Study of Space Cabin Atmospheres

NASA Research Grant NGR-22-007-053

Status Report for the Period

July 1, 1967 to December 31, 1967

Submitted by

Wm. A. Burgess

and

Parker C. Reist, Sc.D.

Harvard School of Public Health

May 1968

TABLE OF CONTENTS

I. Summary of Activities

During the six months ending on December 31, 1967, major attention was focused on earth-bound experiments on particle concentration and size distribution in closed space cabin environments and on calibration of a hot-wire sensing device for detecting and sizing liquid aerosols.

Data from a Langley Integrated Life Support System (ILSS) study were analyzed and test procedures developed for a NASA-OART McDonnell-Douglas 60-Day Space Cabin Simulator test to be carried out during the next report period. The Langley test indicated an average particle concentration in the closed space cabin of approximately 40,000 particles per cubic foot (ppcf). Although there were sharp variations over the three day period, the base-line concentration did not appear to change with time, indicating that particle removal by the environmental control system (ECS) was balanced by new particle generation within the cabin. In preparation for the McDonnell-Douglas test the Aerosol Particle Analyzer (Unit #2) (APA) was calibrated both at atmospheric pressure and at approximately one-half an atmosphere.

In our last progress report we discussed the feasibility of three automatic methods for particle size analysis. Of these three, the hot-wire anemometer device appeared most promising. In order to calibrate this device we have investigated automatic output signal shaping and sorting devices in conjunction with NASA-ERC. A satisfactory conditioning circuit for use with a pulse height analyzer has not been developed to date. Manual calibration of the hot wire sensor is being carried out using a water droplet aerosol with the size distribution identified from size data available from the aerosol formed by a sodium chloride solute after drying.

II. Major Activities

A. Space Cabin Simulator Participation

1. Langley Test

A preliminary field test of the APA was carried out during the Langley Research Center three day space-cabin simulation test. Air concentrations of particulates were determined with the APA at hour intervals. The concentration variations with time are shown in Figure 1 and summarized in Table 1.

Table 1

Summarized Data-Langley Field Test

	Particles per cubic foot				
	Number in Channel				
	2	3	4	5	Total
Mean	1373	2591	3160	14,195	21,319
Range					
High	3412	7998	11,130	45,054	67,595
Low	13	504	105	9	631

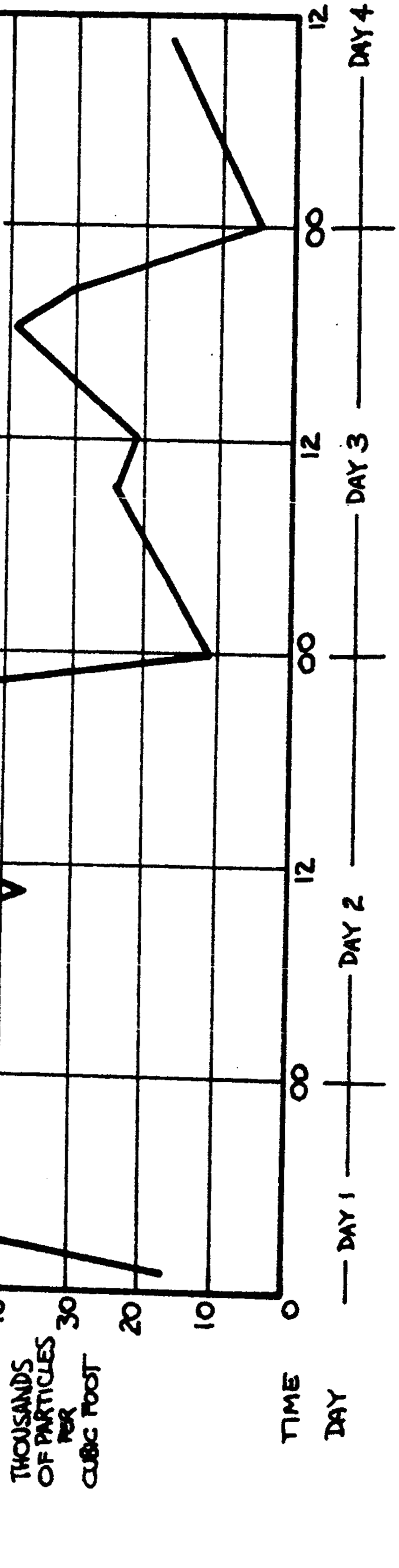

FIGURE 1
LANGLEY INTEGRATED LIFE SUPPORT SYSTEM TEST DATA

In this particular cabin simulator, aerosol levels were quite low and in the range noted in clean room installations. Although there were sharp variations in the data, overall levels remained fairly constant indicating steady-state conditions existing within the cabin. When one of the catalytic burners was out of service an increase in particulate concentration was noted which may indicate that these burners have some capacity for aerosol particle removal.

