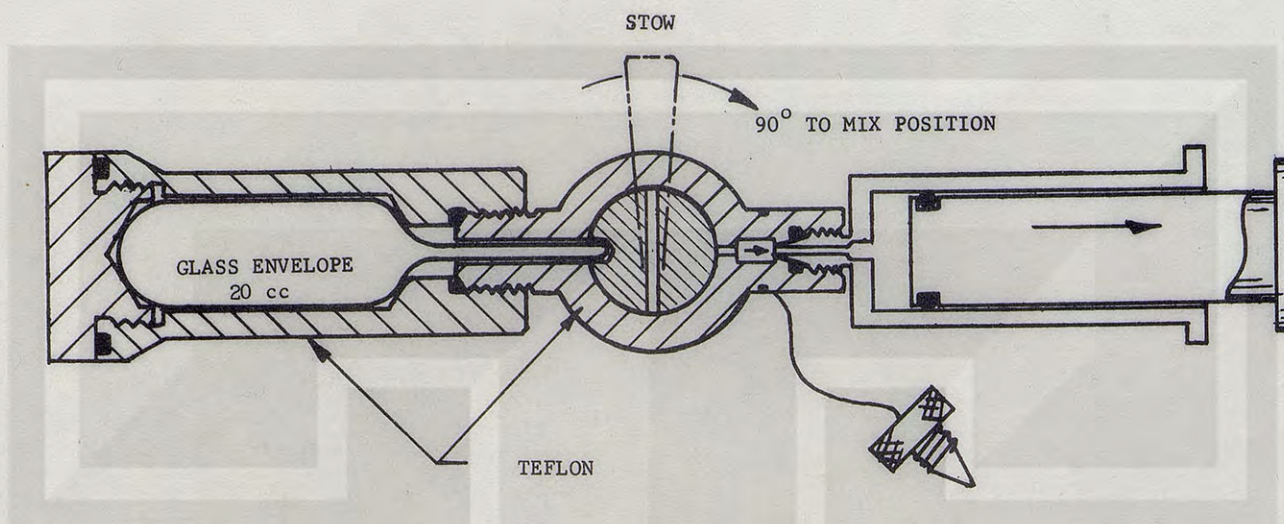


Fig. 9-44 Gaseous Reagent Addition Device

Cytological Determinations. Devices for performing these determinations are described in the following paragraphs:

- Staining Apparatus. The staining apparatus (Fig. 9-45) was designed for staining of blood smears in the zero-g environment. The staining apparatus consists of a waste receptacle, a slide holder, and a septum with retainer and T-spreader. The waste receptacle with a permanent septum connects to the back of the slide holder by means of an O-ring seal and snap lock. The needle on the back of the slide holder penetrates the septum of the waste receptacle to interconnect the two compartments. A check valve in the slide holder prevents waste from returning into the slide holder.

The septum with the T-spreader is affixed to the front of the slide holder (T portion of the spreader in compartment) by means of the threaded retainer.

Blood and stains and reagents are injected into the glass or plastic slide through the septum, spread by the T-spreader, and transferred into the waste receptacle by centrifugation. The drying operations are carried out by passing dry, inert gas through the slide holder by means of the inlet and outlet ports on the side of the slide holder. At the end of the operation the waste receptacle is transferred to the solid waste container, and the slide compartment is transferred to the storage area to be reused with a new waste receptacle.

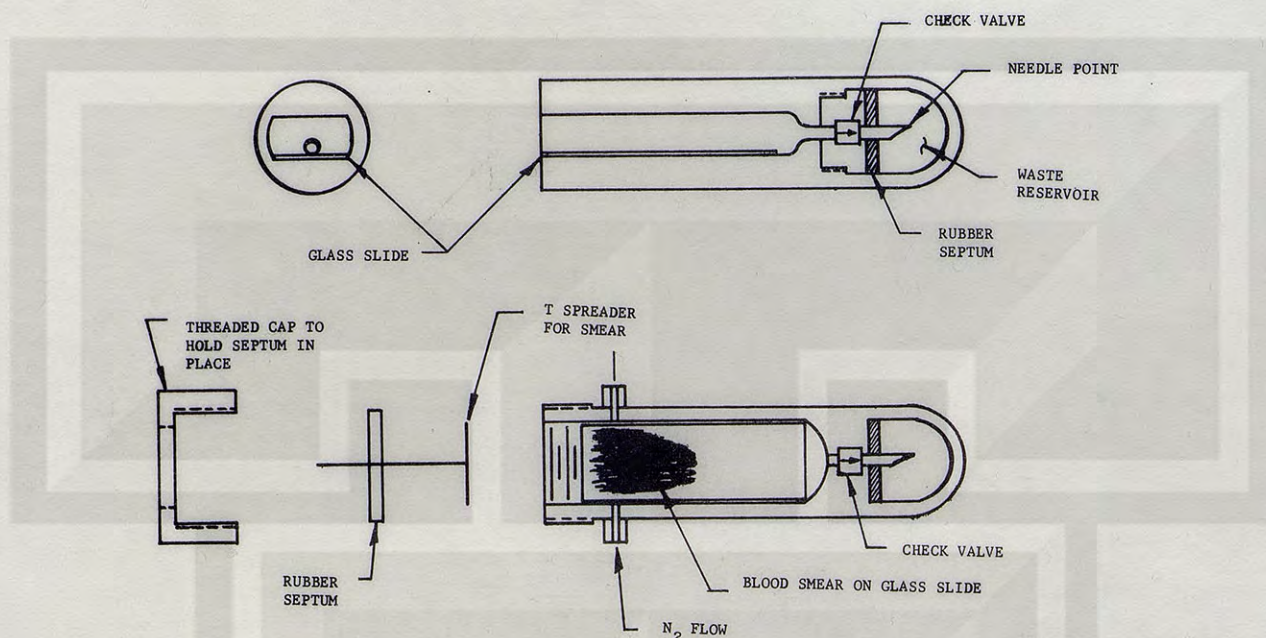


Fig. 9-45 Staining Apparatus

- Culture Chamber for Microorganisms. Two types of culture chambers have been provided (Figs. 9-46 and 9-47), for liquid and particulate samples. The two chambers are identical in design except for the sample induction ports. The liquid sample is transferred into the chamber through a septum at the induction port. The particulate or semisolid samples are administered with a cotton swab through a sealable port. For purposes of providing an anaerobic atmosphere to the culture, gas induction and exhaust ports have been provided on the sides of the chamber.
- Electromagnetic Trap. Leukocyte phagocytic activity is determined when a sample of leukocytes containing ingested iron particles is passed through an electromagnetic trap (Fig. 9-48). The leukocytes are trapped and the remainder of the sample passed through the field to the particle counter. For purposes of counting the trapped cells, the field is deactivated, and the cells flushed into the particle counter.

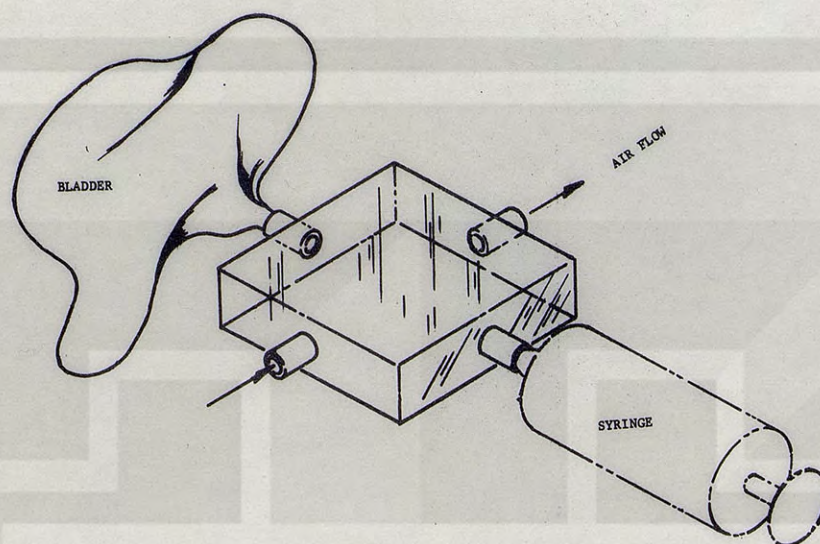


Fig. 9-46 Microorganism Culture Chamber (Liquid)

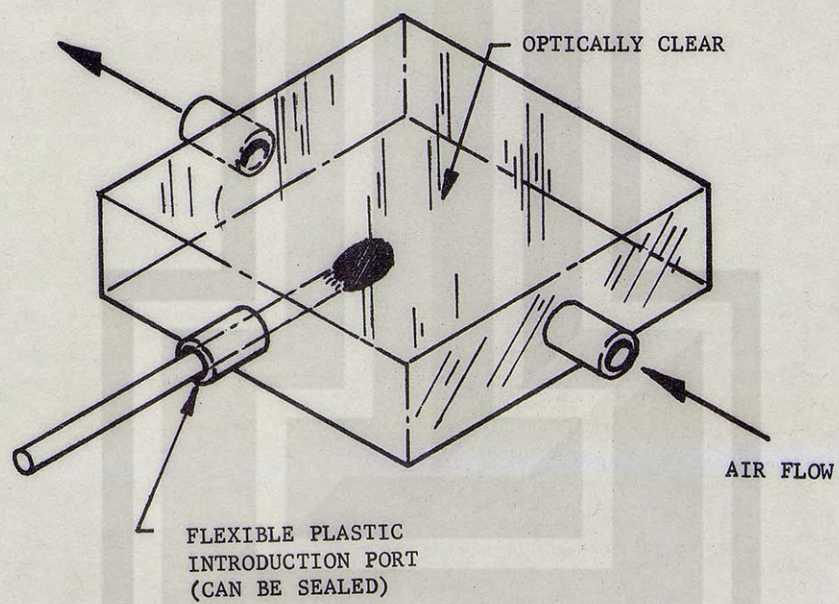


Fig. 9-47 Microorganism Culture Chamber (Particulate)

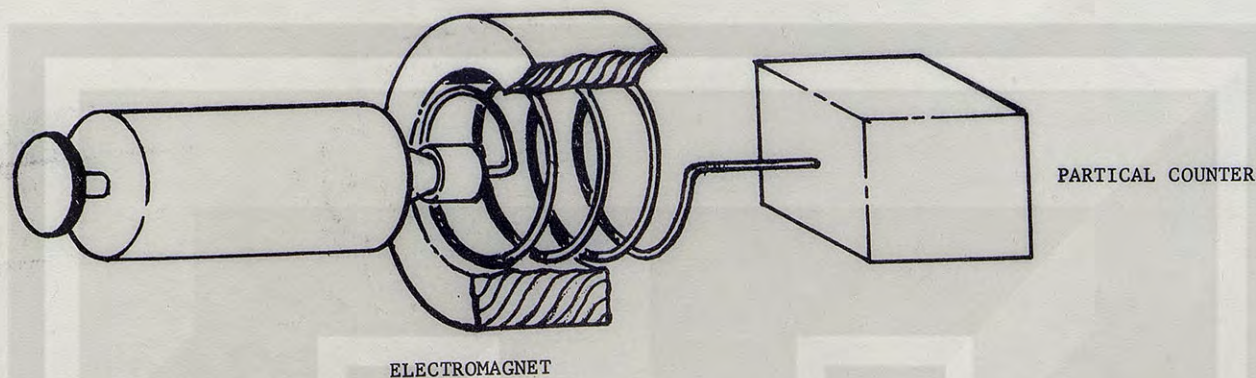


Fig. 9-48 Electromagnetic Trap

- Telemicroscope. The microscope can be constructed from available optical components. A typical example is a condenser system which includes lenses, diaphragm, green filter, discs, and mount. These component assemblies are packaged in a workbench-oriented housing. The complete telemicroscope package includes the microscope and a light source, a vidicon tube, and a video pre-amplifier. Folded optics have been used to reduce the volume of the unit to a minimum. A binocular eyepiece provides maximum viewing comfort. The vidicon tube makes the image available for transmission to the ground. There is a point in the optical path which can be used for photography. A suggested instrument design is illustrated in Fig. 9-49.

The microscope can be mounted on the micro-chem work table for use during reasonably long periods of biological specimen examination. A television link with the ground can be provided. Specifications are as follows:

- Magnification - 250 to 1,000 diam. (zoom)
- Condenser system - Phase-contrast with diaphragm
- Stage adjustment - Mechanical
- Vidicon tube - 1.5-in. diam.
- Binocular eyepiece
- Focusing reticle - double crosshair

The video accommodation will be minimum. Signal conditioning will be required only to the extent necessary for presenting a usable signal at the second stage of amplification of an existing unit.

9-95

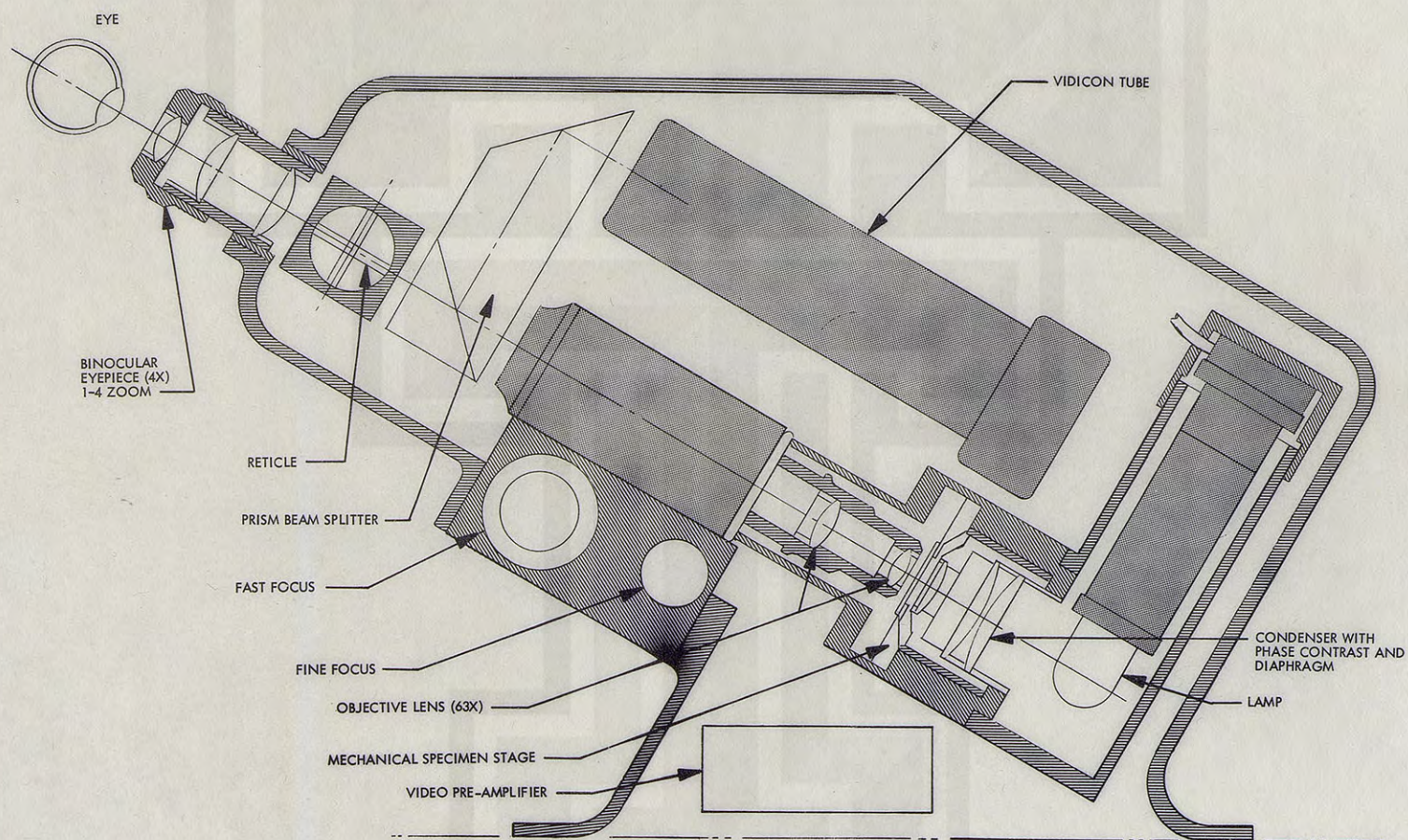


Fig. 9-49 Telemicroscope

9.3.3 Biochemical and Cytological Kits and Supplies

Various materials and supplies are required to support the measurements, determinations, and evaluations made during the conduct of the biochemical and cytological experiments. In order to provide the support required, kits containing specific materials have been designed to supplement each major parameter determination. These kits are summarized in Table 9-5. In addition to the kits, reagent supplies will also be required to support the biochemical and cytological determinations. These reagent supplies are presented in Table 9-6. Spectrophotometer filter requirements are presented in Table 9-7.

