

FOREWORD

This project was sponsored by the 6570th Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The design of the console was accomplished by E. E. Beson, Senior Design Engineer, and M. P. Dickey, Project Engineer of Minneapolis-Honeywell Regulator Company, Aeronautical Division, Minneapolis, Minnesota, under Contract AF33(616)8349, Project 6373, "Equipment for Life Support in Aerospace," and Task 637305, "Life Support Accommodations, Integration, and Analysis." Captain William Mickelson of the Sustenance Branch, Life Support Systems Laboratory, 6570th Aerospace Medical Research Laboratories, was contract monitor. Design of the Life Support Systems Evaluator Instrumentation Console was begun in May 1961; the project was completed in February 1962.

This report is designated by Minneapolis-Honeywell Regulator Company, Aeronautical Division as MH Aero Report 2662-TR2.

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ABSTRACT

The Life Support Systems Evaluator Console was built to monitor and record the changes in environmental parameters occurring during the test of men and life systems in an evaluator or space flight test chamber.

The problems involved in furnishing the necessary instrumentation and displays were considered in a preliminary design investigation. The system design which evolved from the preliminary study embodies a four-module steel enclosure or console, with turret top section, work table surface, and rollaway table section, which contains the complete monitor system. The evaluator instrumentation includes sensors, indicators, and recorders which enable the investigators to monitor the following:

- Absolute and differential pressures at six different stations in the test chamber.
- Temperatures at 24 stations within the forward and aft sections of the chamber.
- Relative humidity in forward and aft sections of the test chamber.
- Analyses of chamber atmospheric composition.
- Continuous recording of the variables.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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INTRODUCTION

The Evaluator Instrumentation Console described in this report was designed with the aim of providing a flexible, portable system suitable for use with any typical life support test chamber. Its first use by ASD will be as a monitor of the functions of crew and equipment associated with a simulated 14-day, three-man voyage similar to the Apollo lunar mission. The ASD test chamber is approximately 29 feet long by 7.5 feet in diameter and is divided into two separate compartments. Both compartments are surrounded by walls containing sealed air spaces. The pressure in these wall spaces is maintained slightly lower than the inner compartment pressures so as to prevent ambient air from leaking into the inner compartments.

This report is intended to serve not only as a documentation of the Life Support Systems Evaluator Instrumentation project but also as a guide to the operation and maintenance of the equipment. Therefore, in addition to the system and component descriptions, instrument calibration procedures and methods of operation are outlined.

SYSTEM DESCRIPTION

The Life Support Systems Evaluator Console is an integrated system of instruments, sensors, indicators, and recorders contained in a modular enclosure, designed to monitor the environmental parameters in a life support system test chamber. The console contains the following instrumentation:

- Temperature measurement devices including:
 1. Twenty-four thermistor sensors.
 2. Three temperature indicators operable in low, middle, and high ranges, with a total range of -40 to +250° F.
 3. Twelve three-position switches for switching the output of any sensor to the appropriate meter or recorder for read-out or printout.
 4. A multipoint recorder capable of producing a permanent record of the 24 temperatures sampled in a sequential fashion.

- Pressure measurement instruments including:
 1. Four electromechanical sensors (aneroid - slide-wire type).
 2. Two differential indicators of the aneroid type.
 3. Five absolute indicators, one of which will be used for ambient barometric pressure.
 4. A multipoint recorder for producing a permanent record of pressures sequentially sampled.

- Relative humidity measured for both forward and aft sections of the test chamber by gold grid sensor and displayed by a calibrated microammeter type indicator. Relative humidity for both sections of the test chamber is recorded on a multipoint recorder.

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- Gas analysis equipment including:
 1. An LB-15A infrared analyzer for CO₂ detection.
 2. An F3A3 oxygen analyzer.
 3. A panel containing valves, flow meters, and gages for obtaining a gas sample and indicating partial pressures.
 4. A gas chromatograph and hydrogen flame detector accessory for analysis of other gases.
 5. A chromatograph recorder (Honeywell Brown Instrument Co.) for providing a permanent record of the gas analysis.

- Audio-visual Communications
 1. Two 17-inch television monitors with switching circuitry to permit viewing of the subjects in either the forward or aft section of the test chamber from either or both cameras.
 2. Microphone, speaker, switches, and controls for complete two-way oral communication with either section of the test chamber from the console station.

Figure 1 shows the arrangement and location of the instrumentation.



Figure 1. Life Support Systems Evaluator Console

COMPONENT DESCRIPTION

PRESSURE

Two different types of pressure instruments are used to measure the six different pressures in the evaluator system. An aneroid instrument is used for direct sensing and dial display, and an electromechanical method involving aneroid slide-wire sensor and recorder is used for display and permanent record. Both modes are necessary since the purely mechanical method provides no signal for driving the multipoint recorder.

Operation

The Wallace and Tiernan Model FA-160 Pressure Indicator gives direct pressure indications (in feet altitude and millimeters of mercury) of the absolute pressures in the chamber forward and aft sections and walls surrounding these locations. The model FA-141 differential indicators provide a direct indication of the chamber-to-wall pressure differential in both forward and aft sections. These indicators read pressure differentials in plus and minus values ranging from -50 to +50 inches of water.

In addition to the indicators mentioned, a model FA-160 absolute pressure instrument has been calibrated to read the ambient barometric pressure in millimeters of mercury.

All the Wallace and Tiernan instruments displaying pressures sensed at the chamber are connected directly to the chamber by 1/4-inch copper tubing.

The signal for the multipoint recorder which produces a permanent record of these pressures is supplied by absolute and differential transducers manufactured by the H. E. Sostman Company of Cranford, New Jersey.* The evaluator console contains six of these transducers connected in parallel with the Wallace and Tiernan indicators. The aneroid slide-wire element working in conjunction with the power supply provides a signal from 0 to 10 millivolts to drive the Honeywell Brown Electronik recorder.

Calibration

Calibration of the Wallace and Tiernan indicators should be performed using a Hass Cistern Manometer or equivalent. Figure 2 shows a scheme for gage calibration using the Hass Manometer, a control station consisting of vacuum pump and needle valves, and a bellows for fine pressure control. With the setup shown, various pressures are imposed upon the indicator, and a comparison of indicated and manometer measured values is made. If errors determined by this method exceed the acceptable limits, the indicators should be returned to the manufacturer for recalibration. Wallace and Tiernan describe** the proper method for zero adjustment.

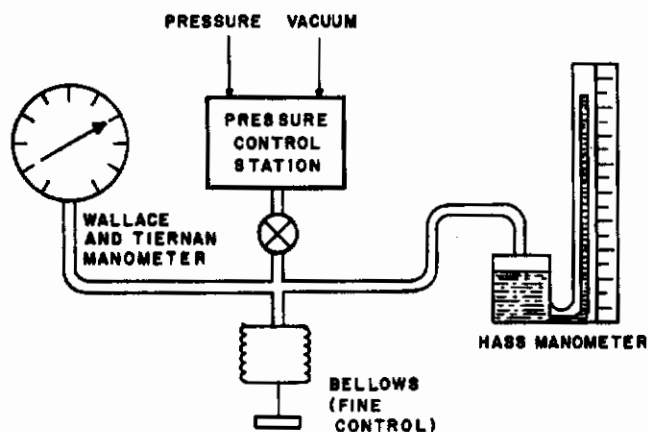


Figure 2. Manometer and Gage Test

*See H. E. Sostman and Company General Specification No. IP-2010 for additional information on the Sostman Pressure Transducers.

**"Instructions for Installation, Operation and Maintenance of Wallace and Tiernan Indicators", Books No. F1A-160-3a and No. F1A-141-1-26.

Figure 3 shows the calibration setup that may be used to check the Sostman transducers. With the apparatus shown, the output of the slide-wire transducer may be measured as a function of pressure changes induced by the control station and bellows.

Using the arrangement shown in Figure 4, the Wallace and Tiernan indicators may be utilized to prove the output of the Sostman transducers and to adjust zero and span on the Honeywell Brown recorder. Evaluation test setups made in accordance with Figures 2, 3, and 4 simulate the actual plumbing and wiring arrangement of the evaluator console and thus are able to prove the calibration of the actual working system.

TEMPERATURE

The evaluator console offers a means of sensing, indicating, and recording temperatures at 24 different stations in the test chamber (evaluator). Two types of Yellow Springs Instrument Company thermistors are used as temperature sensors: the banjo configuration for contact or surface temperature measurement, and the air probe for measurement of temperature in free air. Seventeen of the banjo types and seven of the air-probe types have been furnished. Two jack boxes, one with 12 receptacles and the other with 24, are part of the temperature measurement system supplied. Temperature probes of either type may be plugged into either of these jack boxes to produce indication and recording of temperature at a particular location. All thermistors are matched and may be used interchangeably; that is, each of the thermistors exhibits the same temperature-versus-resistance-change characteristics.

Operation

Temperatures are displayed on three Yellow Springs Instrument Company Telethermometers, each operating in a separate range with its own power