2. McDonnell-Douglas Space Cabin Simulator Test

Following the Langley test an addition field test was planned with ERC as a "piggy-back" experiment with the McDonnell-Douglas Space Cabin Simulator Test scheduled to take place in early 1968. The purpose of this experiment will be to determine the variation with time of the airborne particle size distribution and concentration within a closed space cabin environment; to determine the gross chemical and physical constituents of this aerosol, and to operationally check the APA in a simulated flight situation using a conventional dust counting method.

Completion of this experiment will provide valuable data on the number, size, and composition of particles and droplets which may be dispersed during extended manned space flights. It is hoped that this experiment will provide greater insight into problems which may be encountered during actual flight experiments.

To achieve the objectives of this experiment two techniques will be used. Total particle count and size distribution will be measured with the APA at the four locations shown in Figure 2. One sample will be taken at the surface of the desk in the Command Center Area; the second sample will be collected at the surface of the preparation table in the Food Management Area; the third and fourth samples will be taken at a delivery diffuser and return grille of the Air Distribution Sub-System. Samples will be collected four times a day at approximately 0400, 0900, 1430, and 2300 hours. Every three days the APA will be passed out of the chamber for battery replacement.

In addition to the APA samples, a single integrated air sample will be collected each day on a membrane filter. The sampling pump and membrane filter will be positioned adjacent to the return air grille above the sink in the Food Preparation Area. The pump will be turned on at 0800 and turned off at 1100 each day. The sampling pump and filter holder will be "locked out" of the chamber at the first opportunity for recharging