9.4 BEHAVIORAL EXPERIMENT EQUIPMENT DESCRIPTION

Numerous studies have and are being conducted to determine optimum techniques and equipment for measuring and evaluating astronaut behavioral status and performance in space. The three major categories of measurements for which equipment techniques are being developed are as follows:

- Sensory and perceptual processes
- Psychomotor function processes
- Higher mental processes

The equipment selected for the three behavioral experiments must be capable of assessing performance and status reliably and with a high degree of validity. To date, synthetic performance tasks have been the primary target of equipment development. However, with the advent of simulators and the high degree of user acceptance of simulators by the astronauts, it is essential to consider the use of operational-like equipment for use in behavioral measurement and evaluation.

Before operational-like equipment and the associated tasks can be used as performance predictors and status indicators, however, considerably more effort must be expended in study and in analysis of the approach. The equipment suggested for use in Experiments 0202 and 0203 is based on the premise that operational-like tasks can be

Table 9-5

DESCRIPTION OF KITS REQUIRED TO SUPPORT BIOCHEMICAL
AND CYTOLOGICAL EXPERIMENTS

Kit	Description
Chloride	Syringe R (Type B) containing 0.5 ml 0.10 N KCl
Potassium, Serum	Syringe A (Type B) 10 ml cap., containing 8 ml H ₂ O + 1 ml 10% TCA R (Type B) 6 ml cap., containing 5 ml H ₂ O S (Type B) 6 ml cap., containing 5 ml standard solution X (Type B) 6 ml cap., containing 4 ml H ₂ O TPB (Type B) containing 3 ml tetraphenylboron
Sodium	Syringe A (Type B) 2.5 ml cap., containing 2.0 ml 10% TCA R (Type C) 5 ml cap., containing 0.5 ml H ₂ O S (Type C) 5 ml cap., containing 0.5 ml standard solution X (Type C) 5 ml cap. UZA (Type B) containing 3.0 ml uranyl zinc acetate
Manganese	Syringe X (Type B) 5 ml cap. R (Type B) 5 ml cap., containing 0.3 ml N HCl + 0.85 ml H ₂ O S1 (Type B) 5 ml cap., containing 0.1 ml standard solution + 0.3 ml HCl + 0.75 ml H ₂ O S2 (Type B) 5 ml cap., containing 0.2 ml standard solution + 0.3 ml HCl + 0.65 ml H ₂ O S3 (Type B) 5 ml cap., containing 0.3 ml standard solution + 0.3 ml HCl + 0.55 ml H ₂ O Buffer (Type B) containing 11.5 ml buffer NaOH (Type B) containing 2.25 ml N NaOH Malachite green (Type B) containing 1.5 ml malachite green Sodium periodate (Type B) containing 1.5 ml sodium periodate
Magnesium	Syringe A (Type B) 5 ml cap., containing 3 ml H ₂ O B (Type B) 5 ml cap., containing ml standard solution C (Type C) 5 ml cap., containing 2.5 ml H ₂ O R (Type C) 5 ml cap., containing 1.0 ml PVA S (Type B) 5 ml cap., containing 1.0 ml PVA X (Type B) 5 ml cap., containing 1.0 ml PVA Titan yellow (Type A) 1.5 ml cap., containing 0.75 mg titan yellow in chamber A and 1.5 ml H ₂ O in chamber B NaOH (Type B) containing 3 ml 4N NaOH
17-OH	Syringe A (Type B) 25 ml cap., containing 1 ml β -glucuronidase B (Type B) 20 ml cap., containing 5 ml 0.1 N NaOH C (Type B) 10 ml cap. D (Type B) 25 ml cap. E (Type B) 16 ml cap., containing 10 ml 4% methanol-chloroform F (Type B) 25 ml cap. X (Type B) 4 ml cap. XB (Type B) 4 ml cap. RB (Type B) 2 ml cap. S (Type B) 2 ml cap., containing dried standard Penicillin 0.25 ml Sodium sulfate column Florisil column 16 ml 25% methanol-chloroform Syringe phenylhydrazine (Type A), containing 2 mg phenylhydrazine in Chamber A and 2.0 ml blank reagent in chamber B
Urine Calcium	Syringe A (Type B) 10 ml cap. B (Type B) 5 ml cap., containing 4.0 ml H ₂ O R (Type B) 6.2 ml cap., containing 0.2 ml H ₂ O S (Type B) 6.2 ml cap., containing 0.2 ml standard solution X (Type B) 6.2 ml cap. Dye solution (Type A), containing 0.4 ml dye solution in chamber A and 19.6 N NaOH in chamber B
Zinc	Syringe R (Type B) 10 ml cap., containing 4 ml H ₂ O S (Type B) 10 ml cap., containing 4 ml standard solution X (Type B) 10 ml cap. Cyanide solution, 1.5 ml Zincon reagent, 4.5 ml Chloral hydrate, 4.5 ml

Table 9-5 (Continued)

Kit	Description
Serum Calcium	Syringe R (Type B) 3.1 ml cap., containing 0.1 ml H₂O S (Type B) 3.1 ml cap., containing 0.1 ml standard X (Type B) 3.1 ml cap. Dye solution (Type A) 10 ml cap., containing 0.2 ml dye solution in chamber a 9.8 ml N NaOH in chamber B
Serum Phosphate	Syringe A (Type B) 6 ml cap., containing 4.5 ml H₂O R (Type B) 3.2 ml cap., containing 1 ml 5% TCA S (Type B) 3.2 ml cap., containing 1 ml standard solution X (Type B) 3.2 ml cap. Ammonium molybdate 0.6 ml TCA (Type B) containing 1 ml 30% trichloroacetic acid
Urine Potassium	Syringe A (Type B) 5 ml cap., containing 4.5 ml H₂O R (Type B) 6 ml cap., containing 5 ml H₂O S (Type B) 6 ml cap., containing 5 ml standard solution X (Type B) 6 ml cap., containing 4 ml H₂O TPB (Type B) containing 3 ml tetraphenylboron
Sulfate	Syringe A (Type B) 4 ml cap. R (Type C) 7 ml cap., containing 0.5 ml H₂O and powdered glass S (Type C) 7 ml cap., containing 0.5 ml standard solution + powdered glass X (Type C) 7 ml cap., containing powdered glass Benzidine (Type A) 15 ml cap., containing 140 mg benzidine in chamber A and 14 ml ethanol in chamber B Uranyl acetate (Type B) 6 ml Alcohol-ether (2 Type B) 21 ml Sodium borate (Type B) 1.5 ml Naphthoquinone (Type A) 16.5 ml cap., containing 2.25 mg naphthoquinone in chamber A and 16.5 ml H₂O in chamber B
Mucoprotein	Syringe A (Type A) 7.5 ml cap., containing 4.5 ml saline R (Type C) 10 ml cap., containing 0.5 ml H₂O S (Type C) 10 ml cap., containing 0.5 ml standard X (Type C) 10 ml cap., containing 1.0 ml phosphotungstic acid Orcinol (Type B) containing 3.75 ml orcinol reagent Perchloric acid (Type B) containing 2.5 ml 1.8 M HClO₄
NPN	Syringe A (Type B) 2 ml cap. L (Type B) 3 ml cap., containing 3 ml phenol color reagent M (Type B) 3 ml cap., containing 3 ml alkali-hypochlorite R (Type B) 5 ml cap. S (Type B) 5 ml cap. X (Type B) 5 ml cap. W (Type B) 2 ml cap. Micro-sampler
Amino Acid Nitrogen	Syringe A (Type B) 10 ml cap., containing 8 ml H₂O + 0.5 ml 2/3 N H₂SO₄ R (Type B) 15 ml cap., containing 5 ml H₂O S (Type B) 15 ml cap., containing 5 ml standard X (Type B) 15 ml cap. Phenolphthalein (Type B), containing 2.0 ml phenolphthalein Borax (Type B), containing 3 ml borax solution Naphthoquinone (Type A), containing 15 mg naphthoquinone in chamber A and 3.0 ml H₂O in chamber B Acid formaldehyde (Type B), containing 3 ml acid formaldehyde reagent Sodium thiosulfate (Type B), containing 3 ml sodium thiosulfate
Protometer	Protometer Syringe (Type B) 1 ml cap. Lense papers
Albumin	Syringe R (Type B) 5.2 ml cap., containing 5 ml dye solution S (Type B) 5.2 ml cap., containing 5 ml dye solution X (Type B) 5.2 ml cap., containing 5 ml dye solution Standard (Type B), containing 0.2 ml albumin standard

Table 9-5 (Continued)

Kit	Description
Creatinine	Syringe A (Type B) 8 ml cap., containing 3.0 ml H₂O + 2 ml 2/3 N H₂SO₄ R (Type B) 5 ml cap., containing 3.0 ml H₂O S (Type B) 5 ml cap., containing 2.0 ml H₂O X (Type B) 5 ml cap. Standard (Type A), containing 0.2 ml stock standard in chamber A and 19.8 ml H₂O in chamber B Picric acid (Type B), containing 3 ml picric acid NaOH (Type B), containing 3 ml 0.75 N NaOH
Bilirubin	Syringe R (Type B) 8 ml cap., containing 3.6 ml H₂O X (Type B) 8 ml cap., containing 3.6 ml H₂O Diazo blank (Type B), containing 2 ml 1.5% HCl Diazo reagent (Type A), containing 0.1 ml 0.5% sodium nitrite in chamber A and 3.3 ml sulfanilic acid
Uric Acid	Syringe A (Type D) 5 ml cap., containing 4.0 ml H₂O and 0.25 ml 2/3 N H₂SO₄ R (Type B) 2.5 ml cap., containing 1.5 ml H₂O S (Type B) 2.5 ml cap., containing 1.5 ml standard solution X (Type B) 14% Na₂ CO₃ (Type B), containing 1.5 ml 14% Na₂ CO₃ Phosphotungstic acid (Type B), containing 1.5 ml phosphotungstic acid reagent
Fat Tolerance	Syringes 1, 2, 3, 4, 5, 6, 7, 8, 9 (Type B) 2 ml cap., containing 1.5 ml saline-phenol reagent R1 (Type B), containing 1 ml standard No. 1 R2 (Type B), containing 1 ml standard No. 2 R3 (Type B), containing 1 ml standard No. 3
Lactic Acid	<u>Kit A</u> Syringe R (Type B) 2.0 ml cap., containing 2.1 ml glycine semicarbazide buffer + 0.15 ml H₂O S (Type B) 2.0 ml cap., containing 2.1 ml glycine semicarbazide buffer X (Type B) 2.0 ml cap., containing 2.1 ml glycine semicarbazide buffer Lactate standard (Type A) 2.5 ml cap., containing 0.5 ml stock standard in chamber A and 2.0 ml H₂O in chamber B DPN (Type A) 1 ml cap., containing DPN powder in chamber A and 1 ml H₂O in chamber B <u>Kit B</u> Syringe LDH (Type B) 0.5 ml cap., containing 0.3 ml LDH solution
Urea Nitrogen	Syringe R (Type B) 10.2 ml cap., containing dried urease S (Type B) 10.2 ml cap., containing dried urease X (Type B) 10.2 ml cap., containing dried urease Standard (Type B), containing 0.1 ml standard solution Buffer (Type B), containing 0.6 ml pH 6.5 buffer Phenol color reagent (Type B), containing 3.0 ml phenol color reagent Alkali hypochlorite (Type B), containing 3.0 ml alkali hypochlorite 20 µl Micro-sampler
Glucose Tolerance	Syringes A1, A2, A3, A4, A5 (Type B) 10 ml capacity F1, F2, F3, F4, F5 (Type A) 2 ml cap., containing dry powder in chamber A and 1.0 ml H₂O in chamber B R1, R2, R3, R4, R5 (Type B) 2 ml cap., containing 0.5 ml H₂O S1, S2, S3, S4, S5 (Type B) 2 ml cap., containing 0.5 ml standard X1, X2, X3, X4, X5 (Type B) 2 ml cap. C L (Type B), containing 2.5 ml zinc sulfate N (Type A), containing dried glucostat in chamber A and 7.5 ml H₂O in chamber B O (Type B), containing 1.5 ml 5 N HCl Bag D and E 0.05 ml Micro-sampler

Table 9-5 (Continued)