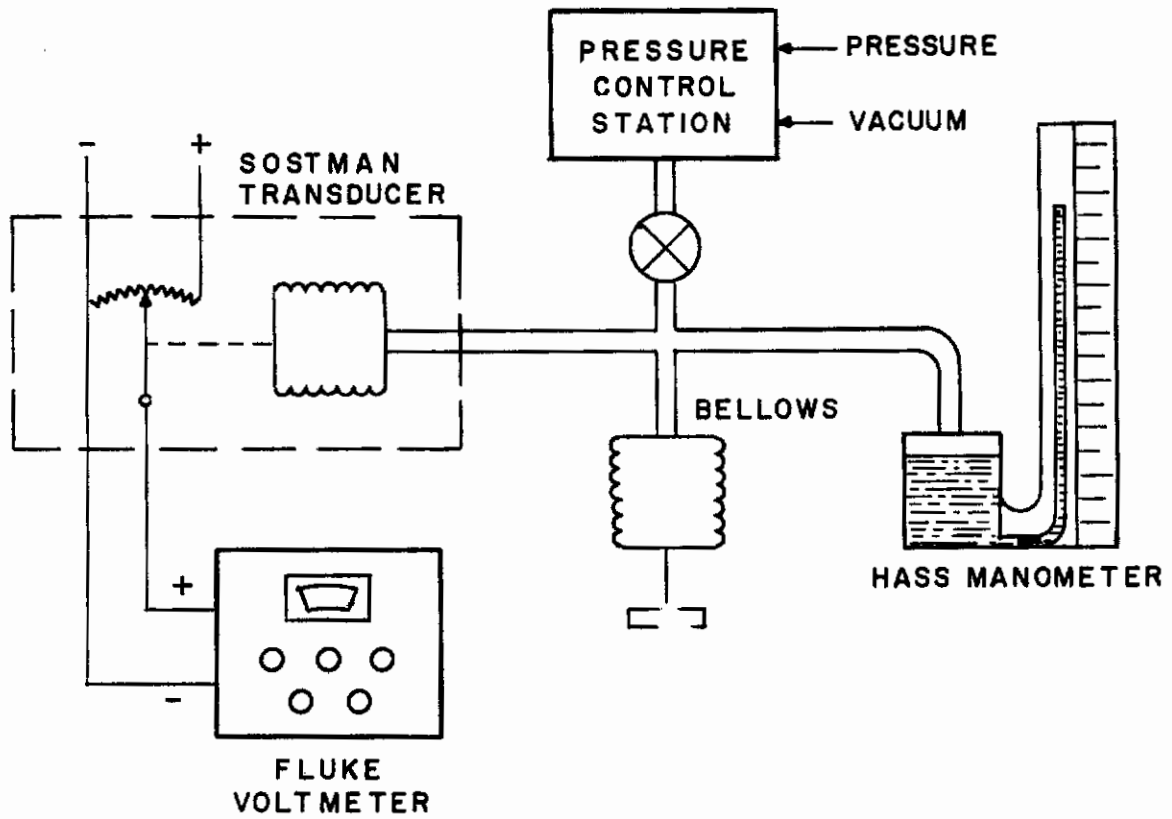


Figure 3. Transducer Test

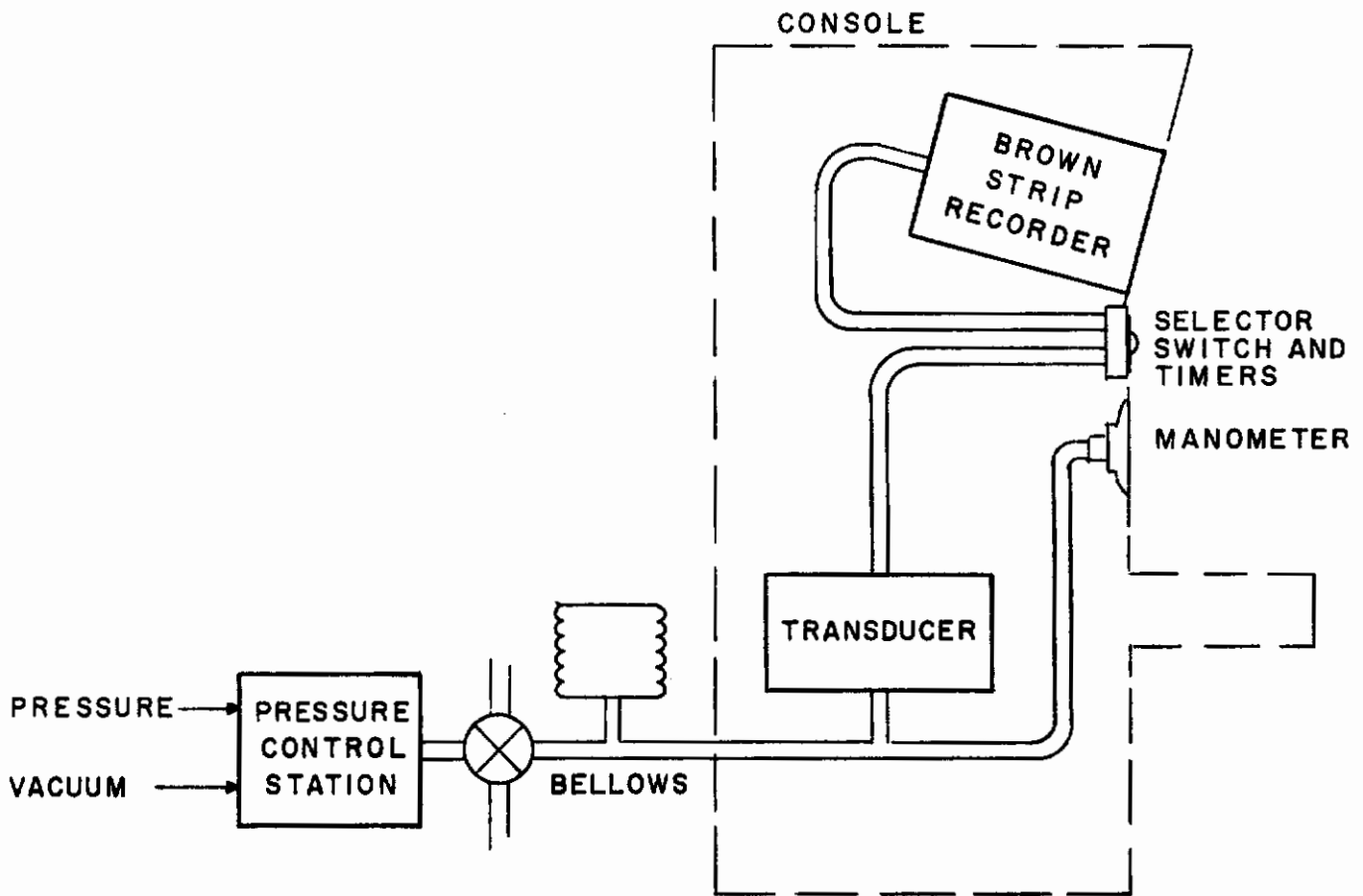


Figure 4. System Test

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supply and matching bridge circuit. A bank of 12 three-position panel-mounted switches is used to switch the output of the sensors to either the recorder or the indicator. Each switch selects a station for each of the UP and DOWN positions and a RECORD position in the center. Both the indicators and the recorders have bridge circuits to match the output of the thermistors which function in the low (-50 to +50° F), middle (40 to 120° F), and high (100 to 250° F) ranges.

The switching circuitry is arranged so that when a station is selected for read-out on any of the three indicators simultaneously with the printout on the multi-point recorder, the recorder will not print a proper value for the station selected for indication. This interaction is the effect of indicator and recorder bridge mismatches and is only of concern when a temperature station is selected for indication at the exact moment the print wheel of the recorder is passing the same numbered station. When the station selector switch is repositioned to the center or neutral position, the thermistor output will be routed to the recorder and sequentially sampled with all other stations selected for RECORD.

The three Yellow Springs indicators are calibrated in degeees Fahrenheit and degrees centigrade.

Calibration

Honeywell Evaluation has proved the accuracy of the Yellow Springs indicators and thermistors. The test setup shown in Figure 5 provides a method for calibrating the Telethermometers (indicators) by using a regulated temperature sensor and indicator (thermocouple and indicating potentiometer), and thermistor probes. When the test was performed at Honeywell, the thermistors were immersed in a fluid heat sink (synthetic oil, MIL-L-7808) for high temperature and in Ponsolve for low temperatures to eliminate rapid temperature fluctuations. The thermistors with air probes were placed in test tubes as shown in Figure 5.

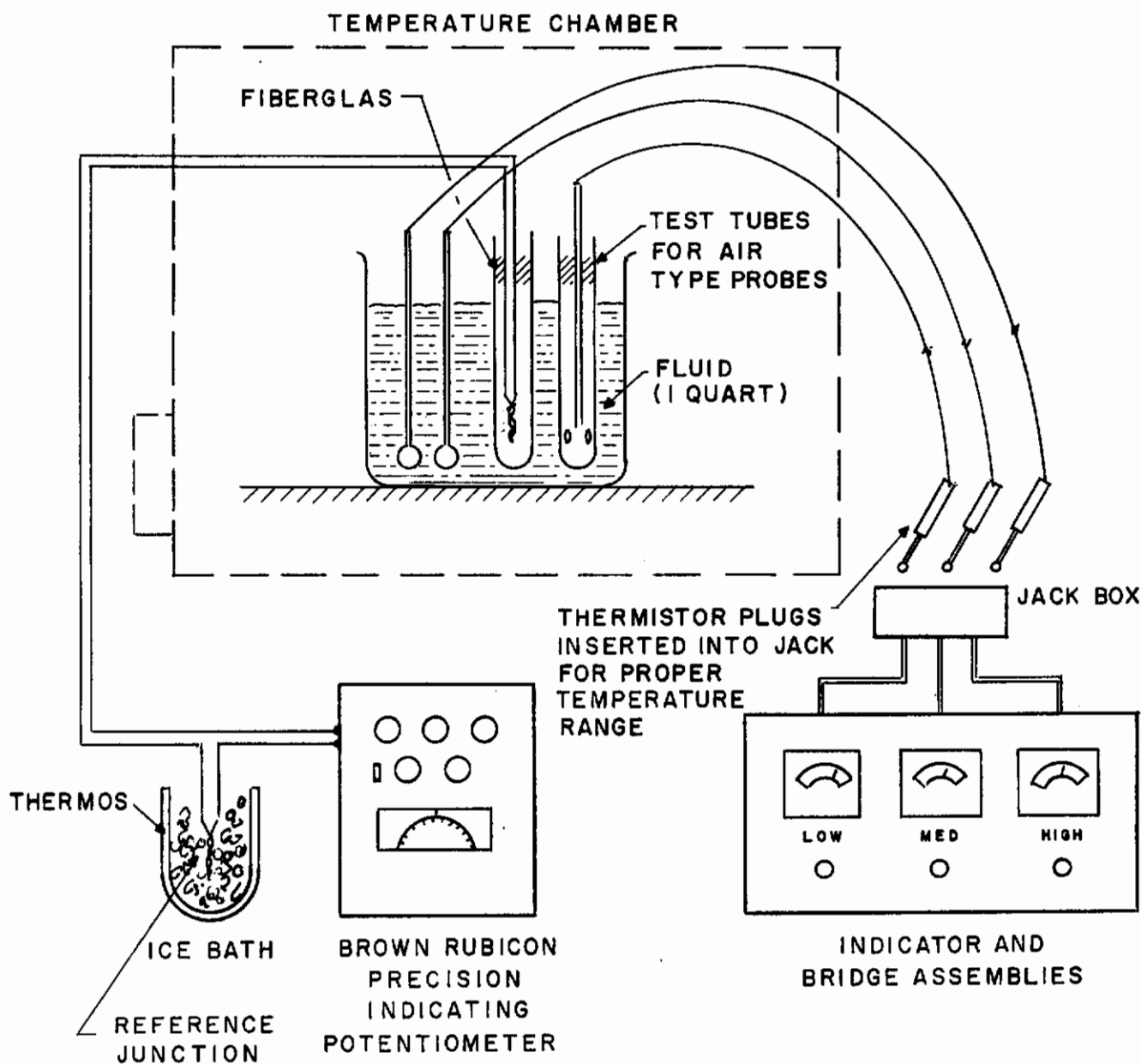


Figure 5. Thermistor Test Setup

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In addition to the test described above, instrument calibration at the low and high ends of temperature indication may be made by applying proper resistance corresponding to temperatures indicated in Table 1.

