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THE GARRETT CORPORATION

AiResearch Manufacturing Division

LOS ANGELES 45, CALIFORNIA

REPORT NO. FC-4550

Final Contract Report

BLOOD PRESSURE MEASURING SYSTEM 54803

PROJECT GEMINI

Contract NAS 9-2887

FC-4550 April 7, 1965

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SECTION I

INTRODUCTION

AiResearch's development of Project Mercury, Gemini, and Apollo environmental control systems, advanced life support system studies, etc., has caused AiResearch to take a vital interest in life support functions in spaceflight, and has naturally led to a deeper study of aerospace medical instrumentation.

Blood pressure studies were initiated at AiResearch in 1958 to support the then current studies of the Project Mercury environmental control system studies and hardware development. Initially, the effort was concerned with obtaining correlations which would allow interpretation of conventional spnygmograms. The primary requirement for the study was that the blood pressure indicies must be exceedingly close to those measured with the stethoscope. Although other indicies may be useful, they cannot be interpreted within the framework of more than 50 years of data taken by physicians all over the world. As a result of these studies, a compact, portable electronic blood pressure system was developed which unambiguously presented the conventional systolic and diastolic indicies in a clear, graphical display.

With one exception, the electronic blood pressure system, differs only slightly in principle from the standard clinical (ausculatory) instrumentation. Both employ an occluding cuff pressurization source, a bleed rate device, an occluding cuff, and a cuff pressure transducer, pressure gauge, or mercury manometer. The one exception is that the stethoscope (ausculatory method) is replaced by a microphone, the output of which is conditioned by an electronic amplifier and selective filter. The resulting output on a strip chart recorder is a plot of cuff pressure vs time, depicting the selected bleed-down with superimposed pulses from the Korotkoff sound detection channel. The first pulse during bleed-down denotes the systolic pressure, while the last pulse denotes the diastolic pressure. A more thorough discussion of the electronic blood pressure system is presented in Appendix A, "AiResearch Blood Pressure Measurement System, Theory of Operation," FC-4076-R, Rev. 1.

SECTION 2

PROJECT MERCURY (CONTRACT NAS 5-59)

GENERAL

Effort on the subsequent development contract for a blood pressure measuring system (BPMS) for Project Mercury was primarily aimed at improving the performance of the pulse channel, adding required pneumatic cycling, and repackaging for compatibility with space capsule installation. Installation problems encountered at various stages through the Project Mercury program caused a multiple number of systems to be developed with varying degrees of sophistication. Pneumatic cycling ranged from completely manual to semi-automatic, to completely automatic.

The semiautomatic systems were completely qualified, and successfully completed multiple orbital missions. The following areas left room for improvement for subsequent contracts and projects:

1. Packaging
2. Pressure transducer performance
3. Gain control adjustment

Packaging of the semiautomatic system suffered from program timing, etc., to the extent that AiResearch and the customer had to agree to spread components throughout the space capsule. Weight and size improvements were obviously available if the function of the system could be redefined, if more state-of-the-art components were substituted, and if more advanced electronic packaging were employed.

Though probably the best pressure transducer was employed for the application at hand, its performance left much to be desired. Redefinition of the required output and employment of subsequent developments would much improve this picture.

The gain control functions properly, but left something to be desired when considering a new or untrained operator. If it was inadvertently set incorrectly, correct data could be masked by spurious noise or missing pulses.

REPORTS AND DATA SUMMARIZED

For the reader's convenience, listed on succeeding pages are reports prepared on this related previously completed contract. The reports are grouped by subject.

Design Data

FC-3989-MC	Comparison of Cuff Pressure Cycling Methods for Automatic Blood Pressure Measuring Systems	June 23, 1961
FC-4018-MR	Project Mercury Blood Pressure Measuring System, AiResearch Comments to McDonnell Specification SCD45-68727, dated 26 June 1961	July 31, 1961
FC-4033-MR	Preliminary, Interference Control Plan for the Blood Pressure Measuring System P/N 54741	August 17, 1961
F-3868-MR	Test Plan for Radio Interference Control Blood Pressure Measuring System P/N 54741	August 30, 1961
EKFJ/101	Power Analysis, Blood Pressure Measuring System 54741, Project Mercury	August 31, 1961
FC-4040-MR	Failure Analysis, Blood Pressure Measuring System 54741, Project Mercury	September 8, 1961
FC-4042-MR	Description of the Gain Control for the Microphone Preamplifier for AiResearch P/N 54741	September 12, 1961
FC-4041-MR	Description of the 400 CPS Inverter and Voltage Regulator for AiResearch P/N 54741	September 12, 1961

FC-4045-MR	Preliminary Power Analysis, Blood Pressure Measuring System 54754, Project Mercury	September 18, 1961
FC-4044-MR	Spare Parts Proposal for the Blood Pressure Measuring System 54741, Project Mercury	September 19, 1961
FC-4049-MR	Proposed Milestone Chart and Data Submittal Schedule, Blood Pressure Measuring System 54741 and 54754 Project Mercury	September 22, 1961
FC-4046-MR	Milestone Chart and Data Submittal Schedule for Blood Pressure Measuring System 54741, Project Mercury	September 22, 1961
BSTE 203	Recommended Ground Support Equipment for Blood Pressure Measuring System 54741	September 25, 1961
RC-59-MR	Reliability and Stress Analysis, AiResearch Blood Pressure Measuring System 54741, Project Mercury	October 20, 1961
SA-1147-MR	Stress Analysis of the 54741 Blood Pressure Measuring System on Project Mercury for McDonnell Aircraft and NASA	December 15, 1961
FC-4076-R, Rev.1	AiResearch Blood Pressure Measurement System, Theory of Operation	February 28, 1962
FC-4141-MR	AiResearch Comments to McDonnell Specification SCD45-88727, Revision C, dated 14 December 1961, Project Mercury Blood Pressure Measuring System	March 7, 1962
SA-1170-MR	Stresscoat and Burst Tests of the 134690 Oxygen Bottle for the Blood Pressure Measuring System on Project Mercury	March 14, 1962

FC-4094-R	Correlation Tests on AiResearch Blood Pressure Measuring System 54743	April 30, 1962
FC-4236-MR	AiResearch Comments to McDonnell Specification SCD45-88727, Revision E, dated 17 August 1962, Project Mercury Blood Pressure Measuring System	October 18, 1962
FC-4242-MR	AiResearch Recommended Procedure for Installation of Blood Pressure Cuff and Microphone BPMS 54778, Project Mercury	October 19, 1962
FC-4276-MR	Procedure for Setting Gain Control and for Data Readout Blood Pressure Measuring System Controller 510916, Project Mercury	December 21, 1962

Acceptance Testing

FC-3977-MR	Acceptance Test Procedure Manifold, Gaseous 513827 Manifold, Gaseous 513828 Manifold, Gaseous Aux. 513903 Project Mercury	March 15, 1961
FC-4096-MR, Rev.1 FC-4096-MR, Rev.2 FC-4096-MR, Rev.3	Acceptance Test Procedure, Blood Pressure Measuring System Controllers 510916-1,-2,-3, and -4	December 2, 1961 February 5, 1962 September 6, 1962
FC-4101-MR	Acceptance Test Procedure, Pneumatic Components, Blood Pressure Measuring System 54769, Project Mercury	January 2, 1962
FC-4139-MR	Acceptance Test Procedure, Microphone 513513, Project Mercury	March 13, 1962

FC-4139-MR, Rev.1	Acceptance Test Procedure, Microphone 51313, Project Mercury	August 29, 1961
FC-4071-MR	Bench Test Procedures, Blood Pressure Measuring System 54741, Project Mercury	October 2, 1962
FC-4069-MR	Post-Installation Checkout Procedures Blood Pressure Measuring System 54741, Project Mercury	
FC-4274-MR	Bench Test Procedures, Blood Pressure Measuring Systems 54767, 54769, and 54778, Project Mercury	October 25, 1962
FC-4113-MR	Post-Installation Checkout Procedures, Blood Pressure Measuring Systems 54769 and 54778, Project Mercury	October 26, 1962

Qualification and Flight-Worthiness Testing

FC-4050-MR	Flight-Worthiness Test Procedure, Blood Pressure Measuring System 54741, Project Mercury	September 26, 1961
FC-4117-MR	Qualification Test Procedure, Semi-Automatic Blood Pressure Measuring Systems 54769 and 54778, Project Mercury	February 2, 1962
FC-4143-MR	Failure Report No. 1 of Blood Pressure Measuring System 54778	March 8, 1962
FC-4117-MR, Rev.1	Qualification Test Procedure, Semi-Automatic Blood Pressure Measuring Systems 54769 and 54778, Project Mercury	March 9, 1962
FC-4167-MR	Failure Report No. 2, Blood Pressure Measuring System 54778, Project Mercury	May 9, 1962
FC-4184-MR	Failure Report No. 3, Blood Pressure Measuring System 54778, Project Mercury	May 29, 1962

Progress Reporting

FC-4022-MR	Progress Report, Blood Pressure Measuring System-PMS	July 21, 1961
FC-4035-MR	Progress Report No. 2, Blood Pressure Measuring System-PMS	August 30, 1961
FC-4151-MR	Progress Report No. 3, Blood Pressure Measuring System-PMS	April 5, 1962
FC-4277-MR	Final Progress Report No. 4, Blood Pressure Measuring System, Project Mercury	December 28, 1962

Weight Reporting

FC-4032-MR	Weight Report No. 1, Blood Pressure Measuring System 54741, Project Mercury	August 23, 1961
FC-4048-MR	Weight Report No. 2, Blood Pressure Measuring System 54741, Project Mercury	September 22, 1961
FC-4074-MR	Weight Report No. 3, Blood Pressure Measuring System 54741, Project Mercury	October 13, 1961
FC-4131-MR	Weight Comparison Report, Blood Pressure Measuring Systems 54768 and 54778, Project Mercury	February 19, 1962

SECTION 3

PROJECT GEMINI - PROTOTYPE (CONTRACT NAS 9-1189)

Redefinition of the output and function of the BPMS made possible a drastic reduction in the size and weight as compared to the Project Mercury BPMS. A very thorough and exhaustive program to develop a solid-state semiconductor strain-gauge pressure transducer resulted in a miniature strain-gauge pressure transducer surpassing the performance of the Project Mercury counterpart with a large savings in weight, size, and power consumption. Further development of the pulse channel made possible the elimination of one of the two amplifier-filter sections (previously required for Project Mercury), drastically reduced the required dynamic range of the gain control, and made adjustment of the gain control almost foolproof. For ease of adjustment, log gain vs turns was optimized and was made linear within ±10 percent.

The design concept of the Project Gemini prototype is based upon the identical physiological factors considered during the development of Project Mercury Blood Pressure Measuring Systems. The prototype design monitors the Korotkoff sounds emanating from the brachial artery and superimposes this pulse signal on the required 0 to 20 mv d-c signal proportional to cuff pressure. Differences between the two systems stem from circuit redesign relative to signal flow and gain, component miniaturization, and the requirements for manual cuff inflation rather than semiautomatic inflation.

The prototype system designed to be carried on the astronaut rather than installed on the space capsule consists of the following miniature components:

1 signal conditioner
1 microphone
1 manual inflator
1 occluding cuff (government furnished)
1 suit fitting (government furnished)

Operation as described in Appendix A, "Operating Instructions, Prototype Blood Pressure Measuring System 5480A, Project Gemini," FC-4550-MR, dated

July 29, 1963) is nearly identical to the operation required for the Project Mercury semiautomatic system except that the occluding cuff is manually inflated.

Size, power consumption, performance, and location were the major factors to be considered for the development of a solid-state strain-gauge pressure transducer. One of the first pressure transducers employed was a CEC 4-325. During the initial stages of the program, it appeared that it would be replaced by a competitor's transducer, since it was not solid-state (hence it required excessive current or an add-on differential d-c amplifier), it exhibited a form factor that was not conducive to the locations then considered, and it had an exposed sensory diaphragm which, with time, proved to be a serious handling problem; transducers were damaged beyond repair and replacement was hampered by short supply and long lead time. However, continued effort with other pressure transducer manufacturers uncovered even more insurmountable problems, as discussed in Appendix C, "Transducer Evaluation Report, Solid-State Semiconductor Strain-Gauge, Project Gemini BPMS," FC-4303-PR, dated October 9, 1963.

One of the alternative manufacturers discussed in Appendix C manufactured and delivered, excessively late, a pressure transducer which appeared to be satisfactory during preliminary tests, but declined to deliver a second pressure transducer on the same order (due to excessive manufacturing costs and serious technical problems encountered). Another of the alternative manufacturers submitted several pressure transducers for evaluation through the program but was plagued with serious problems and finally could not complete the required development to eliminate these problems in the allotted time.

In the end, modification of CEC's 4-325 transducer proved to be the most practical solution. A very stable differential d-c amplifier was delivered to amplify output, thus reducing the required excitation and hence limiting current consumption to an acceptable level. The case design was modified to enclose the sensory diaphragm, thus eliminating handling problems, and to allow incorporation of the pressure transducer into the signal conditioner module, thus eliminating any location problems. The modified transducer is identified by P/N 171-559-0100.

Since the reduction in size and weight required the use of many miniature components, some of which were unproven, an extensive component evaluation program was conducted. To avoid destruction or repair of welded modules, various test jigs were designed and employed to test components in the final circuit configuration prior to welding.

The program for development of manual inflators was expanded beyond that required for the systems originally ordered. The expansion in the program, described in Appendix D, "Development and Test Program, Dual-Purpose Manual Inflator 53t136-2-1," FC-4472, dated December 16, 1963, was due to the following NASA requests:

1. Change the pneumatic connector from the Mercury-type probe to that compatible with the Gemini-type connector developed later in the program.

2. Provide functions required for water tank pumping in addition to blood pressure functions.

Additional modification was included in the dual-purpose manual inflator to replace the fixed bleed orifice. This addition allowed tightening of the tolerance on bleed-down time and made provision for revision of the desired bleed-down time if required at a later date.

As the program progressed, it was noted that the "epoxy" potting material used during the final stages of signal conditioner manufacture changed the temperature coefficient of the pressure transducer. To avoid this change and consequent upsetting of the temperature compensation, a preplotting modification was added to the pressure transducer, identified by P/N 171859-0101.

REPORTS AND DATA SUMMARIZED

For the reader's convenience, listed on succeeding pages are reports prepared on this related previously completed contract. The reports are grouped by subject.

Design Data

FC-4325-IR — Parts List, Breadboard of Blood Pressure Measuring System 54803, Project Gemini — April 22, 1963

FC-4327-MR	Operating Instructions for Breadboard of Blood Pressure Measuring System 54803, Project Gemini	April 26, 1963
Appendix C FC-4327-MR	Testing of Microphone 538290	May 21, 1963
FC-4327-MR, Rev. J	Operating Instructions for Breadboard of Blood Pressure Measuring System 54803, Project Gemini	May 21, 1963
FC-4366-MR	Specification Review, Blood Pressure Measuring System 54803, Project Gemini	July 23, 1963
FC-4365-MR	Parts List, Protype of Blood Pressure Measuring System 54803, Project Gemini	July 24, 1963
FC-4359-MR	Operating Instructions, Prototype Blood Pressure Measuring System 54803, Project Gemini	July 29, 1963
FC-4403	Transducer Evaluation Report, Solid-State Semiconductor Strain-Gauge, Project Gemini GPMS	October 9, 1963
Appendix A FC-4403-MR	Appendix A, Transducer Evaluation Report, Vendor "C" Project Gemini Blood Pressure Measuring Syste	December 27, 1963
FC-4465-MR	Specification Review, Blood Pressure Measuring System 54803, Project Gemini	November 20, 196
FC-4472	Development and Test Program, Dual-Purpose Manual Inflator 538186-2-1	December 16, 196

Progress Reporting

FC-4314-MR	Progress Report No.1, Blood Pressure Measuring System, Project Gemini	March 21, 1963
FC-4320-MR	Progress Report No.2, Blood Pressure Measuring System, Project Gemini	April 5, 1963
FC-4332-MR	Progress Report No.3, Blood Pressure Measuring System, Project Gemini	May 2, 1963
FC-4344-MR	Progress Report No.4, Blood Pressure Measuring System, Project Gemini	May 29, 1963
FC-4360-MR	Progress Report No.5, Blood Pressure Measuring System, Project Gemini	July 9, 1963
FC-4390-MR	Progress Report No.6, Blood Pressure Measuring System, Project Gemini	September 20, 1963
93-9-MR-95	Final Contract Report, Blood Pressure Measuring System 54803, Project Gemini, Contract NAS 9-1139	September 26, 1964

SECTION 4

PROJECT GEMINI - PRODUCTION CONTRACT NAS 9-2887

GENERAL

The production contract for the Gemini BPMS is, in essence, a continuation of the development program encountered in the prototype contract. A new potting material was substituted in an effort to ease temperature compensation problems and to avoid the brittleness of the previously employed materials. A calibration circuit was developed and incorporated in all production signal conditioners. A qualification test program was conducted and successfully passed. The manual inflator was modified to provide additional structural strength.

A program was conducted to eliminate the stage of manufacture employed in the prototype contract where jigs were employed to test all components in the final circuit configuration prior to welding. As a result, specific selected components are left out during a first-stage welding. With the use of special welded-circuit holding jig and test panel, the selected components are chosen and tested in the nearly completed welded circuit. Special preparation of the mylars allows insertion of these selected components during a second welding stage.

A technique has been reduced to practice for temperature-compensating signal conditioners by taking advantage of the base-to-emitter voltage temperature coefficient by varying the current in the two legs of the differential amplifier. This reportable item is described in Docket A-2617. It has not yet been established if this item constitutes an invention.

DELIVERIES (SUMMARIZED)

Listed below is all the hardware delivered to the government as a part of Contract NAS9-2887:

Quantity	Description
4	BPMS 54803-2 (unqualified)
2	BPMS 54303-2 (for qualified testing)
15	BPMS 54803-2 (qualified)
21 Total	

NOTE: Per the terms of the contract, NASA supplied AiResearch with the first 10 pressure transducers. Each PPS 54803 consists of the following:

1 signal conditioner, 538180-1-2

1 microphone, 538176-2-1

1 manual inflator, 538156-2-1

REPORTS AND DATA (SUMMARIZED)

The following reports were prepared as a part of this contract and are grouped by subject:

Design Data

93-9MR80	Power Requirements Data, Blood Pressure Measuring System 54803, Project Gemini	July 24, 1964

Acceptance Testing

FC-4522	Acceptance Test Procedure, Blood Pressure Measuring System P/N 54803 Gemini	September 15, 1964
FC-4522, Rev.1	Acceptance Test Procedure, Blood Pressure Measuring System P/N 54803 Gemini	October 12, 1964

Qualification Testing

FC-4524	Qualification Test Procedure For Project Gemini Blood Pressure Measuring System, AiResearch P/N 54803	September 30, 1964
FC-4524, Rev.1	Qualification Test Procedure for Project Gemini Blood Pressure Measuring System, AiResearch P/N 54803	October 20, 1964

93-9MR104	Failure Report No. 1, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	December 3, 1964
93-9MR106	Failure Report No. 2, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	December 22, 1964
93-9MR110	Failure Report No. 3, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	January 12, 1965
FC-4541	Qualification Test Report, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	January 22, 1965

Progress Reporting

93-9MR85	Progress Report No. 1, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	July 20, 1964
93-9MR89	Progress Report No. 2, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	August 4, 1964
93-9MR92	Progress Report No. 3, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	August 18, 1964
93-9MR95	Progress Report No. 4, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	September 14, 1964
93-9MR99	Progress Report No. 5, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	October 4, 1964

93-9MR101	Progress Report No. 6, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	October 22, 1964
93-9MR102	Progress Report No. 7, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	November 9, 1964
93-9MR105	Progress Report No. 8, Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	December 7, 1964
93-9MR111	Progress Report No. 9 Blood Pressure Measuring System 54803 Project Gemini, Contract NAS9-2887	January 15, 1965

Acceptance test data accompanied each of the 21 systems when shipped to the government. An example of the data accompanying each system is that shown in Figures 1 through 7.

DETAILED FABRICATION DRAWINGS (SUMMARIZED)

Drawings prepared or still in effect for this contract are listed below as applicable to the part in the system:

Part Name	Part Number
Blood Pressure Measuring System	
Measuring System, Blood Pressure	54803
Wiring Diagram, Schematic, Blood Pressure Measuring System	806130
Microphone	
Microphone, Blood Pressure	538178
Microphone Assembly, Blood Pressure	538179
Diaphragm, Microphone	806121
Sleeve, Wire Entry	806121

Part Name	Part Number
Housing, Microphone	806122
Terminal Assembly, Microphone	806123
Plate, Identification, Microphone	806124
Housing Assembly, Microphone	806125
Terminal Board, Microphone	806126
Cable Assembly, Microphone	806127
Crystal, Piezo-Electric, Bimorphic	537148
Signal Conditioner	
Signal Conditioner, Blood Pressure Measuring System	538180
Transducer and Thermistor Assembly	806131
Plate Identification, Signal Conditioner	806131
Manual Inflator	
Inflator, Outline, Manual	538186
Inflator Assembly, Dual-Purpose	806110
Valve Assembly, Air Control	806100
Housing, Valve Seat	806104
Adapter, Air Control Valve	806105
Pin, Shoulder, Headless	806106
Retainer	806107
Housing, Check Valve	514911
Valve Assembly, Check, Stop	51412
Body Assembly, Valve	806112
Body, Valve	806113
Orifice Valve	806114

Part Name	Part Number
Stem, Valve	806115
Bulb, Rubber-Squeeze	806116
Hose Assembly, Rubber, Pressure Control	806117
Hose Assembly, Rubber, Pressure Check	806118
Valve Seat Assembly, Rubber	802084
Lock Collar, Inflator Assembly	802386
Nut, Hose Coupling	806097
Adapter, Straight Tube to Hose	806098
Nut, Coupling	806099

Blood Pressure Measuring System P/N 54803

CDS-54803, Rev. 1
Oct. 13, 1964

Microphone S/N 124-D7

Manual Inflator S/N 104-D6

Date 10-23-64

Signal Conditioner S/N 94-D6
(FC-4522)

4.6.3 Blood Pressure Trace — Accept ✓ Reject ☐

4.6.4 Power Consumption

Power Supply	Current Reading (ma)	Max (ma)
-17.1 v dc	9.3	12.0
+10.1 v dc	3.7	5.0

4.7 System Burn-In Test

Microphone Sensitivity			
	Actual Reading		
Min	Before	After	Max
-98 db	-84.7	-84.2	-80 db

Pressure Calibration				
	Output Voltage (mv)			
Input Pressure (mm Hg)		Actual Reading		
	Min	Before	After	Max
25	-0.4	+.29	+.31	+0.4
125	+9.6	+10.38	+10.38	+10.4
225	+19.6	+20.23	+20.20	+20.4

Gain Adjustment				
	Gain			
		Actual Reading		
Potentiometer Setting	Min	Before	After	Max
Full CCW	-	23	23	30
Full CW	200	240	242	-

AiResearch Mfg. Co.
Los Angeles, Calif.

FIGURE 1

(FC-4522)

Date 10-23-64

4.7

Length of Test	Start		Finish	
	Date	Hour	Date	Hour
50 hr	10/24/64	0710	10-26-64	0912



FIGURE 2

P/N 538176-2-1 Date 10-23-64

S/N 124-D7

4.1 Examination Accept [✓] Reject [ ]

4.2 Weight Maximum allowable = 25 grams

20.89 grams

4.3 Microphone Sensitivity

Min	Actual Reading	Max
-88 db	-84.7	-80 db

FIGURE 5

P/N 538180-2-1

Date 10-10-64

S/N 104-D6

4.1 Examination — Accept [✓] Reject [ ]

4.2 Weight — Maximum Allowable = 120 grams

111 grams

4.4.1 Pressure Test

Run	Number of Squeezes (10 max)	Quantity of Water (oz)
1	7	4
2	8	5

4.4.2 Vacuum Test

Run	Number of Squeezes (10 max)	Vacuum (IN. H_2O)
1	5	36.5
2	6	38.0

FIGURE 4

P/N 538.89-1-2
S/N 94-D6

Date 10-23-84

4.1 Examination — Accept [✓] Reject [ ]

4.2 Weight — Maximum allowable = 47 grams

45 grams

4.5.1.4 Pressure Calibration

Input Pressure (mm Hg)	Output Voltage (mv) Min	Actual Reading	Max
25	-0.4	+.24	+0.4
125	+9.6	10.38	+10.4
225	+19.6	20.24	+20.4

4.5.2 Linearity — Accept [✓] Reject [ ]

FIGURE 5

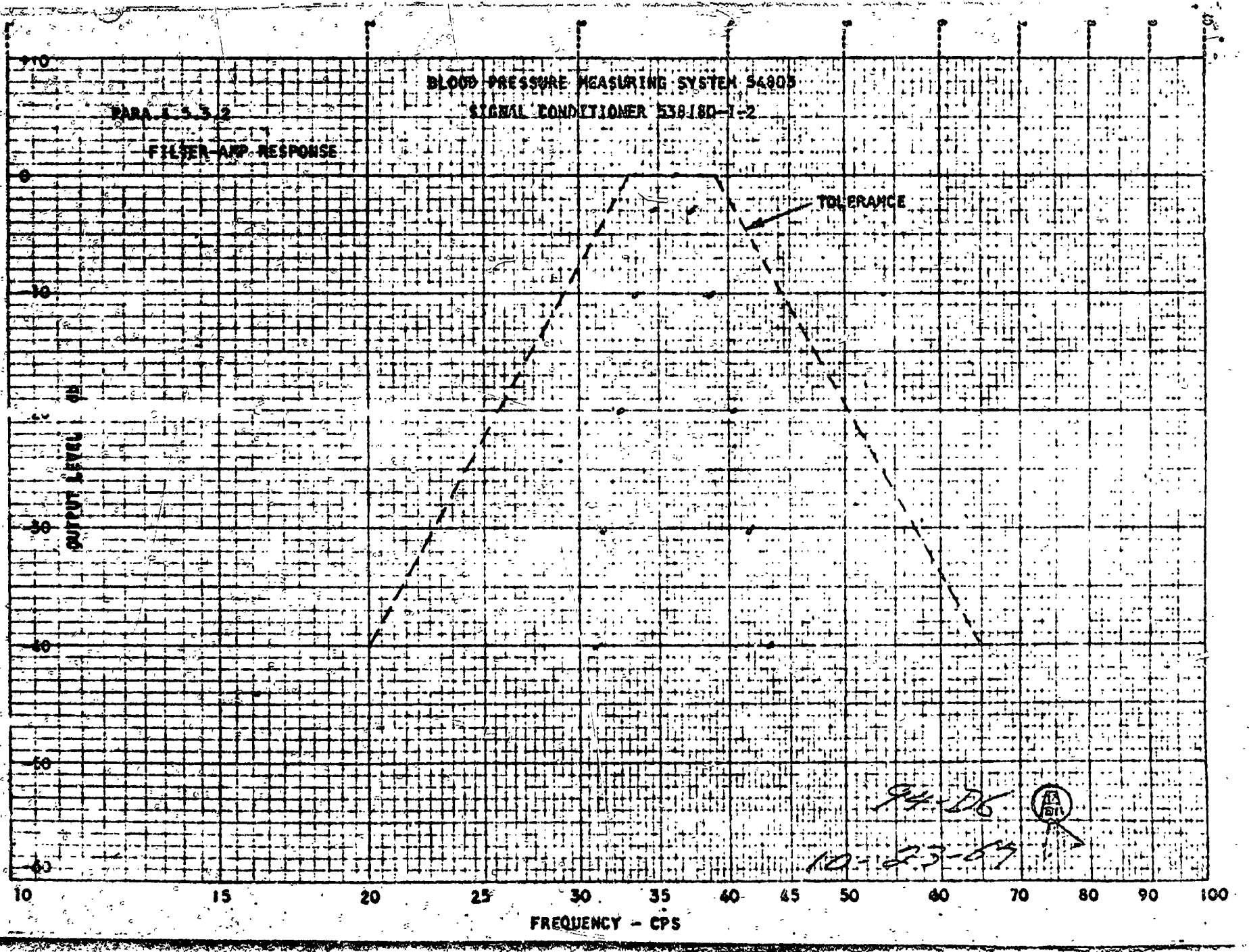

BLOOD PRESSURE MEASURING SYSTEM 54803
SIGNAL CONDITIONER 538180-1-2
PARA. 4.5.3.2
FILTER-AMP RESPONSE
TOLERANCE
OUTPUT LEVEL dB
0
-10
-20
-30
-40
-50
-60
10
15
20
25
30
35
40
45
50
60
70
80
90
100
FREQUENCY - CPS

FIGURE 6

P/N 538180-1-2
S/N 94-D6

Date 10-23-64

4.5.4 Gain Adjustment

Potentiometer Setting	Gain		
	Min	Actual Reading	Max
Full counter-clockwise		23	80
Full Clockwise	200	240	-

4.5.5 Calibration Check

Output Voltage (V)		
Min	Actual Reading	Max
+9.5	9.90	+10.4

4.5.6 Input Voltage Variation

Input Voltage	Potentiometer Setting	Gain		
		Min	Actual Reading	Max
+9.9 v dc	Full CCW	-	23.5	80
	Full CW	200	242	-
+10.1 v dc	Full CCW	-	24	80
	Full CW	200	244	-

FIGURE 7

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

For future spaceflights such as Project Gemini and Project Apollo and even in the laboratory, it appears that the Gemini-BPMS has been developed to a near fool-proof operational system for the measurement of any subject's blood pressure, especially where a permanent record is desired. Considering the probable future applications, no additional miniaturization or refinement appears practical.

Where the subject's upper arm is not readily available, where repeated measurements are required but continuous installation of the system is undesirable and repeated re-installations are difficult, or where repeated measurements are desirable in a short period of time; a logical extension of the Gemini-BPMS is recommended. The basic know-how, signal characteristics, and operating principles established in the development of the Gemini-BPMS have put AiResearch in an excellent position to develop an operational digit plethysmograph (DPG). It is suggested that correlation of the two systems could be exceedingly close. Also, readout of the DPG could be a permanent graphical recording identical to the BPMS or some other more desirable output such as a subject-read meter.

APPENDIX A

AIRESEARCH BLOOD PRESSURE MEASURMENT SYSTEM THEORY OF OPERATION

(FC-4076-R, Rev. 1 DATED FEBRUARY 28, 1962)

THE GARRETT CORPORATION
AiResearch Manufacturing Divisions

REPORT NO. FC-1076-R, Rev. 1

AIRESEARCH BLOOD PRESSURE MEASUREMENT SYSTEM THEORY OF OPERATION

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FOREWORD

This report presents the medical and engineering theory of operation of the Blood Pressure Measuring system in compliance with Item 30, titled "Theory of Operation", of McDonnell Aircraft Corporation, Document No. 45-88727. In particular, the influence of the components and the environmental conditions on the detection of the diastolic and systolic pressures is discussed.

AiResearch expresses its gratitude to the staff of the U. C. L. A. medical school and the Department of Cardiology, and its chairman Dr. A. A. Kattus, M. D. Acknowledgment is given to Dr. L. A. Geddes, M. D. and associates at Baylor University for their prior work in blood pressure recording.



SECTION I

INTRODUCTION

Considerable time has been expended in attempting to gain more information concerning the health of the heart without resorting to surgical techniques. The primitive means of observing the heart was to listen directly to the heart sounds and then compare these sounds with those of other "normal" hearts. Originally these sounds were received by the human ear against the chest. These sounds are caused by muscle contractions, blood flow, and other vibrations which are transmitted through the muscle and tissue to the chest exterior. In 1819, Laennec introduced the monaural stethoscope. Much later, Cammann introduced the binaural version. The next logical development was to replace the ear with a pressure transducer and to record the heart sounds on a graph. This technique of graphically recording the acoustic phenomena associated with the cardiac actions is termed phonocardiography.

Since AiResearch has a vital interest in life support functions in spaceflight (Project Mercury environmental system, Apollo environmental system, advanced life support system studies, etc.), these problems led, naturally, into a deeper study of aerospace medical instrumentation. As a result of these studies, a compact, portable electronic blood pressure system has been developed which unambiguously presents the conventional systolic and diastolic indices in a clear, graphical display.