Kit	Description
Endoradiosonde	Endoradiosonde pill
Alkaline Phosphatase	<u>Kit A</u> Syringe R (Type B) 20 ml cap., containing 1 ml frozen substrate X (Type B) 20 ml cap., containing 1 ml frozen substrate <u>Kit B</u> Syringe NaOH, containing 10 ml 0.02 N NaOH Apparatus M, containing HCl gas Apparatus N, containing HCl gas
Catecholamines	Syringe A (Type B) 15 ml cap. C (Type B) 20 ml cap. L (Type A), containing 10 mg ascorbic acid powder in chamber A and 5 ml 18% NaOH in chamber B M (Type B) 25 ml cap. R (Type B) 7 ml cap. S (Type B) 7 ml cap. X (Type B) 7 ml cap. N (Type B), containing 0.5 ml dilute standard O (Type B), containing 3.0 ml acetate buffer P (Type B), containing 0.3 ml potassium ferricyanide Q (Type B), containing 3.0 ml 20% NaOH 0.1 ml Micro-sampler
PBI	Syringe R (Type B) 12.5 ml cap., containing 0.2 ml H₂O S1 (Type B) 12.5 ml cap., containing 0.2 ml standard solution S2 (Type B) 12.5 ml cap., containing 0.2 ml standard solution S3 (Type B) 12.5 ml cap., containing 0.2 ml standard solution X (Type C) 12.5 ml cap., containing 5 ml 5% TCA TCA (Type B) 5 ml cap., containing 5 ml 5% TCA Chloric acid (Type B), containing 15 ml chloric acid Sodium chromate (Type B), containing 0.5 ml sodium chromate Sulphuric acid (Type B), containing 50 ml 1- NaCl in N H₂SO₄ Arsenious acid (Type B), containing 10 ml arsenious acid Ceric sulphate (Type B), containing 2.5 ml 2% ceric sulphate
Urine Protein	Syringe R (Type B) 6 ml cap., containing 1 ml H₂O S (Type A) 6 ml cap., containing dried standard in chamber A and 4 ml H₂O in chamber B X (Type B) 6 ml cap. TCA (Type B), containing 3 ml 12.5% trichloroacetic acid
Reticulocyte Count	WBC pipette attached to syringe Fluid collection device for staining apparatus Syringe (Type B with needle attached), containing 1 ml Wright's stain Syringe (Type B with needle attached), containing 2 ml pH 6.4 buffer 2 slides Dye syringe, (Type B), containing 0.5 ml 0.3% brilliant cresyl blue in saline
WBC Differential Count	Fluid collection device for staining apparatus 2 syringes (Type B) Glass slide Syringe (Type B with needle attached), containing 1 ml Wright's stain Syringe (Type B with needle attached), containing 2 ml pH 7.4 buffer
Cell Counting	Sterile swab Lancet Pipet attached to syringe (Type B), 5 ml cap
Micro-Hematocrit	Hematocrit cell Syringe (Type B), containing 1 ml saline-acetone wash solution Vacuum cuvette

Table 9-5 (Continued)

Kit	Description
Red Cell Survival	Syringe (Type B) 15 ml cap., containing anticoagulant and Cr ⁵¹ Syringe (Type B), containing ascorbic acid 8 syringes (Type B), containing ammonium potassium oxalate 8 sterile swabs
Hemoglobin	Sterile swab Lancet Pipet attached to syringe S Syringe S (Type B), containing 1 ml standard solution Syringe D (Type B) 6 ml cap., containing 6 ml Drabkin's Reagent
Leukocyte Phagocytic Activity	Sterile swab Lancet Pipet attached to syringe Syringe (Type B), containing 2 ml iron-starch solution Electromagnet
Bleeding Time	Sterile swab Lancet Filter paper
Coagulation Time	2 blood-collecting syringes (Type B) 2 ml cap. Clot-timer
Clot Retraction Time	Timer Clot retraction tube
Culture	12 sterile collecting swabs 12 culture chambers, containing microbial medium 6 culture chambers, containing mycological medium
Creatine	Syringe A (Type B) 8 ml cap., containing 3.0 ml H ₂ O + 2.0 ml 2/3 N H ₂ SO ₄ Syringe R (Type B) 7 ml cap., containing 6 ml H ₂ O Syringe S (Type B) 7 ml cap., containing 5 ml H ₂ O Syringe X (Type B) 7 ml cap., containing 0.25 ml 0.75 N NaOH Syringe B (Type B) 6 ml cap.
17-Keto	Syringe A (Type B) 10 ml cap. R (Type B) 3.4 ml cap. S (Type B) 3.4 ml cap., containing 25 µg dried standard DNB (Type A) 1 ml cap., containing 11.6 mg m-dinitro-benzene in chamber A and 0.8 ethanol in chamber B Ethanol (Type B), containing 9 ml absolute ethanol
Blood Collection	Tourniquet Sterile swabs Blood-collecting device (holder, needle, tubes S and B) Syringe S (Type B) 25 ml cap.

Table 9-6

REAGENT SUPPLY REQUIREMENTS

Reagent	Volume	Exper. No.	Parameter
Zinc Sulfate, 10%	0.5 ml	0113	Glucose Tolerance
Sodium Hydroxide, 0.5 N	0.5 ml		
Standard Solution (Glucose)	0.5 ml		
Glucostat	4.5 ml		
HCl 5N	0.15 ml		
Trichloroacetic Acid, 12.5%	2.0 ml	0117	Urinary Protein
Standard Protein, 0.25 mg/ml	4.0 ml		
Acetic Acid	2.0 ml	0117 0112	17-Hydroxycorticosteroids
Sodium Acetate	2.0 ml		
Penicillin - Glucoronidase	2.0 ml		
Na OH, 0.1 N	10.0 ml		
HCl, 0.1 N	5.0 ml		
Sodium Sulfate	3.0 g		
Florisil	7 mm diam. column		
4% Methanol in CH Cl ₃	25.0 ml		
25% Methanol in CH Cl ₃	45.0 ml		
Methanol	4.0 ml		
Blank	13.0 ml		
Phenylhydrazine (color reagent)	6.0 ml		
CH Cl ₃	110.0 ml		
17-Hydroxycorticosteroid . Standard	1.0 ml		
Stock Dye Solution	1.0 ml	0117 0112	Calcium Serum
1.0 N NaOH	49.0 ml		
Calcium, Standard	0.2 ml		
Stock Dye Solution	1.0 ml		Calcium Urine
1.0 N NaOH	49.0 ml		
Calcium Standard	0.2 ml		
Concentrated HCl			
Iron Starch Solution	10 g solution of starch in 200-ml-iso- tonic NaCl 20 g powered Mon.	0119	Leukocyte Phagocytic Activity
Drabkin's Reagent		0118	Hemoglobin

Table 9-6 (Continued)

Reagent	Volume	Exper. No.	Parameter
Urease	90.0 μ g	0113	Urea Nitrogen
Buffer Solution, pH 6.5	0.6 ml		
Phenol Color Reagent	3.0 ml		
Alkali-Hypochlorile	3.0 ml		
Urea, Standard	0.02 ml		
WBC Diluting Fluid	5.0 ml	0118	WBC and RBC Total
Uranyl Acetate, 0.4%	6.0 ml	0112	Sulfates, Serum or Urine
Glacial Acetic Acid	1.5 ml		
Benzidine 1% in Ethanol	13.5 ml		
Alcohol	4.5 ml		
Alcohol-Ether Wash	30.0 ml		
Sodium Borate	1.5 ml		
Naphthoquinone	27.5 ml		
Acetone	3.0 ml		
Sulfate, Standard Solution	0.5 ml		
Phosphate Acetate Buffer	11.5 ml	0112	Manganese, Serum
Malachite Green	1.5 ml		
Manganese, Standard	0.6 ml		
HCl 1N	1.5 ml		
NaOH 1N	2.25 ml		
Sodium Periodate, 0.5%	1.5 ml		
H ₂ SO ₄ 2/3N	3.0 ml	0112	Magnesium Serum
Sodium Tungstate, 10%	3.0 ml		
Na OH 4N	3.0 ml		
Titan Yellow	1.5 ml		
PVA 0.05% Polyvinyl Alcohol	3.0 ml		
Magnesium, Standard	2.0 ml		
Saline Acetone Solution	1.0 ml	0118	Hematocrit
Human Whole-Blood, Standard and Control	0.1 ml		
Physiological Saline	0.1 ml		
Absolute Methanol	10.0 ml	0113	Bilirubin, Serum
Diazo	1.0 ml		
Diazo, Blank Solution	1.0 ml		
Sulfanilic Acid	10.0 ml		
Sodium Nitrate	1.0 ml		
H ₂ SO ₄ , 30%	1.0 ml	0112	Zinc, Serum
HNO ₃ Concentration	1.0 ml		
HCl O ₄ Concentration	1.0 ml		
NH ₄ OH Concentration	1.0 ml		
Cyanide Solution	1.5 ml		
Buffer Solution pH 9.0	7.5 ml		
Zicon	4.5 ml		

Table 9-6 (Continued)

Reagent	Volume	Exper. No.	Parameter
Chloral Hydrate	4.5 ml	0113	Uric Acid, Serum
Zinc Standard Solution	3.0 ml		
H ₂ SO 2/3 N	0.5 ml		
Sodium Tungstate, 10%	0.5 ml		
Na ₂ CO ₃ , 14%	3.0 ml		
Phosphotungstic Acid	3.0 ml	0112,	Inorganic Phosphorus Serum
Trichloroacetic Acid, 30%	2.0 ml		
Ammonium Molybdate	0.6 ml	0117	
p-Semidine	6.0 ml		
Phosphorus, Standard	1.0 ml		
Phenol Salt	1.8 ml	0113	Fat Tolerance
Heparin	0.1 ml	0118	Red Cell Survival
Cr ⁵¹ Na ₂ CrO ₄	100.0 μ c		
Ascorbic Acid	50.0 mg		
Ammonium-Potassium Oxadate	1.0 gm		
Uranyl Zinc Acetate	3.0 ml	0112	Sodium, Serum and Urine
Ethanol, 95%	6.0 ml		
Trichloroacetic Acid, 10%	2.0 ml		
Sodium, Standard	0.5 ml		
Castor Oil Test Tube	1 ea.	0120	Bleeding, Coagulation, and Clot Retraction Times
Brain-Heart Infusion Culture Vessels	2 ea.	0121	Collection and Culture of Microorganisms
Mycological Broth Culture Vessels	1 ea.		
Wright's Stain	2.0 ml	0118	Platelet Count, Differential White Cell Count
Buffer Solution, pH 7.5	3.0 ml		
Brilliant Cresyl Blue, 0.3%	2.0 ml	0118	Reticulocyte Count
Wright's Stain	2.0 ml		
Buffer Solution, pH 6.4	2.0 ml		
NaCl, 0.85%	4.5 ml	0113	Mucoproteins
Perchloric Acid, 1.8 M	2.5 ml		
Phosphotungstic acid, 5% 2N HCl	1.0 ml		
Ethanol, 95%	5.0 ml		
NaOH 0.1 N	0.5 ml		
Protein, Standard Solution	0.5 ml		
Orcinol, 2% in 30% H ₂ SO ₄	3.75 ml		
H ₂ SO , 60%	22.5 ml		
Trichloroacetic Acid, 10%	1.0 ml	0112	Potassium, Serum and Urine

Table 9-6 (Continued)

Reagent	Volume	Exper. No.	Parameter
Sodium Tetraphenylboron, 3% buffered	3.0 ml	0113	Amino Acid Nitrogen, Plasma
Potassium, Standard Solution	5.0 ml		
H ₂ SO ₄ 2/3 N	0.5 ml		
Sodium Tungstate, 10%	0.5 ml		
Phenolphthalein Indicator	0.2 ml		
NaOH 0.1 N		0113	Creatinine, Serum
Borax Solution, 2%	3.0 ml		
Naphthoquinone	3.0 ml		
Acid Formaldehyde	3.0 ml		
Sodium Thiosulfate	3.0 ml		
Amino Acid Standard	5.0 ml		
Sodium Tungstate, 10%	1.0 ml		
H ₂ SO ₄ 2/3 N	2.0 ml		
Picric Acid 0.04 M	3.0 ml		
NaOH 0.75 N	3.0 ml		
Creatinine Standard Solution	1.0 ml	0113	Proteins, Serum
Dilute, Standard Solution	1.0 ml		
NaOH, 6%	7.5 ml		
Biuret	3.0 ml		
Protein, Standard	2.5 ml		
Methyl Orange Dye Solution	15.0 ml		
NaCl, 0.85%	0.2 ml		
Albumin, Standard	0.2 ml		
Buffer Substrate	2.0 ml		
NaOH 0.02 N	10.0 ml	0117	Alkaline Phosphatase, Serum
Conc HCl	0.1 ml		
Sulfuric Acid 6N			
Sodium Carbonate, 14%			
Activated Alumina Alcoa F-20			
Sodium Acetate Trihydrate 0.2 M	25.0 ml		
Acetic Acid 0.2 M	20.0 ml		
Acetate Buffer	3.0 ml		
Potassium Ferricyanide, 0.25%	0.3 ml		
Sodium Hydroxide, 20%	5.5 ml		
Ascorbic Acid, 2.0%	0.5 ml	0117	Catecholamines, Urine
Ascorbic Acid-Sodium Hydroxide			

Table 9-6 (Continued)

Reagent	Volume	Exper. No.	Parameter
Catecholamine, Standard			
Dilute, Standard			
0.2 M Glycine - 0.2 M Semi-carbide, pH 10	4.2 ml	0113	Blood Lactic Acid
0.02 M DPN	0.9 ml		
LDH	0.6 ml		
Lithium Lactate, Standard	1.0 ml		
Dilute Lactate, Standard	0.1 ml		
Chloric Acid 28%	15.0 ml	0117	PBI
Sodium Chromate Solution, 0.4%	0.5 ml		
Arsenious Acid 0.2 N	10.0 ml		
1% NaCl in 1N H ₂ SO ₄	50.0 ml		
Trichloroacetic Acid, 5%			
Standard (1) 0.01 µg Iodine 10.2 ml	0.2 ml		
(2) 0.02 µg Iodine 10.2 ml	0.2 ml		
(3) 0.03 µg Iodine 10.2 ml	0.2 ml		
Ceric Sulfate, 2%	2.5 ml		
H ₂ SO ₄ 2/3 N	0.1 ml	0113	NPN Blood
Sodium Tungstate, 10%	0.1 ml		
H ₂ SO ₄ , 30%	0.3 ml		
Phenol Color	3.0 ml		
Alkali Hypochlorite	3.0 ml		
Na OH 1N	3.0 ml		
NPN Standard	0.5 ml		

(Reagents for 1 determination only)

Table 9-7

SPECTROPHOTOMETER FILTER REQUIREMENT

Parameters	Filter (m μ)
Lactic Acid	340
17-OH, Alkaline Phosphatase, Glucose	410
PBI, Urine Protein	415
Sodium	430
Amino Acid N	470
Sulfates	485
Mucoprotein, Creatinine, Creatine, 17-K	520
Hemoglobin	530
K, Mg, Bilirubin	540
Albumin	550
Mn, Zn	620
Ca, NPN, BUN	630
Fat	650
Uric Acid	710
Phosphates	770
Catecholamines	5970/3387 (fluorometer)

conclusively demonstrated as reliable and valid performance predictors, and that there are several advantages to be gained in their application. First, it will (in all probability) result in higher user acceptance by the astronauts as compared to the use of synthetic tasks. Second, the operational-like tasks (e.g., fuel management, re-entry, and/or spacecraft attitude stabilization) can be utilized not only perform performance prediction on system tasks but also to aid in maintaining skills and knowledge previously learned in simulators.