Table 1. Instrument Calibration Check

| Indicator Reading (° C)* | Resistance Setting (ohms) |
|-----------------------------|------------------------------|
| -45 | 110,000 |
| 0 | 7,336 |
| 10 | 4,477 |
| 40 | 1,200 |
| 50 | 80.9 |
| 120 | 80.71 |

*The indicator shall read within $\pm 1^\circ \text{C}$ of these values.

Instrument linearity (in 10°C increments) may be checked by applying the resistance shown in Table 2. Indicator readings shall be within $\pm 1^\circ \text{C}$ of the temperatures corresponding to these resistances.

Table 2. Instrument Linearity Check

| Indicator Reading (° C) | Resistance (ohms) |
|----------------------------|----------------------|
| -40 | 78,000 |
| -30 | 40,674 |
| -20 | 22,172 |
| -10 | 12,586 |
| 0 | 7,336 |
| 10 | 4,477 |
| 20 | 2,806 |
| 30 | 1,812 |
| 40 | 1,200 |
| 50 | 809 |
| 60 | 560 |
| 70 | 396 |
| 80 | 285.5 |
| 90 | 208.6 |
| 100 | 155.4 |
| 110 | 116.28 |
| 120 | 88.71 |

Procedure

Following is a detailed procedure for checking the calibration of each telethermometer operating in low, medium, and high ranges:

Low Range

1. Power off - set mechanical adjustment to 10° C.
2. Connect resistor decade (5 dial, 10K steps max) to pins A-B of connector J31 (aft sensors - top).
3. Set decade to 4477 ohms.
4. Turn on power switch and set station selector switch in No. 1 position. (All others must be centered.)
5. Adjust R_1 for 10° C on indicator.
6. Set decade to 52,200 ohms.
7. Adjust R_3 for -34° C (red line).
8. Recheck steps 3 through 7.
9. Energize test switch on back of panel.
10. Adjust R_2 to -34° C (red line).
11. R_2 should not need periodic resetting.
12. Before each use, check red line setting and adjust R_3 if necessary.

NOTE: Indicators will not be damaged by hardover deflection when connectors are removed.

Tap indicators lightly when making mechanical and electrical adjustments which follow.

Medium Range

1. Power off - set mechanical adjust to 50° C.
2. Connect resistor decade to pins N-P of connector J31 (aft sensors - top).
3. Set decade to 809 ohms.
4. Turn on power and set station selector switch in No. 9 position. (All others must be centered.)
5. Adjust R_1 for 50° C on indicator.
6. Set decade to 5741 ohms.
7. Adjust R_3 for 5° C (red line).
8. Recheck steps 3 through 7.
9. Energize test switch on back panel.
10. Adjust R_2 to 5° C (red line).
11. R_2 should not need periodic resetting.
12. Before each use, check red line setting and adjust R_3 if necessary.

High Range

1. Power off - set mechanical zero to 120° C.
2. Connect decade resistor to pins E and F of connector J30 (aft sensors - bottom).
3. Set decade to 88.71 ohms.

4. Turn on power switch and set station selector switch in No. 17 position. (All others must be centered.)
5. Adjust R_1 for 120° C on indicator.
6. Set decade to 696 ohms.
7. Adjust R_3 for 54° C (red line).
8. Recheck steps 3 through 7.
9. Energize test switch on back of panel.
10. Adjust R_2 to 54° C (red line).
11. R_2 should not need periodic resetting.
12. Before each use, check red line setting and adjust R_3 if necessary.

The following is a detailed procedure for setting the temperature recorder. The settings, deflections, and temperatures for each range are summarized in Table 3.

Low Range

1. Connect decade resistor (5 dial, 10K steps maximum) to pins A-B of connector J31 (aft sensors - top).
2. Set decade resistor to 11,800 ohms, printout selector to No. 1 position, and station selector switches to NEUTRAL position.
3. Adjust ZERO 11 for 90 per cent recorder deflection.
4. Set decade to 70,800 ohms.

5. Adjust SPAN 1 for 10 per cent deflection.
6. Alternately adjust ZERO 11 to 100 per cent with 4477 ohms and adjust SPAN 1 to 0 per cent with 78,000 ohms until both ends agree simultaneously.

Medium Range

7. Connect decade resistor to pins N-P in J31 (aft sensors - top).
8. Set decade to 1360 ohms and printout selector to 9.
9. Adjust ZERO 12 to 90 per cent deflection.
10. Set decade to 5230 ohms.
11. Adjust SPAN 2 to 10 per cent deflection.
12. Alternately adjust ZERO 12 to 100 per cent with 875.5 ohms and adjust SPAN 2 to 0 per cent with 5741 ohms.

High Range

13. Connect resistor decade to pins E-F in J30 (aft sensors - bottom).
14. Set decade to 200 ohms and printout selector to 17.
15. Adjust ZERO 13 to 90 per cent recorder deflection.
16. Set decade to 1170 ohms.
17. Adjust SPAN 3 to 10 per cent deflection.
18. Alternately adjust ZERO 13 to 100 per cent with 88.7 ohms and adjust SPAN 3 to 0 per cent with 1303 ohms.

Table 3. Data for Setting Temperature Recorder

| Range | Recorder Deflection (per cent) | Temperature (°C) | Resistance (ohms) |
|--------|--------------------------------|------------------|-------------------|
| High | 100 | 120 | 88.7 |
| | 90 | | 200 |
| | 10 | 38 | 1,170 |
| | 0 | | 1,303 |
| Medium | 100 | 48 | 875.5 |
| | 90 | | 1,360 |
| | 10 | 5 | 5,230 |
| | 0 | | 5,741 |
| Low | 100 | 10 | 4,477 |
| | 90 | | 11,800 |
| | 10 | -40 | 70,800 |
| | 0 | | 78,000 |

RELATIVE HUMIDITY MEASUREMENT

The evaluator console has two panel-mounted humidity indicators, one each for the fore and aft sections of the test chamber. Each indicator operates with its own Honeywell gold grid humidity sensor. Separate sensors are also provided for the fore and aft sections to drive the Honeywell recorder, which provides a permanent record of these humidities. The complete humidity subsystem consists of a temperature-compensated humidity sensor, bridge circuit, and remotely located power supply. The combined functions of this subsystem provide a d-c signal proportional to humidity.

The gold grid humidity element consists of deposited gold paths coated with hygroscopic material, the electrical resistance of which is a direct function of humidity (see Figure 6). To obtain a wide linear range of humidity coverage and to compensate for temperature variations, the gold grid elements are combined with resistors and a temperature-sensing bulb in a series-parallel combination to form the composite sensor.

Operation

The operating range of the system is from 5 to 95 per cent relative humidity at temperatures from 40° F to 120° F. Precautions must be taken if the system is operated above 120° F. When temperatures exceed 140° F, electrical characteristics will change and the useful life of the sensor will be shortened.

Calibration

Factory calibration of the composite sensor will lie within ± 1.3 per cent relative humidity at the nominal temperature of 70° F. Since the humidity sensors will tend to become less accurate with age, it will be necessary to check periodically for this possible change. It is advisable each month

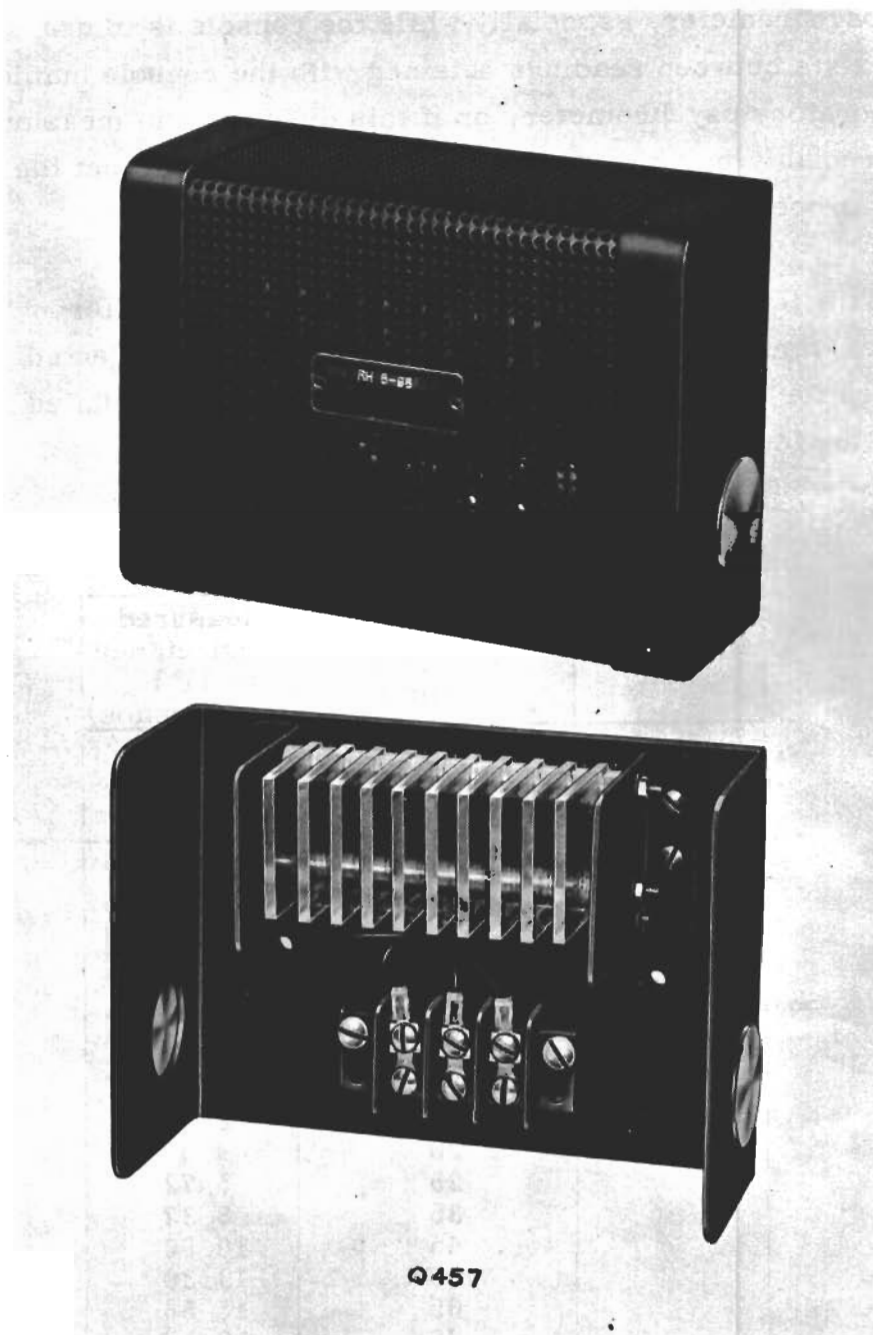


Figure 6. Humidity Indicators

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to compare the humidity readings obtained with the sensor-indicator and sensor-recorder combinations to the humidities measured with a sling or aspirated psychrometer, especially while the console is in use. If a great disparity exists between readings obtained with the console humidity devices and the laboratory psychrometer, or if this difference in measured values varies appreciably in a short period, it may be assumed that the sensor is not functioning properly.