SECTION II

CONVENTIONAL BLOOD PRESSURE MEASUREMENT SYSTEMS

A. BACKGROUND

The science of blood pressure measurement is referred to as sphygmomanometry. The blood pressure varies between the peak and trough values of the pulse. The peak and trough wave are referred to as the systolic and diastolic pressures, respectively. The variation of the pressure through the circulatory system is indicated in Figure 1. This shows that the pressure does not decrease appreciably until in the large arteries, but does drop on passage through the arteries and capillaries.

The sphygmomanometer has been part of the standard practicing equipment of the physician for the past half century. Although it was preceded by earlier aids, the development of this relatively simple device required more than a century of research and experimentation by a succession of famous physiologists and physicians.

In 1733 Stephen Hales effected the first recorded measurement of blood pressure by insertion of a tube (cannulation) into the leg artery of a horse and connecting it to a vertical tube. The blood in the tube rose slightly more than 8 ft, an accurate measurement of blood pressure in the left ventricle. It was nearly a century later that Poiseuille introduced the U-shaped mercury manometer, shown in Figure 2 in use with cannulation. This manometer, which was filled with a solution of carbonate of soda to prevent clotting was attached directly to the artery.

An early practicable instrument for measuring indirectly human arterial pressure was the Herrison "Sphygmometre", shown in Figure 3. This device consisted of a metal hemisphere covered with a membrane.

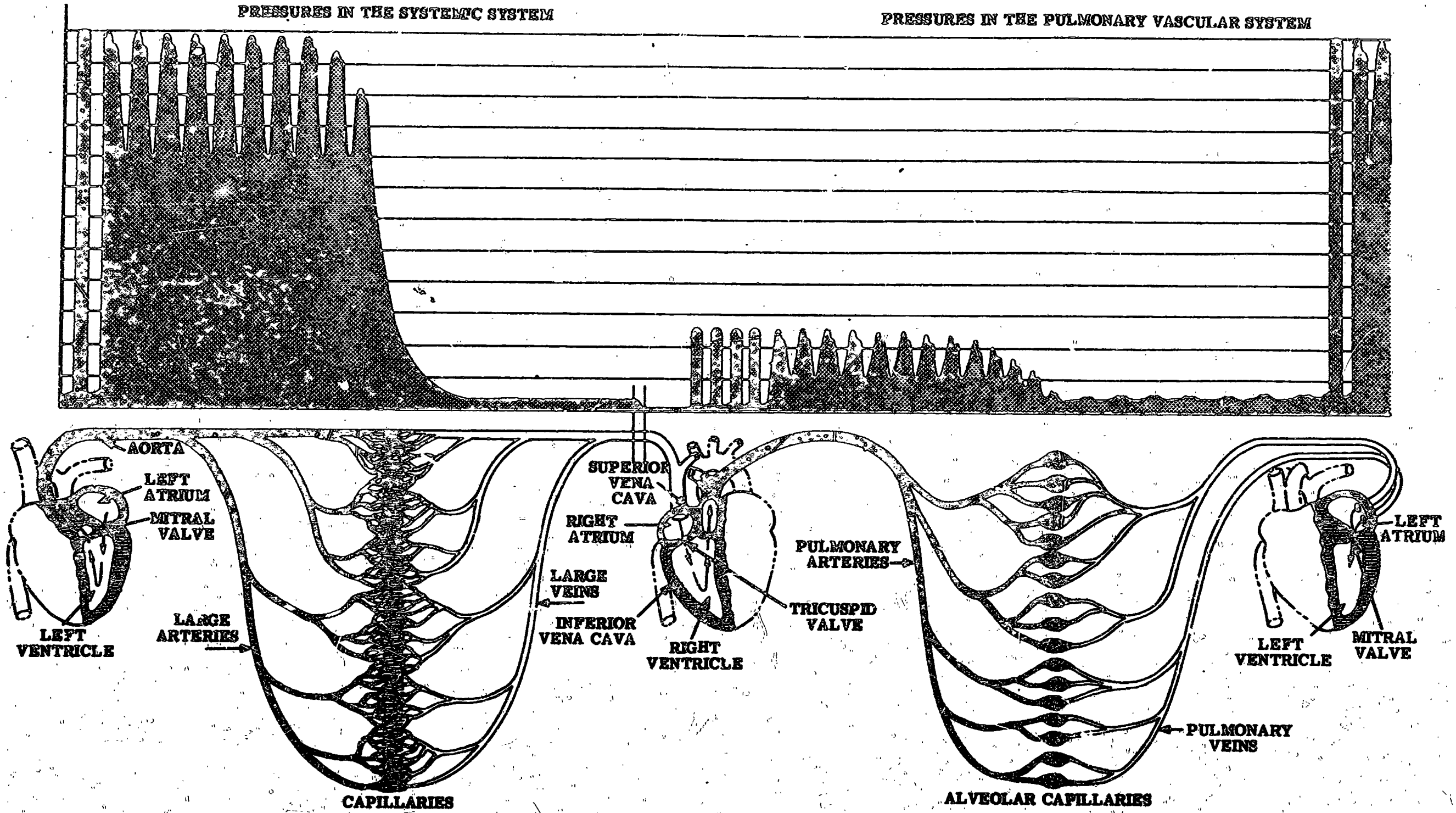


FIGURE 1
BLOOD PRESSURE IN THE CIRCULATORY SYSTEM

THE GARRETT CORPORATION
AiResearch Manufacturing Divisions
Los Angeles 45, California

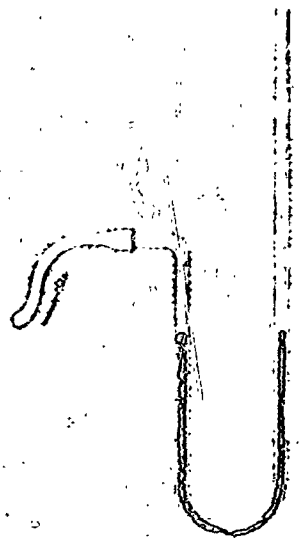


Figure 2

POISEUILLE "HEMODYNAMOMÈTRE"
(1828)

U tube filled with mercury. Short arm connected to artery of animal, and filled with solution of subcarbonate of soda, to prevent clotting.

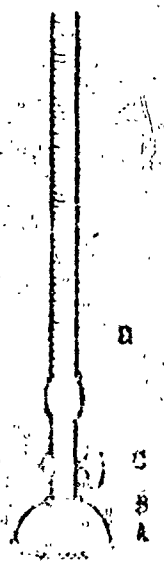


Figure 3

HERRISON "SPHYGMOMÈTRE"
(1834)

AB-half a metal sphere covered with membrane. C-stopcock. D-capillary tube filled with mercury. The membrane is placed on the radial artery and the magnitude of oscillation of the mercury column is noted.



Mosso the membrane was a capillary tube filled with mercury. When the membrane is placed over an artery, the column of mercury oscillates because of the pulse variation. The magnitude of oscillations is used as the index of blood pressure.

Later Marey developed a compact and convenient sphygmograph which recorded radial artery pulsations, shown in Figure 4.

He then developed an instrument which compressed equally all arterial vessel walls of the forearm and measured pulsations from a single finger, Figure 5. Later, in 1896, a marked advance occurred when Riva-Rocci devised a sphygmomanometer utilizing the principle presently used, Figure 6. In 1901, Von Recklinghausen suggested use of the 12 to 14 cm cuff instead of the earlier 5 cm cuff. In 1905 Korotkoff introduced auscultation, the conventional principle being utilized today.

B. OCCLUDING CUFF-STETHOSCOPE

This present means of effecting an indirect blood pressure measurement consists of an occluding cuff positioned over the brachial artery in the upper arm and a stethoscope with its diaphragm placement at the inside of the elbow (the antecubital fossa). Normally if a stethoscope is placed lightly on the artery, the blood flow is inaudiable. If the cuff pressure is raised so as to block (occlude) the flow of blood, and then released, a sharp tapping sound in rhythm with the heart beat can be heard with the onset of the blood flow past the cuff. This first sound is taken as the index of the systolic pressure. As the cuff pressure is lowered, there is a series of changes in the sound: first, the sound is murmurish; it then becomes louder, finally it becomes muffled. The instant the sound disappears is usually taken as the index of the diastolic pressure. This nearly coincides with the moment that the blood escapes beneath the cuff in a continuous rather than an intermittent stream. The sounds have been explained as being vascular in nature associated with the turbulence in the blood flow caused by the occluding cuff.



Figure 4

MAREY SPHYGMOGRAPH

Improved model. Indirect (pneumatic) transmission sphygmograph. The movements of the pulse are transmitted to a rubber tambour and the changes in pressures in this tambour are recorded on the smoked paper.

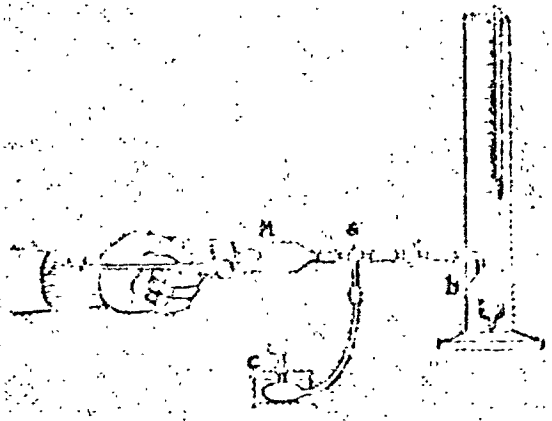


Figure 5

MAREY FINGER SPHYGMOMANOMETER (1878)

M-glass receptacle. b-mercury manometer. a-T tube. c-bulb to increase pressure in water-filled system. Oscillations of digital arteries are transmitted directly to the mercury column.

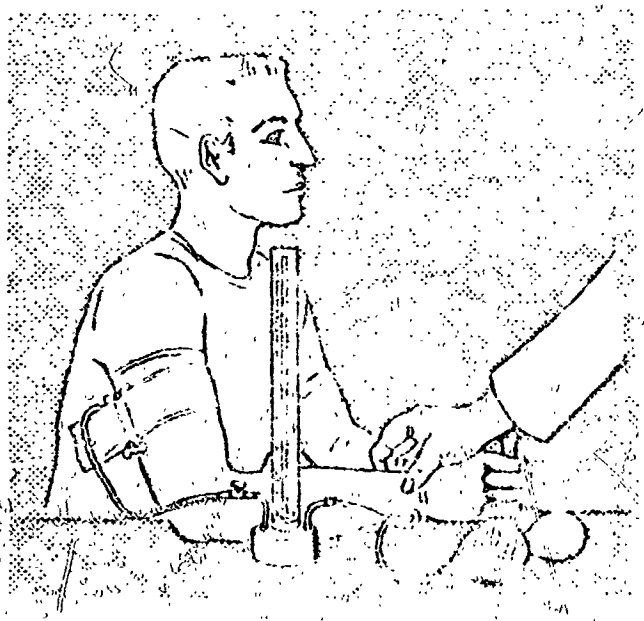


Figure 6

RIVA-ROCCI SPHYGMOMANOMETER (1896)

In principle the model used at present.



Since the pulse waves spread rapidly throughout the arterial system and are modified in varying degrees by the nature of the occluding cuff and by the reflected waves, it is clear that determinations of arterial pressure represent the maximal and minimal pulse wave pressures at the point of measurement.

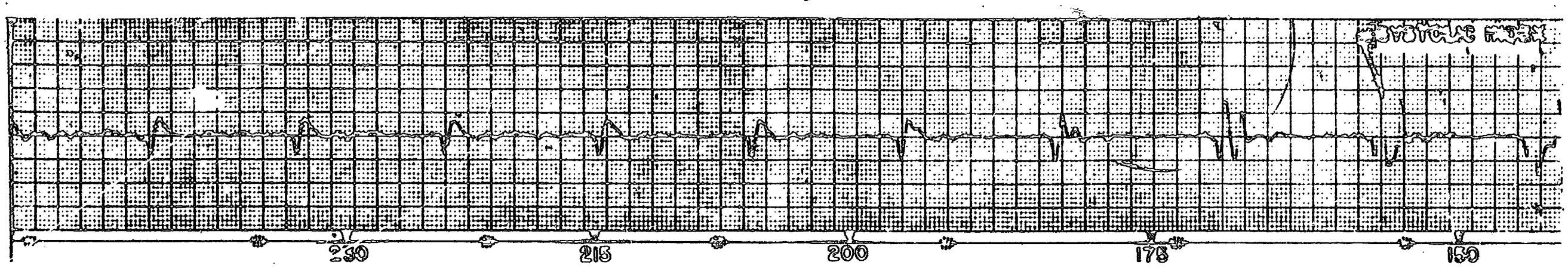
The primary limitation with this technique is that it is highly subjective in nature, depending on such things as the hearing ability of the examiner, the quietness of the surroundings, and the resistance of the arterial wall.

C. SPHYGMOGRAM INTERPRETATION

Another method of measuring blood pressure is to use a pressure pickup at an artery with the occluding cuff and record the arterial pressure pulses on a graph as the cuff pressure is released. This type of trace is referred to as a sphygmogram. Then by observing the shape of the record, an attempt is made to determine the systolic and diastolic pressures. In the past, the recorded shape of the catacrotic limb of the radial artery pulse curve has been attemptedly used as an indication of the diastolic value. This was introduced with the Marey sphygmographs in the 1890s. However, by reference to Figure 7, which is a typical sphygmogram, it is seen that it is very difficult to determine where the systolic and diastolic values occur. This index becomes nearly impossible to determine if the subject is under stress, or indulges in physical exercise.

D. CATHETERIZATION

Another heart instrumentation technique is to insert a tube directly into the various heart regions. This procedure, termed catheterization, allows pressure measurement across the valves, and also is used to sample blood to determine oxygen concentration. The pressure levels and vibratory signals can be sensed with a high degree of accuracy using the technique if a transducer is used at the proper



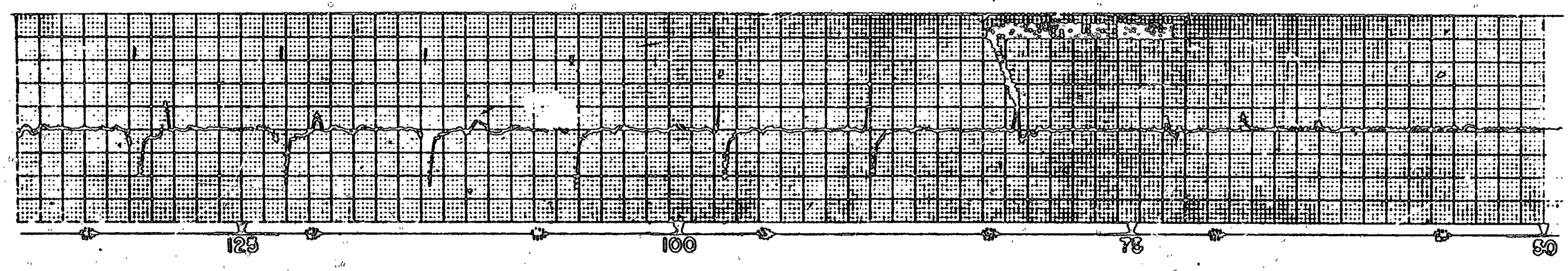


FIGURE 7

BLOOD PRESSURE MEASUREMENT
BY
SPHYGNOGRAM INTERPERTATION

location. Care must be taken not to attenuate the vibratory signals, particularly the low frequency ones, by using small diameter tubings or openings.

This procedure although entailing some risk to the patient, is rapidly becoming a powerful diagnostic method in certain heart disease cases. There are over 40 centers in this country where catheterization is performed, and the number of competent medical specialists is rapidly increasing.

Schematics of catheterization procedures either by insertion of a tube up a large vessel or puncture of needle tubing through the chest are shown in Figures 8, 9, and 10.

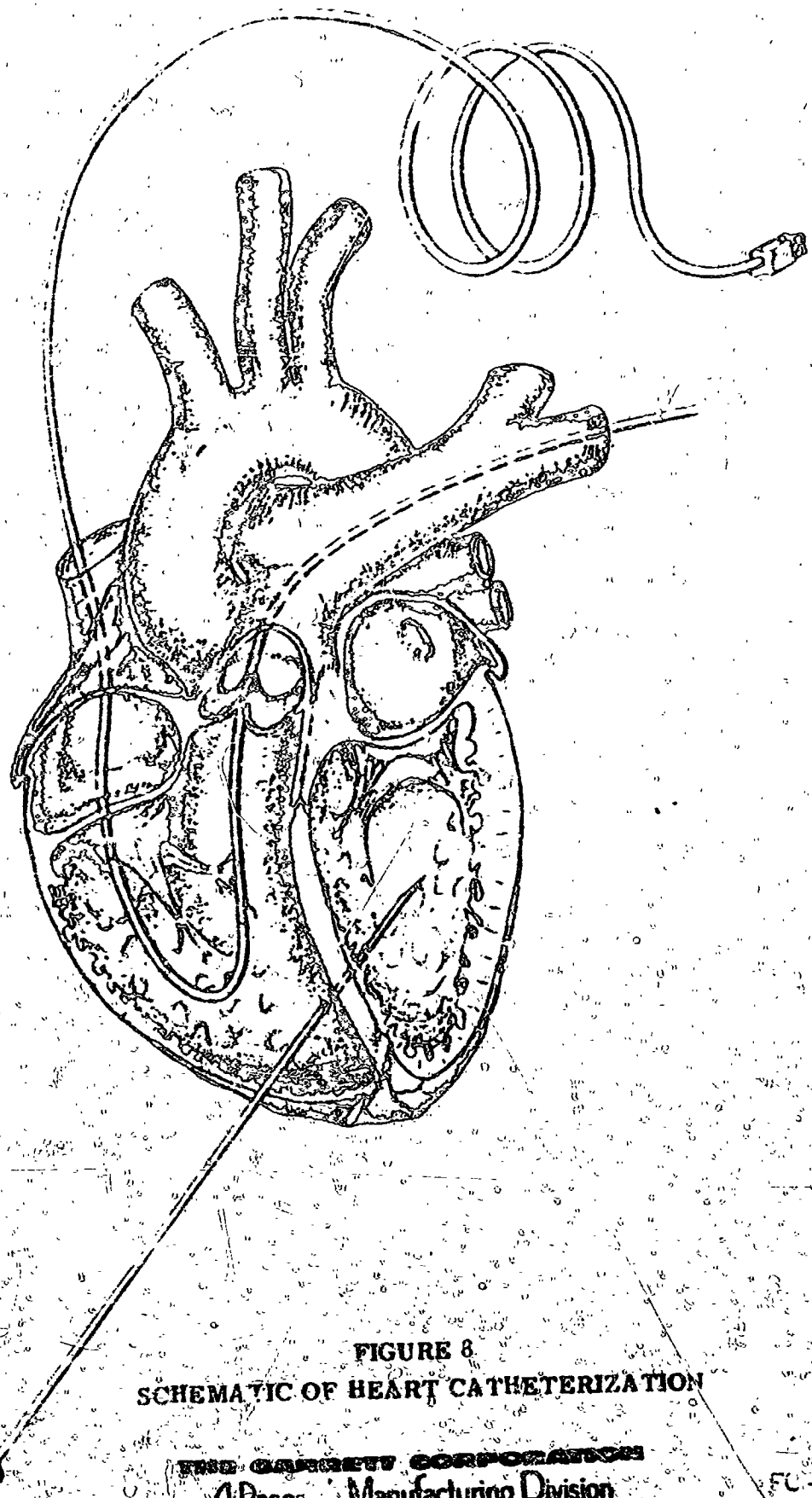


FIGURE 8
SCHEMATIC OF HEART CATHETERIZATION



FIGURE 9
COURSE OF THE HEART CATHETER

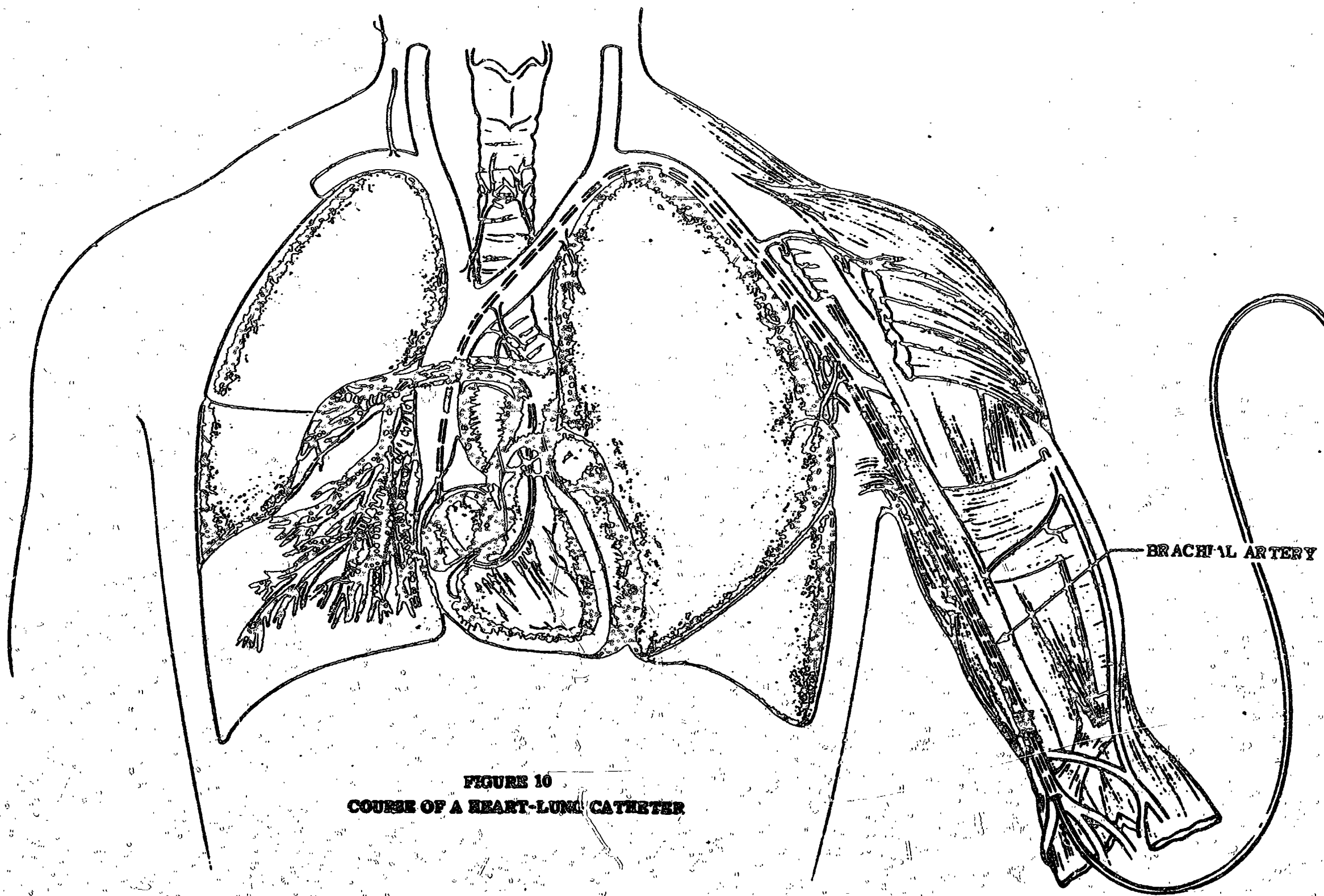


FIGURE 10
COURSE OF A HEART-LUNG CATHETER

SECTION III

AIRESEARCH BLOOD PRESSURE MEASUREMENT SYSTEM

A. INITIAL STUDIES

The blood pressure studies at AiResearch were initiated in 1958 to support the Environmental Control System studies and hardware development. Initially the effort was concerned with obtaining correlations which would allow interpretation of conventional sphygmograms. The primary requirement for the study was that the blood pressure indices must be exceedingly close to those measured with the stethoscope. Although other indices may be useful, they cannot be interpreted within the framework of over 50 years of data taken by physicians all over the world. Several hundred sphygmograms were taken and compared with the average systolic and diastolic indices as recorded by several trained nurses. Although somewhat ambiguous, the systolic value could usually be determined by observation of the sphygmograms. Interpretation of the diastolic was more difficult. Finally, the slope of the catacrotic notch of the pressure wave was selected as one of the best correlations with the diastolic value. However, all the correlations proved misleading on subjects under stress or on subjects who had mildly exercised. Such a technique was obviously a poor criterion for physiological evaluation of a man and his performance in an aerospace environmental control system.

B. SPECTRUM ANALYSIS

In order to find a better correlation, spectrum analysis were conducted on the tape-recorded sphygmograms. Various frequencies were investigated ranging from several cps to several hundred cps. Higher frequencies were not extensively investigated since these amplitudes are considerably lower. Some frequencies were discovered which correlated well with the upper and lower blood pressure values

determined with a sterhoscope. The first appearance of the selected frequency agrees with the systolic index while the disappearance of the signal correlates with the diastolic value. Further tests on various individuals indicated that one particular frequency, around 35 cps, produced the most unambiguous results. In some individuals, the 17-18 cps or the 70 cps signals are higher in amplitude, but 35 cps will give correct readings even for these individuals.

In addition to the selection of a particular signal, tests were conducted to verify the optimum position of a microphone to detect the strongest signals. The optimum location appears to be on the brachial artery, near or under the occluding cuff on the arm. Measuremen can be taken at other points, such as on the leg, but the signal strength is considerably reduced. The brachial artery position is shown by the cross in Figure 10.

The 35 cps signal can be compared to a wide pass band signal (sphgmogram) by reference to Figure 11. This figure shows the 35 cps signal superimposed on the cuff pressure signal as the cuff is slowly bled. The first appearance of the 35 cps signal, which corresponds to the systolic value of blood pressure occurs at approximately 130 mm Hg, while the first appearance of the wide bandpass signal occurs at 155 mm Hg. The disappearance of the 35 cps signal is at 100 mm Hg while the wide bandpass signal continues to about 80 mm Hg. The measurement using the stethoscope for this subject was approximately 128/95.

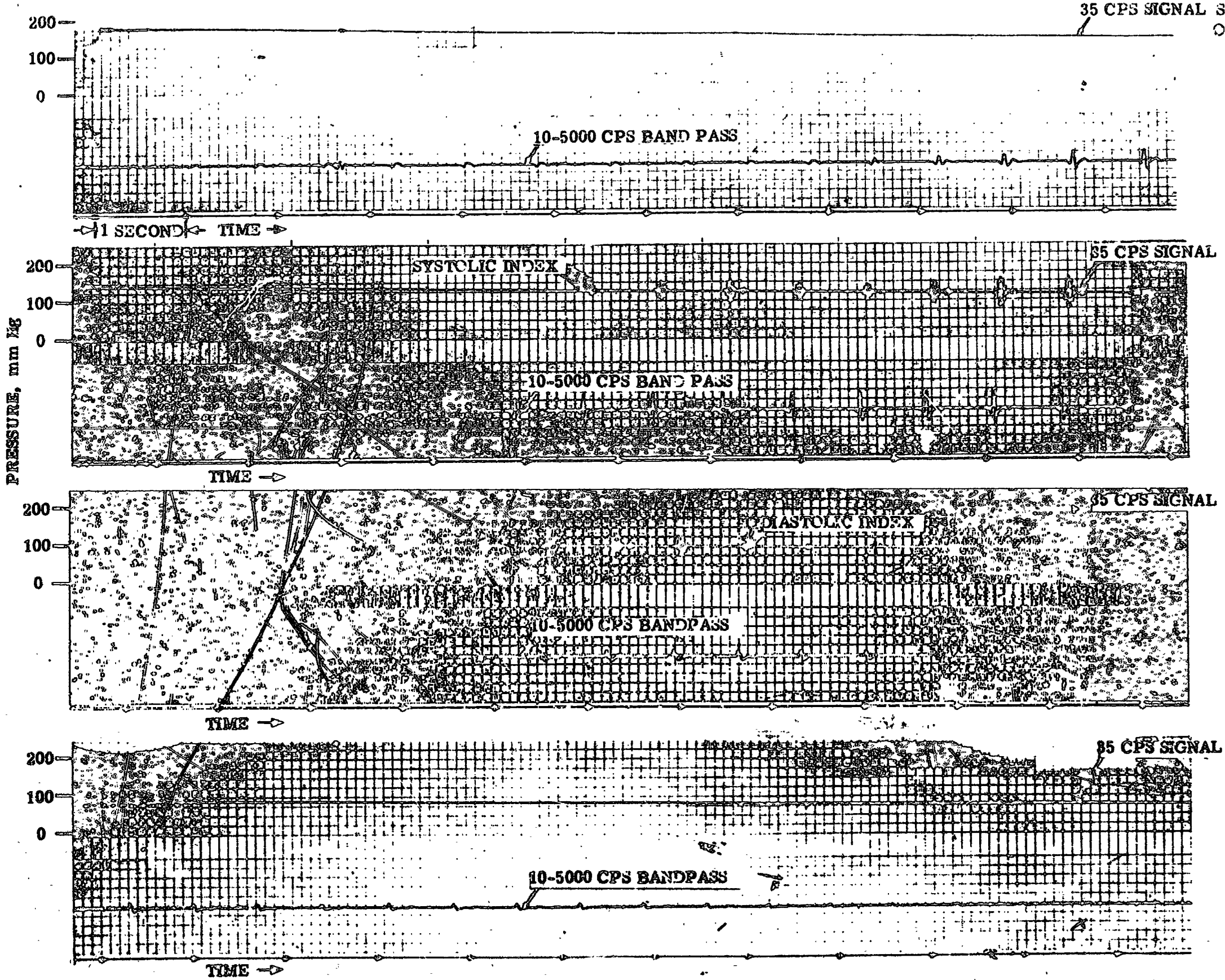


FIGURE 11

PRESSURE-TIME TRACE
FOR
FILTERED AND UNFILTERED
CUFF SIGNALS

C. SYSTEM DESCRIPTION

The AiResearch blood pressure system, shown schematically in Figure 12 consists of the following:

1. Cuff pressurization source
2. Pressure regulator and bleed rate device
3. Occluding cuff
4. Cuff pressure transducer
5. A crystal microphone
6. An amplifier with a built in 35 cps filter
7. Signal mixing and conditioning circuitry
8. Readout device
9. Timers, cycle initiation circuitry, switching, misc.

The operation is fairly simple; the cuff is pressurized and bled off at a fixed rate, while the cuff pressure is measured with a pressure transducer. The microphone picks up the blood flow sounds under the cuff. These sounds are amplified, filtered and mixed with the cuff pressure signal. The signals are recorded on a strip chart recorder and interpreted. The first appearance of the 35 cps sound is taken as the systolic value while the disappearance is taken as the diastolic, as shown in Figure 14.

D. CORRELATION WITH CLINICAL METHOD

Since this device was developed, over 2000 blood pressure measurements have been taken using this system on various individuals, and many of these have been compared with the stethoscope technique. In only a few instances were the readings off by more than a few mm Hg, which is within the inherent limits of accuracy of the measuring system.