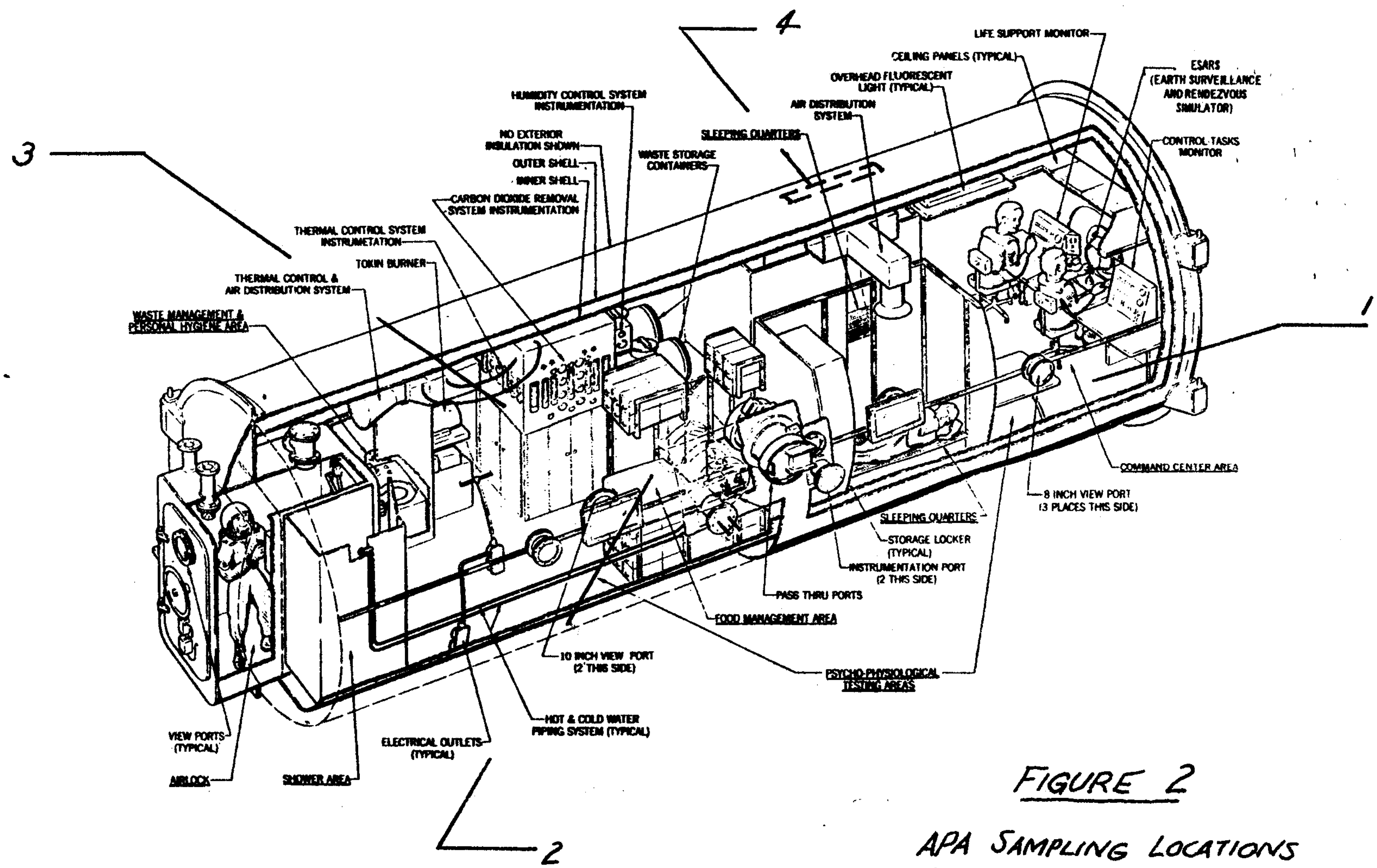

FIGURE 2

APA SAMPLING LOCATIONS
M^c^DONNELL - DOUGLAS
SPACE CABIN SIMULATOR

and replacement of the filter. The filters will then be returned to this laboratory for counting and analysis.

B. APA Calibration

In preparation for the McDonnell-Douglas test, an APA unit was calibrated using polystyrene latex particles generated by the technique which we have described in previous progress reports. The calibration was carried out at one atmosphere as well as the Space Cabin Simulator operating pressure of 8.6 psia. Three APA samples were collected for each particle size over a ten minute period. During this same period a sample was collected on a membrane filter for absolute determination of the aerosol concentration. Simultaneous measurements were also made with the Bausch and Lomb Model 40-1 Dust Counter.

Seven background samples were measured with the APA at atmospheric pressure and ten measurements were made at 8.6 psia. The results were averaged for each of the two conditions and are presented in Table 2.

Table 2
Average Background Data (clean air)
APA Unit No. 2

Channel No.:	1	2	3	4	5
14.7 psia	0	2	9	40	243
8.6 psia	0	2	10	31	185

Although the only significant difference in the average background noted at the two pressures appears in channel five, the data was treated as two separate sets of information and the runs at different pressures were corrected with the background measured at that pressure. These findings are consistent with the findings of Gucker and O'Konski in which they concluded that a significant fraction of instrument background arises from Rayleigh scattering by air molecules in the sensitive volume of the detector (1).

Figure 3 shows a plot of the percent count in each channel as a function of the test particle size for the tests run at 14.7 psia. Curves are plotted for each channel. Because of the lack of data, no information is plotted for channels one and two. Figure 4 is a similar plot for the data collected at 8.6 psia. A review of these two figures reveals that there is not an appreciable difference in the percent response in the runs made at 14.7 psia compared to the runs made at 8.6 psia. This means that the size distributions indicated on the APA unit should not shift appreciably if the pressure in a space vehicle is varied.

As mentioned above, membrane filter samples were collected for absolute calibration of the APA unit. Approximately 500 particles were counted in each size giving an indicated