Each sensor will have a value of conductance (probably different from any other sensor) for each relative humidity to which it is subjected. These conductances for humidities from 10 to 85 per cent are tabulated in Table 4 for each of the four composite sensors.

Table 4. Conductances versus Relative Humidity for Four Composite Sensors

| Composite Sensor | Actual Per Cent Relative Humidity | Measured Conductance at 77° F (micromhos) |
|------------------|-----------------------------------|---|
| 1384* | 10 | 2.10 |
| | 15 | 3.26 |
| | 20 | 4.50 |
| | 25 | 5.82 |
| | 35 | 8.39 |
| | 45 | 10.90 |
| | 55 | 13.15 |
| | 65 | 15.45 |
| | 75 | 18.05 |
| 85 | 20.60 | |
| 1385** | 10 | 2.10 |
| | 15 | 3.26 |
| | 20 | 4.53 |
| | 25 | 5.72 |
| | 35 | 8.37 |
| | 45 | 10.90 |
| | 55 | 13.30 |
| | 65 | 15.58 |
| | 75 | 18.17 |
| 85 | 20.70 | |

* This sensor used with panel indicator.

** This sensor used with multipoint recorder.

Table 4. (Cont)

| Composite Sensor | Actual Per Cent Relative Humidity | Measured Conductance at 77° F (micromhos) |
|------------------|-----------------------------------|---|
| 1386** | 10 | 2.10 |
| | 15 | 3.26 |
| | 20 | 4.45 |
| | 25 | 5.70 |
| | 35 | 8.36 |
| | 45 | 10.95 |
| | 55 | 13.27 |
| | 65 | 15.63 |
| | 75 | 18.08 |
| 85 | 20.43 | |
| 1387* | 10 | 2.10 |
| | 15 | 3.28 |
| | 20 | 4.57 |
| | 25 | 5.70 |
| | 35 | 8.36 |
| | 45 | 10.83 |
| | 55 | 13.27 |
| | 65 | 15.54 |
| | 75 | 18.05 |
| 85 | 20.60 | |

* This sensor used with panel indicator.

** This sensor used with multipoint recorder.

For the following discussion of calibration checks, refer to Table 4 and Figure 7.

Recorder and Bridge Calibration Check -- The following test will prove the function of the recorder, which contains its own bridge circuit for matching the two sensors that are used only with the recorder (sensors 1385 and 1386).

1. Connect the decade box and substitute resistance values at the output terminals of the sensor; i. e. , disconnect the wire from the sensor to TB4-1B. Then attach the decade resistor to TB4-1B and TB4-2B. The recorder will respond as though excited by a signal from the sensor.

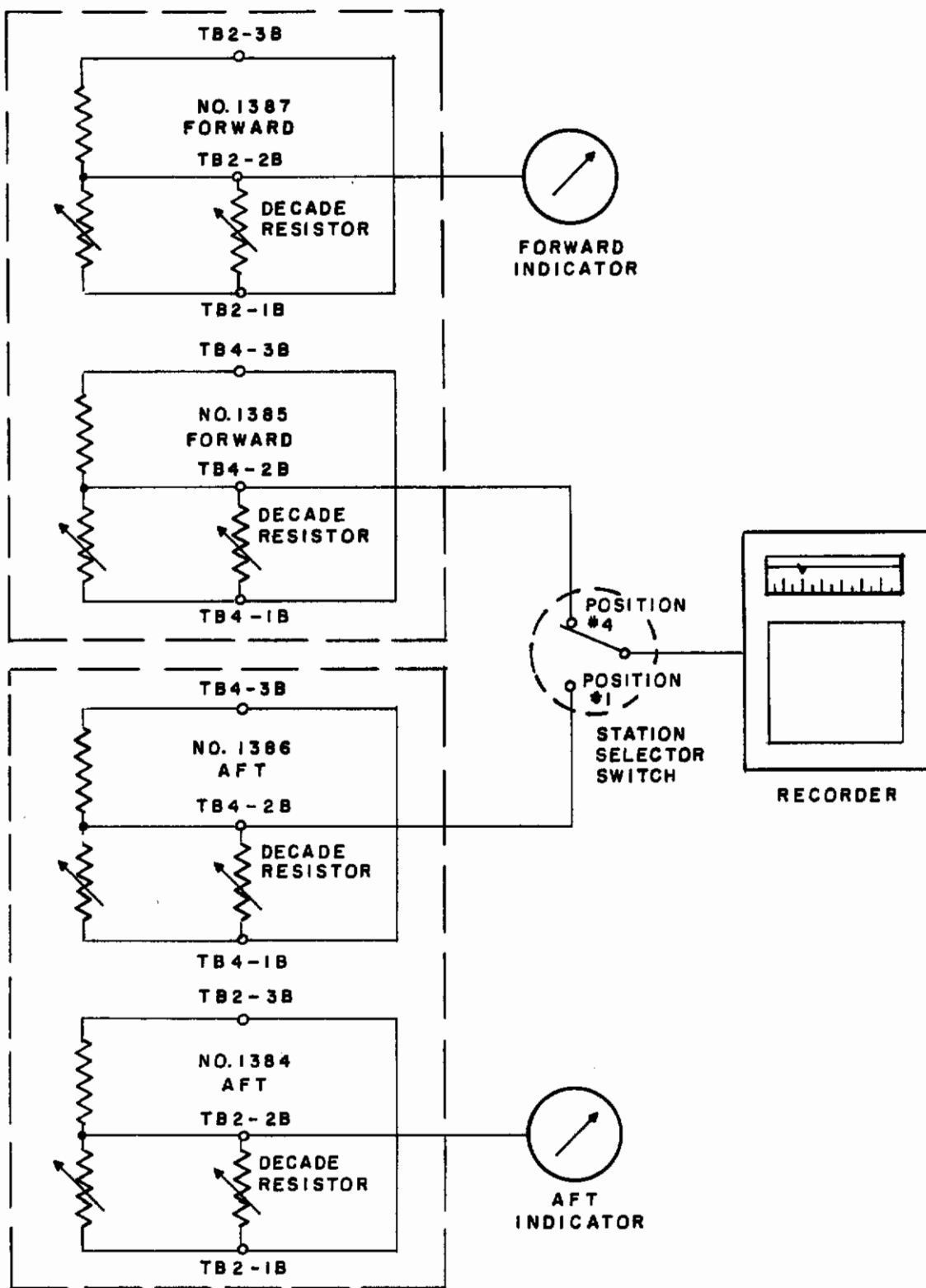


Figure 7. Humidity Circuits (Calibration Arrangement)

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2. Check the recorder response (i. e., scale deflection in per cent relative humidity) as per Table 4 for the appropriate sensor.
3. If the sensor is at 77° F, the voltage measured across points C and E (refer to MH Drawing LO8078) should be 17 volts ac. If voltage varies from this value, adjust R1 to give the correct reading.

The foregoing check will reveal the source of any error in the humidity measurement system. If the composite sensor is not functioning properly, it should be returned to Honeywell for replacement. No attempt should be made to repair it.

Indicator Calibration Check -- The humidity indicator is a Phaostron 100-microammeter which has been calibrated and modified with a characterized dial to indicate humidites from 0 to 100 per cent.

A check of the humidity measurement system should start with the indicator. The following procedure is used:

1. Excite the meters with the microampere inputs shown in Table 5. The meters should indicate the per cent of relative humidity corresponding to these values.

Table 5. Inputs versus Relative Humidity for Indicators 1387 and 1384

| Indicator No. | Microampere Input | Per Cent* Relative Humidity |
|---------------|-------------------|--------------------------------|
| 1387 | 10.4 | 5 |
| | 50 | 46 |
| | 90 | 90 |
| 1384 | 10 | 5 |
| | 50 | 45 |
| | 90 | 90.5 |

* Tap meter lightly to reduce stiction error.

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2. Vary the input to the meter over the full range of indication. Check for stickiness in the movement. Motion of the pointer should be smooth.
3. A 100-microampere input should give full-scale deflection and the meter should read 100 per cent relative humidity.

If the meter performs satisfactorily, it may be assumed that errors in humidity measurement may be found in the composite sensor or the recorder.

Sensor-Bridge Combination Calibration Check -- The following procedure will prove the function of the humidity sensor and bridge circuit combination. All terminal and lead identification numbers mentioned in these instructions are references to Honeywell Drawing No. LO 8078 "Sensor and Control Assembly, Humidity".

1. Remove the sensor lead from TB2- 1B.
2. Connect the decade resistor box between TB2- 1B and TB2-2B.
3. With power applied to the console and with the relative humidity sensor located in the test chamber and connected to the console, maintain the ambient temperature at $77^{\circ} \text{F} \pm 2^{\circ} \text{F}$.
4. Adjust R5 until the humidity indicator reads 10 per cent relative humidity with the decade resistor set for the value corresponding to 10 per cent relative humidity listed in Table 4.
5. Adjust the simulated sensor resistance to that corresponding to 85 per cent relative humidity in Table 4, and adjust R8 to give an indication of 85 per cent.
6. Check for interaction between adjustments by repeating steps 4 and 5.
7. Record the relative humidity reading at regular increments from 10 to 85 per cent at $77^{\circ} \text{F} \pm 2^{\circ} \text{F}$. Indicated values should be within 1.5 per cent of the values given in Table 4.