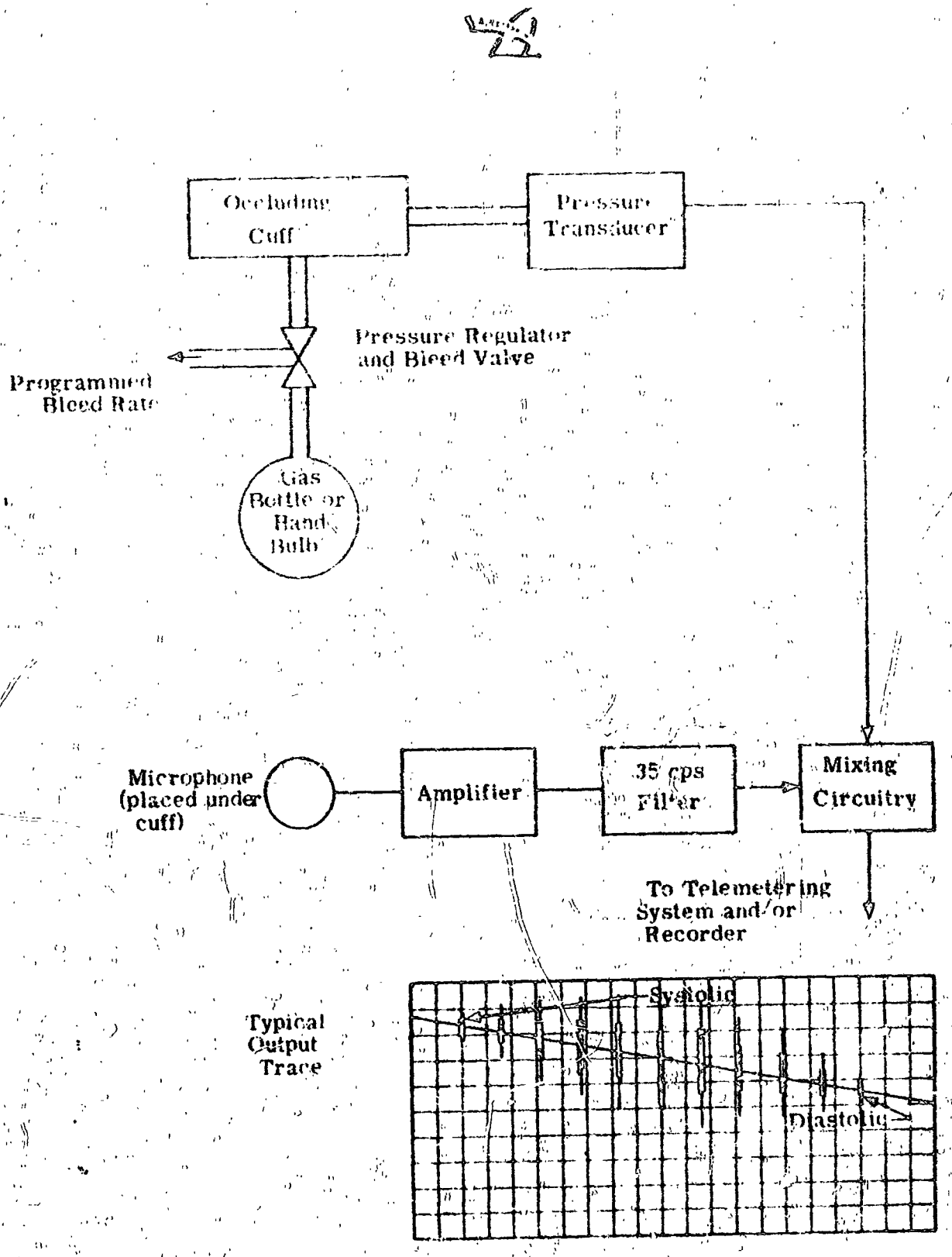


FIGURE 12

AiResearch Blood Pressure System Schematic



Proof that this signal correlates well is shown in Figure 13, where the results with the AiResearch system are compared with the clinical (auscultation) values for several hundred subjects. The clinical data, which are summarized in the Appendix, were averaged from several trained personnel. As shown in this figure, the AiResearch system measures slightly higher systolic and slightly lower diastolic values, probably since the microphone is superior to the human ear in sound discrimination.

Figure 14 shows the variation in the clinical values themselves. This indicates that there is considerable spread in blood pressure measurements on the same subject if different testers are used. The variation shown in Figure 13 between the AiResearch system and the clinical method average does not seem large when compared to Figure 14.

AiResearch's method of measuring systolic and diastolic pressures is related only to the clinical method. No attempt was made, from its inception, to correlate with any practice other than that which has been clinically practiced for 65 plus years. There are, in the medical literature, reports of investigations attempting to establish relations between direct and indirect methods. *1, 2.

E. SOURCE OF SIGNALS

Some additional studies were conducted to determine the source of these signals. A large catheter with a barium titanate crystal was inserted in the carotid artery of a large dog. The catheter was inserted via the carotid artery through the aortic arch and valve into the dog's left ventricle and then withdrawn slowly. The results of this test are reproduced in Figure 15. Trace C shows the 35 cps signal which was filtered from Trace B. The signal was apparent in the heart region but initially could not be detected when the catheter was in the artery. Subsequent investigation and study in the human subject yielded a means of overcoming the instrument limitations and the signals were detected.

The obvious question is whether the correlating blood pressure signals are associated purely with turbulence or are they imparted by the heart to the arterial blood stream and only detectable when the arterial wall is extended into the blood stream. The catheter tests seem to indicate these particular frequencies are present in the pulse wave itself. However, the Korotkoff sounds themselves may be a

1. Joint recommendations of the American Heart Association and the Cardiac Society of Great Britain and Ireland: Am. Heart J. 18:95, 1939.

2. Bordley, J., Conner, C. A. R., Hamilton, W. F., Kerr, W. G., and Wiggers, C. J.: Circulation 4:503, 1951.

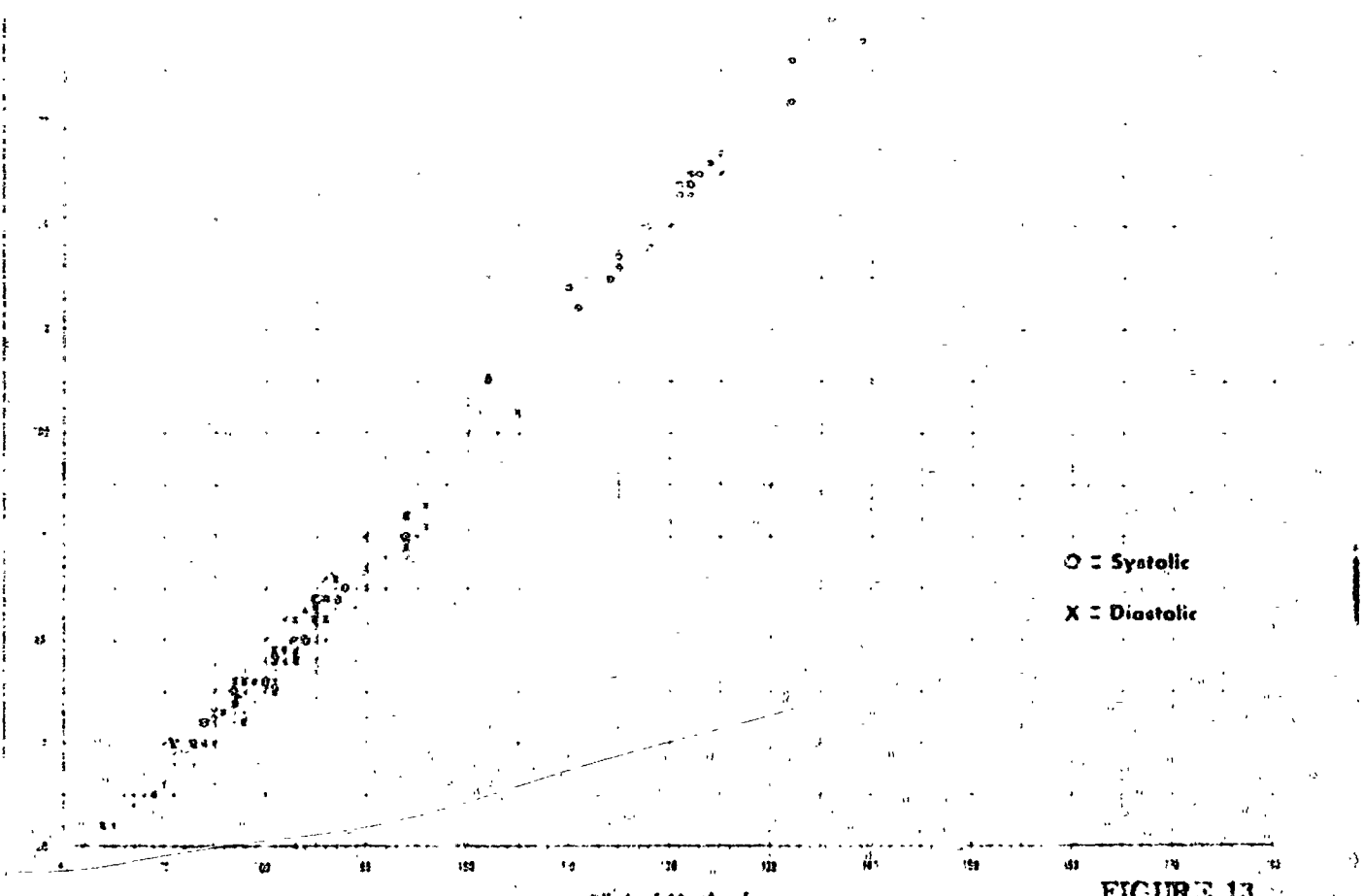


FIGURE 13
COMPARISON OF AIRESEARCH AND CLINICAL BLOOD PRESSURE MEASUREMENTS

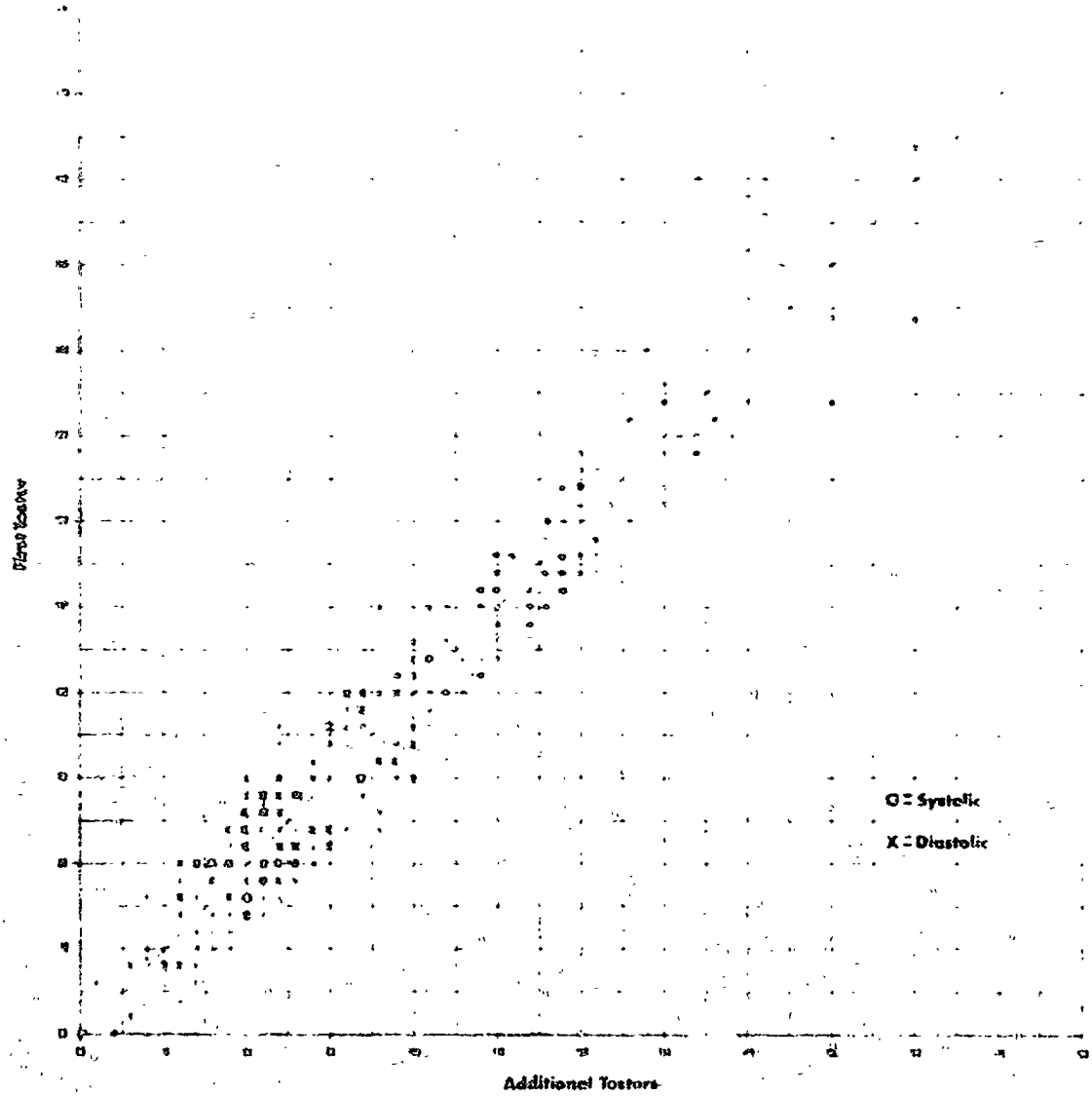
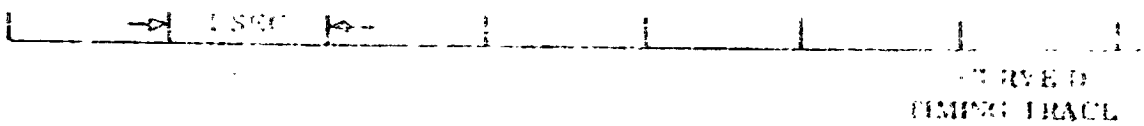


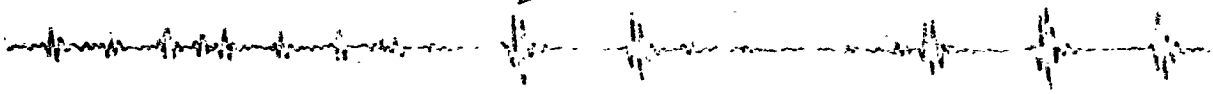
FIGURE 11

COMPARISON OF CLINICAL BLOOD PRESSURE MEASUREMENTS USING DIFFERENT TESTERS

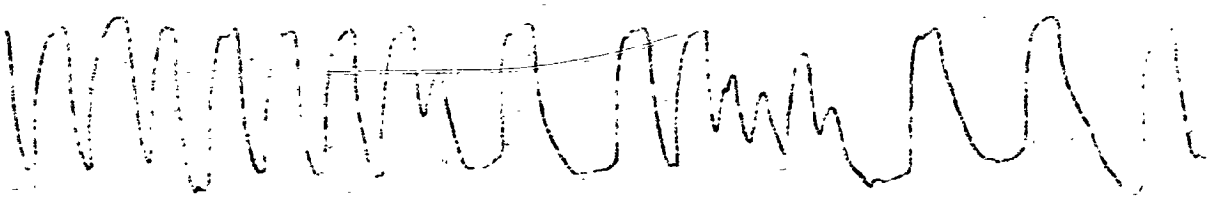


CURVE D
TIMING TRACE

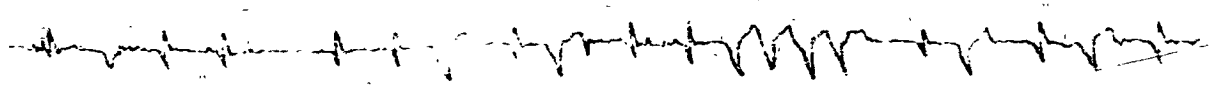
SINUSOID COMPONENT OF THE JUST HEART BEAT



CURVE C
A SELECTED FREQUENCY



CURVE B
GROSS PRESSURE TRACE
LEFT VENTRICLE



CURVE A
ELECTROCARDIOGRAM

FIGURE 13

EXPLORATION OF CATHETER SIGNALS
DURING ISOMETRIC CONTRACTIONS
OF A DOG HEART.
SUBJECT: DOG (LARGE YELLOW MALE)



FIGURE 13

combination of the turbulence sounds caused by occlusion and those carried by the pulse waves. In any event, the filtered signals being detected by the AiResearch Blood Pressure System are probably a component of what are commonly referred to as the Korotkoff sounds. Some typical traces of these sounds from 12 to 56 cps is shown in Figure 16. A complete explanation of what the Korotkoff sounds consist of would entail considerable study.

F. SUMMARY

The medical theory behind this device is that signals were discovered which correlate well with the conventional audible Korotkoff sounds heard during auscultation. These signals when detected and filtered provide a convenient method of presenting blood pressure information.

SECTION IV

COMPONENT AND ENVIRONMENT INFLUENCE ON OPERATION

A. GENERAL

This section presents a discussion of the effects of the environment and various components in the blood pressure system on the detection and accuracy of the diastolic and systolic pressures. Other characteristics such as power, size, etc. are not discussed except as they affect the blood pressure measurement accuracy.

One difficulty inherent in these studies is that some of the apparent change in the blood pressure indices can be physiological rather than a function wholly of the blood pressure measurement system itself. This condition was noted and recorded during the University of Southern California centrifuge tests conducted in June 1961. The excerpt and figure following have been reproduced from AiResearch Report FC-4094-R, Revision 1, "Correlation Test on AiResearch Blood Pressure Measuring System 54743".

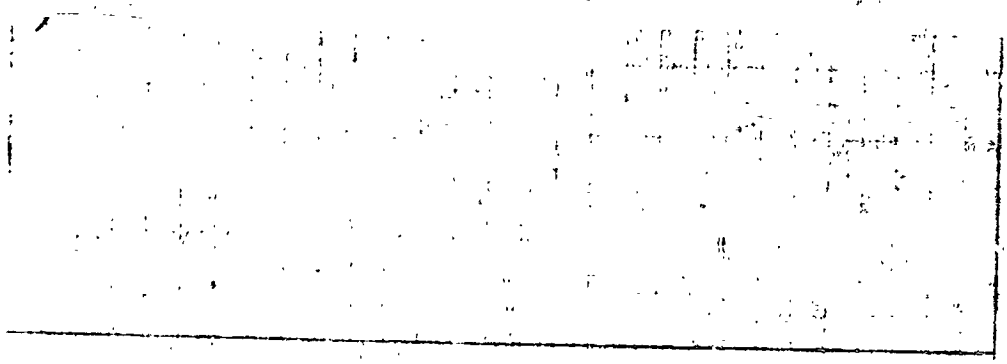
"(2) The catheter record clearly shows that systolic and diastolic pressures rarely remain quiescent for any length of time. Transients were particularly in evidence when test cell activity attracted the attention of, or startled, the subject. An instance of the latter was a cuff pressurization without warning early in the tests (Figure 1). After the subject became accustomed to the cuff pressurization cycle, blood pressure transients were more moderate, but rarely absent for more than a few seconds. Another aspect of the human organism which may be inferred from the record is the time-dependence of blood pressure following the onset or removal of additional "g"'s with the centrifuge. Some runs suggest that the body's mechanism for adjusting blood pressure to meet new situations may behave as a slightly underdamped servomechanism."

In support of the correlation tests conducted during the BPMS development program, AiResearch attempted to reduce the extraneous disturbance factors to a minimum.

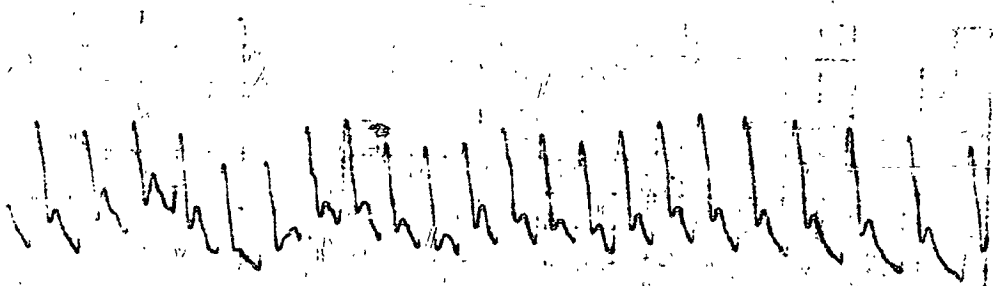
B. COMPONENTS

The blood pressure system consists basically of a transducer to convert the pressure signals to electrical, an amplifier, a filter, a data transmission system, a read-out device. The arterial occlusion is accomplished by means of a high pressure gas supply, a pressure regulator and bleed rate device, and an occluding cuff. The cuff pressure is measured by a transducer which feeds an electrical signal to an amplifier and then by means of a transmission link to a read-out device. The complete system also includes a timer and a cycle control device.

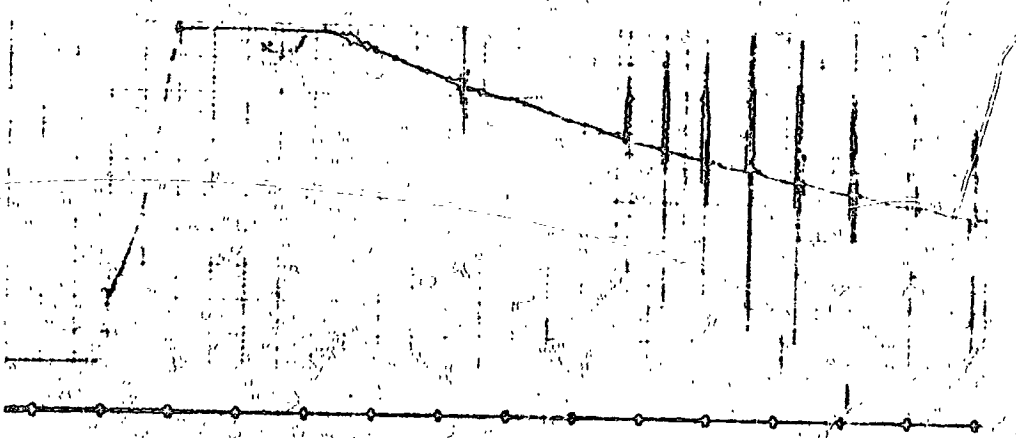
Table I lists the major components and their primary medical and engineering effect. If the component can actually cause a false systolic or diastolic reading, it is termed a medical effect. By engineering effect is meant whether or not the component can interfere with the system operation. This table shows that only the filter and the cuff appear to be critical from a medical standpoint. The other components can malfunction, but if replaced with an equivalent device, the performance will be restored.



ACCELERATION



BLOOD PRESSURE (CATHETER TRACE)



SPHYGMOMANOMETER TRACE

Unexpected cuff inflation causes subject's blood pressure to undergo transient changes. Scale is approximately 20 mm per half-cm major division.

FIGURE 1

TABLE 1

Effect of Components and Their Variation
on the
Medical and Engineering Operation

Component	Medical Effect	Primary Engineering Effect
Microphone (Korotkoff sounds transducer)	None	Insufficient signal strength, noise
Amplifier	None	(a) Low signal to noise ratio (b) Insufficient dynamic range for different individuals or situations
Filter	Bandpass Frequency	Too wide or too narrow bandpass
Occluding cuff	Width	Inadvertent leakage
Gas source	None	Insufficient volume
Pressure regulator	None	Over or under pressure
Cuff pressure transducer	None	Accuracy inadequte
Read-out device	None	Calibration off
Power supply	None	Insufficient regulation
Timer, cycling motor and cams	None	Mechanical or electrical failure, too rapid a bleed-rate.
Misc. switches, controls, etc.	None	Failure



Occluding Cuff

The cuff used, must be of a minimum width, otherwise the systolic and diastolic values will not correlate with the accepted indices. A narrow cuff is highly desirable from the standpoint of comfort and minimum restriction of mobility. The responsibility for the cuff selection was held by the Space Task Group of NASA. Tests conducted by NASA indicate that a cuff approximately 3.75 to 4.5 inches will yield acceptable blood pressure values. The NASA cuff is shown in Figure 17. The notch in the cuff is for ease of arm movement.

Filter

The selected bandpass frequencies significantly affect the system accuracy, as shown in Figure 11. The 35 cps, or some other harmonic is strongly recommended as being the best correlate with the conventional systolic and diastolic indices.

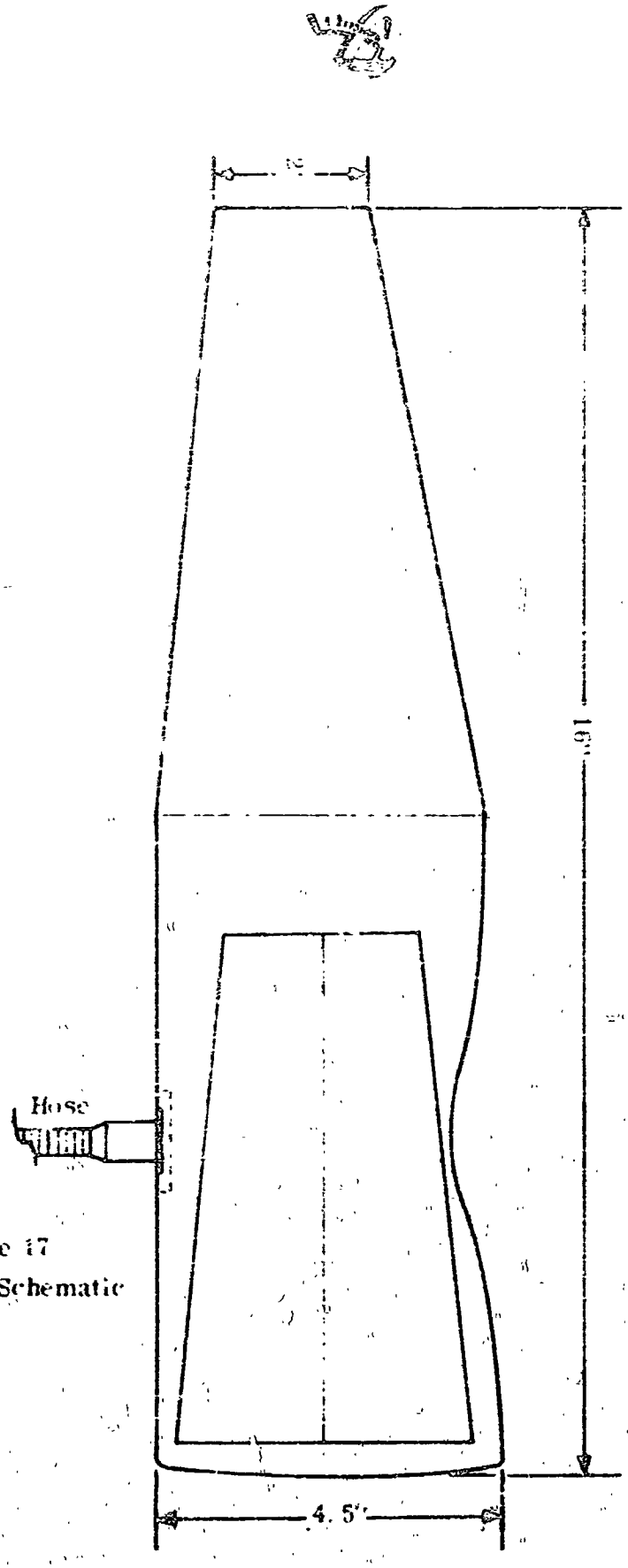


Figure 17
NASA Cuff Schematic

C. ENVIRONMENTAL FACTORS

The relative effects of the environment on the mechanical and engineering aspects of operation are tabulated in Table 2. These effects are discussed in more detail below.

Temperature

Since nearly all the components are temperature sensitive, some change is to be expected. There is no significant variation in accuracy over a temperature range of +40 to +160F hence the overall effect must be less than a few per cent.

Humidity

All the critical electronic components are encapsulated in a suitable insulation material which offer protection against humidity. The mechanical components are relatively insensitive. No significant change in accuracy as a function of humidity has been noted over a relative humidity range from 3 to 5%.

TABLE 2

Effect of Environmental Factors on Operation of the Blood Pressure Measuring System

Environmental Factor	Principal Effect
External Pressure	Microphone output changes
Humidity	None
Vibration	Slight (with microphone on arm)
Acoustic Noise	Slight
Temperature	Slight

Pressure

The ambient pressure does not affect the electronic components, and does not appear to affect the pressure reducer-regulator valve. Some effect is noticed on the microphone itself. The external impedance caused by the air is directly proportional to the air density and thus some effect is anticipated. Figure 18 shows essentially the microphone output for three microphones as a function of ambient pressure. Variations in data are attributed to differences in the technique of bonding the barium titanate crystal to the metal backing.

Accustic Noise

Since the 35 cps signal is used as the blood pressure correlate, the effect of 35 cps interference on microphone performance was of considerable interest. A subject was seated in AiResearch's audiometric chamber, instrumented with the microphone and occluding cuff, and subjected to selected frequencies at a specified sound intensity. The upper trace in Figure 19 is a reproduction of the data recorded from the test. As expected, the filter favored the 35 cps sound and attenuated those frequencies on either side of the band pass peak. Shown in the lower trace of Figure 19 is a reproduction of the data from an additional test in which the chamber was exposed to a swept single frequency band from well below 35 cps to a decade above. Although the signal to noise ratio is not as good as in the absence of 35 cps noise, the blood pressure signal is still intelligible.

Vibration

The degree to which the system will be affected by a microphone being subjected to vibration depends upon the transmitting medium. For the case where the microphone is rigidly mounted to the vibrating surface, the acceleration vector being perpendicular to the diaphragm face, the sensitivity may be observed by referring to Figure 20. For this test both the microphone and a standard Endevco sensor were rigidly mounted to a shaker table. What is shown in Figure 20 is the RMS voltage output read in G units of both sensors. Qualitatively, one would predict a reduced effect when the transmitting medium was the fleshy part of the arm, the body acting as a vibration damper.



In the centrifuge tests held at the University of Southern California on July 25-27, 1961, there was possibly some effect caused by bone conduction.

G Forces

The effect of acceleration forces on the blood pressure system was evaluated by the University of Southern California using their centrifuge. Blood pressure was measured with the AiResearch system and compared to catheter readings. The results of these tests is given in AiResearch Report No. FC-4094-R and summarized in Table 3 below and in Figures 21, 22, and 23. This table indicates that there is a generally satisfactory correlation between the catheter and AiResearch system up to 2.5 to 3.0 g's. Above 2.5 g's there was a significant increase in apparent diastolic pressure measured by the AiResearch system. However, this seems to depend on the subject and the instrumentation technique used. This influence is shown in Figure 24, which presents a blood pressure measurement on two different subjects under 8 g's. On one subject good readings were obtained, but not on the other subject using the same techniques. These tests were conducted at the Aviation Medicine Acceleration Laboratory at Johnsville, Pa., on September 23, 1961. No definite conclusions should be drawn then on the effect of acceleration on the system.

With regard to the effects of sustained or vibratory acceleration on the equipment, it is known that they are not permanent. Further information may be found in AiResearch report FC-1214-R, October 24, 1962, entitled "Qualification Test Report, Blood Pressure Measuring System 54769 and 54778, Project Mercury."