If, however, this concept cannot be demonstrated as valid and reliable, synthetic tasks (e.g., non-operational in nature or equipment configuration) may have to be employed. Synthetic equipment requirements, in general, will be the same. However, the layout, equipment configuration, and procedural tasks will be dissimilar from those required for operationally-oriented tasks.

With respect to availability, equipment required for Experiment 0201 is relatively well defined and currently available in laboratory model configurations. Equipment requirements for Experiments 0202 and 0203 vary as previously discussed. In general, the synthetic task approach for performance prediction of psychomotor functioning and higher mental processes requires slightly less equipment and panel area.

Equipment utilized in the study for the conduct of the behavioral experiments is described in the following paragraphs.

Oculometer. An oculometer is currently being built for NASA and may be flight-tested in Gemini. Tests to be performed with the oculometer include those to determine visual acuity, phoria, depth perception, and color discrimination.

The essential elements of such a device are illustrated in Fig. 9-50. They include eyepieces to correct the apparent distance to the subject at near and far points, illumination, and a set of displays incorporated into cards or films. In addition to these essential elements, there are additional requirements for the performance of reliable tests. The distance between the axes of the eyepieces and the displays should be adjustable to accommodate the interpupillary dimensions of the various subjects. If the eye test is performed in a motion chair, it will be necessary to move the displays and light the lamps from a remote position. To achieve such flexibility, the displays can be placed on 70 mm film on motor-driven reels.

The film can move horizontally and the subject will view two adjacent frames. Some excess will be required between frames to provide a loop to accommodate the interpupillary adjustment. The displays will be numbered so that the subject can state the

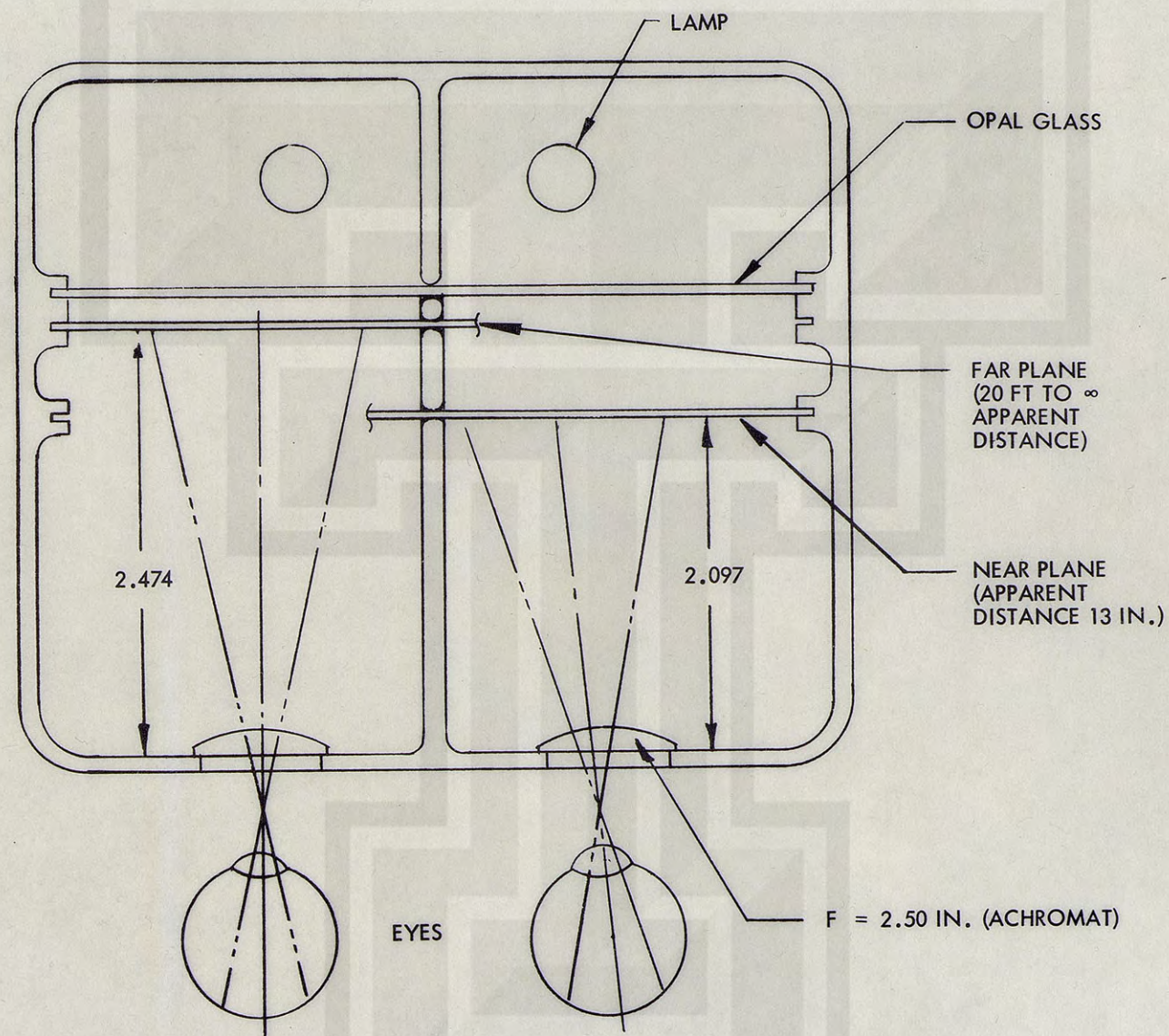


Fig. 9-50 Oculometer

number when he reports what he sees on any display. A mounting bracket is required to attach the oculometer to the biometric console.

Audio Tapes. Special audio tapes can be developed which will operate on the spacecraft audio tapedeck. The tapes will be programmed with intensity and pitch test patterns and, in addition, can include the clipped messages suggested in Experiment 0203. Each tape will have a different test pattern, and both sides will be programmed with test stimuli. The audio tapes will be channeled through the on-board tape deck to the audio patch center leading to a headphone jack in the biometric console. Special ear/head contour cups will be provided for the headphone set to minimize noise in the ear canal. The test pattern tone frequency range is 100 to 16,000 cps, and intensities are of 20 to 100 db, re:0.0002 dyne/cm².

Pressure Suit. In all probability, the Apollo Block-II pressure suit will be utilized for the AAP. This study utilized a G-3C Gemini full-pressure suit in a vented mode, visor up, and gloves off (Fig. 9-51). The suit weighs approximately 25 lb and is of multilayer construction. It is fitted with a crotch-to-shoulder vertical zipper for donning or doffing and includes a special zipper seal. The boots are integral with external straps for tightening. The helmet, attached to the suit by a mechanically locking neck ring, is intimately fitted, and is able to swivel (as the head is turned) by means of bearing surfaces on the pressure seal of the neck ring. Gloves are connected to the suit sleeves with pressure-sealed, mechanically locking, metal rings equipped with bearings to allow rotation.

Although a bioinstrumentation package is an integral part of the suit, it was not utilized in the study because the physiological experiment equipment was not designed for use with this suit.

Performance Panel. The performance panel is a composite of equipment identical to a portion of the main display and control panel of the current Apollo configuration, supplemented by several ancillary displays and controls. Several panel layout and equipment recommendations have been identified for this panel. The panel includes a



Fig. 9-51 Gemini Full-Pressure Suit (G-3C) Utilized in the Study (Visor Up, Gloves Off, Vented Mode)

CRT, flight-attitude indicator, and numerous displays (e.g., indicator lamps, speaker, and meters) and controls (e.g., push buttons, switches, and joystick). A computer entry keyboard is provided in the sloped panel area in addition to the timer and joystick.

Figure 9-52 illustrates the present configuration of the main display and control panel of the Apollo CM. It is suggested that the display/control portion of the panel associated with an operational task (e.g., reentry, fuel management, and/or spacecraft attitude stabilization) be included on the behavioral panel. Incorporation of this design concept is contingent upon a conclusive demonstration that an operational task is suitable for the monitoring of the fine motor, continuous processes, and discrete processes parameters of Experiment 0202. If it is also demonstrated that an operational task is suitable for measurement of the parameters of Experiment 0203 (higher mental processes), the panel can serve a dual function.

As previously indicated, operational tasks are somewhat more desirable than synthetic tasks because of significantly greater user acceptance and their potential use as a tool for maintaining previously developed skills and levels of training. However, synthetic tasks may have to be implemented if the operational task concept does not produce reliable and valid measurements. The equipment associated with the synthetic tasks will basically be composed of a CRT, flight-attitude indicator, push button matrix meters, digital time readout, computer entry keyboard, earphones, and joystick. In addition, a speaker will be incorporated in the panel to provide auditory stimuli.

9.5 BIOMEDICAL EQUIPMENT WEIGHT, POWER, AND VOLUME

Equipment characteristics of weight, power, and volume are presented in Tables 9-8, 9-9, and 9-10. These data are preliminary in nature since many of the items have not yet been developed. In order to provide information on such items, two approaches were utilized. Inquiry was made of LMSC engineering personnel, and discussions held with cognizant design and fabrication personnel concerning preliminary conceptual sketches and descriptions prepared for use as a basis for determining gross engineering

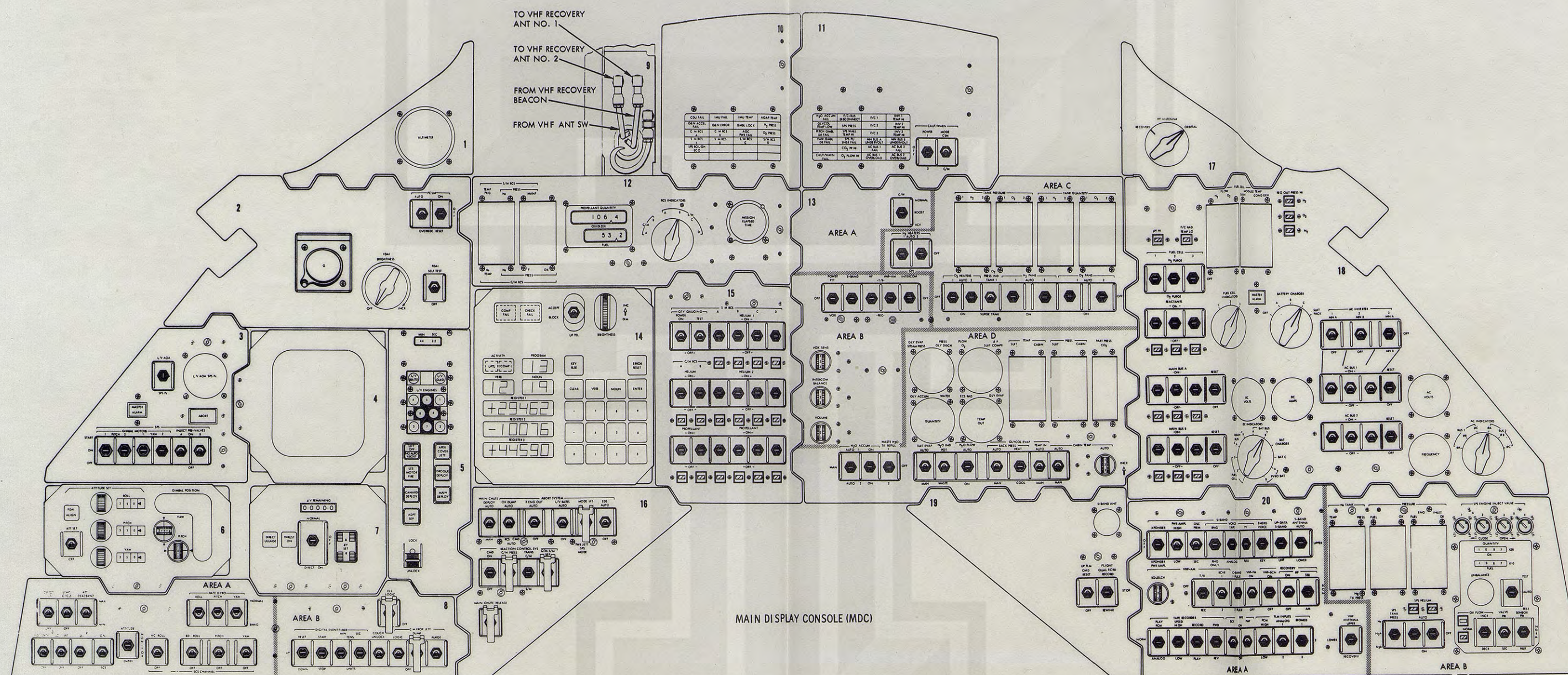


Fig. 9-52 Main Display and Control Panel Configuration of Apollo Command Module

Table 9-8

PHYSIOLOGY EQUIPMENT PROFILE

Equipment	Estimates Per Unit (Unless Otherwise Stated)		
	Weight (lb)	Power (w)	Volume, Stored (cu in.)
Cardio Kit			
Signal Conditioners			
Electrocardiograph (Apollo ECG)	0.15	0.1	1.7
Impedance Pneumograph (Apollo ZPN)	0.15	0.1	1.5
Oral Temperature (Gemini Oral Temp.)	0.15	0.1	1.5
Body Skin Temperature (Apollo)	0.15	0.1	1.5
Blood Pressure (Modified Gemini BP)	0.15	0.1	1.5
Impedance Cardiograph (Apollo ZCG)	0.15	0.1	1.5
Phonocardiograph (Apollo PCG)	0.15	0.1	1.5
Capacitance Plethysmograph (CPG)	0.15	0.1	1.5
Electromyograph (EMG)	0.15	0.1	1.5
DC-DC Converter (Apollo d-c Converter)	0.15	0.32	1.5
Sensors			
Electrodes & Packaging Kit (25 Electrodes, Including Spares)	0.23	—	12
Thermistor Probe (Oral)	0.03	—	0.4
Body-Temperature Thermistor Probes & Vest	0.6	—	40
B.P. Cuff, Microphone, and Actuating Device	0.8	—	54
ZCG Band Electrodes	0.3	—	38
PCG Microphone	0.02	—	0.5
CPG Mesh Cuff and Calibration Device	0.5	—	50
Other			
Electrode Skin Preparing Apparatus	0.25	—	7
Sensor Harnesses, Signal Conditioner Belt, & Umbilical Cable	1.5	—	50
Total Cardio-Kit Subsystem	5.73	1.22	268
Pulmonary Kit			
Face Mask, Tubes, and Valves	1	—	100
Ear Oximeter	0.25	0.1	2.5
Total Pulmonary-Kit Subsystem	1.25	0.1	103
Biometric Console, Physiology			
Mass Spectrometer	35	1.2	1,000
or Gas Analyzer	3	0.9	50
Flowmeter	1	0.5	15
or Gas Volume Detector	5	5.0	400
Rebreathing Reservoir and Pneumatic Plumbing	3	—	224
Physiology Panel Subsystem (Less Computer and Respiratory-Analyzer Subsystem)	72	50	4,600
Physiological Conditioning Equipment			
Ergometer	25	0	3,230
LBNP Device	20	1	3,500
Neck Cuff Device	2	1	340
Occlusion Cuff	3	1	375
Physiological Monitoring and Support Equipment			
Urine Collection System	35	15	1,981
Thermal Suit and Support Equipment	35	0	750
Motion Chair	40	15	3,612
Strength Measurement Device	4	0	90
Endoradiosonde Pills	0.005	0	0.01
Goggles and Fiber-Optics Bundle	1.5	25	160
TV Camera (On-Board, Not Included in Profile)	(10)	(50)	(200)
Cameras and Film (On-Board, Not Included in Profile)	(7)	(0)	(1,500)
Scintillation Counter (Including RISA & Tritiated H ₂ O)	25		
Bone Densitometer	20	15	384
Computer	20	150	448
Total	356.48		