GAS ANALYSIS

Sample Handling System

The console sample handling system is designed to provide a means of obtaining a gas sample from the test chamber and to supply this sample to the oxygen and carbon dioxide analyzers and the gas chromatograph at a pressure of 1 atmosphere. The basic components of the system are a pump, filters, needle valves, and two back pressure regulators.

The oilless diaphragm pump draws a gas sample from the test chamber irrespective of its pressure; forces it through filters, needle valves, flow meters, O₂ and CO₂ analyzers, and gas chromatograph; and returns it to the chamber. The location of back pressure regulators as shown in Figure 8 serves to restrict the line flow to afford pressure-controlled flow through the three analyzing instruments. The back pressure regulator shown in the line returning to the test chamber maintains a 3-psia pressure drop in this loop of the circuit to ensure sufficient flow through the analyzers. The back pressure regulator located downstream from the analyzers provides the constant pressure of 1 atmosphere at the analyzers necessary for accurate quantitative measurement. The needle valves allow the operator to shut off sample flow and check the analyzer indicators for zero and span adjustment. The zero valves located near each analyzer indicator are connected to a nitrogen tank located in the bottom of the console enclosure. This nitrogen gas supply is the means of furnishing an inert gas to the instruments for setting the zero adjustment. The span valves, similarly located, are connected to separate supplies of up-scale calibration gas containing a known per cent of the gas to be measured. This gas is used to set the indicator span. All gases controlled by the needle valves are monitored by flow meters. The two flow meters permit the operator to repeat flow settings for consecutive samples and to establish the recommended flow rates for effective sampling.

Gas bottles containing the zero and span gases are the No. 4 size cylinders approximately 4.5 by 14 inches. The bottles located in a storage section of

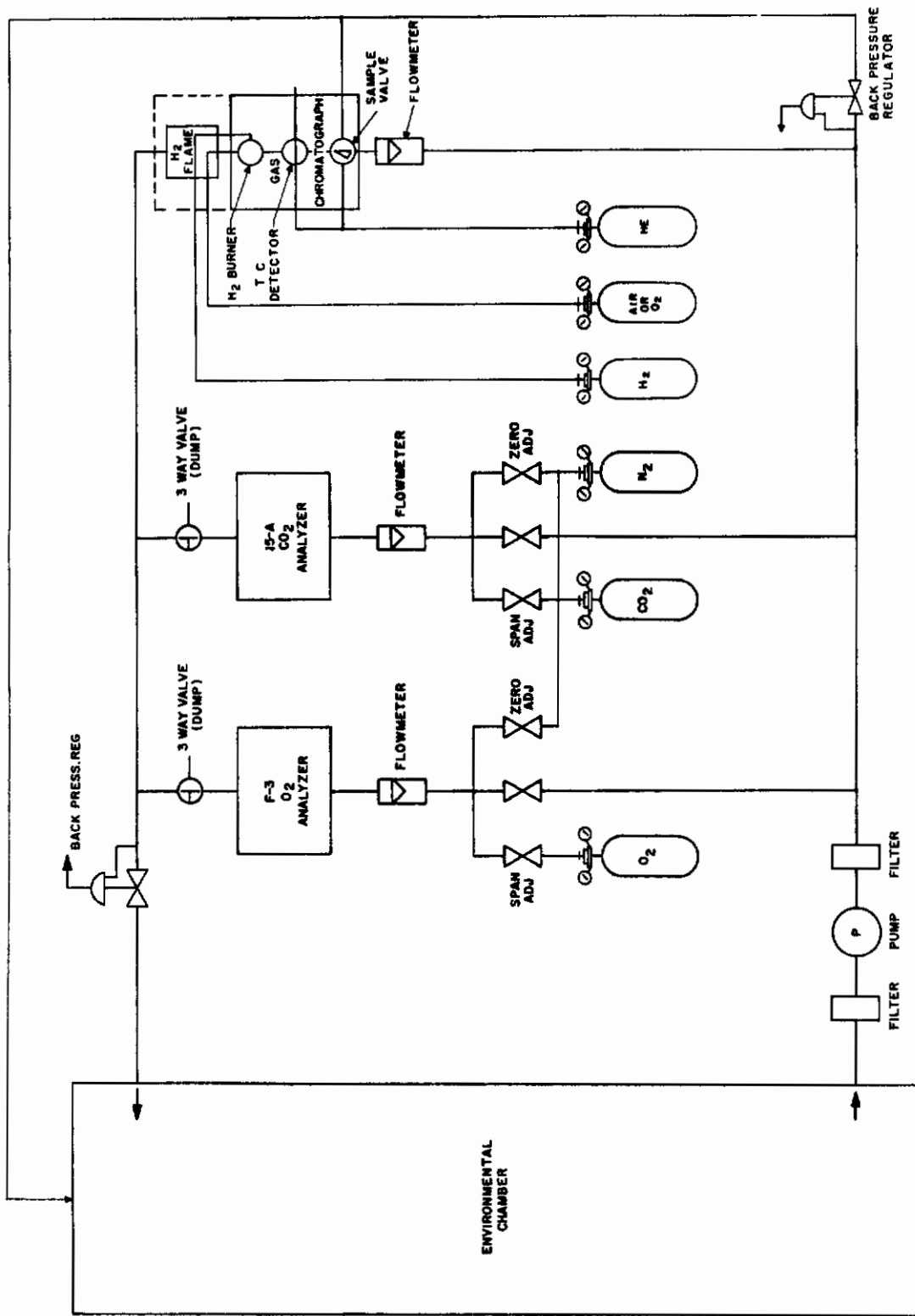


Figure 8. Sample Handling System Schematic

the console contain approximately nine cubic feet of gas at 1600 psi storage pressure. The bottles are equipped with dual gages (line pressure storage pressure) and a single-stage pressure regulator.

To start sample flow of test chamber gas through the analyzers:

1. Turn on pump switch.
2. Close all zero and span gas needle valves.
3. Open sample gas needle valve.
4. Adjust needle valve for either analyzer to give 150 to 300 cc/minute. (Higher flow rates will cut response time for indication of chamber fluctuations.)

Carbon Dioxide Analysis

The Beckman LB-15A Analyzer* is used to measure carbon dioxide concentration in the Evaluator (test chamber). The analyzer indicator is calibrated to read per cent carbon dioxide in the range of 0 to 6 per cent.

The LB-15A Analyzer is a two-component instrument consisting of the amplifier - control panel and analyzer units. The amplifier - control unit contains the amplifier; the power supply; and a control panel containing the power switch, indicator light, gain control, and meter switch. In the Honeywell-designed console, the controls have been removed from the amplifier unit and are mounted remotely on the gas analyzer panel which also contains the controls for the oxygen analyzer and for obtaining a gas sample from the test chamber.

Operation -- Operation of the analyzer, detector, amplifier, and power supply is discussed in the following paragraphs.

Analyzer -- The two energy sources emit infrared energy, both beams being chopped by a motor-driven chopper. The beam of energy from one

*Beckman Instruction Manual, Bulletin No. 1005, L/B Infrared Analyzer.

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source passes through the sample cell; the beam of energy from the other source passes through the reference cell. The sample gas absorbs infrared energy of the wave lengths of its absorption bands. This results in a greater absorption of infrared energy in the sample cell than in the reference cell, which contains gas that does not absorb infrared energy. These unequal beams of energy emerging from the cells strike the detector.

Detector -- The detector consists of two chambers filled at equal pressures with the gas which the instrument is to analyze. The chambers are separated by a pressure-sensitive diaphragm in which there is a small hole. With zero reference gas in the sample cell, the instrument is adjusted so that pressure is equal on both sides of the diaphragm. This adjustment is made by mechanically attenuating the stronger of the two beams by means of a sliding shutter.

Absorption of energy by the gases in the detector chambers causes the gases to expand and exert pressure against the diaphragm. When, during analysis, unequal beams of energy strike the detector, unequal pressures are produced in the detector chambers. The diaphragm moves in the direction of the chamber with the lesser pressure.

The diaphragm is one plate of the variable detector capacitor, which is part of an LC series circuit tuned by means of a variable inductor to an energy level 75 per cent of resonance and on the capacitive side. The LC circuit is driven by a 10-megacycle oscillator coupled inductively to the detector circuit.

Movement of the diaphragm changes capacitance and produces a 10-cps electrical signal. This detector signal modulates the oscillator signal, and the resultant is detected by one-half of electronic tube V-4, the 10-megacycle component being filtered out by C-9. The resultant 10-cps signal is fed to the amplifier input.

Contrails

Amplifier -- The 10-cps signal is fed to the input of an electronic tube through a capacitor and resistor (Gain Control Potentiometer). The amplified signal passes to an output transformer. The output transformer is connected across a breaker contact which leads to the negative terminal of the recorder filter. The breaker contacts are connected to the chopper motor shaft so the breakers are synchronized with the chopped signal. The breakers rectify the a-c signal from the amplifier, reacting only to 10-cps signals so they effectively act as a filter. The full-wave rectified signal is fed to the galvanometer-type recorder (or to a special filter if a high-speed recorder is used), which records a value proportional to the detector signal.

Power Supply -- The source of power for the instrument is a regulating transformer which puts out regulated a-c voltage. The regulated a-c is for the infrared sources, the motor, the thermostat, the heaters, and the d-c power supply circuit.

The d-c power supply consists of an electronic tube (rectifier) and filters consisting of inductors, capacitors, and a resistor. Regulated B+ voltage is furnished to the oscillator in the analyzer unit and to the amplifier tubes.

The power switch on the amplifier closes the common line, completing the power circuit. The motor switch on the analyzer closes the line to the chopper motor. The thermostat switch (if present) on the amplifier closes the line to the thermostat and heaters.

Calibration or Adjustment -- Referring to the operation manual furnished with the device, the instrument detector is tuned to its maximum output. This will be an input to the meter of approximately 52 millivolts. The meter will read 2.15 on the 0 to 6 per cent scale. The detector is retuned to read an output of 39 millivolts or 75 per cent of the maximum output.

Contrails

For zero adjustment, the zero adjust (located on the side of the box containing the detector) is set with the output jack (to recorder) shorted and while passing approximately 150 cc/minute of dry nitrogen through the instrument. For span adjustment, a 5 per cent mixture of CO₂ is passed through the instrument and the gain control is set to give an up-scale deflection corresponding to this value.