TABLE 3

Comparison of AiResearch System with Catheter under G Forces

Acceleration (g's)		Systole		Diastole	
		Mean Difference	Standard Deviation	Mean Difference	Standard Deviation
1	21 pairs of points	-8.8 mm	5.4 mm	-3.4 mm	4.6 mm
2	8 pairs of points	-7.1 mm	12.1 mm	+10.1 mm	8.8 mm
2.5	8 pairs of points	-10.0 mm	9.3 mm	+9.6 mm	6.4 mm
3	10 pairs of points	-4.0 mm	10.7 mm	+24.1 mm	7.1 mm
3.5	4 pairs of points	+13.25 mm	4.8 mm	+46.25mm	2.3 mm

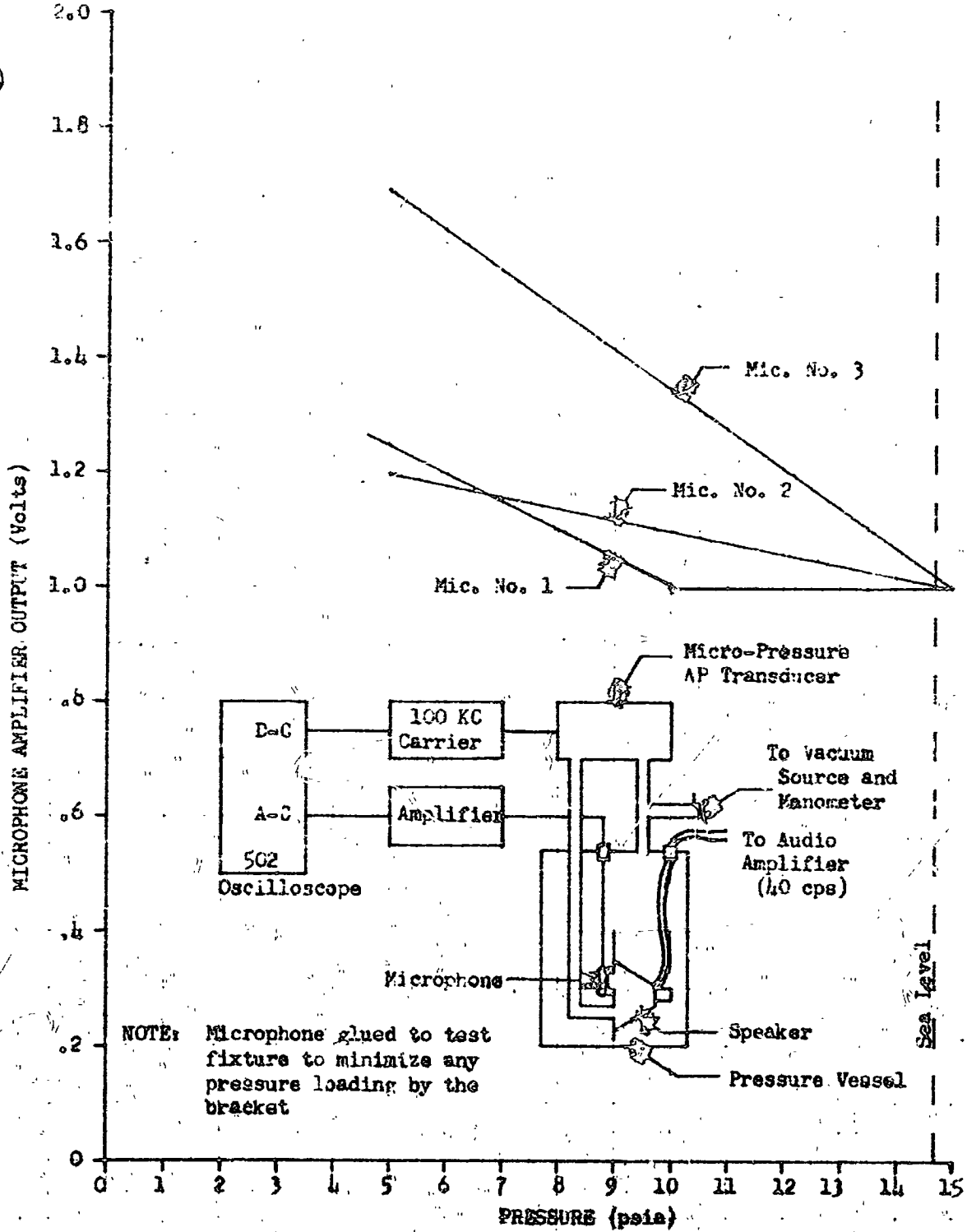
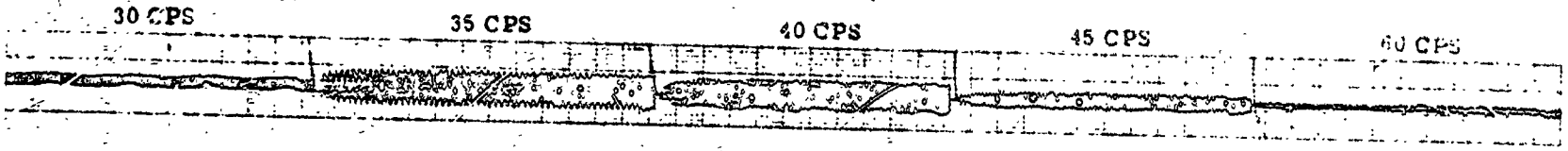


FIGURE 18

CALCULATED BY			EFFECT OF REFERENCE PRESSURE ON MICROPHONE OUTPUT	
TRACED BY				
CHECKED BY				
APPROVED BY			AIRESEARCH MANUFACTURING CO	
UNIT NO			LOS ANGELES CALIFORNIA	

15" ALTEC SPEAKER
106 db SOUND INTENSITY

MICROPHONE PLACED NEXT TO SPEAKER. SINGLE FREQUENCY GENERATED.



15" ALTEC SPEAKER
113 db SOUND INTENSITY
SINUSOIDAL SWEEP FREQUENCY

MICROPHONE PLACED UNDER CUFF RECORDING BLOOD PRESSURE

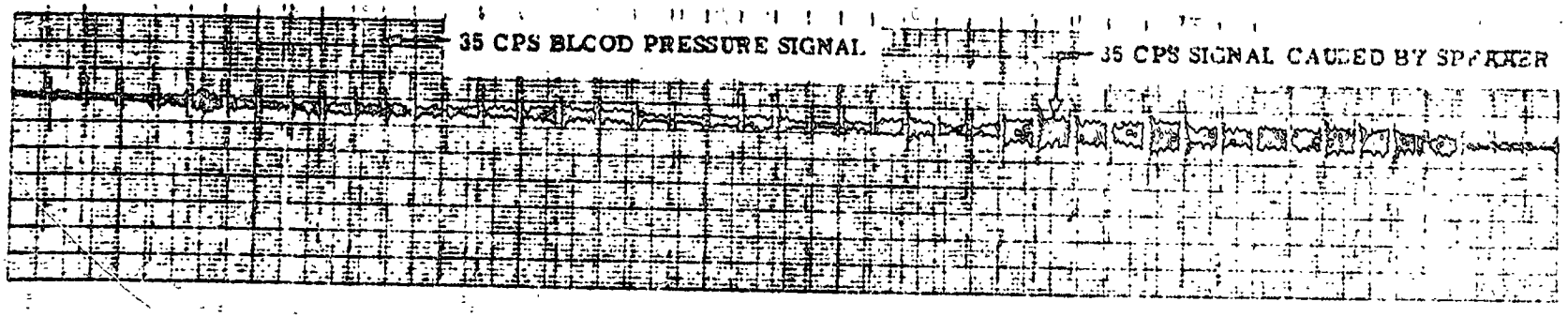
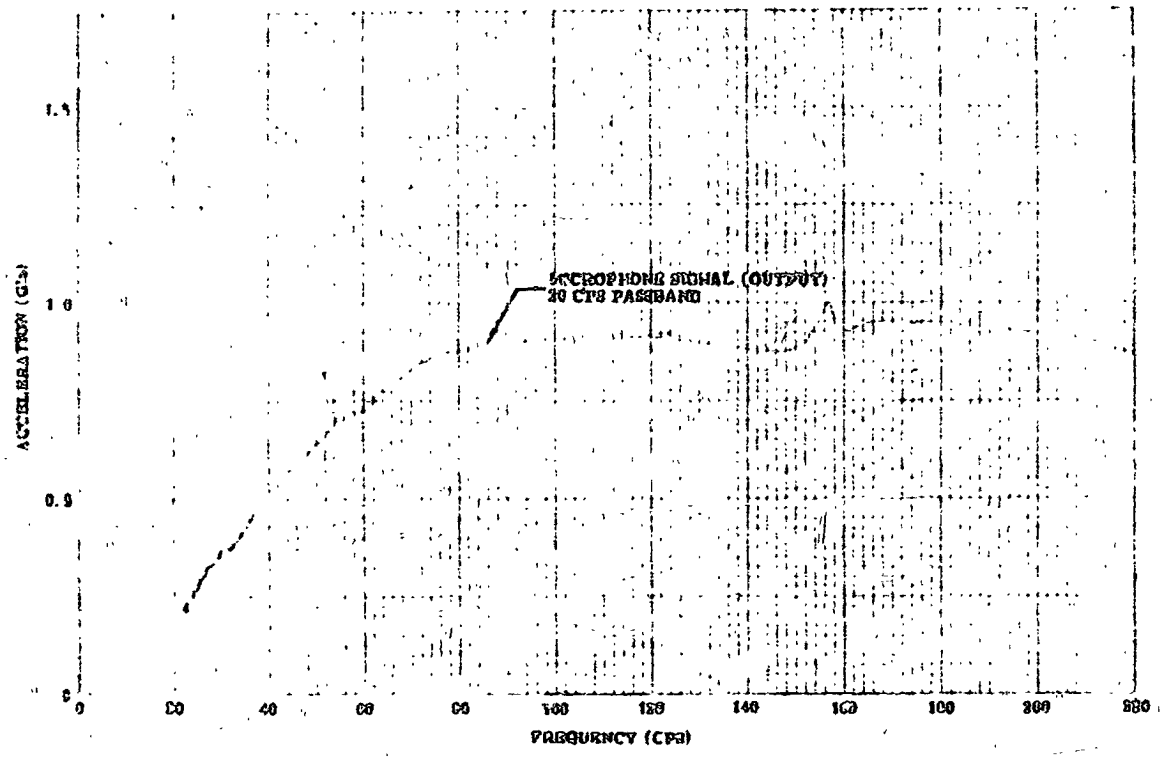


FIGURE 19

EFFECT OF ACOUSTIC NOISE ON BLOOD PRESSURE SYSTEM OPERATION



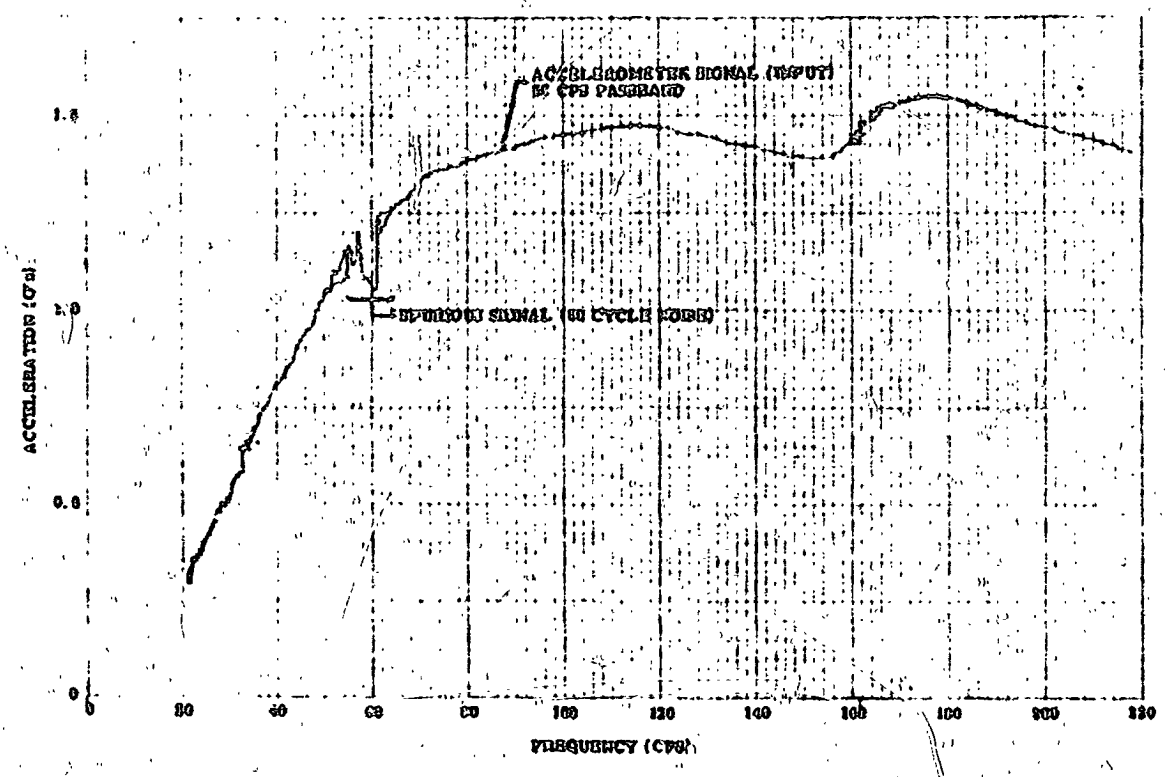


FIGURE 20

EFFECT OF VIBRATION ON MICROPHONE

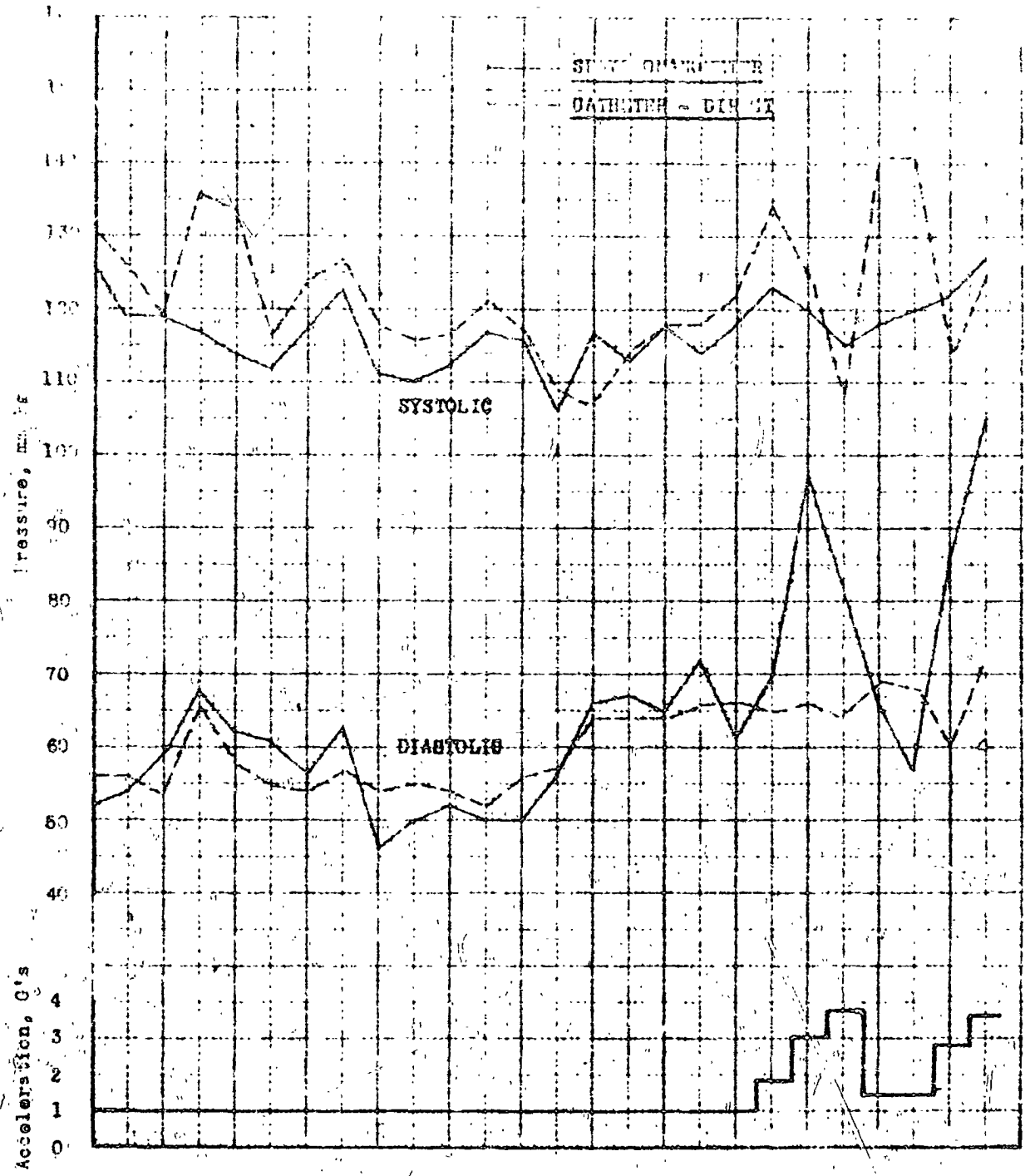


FIGURE 21

EFFECT OF [illegible] ON [illegible] BLOOD PRESSURE SYSTEM

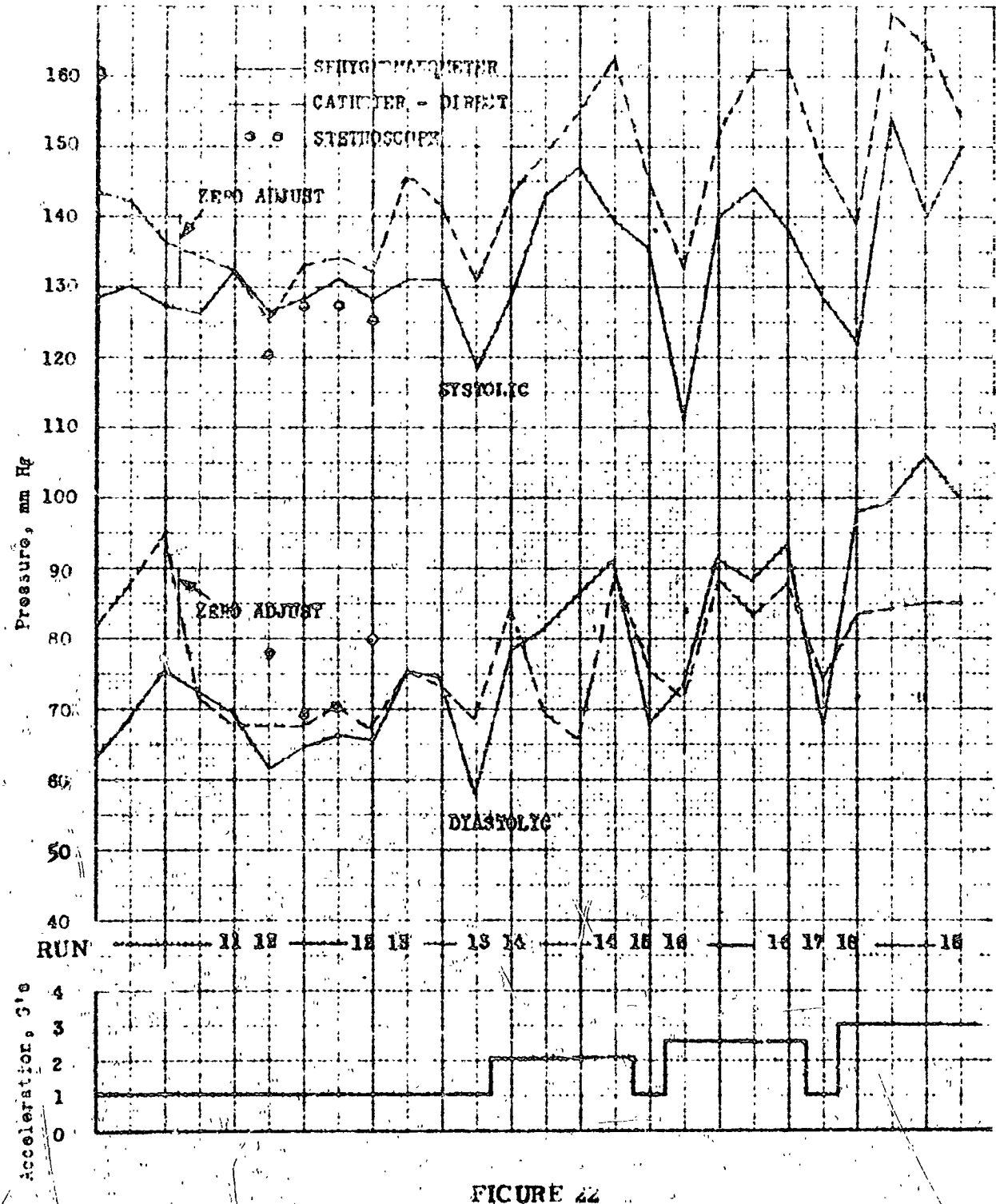

SPHYGMOMANOMETER
CATHETER - DIRECT
STETHOSCOPE
ZERO ADJUST
SYSTOLIC
ZERO ADJUST
DIASTOLIC
Pressure, mm Hg
160
150
140
130
120
110
100
90
80
70
60
50
40
RUN
11 12
12 13
13 14
14 15 16
16 17 18
Acceleration, G's
4
3
2
1
0

FIGURE 22

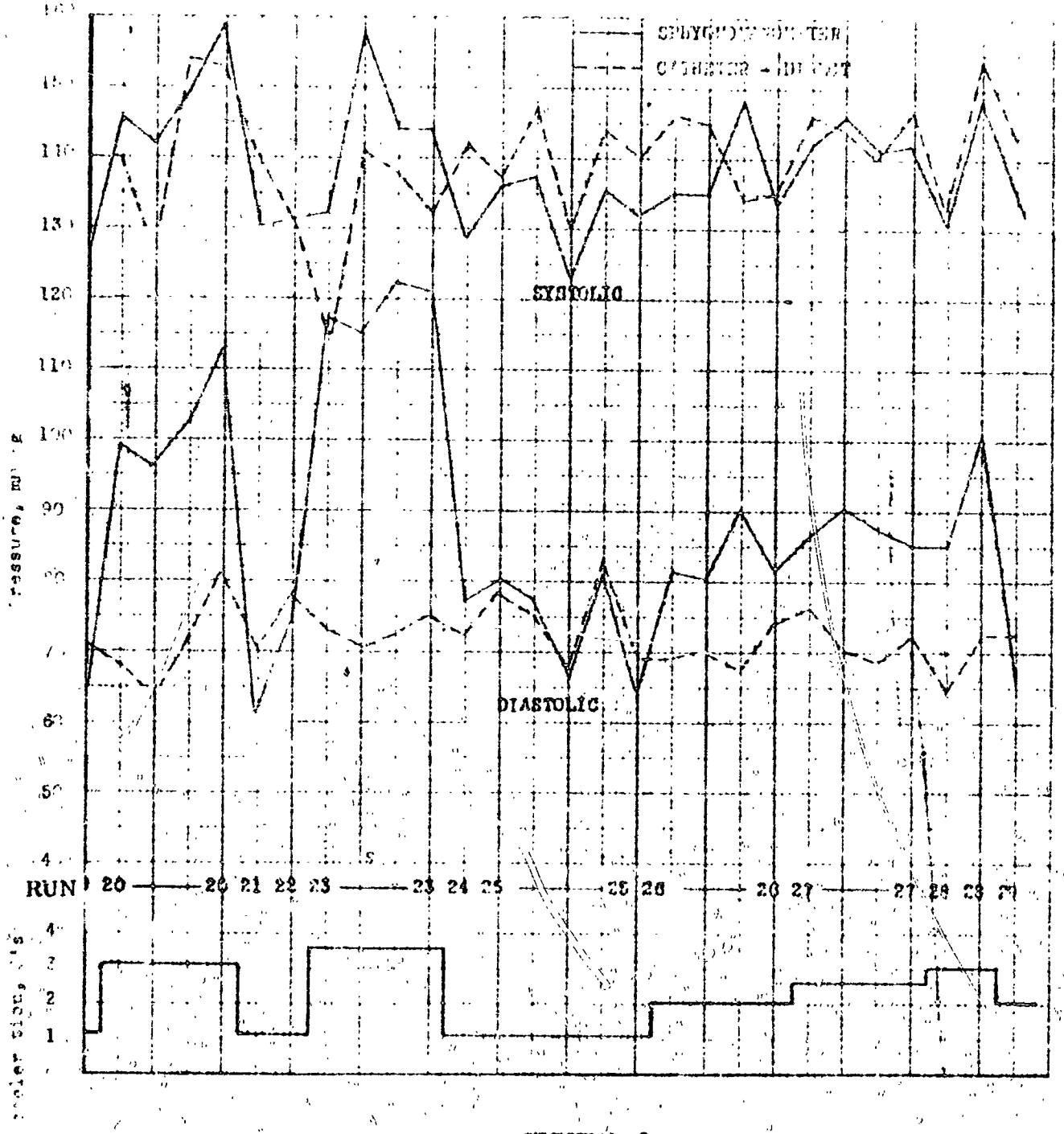

SYSTOLIC
DIASTOLIC
RUN 20 20 21 22 23 23 24 25 25 26 26 27 27 28 28 29

FIGURE 23

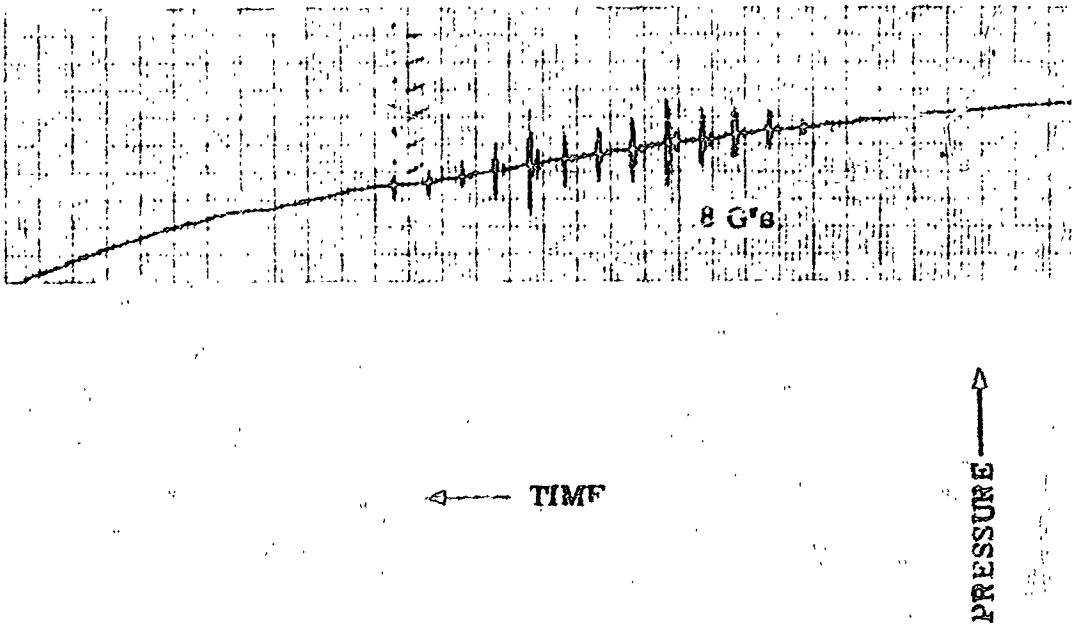


FIGURE 24

SOME HIGH G TESTS
CONDUCTED AT AMAL,
JOHNSVILLE, PA, ON 9/23/61

D. MISCELLANEOUS

Gas Source

A decrease in the oxygen supply pressure occurs as the supply is depleted during the mission. The pressure reducer-regulator through its internal force balancing arrangement effectively charges the cuff to the desired initial pressure irrespective of the bottle pressure. Since the gas flows through a small orifice, there is a slight difference in forces on the internal balancing arrangement as the pressure decreases. This decrease is apparently around 3 - 5% of the initial 220 mm Hg cuff pressure, and thus falls within the specified tolerance of ± 10 mm Hg. This variation (or even a higher one) does not affect the operation of the system. Neither does the automatic cycling of pressure since this merely causes repetitive occlusions of the subject's arm.



Physical Effects on Subject

The physical effects on the subject during normal operation can be expressed qualitatively. The comments of several observers are summarized in the table below.

Item		
1	No cuff	Normal arm movements No discomfort
2	Uninflated cuff	Nearly normal arm movements Slight feeling of encumbrance
3	Inflated cuff	Arm movement slightly impaired and slight discomfort initially; numb feeling with severely impaired arm movement after sustained usage
4	Typical blood pressure measuring cycle (35 seconds cycle)	Nearly normal arm movements Slight discomfort

Cuff Pressure Lapse Rate (Bleed Rate)

Blood pressure is not detected between pulses. Therefore on any single deflation of the cuff, systolic and diastolic pressure can be observed only in discrete increments, giving rise to a random error. The maximum possible value of this error is the cuff pressure increment between consecutive heart beats. The maximum error is illustrated by this example:

$$\Delta P = \Delta T \frac{dp}{dt},$$

where $\frac{dp}{dt} = \frac{(120-60)\ \text{mmHg}}{30\ \text{sec.}}$ = cuff pressure lapse rate.

$$\frac{dp}{dt} = 6\ \frac{\text{mmHg}}{\text{sec.}},$$

and ΔT is the pulse interval. For a rate of 60 beats per minute, ΔT = 1 second. Hence ΔP = 1 sec. x 6 $\frac{\text{mmHg}}{\text{sec.}}$

ΔP = 6 mmHg.

Body Movement

Interference due to body movements is dependent on several factors. These include the material between the microphone and the subject's skin, his physique, microphone placement, the type of movement, etc.

Experimental evidence indicates the preferred location for the microphone is under the lower edge of the cuff and positioned directly over the brachial artery. The sounds picked up at stations further under the cuff or at stations to either side of the brachial artery tend to become indistinct relative to those recorded as recommended.

Using an incorrectly positioned microphone one can predict what will happen. The recorded pulses will appear weak indicating more gain is required. The gain will be increased to the point where the microphone is sensitive to the slightest disturbance. Finally when the gain is increased to a level which would permit recognition of a pulse wave it will be more easily obscured by disturbances due to noise and artifacts. Correct microphone positioning should conform to that shown in Figures 2 and 3, reproduced from AiResearch Report FC-4242-MR.

Blood pressure recordings have been taken with a microphone positioned over a subject's overcoat. Susceptibility to extraneous disturbance, however, is increased relative to recordings taken with the microphone taped to the skin or placed in the pocket of the occluding cuff.



Though the electronic circuitry is designed to be selective it is incapable of rejecting those high intensity components of the disturbance within the pass band. Positioning the microphone as indicated places it away from the bulk of the biceps and triceps and minimizes the disturbances due to their flexing.