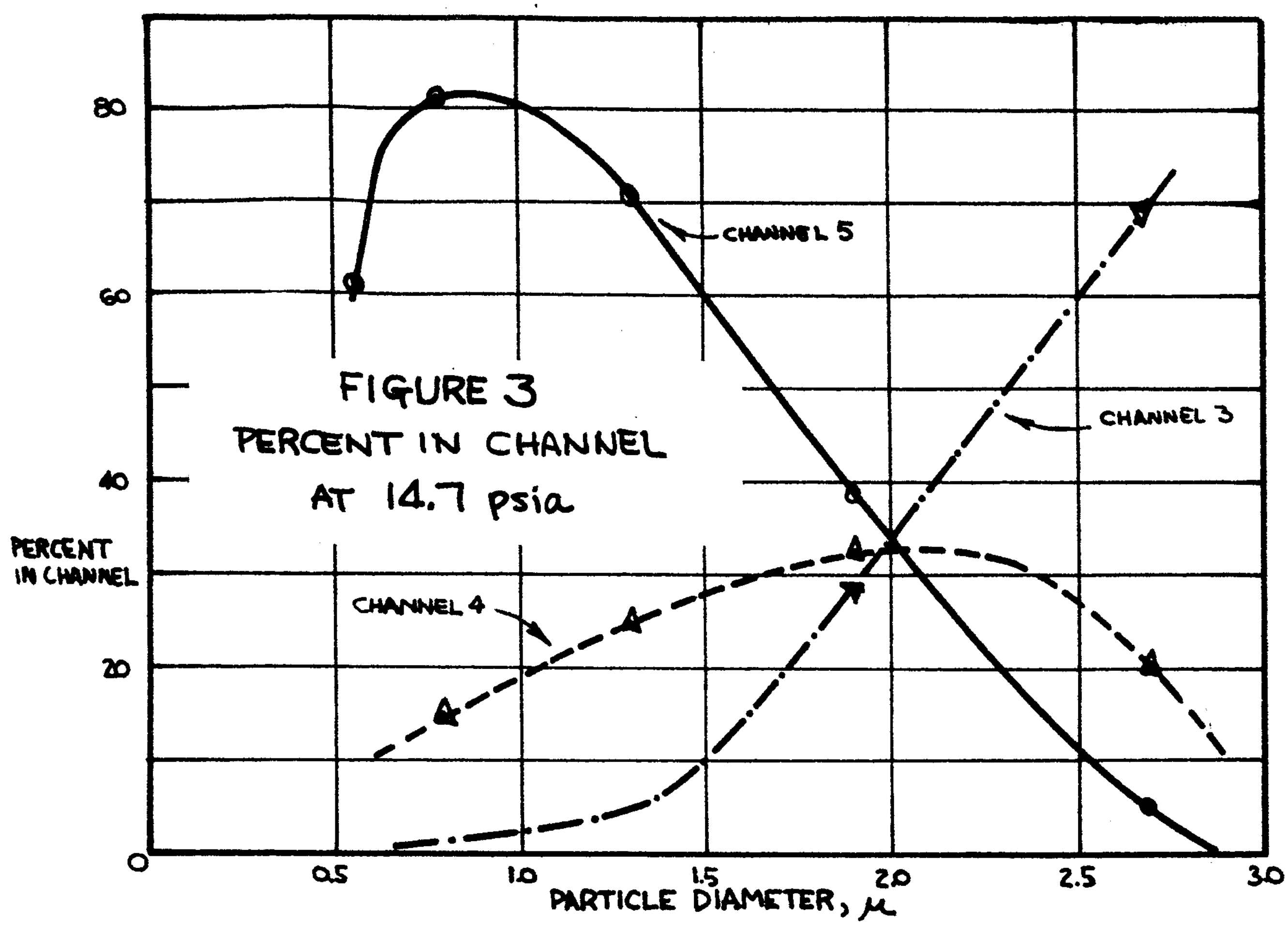
FIGURE 3
PERCENT IN CHANNEL
AT 14.7 psia
CHANNEL 5
CHANNEL 3
CHANNEL 4
PERCENT IN CHANNEL
PARTICLE DIAMETER, μ
0
20
40
60
80
0.5
1.0
1.5
2.0
2.5
3.0

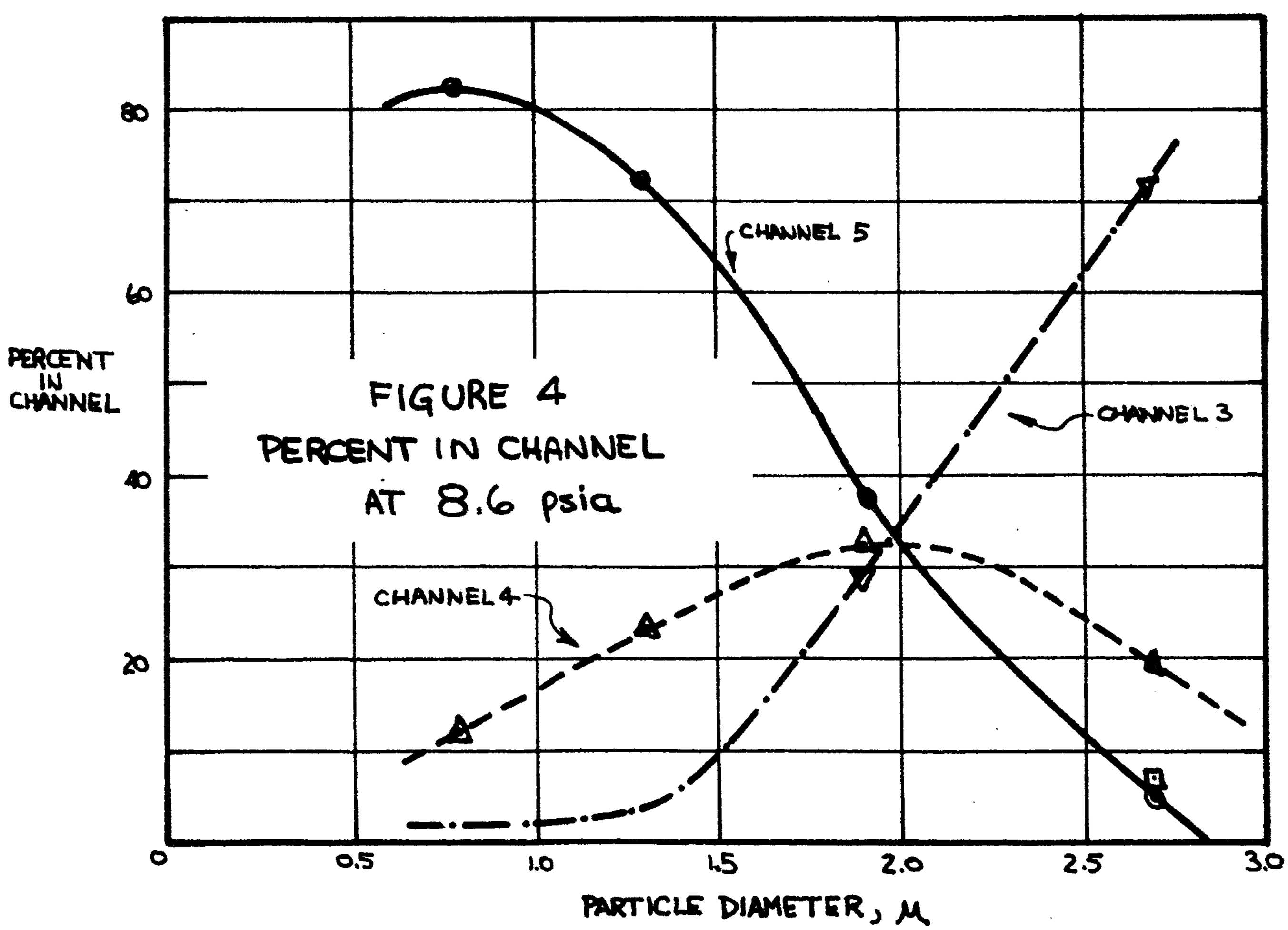
FIGURE 4
PERCENT IN CHANNEL
AT 8.6 psia
CHANNEL 5
CHANNEL 3
CHANNEL 4
PERCENT IN CHANNEL
PARTICLE DIAMETER, μ
0
20
40
60
80
0.5
1.0
1.5
2.0
2.5
3.0