Middle range adjustment of the CO₂ analyzer may be obtained similarly by passing a known concentration of CO₂ of approximately three per cent through the instrument at the same flow rate. The indicator should read within one per cent of the known value.

Several curves furnished as part of the Beckman LB-15A Instruction Manual give the correct recorder deflection for various CO₂ concentrations measured at chamber pressures which vary from 260 to 760 mm Hg. Note that the deflection versus CO₂ concentration is not a linear relationship. With the sampling system provided wherein the back pressure to the CO₂ instrument is maintained at ambient barometric pressure, only the curve corresponding to barometric pressure is pertinent.

Oxygen Analysis

Oxygen partial pressure in the evaluator instrumentation system is measured by a Beckman F3M3-1A3A Oxygen Analyzer. The sensor is part of the thermostatically controlled enclosure which contains the magnetic analysis unit, the regulated power supply, the amplifier, and the temperature control circuits. This package is located in the back of the console approximately 48 inches from the indicator. The calibration panel containing the indicator and the resistor networks for supplying voltages to the vanes and for matching the analyzer output to the recorder has been moved from its normal location on the cover of the enclosure containing the sensor and electronics to the console gas analyzer panel. This panel also contains the carbon dioxide analyzer and gas sampling controls.

The oxygen indicator has a three-range readout capability. The dial face shows a range of 0 to 200 mm Hg (partial pressure of oxygen). The desired sensitivity

Contrails

may be selected by turning the range knob to 0-200, 0-400, or 0-800 mm Hg. If, for example, the gas sample were actually 199 mm Hg, the indicator would show approximately full scale if the range selected were 0-200 mm. The indicator would show a half-scale deflection for a selection of 0-400 mm and a quarter-scale deflection if the range selected were 0-800 mm.

Operation -- The following is an explanation of the F3 operation taken from the Beckman Instruction Manual:*

The Model F3 measures the paramagnetic properties of the sample gas and thus its oxygen content. A light dumbbell is supported on a quartz fiber between magnetic pole pieces. Each ball of the dumbbell is in a non-uniform magnetic field. The dumbbell assembly itself has a fixed magnetic susceptibility. When a sample gas containing oxygen surrounds the dumbbell suspension, the suspension experiences a force dependent upon the difference between the magnetic properties of the tested gas and the suspension itself. The effect of the force exerted tends to rotate the dumbbell about the quartz fiber. The magnitude of this force is proportional to the oxygen content of the sample gas.

The way in which the analyzer's basic principle is adapted to operating a recorder is simple and positive. The dumbbell suspension is coated with rhodium to make it conductive. Near one ball of the dumbbell is a pair of electrodes or vanes, each of which is held at a constant potential. Thus the ball is in an electrostatic field and can be subjected to an electrostatic force by varying the ball's potential in the electric field. The varying potential applied to the suspension is the balancing potential.

When a force is excited on the suspension, it can be counteracted by the electrostatic balancing force so that the dumbbell remains stationary. Therefore the magnitude of the balancing potential necessary is proportional to the forces exerted on the suspension, which, in turn, are directly proportional to the oxygen content of the sample gas.

A light beam, reflected from a mirror attached to the suspension, is divided between two phototubes. These phototubes have equal resistances when the suspension is in its null position.

When the suspension rotates, due to a change in oxygen content, the amount of light on the phototubes is unequal. This decreases the resistance of one of the phototubes and increases the resistance of the other. When this occurs, voltage at the center tap between the phototubes either increases or decreases depending upon the direction of rotation of the suspension. This voltage is amplified and is the rebalance potential applied to the suspension to return it to null position.

*Beckman Instruction Manual: Model F3 Oxygen Analyzer.

Contrails

The rebalance potential is measured and is recorded by almost any type of recorder or meter. Readings obtained by this method are linear and proportional to the oxygen content of the sample gas.

Calibration -- The oxygen analyzer is fed the air to be analyzed through the same sample handling system (i. e. , valves, pumps, filters, etc.) that serve the CO₂ analyzer and the gas chromatograph. Three middle valves located near the analyzer controls on the instrument console permit introduction of the zero gas (N₂) or any known concentration of O₂ from a separate source to give a span adjustment.

Before beginning calibration checks, the instrument must be warmed up for approximately 24 hours. The following procedure is used for calibration:

1. With the dump valve set to VENT and with span and sample valves closed, start a flow of the zero adjust gas (pure nitrogen) through the instrument at a rate of approximately 150 cc/minute.
2. Set indicator at zero by turning the zero adjust potentiometer with a screwdriver.
3. Close the zero adjust gas valve and open the span gas valve until the rate of flow of the span gas (99.5 per cent pure O₂) is 150 cc/minute.
4. Set span adjust so that meter reads (pO₂)_A on the 0-800 mm scale.

$$(pO_2)_A = 0.995(p_B)$$

where (pO₂)_A is the oxygen partial pressure at the analyzer and p_B is the barometric pressure. The relationship between the pO₂ at the analyzer and the pO₂ in the evaluator chamber is given by

$$\frac{(pO_2)_A}{(pO_2)_C} = \frac{p_B}{p_C}$$

where p_C is the total chamber pressure.

Contrails

5. If convenient, check the above settings with a known, midspan mixture of O₂ and N₂.
6. For monitoring the evaluator chamber, close the span gas and zero gas valves, open the sample gas valve, and set the dump valve to the ON position (sample gas returned to chamber).

It is recommended that standardization of the oxygen analyzer be accomplished every 24 hours. The analyzer should also be standardized whenever there is an appreciable change in barometric pressure since this pressure is the reference for the back pressure regulator.

In order that the indicator and strip chart on the Honeywell Brown recorder may be read directly in per cent O₂, the recorder span should be adjusted to read 99.5 at the time that the 99.5 per cent O₂ span gas is applied to the analyzer. It is usually not necessary to readjust the recorder when the analyzer is restandardized. The accuracy of the recorded per cent O₂ values will be affected by changes in barometric pressure, however, just as in the case of the analyzer indicator. If the barometric pressure at the time of recording (p_B)_R is different from the barometric pressure during standardization (p_B)_S, then the actual per cent oxygen is related to the recorded per cent oxygen (%O₂)_R by

$$\text{actual } \%O_2 = \frac{(p_B)_S}{(p_B)_R} (\%O_2)_R$$

The actual and recorded per cent O₂ are the same right after standardization and until the barometric pressure changes.

The partial pressure of oxygen in the chamber is related to the actual per cent O₂ by

$$\text{actual } \%O_2 = \frac{(pO_2)_C}{P_C} = \frac{(pO_2)_A}{P_B}$$

Gas Chromatograph and Hydrogen Flame Detector

The Beckman GC-24 Gas Chromatograph, Hydrogen Flame Detector, and Honeywell Brown Recorder (Figure 9) are the means of measuring and recording the composition of atmosphere in the Evaluator Instrumentation Console. The Life Support Systems Laboratory application necessitated several changes in the standard GC-2A and Flame Detector arrangement. Comparison of the Honeywell configuration shown in Figure 10 with the Beckman standard configuration illustrated in the instruction manual shows that several components have been added to the basic system. A second adsorption column, a dual column valve, and a variable restrictor have been added to provide the flexibility and extra capability required to measure the number and kinds of gases anticipated.

The second adsorption column, valve, and restrictor combination make it possible to use either the armean and carbowax column singly, or in series with the molecular sieve column. This flexibility allows a qualitative analysis of a gas sample which may contain any or all of the following constituents in the quantities indicated in Table 6.