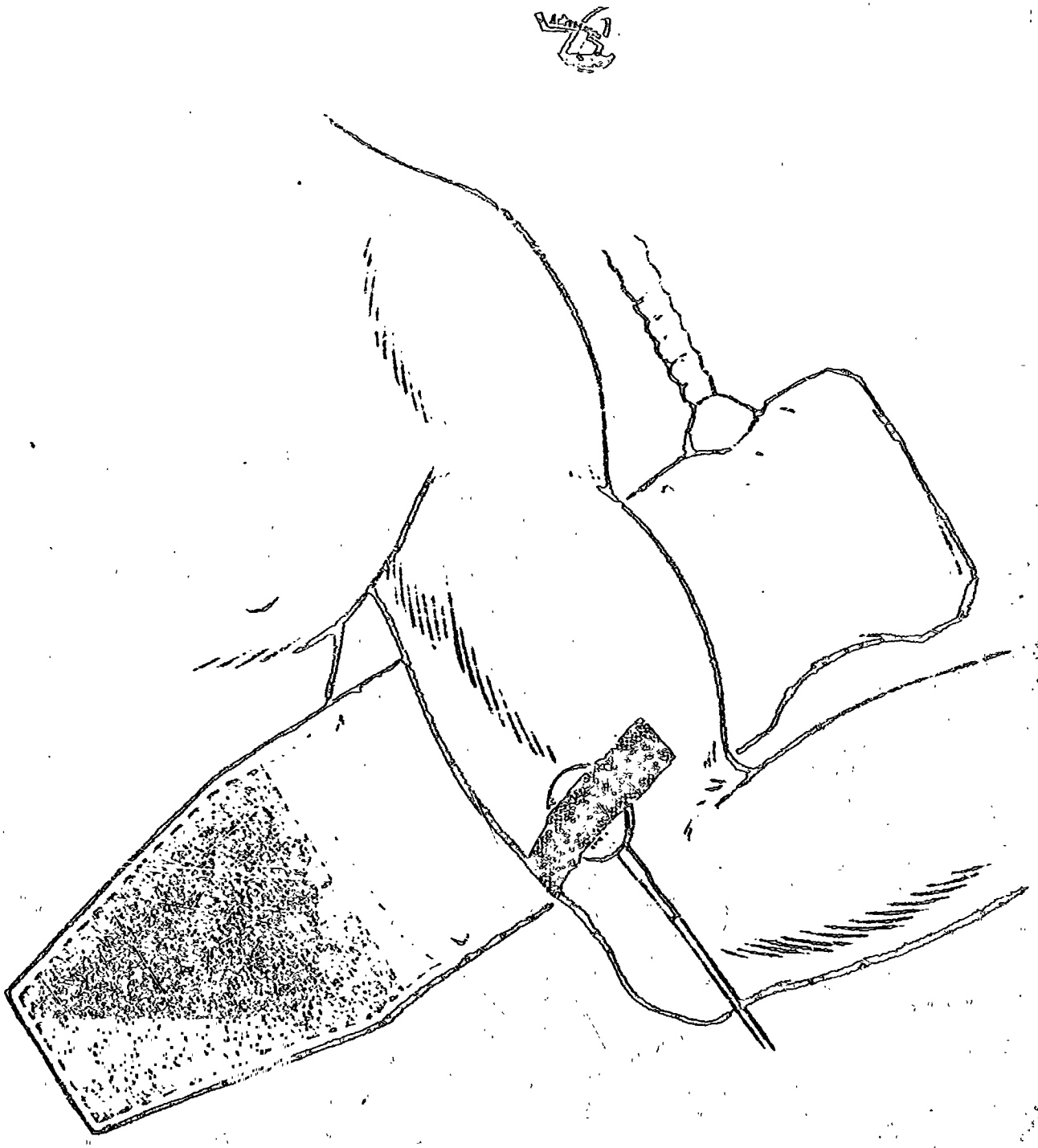


FIGURE 2

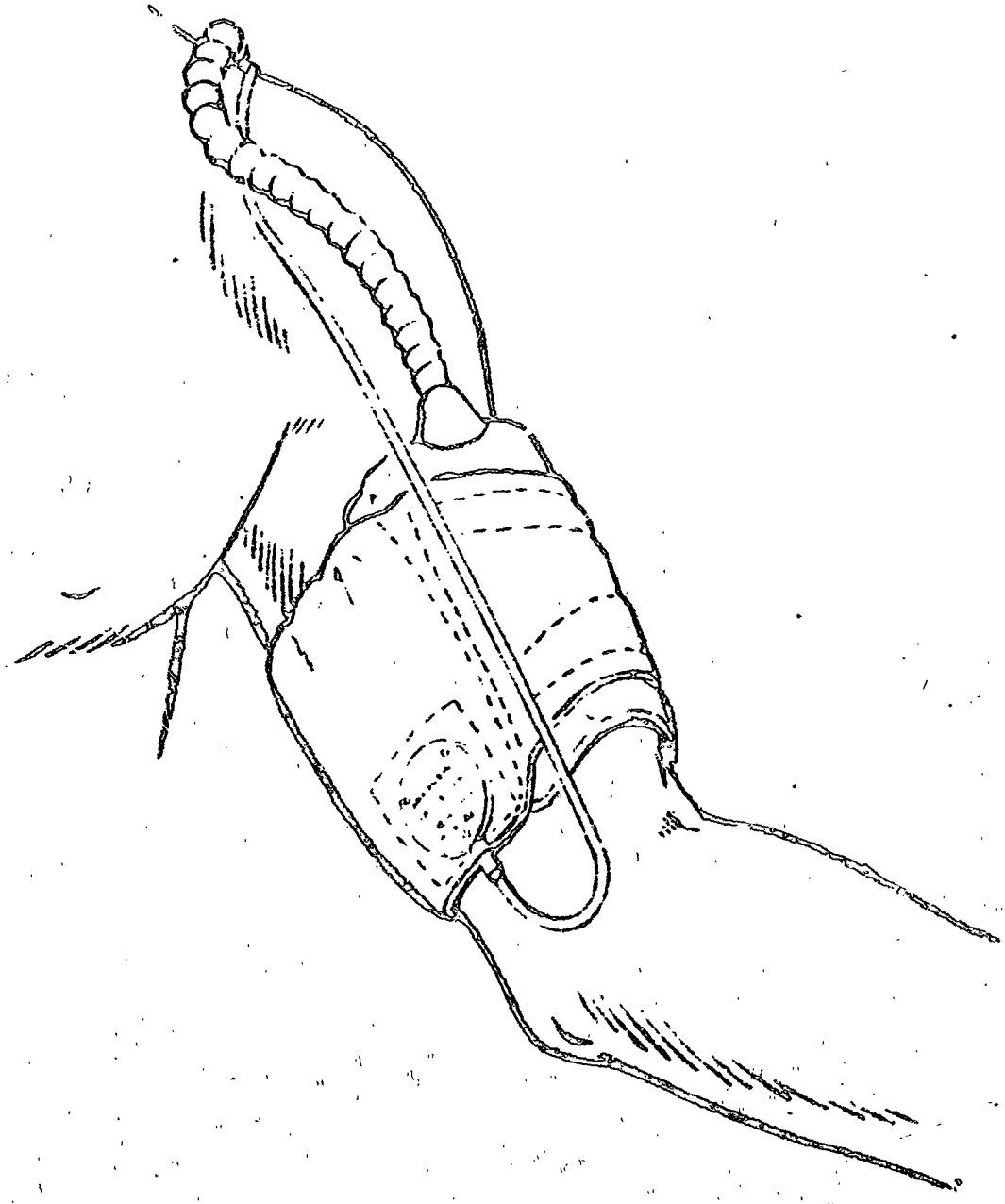


FIGURE 3



[illegible]

[illegible]

[illegible]

Subject	B.P. [illegible]	After 1	2	3	4	5	6	7	After Average
J. Z.	116/78		114/80		112/80	116/86			114/83
J. M.	107/72	112/[illegible]		106/74	104/74			108/76	1[illegible]/74
L. B.	136/[illegible]		130/[illegible]	136/80			134/84		134/82
D. F.	122/78		120/82		116/84				118/83
G. S.	132/84	134/[illegible]		126/86	144/[illegible]			1[illegible]2/[illegible]	135/86
H. W.	114/76				110/78	112/82	108/80		110/[illegible]
L. A.	120/80	116/[illegible]	122/86			118/84			119/83
L. C.	104/69			100/72			98/74		99/73
C. A.	118/72	120/[illegible]	116/76	118/74		114/74		122/[illegible]8	118/74
C. L.	128/[illegible]6		120/80		116/78			114/74	11[illegible]/77
S. M.	106/73	102/[illegible]4		104/72	108/[illegible]		106/[illegible]6		105/75
[illegible]	115/76		112/[illegible]4		110/76	114/80			102/77
[illegible]	126/82			122/86		124/88	120/82		122/[illegible]
[illegible]	98/[illegible]	98/[illegible]	[illegible]	100/74			96/[illegible]0		99/[illegible]1
[illegible]	1[illegible]/74			12[illegible]/[illegible]	118/[illegible]			116/72	11[illegible]/77
[illegible]	14[illegible]	134/[illegible]4				132/82	1[illegible]		13[illegible]/[illegible]4
[illegible]	1[illegible]/84	[illegible]		142/[illegible]	14[illegible]/[illegible]	[illegible]/[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]/[illegible]		[illegible]/[illegible]	106/[illegible]4		[illegible]/[illegible]8	[illegible]/75
[illegible]	[illegible]	[illegible]/[illegible]	12[illegible]/[illegible]8			126/[illegible]4			[illegible]

CLINICAL METHOD

Subject	B.P.M.S.	Tester 1	2	3	4	5	6	7	Tester Means
J. F.	132/84		128/88	130/84			134/86		131/
R. R.	140/91	136/98		132/102	136/94	142/92		140/96	142/
E. P.	112/76	114/78	112/82			116/80			115/
A. G.	124/79			120/80	122/84				121/
M. B.	136/86		134/88		136/84	134/90		130/92	133/
N. T.	123/77		118/82	124/80			120/78		121/
T. C.	99/62	96/64		90/60	96/66			102/68	96/
B. H.	119/76		114/80	118/80		116/78	120/		117/
B. B.	136/				138/94		132/	134/	135/
M. P.	113/74		112/	110/78		108/			109/
C. J.	124/	122/	11 /82					12 /84	120/
T. L.	139/84			134/90	138/94			14 /92	137/
L. P.	102/68	98/70	100/			104/74			101/
L. L.	118/73			114/	112/80		116/		114/
J. G.	116/	116/80		112/74		110/78			113/
J. F.	105/70		106/		102/72	104/74		100/	103/
D. K.	127/		124/	122/	126/				125/
C. S.	152/92	152/96		146/92	166/104	149/94	150/98		150/92
D. S.	117/	116/84			114/86		118/82		116/84
A. S.	106/		102/	104/74	100/72				108/
E. T.	116/80	114/					110/84		112/
E. K.	114/76		116/	114/	110/			112/82	113/



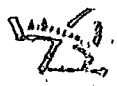
CLINICAL WEEKLY

Subject	W.P.W.S.	1	2	3	4	5	6	7	Roster Average
E. S.	96/62	98/64		92/62				94/68	96/64
W. S.	124/80				120/82	124/86	122/84	122/84	123/84
J. K.	109/72		110/80	104/76		108/78			107/78
M. E.	134/84	132/86			136/88			134/82	134/85
L. B.	140/89		138/90	138/98	154/96		134/90	140/92	142/94
J. P.	120/78	120/84			118/82	118/84			119/82
B. M.	100/65		96/64	96/66			100/68		98/66
M. R.	126/82		128/88	124/86	126/84			122/82	124/86
R. T.	116/76	110/74				114/80	112/78		112/77
D. D.	112/72		114/76	108/72				110/74	111/74
B. F.	138/90	136/96			134/94	132/92			134/94
B. J.	118/80		118/96	120/88	116/84				118/86
K. L.	126/81			124/86			122/82	126/88	124/86
F. M.	98/65	94/66	96/70		98/68	100/72			97/69
N. B.	144/94		158/102		142/98		140/96		122/78
C. P.	126/76	124/78		122/80				120/76	123/79
F. C.	118/88	116/92		112/80	114/78		118/84		115/81
E. K.	106/70		100/72	104/76					103/74
M. B.	136/87				134/90	132/92		130/88	132/90
G. L.	116/75	114/78		116/80			112/76		114/78
E. L.	132/94		134/96	132/96		130/94			132/96
R. N.	114/78			110/76	112/74			114/80	112/77



Subject	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S. G.	125/[illegible]	[illegible]/64		112/[illegible]		12[illegible]/[illegible]	126/[illegible]		[illegible]/83
W. S.	124/72		12[illegible]/6		124/78			122/[illegible]	[illegible]/7[illegible]
J. S.	102/68		[illegible]/[illegible]	1[illegible]2/72		[illegible]9/7[illegible]	[illegible]04/[illegible]		[illegible]01/71
L. T.	117/78	116/[illegible]			114/[illegible]2				116/81
D. S.	12[illegible]/82	124/[illegible]				12[illegible]/80	124/[illegible]8		126/83
W. S.	14[illegible]/90	[illegible]/[illegible]		136/[illegible]	134/94		14[illegible]/9[illegible]	139/96	142/94
R. D.	116/84	114/[illegible]				11[illegible]/[illegible]8			114/81
J. D.	[illegible]8/64			96/6[illegible]			[illegible]4/6[illegible]	[illegible]2/70	96/67
I. C.	122/80		124/84	120/[illegible]6	11[illegible]/[illegible]				121/83
A. B.	108/73			104/78		106/[illegible]6	10[illegible]/72		104/75
D. B.	126/83	122/[illegible]4			104/82			126/88	124/85
R. H.	14[illegible]/90		136/[illegible]6	134/92	14[illegible]/96		14[illegible]/94	150/98	1[illegible]0/94
J. S.	123/78	124/82		102/84		120/80			122/82
T. C.	114/76		11[illegible]/84	11[illegible]/[illegible]2		120/80		114/82	117/81
W. S.	124/[illegible]9	122/[illegible]4		124/[illegible]6			12[illegible]/[illegible]0		1[illegible]2/83
[illegible]. [illegible].	[illegible]4/80		[illegible]/[illegible]		[illegible]2/80	[illegible]1/[illegible]4			[illegible]0/81
K. Y.	[illegible]2[illegible]/82		12[illegible]/84	12[illegible]/[illegible]6				11[illegible]/[illegible]2	1[illegible]/[illegible]4
[illegible]	117/[illegible]	11[illegible]/[illegible]			11[illegible]/71	114/[illegible]	11[illegible]/[illegible]0		11[illegible]/[illegible]2
[illegible]	1[illegible]/[illegible]8	[illegible]1/[illegible]	[illegible]					[illegible]/[illegible]	[illegible]/[illegible]
[illegible]	[illegible]/[illegible]3		1[illegible]/[illegible]	12[illegible]/[illegible]	[illegible]/[illegible]	1[illegible]/[illegible]8			[illegible]/89
[illegible]	1[illegible]/[illegible]4	[illegible]/[illegible]			1[illegible]/[illegible]		1[illegible]/[illegible]		1[illegible]/77
[illegible]	[illegible]/[illegible]		11[illegible]/[illegible]	11[illegible]/[illegible]		[illegible]1/[illegible]4			1[illegible]/[illegible]
[illegible]	[illegible]/[illegible]	[illegible]/[illegible]		[illegible]/[illegible]	13[illegible]		[illegible]/[illegible]	[illegible]/[illegible]	[illegible]/[illegible]





Subject	[illegible]	1	2	3	4	5	6	7	Season Average
[illegible]	114/94		114/96	[illegible]	[illegible]				115/91
[illegible]	[illegible]					[illegible]	[illegible]		[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	116/92			[illegible]	[illegible]
[illegible]	140/88	140/84		134/[illegible]		139/96			140/84
[illegible]	106/70		[illegible]/94	106/76			124/92		[illegible]/84
[illegible]	[illegible]	[illegible]		124/[illegible]		[illegible]			[illegible]
[illegible]	113/76	[illegible]	[illegible]/82		130/80				[illegible]/79
[illegible]	124/[illegible]	[illegible]					120/84		[illegible]/84
[illegible]	[illegible]/96		[illegible]		122/[illegible]	[illegible]			[illegible]
[illegible]	14[illegible]/96			144/[illegible]	[illegible]		15[illegible]/88		[illegible]/88
[illegible]	[illegible]/[illegible]	[illegible]		[illegible]/[illegible]		104/[illegible]			[illegible]/89
[illegible]	122/[illegible]	138/92	[illegible]/[illegible]					144/98	141/[illegible]
[illegible]	136/75			130/82		[illegible]/[illegible]			[illegible]/91
[illegible]	146/[illegible]				142/[illegible]				[illegible]/[illegible]
[illegible]	150/[illegible]	144/[illegible]				149/[illegible]		16[illegible]/96	151/[illegible]
[illegible]	115/76		[illegible]/[illegible]	[illegible]/[illegible]	116/94				113/82
[illegible]	120/[illegible]			116/88				[illegible]/[illegible]	[illegible]/87
[illegible]	[illegible]/72	[illegible]/76	[illegible]/72	[illegible]					[illegible]/84
[illegible]	[illegible]/[illegible]	[illegible]/[illegible]		[illegible]/[illegible]					[illegible]/[illegible]
[illegible]	113/79					[illegible]/[illegible]	[illegible]/[illegible]		[illegible]/[illegible]
[illegible]	[illegible]/89		[illegible]/[illegible]	[illegible]/92		[illegible]/[illegible]			[illegible]/94
[illegible]	[illegible]/[illegible]	[illegible]/[illegible]		[illegible]/[illegible]	[illegible]/[illegible]				[illegible]/[illegible]
[illegible]	[illegible]/[illegible]		[illegible]/[illegible]			[illegible]/[illegible]		[illegible]/[illegible]	[illegible]/[illegible]

FC-4076-R
Page 49



CLINICAL [illegible]

Subject	B.P.M.S.	Tester 1	2	3	4	5	6	7	Tester Average
H. F.	173/99	172/[illegible]		186/110		170/100		174/[illegible]	[illegible]
D. L.	135/74	122/[illegible]		144/78	126/80				[illegible]
L. C.	[illegible]		134/68						[illegible]
C. [illegible]	140/90	136/[illegible]		142/92	136/96	138/94		102/74	[illegible] 71
B. L.	116/[illegible]	114/66	112/68						[illegible]
D. B.	126/78			122/78	114/76		118/82		[illegible]
W. L.	127/84	122/68	124/[illegible]	126/86		128/84		114/86	[illegible]
C. L.	105/73	104/[illegible]		100/74			102/74		125/87
R. M.	118/82		114/[illegible]	116/84		112/80			102/76
P. W.	124/78	120/[illegible]	[illegible]		114/[illegible]	[illegible]			[illegible]
L. I.	95/60			92/56	94/62	92/66			131/83
G. S.	138/86	120/[illegible]	[illegible]				116/90		92/62
J. I.	[illegible]	132/[illegible]		124/78				126/[illegible]	121/[illegible]
D. C.	126/86		[illegible]		130/78	132/[illegible]			127/82
W. E.	112/78			108/78		110/80	114/84		139/[illegible]
E. J.	115/76		112/[illegible]	116/82				114/[illegible]	111/81
D. [illegible]	126/84	[illegible]		128/82	124/[illegible]	[illegible]			112/80
B. M.	144/94		[illegible]		[illegible]		[illegible]	144/[illegible]	[illegible]
D. S.	[illegible]	[illegible]		[illegible]		[illegible]			[illegible]
P. D.	132/[illegible]		[illegible]	[illegible]					[illegible]
[illegible]	115/[illegible]		[illegible]		[illegible]	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]						[illegible]
M. S.	132/[illegible]	[illegible]		[illegible]				[illegible]	[illegible]



Subject	Pre-Test	Test 1	2	3	4	5	6	7	Post-Test Average
M. L.	130/92	128/92					128/94		129/93
J. [illegible]	126/93		132/94	128/96	134/92				130/94
C. L.	128/90			164/96			162/94	160/94	161/94
L. F.	129/92	128/90		128/98					128/97
J. D.	132/94		134/98		142/92	136/96			137/95
B. T.	146/92	140/90		144/96	142/94				142/93
F. N.	156/97		154/94	164/96		158/90		154/92	156/93
T. G.	126/86		126/94	120/88			122/90		123/87
F. C.	132/94				128/94		130/86		129/87
F. B.	160/102	156/106				166/104	158/104		160/105
R. D.	132/94		128/86	132/90		134/98			131/95
N. D.	140/92	134/90			138/98		136/94		136/94

Below listed are the seven testers:

J. N. Waggoner,	M. D.
R. G. Williamson,	M. D.
G. R. Scherer,	M. D.
M. Carpenter,	R. N.
T. Waldal,	R. N.
E. Lawrence,	R. N.
M. Smith,	R. N.

APPENDIX B

OPERATING INSTRUCTIONS
PROTOTYPE BLOOD PRESSURE
MEASURING SYSTEM 54803
PROJECT GEMINI

(EC-4369-MR DATED JULY 29, 1963)

OPERATING INSTRUCTIONS
PROTOTYPE
BLOOD PRESSURE MEASURING SYSTEM
54803
PROJECT GEMINI

EC-4459-MR July 27, 1963

Prepared By:

C. Kayser

Edited By:

M. W. Castle

Approved By

AIRESEARCH MANUFACTURING DIVISION
Los Angeles & Torrance

OPERATING INSTRUCTIONS
FOR PROTOTYPE OF
BLOOD PRESSURE MEASURING SYSTEM 54803
PROJECT GEMINI

4359-MR DATE July [illegible] 964

INTRODUCTION

In principle, BPMS 54803 is essentially the same as Project Mercury BPMS 54707. The composite electrical output signal is a d-c signal proportional to cuff minus suit differential pressure and superimposed intermittent pulses which are representative of Korotkoff sounds.

BPMS 54803 consists of the following.

PART NAME	AIRESEARCH P/N	NASA DESIGNATION
Signal Conditioner	538180	MSC-BPS-SIC-GR-A2
Microphone	536178	MSC-BPS-MIC-GP-A2
Inflation Control	538186	MSC-BPS-INF-GR-A1
Occluding Cuff	GFE	
Suit Fitting	GFE	

The signal conditioner is a small, lightweight module designed to operate with a full pressure suit. Construction is of the potted, welded circuit type.

The piezo type microphone is nearly identical in exterior dimensions to Project Mercury Microphone 513513 but differs internally in that it includes an integral pre-amplifier. The inflation control consists of a squeeze bulb, check valves, bleed orifice, and a pneumatic probe. Inflation is accomplished by the squeeze bulb. A more reliable deflation in the presence of contamination is assured through the use of a dual orifice rather than single orifice.

GENERAL INFORMATION

Power Required:	+10 volts D-C ±1% at 5 ma -10 volts D-C ±1% at 12.5 ma
Pressure Transducer Scale Factor (Including d-c Amplifier):	10^{-5} volts/mm Hg
Pressure Transducer Range (Normal Operation):	50 to 250 mm Hg differential
Pressure Transducer Range (Without and without permanent damage).	Plus or Minus 7.5 p. d.
Pneumatic Source:	Squeeze Bulb (An alternate regulated source of clean air or inert gas may be substituted if desired)
Composite Signal Output Impedance	5000 ohms maximum d-c (1000 ohms maximum a-c (for frequencies of interest).

RECORDING PRINCIPLE

SPMS 5480 senses cuff minus cuff differential pressure with a strain-gage type pressure transducer which is integrally mounted with the signal conditioner. After appropriate signal conditioning of the pressure transducer output, a null output corresponds to an applied differential pressure of 50 mm Hg. An increase in the applied differential pressure generates a proportional differential d-c voltage output signal. An output of 20 millivolts d-c differential corresponds to an applied differential pressure of 250 mm Hg. Superposed on the pressure signal are pulse signals of 10 to 15 millivolts peak-to-peak.

A microphone with an integral pre-amplifier is employed for detecting the Korotkoff sounds. The microphone signal is amplified, passed through a selective filter, and mixed with the pressure transducer output signal. The typical resulting composite trace as recorded on a single-channel direct-writing oscillograph appears as in Figure 1.

the first and last pulses on the composite trace "flag" the pressures corresponding to the systolic pressure and the diastolic pressure, respectively.

OPERATION

Installation of Signal Conditioner 538180 (Refer to Figures 2 and 3)

Connect Microphone 538178 cable terminated with connector P2 to signal conditioner connector J2.

Connect capsule power cable as terminated with connector P3 to signal conditioner connector P3.

Adjust gain control potentiometer R37 to approximately mid range or previously determined optimum position.

Connect the 1/16 inch I.D. rubber hose teed from the occluding cuff pressure to the 0.080 inch O.D. tube protruding from the end of the signal conditioner. No reference pressure line is required as the pressure transducer is vented to the ambient pressure adjacent to the signal conditioner. Care should be taken to insure that the transducer vent on the face of the signal conditioner is not obstructed.

Installation of Occluding Cuff (GFE) and Microphone 538178

Install the occluding cuff on the subject's upper left arm, close to the elbow. Insert the pneumatic probe attached to the end of the cuff hose into the suit fitting (GFE). For more detailed information on installation of the occluding cuff and for relative placement of the microphone, refer to Report No. 4242-MR, included in this report as Appendix A. The microphone should be placed such that it is directly over the brachial artery. Care should be taken to insure that the microphone diaphragm is facing the arm.

Installation of Inflation Control 538186

The pneumatic probe end of the inflation control needs only to be inserted in the suit fitting (GFE) to complete the installation of the BPMS.

Recording of Blood Pressure

It is assumed that all associated systems, such as telemetry, ground station recorder, and dc power supplies, are operative. To generate a blood pressure recording, the astronaut is required to inflate the occluding cuff.

To inflate the cuff, place the thumb over the hole in the valve body of the Manual Inflator and squeeze the bulb several times (with practice, the number of squeezes required to reach the desired pressure will be determined). To deflate the cuff (the period when blood pressure is actually determined), simply remove the thumb from the valve body. A deflation rate causing the pressure to drop from 250 mm Hg to 50 mm Hg in a minimum of 30 seconds is suggested. Some control over this time can be exercised by loosening the cuff to extend the time or vice-versa. This will also affect the number of squeezes required for a given cuff pressure. It should be noted that the change in ambient pressure with increased altitude will cause the deflation time to be increased. (For example, a deflation time of 20 seconds at sea level corresponds to a deflation time of approximately 30 seconds at 27,000 feet.

During deflation of the cuff pressure watch the readout instrument for appearance of pulses (Refer to Figure 1). If microphone placement is satisfactory, a train of pulses will be obtained during the pressure decay. Pulse amplitude should be from 10 to 15 millivolts peak-to-peak with the exception of the first and last pulses, which may be of reduced amplitude. If the pulses are present but the amplitude is low, microphone placement should be checked, and secondly, the gain control adjusted as necessary. If the pulses appear normal but the remainder of the trace exhibits noticeable noise, it is recommended that the gain control be re-adjusted to a lower value. In general, it may be expected that the need for gain adjustment will be infrequent when compared with previous systems.

Bench testing and typical checkout procedures that might be followed are presented in Appendix B.

C. W. Kayser
Flight Data and Electronic Systems

Approved by: J. S. Gould

Approved by: S. E. Westman

Figure 1. Typical Blood Pressure Trace

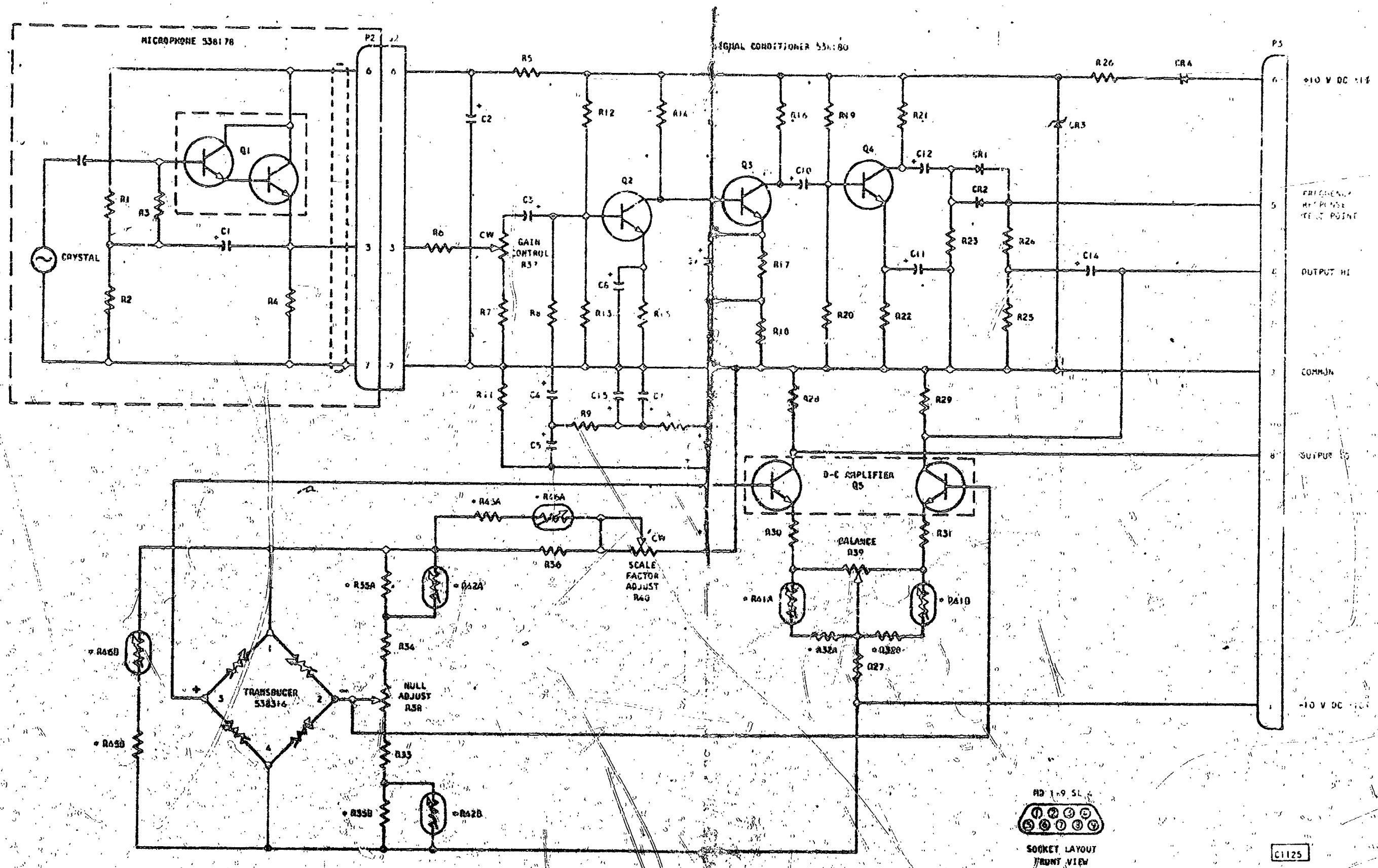


Figure 2. BPMS 54803 Processor Wiring Schematic

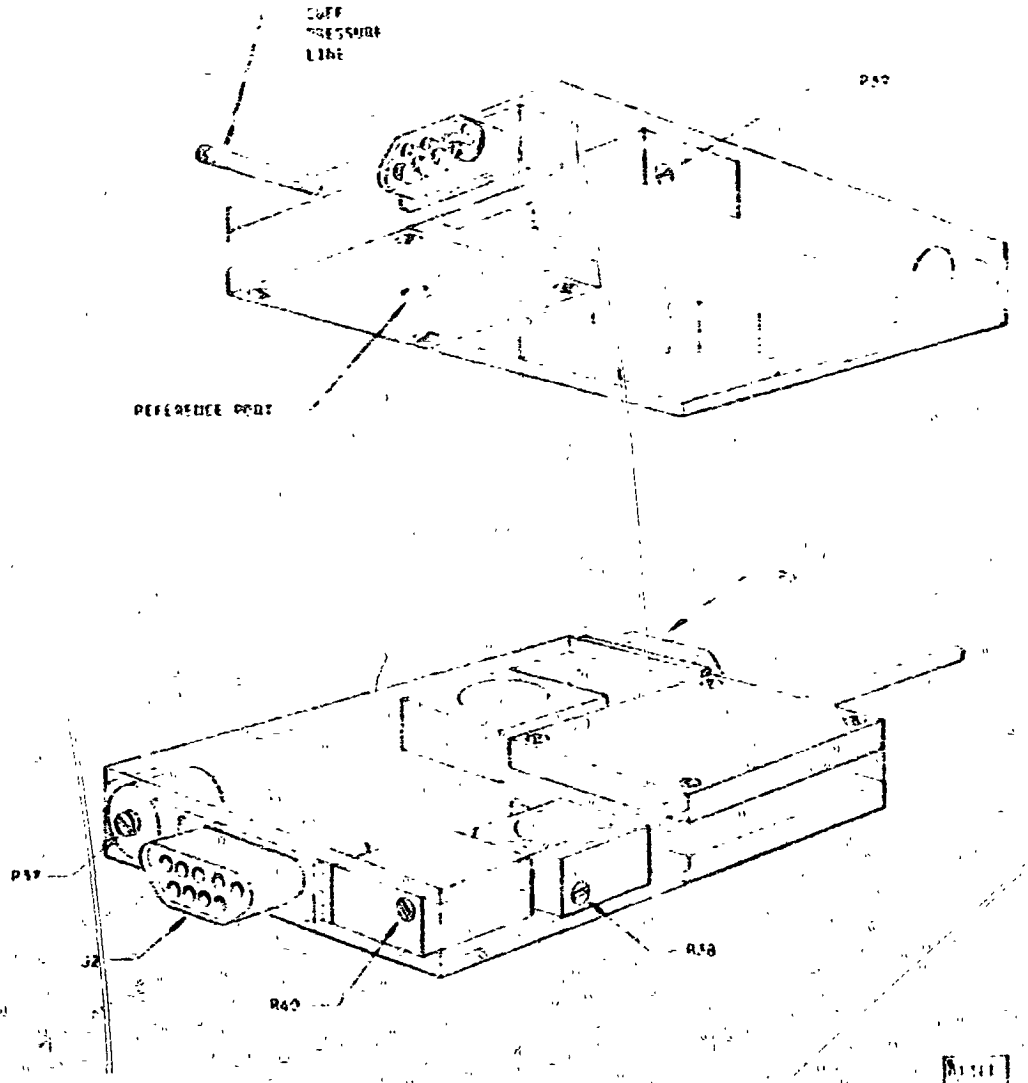


Figure 3. Signal Conditioner Gemini
BPMS 54803 Prototype

APPENDIX A

AIRESEARCH RECOMMENDED PROCEDURE
FOR INSTALLATION OF BLOOD PRESSURE
CUFF AND MICROPHONE
FC-4242-MR

AIRESEARCH RECOMMENDED PROCEDURE FOR INSTALLATION OF BLOOD PRESSURE CUFF AND MICROPHONE LPNS 54778 - PROJECT MERCURY

FC-4232-MR October 17, 1962

Step 1 Install the microphone in the pocket of the blood pressure cuff as shown in Figure 3. Note that the microphone is placed with the diaphragm facing the inner side of the cuff (see Figure 1).

If a cuff without a pocket is used, the procedure is modified as follows.

Attach the microphone as shown in Figure 2, with the diaphragm side of the microphone next to the subjects skin and approximately over the brachial artery. Tape in position. It is important to maintain the correct position of the microphone relative to the cuff. (The microphone must always be located at the lower edge of the cuff.)

Step 2 With the subjects left arm bent 90° at the elbow, hand relaxed, fit the cuff about the arm as shown in Figures 2 and 3. Notice that the microphone is approximately over the brachial artery, and the cutout in the cuff is adjacent to the inside of the elbow.

The cuff should be fastened as snugly as possible without becoming uncomfortable.

Step 3 Have the subject check for comfort by simulating the normal movements required for a mission. Re-adjust the cuff installation as necessary, to correct any pressure points, etc.