percent error of approximately 10% assuming a 95% confidence interval. Table 3 lists the count data and APA data, as well as the multiplication factor, f, which is defined as the actual number concentration obtained from the membrane filter samples divided by the number concentration measured with the APA. The theoretical value of this factor, presuming an instrument counting efficiency of 100 percent, is 60. Values higher than 60 indicate a detector efficiency for that particle size of less than 100%.

The data in Table 3 indicate essentially 100% efficiency when the APA unit is operated at 14.7 psia with particles larger than about 1.9 microns but less efficient operation for the same size particles when operated at 8.6 psia. In addition, efficiency appears to fall as the size of the particle decreases.

Table 3

Calibration of APA Unit #2

Particle size, microns	14.7 psia			8.6 psia		
	mppcf	APA	f	mppcf	APA	f
0.796	2.71	1,240	2,185	5.21	1,941	2,684
1.30	3.47	12,236	284	6.12	7,138	857
1.90	0.048	874	54.9	0.043	417	103
2.68	0.597	11,822	50.5	0.750	5,981	125

Volume sampled: @14.7 psia = 2.48 cubic feet
@ 8.6 psia = 1.21 cubic feet

C. <u>Hot Wire Aerosol Detector</u>

1. Automatic Pulse Shaping and Handling

A liquid droplet will produce a voltage pulse when it impacts on a constant temperature hot-wire anemometer probe. In a previous report (2) we discussed the application of such a device for counting and sizing of droplets.

The output pulse of the hot-wire anemometer appeared to be amenable to display by pulse height techniques to provide number and size distribution information. To carry out this function the circuit design shown in schematic in Figure 5 was developed in cooperation with ERC. Figure 6 shows the detailed design of the circuit. Following assembly the design was tested but was unsatisfactory for the following reasons:

i) The output of the μA712 integrated circuit could not be switched off for 3μ sec intervals by switching its power supply voltage;

ii) The μA710 integrated circuit was extremely unstable as a voltage comparator;

iii) Due to the low impedance level locking-out of the peak detect diode-storage capacitor junction the capacitor was not able to hold a charge. This caused incorrect phasing for sample and