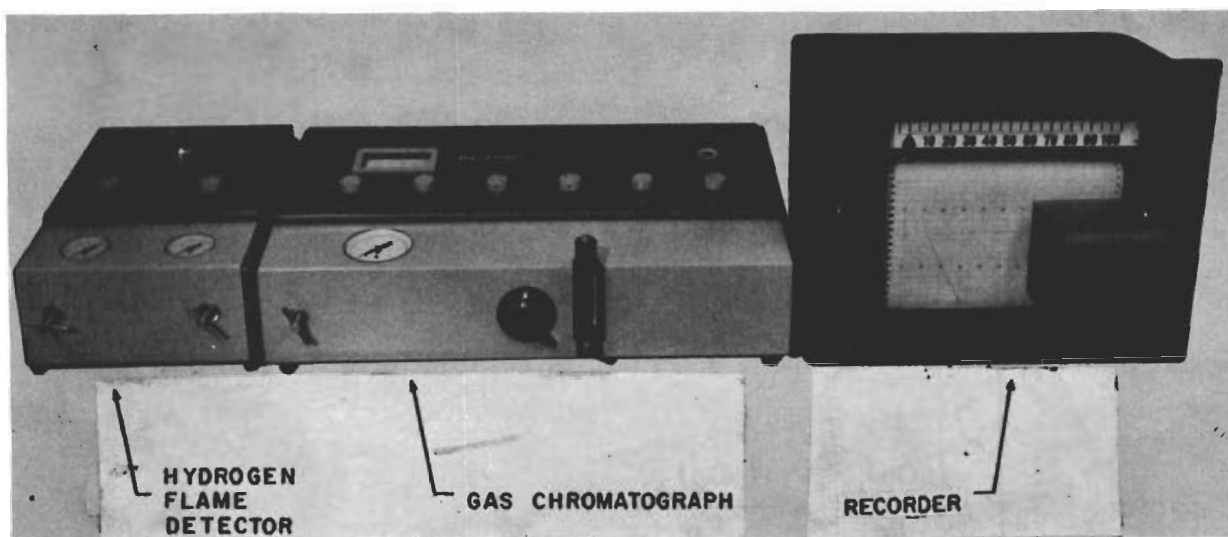


Figure 9. Gas Analysis Instruments

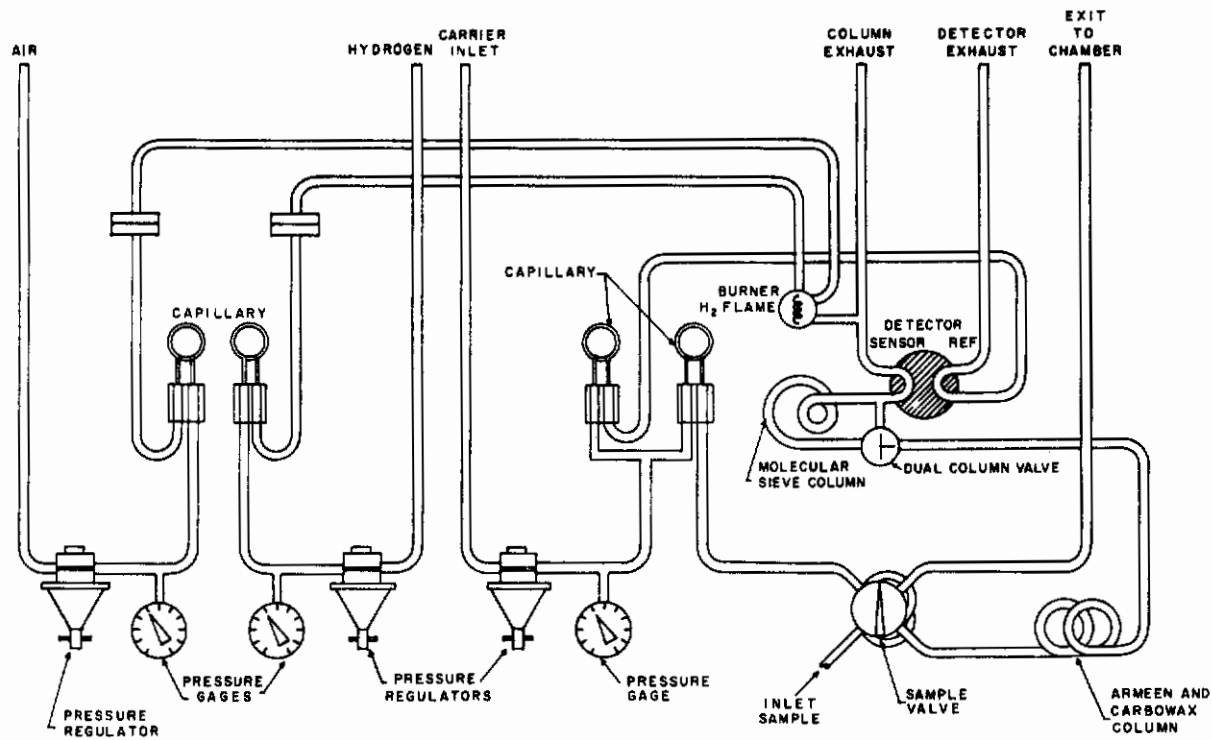


Figure 10. Complete Circuit - Hydrogen Flame Detector and Chromatograph

Table 6. Gases to be Analyzed

| Gas | Concentration | Remarks |
|--------------------|-----------------------|--|
| CH ₄ | 50 - 700 ppm | Measure |
| H ₂ | 200 - 2500 ppm | Measure |
| H ₂ S | ppb | Measurement not required |
| N ₂ | 5 - 80 per cent | Measure |
| O ₂ | 10 - 100 per cent | Measure |
| H ₂ O | 5 - 90 per cent R. H. | Measure |
| CO ₂ | 150 ppm - 5 per cent | Measure |
| CO | 10 - 100 ppm | Measure |
| Other hydrocarbons | Unknown | May be measured in future applications |

Operation -- The following description is taken from the Beckman Chromatograph Instruction Manual.

Sample components, introduced into the flow system of the GC-2A through the gas sampling valve, are swept by the carrier gas into the chromatographic column. Here, the sample components are retarded by adsorption or absorption by the column filling material or by solution, and as the carrier gas continually flows through the column, the individual sample components emerge (elute) from the column at different times. This elution time sequence is directly proportional to the affinities of the sample components for the column packing. Therefore, under proper conditions, the stream emerging from the column is composed of carrier gas and dilute bands of components.

From the column, the gas stream flows through the sensing side of the thermal conductivity detector and is exhausted at the rear of the instrument. A corresponding stream of pure carrier gas flows through the reference side of the thermal conductivity detector and out an exhaust line. Since the reference gas passes through the thermal compartment of the instrument, it is the same temperature as the sample gas stream when it reaches the detector.

The elements in the thermal conductivity detector, which are arranged in a Wheatstone bridge configuration, measure the difference in thermal conductivity between the sample-carrier gas mixture and the reference stream of pure carrier gas. The bridge is balanced when pure carrier gas is in both sides of the detector. As sample-carrying gas enters

the sample-measuring side of the detector, it alters the transfer of heat from a heated filament to the detector-cell wall. This change in the temperature of the filament varies its resistance and creates a voltage imbalance between the reference side and the sample side of the detector. This imbalance is recorded as a function of time on a MH Brown Recorder. As the dilute plug of sample in carrier gas leaves the detector, the resistance of the filament returns to its original value. The area of the resulting recorder peak provides a quantitative index of the sample component. The interval between the sample injection and the elution of a sample component (retention time) can be interpreted to identify the component.

The effectiveness of the GC-2A chromatograph for the Life Support Systems Laboratory application will depend upon the operator's knowledge of chromatography and his familiarity with the operation of the instrument. The discussion that follows does not purport to be a complete description of instrument operation or of the techniques of chromatography; it is included to apprise users of this instrumentation of special considerations not mentioned in the Beckman Instruction Manual.

The chromatograph and flame detector (if it is to be used) should be thoroughly flushed with the operating gases before an attempt is made to analyze gas samples. This means that the chromatograph should be flushed with helium to clear the tubing, valves, and adsorption columns of impurities; the hydrogen flame detector burner should be flushed with hydrogen and air to clear this critical part of contaminants. Flow rates for flushing should be set at 15 to 31 psi (on pressure indicators), depending upon maximum time allowed for purging the instrument. Purging should continue for at least 24 hours before an analysis is attempted.

The flush or purge procedure described above applies only if the system has been inoperative for an extended period or if the system plumbing has been disturbed so as to introduce impurities. For normal operating conditions where the instrumentation is idle for short periods between runs, the method described in steps 1 through 3, below is applicable.

1. With the dual-column valve set for single-column operation, purge the first column (armeen SD) through the restrictor and thermal conductivity detector.

Contrails

2. Turn the valve for dual-column operation and purge the second column (molecular sieve) with the effluent from the first column.
3. When purging is complete, adjust and measure the flow rate through the two columns in series so that it is between 60 and 90 cc/minute.
4. Switch to single-column operation and adjust the restrictor so that the flow is the same as in dual-column operation.
5. Inject a known sample.
6. The armeen SD column will separate four components. The first component consists of hydrogen, oxygen, nitrogen, and methane. In single-column operation, the time that the first component takes between injection and detection at the thermal conductivity detector should be noted. The remaining three components in the armeen SD column should elute in the following order:
 - a. Hydrogen Sulfide
 - b. Carbon Dioxide
 - c. Water
7. Purge and then switch to dual-column operation.
8. Inject another known sample.
9. After time is allowed for the first component (H_2 , O_2 , N_2 , CH_4 , and CO) to pass through the dual-column valve and reach the molecular sieve, rotate the dual-column valve to single-column operation through the restrictor and permit the second group of components (H_2S , CO_2 , and H_2O) to be measured by the thermal conductivity detector.

10. After these have eluted and there are no other components in the armeen SD column, rotate the valve to dual-column operation and permit the H_2 , O_2 , N_2 , CH_4 , and CO to be measured in that order. (NOTE: Quantities of oxygen greater than a few parts per million should not be measured when the instrument is set at high sensitivity. The power to the thermal conductivity detector should be turned off while the oxygen component is passing through the detector.)

If the hydrogen flame detector is in series with the thermal conductivity detector outlet, all the gaseous components will go through that instrument in the same order, and only the methane will be measured. If a false peak is registered during the thermal conductivity analysis, this may be due to hydrocarbon impurities. Should this be the case, the same peak should appear during the hydrocarbon analysis.

Various times of elution are not mentioned in Steps 6 through 10 because these times cannot be established before each gas constituent has been processed through the instrument. Elution times for the same gas samples vary with the particular characteristics of each adsorption column; i. e. , samples processed through two different instruments may show different elution times. Though elution times may vary from instrument to instrument, the time of elution for any constituent from the same instrument will remain unchanged even though a given gas sample may contain this element in a mixture of gases.

Application Recommendations -- The gas supply contained in the rollaway table section of the evaluator console consists of three No. 4 bottles of helium, hydrogen, and compressed air. These small bottles contain approximately 9 cubic feet of gas at 1600 psi storage pressure. At an air flow rate of 500 cc/min, the small bottle supply will last approximately 9 hours. If a H_2 flow rate of 40 cc/min is chosen, the optimal flow of helium will be 90 cc/min. At these flow rates, the helium will last approximately 47 hours and the hydrogen 106 hours. The Beckman Instruction Manual for the Hydrogen Flame Detector illustrates on pages 17 and 18 the typical relationship between

Contrails

relative signal versus hydrogen-helium flow rates, air flow rate versus pressure regulator setting, and hydrogen flow rate versus pressure regulator setting.

The rollaway table section of the Evaluator Console was designed to hold the chromatograph, hydrogen flame detector, and recorder as a portable gas analysis system with its self-contained working gas supply, power transformer, and chamber-to-analyzer connections.

For routine operation, with the chromatograph, hydrogen flame detector, and recorder located at the main console, large size tanks containing the working gases should be substituted for the smaller tanks located in the rollaway section. This will minimize the need for frequent replacement and will obviate the difficulties which may arise as impurities are introduced during frequent cylinder changes.

RECORDERS

Three recorders are used in the evaluator console system -- two of the multi-point printout type and one of the single-pen multi-channel type. All are class 15 potentiometric types manufactured by Honeywell.

Pressure Recorder

This recorder provides a permanent record of oxygen, carbon dioxide, water vapor content (per cent relative humidity), and pressure at six stations - a total of ten parameters - sensed at a remotely located test chamber.

Characteristics and features of the recorder are outlined below:

Electrical Characteristics -- The recorder operates on 115-volt, 60-cycle ac.

Input -- Input to the recorder from all transducers is in the range of 0 to 10 millivolts. The following transducers will supply inputs to the recorder:

Per Cent Relative Humidity -- Honeywell Gold Grid Sensor - Separate sensors for recorder and for indicator.

Per Cent CO₂ -- Beckman G15A CO₂ Analyzer - 0 to 10 millivolts dc output.

Per Cent O₂ -- Beckman F-3 Oxygen Analyzer - 0 to 10 millivolts dc output.

Pressure -- H. E. Sostman Transducers - two differential and four absolute types - 0 to 10 millivolts dc output.

Contrails

Accuracy -- 0.25 per cent.

Range -- Double range.