C. W. Kilgore

A. S. Gould

Approved: E. E. Gustafson

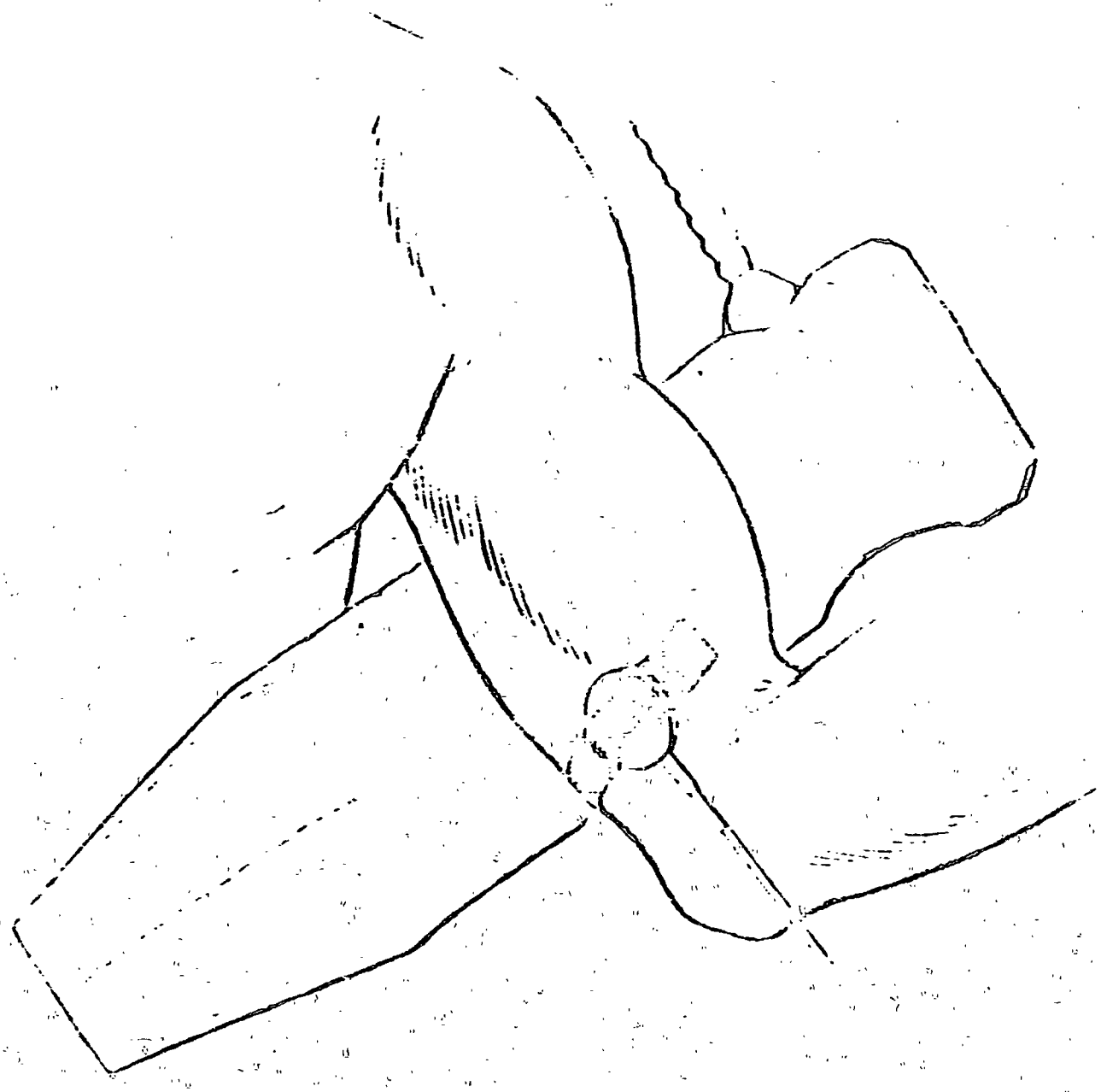


FIGURE 2

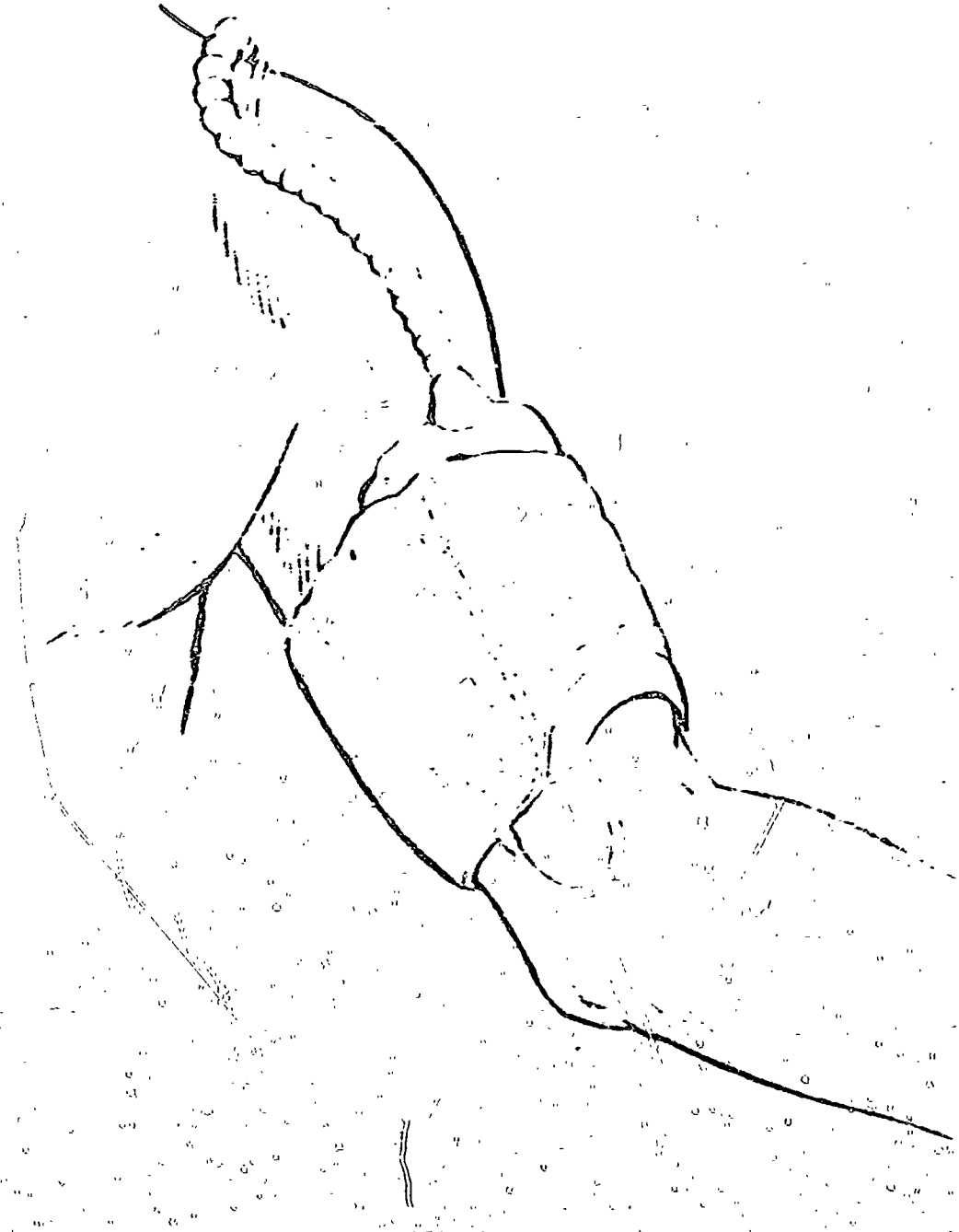


FIGURE 3

APPENDIX B

BENCH TESTING AND TYPICAL CIRCUIT CHECKOUT PROCEDURES FOR PROTOTYPE OF BPMS 54803

APPENDIX B

BENCH TESTING AND
TYPICAL CIRCUIT
CHECKOUT PROCEDURES
FOR PROTOTYPE OF
BPMS 54803

INTRODUCTION

The following procedures are presented to enable the reader to operate the BPMS outside the capsule with or without a subject and to more effectively check out the circuit of BPMS 54803. The procedures presented are employed in one form or another during the manufacture of BPMS 54803 to determine that its performance is optimum.

OPERATION

Preparation of Signal Conditioner 538180 (Refer to Figure 2 of basic report)

Connect Microphone 538178 cable terminated with connector P2 to signal conditioner connector J2. (Microphone simulator may be connected at this time if preferred.)

Connect Control Panel 538292 cable terminated with connector J3 to signal conditioner connector P3.

Adjust gain control potentiometer R37 to maximum (full clockwise).

Connect the 1/16 inch I.D. rubber hose teed from the occluding cuff hose to the 0.080 inch O.D. tube protruding from the end of the signal conditioner. No reference pressure line is required as the pressure transducer is vented to the ambient pressure adjacent to the signal conditioner. Care should be taken to insure that the transducer vent on the face of the signal conditioner is not obstructed.

Preparation of Control Panel 538292 (Refer to Figure 7)

Set controls as follows:

1. Power switch to "OFF"
2. "Function" switch S2 to operate

NOTE: The best point selector switch is for use only with the breadboard of BPMS 54803. Hence no procedure is given for its use.

Connect plus and minus 10 volts ±1 percent and power supply common to the indicated posts on the back of the control panel.

Connect readout device (recorder, VTVM, etc.) with 500K or greater input impedance to output posts on the back of the control panel. (CAUTION: DO NOT USE SINGLE-ENDED EQUIPMENT.)

Connect A-C VTVM or oscilloscope to A-C Test-Point output.

Connect audio oscillator to microphone simulation input.

Place power switch to "ON" position.

Calibrate readout device electrically (see calibration section).

Preparation of Occluding Cuff (GFE) and Microphone 538178

Install the occluding cuff on the subject's upper left arm, close to the elbow. Insert the pneumatic probe attached to the end of the cuff hose into the suit fitting (GFE). For more detailed information on installation of the occluding cuff and for relative placement of the microphone, refer to Appendix A. The microphone should be placed such that it is directly over the brachial artery. Care should be taken to insure that the microphone diaphragm is facing the arm.

Preparation of Inflation Control 538186

The pneumatic probe end of the inflation control needs only to be inserted in the suit fitting (GFE) to complete the preparation of the BPMS.

Recording of Blood Pressure

It is assumed that all associated systems, such as the recorder, graph and d-c power supplies are operative. To generate a blood pressure recording, inflate the occluding cuff by placing the thumb over the hole in the valve body of the Manual Inflator and squeezing the bulb several times (with practice, the number of squeezes required to reach the desired pressure will be determined). To deflate the cuff (the period when blood pressure is actually determined), simply remove the thumb from the valve body.

A deflation rate causing the pressure to drop from 250 mm Hg to 50 mm Hg in approximately 30 seconds is suggested. Some control over this time can be exercised by loosening the cuff to extend the time or vice-versa. During deflation of the cuff pressure watch the readout instrument for appearance of pulses. (Refer to Figure 1 of basic report.) If microphone placement is satisfactory, a train of pulses will be obtained during the pressure decay. Pulse amplitude should be from 10 to 15 millivolts peak-to-peak with the exception of the first and last pulses, which may be of reduced amplitude. If the pulses are present but the amplitude is low, microphone placement should be checked, and secondly, the gain control adjusted as necessary. If the pulses appear normal but the remainder of the trace exhibits noticeable noise, it is recommended that the gain control be readjusted to a lower value. In general, it may be expected that the need for gain adjustment will be infrequent when compared with previous systems.

System Operation Without a Subject

Sometimes, either for reasons of calibration or system checkout, it is desirable to operate the BPMS without occluding the arm or other extremity of a subject. Since it is not a recommended practice to pressurize an unrestrained occluding cuff, the cuff should be placed around a wood mandrel approximately 3.5 inches in diameter. If it is desired to also check the pulse channel at this time, one of two methods may be employed. The microphone may be removed from underneath the occluding cuff and placed over the port of a sound generator. A sound pressure imparted to the diaphragm of the microphone of 72 dynes/cm^2 (111.3 db relative to 0.0002 dynes/cm^2) at 36 cps is recommended. Alternatively, Plug P2 of the microphone may be disconnected from J2 of the signal conditioner and an alternate plug from the control panel may be substituted in its place. With the use of an audio oscillator, a microphone simulator circuit provided in the control panel is now activated. For more detailed information, refer to Frequency Response Checkout of Signal Conditioner 538180.

CALIBRATION

In the following text, calibration schemes have been categorized as follows:

a. Recording Equipment Calibration

b. Pneumatic Calibration of Signal Conditioner

"Recording Equipment Calibration" describes special features incorporated into the Control Panel to facilitate adjustment of laboratory recording equipment. "Pneumatic Calibration" is required only if the integrity of the Signal Conditioner circuitry calibration is suspected or if a check of the integral pressure transducer is desired.

Recording Equipment Calibration

The composite output signal from Control Panel 538292 is a true differential signal and is balanced with respect to ground (both leads may be several volts below ground potential). Grounding of either output lead will not damage the BPMS, but may damage the readout equipment as this could result in an output signal of several volts D-C. In the ensuing discussion, signal voltages are referred to the "output low" terminal.

The "Function" switch (Figure 1, Switch S2) on the control panel connects the output terminals of the control panel to the composite signal output of the signal conditioner, power supply common (0 millivolts output) or one of two voltage dividers (10 and 20 millivolts output). This permits the operator to easily calibrate the readout equipment.

As furnished, zero signal corresponds to 50 mm Mercury, 10 millivolts corresponds to 150 mm Mercury, and 20 millivolts corresponds to 250 mm Mercury. EXAMPLE: The readout equipment consists of a recorder which has a low level differential input and zero adjustment. The ten 1/2-cm major scale divisions (5 cm paper) are to correspond with 50 to 250 mm Mercury.

1. Set "Function" switch to "0 mv." Adjust zero on recorder until pen is at lower edge of scale (0 percent full scale).

2. Set "Function" switch to "20 mv." Adjust recorder gain until pen is deflected to the upper edge of the scale (100 percent full scale).

3. Set "Function" switch to "10 mv." Pen should deflect to the center of the scale (50 percent full scale). If it does not, repeat Steps 1 through 3.

4. Set "Function" switch to "Operate" and proceed.

Pneumatic Calibration of Signal Conditioner

A definitive pneumatic calibration can only be made with an appropriate pressure standard. A clean mercury Manometer certified to be accurate to approximately 0.5 mm Mercury should be used for this purpose. The pressure standard may be connected in parallel with the cuff, or the cuff may be removed and the pressure standard connected directly to the pressure transducer. The bleed orifice should be closed off except when it is desired to drop the pressure. Inflation may be controlled by Manual Inflator 538186 or an alternative clean pneumatic source. As the hysteresis in these transducers is so small as to be insignificant, calibration may be effected during either ascending or descending pressure.

The two criteria to be established in pneumatic calibr ... are:

1. That the output voltage vs pressure function of the transducer is linear within prescribed tolerances under the prescribed environmental conditions.

2. That the null and scale factor potentiometers in the signal conditioner are adjusted to optimize the pressure transducer performance.

It is suggested that a series of pressures at 20 mm Mercury increments be logged along with corresponding output voltages, and these be plotted on cross section paper (Figure 2). Linearity may then be judged visually.

If linearity appears satisfactory, but the output exhibits an excessive offset or scale factor error, it is necessary to readjust the potentiometers establishing the scale factor and null point. Trimpot R38 provides zero voltage adjust for Pressure Transducer 538314 and has an adjustment range of ±2.5 percent. Trimpot R40 provides scale factor adjustment as necessary.

The recommended procedure for adjustment of the null and scale factor potentiometers affecting Pressure Transducer 538314 is as follows:

1. Pressurize to 50 mm Hg.
2. Adjust R38 to give 0 mv output (See note following this paragraph).
3. Pressurize to 250 mm Hg.
4. Adjust R40 to give 20 mv output (See note following this paragraph).
5. Drop pressure to 50 mm Hg and check output. If it is still outside tolerances, repeat steps 2 through 5.

NOTE: The values given above are ideal end points assuming a linear transducer output. In practice, it is normally found that these points are purposely offset to compensate for tolerance buildup in other parts of the pressure range due to either non-linearity or temperature effects. For the amount of offset required at room temperature, refer to the data sheet accompanying the signal conditioner.

SYSTEM PERFORMANCE CHECKOUT

The following procedures when executed in addition to the calibration procedures previously described will provide a comprehensive checkout of the performance capabilities of the BPMS undergoing test. The procedures described are based on the procedures utilized during the manufacture and acceptance testing of the BPMS.

Frequency Response Checkout of Signal Conditioner 538180

It is first necessary to establish that the center frequency corresponds to a level of zero db at Pin 5 of P3 on the 0.3 volt range of the VTVM. To do this, proceed as follows:

Connect an audio oscillator to the microphone simulation input on Control Panel 538292. Set it at 36 cps. If the dial calibration on the oscillator is in doubt by more than one cycle, a counter should be used to read the oscillator frequency.

Set the test point selector switch to position 16. Adjust the oscillator amplitude until the VTVM on the a-c test point output jacks indicates approximately one millivolt. Change the VTVM to the 1 volt range.

Connect the VTVM to the Frequency Response Test Jack (Reference Figure 1) and scan the oscillator frequency between 30 and 40 cps until the center frequency is located (maximum voltage). Adjust the oscillator voltage until the VTVM indicates zero db when set on the 0.3 volt range. Scan to make sure the oscillator is still at center frequency and adjust if necessary.

A plot of output db vs log frequency as shown in Figure 3 may now be obtained by setting the oscillator frequency to the values called out in Figure 3, recording the indicated db value, and plotting. Tolerance limits are indicated in Figure 3, and are based upon the checkout being conducted in the manner described.

Temperature Tolerance Checkout of System 54803

Adherence to temperature tolerances may be confirmed by placing the signal conditioner in a temperature chamber, adjusting to the desired temperature, and checking the following facts:

(1) Center frequency shall remain within tolerance (30 cps ±3 cps).

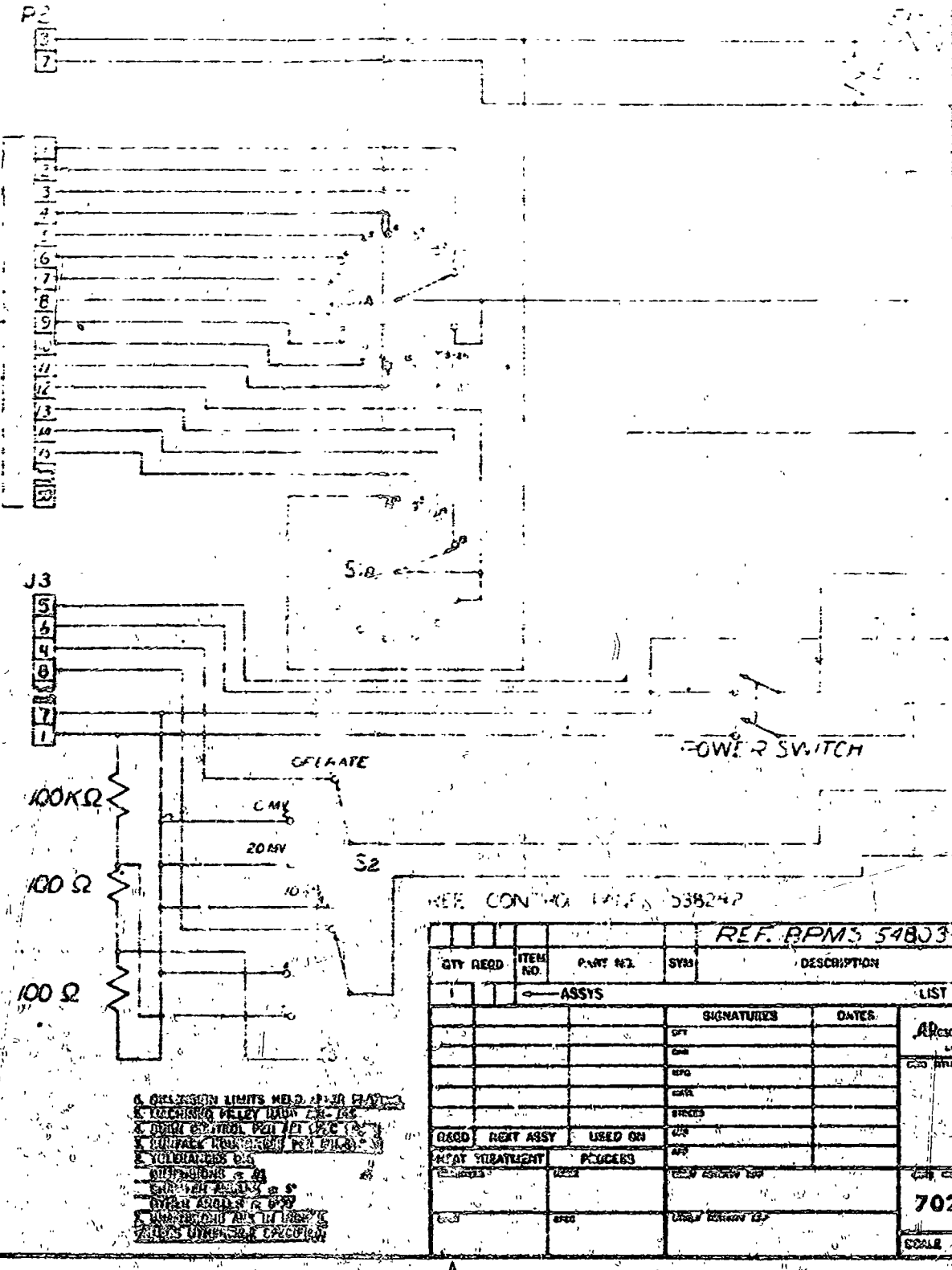
(2) D-C output voltage vs pressure shall be within tolerance (±2 percent).

(3) Output level vs frequency shall remain within tolerance (Figure 3).

NOTE: As pulse amplifier gain changes somewhat over the temperature range, it may be necessary to re-establish zero db output at center frequency at each temperature. Blood pressure observations are insensitive to moderate pulse gain changes, making elaborate temperature-gain compensation unnecessary.

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REVISIONS			
SYM		DATE	APPROVED



REF. CONTROL DWG. 538242

REF. BPMS 54803

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL	SPECIFICATION	UNIT WT
1		ASSYS		LIST OF MATERIAL				

	SIGNATURES	DATES
DFT		
DWN		
DES		
ENGR		
CHKD		
APP		

REQD	NEXT ASSY	USED ON
HEAT TREATMENT	PLATING	

AiResearch Manufacturing Company
LOS ANGELES CALIFORNIA

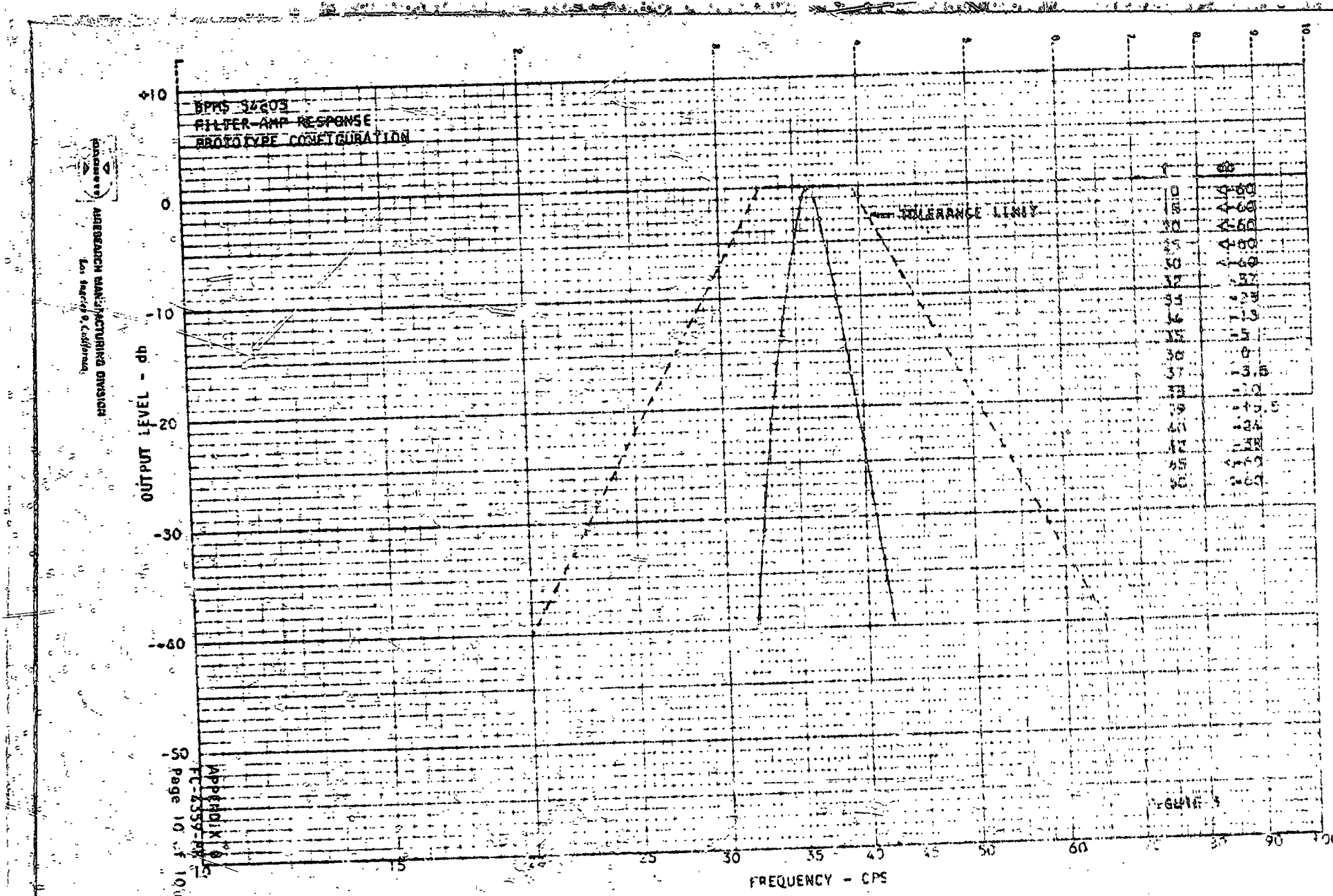
CONTROL PANEL
WIRING DIAGRAM

70210 | C | PA 51979

SCALE | SHEET 2 of 2

FIGURE 1

AIRESEARCH MANUFACTURING DIVISION
Los Angeles 9, California


BPMS 54203
FILTER-AMP RESPONSE
PROTOTYPE CONFIGURATION
TOLERANCE LIMIT
OUTPUT LEVEL - db
FREQUENCY - CPS
+10
0
-10
-20
-30
-40
-50
15
25
30
35
40
50
60
90
100

APPENDIX C

TESTING OF MICROPHONE 538178

APPENDIX C

TESTING OF MICROPHONE 538178

SENSITIVITY TEST

Figure 1 shows the test setup AiResearch uses to check microphone performance. Important points to note are:

1. The microphone under test and reference microphone are located in close proximity to each other, to insure equal sound pressure levels.
2. An oscilloscope is used to verify that the audio source is delivering a reasonably undistorted waveform.
3. The microphone under test is connected to the "breadboard" signal conditioner for this checkout, and its output is monitored on a-c test point No. 1.
4. The audio oscillator is set at 30 cps.

It is recommended that the audio level be adjusted to approximately 72 dynes/cm^2. Any sound pressure level from 10 to 100 dynes/cm^2 may be used however, as AiResearch furnishes a graph (Figure 2) with each microphone simplifying the reduction of test data.

The normal procedure to follow is:

1. Set up the equipment as shown in Figure 1
2. Adjust the sound pressure to the desired level.
3. Check waveforms.
4. Monitor test point 1 (microphone output). As the sound pressure level and the microphone output are now known, these values can be entered on a graph similar to the enclosed graph (Figure 2) to determine the microphone sensitivity.

FRONT TO BACK RATIO TEST

Turn the microphone under test over and repeat the sensitivity test. The output shall be a minimum of 10 db down to meet the specified tolerance (3 to 1), and it is normally so far down as to be unmeasurable over the specified sound pressure level range.