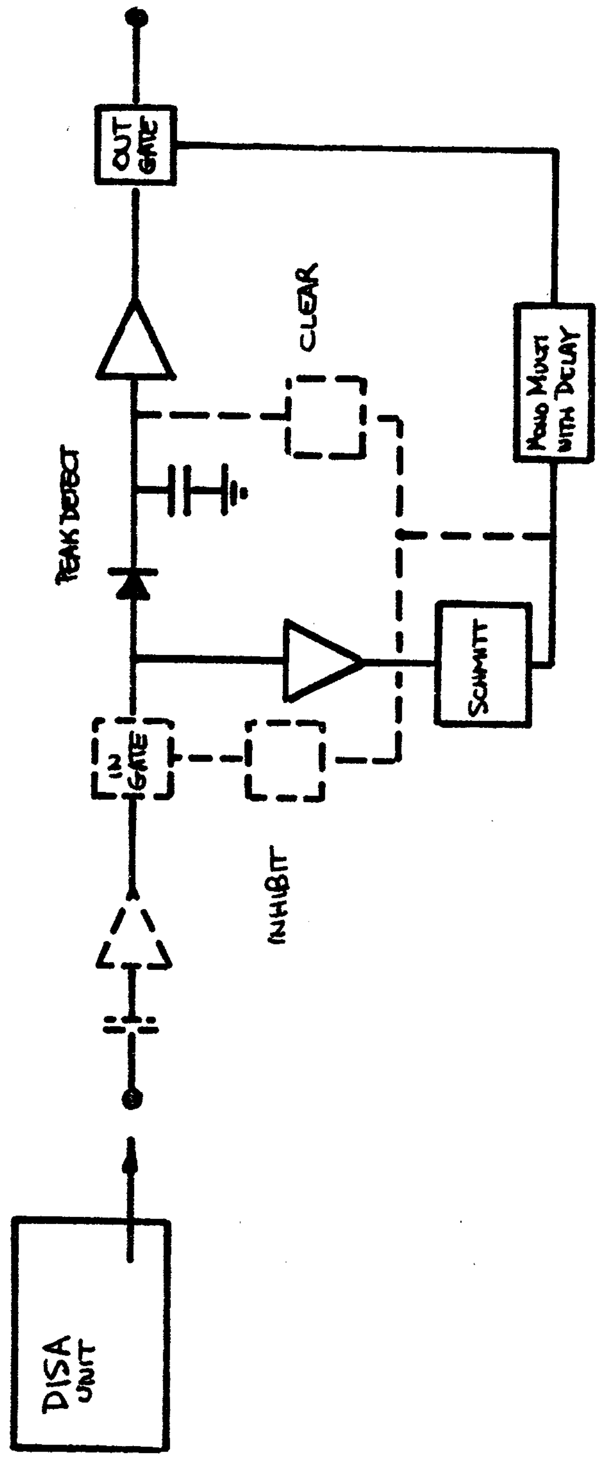

FIGURE 5
PULSE CONDITIONING
CIRCUIT-SCHEMATIC

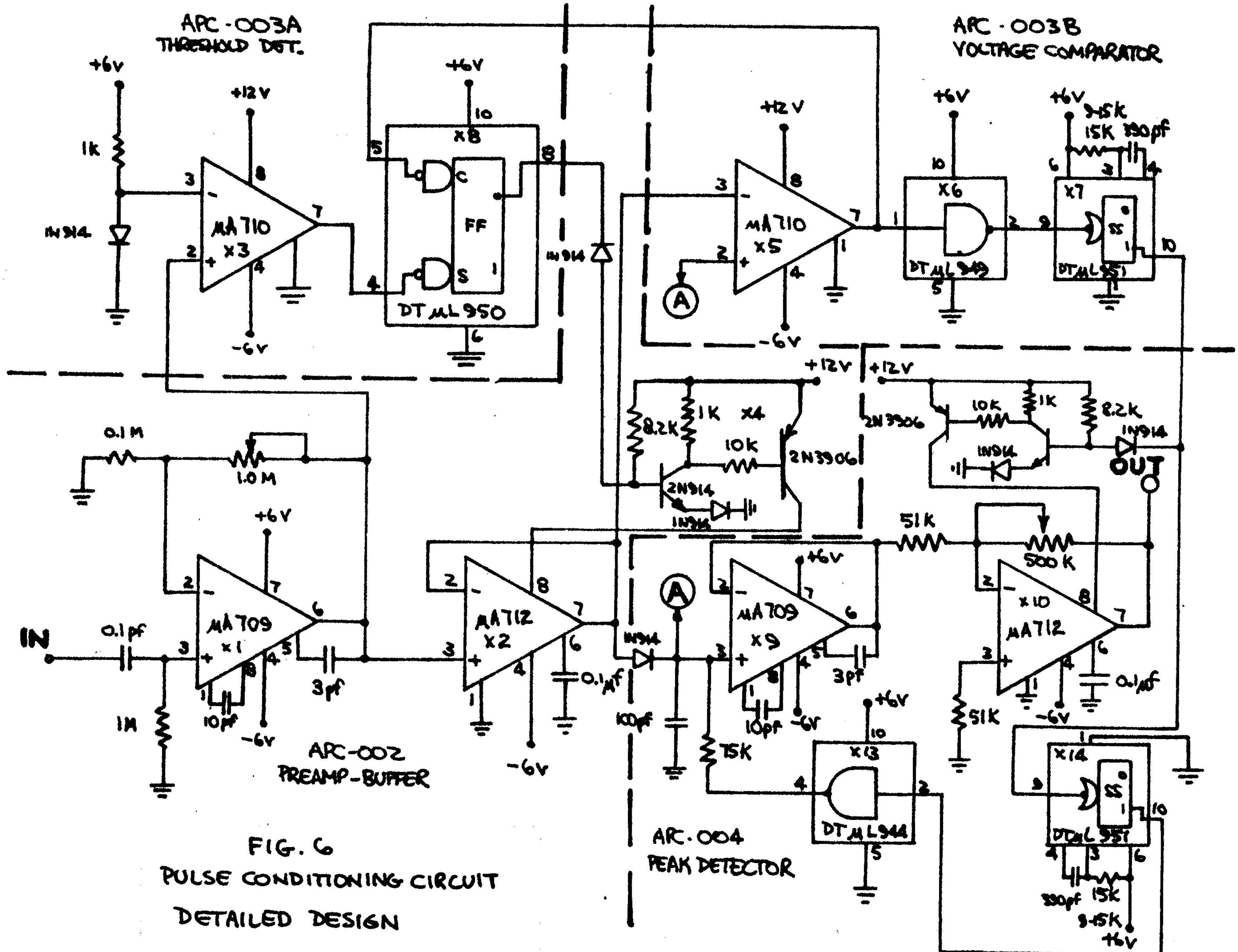

FIG. 6
PULSE CONDITIONING CIRCUIT
DETAILED DESIGN

clear pulses;

iv) Pulses appearing on power supply lines may have caused false triggering which showed up as spurious pulses.

The circuit was subsequently modified to make it functional. This involved the design and development of field effect transitor (FET) gate circuits to replace gating designed with the μA712. Additional FET circuitry was designed to eliminate low impedance problems associated with the μA710 comparator and the storage capacitor. The problem of spurious pulses was attacked from the standpoint of decoupling the power supply lines of suspected components. This was done by zener diode regulating each of them from the high voltage supply. This reduced spurious pulses but did not completely resolve the problem.

These modifications made the circuit functional, however, its dynamic range was not sufficient and there was a hysteresis effect in the input-output amplitude relationship. To improve the dynamic range the power supply voltage of the preamp (μA710) was increased and the FET units associated with the peak detector and storage capacitor were adjusted to optimize their range. It was found that dynamic range and hysteresis were related in such a way that adjustments which improved dynamic range also increased hysteresis losses. Work is continuing on the modified circuit in order to make it more useable.

2. Calibration of the Sensor

The detection characteristics of the hot-wire device for various size droplets was further investigated during this report period. In this study distilled water droplets were used as the test aerosol.

The test aerosol was generated using a Mistogen EN-140 Ultrasonic Nebulizer. Figure 7 is a schematic illustration of the experimental apparatus. Output from the hot-wire system was fed into an oscilloscope and 16 mm movies were made of the oscilloscope display. Each frame of the developed film was projected on an opaque screen and the area and pulse height of each individual pulse were measured. No difficulties were encountered in counting the pulses even though pulse images tended to persist for several frames. Approximately 1800 pulses were measured in this manner.

To calibrate the hot-wire unit a 0.1% NaCl solution was generated from the ultrasonic nebulizer and the dried aerosol was sampled using an electrostatic precipitator. Photomicrographs of the collected samples were then used to establish the size distribution of the dried NaCl particles from which an