Table 9-9

MICROSCOPY/CHEMISTRY EQUIPMENT PROFILE

Equipment	Weight (lb)	Power (w)	Volume, Stored (cu in.)
Micro-Chem Station (Installed Equipment)			
Centrifuge	8	15	800
Spectrophotometer	5	8	160
Fluorometer	5	10	140
pH and pCl Controls	1	1	40
Particle Counter	1.5	3	60
FM Receiver	2	5	0.05
Reagents (One Series of Experiments)	1.01	0	20
Sonic Mixer	0.4	2	14
Temperature Blocks	10	20	108
Timers	0.5	10	12
Console Panel and Electronic Wiring	23	—	1,620
Micro-Chem Equipment			
Protometer	0.2	0	10
Telemicroscope	5	15	864
Cameras and Film (On-Board, Not Included in Profile)	(7)	(0)	(1,500)
Clot Timer	0.4	1	5
Electromagnet Trap	0.1	2	1
Staining Apparatus	0.1	0	5
Electronic Hematocrit	0.5	1.0	12
Experiment Kits (Syringes, Micro-Samplers, Manipulation Devices, Reagents, etc. for One Series of Experiments)	14.9	0	645
Lyophilizer (Not Used in Presently Defined Experiment Procedures)	(10)	(10)	(160)
Total	63.22		

Table 9-10

BEHAVIORAL EQUIPMENT PROFILE

Equipment	Weight (lb)	Power (w)	Volume, Stored (cu in.)
Oculometer	4	28	600
Audio Tapes	1	20	36
Pressure Suit (On-Board, Not Included in Profile)	(32)	(0)	(NA)
Performance Panel (Displays, Controls, Speaker, Microphone, and Timer)	65	100	4,460
Total	70		

estimates of weight, power, and volume. When necessary, other organizations were queried for the needed information. The data presented in Tables 9-8, 9-9, and 9-10 represent a composite of information based on equipment currently available or in development, and for which best engineering estimates had to be made. The values thus presented, are not, in general, similar to the equipment weight, power, and volume used in connection with the study, but are more representative of those which could be associated with prototype hardware.

9.6 DATA MANAGEMENT CHARACTERISTICS

The data management system proposed for the AAP spacecraft is required to provide a variety of data recording, storage, and transmission functions.

9.6.1 Biomedical Measurements

The system considered for AAP may measure as many as 175 to 200 biomedical quantities, the majority presented as voltages in the 4-nv or 5-v ranges or as keyboard input. The remainder may be presented in such forms as impedance variations, non-standard voltages, time intervals, or variations in light intensity. The combination of frequencies and numbers of quantities to be measured at any time should not exceed the

equivalent of 5×10^4 bits/sec. The schedule of measurement should be flexible, allowing variation in the quantities measured and their order and sample rates.

9.6.2 Data Computation

The system can compute derived quantities based on one or more measured quantities, according to instructions stored on digital tape or telemetered in digital form from earth, with provision for limited modification of the instructions by the on-board experimenter.

9.6.3 Telemetry and Recording

Measured and computed quantities for telemetry and/or magnetic tape recording can be prepared by adding synchronization, identification (format), and time information.

9.6.4 Data Receipt and Decoding

The system should be capable of receiving and decoding the up-link control, data, and information signals; generate the appropriate output signals; and route them to the control system, digital tape recorder, and/or display equipment. This function would be controlled by magnetic-tape stored-computer programs, as modified by the up-link telemetry data or according to options available to the experimenters through keyboard control.

9.6.5 Visual Information Detector

Visual information can be detected directly by the video camera or through the telemicroscope, in either of two modes - low-resolution TV or high-resolution facsimile. This function can include the recording, transmittal, and/or display of the information. Provision for incorporating time and audio signals should be included.

9.6.6 Audio Data

This function should provide flexible audio signal input, intercommunication, recording, communication with earth or EVA transceiver, and input to the video system.

9.6.7 Biomedical Equipment Data Management Profile

A data management profile is presented for those items of equipment associated with the microscopy/chemistry, physiology, and behavioral experiment series. Certain equipment may not exhibit a data management interface simply because the information is graphic or verbal in nature. The video camera has not been included in the profile since it is an on-board equipment item and is used for other than biomedical experiment purposes. The data management profile for the biomedical equipment is presented in Tables 9-11, 9-12, and 9-13.

9.7 EQUIPMENT DEVELOPMENT SCHEDULE AND STATUS

This section presents the estimated biomedical equipment development schedule and the current status of this equipment. Each experiment was analyzed and an equipment list prepared for the total biomedical experiment equipment package. Equipment items were reviewed to determine the current level of development status. The results of this analysis are presented in Tables 9-14, 9-15, and 9-16 for the equipment suggested in this study for conduct of the AAP in-flight biomedical program.

In order to determine equipment development status, inquiries were made of LMSC study team and other qualified personnel and to other organizations, where necessary.

As a result, the majority of equipment items can be positively identified in connection with a supplier. Certain items are government-furnished equipment or can be obtained from a variety of sources. In order to present this information in the most usable form, the experiments were grouped into logical categories, the measurement parameters

Table 9-11
MICROSCOPY/CHEMISTRY DATA MANAGEMENT PROFILE

Equipment	Data Format				Data Load			Data Acquisition Mode	
					Analog Signal Output (0 to 5 v)	Analog Code Outputs (0 to 5 v, 5% Accuracy)	Samples/Sec	Automatic	Manual
	Analog	Digital	Verbal	Graphic	Accuracy				
					1/4% 1%				
Spectrophotometer	X				X		4	5	X
Lyophilizer									
Temperature Blocks	X					X	2	1	
Particle Counter	X				X		4	5	X
pH & pCl Electronics	X				X		3	5	X
Centrifuge			X						
Timer									
Mixer									
Electronic Hematocrit	X				X		2	5	
FM Receiver	X				X		3	1	X
Endoradiosonde									X
Type A Micro-Sampler									
Type B Micro-Sampler									
Absorption Column									
Reagent Bottles									
Reagent Ports									
Gaseous Reagent Addition Device									
Staining Apparatus									
Culture Chambers				X				X	
Electromagnetic Trap									
Syringe, Type A				X					
Syringe, Type B				X					
Syringe, Type C				X					
Syringe, Type D				X					
Clot Timer	X							1	X
Protometer	X							1	X
Microscope				X				1	X

Table 9-12 Physiology Data Management Profile

M-61-64-1
Vol. VI

Measured Parameters	Equipment	Data Format				Data Bandwidth (cps)	Required Amplitude Accuracy (% of full scale)	Data Acquisition Mode	
		Analog (0 to 5 v)	Digital	Verbal Supplement	Graphic			Auto	Manual
Electrocardiogram	Cardio Kit	X				0.2 to 100	5	X	
Heart Rate		X	and/or	X		0 to 5	1	X	
Impedance Pneumogram	Cardio Kit	X				0.05 to 10	5	X	
Respiration Rate		X	and/or	X		0 to 2	1	X	
Oral Temperature	Cardio Kit	X				0 to 1	1	X	
Body Skin Temperature	Cardio Kit	X				0 to 1	1	X	
Cabin Temperature	Spacecraft ECS				X	0 to 1	1		X
Blood Pressure	Cardio Kit	X				0 to 100 (incl. Korotkow sounds)	4	X	
Impedance Cardiogram	Cardio Kit	X				0.1 to 40	2	X	
Phonocardiogram	Cardio Kit	X				20 to 700	5	X	
Cardiac Output		X	and/or	X		0 to 1	2	X	
Capacitance Plethysmogram	Cardio Kit	X				0.1 to 40	2	X	
Electromyogram	Cardio Kit	X				10 to 1,000	5	X	
Lower Body Negative Pressure	LBNP Device	X	and/or	X		0 to 0.1	2	X	
Neck Cuff Pressure	Neck Cuff Device	X	and/or	X		0 to 0.1	2	X	
Occluding Cuff Pressure		X	and/or	X		0 to 0.1	2	X	
Work Output	Tach.	X	and/or	X	X	0 to 2	2	X	
(Ergometry)	Ergometer Watt-Meter	X	and/or	X		0 to 2	2	X	
Body Mass	Motion Chair	X		X	X	10 to 100	0.5	X	
Physical Appearance	TV, Photo. (PAT)			X	X				X
Lung Gas Flow Rates	Pulmonary Kit	X				0 to 10	1	X	
Lung Volumes	(Flow Integrator	X				0 to 10	1	X	
He Concentration	Pulmonary Kit (Mass Spec.)	X				0 to 10	1.5	X	
O ₂ Concentration	Pulmonary Kit (Mass Spec.)	X				0 to 10	1.5	X	
CO ₂ Concentration	Pulmonary Kit (Mass Spec.)	X				0 to 10	1.5	X	
Arteriolar O ₂ Saturation	Pulmonary Kit (Oximeter)	X	and/or	X		0 to 5	2	X	
Eye/Head Movements	Fiber Optics, Test Goggles & Video	X		X	X	0 to 10	1.5	X	
Gastrointestinal Status	Endoradiosonde Pill	X				10 to 1,000	5	X	
Force Output	Strength Measurement Device			X	X				X
None	Urine Collection System			X	X				X
None	Thermal Suit and Support Equipment			X	X				X
Plasma Volume Total Body Water	Scintillation Counter			X	X				X
Mineral Density	Bone Densitometer			X	X				X

Table 9-13

BEHAVIORAL DATA MANAGEMENT PROFILE

Equipment	Data Format				Data Bandwidth	Required Amplitude Accuracy (% of Full Scale)	Data Acquisition Mode	
	Analog (0 to 5 v)	Digital	Verbal	Graphic			Auto	Manual
Oculometer				X				X
Audio Tapes			X		100 to 16,000 cps	0.5		X
Pressure Suit			X	X				X
Performance Panel	X	X			Milli-seconds (maximum)	1.0	X	

specified, equipment for each experiment identified, the development time indicated, and the suggested supplier proposed. Table 9-17 summarizes this information. Each category is self-explanatory except, perhaps, for development time. Development time is defined as the total time required to initiate design, manufacture, test/check-out, and conduct acceptance, design approval, and qualification tests. Thus, the number of months indicated in the development time column represent the total time required to provide the first flight-qualified unit (to be used for the training or a baseline data-acquisition program).

Table 9-14

PHYSIOLOGY EQUIPMENT DEVELOPMENT STATUS IDENTIFICATION

Equipment	Off-Shelf Hardware	Qualification Stage	Development Stage	Breadboard Stage	Conceptual (Experimental) Stage
<u>Cardio Kit</u>					
Signal Conditioners					
Electrocardiograph (Apollo ECG)		X			
Impedance Pneumograph (Apollo ZPN)		X			
Oral Temperature (Gemini Oral Temp.)	X				
Body Skin Temperature (Apollo Body Skin Temp.)		X			
Blood Pressure (Modified Gemini BP)			X		
Impedance Cardiograph (Apollo ZCG)			X		
Phonocardiograph (Apollo PCG)		X			
Capacitance Plethysmograph (CPG)					X
Electromyograph (EMG-Modified Apollo ECG)			X		
DC-DC Converter (Modified Apollo DC Converter)			X		
Sensors					
Electrodes and Packaging Kit		X			
Thermistor Probe (Oral)	X				
Body Skin Temperature Probes and Vest					X
B. P. Cuff, Microphone, and Actuating Device			X		
ZCG Band Electrodes			X		
PCG Microphone		X			
CPG Mesh Cuff and Calibration Device					X
Other					
Electrode Skin Preparing Apparatus					X
Sensor Harnesses, Signal Conditioner Belt, and Umbilical Cable					X
Cardio Kit Subsystem					X
<u>Pulmonary Kit</u>					
Face Mask, Tubes and Valves					X
Ear Oximeter					X
Pulmonary Kit Subsystem					X
<u>Biometric Console, Physiology Section</u>					
Mass Spectrometer (or Gas Analyzer)			X		
Flowmeter (or Gas Volume Detector)			X		
Alternate Cardiac Output Measuring Equipment					X
Integrating, Rate, and Special-Purpose Computer					X
Respiratory Analyzer Subsystem					X
Oscilloscope, Eight-Channel, Storage, and X-Axis					X
Digital Readout Display		X			
Alarm Circuit				X	
Intercom	X				
Analog Limit Meters, Three (H. R., R. R., Ox)					X
Analog Meters (Two, C. O. and Wattmeter)	X				
Pressure Gages (Two)	X				
Pressure Regulators (Two)	X				
Data Routing and Control Matrix					X
Time-Code Generator and Digital Time Display	X				
Input Keyboard					X
Biometric Console Subsystem					X
<u>Physiological Conditioning Equipment</u>					
Ergometer			X		
LBNP Device			X		
Neck Cuff Device					X
Occlusion Cuff	X				
<u>Physiological Monitoring and Support Equipment</u>					
Urine Collection System					X
Thermal Suit and Support Equipment			X		
Motion Chair			X		
Strength Measurement Device				X	
Endoradiosonde Pill				X	
Goggles and Fiber Optics			X		
Scintillation Counter				X	
Bone Densitometer				X	

Table 9-15

MICROSCOPY/CHEMISTRY EQUIPMENT DEVELOPMENT STATUS IDENTIFICATION

Instrument	Off-Shelf Hardware	Qualification Stage	Development Stage	Breadboard	Conceptual (Experimental Stage)
Spectrophotometer			X	X	
Lyophilizer				X	X
Temporary Blocks			X		
Particle Counter			X	X	
pH & pCl			X	X	
Electronics					
Centrifuge					X
Timer		X	X		
Mixer		X	X		
Electronic			X	X	
Hematocrit					
FM Receiver		X	X		
Endoradiosonde					X
Type A Micro-Sampler					X
Type B Micro-Sampler					X
Absorption Column					X
Reagent Bottles					X
Reagent Ports					X
Gaseous Reagent					X
Addition Device					
Staining Apparatus					X
Culture Chambers					X
Electromagnetic					X
Trap					
Syringe Type A					X
Syringe Type B					X
Syringe Type C					X
Syringe Type D					X
Clot Timer				X	
Protometer		X			
Telemicroscope			X		