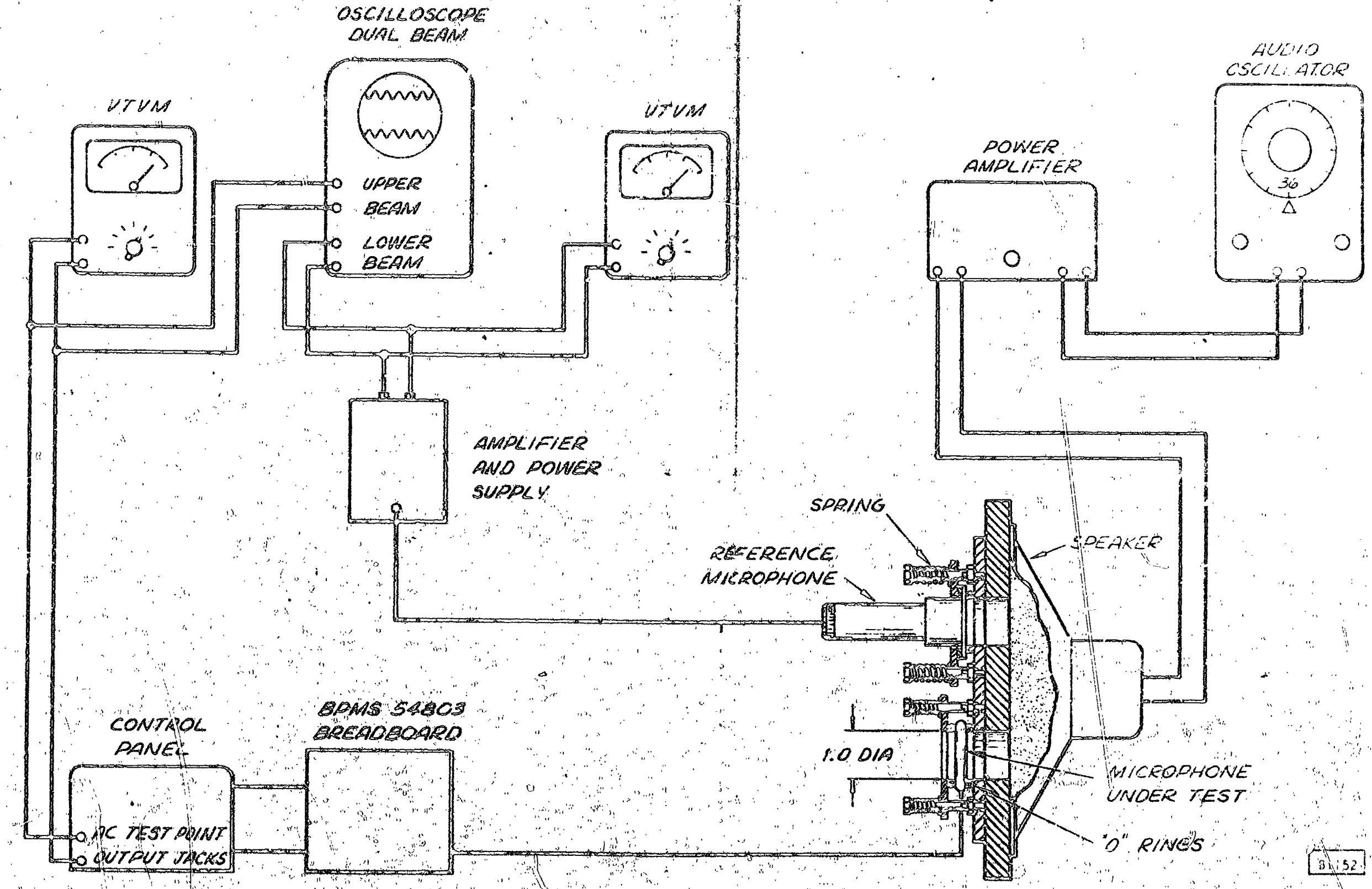


Figure 1. Microphone Test Setup

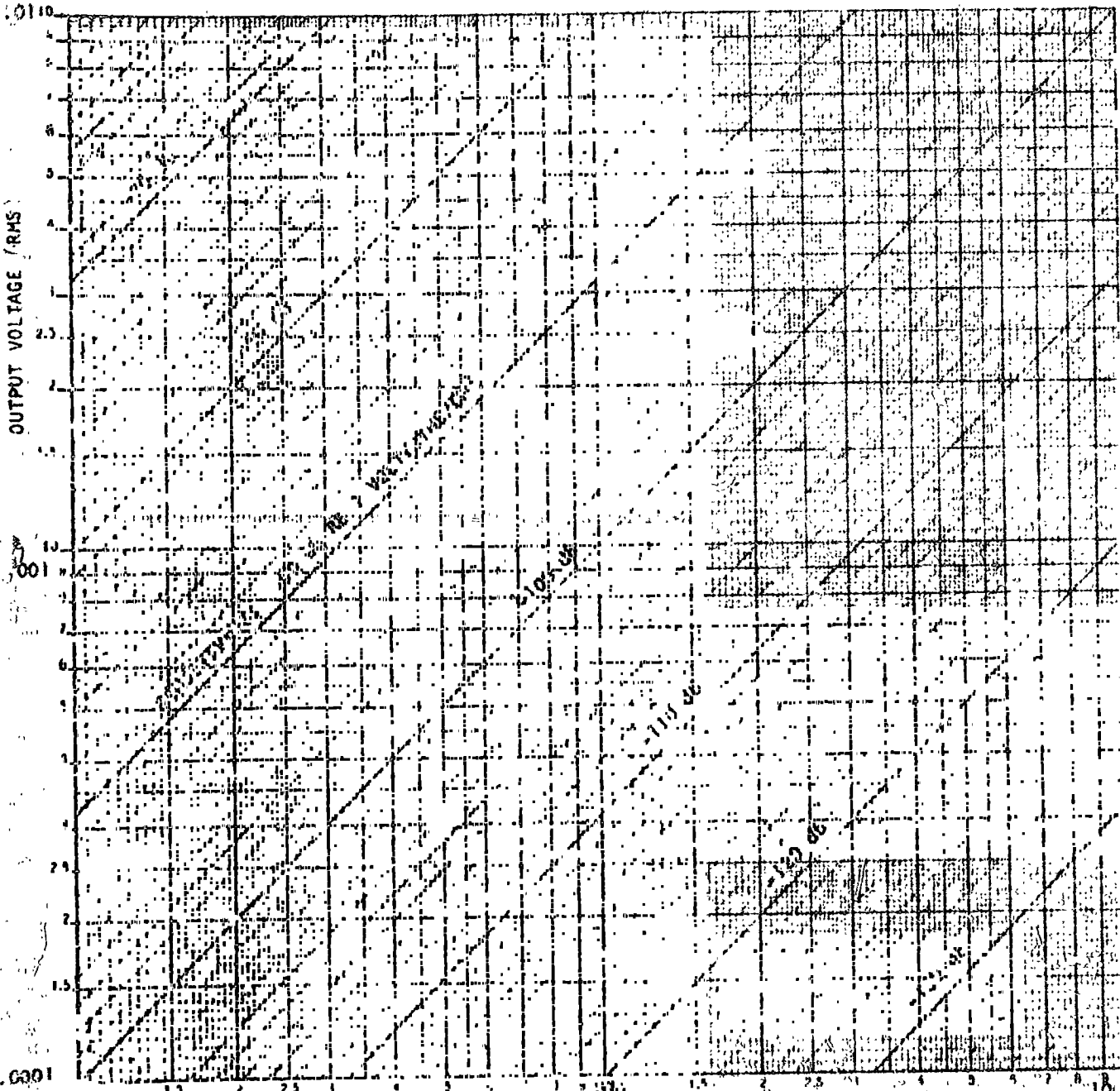
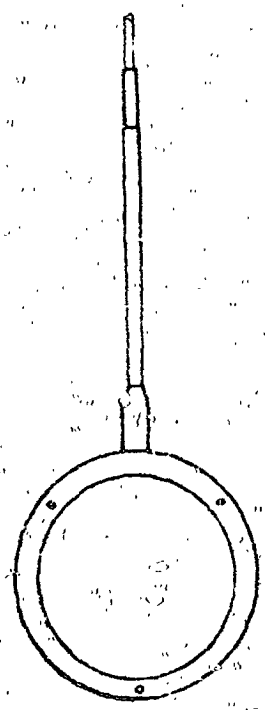
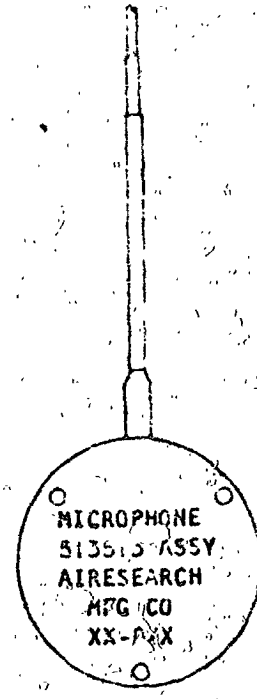


FIGURE 2

ENDEVCO
ENDEVCO RESEARCH MANUFACTURING DIVISION
Los Angeles 9, California



DIAPHRAGM



BACK

FIGURE 1

APPENDIX C

TRANSDUCER EVALUATION REPORT
SOLID-STATE SEMICONDUCTOR STRAIN-GUAGE
PROJECT GEMINI EPHS

(FC-4403-HR DATED OCTOBER 9, 1963)

TRANSDUCER EVALUATION REPORT
SOLID-STATE SEMICONDUCTOR STRAIN-GAGE
PROJECT GEMINI DPTS

FC-4403-HR Date: October 9, 1963

Several transducer manufacturers were contacted early in 1963 in an effort to acquire a small, solid-state semiconductor strain-gage transducer for use on the Project Gemini DPTS.

It was determined that of the companies contacted, only two promised sufficient interest and capability to justify the award of a contract for evaluation units. Contracts were consequently awarded to two vendors for the development, construction, and delivery of two transducers (from each vendor) for evaluation purposes.

Vendor "B" encountered considerable difficulty in solving some of their problems. After at least two revisions of delivery date their first transducer was delivered approximately 104 days ARO. Work on the second transducer was stopped, and Vendor "B" advised that they were discontinuing the effort. Vendor "C" delivered both of their transducers several days ahead of the promised delivery date (less than 6 weeks).

This report summarizes the tests to which these transducers were subjected, the results of these tests, conclusions derived from the test results, and anticipated follow-up action to be taken.

VENDOR "B" TRANSDUCER S/N AA-2

Figure 1 shows the test circuit used for this transducer evaluation. Table I is a tabulation of the test data, and Figure 4 is a plot of the linearity and hysteresis. It should be noted at this time that the transducer performance was monitored using an ordinary mercury manometer to read the pressure, with a Rubicon millivolt potentiometer to read the output.

Figure 4 shows an apparent negative hysteresis, which is attributed to either, (1) a zero shift, or (2) hysteresis of the mercury column

itself. In any case, it is felt that there is sufficient evidence that hysteresis and linearity are well within the specified tolerances, and further testing is not currently planned for this unit.

Inspection of Table I, runs 1 through 14, shows that there is a slight instability, being insignificant except for run 14 which has a slightly larger error than that seen on the other runs. It is within the specified tolerance in all cases however (up to and including run 14).

It was decided that the error due to thermal sensitivity at 0°F and 150°F should be measured even though compensation on this transducer was required only from 55°F to 115°F. Runs 15 and 16 show an error of approximately 10 percent at 0°F, with the output returning to approximately nominal when the transducer returned to 80°F. Runs 19 and 20 show an error of only 3.6 percent (maximum) at 150°F. It should be noted, however, that the error increased to 4.5 percent when the transducer was returned to 80°F. A re-examination of run 14 shows that it follows a 115°F run. It is conjectured that operating the transducer at even the moderately elevated temperature may cause a permanent change in calibration.

Overall performance of the transducer was judged to be satisfactory and in full compliance with the specifications.

As Vendor "B" declined to deliver additional units, AiResearch at this time has no plans for further testing on this unit.

VENDOR "C" S/N 2928

Figure 3 shows the test circuit used for this transducer evaluation. Table 3 is a tabulation of the test data, and Figure 3 is a plot of the linearity and hysteresis. As can be seen from Figure 3, an Ideal Aerosmith Model 1010M photocell-scanned manometer and a Leeds and Northrup K-2 potentiometer were used to obtain one set of readings, while an ordinary mercury manometer and a John Fluke potentiometric voltmeter Model 801 were used for another set. The nonlinearities apparent in the latter case are believed to be the result of either (1) transducer oil canning, or (2)

resolving power of the Fluke voltmeter. It is believed that the readings obtained with the Ideal Aerosmith and K2 are much more reliable. As can be seen, linearity and hysteresis are both excellent.

Inspection of Table 3 will show that there is a high degree of instability in this transducer. Runs 1 through 17 were made without the 50Ω balance pot as indicated in Figure 3, hence the offset at 50mm Hg pressure. These readings show, in general: (1) Temperature compensation is good from 0°F to 69°F (Runs 5 through 9), (2) A large degree of instability (Runs 1, 2, and 3) exists which is erratic and unpredictable. Total temperature error from 55° to 115°F is approximately ±1.5 percent (Runs 18 through 35).

In summary, it was determined that the overall performance of this transducer, with the exception of the instability problem, was entirely satisfactory.

Vendor "C" was contacted and made aware of the performance as noted here. They promised to ship two new transducers to AiResearch at no additional cost by September 27. This date was later revised to October 3. These transducers are to demonstrate that Vendor "C" has determined and corrected the cause of the instability, and will not be temperature compensated.

Vendor "C" also gave AiResearch the option of purchasing two new evaluation transducers, which will meet all specifications, at the production prices. This option may be exercised if the two transducers shipped October 3 perform satisfactorily.

VENDOR "C" S/N 2931

Figure 2 shows the test circuit used for this transducer evaluation. Table 2 is a tabulation of the test data.

Inspection of Table 2 shows the same general performance as was seen from S/N 2928. Run 1 was made without the 100Ω balance pot as shown in Figure 2. It should be noted that the balance pot was adjusted to provide a zero output at Runs 2, 30, and 40. The same conclusions were reached after examination of these data as were reached for S/N 2928, and hence will not be repeated here.

A report on the performance of the forthcoming Vendor "E" transducers will be included as an appendix to this report as soon as the evaluation is completed.

C. Kayser
C. Kayser
93-9

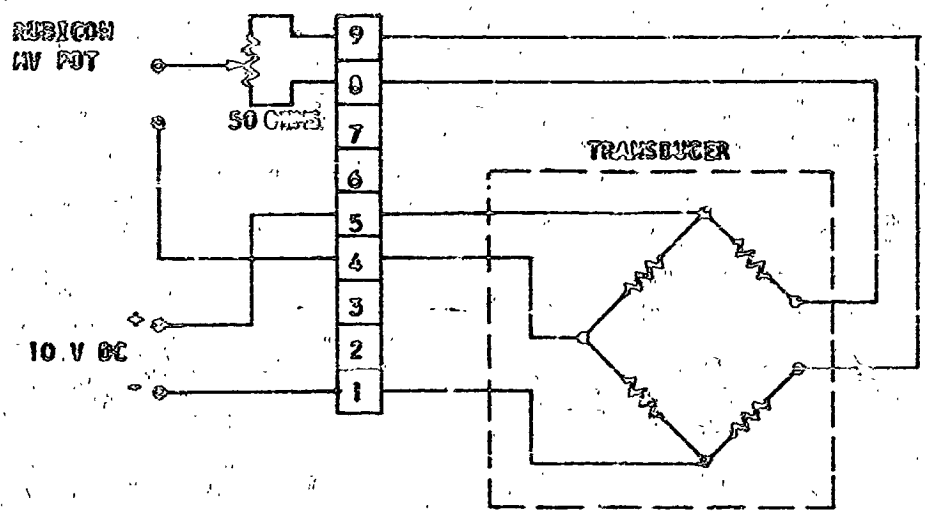


Figure 1. Vendor "B" AA-2

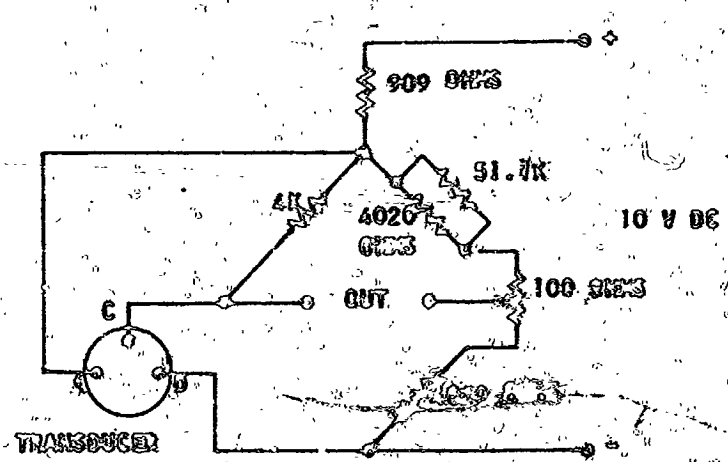


Figure 2. Vendor "C" A-2951

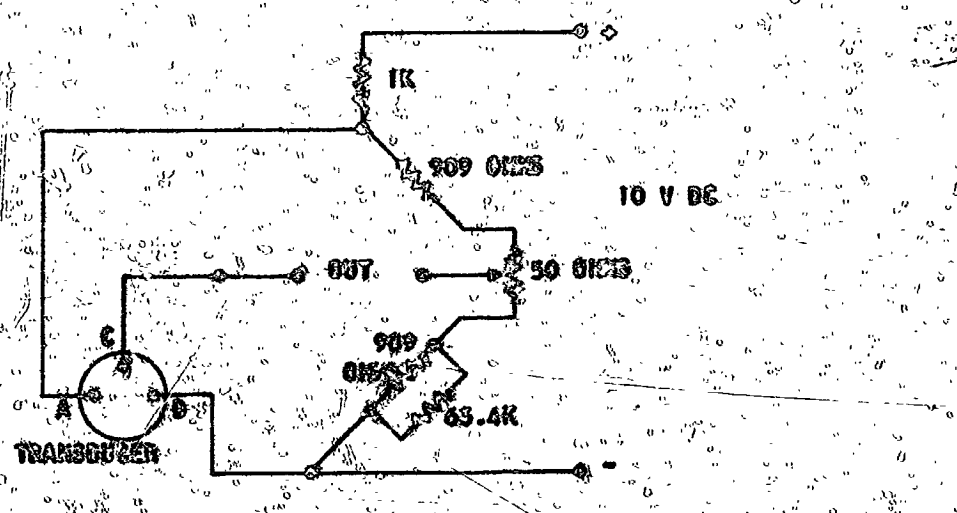


Figure 3. Vendor "C" A-2928

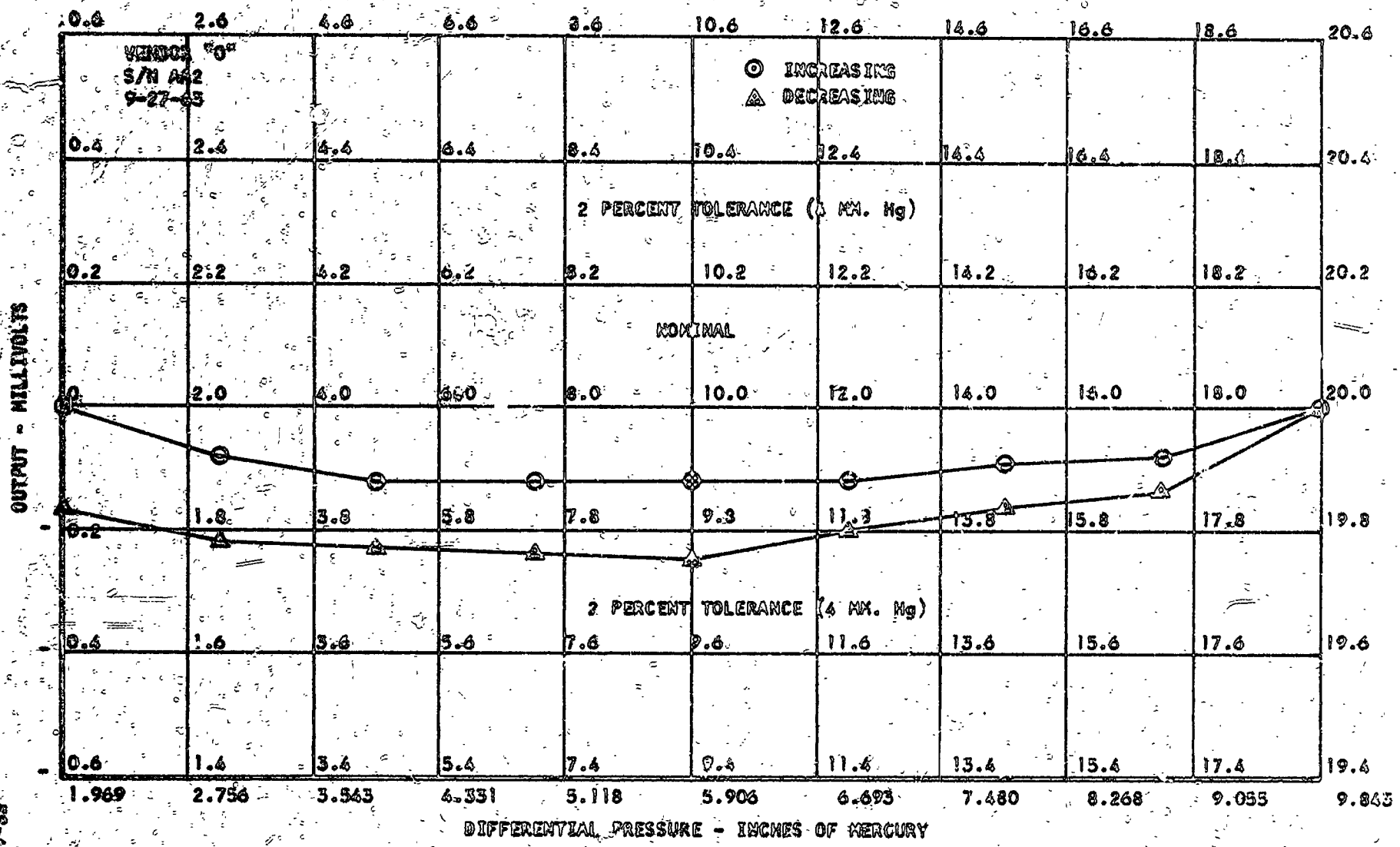


Figure 4. Pressure Channel Performance

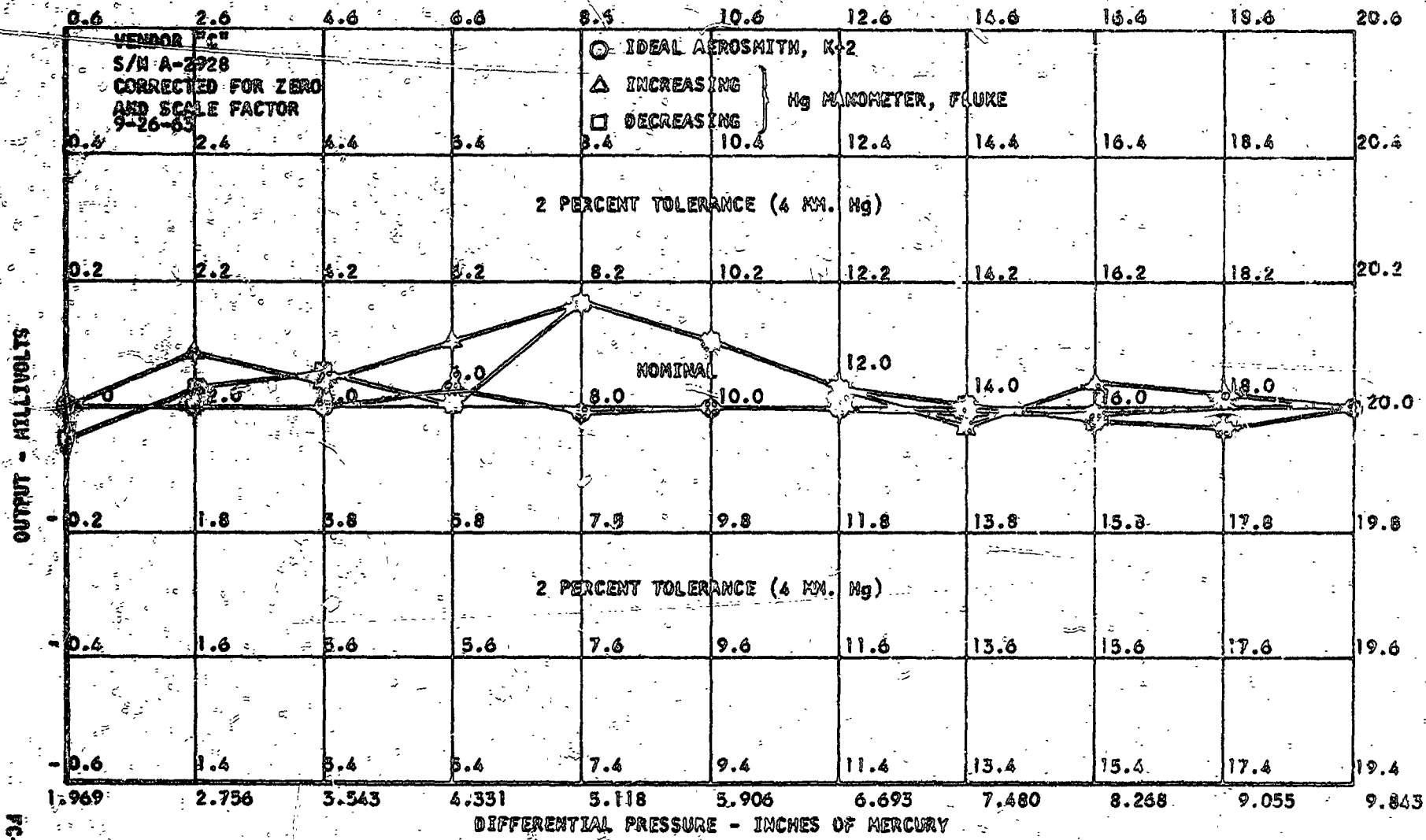


Figure 5. Pressure Channel Performance

Run No.	Temp. °F	Output MV		Date Recorded
		50mm	250mm	
1	80	0.00	20.00	9-19-63
2	80	-0.17	20.00	9-19-63
3	115	-0.11	19.84	9-19-63
4	115	-0.48	19.75	9-19-63
5	79	+0.09	20.16	9-20-63
6	79	-0.01	20.16	9-20-63
7	55	-0.27	19.90	9-20-63
8	55	-0.15	19.90	9-20-63
9	80	+0.05	20.13	9-20-63
10	80	-0.07	20.12	9-20-63
11	80	-0.07	"	9-20-63
12	55	-0.41	"	9-20-63
13	115	-0.25	"	9-20-63
14	81	-0.59	"	9-20-63
15	0	-1.92	18.23	9-20-63
16	0	-1.95	"	9-20-63
17	81	-0.07	"	9-20-63
18	78	+0.33	"	9-23-63
19	150	-0.34	19.38	9-23-63
20	150	-0.68	"	9-23-63
21	80	-0.90	"	9-23-63
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				

CALCULATED		
RECORDED		
DRAWN		
CHECKED		
APPROVED		

Transducer S/N: AA 2

Manufactured By: Vendor "D"

Date: 9-26-63

AIRESEARCH MANUFACTURING CO.
LOS ANGELES, CALIFORNIA

TABLE I

Run No.	Temp. °F	Output MV		Date Recorded				
		50mm	250mm					
1	75	10.29	30.12	7-30-63				
2	81	0.0	19.70	9-10-63				
3	84	0.0	19.70	9-10-63				
4	85	0.0	19.70	9-10-63				
5	85	0.0	"	9-10-63				
6	116	-0.1	19.86	9-10-63				
7	116	-0.1	19.90	9-10-63				
8	116	-0.1	19.90	9-10-63				
9	116	-0.1	"	9-10-63				
10	85	+0.70	20.3	9-10-63				
11	85	+0.70	20.34	9-10-63				
12	85	+0.70	20.34	9-10-63				
13	85	+0.70	"	9-10-63				
14	55	+0.30	19.80	9-10-63				
15	55	+0.3	19.80	9-10-63				
16	55	+0.3	19.90	9-10-63				
17	55	+0.3	"	9-10-63				
18	85	+0.5	20.11	9-10-63				
19	85	+0.5	20.15	9-10-63				
20	85	+0.6	22.20	9-10-63				
21	85	+0.6	"	9-10-63				
22	115	+0.1	19.80	9-10-63				
23	115	+0.1	19.80	9-10-63				
24	115	+0.1	19.80	9-10-63				
25	115	+0.1	"	9-10-63				
26	85	+0.3	19.90	9-10-63				
27	85	+0.3	19.90	9-10-63				
28	85	+0.3	19.90	9-10-63				
29	85	+0.3	"	9-10-63				
30	85	0.0	"	9-13-63				
31	115	-0.4	"	9-13-63				
32	85	-0.5	"	9-13-63				
33	55	-0.5	"	9-13-63				
34	0	-0.5	19.0	9-13-63				
35	0	-0.6	"	9-13-63				

CALCULATED			Transducer S/N A-2951 Manufactured By: Vendor "C"
RECORDED			
DRAWN			
CHECKED			
APPROVED			AIRESEARCH MANUFACTURING CO. LOS ANGELES, CALIFORNIA

Date: 9-26-63

TABLE 2

Run No.	Temp. °F	Output MW		Date Recorded
		50	250	
36	80	-0.2	-	9-13-63
37	130	-2.8	16.4	9-13-63
38	150	-2.9	-	9-13-63
39	80	-1.80	-	9-13-63
40	81	0.0	-	9-18-63
41	115	-0.84	-	9-18-63
42	81	-0.78	-	9-18-63
43	55	-0.75	-	9-18-63
44	81	-0.54	-	9-18-63
45	32	-1.00	-	9-18-63
46	81	-0.33	-	9-18-63
47	150	-2.88	-	9-18-63
48	82	-1.69	-	9-18-63
49	76	-0.73	-	9-18-63

CALCULATED	Transducer S/N A-2951	DATE:
RECORDED	Manufactured By: Vendor "E"	9-26-63
DRAWN		
CHECKED	AIRESEARCH MANUFACTURING CO.	
APPROVED	LOS ANGELES, CALIFORNIA	

TABLE 2 (Continued)

Run No.	Temp. °F	Output MW		Date Recorded				
		50mm	250mm					
1	75	1.63	21.85	7-30-63				
2	75	1.08	21.50	7-30-63				
3	75	2.84	23.30	8-29-63				
4	75	2.79	23.30	8-29-63				
5	0	2.12	22.73	8-29-63				
6	20	2.22	22.80	8-29-63				
7	40	2.42	22.68	8-29-63				
8	55	2.42	22.82	8-29-63				
9	65	2.42	22.82	8-29-63				
10	70	1.80	22.20	8-29-63				
11	70	1.78	22.22	8-29-63				
12	80	2.70	23.25	8-29-63				
13	80	2.66	23.2	8-29-63				
14	80	2.68	23.25	8-29-63				
15	80	2.49	22.95	8-29-63				
16	80	2.38	22.98	8-29-63				
17	80	2.46	22.88	8-29-63				
18	80	0.00	20.30	9-16-63				
19	80	0.00	20.32	9-16-63				
20	80	0.09	20.53	9-16-63				
21	80	0.03	"	9-16-63				
22	115	-0.46	20.28	9-16-63				
23	115	-0.60	20.24	9-16-63				
24	115	-0.60	20.20	9-16-63				
25	115	-0.53	"	9-16-63				
26	81	0.00	20.45	9-16-63				
27	81	0.00	20.50	9-16-63				
28	81	0.00	20.50	9-16-63				
29	81	0.00	"	9-16-63				
30	55	-0.40	20.20	9-16-63				
31	55	-0.40	20.20	9-16-63				
32	55	-0.00	20.20	9-16-63				
33	81	0.0	20.30	9-16-63				
34	75	0.0	"	9-17-63				
35	115	-0.5	"	9-17-63				

CALCULATED		Transducer S/N: A-2928
RECORDED		Manufactured By: Vendor "C"
DRAWN		
CHECKED		
APPROVED		

AIRESEARCH MANUFACTURING CO.
LOS ANGELES, CALIFORNIA

Date: 9-26-63

TABLE 3

APPENDIX D

DEVELOPMENT AND TEST PROGRAM DUAL PURPOSE MANUAL INFLATOR 538196-2-1

(FC-4472 DATED DECEMBER 16, 1963)

THE GARRETT CORPORATION
AiResearch Manufacturing Division
LOS ANGELES 45, CALIFORNIA

REPORT NO. FC-4472

DEVELOPMENT AND TEST PROGRAM
DUAL PURPOSE MANUAL INFLATOR
538186-2-1

FC-4472 December 16, 1963

NO. OF PAGES 25

DATE December 16, 1963

PREPARED BY J. A. Phillips

EDITED BY J. S. Gould

APPROVED BY J. S. Gould for
S. E. Westman

REVISIONS				ADDITIONS			
PAGE	DATE	PAGE	DATE	PAGE	DATE	PAGE	DATE

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3	PRELIMINARY DUAL PURPOSE MANUAL INFLATORS	3
4	DEVELOPMENT PROGRAM EVALUATION	3
5	SUMMARY AND CONCLUSIONS	4

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APPENDIX

Appendix	
A	Specification Review, Blood Pressure Measuring System 54803, Project Gemini

DEVELOPMENT AND TEST PROGRAM
DUAL PURPOSE MANUAL INFLATOR
538186-2-1

1. INTRODUCTION

In this report the work on the Development and Test Program for the AiResearch Dual Purpose Manual Inflator for Project Gemini is presented. This work is in compliance to requirements of Change Notice No. 1, Contract No. NAS9-1189, Contractor Reference Number HQFGD-0728-0708, dated October 15, 1963 (amendment to "Statement of Work for a Blood Pressure Measuring System for Project Gemini").

2. COMPONENT EVALUATION

2.1 The component evaluation covered the three major components, the squeeze bulb and the two check valves (one each for the vacuum inlet and pressure outlet of the Dual Purpose Manual Inflator).

2.2 A thorough search of the industry was made to locate and obtain samples of various available squeeze bulbs. Six different bulbs were obtained and tested for vacuum capability. The results are shown in Table I. Bulb B is the present one being supplied as part of the Manual Inflator for the Project Gemini Blood Pressure Measuring System 54803. Although the pressure produced by this bulb is satisfactory, the vacuum capability was inadequate. Only two bulbs, D and F, produced the required 60 inches of water vacuum. Bulb F was found to be made of a toxic material, polyvinyl chloride. Therefore bulb D, made by Davol Rubber Company as number 1704, was the only bulb capable and suitable for producing the required vacuum and pressure. It should be noted that these values of vacuum are maximum values as the measurements were made with a manometer of low load volume and the bulbs were exhausted to their fullest extent.

2.2.1 Upon contacting the Gemini Environmental Control System Group, the water tank was found to have a 16 lb capacity. The equivalent volume of 443 cu in. was used as a load volume for use in testing the selected bulb, D to determine the number of squeezes of the bulb for satisfactory

operation at sea level. Note that the total volume of the water tank was used as a load. The number of squeezes was found to be from 14 to 16 to produce 36 in. of water vacuum and 10 to 11 to produce 36 in. of water pressure.

2.3 Two air control valve designs were evaluated for use on the pressure outlet of the Dual Purpose Manual Inflator. Two check valve designs were also evaluated for the vacuum inlet to the unit.

2.3.1 The two air control valve designs for the pressure outlet contained air flow check features that utilized a ball and rubber seat in one design (hereafter called Design A) and a flexible rubber diaphragm and fixed seat in the second design (hereafter called Design B). Design B contained an undesirable feature. The valve was tested for 300 millimeters of mercury pressure differential across the check valve. After the pressure differential was removed a cracking pressure in excess of 120 millimeters of mercury was required to unseat the flexible diaphragm. Design A air control valve, which is being used on the Manual Inflator 538186-1-1, was tested and found to function satisfactorily for the required maximum pressure conditions.

2.3.2 A ball and metal seat check valve (hereafter called Design C) and the check valve feature of Design B were evaluated for use on the vacuum inlet of the Dual Purpose Manual Inflator. When the squeeze bulb was attached to Design B air control valve, the time duration was too long for the bulb to return to a fully inflated condition after having been squeezed and released. The valve was modified to reduce the time for reinflation of the squeeze bulb, however this caused the flexible rubber diaphragm to become lodged on the fixed seat when 60 in. of water vacuum differential was applied across the valve. Design C was tested and functioned satisfactorily under the required vacuum conditions.