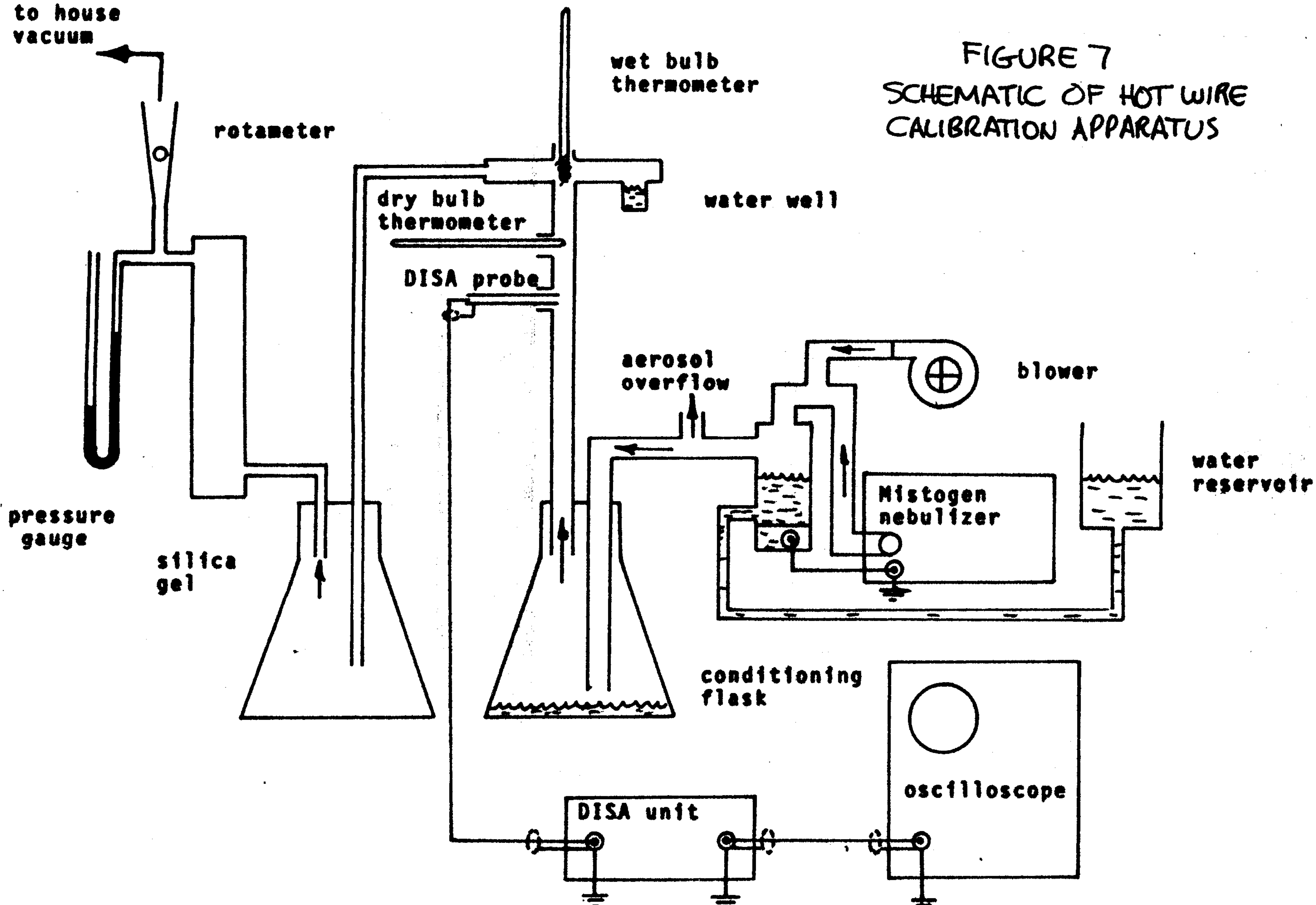

FIGURE 7
SCHEMATIC OF HOT WIRE
CALIBRATION APPARATUS

estimate of the size distribution of the initial droplets was made. In addition, by assuming a collection efficiency of 2% for the electrostatic precipitator sampler an estimate of the output number concentration of the nebulizer was also determined. (3) These data are listed in Table 4.

Table 4

Calibration Aerosol Characteristics

Droplets	Mean	Standard Deviation	α	Estimated Droplet Concentration per liter
Number	4.12μ	1.64μ	0.398	1.91×10^7
Mass	2.19μ	2.28μ	1.04	1.91×10^7

It appears that the output of the detector approximately reproduces the size distribution input of the test aerosol. Measured standard deviations were always greater than expected when compared to a collection technique which is considered to be relatively non size-selective. In addition, we found that stream velocity variations above some threshold did not affect counting efficiencies significantly. We did find that wire temperature significantly affects detector output, contrary to what had been deduced by Goldschmidt. (4) For example, we found that a hotter wire detected fewer particles than a colder wire. The pulse heights were smaller for the lower temperature wire than for the higher temperature wire, whereas the reverse was true for pulse areas. These results reflect that with a hotter wire temperature the water droplets evaporate more quickly - hence one obtains a larger initial voltage pulse and smaller pulse area.

Although the hot-wire technique for counting and sizing particles is dramatic there are still limitations which must be overcome before the technique can be readily utilized.

III. Future Activities

It is intended to devote major effort during the next report period to the McDonnell-Douglas 60 Day Space Cabin Simulator Study.

REFERENCES

1. Gucker, F. T. and O'Konski, C. T., "Electronic Methods of Counting Aerosol Particles", Chem. Rev. 44, 373 (1949).
2. Reist, P. C., and Burgess, W. A., "A Comparative Evaluation of Three Aerosol Sensing Methods", AIHAJ, 29, 123 (1968).
3. Reist, P. C., "Size Distribution Sampling Errors Introduced by the Point-Plane Electrostatic Sampling Device", Proc. of the 9th Air Cleaning Conference, CONF-660904, 2, 781 (1967).
4. Goldschmidt, V. W., "Measurement of Aerosol Concentrations with a Hot Wire Anemometer", J. Colloid. Sci. 20, 617 (1965).