Table 9-16

BEHAVIORAL EQUIPMENT DEVELOPMENT STATUS IDENTIFICATION

Equipment	Off-Shelf Hardware	Qualification Stage	Development Stage	Breadboard Stage	Conceptual (Experimental Stage)
Oculometer			X		
Audio Tapes				X	
Pressure Suit		X	X		
Performance Panel					X

Table 9-17

BIOMEDICAL EXPERIMENT GROUP DEVELOPMENT SCHEDULE

Experiment Group	Measurement Parameters	Equipment	Development and Flight Qualification Time (months)	Manufacturer
<u>Group A</u> 0101 0102	Somatic Inversion Threshold Somatic Uprightness Threshold Ocular Counterrolling Visual Performance Bodily Sensations Susceptibility to Malaise Oculogravic Illusions Coriolis Illusion Nystagmus	Motion Chair Vision Goggles Fiber Optics Bundle Vision Test Targets	14 6 Available 3	LMSC Other Other LMSC
<u>Group B</u> (Cardiovascular) 0103 0106 0107 0108	ECG Heart Rate Respiration Rate Cardiac Contraction Strength Oral Temperature Volume Changes in Leg Blood Pressure Cardiac Output Lower Body Negative Pressure Clinical Observation (Syncope) Venous Distensability Neck Cuff Pressure Occlusion Cuff Pressure Work Output (Ergometry)	Cardio Kit Physiological Display/Control Panel in Biometric Station Lower Body Negative Pressure Device Neck Cuff Device Occluding Cuffs Ergometer	11 15 9 9 6 9	Spacelabs Spacelabs LMSC/D. Clark LMSC/D. Clark Beckman LMSC
<u>Group C</u> (Cardiopulmonary) 0104 0109 0110	ECG Heart Rate Respiration Rate Oral Temperature Blood Pressure Cardiac Output Work Output Clinical Observation Vital Capacity Tidal Volume Inspiratory Reserve Expiratory Reserve Respiration Rate He Clearance Rate (He, O ₂ & CO ₂ Concentration) Residual Volume Total Lung Capacity Gas Flow Rate Inspired O ₂ Inspired CO ₂ Expired O ₂ Expired CO ₂ Breath Holding Time Arteriolar Hemoglobin Saturation by O ₂	Cardio Kit Pulmonary Kit Physiological Display/Control Panel in Biometric Station Mass Spectrometer (if on-board unit not available) Ergometer	11 9 15 9 9	Spacelabs Spacelabs Spacelabs Consolidated Systems Corp. LMSC
<u>Group D</u> (Biochemical) 0111 (Partial) 0112 0113	Creatine Creatinine Sodium	Micro-Chem Station Console Centrifuge Spectrophotometer	22 22	Beckman

Table 9-17 (Cont.)

Experiment Group	Measurement Parameters	Equipment	Development and Flight Qualification Time (months)	Manufacturer
Group D (Biochemical) 0117	Potassium Chlorides Phosphates Alkaline Phosphatase Bicarbonate Mucoproteins Calcium Magnesium Zinc Sulfates Bone Density NPN BUN Uric Acid Glucose Tolerance Fat Tolerance Serum Proteins Amino Acid Nitrogen Blood Lactic Acid Bilirubin Respiratory Quotient Metabolic Rate Water Intake/Output Food Intake Urine & Feces Output PBI 17-Hydroxy-corticosteroids Catecholamines 17-Ketosteroids Urine Specific Gravity Urinary Proteins Urine pH	Fluorometer pH & pCl Controls FM Receiver Reagent Bottles & Ports Data-Entry Keyboard Sonic Mixer Temperature Blocks Timers Refractometer Experiment Kits Bone Densitometer Urine Collection System	22 10 6 12 8 9 10 9 9 3 18 15	Beckman LMSC LMSC
Group E (Cyto-Microbiological) 0118 0119 0120 0121	Hematocrit Reticulocyte Count RBC (total) WBC (total) WBC Differential RBC Cell Mass RBC Survival Hemoglobin Platelet Estimate WBC Motility and Phagocytic Activity Clotting Time Bleeding Time Clot Retraction Time Colony Counts Identifications, Microbiological	Micro-Chem Station Console Centrifuge Spectrophotometer Particle Counter Reagent Bottles & Ports Data-Entry Keyboard Sonic Mixer Temperature Blocks Timers Telemicroscope Camera-35mm (on-board) Clot Timer Electromagnetic Trap Staining Apparatus Electronic Hematocrit Experiment Kits	22 22 22 12 8 9 10 9 13 Avail 11 10 5 9 3	Beckman LMSC GFE Beckman
Group F (Behavioral) 0201 0202 0203	Vision Brightness Acuity Depth Perception Form Discrimination	Oculometer Audio Tapes Performance Panel Pressure Suit	9 4 15 Avail.	Scripps Institute LMSC LMSC GFE

Table 9-17 (cont.)

Experiment Group	Measurement Parameters	Equipment	Development and Flight Qualification Time (months)	Manufacturer
Group F (Behavioral) 0203	(Continued) Vision Phoria Audition Intensity Pitch Kinesthesia (Meas. in 0101 & 0102) Orientation (Meas. in 0101 & 0102) Gross Motor Processes Locomotion Dexterity Fine Motor Manipulation Digital Steadiness Continuous Processes Pursuit Tracking Compensatory Tracking Discrete Processes Simple & Complex Reaction Complex Sequence Higher Mental Processes Vigilance Attention Problem Solving Memory Speech Perception Reading-Comprehension Time Estimation			
Miscellaneous 0105	Plasma Volume Total Body Water Extra Vascular	RISA Kit; Tritiated Water Kit Scintillation Counter*	Avail. 18	Abbot Radio Corp. LMSC
0114	Gastrointestinal Status Motility Pressure Temperature pH	Urine Collection System FM Receiver Endoradiosonde Pills	15 4 27	LMSC Beckman U. of Calif.
0115	Skin Temperature (Calorimetry) ECG Heart Rate Respiration Rate Blood Pressure	Cardio Kit Physiological Display/Control Panel in Biometric Station 12-Thermistor Harness Lower Body Negative Pressure Device	11 15 6 9	Spacelabs Spacelabs Spacelabs LMSC/D. Clark
0111	Mass Measurement Strength Measurement ECG Heart Rate Respiration Rate Blood Pressure Electromyogram	Thermal Suit & Support Equipment Motion Chair Strength Measurement Device Cardio Kit Urine Collection System Electromyograph	Avail. 14 6 11 15 6	GFE LMSC LMSC Spacelabs LMSC Spacelabs
0116 (Deleted)	Deleted by NASA Direction			

SYNOPSIS

This section describes recommended future Biolabs study effort based on the previous Biolabs program and the results of the current study. The study objectives and scope are presented and the technical approach specified. Specific program tasks are identified, and the interrelationship of the future study to the development of the NASA biomedical and behavioral experiment program is discussed.

Section 10
RECOMMENDED FUTURE BIOLABS STUDY

10.1 BACKGROUND

The successful completion of the Project Mercury program demonstrated clearly man's ability to withstand the rigors of short-term spaceflight and contribute significantly to space-system performance and reliability. Shortly thereafter, studies were initiated by NASA Headquarters to determine the biomedical and human factors requirements for prolonged spaceflight. These studies were directed at defining the anticipated effects of the various environmental factors of spaceflight on the crew member and the potential health and performance impairments that might occur in spaceflight. Methods of detecting such detrimental effects were investigated very early as well as the state-of-the-art in bioinstrumentation and laboratory procedures compatible with the engineering and operational constraints of the space vehicle.

Since the initiation of these studies, a considerable amount of human experience in spaceflight has been obtained. Further, extensive analysis has been conducted by the medical and engineering professions to identify the critical parameters by which to evaluate man in space and to determine the extent to which measurement during prolonged spaceflight is feasible from the engineering standpoint.

Figure 10-1 is a historical presentation of prior studies and future needs for applying this knowledge to the development of flight-qualified hardware in order to derive a meaningful medical appraisal of man in spaceflight within the next two to three years. In addition to the initial industrial studies (designated as Biostat in Fig. 10-1), a NASA in-house committee was convened and a Space Medical Advisory Group was appointed to evaluate these and related studies and to determine the requirements and means for monitoring astronauts in flight. This expanded activity has resulted in the selection of

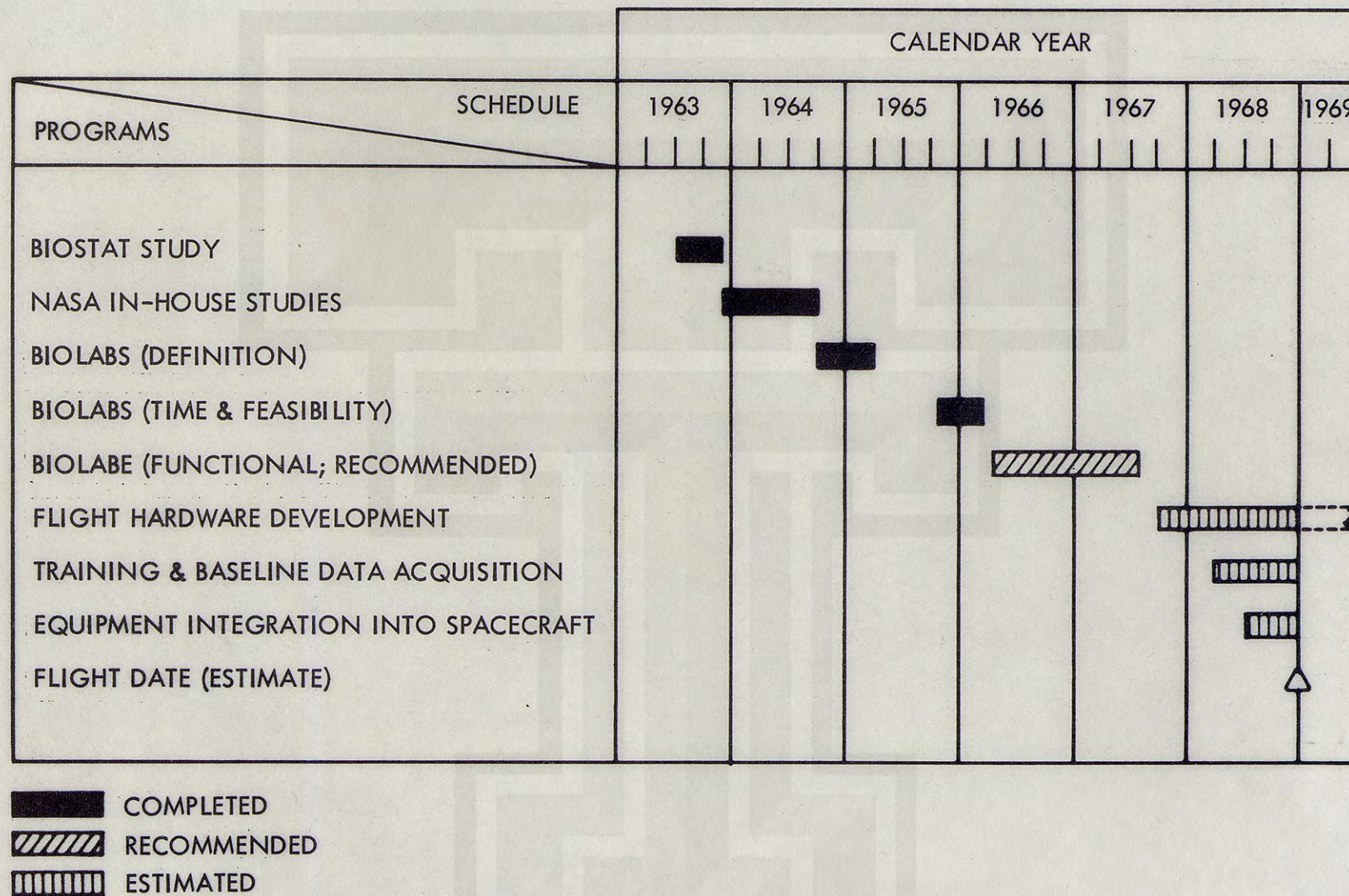


Fig. 10-1 Biomedical Laboratory Development Schedule

a group of 24 biomedical/behavioral experiments. Subsequently, the Biolabs Program was established to determine the design feasibility of incorporating the selected series of measurements in specific space vehicles, including the Apollo-X, the Manned Orbiting Research Laboratory (MORL), and the Apollo Extension System (AES).

These studies were initiated in the third quarter of 1964 and completed in March of 1965. The current time-line and feasibility study is an extension of the initial Biolabs Program and is directed at specifying experiment procedures, the time required to conduct these experiments, and experiment feasibility.

This effort, now in the first quarter of 1966, represents almost three years of endeavor by NASA personnel, space medical advisory personnel, and industrial contractors. This work has been directed at defining the requirements, determining design feasibility, developing ways of incorporating the experiment package into specific spacecraft, and identifying critical development items. In general, it appears that the medical and human factors experiment requirements for prolonged spaceflight have been well assessed by NASA personnel and by industrial scientists and engineers under the direction of NASA. Although these studies have been directed toward identifying the requirements for longer-duration manned spaceflight, the NASA Manned Spacecraft Center has been conducting an operational spaceflight program of increasing flight duration. This program has provided a strong practical foundation of knowledge and hardware applicable to implementation of the Biolabs Program.

In looking ahead to prolonged spaceflight anticipated in late 1968 and beyond, it is apparent, despite the advanced planning and study already undertaken, that a serious operational schedule constraint exists with respect to implementing the required measurement program results into flight-qualified hardware in time for adequate integration into the vehicle, for astronaut training, and for the acquisition of baseline data on equipment and on astronaut personnel (Fig. 10-1). The extensive experience gained to date indicates that a time requirement over one year can be anticipated for the development, test, and delivery of flight-qualified hardware for the biomedical/behavioral

experiment program. Prior to the development of such hardware, specific experiment and equipment requirements, design, and specifications are necessary, and these must be the immediate objectives of the continuing effort toward flight goals. Specifically, the medical and engineering analysis and decisions of the past three years must be distilled and applied to flight hardware design and specifications. Much of the current clinical laboratory equipment must be extensively modified to meet the weight, power, and volume constraints of spaceflight. In addition, to assure the suitability of such equipment for use in a weightless environment, a certain degree of feasibility testing must be conducted before commitment of flight-hardware development.