2.3.3 Since the ball of the valve in Design A was not spring loaded against the valve seat this could possibly allow some leakage. Several valves were tested for leakage as shown in Figure 1. After the pressure

reached 300 millimeters of mercury the valve V) was closed off. This allowed the air to bleed down through the fixed bleed orifice only, as this effectively removed the check valve feature. The squeeze bulb was attached to point A and the same test above was repeated. After the pressure had been applied this allowed the inlet side of the check valve to be vented to room ambient pressure. The bleed down time from 230 millimeters of mercury to 70 millimeters of mercury was measured on the recorder for the two cases stated above. The bleed times in both cases were almost identical which indicated that the leakage through the ball and seat check feature of the air control valve is negligible.

3. PRELIMINARY DUAL PURPOSE MANUAL INFLATORS

3.1 Six Preliminary Dual Purpose Manual Inflators were fabricated as shown in Figure II. These units were supplied in compliance with Paragraph 2.3(a) of Change Notice No. 1.

3.2 The assembled preliminary units were tested under simulated operating conditions to determine the vacuum and pressure produced.

3.2.1 The test setup for the vacuum test is shown in Figure III(a). The test results are shown in Table II.

3.2.2 The test setup for the pressure test is shown in Figure III(b). The test results are shown in Table II.

3.3 After completing the above pressure and vacuum testing the six Preliminary Dual Purpose Manual Inflators, P/N 538186-2-1 were shipped to NASA-Houston.

4. DEVELOPMENT PROGRAM EVALUATION

4.1 In an attempt to establish a realistic test evaluation program for the final design of the Dual Purpose Manual Inflator, a coordination meeting was held. Represented were NASA; AiResearch, Project Gemini, Environmental Control System Group; and AiResearch, Project Gemini, Blood Pressure Measuring System Group. The results and conclusions of

the meeting were reported in "Specification Review, Blood Pressure Measuring System 54803, Project Gemini" AiResearch Report FC-4465-MR dated November 20, 1963. A copy of this report is included as Appendix A for reference purposes.

4.2 The test program for evaluation of the final design is as specified in Paragraph 2.3(d) of FC-4465-MR. Pressure and vacuum testing were performed at both sea level and at a simulated altitude of 27,000 ft.

4.2.1 With the test setup as in Figure I of FC-4465-MR, testing at sea level of vacuum capability, Paragraph 2.3(d).1., and pressure capability, Paragraph 2.3(d).2 was performed with a Dual Purpose Manual Inflator. The unit was tested in three different attitudes to take into account any effects of the check valves. Figure IV shows the three attitudes for vacuum testing and Figure V shows the three attitudes for pressure testing. The test data for the vacuum and pressure tests at sea level are shown in Tables III and IV respectively.

4.2.2 The test of Paragraph 4.2.1 above was repeated except the surrounding pressure was equivalent to an altitude of 27,000 ft. Photographs 49427-1 and 49427-2 show the test set up in the altitude chamber. The test data for vacuum and pressure testing at 27,000 ft. are presented in Tables V and VI respectively.

5. SUMMARY AND CONCLUSIONS

Taking the horizontal attitude as the most representative of actual operating conditions, it can be seen from the data in Table III that 4 to 5 squeezes of the bulb will produce 36 in. of water vacuum at sea level environment. From Table IV the data reveals that 4 squeezes of the bulb will produce 36 in. of water pressure at sea level. In a 27,000 ft environment, Table V reveals that 20 to 21 squeezes are required to produce 36 in. of water vacuum. Table VI reveals that 12 to 13 squeezes will produce 36 in. of water pressure at 27,000 ft. In general, the Preliminary Dual Purpose Manual Inflator functioned very satisfactorily when tested under simulated operational conditions in

drawing water into the Water Storage Reservoir and pumping water up into the drinking cup. Upon approval of this report by NASA and based on the results herein, control procedures for the final selected devices shall be prepared. These procedures shall include manufacturing drawings and an acceptance test procedure.

TABLE I

BULB CAPABILITY

Bulb Type	Vacuum (In. of Water)
A	36.3
B	37.7
C	52.7
D	62.2
E	52.7
F	101.8

TABLE II

PRELIMINARY MANUAL INFLATOR TEST DATA

Unit S/N	Practical Maximum Vacuum* (In. of water)	Pressure**	
		(In. of water)	(mm Hg.)
1	45.5	> 187.3	> 350
2	46.2	> 187.3	> 350
3	48.3	> 187.3	> 350
4	50.1	> 187.3	> 350
5	48.8	> 187.3	> 350
6	46.7	> 187.3	> 350

*The bulb was pumped until a practical maximum vacuum limit was obtained. This left the bulb in a deflated state and further exhaustion was stopped as this was deemed a practical maximum vacuum limit.

**Since the pressure capabilities far exceeded the required pressure, a test maximum limit of 350 mm Hg. was selected.

TABLE III

SEA LEVEL VACUUM TEST DATA

Run Number	Vertical 1*	Unit Attitude Vertical 2*	Horiz 3*	Number** of Squeezes	Vacuum (In. of Water)
1	X			4-5	36
2	X			4-5	36
3	X			4-5	36
4		X		4-5	36
5		X		4-5	36
6		X		4-5	36.5
7			X	4-5	36
8			X	4-5	36
9			X	4-5	36

Notes:

* Refer to Figure IV.

**On all runs, 36 In. of water was obtained between the 4th and 5th squeeze.

TABLE IV

SEA LEVEL PRESSURE TEST DATA

Run Number	Unit Attitude			Number of Squeezes	Pressure (In. of Water)	Water In Cup (cu cm)
	Vertical 1*	Vertical	Horiz. 3*			
1			X	4	36	33
2			X	4	36	28
3			X	4	36	25
4			X	4	36	27
5	X			4	36	53
6	X			4	36	60
7	X			4	36	60
8		X		4	36	60
9		X		4	36	48
10		X		4	36.5	30
11	X			4	40	76
12	X			5	45	110
13	X			6	50	165
14		X		4	36	58
15		X		5	42	65
16		X		6	46	128
17			X	4	36	45
18			X	5	44	88
19			X	6	50	175

Note:

*Refer to Figure V

TABLE V

VACUUM TEST DATA AT 27,000 FT

Number	Unit Attitude			Number of Squeezes	Vacuum (In. of Water)	Water Into Tank (cu cm)
	Vertical 1*	Vertical 2*	Horiz. 3*			
1	X			17	37.5	-
2	X			16-17	38.0	-
3	X			17	37.5	-
4		X		21	38.0	-
5		X		22	37.7	-
6		X		22	38.0	-
7			X	21	37.5	-
8			X	20	37.7	-
9			X	21	38.0	-
10			X	0	0	-
11			X	18	37.0	-
12			X	23	40.75	82.3
13			X	28	43.5	233.9
14			X	33	44.75	421.6

*Refer to Figure IV

Note:

1. There was no noticable change in the effort required to pump the squeeze bulb at 27,000 ft. compared to sea level effort.

2. For a cross-check of the above data, the bulb was pumped at a rapid rate in the horizontal attitude at 27,000 ft. On the 20th squeeze water was drawn into the tank just as in the above data.



TABLE VI

PRESSURE TEST DATA AT 27,000 FT.

Run Number	Unit Attitude			Number of Squeezes	Pressure (In. of Water)		Water In Cup (cu cm)	Comments
	Vert. 1*	Vert. 2*	Horiz. 3*		(a)	(b)		
1		X		12	-	27	-	
2		X		13	33	28	-	
3		X		13	33.5	28.5	-	
4	X			12	34.5	28.8	-	
5	X			11	36	28	-	
6	X			12	34.5	28.5	-	
7			X	13	34	28.5	-	
8			X	12	36	28	-	
9			X	12	34.5	28.3	-	
10		X		11	-	-	0	
11		X		12	-	-	0	
12		X		13	34	27	54	
13		X		1	-	-	34	Water level was at the top of the tube to the drinking cup before squeeze.
14		X		1	-	28	37	Same as step 13.
15		X		5	-	-	194	Water level was at the top of the tube to the drinking cup before starting squeezes.
16	X			5	-	-	260	Same as step 15.
17			X	5	-	-	205	Same as step 15.

*Refer to Figure V.

Notes:
(a) Pressure at start of water flow into drinking cup.
(b) Pressure after water stopped flowing into drinking cup.

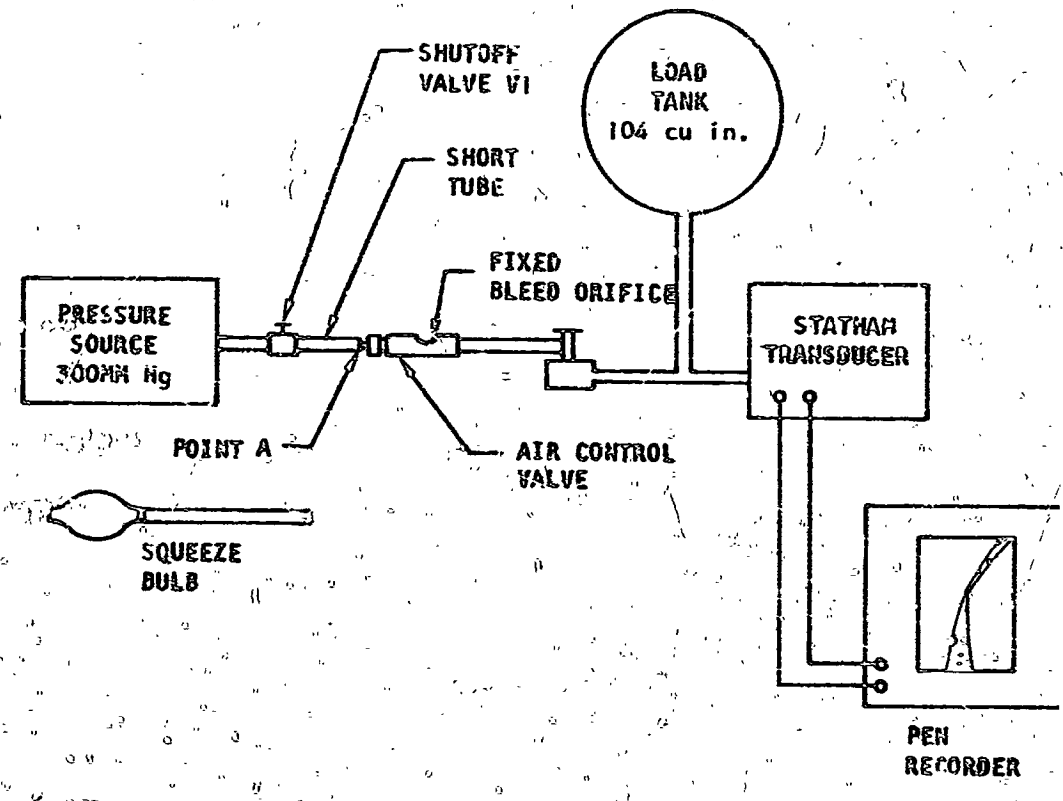
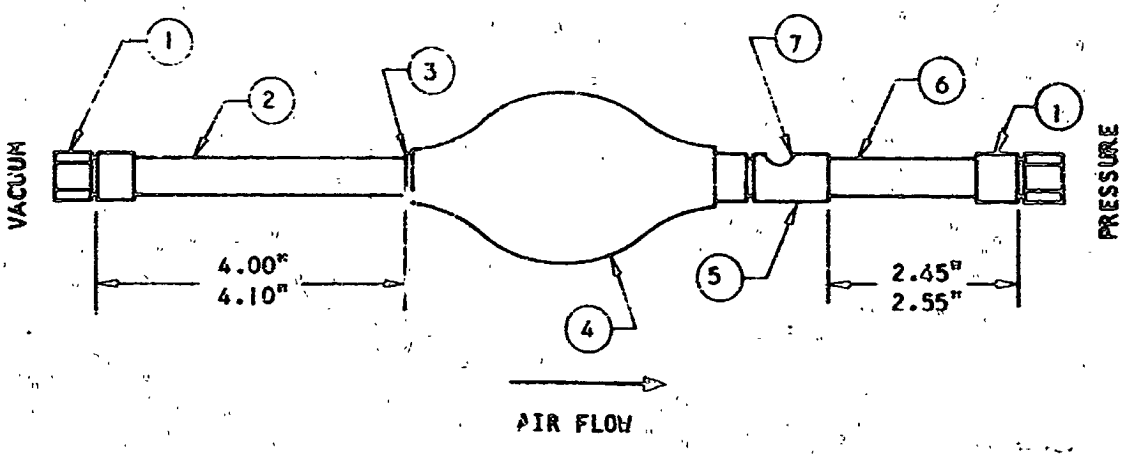
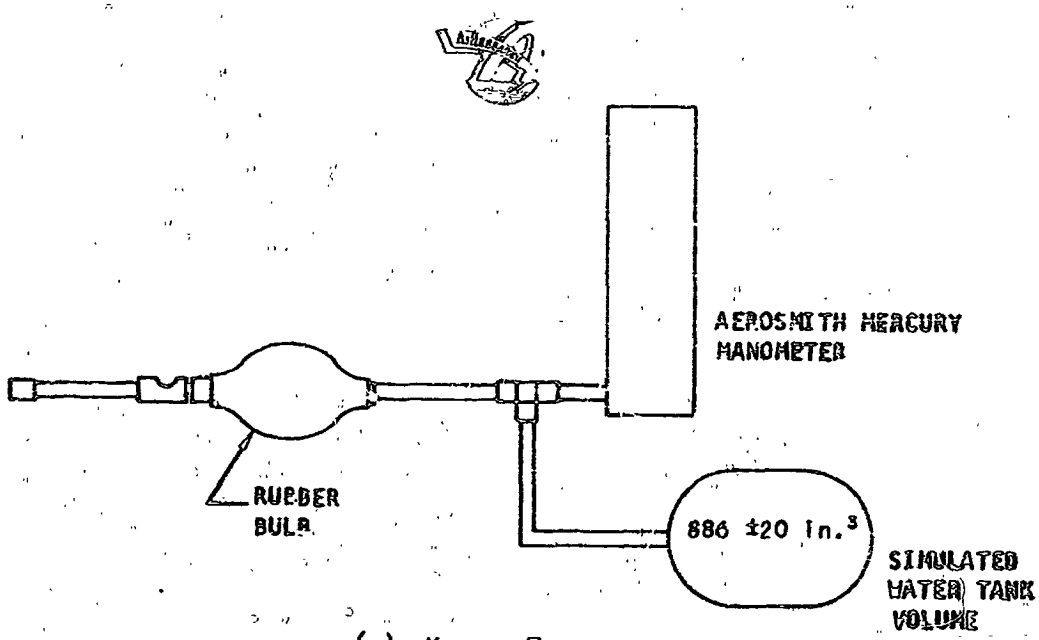


Figure 1. Air Control Valve Leakage Test

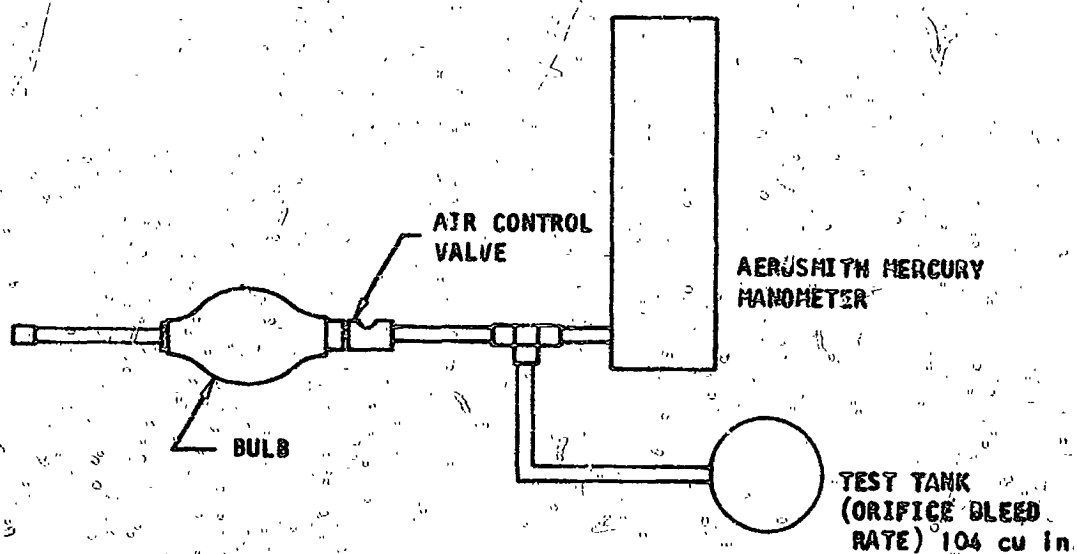


Item No.	Part No.	
7	514575-7	Bleed Orifice
6	-5	3/16" I.D.x 1/8" Wall Thick x 2.60 lg. Rubber Hose
5	1983	Valve, Air Control
4		Rubber Bulb (Davol No. 1704)
3		Check Valve
2	-3	3/16" I.D. x 1/3 Wall Thick x 4.30 lg. Rubber Hose
1	AN773-4D	Hose Fitting - Clear Alum. Anodized

Figure 2. Preliminary Dual Purpose Manual Inflator

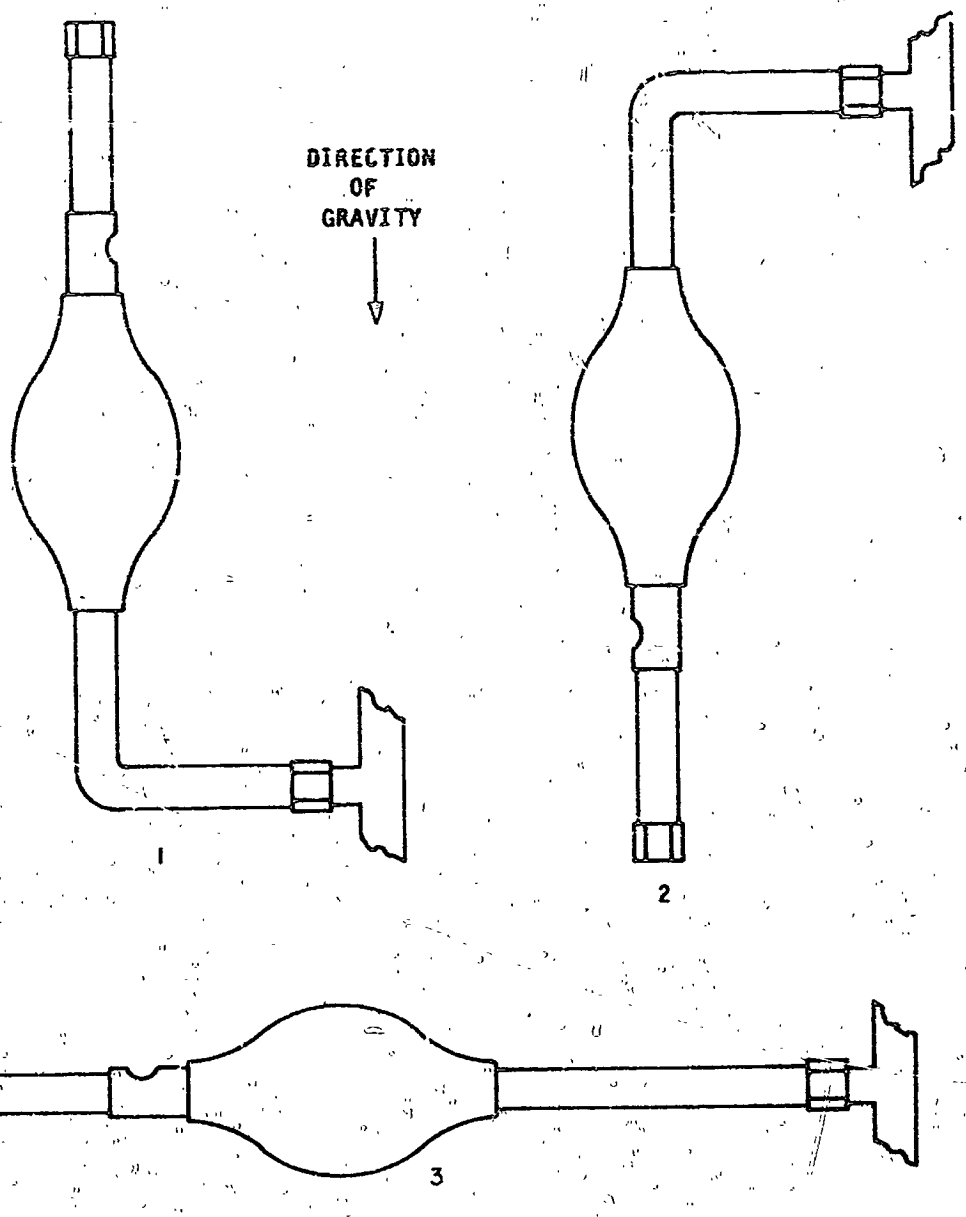


(a) Vacuum Test



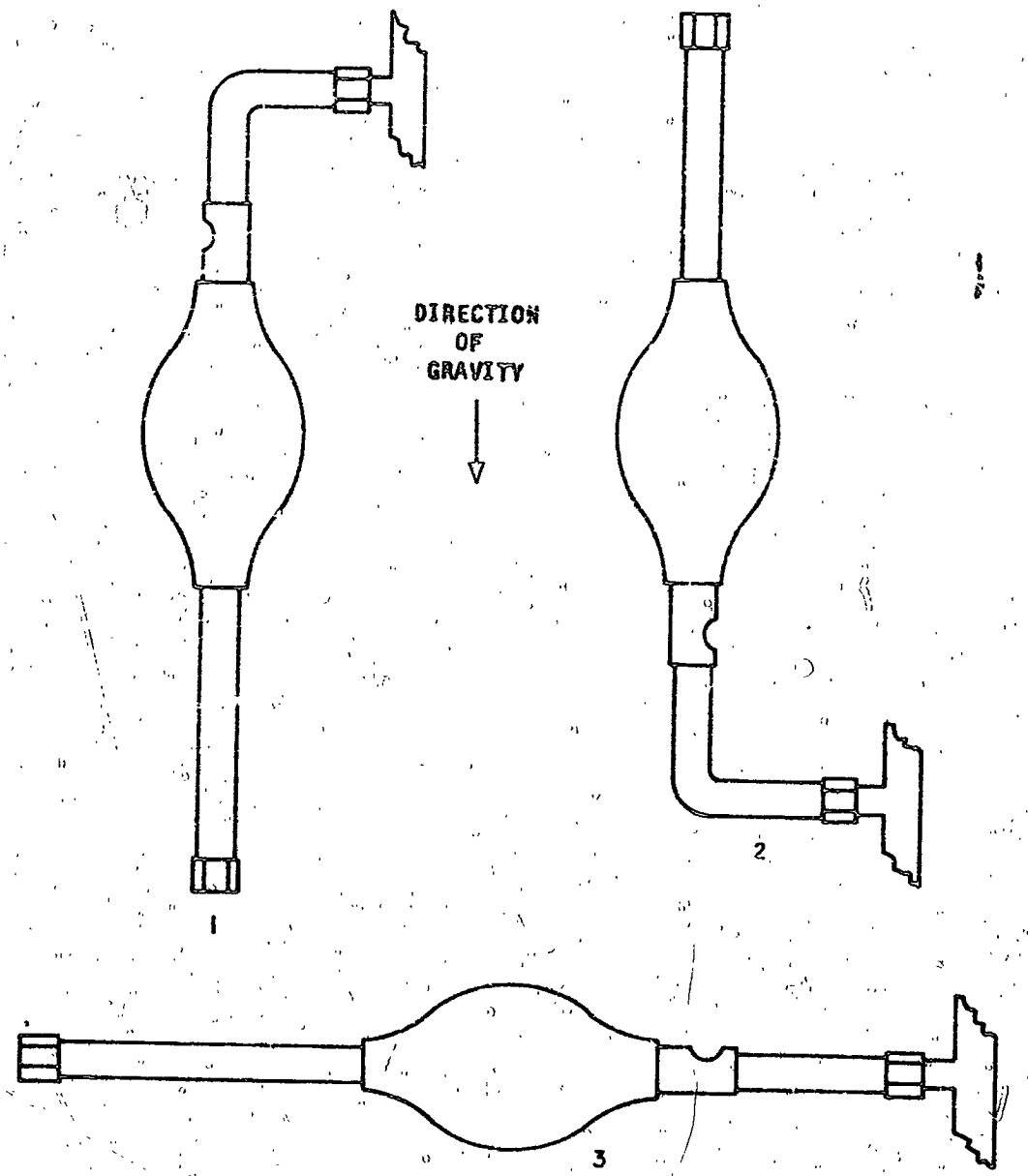
(b) Pressure Test

Figure 3. - Preliminary Dual Purpose Manual Inflator Test Setup



NOTE: In view 1 the ball in the check valves is resting against the valve seat.

Figure 4. Bulb Attitudes for Vacuum Test



NOTE: In view 1 the ball in the check valves is resting against the valve seat.

Figure 5. Bulb Attitudes for Pressure Test

APPENDIX A

Specification Review
Blood Pressure Measuring System 54803
Project Gemini
(FC-4465-MR)

SPECIFICATION REVIEW
BLOOD PRESSURE MEASURING
SYSTEM 54803
PROJECT GEMINI

PC-4465-M DATE: November 20, 1963

Comments on Change Notice Number 1, Contract Number NAS 9-1109, Contractor Reference Number HOFGD-0728-0708, dated October 15, 1963 are contained herein.

In a co-ordination meeting between the AiResearch Blood Pressure Measuring System Group and the Environmental Control Systems Group for Project Gemini, the compatibility of the Dual Purpose Manual Inflator 538186-2-1 with the Environmental Control System was discussed. Present at the meeting on November 13, 1963 were Robert Frost of NASA; Dick Nelson and Joe Gilleman of Project Gemini Environmental Control System; Syd Westman, Jim Gould and Jerry Phillips of the Project Gemini Blood Pressure Measuring System. As a result of the discussions, a proposed compatible test program for the Dual Purpose Manual Inflator was formulated and is reflected in the following specification review.

The comments following refer to paragraph numbers of NASA Change Notice Number 1, dated October 15, 1963.

2.5(a) It is requested that the paragraph be changed to read as follows: "In addition to the Manual Inflator supplied with each prototype Blood Pressure Measuring System, the contractor shall supply a quantity of six (6) each Dual Purpose Manual Inflators which are capable of producing 36 inches of water vacuum or pressure. These devices will be used to pressurize and evacuate the on-board water tank as well as inflate the blood pressure cuff."

2.3(b) In the discussion with Robert Frost of NASA it was revealed that the minimum water level likely to be reached in the on-board water tank would be 10 lb of water. It is requested that since the water tank capacity is 16 lb of water that the first sentence shall be replaced with "The contractor shall further evaluate various types of squeeze bulbs and shall perform tests which shall include the requirement of determining the number of squeezes necessary to reach the specified pressure or vacuum at both sea level and at a simulated altitude of 27,000 ft while connected to a load tank of 166 cubic inches, which simulates the air volume of the water tank at the worst expected condition (16 lb minus 10 lb or equivalent volume of 6 lb of water)."

2.3(d) To insure mutual understanding of the test program, it is suggested that this paragraph be added:

"The test set up for checking operational performance of the Dual Purpose Manual Inflator shall be as shown in Figure 1.

1. Vacuum Test

Referring to Figure 1, the vacuum end of the Dual Purpose Manual Inflator shall be connected to point A, valve V1 shall be closed, and valve V2 shall be opened. The squeeze bulb shall be pumped until water is drawn into the Simulated Water Tank. The number of squeezes required and the vacuum produced shall be recorded.

2. Pressure Test

Referring to Figure 1 the pressure end of the Dual Purpose Manual Inflator shall be connected to point A, valve V1 shall be open, and valve V2 shall be closed. There shall be approximately 1 lb of water in the Simulated Water Tank at the start of the test. The squeeze bulb shall be pumped until water begins to flow into the drinking cup. The number of squeezes required and the pressure produced shall be recorded.

B. It is requested that the second paragraph be changed to read "The written report and the prototype Panel Inflators specified in paragraph 2.3(b), (c) and (d) above shall be delivered on or before February 3, 1964."

Jerry Phillips
Jerry Phillips
Flight Data and Electronics Systems

APPROVED BY J. S. Gould
J. S. Gould

APPROVED BY J. E. Hosmon
J. E. Hosmon

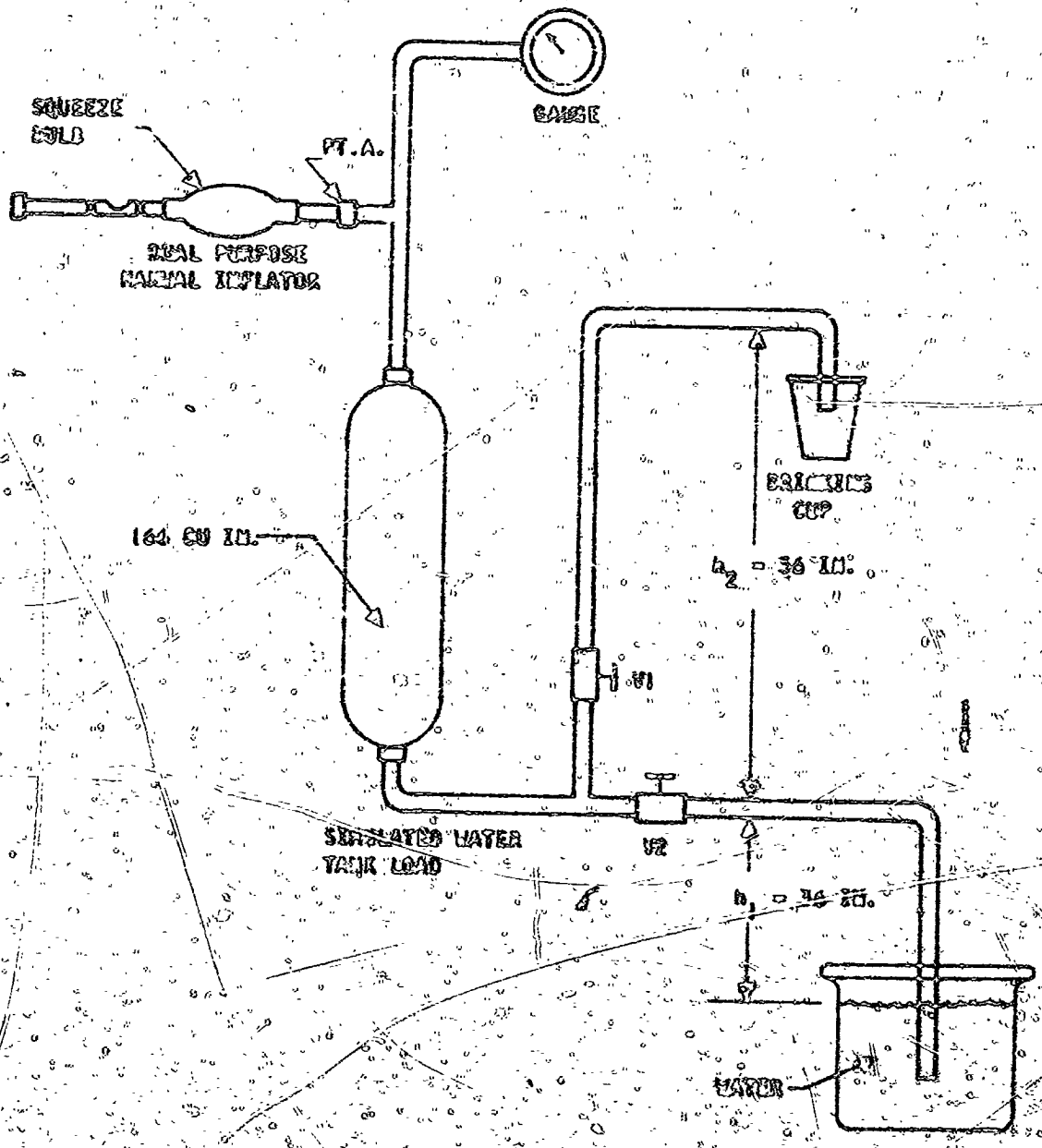


Figure 1. Dual Purpose Manual Inflator Test Setup