It is anticipated that 1 to 1.5 years is a reasonable schedule requirement for performing this task of converting the current requirements into final measurement selection, equipment design, feasibility testing, and, finally, flight-hardware specifications. Based on firm equipment design drawings and specifications, completion of flight-qualified equipment will require 15 to 22 months. Further, a period of at least 6 months is required for subsystem integration into the spacecraft and test prior to flight. Training of the astronauts and the acquisition of baseline data on the astronaut and the equipment are also required prior to flight, and it is apparent that, even with immediate initiation of such a development program, it is unlikely that a flight date of early 1969 can be met. However, it is recognized that all equipment will not be utilized in the early flights and that certain critical development items can be initiated early to shorten the length of the final integration schedule. Further, Biolabs equipment can be modularized to provide optional selection of experiments available for each flight. Those modules comprising a complete Biolab therefore may be selected in the light of medical information gained on previous flights. Although the most extensive effort to date has been in the area of measurement selection, current state-of-the-art of equipment will have a final impact on the measurement selection as reflected in the 24 experiments.

The increasing data-management problem imposed by a broader appraisal of crew medical status for a large number of astronauts in space must be a prime consideration

in the development of the laboratory. Identifying the data required for decision-making in flight will primarily affect the design equipment for data storage and retrieval by the astronaut and the ground-monitoring crew as well as for biological sample acquisition, storage, and analysis. Considerations of schedule, cost, feasibility, and reliability will affect the degree of automation of these laboratories. This will be determined largely through early feasibility testing recommended before the selection of flight hardware.

The final configuration for the flight-qualified biomedical laboratory (Biolabs) must meet the stringent constraints of engineering (e.g., power, weight, and volume), scientific requirements (e.g., criticality, accuracy, and reliability of data obtained), and operational needs (e.g., realistic considerations of available crew time and training requirements). In addition, perhaps the most pressing constraint is the anticipated flight schedule of Apollo and post-Apollo vehicles which will be capable of supporting astronauts in prolonged orbital flight (up to periods of many weeks).

Spaceflight experience to date concerning the ability of astronauts to withstand the rigors of spaceflight has been encouraging, and it is anticipated that astronauts will continue to perform successfully whatever in-flight tasks are required of them. It is equally apparent, on the basis of the broad experience of environmental medicine, that significant and potentially disabling aerospace medical problems may occur. Over a half a century of aviation medical experience provides substantial evidence for such an assumption. Early detection of these problems, by comprehensive medical evaluation, can provide assurance of astronaut health, safety, and performance during spaceflight. Achieving such assurance becomes increasingly important as astronaut duties and time in flight are extended.

10.2 OBJECTIVES AND SCOPE OF FUTURE BIOLABS PROGRAM

The remainder of this section presents the objectives and major aspects of the development of a functional Biolabs Program. This program calls for attainment of the

following objectives:

- Analysis and refinement of biomedical and behavioral experiments
- Design of functional equipment
- Fabrication and test of this equipment
- Fully functional time-line test and feasibility analysis
- Establishment of a definitive program plan for the development of flight prototype equipment

The program recommended to fulfill the foregoing objectives comprises the following major technical tasks:

- Task 1 - Refine and analyze experiments
- Task 2 - Define spacecraft/experiment interface requirements
- Task 3 - Design experiment/equipment packages
- Task 4 - Fabricate functional experiment equipment
- Task 5 - Conduct equipment functional tests, time-line testing, and feasibility analysis
- Task 6 - Define biomedical data-management system and determine spacecraft interface
- Task 7 - Prepare program plan for development of the prototype biomedical experiment/equipment packages

10.3 EXPERIMENT ANALYSIS REFINEMENT

Experiment definition refinement, analysis, and specification of biomedical experiment objectives are considered one of the most important tasks of the proposed program. Only through careful definition of experiments and experiment objectives can information be generated for detailed specifications required for the development of biomedical equipment. Contractor experience, such as that gained in the execution of the Biolabs Program, ORL biomedical experiment and equipment definition study program for IBM, and the present extension to the Biolabs Program (Time-Line Testing and Feasibility Analysis of the AAP Biomedical Experiment Program), is of invaluable assistance in

carrying out these tasks. The methodology proposed for accomplishing such an effort is as follows:

- Preparation of Detailed Experiment Definition Data Sheets
- Discussion With Cognizant NASA Principal Investigators
- Specification of Biomedical Objectives for Each Experiment
- Specification of Biomedical Experiment Measurements/Parameters
- Development of Experiment Functional Flow Diagrams
- Development of Experiment Block Diagrams
- Preparation of Experiment Requirements Analysis Summary
- Preparation of Experiment/Equipment Matrixes
- Development of Detailed Experiment Procedures
- Establishment of Experiment Grouping

Several studies have been performed in the definition of the biomedical experiment program for NASA, and it is suggested that this experience be heavily drawn upon and used as a major source of initial experiment development information. The foregoing specific techniques should reflect the use of this information and will be a natural extension of the experiment refinement already initiated. Following are brief descriptions of these techniques.

Preparation of Detailed Experiment Definition Data Sheets. In order to assimilate standardized data for each experiment, detailed experiment definition sheets will be prepared. Typical of the data items to be considered are statement of the problem, biomedical experiment objectives, measurements and/or parameters, experiment system description, equipment requirements, support requirements, data management, environmental considerations, scheduling, etc. This data form will be used in discussions with cognizant NASA principal investigators relative to experiment refinement.

Discussion With Cognizant NASA Principal Investigators. Biomedical and equipment design personnel will, at NASA's direction, visit cognizant principal investigators

for each of the experiment areas (e.g., cardiovascular/cardiopulmonary, biochemical, behavioral), to develop mutually acceptable definition of the experiment and the associated experiment objectives, requirements, and frequency of conduct.

Specification of Biomedical Objectives for Each Experiment. The specific biomedical objectives for each experiment will be identified together with the experiment definition refinement.

Specification of Biomedical Experiment Measurements/Parameters. A preliminary list of measurements or parameter determinations will be prepared for each experiment. This list will be developed during the discussion with the NASA-specified principal investigator and used as the basis for development of experiment procedures.

Development of Experiment Functional Flow Diagrams. Each experiment will be analyzed and functional flow diagrams prepared indicating the relationship of each experiment function within the total experiment. This information is necessary for development of equipment block diagrams, definition of equipment requirements, and specification of spacecraft interfaces.

Development of Experiment Block Diagrams. Experiment function flow diagrams will be analyzed and objectives reviewed to provide data for the development of experiment block diagrams. The diagrams will indicate the equipment required, equipment interface, and experiment/equipment interface to the spacecraft. Figure 9-1 presents an over-all example of a block diagram for the Physiology Experiment subsystem.

Preparation of Experiment Requirements Analysis Summary. Each experiment will be analyzed, including the flow and block diagrams, to determine specific support requirements necessary for conduct of the experiment. Requirements will be identified, e.g., power, pressurized gas, umbilical lines, data management processing, etc.

Preparation of Experiment/Equipment Matrixes. Each experiment will be reviewed to establish equipment requirements and a matrix prepared to indicate the commonality of equipment. In addition, measurement/parameter commonality will also be identified to determine logical modular experiment blocks based on commonality of equipment and experiment measurements/parameters.

Development of Detailed Experiment Procedures. Once experiments are well defined and functions identified, detailed procedures will be prepared. The detailed procedures also provide verification of equipment requirements and, generally, indicate instances of a need for an additional or different equipment item which cannot be determined until the detailed procedures are prepared.

Establishment of Experiment Grouping. Based on the development of the functional and block flow diagrams, equipment/experiment matrixes, measurement/parameter commonalities, etc., previously mentioned, a realistic experiment grouping can be undertaken. The experiment grouping will provide the recommended modular experiment blocks and from this information equipment packages can be specified and initial flight-schedule planning initiated to determine equipment status readiness for each flight.

Execution of the majority of the foregoing techniques will be performed within the first two months of the study in order to provide definitive equipment information for design, fabrication, and test programs. The techniques previously described have been initiated in varying degrees on previous biomedical experiment definition programs. It is proposed, therefore, to utilize as much of this information as possible in order to provide continuity of program development, maintain proposed NASA program objectives and eliminate the necessity of beginning all over again in many of these areas.

10.4 INTERFACE REQUIREMENTS - SPACECRAFT AND EXPERIMENTS

The biomedical/behavioral experiment package interface with the spacecraft and scientific and engineering experiments and equipment is of major concern in the

design and development of the biomedical/behavioral equipment. Spacecraft constraints, capabilities, and configuration dictate, to a high degree, the nature of the experiment selection and equipment package for the proposed ORL flight program. It is therefore of paramount importance to perform a preliminary analysis of the selected ORL spacecraft and the proposed experiment packages in order to provide the necessary design parameters to the biomedical/behavioral experiment package development team.

Representative interface, configuration, and constraint data to be analyzed are as follows:

- Spacecraft laboratory configuration, cabin envelope, crew operating volume, and equipment packaging constraints
- Spacecraft payload capability and payload allocation to the biomedical program
- Spacecraft power characteristics, availability, and load limits
- Spacecraft plumbing, cable runs, and interface points
- Spacecraft bulkhead design relative to equipment mounting
- Identification of scientific and engineering experiments to determine equipment requirements, volume, power, weight, and data-management requirements
- Scientific and engineering experiment equipment location (operating and stowed)
- Scientific and engineering experiment conduct times (when and how long)
- General spacecraft equipment location, life-support provisioning, and cabin atmosphere

The foregoing areas will be analyzed to a level of detail sufficient to provide general design guidelines for biomedical/behavioral, experiment/equipment development. It is recognized that the ORL spacecraft, at this point in the future program, may not yet have been specifically defined; however, the one to two configurations under consideration could be analyzed or NASA could select the "most likely candidate" for study. Further, the proposed study might, in actuality, contribute significantly to the data on which to base selection among alternate candidates.

In summary, this task is intended to identify interface requirements where possible, determine the laboratory configuration, and specify the constraints where known. The effort is not a design task, by definition, and is basically a review function in scope and objective. The data obtained will be channeled to the appropriate design teams for inclusion in the biomedical/behavioral experiment equipment package design criteria. The intent of the task is to also provide the kind of information that can be utilized to provide criteria applicable to more than one ORL (if more than one spacecraft is under consideration) and thus provide the greatest possible flexibility in the design of the experiment package.

10.5 BIOMEDICAL EXPERIMENT EQUIPMENT DESIGN

During the course of the present study, equipment development status was identified for each item of equipment recommended for the AAP biomedical experiment program (Table 9-16). Several equipment items are currently available in flight-qualified form or are undergoing flight qualification testing. Some equipment items are currently in the initial prototype stage of development while others are still in the breadboard stage. Certain equipment does not exist at all or, at best, exists only in the conceptual design stage.

One of the major objectives of the proposed program is to design and develop a completely functional equipment system in order to conduct time-line testing and feasibility analysis of the selected biomedical experiment package. Equipment must therefore be designed and developed for those items which are unavailable, or which cannot be modified economically or feasibly from off-the-shelf status.

Design responsibility for development of the initial functional biomedical package will involve establishing preliminary performance specifications, general design requirements, biomedical subsystem interface specifications, and design review. A division of subcontractor responsibility will be established for specific equipment design and development requirements. Two primary subcontractors have been identified; these organizations have been associated with the Biolabs Program from its inception.

Several other subcontractor organizations will be called upon, as needed, to meet special equipment design requirements.

It is proposed that one of the major subcontractors be responsible for development of the primary physiological experiment/equipment package, while the other be responsible for the development of the primary microscopy/chemistry, experiment/equipment package. The prime contractor will be responsible for a variety of equipment currently under development and for equipment not allocated to the other two prime subcontractors. Section 9 of this report presents a brief description of the biomedical equipment.

The intention of Task 2 (experiment/equipment design) is to design only equipment which does not exist or which cannot be modified for functional use in the test program. This approach considerably reduces the cost of developing prototype equipment only and assures maximum utilization of existing equipment. Table 9-17 presents a list of equipment and recommended contractor assignment of responsibility for providing that equipment. Equipment assignment to the recommended contractors should be on the basis of (1) logical experiment/equipment packages, (2) demonstrated and related experience of the contractor, and (3) present contractual requirements for equipment on the Gemini and Apollo Programs.

During the Task 2 design phase, all equipment determined as modifiable for use as functional equipment will be analyzed and design modification drawings prepared. These drawings, in addition to modification specifications, will be used in Task 4 for development of functional equipment.

The design approach in Task 2 will be directed toward the design and layout of equipment which represents, as closely as possible within cost and schedule constraints, the ultimate configuration of the prototype equipment based on current conceptual designs. Equipment which must be necessarily designed and developed during the program thus will be the forerunner of flight prototype equipment wherever feasible.

10.6 FABRICATION PLAN

In preparing this recommended future Biolabs Program, a fabrication plan has been prepared relative to development of the biomedical/behavioral functional equipment. Although necessarily general in nature at this time, it represents an attempt to identify fabrication requirements and sequences recommended for development and fabrication of the equipment. More specific versions will be developed as the equipment design detail is progressively defined and ultimately frozen.

10.6.1 Fabrication and Assembly

The fabrication plan philosophy of the development program is to furnish a reliable product within the required schedule and at minimum cost. This will be accomplished by the following:

- Project Organization. Close coordination with engineering, procurement, and product assurance to ensure compliance with specifications, schedule, and cost constraints
- Integrated Shop Approach. Use of highly trained and skilled fabrication personnel, utilizing the latest fabrication techniques and equipment
- Integrated Reliability. Basic part and assembly integrity throughout all phases of manufacturing, and integration of the fabrication test plan to ensure product reliability
- Configuration Control. Design change and configuration control, rigid inventory controls, and complete installation and test records to assure ease of interface with subsystem integration

10.6.2 Development Fabrication

Several items of equipment have been identified for development which range from complex mechanical devices to simple hand-made visual targets. The fabrication

approach can be summarized as follows:

- Utilization of proven and reliable fabrication techniques (which should be an outgrowth of current and past aerospace contracts)
- Utilization of the extensive inventory of fabrication shop versatility within the manufacturing organization
- Reduction of the need for special tooling and fabrication equipment
- Utilization of existing calibration, tooling, and support services
- Utilization of quality and product assurance controls in close association with the fabrication activity

Execution of the fabrication program employing the foregoing approach will assure the fabrication of reliable equipment, development of equipment within specified costs, availability of equipment on schedule, and elimination of excessive fabrication support costs, (e.g., tooling, calibration), etc.

10.6.3 Subcontractor Development Fabrication

Several of the equipment items suggested for development by the proposed subcontractors are or will be available. Since this equipment has been developed under rigorous specification and fabrication controls, there is, by nature of contractual requirement, no further need for fabrication development specifications and requirements. However, many items are either off-the-shelf modifications or initially developed. The prime contractor must impose stringent fabrication control requirements on each subcontractor to assure similar quality and reliability of the equipment items. These fabrication control requirements will be compatible with NASA requirements although they will be relaxed to the extent that equipment fabrication standards will not have to meet flight-qualification requirements and specifications.

10.7 TEST PROGRAM

A multiphase test program is recommended for testing of the individual equipment items and for the integrated biomedical subsystem. The testing program will be designed for

functional equipment only and will not represent a test program associated with flight-qualified equipment. As proposed, it will include (1) design approval test, (2) acceptance tests, (3) time-line and feasibility and analysis tests, and (4) a small-scale zero-g test program. Overall test program objectives are as follows:

- Provide individual items of equipment with demonstrated capability and reliability to meet all test program objectives
- Verify that each item of equipment is in full compliance with NASA-approved specifications
- Combine individual items of equipment into an integrated and functional equipment subsystem and demonstrate subsystem capability to meet the test program objective
- Conduct a time-line test and feasibility analysis program that will determine, more accurately, time to conduct experiments and indicate feasibility of conducting the experiment in the selected ORL
- Conduct a zero-g flight-test program for critical equipment elements

The philosophy of the test program is based on assuring that the individual items of equipment are functionally operable and will withstand the required operator use as called out in the time-line test and feasibility analysis effort.

Prior to equipment delivery, all subcontractors will perform tests as prescribed by prime contractor specifications. These specifications will call for demonstrations regarding functional performance and use environmental tests.

The prime contractor will conduct design-approval tests and acceptance tests at his facility for subcontract units as well as prime-contractor-fabricated items.

Classification of Tests. Four types of tests will be conducted as follows:

- Design-Approval Tests. These tests are to be conducted on all major items of equipment. The testing program will be applied to each initial equipment

for verification and demonstration of the selected design. The test demonstration of equipment encompasses a series of functional performance and ground-use environmental tests to establish functional performance envelopes, verify operation under use environment, and evaluate design margins. These tests are designed to provide data on the design limits of the equipment item and design and engineering data for improvement of the item.

- Acceptance Tests. These tests will be performed to verify that materials, construction workmanship, dimensions, design, and performance comply with applicable drawings and NASA-approved drawings under nonoperating conditions and room ambient environments. The prime contractor will perform a complete visual and quantitative inspection of each unit. Visual inspection will consist of an examination for general workmanship and detection of defective parts, incorrect assembly, and unsatisfactory surface coating. Each unit will be inspected in both the stored and operational configuration with particular attention given to sizing, binding, or interference encountered during repositioning to either the stored or operational configuration. The quantitative inspection will consist of critical dimensions, weight, and electrical measurement. Electrical parameters to be measured include continuity, resistance, and output signal characteristics.
- Time-Line Test. The time-line test and feasibility analysis program will be performed to determine the time required to conduct functional biomedical and behavioral experiments and the feasibility of conducting the functional experiments in the ORL. Functional equipment will be installed in the ORL mockup in the recommended biomedical experiment station configurations. Experiment procedures, developed under Task 1, will be utilized by experimenter personnel (trained, untrained, and untrained in a pressure-suit) to conduct each experiment, utilizing functional equipment within the ORL. The time-line test and feasibility analysis will essentially be a highly refined simulation of the in-flight biomedical experiment program (in an applied crew work/rest cycle) currently under consideration by NASA. The time-line test and feasibility analysis will be conducted in the last phase of the program in order to utilize functional equipment previously developed during the initial phases of the

program. Results of the time-line testing and feasibility analysis should provide definitive experiment times (under 1 g), verify experiment procedures, establish the feasibility and operability of the functional equipment, verify the grouping and ordering of experiments, and provide specific design recommendation feedback to the equipment design teams.

- Flight Test. The flight-test program is concerned with the demonstration of certain critical equipment elements at approximate zero-g condition in the KC-135 aircraft (or suitable alternate). It is proposed that the flight evaluation be initiated with an early testing phase 6 months after go-ahead. An example of a critical, early, in-flight zero-g test program is the successful demonstration of liquid transfer for microscopy/chemistry parameter determinations. In addition, if samples are not analyzed on board the spacecraft, a technique must be developed to preserve them for postflight analysis. Before initiation of the design and development of any of the microscopy/chemistry equipment, the selected subcontractor will be required to design, fabricate, and test under zero-g conditions a device to demonstrate the feasibility of his approach to liquid transfer. The subcontractor will also be required to design, fabricate, and test under zero-g conditions a device to demonstrate the feasibility of his approach to sample preservation, e.g., lyophilization. It is considered highly essential to show the feasibility of these two concepts in advance of microscopy/chemistry equipment development to assure that basic design concepts used in the development of the hardware are feasible and practical, and that they perform assigned functions reliably and with accurate repeatability. Once the two techniques have been successfully demonstrated, the subcontractor will then be directed to design and develop the equipment, instruments, and experiment station console on a schedule compatible with the overall master program equipment delivery, test, and checkout schedule. Final tests can be conducted 12 months after go-ahead on those critical items found to require evaluation.

For planning purposes, the following items have been selected for flight evaluation on the basis of their unique operational requirements or because the system contains material that has indicated the likelihood of problems in the weightlessness environment.

- Motion chair
- Lower body negative pressure device
- Ergometer
- Capacitance plethysmograph
- Strength measurement device
- Urine collection system
- Liquid transfer device
- Lyophilization device

10.8 DATA MANAGEMENT

One of the most critical areas of experiment conduct is the acquisition of reliable and useful data. The specification of data signal outputs from the equipment, and signal routing to the appropriate conditioning, presentation, or storage point, therefore is of considerable importance in the design of the biomedical/behavioral equipment subsystem. Additionally, analysis of the ORL on-board data management system is of importance to determine the biomedical/behavioral data management interface and the requirements for support equipment. The effort to be expended in this task consists of the following subtasks:

- Determine experiment/equipment signal outputs (together with Task 1)
- Determine ORL spacecraft data management system characteristics
- Specify biomedical/behavioral data management requirements
- Identify biomedical/behavioral data management interface with ORL data-management system
- Specify biomedical/behavioral data management equipment requirements
- Specify and implement a laboratory data management system for the time-line test and feasibility analysis task

Execution of the foregoing subtasks will result in a relatively well defined data management subsystem for the experiment program. Typical information to be generated in this effort is as follows:

- Computer requirements and capacity
- Data-handling techniques and requirements
- Data-processing techniques and requirements
- Data compression and storage
- Digital-to-analog and analog-to-digital conversion requirements
- Encoding and time-tagging techniques and requirements

Analysis of the data obtained will result in the generation of information which will be used in the final design of the prototype equipment.

10.9 PREPARATION OF FLIGHT-PROTOTYPE DEVELOPMENT PROGRAM PLANS

The development of the functional biomedical/behavioral equipment package represents one of the major objectives of the recommended program. However, full realization of development of the flight-prototype experiment package is contingent on the successful planning executed during the course of the recommended study. To assure that the appropriate and detailed planning is carried out, program plans should be prepared for the following aspects of the effort:

- Flight-prototype equipment detailed design
- Equipment manufacturing
- Test and flight qualification
- Reliability and quality assurance
- Biomedical/behavioral equipment package integration
- Training requirements and baseline data acquisition
- Subcontractor management and control

Development of program plans during the latter stages of the recommended study will ensure incorporation of the equipment requirements, changes, and characteristics

in the planning information. Realistically sound decisions thus can be made relative to equipment development, schedule planning, and integration requirements.

10.10 PROGRAM PLAN FOR FUTURE BIOLABS STUDY

This plan for accomplishment of the work described in Subsections 10.3 through 10.9 reflects the best judgment as to the time-spans, phasing, and manpower required for the performance of the work in an orderly, timely, and economical fashion.

10.10.1 Overall Program Plan

Figure 10-2 presents the schedule for accomplishment of the entire program. It should be noted, if the entire program is to be accomplished within the 15-month period, that the critical milestones are (1) review with principal investigators, (2) design review and approval, (3) fabrication, and (4) test acceptance.

10.10.2 Key Milestones

Several key milestones are shown in Fig. 10-2. Establishment of experiment/equipment definition is completed by the end of the second month, permitting go-ahead on the design phase. This in turn will permit design and fabrication of some critical equipment for early zero-g flight testing 6 months from go-ahead. Detail design is scheduled for completion 7 months after go-ahead. Fabrication can be initiated after design approval by NASA and is indicated as requiring a 3-month period. Functional and system checkout tests are initiated approximately 9.5 months from go-ahead. The integrated, functional, laboratory equipment subsystem will be installed in the ORL mockup upon completion of the systems test 11 months after go-ahead. The time-line test is scheduled for the next three months and its completion 14 months after go-ahead. Conduct of final zero-g tests is shown for the 12th month. Documentation of the test program and final preparation of the program plan for Flight Equipment Development are indicated for the 15th month of the program.

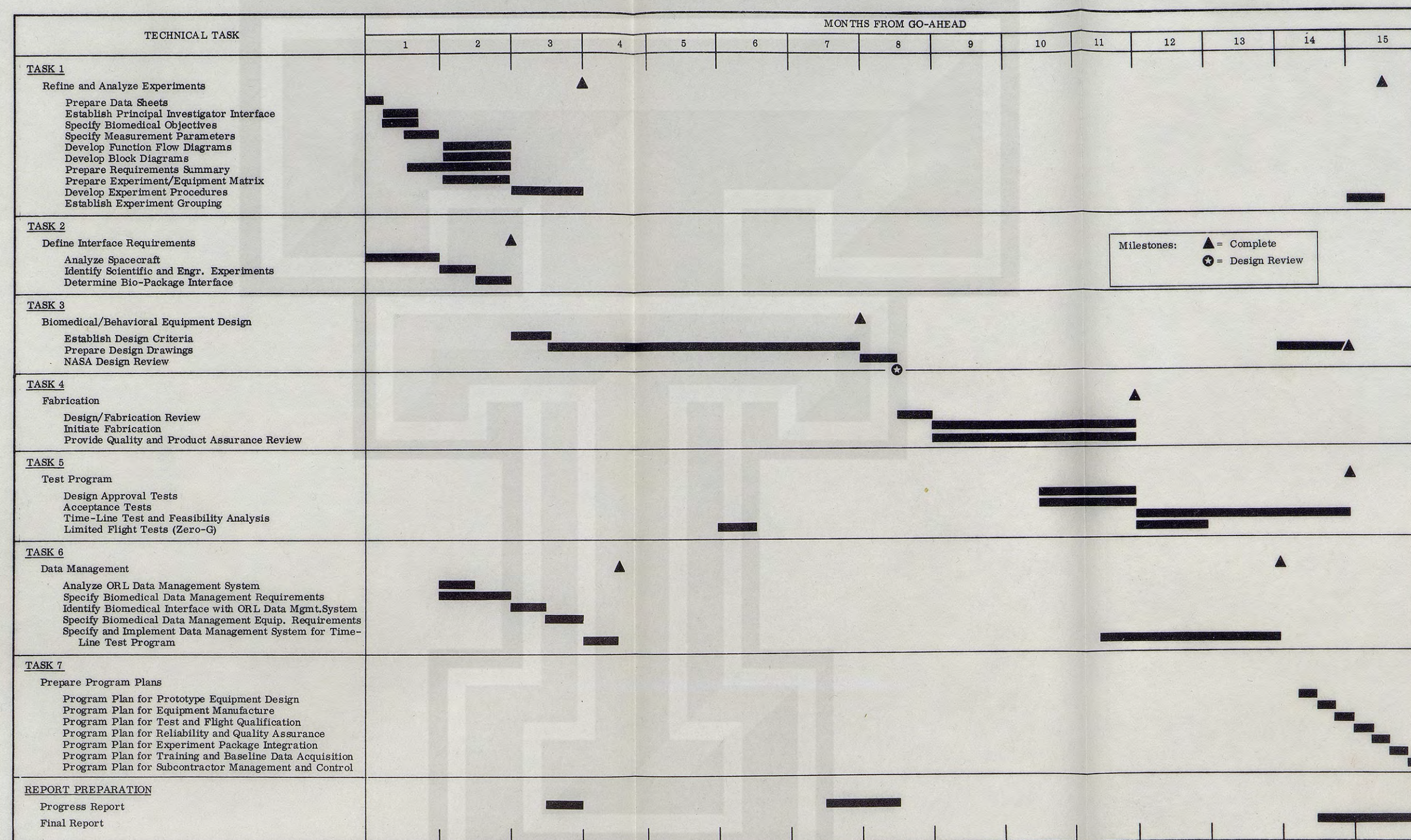


Fig. 10-2 Recommended Schedule for Future Biolabs Study

10.11 ORGANIZATION AND MANAGEMENT

Key elements in the successful execution of a program of this nature are the organizational structure and management techniques employed. The organization conducting the effort should be a direct line function with a central program manager responsible for all program tasks. The program manager should direct a staff of highly competent engineering personnel with selected individuals specifically responsible for functional program tasks. It is recommended that the program manager be medically trained with a staff of highly trained engineering-support personnel.

It is recommended that the management technique evolve about rigorous execution of the program control system method, utilization of PERT techniques, frequent program review sessions, and maximum exchange of information and intercommunication between the program team, subcontractors, consultants, and NASA personnel. Program schedule and cost status should be reviewed weekly to assure maximum attention to program requirements. Technical exchange of information regarding technical developments, tradeoff analyses, problem areas, and status must be initiated among the study team on a weekly basis. In addition, key program personnel should participate in overall program technical interface meetings, in NASA program review and status presentations and technical working meetings, and in necessary technical design, development, and test reviews. It is recommended that three major progress reports be prepared for distribution to NASA.

10.12 PROJECT AND SCHEDULE

A program control system should be applied to provide the necessary information for reviewing schedule status and for exercising control on a timely basis. The following paragraphs describe the proven planning and reporting procedures suggested for this study.

Initial planning involves formal documentation of a detailed plan called the Research and Development Work Plan (RWP). The RWP describes the tasks, identifies the organizations assigning team members to the program, and defines the nature and extent of their participation. A detailed schedule defines appropriate milestones and reflects cost in terms of planned monthly manpower expenditure rates over the duration of the task.

Program performance status information appears in a Planning and Performance Report and a Schedule Status Report. The weekly Planning and Performance Report compares planned expenditure rates (as shown in the RWP) with actual weekly labor expenditures for the current and four prior weeks, and indicates cumulative manhour expenditures since the beginning of the task. Planned expenditure rates are shown for the duration of the program. Deviation of actuals from planned expenditure rates beyond a certain tolerance is reflected in exception reports to the director and vice-president levels of management.

The Schedule Status Report compares actual versus planned progress along a time-scale where key points indicate certain identifiable events occurring during the life of a task, for which specific dates must be met to satisfy major schedule commitments. The report is updated and distributed on a biweekly basis. A separate issue of this report, distributed weekly, identifies critical or potential problems for which remedial action must be taken. Reports of exceptions to actual or potential off-schedule conditions are also summarized weekly for R&D management.



Section 11
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