Chart Width -- 12 inches, calibrated width 10 to 11 inches.

Number of Parameters Recorded -- Ten. CO₂, H₂O (2), O₂, plus pressure at six stations.

Strip Chart -- The strip chart is a standard 0 to 100 scale utilizing the full chart width.

Chart Speed -- Basic chart speed is 12 inches per hour with switch control to permit change to 120 inches per hour.

Pen Carriage Speed -- 2 seconds.

Method of Printout -- 3-second cycle printing.

Automatic Timer -- A timer, furnished as an integral part of the recorder, permits automatic start and stop, and affords a means of timing the duration of run.

Time and Date Printer -- The recorder is equipped with a time and date printer of the Royson RI-2 type or equivalent. The printer marks the strip chart with the time and date at the start of each recording and with the time and date once each hour during continuous printing.

Printing Style -- The printing style consists of a plus (+) and numeral corresponding to the record number.

Chart Speed Changer -- It is possible to change the basic chart speed of 12 inches per hour to 120 inches per hour by a manual switch located on the face of the instrument.

Contrails

Selective Printout -- The recorder is constructed to allow selective printout of any parameter at any station for as long as desired.

Temperature Recorder

The temperature recorder differs from the pressure recorder in that it is a three-range instrument with twenty-four channels. It is the Brown Electronik Twenty-four Point Recorder, Model No. SC153X(67) - (W24U)-II-III-(IV)-(C2) (B5)(BS)(V), designed for this thermistor application to contain the power supplies and matching bridge circuitry for each of the three temperature ranges. Its characteristics and features are outlined below:

Actuation -- Thermistor actuation using matched thermistors (Yellow Springs Type YS1).

Range -- Triple range with one set of span and zero adjustments for each range and automatic range transfer on predetermined points as follows:

Range 1, -40 to +50° F, points 1 through 8

Range 2, 40 to 120° F, points 9 through 16

Range 3, 100 to 250° F, points 17 through 24

New Scale -- Triple range type (over and under) graduated from -50 to +50° F, 40 to 120° F, and 100 to 250° F for Yellow Springs Type YS 1 thermistors.

Chart -- Single range type, graduated from 0 to 100 (even numbers with no time markings).

Printing -- 3-second cyclic, plus (+) and number, unicolor.

Print Carriage Speed -- 2 seconds full-scale travel.

Contrails

Selective Recording -- A manual selector switch to select any one point for continuous recording. The recorder prints symbols in normal sequence although measuring and repeating the printout of only the selected variable.

Selective Indication -- Manual toggle-type key switches are provided to disconnect thermistors from the recorder on points selected for indication on Yellow Spring Type 43 Telethermometers. The recorder prints these points at the left-hand end of the chart.

Chart Drive -- 120 inches per hour with Inscoc solenoid-actuated chart speed changer with 10-to-1 reduction to 12 inches per hour and "On-Off-Remote" switch on door.

Chart and Print Motor -- Wired to terminals in rear of case for remote actuation.

Time and Date Printer -- Royson Type RI-2 time and date printer mounted on right side of recorder door, complete with timer, rectifier, and relay package mounted in a box on the rear of the case. The printer marks the chart with the time and date at start of recording and once each hour during continuous printing.

Special Finish -- The recorder exterior is painted gray-blue.

Zero and Span Adjustment -- The adjustment of zero and span for this recorder differs from the normal arrangement in that the adjustment marked "Span" variable resistor is used for zero adjustment. This is because the thermistor signal input to the recorder varies inversely with temperature fluctuations at the sensor installation point.

Chromatograph Recorder

The chromatograph recorder is a standard instrument supplied by the Brown Instrument Division of Minneapolis-Honeywell, Brown Electronik Strip Chart

Contrails

Chromatograph Recorder, Model No. SY143X(58)-(VB)-II-III-(30)-C2(V)]
specifically for use with the Beckman Gas Chromatograph.

Features of the Brown recorder are outlined below:

Range -- Single range.

Chart and Scale -- 0 to 100 (even numbers over central 10 inches with no time markings).

Pen Speed -- 1 second full-scale travel.

Chart Drive -- 30 inches per hour with change gears for 60, 90, and 120 inches per hour.

Chart Motor -- Wired to terminals in rear of case for remote actuation.

Time and Date Printer -- Royson Type RI-2 time and date printer mounted on right side of recorder door, complete with timer, rectifier, and relay package mounted in a box on the rear of the case. The printer will mark the chart with the time and date at start of recording and once each hour during continuous printing.

Special Finish -- The recorder exterior is painted gray-blue.

RECORDER TIMERS

Recording times (i. e. , start, stop, and duration of run) are controlled by four Model 305 B-022-A-10-MX ATC Timers.

The total "on" time and "off" time can be set for each recorder by using the two clock-type timers located on the panel below each recorder. This timer control panel also displays a repeat - single-cycle switch and a push-to-start button. If power to the timers is interrupted, the mechanisms will reset to begin the cycle again.

The "on" time control is a 240-minute timer which may be set to hold the recorder on for any period of time from 5 minutes to the 4-hour maximum. The "off" time control is a 30-hour timer which regulates the "off" time in a similar manner.

If single-cycle operation is selected, the first timer is set for the "on" time required and the second timer is set for the period the recorder is to be off. The cycle is then started by pushing the START button.

The START button energizes the clutch and relay, which starts the timer motor. The recorder is started simultaneously with this function.

At completion of the "on" time, the first timer continues to run for approximately 2.5 minutes while pulsing the second timer. At the end of 2.5 minutes, the first timer stops. The second timer switch relay has locked in to hold the timer motor in operation for the full duration of the preset "off" time.

When the "off" time is complete, the timer and recorder stop and the control of recorder operation is terminated. If power to the timers is interrupted, the mechanism will reset and begin a new cycle when the START button is operated.

If "Repeat Cycle" operation is selected, the operation will be as described above, except that the second timer ("off" timer) will re-energize the first timer before stopping. This will start the subsequent cycle of operation until the desired number of cycles is completed.

MODULAR ENCLOSURE

The four -module cabinet or enclosure was manufactured to Honeywell specifications by Amco Engineering Company of Chicago, Illinois.

The four sections, each measuring 19 inches wide by 22 inches deep by 78 inches high, are bolted together to form the arrangement shown in Figures 1 and 11. The left module has been turned 45 degrees toward the operator, and each section has a turret top section inclined 20 degrees toward the monitor. The over-all effect is to provide the operator with a clear view of all controls and displays while seated approximately in the center of the console. A table work surface extends the full length of the console.

Each of the modular sections is fitted with a 70-inch door located on the back of the cabinet to allow access to equipment located behind the display panels.

The right end of the console abuts the 60-inch table which has been designed as a rollaway section. It has been made separate from the main console and fitted with casters to permit easy portability. The enclosed left end of the rollaway section is large enough to contain the small gas supply tanks, controls, and wiring that are part of the gas analysis equipment. The top or table surface of this section is made to hold the gas chromatograph, hydrogen flame detector, and recorder.

Though the configuration of the Honeywell console design is unique, the component parts and assemblies which form the complete unit are standard and readily available from Amco Engineering, Chicago, Illinois.

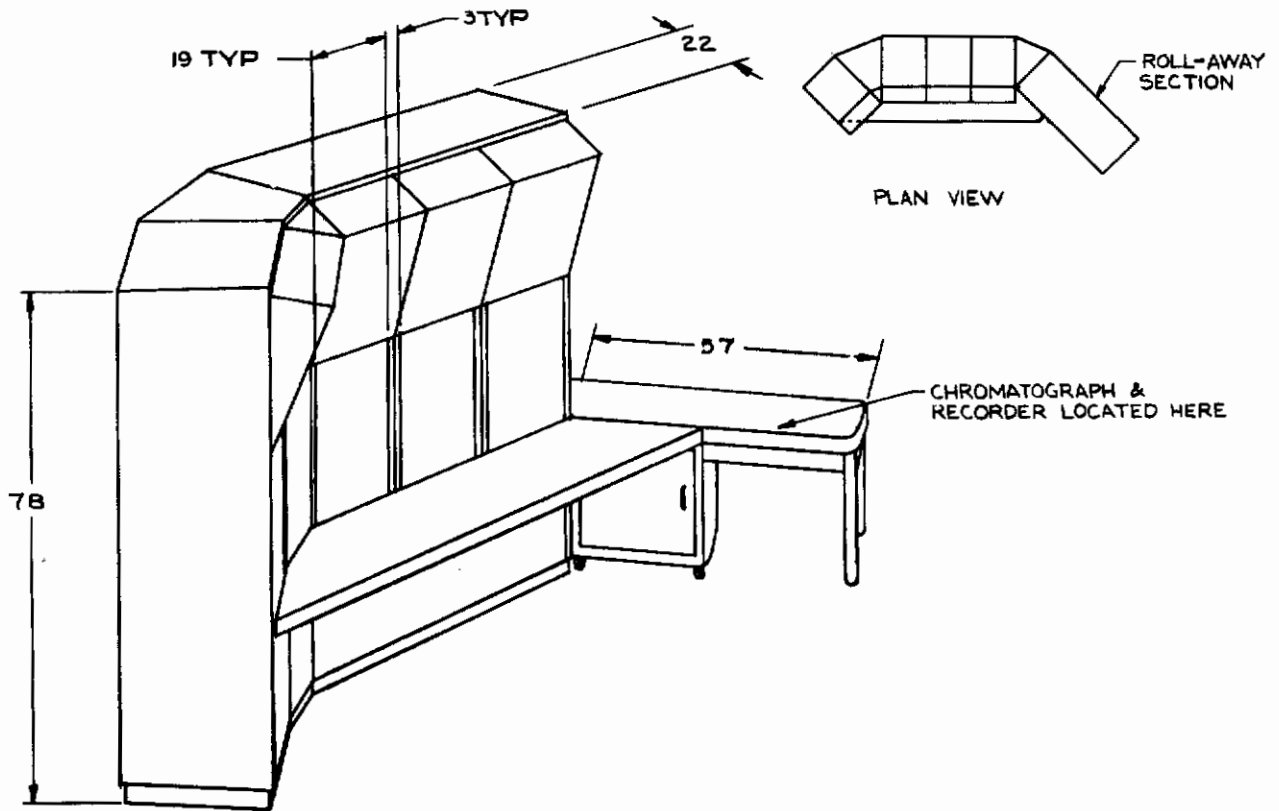


Figure 11. Console Perspective

TELEVISION MONITOR

The console television installation comprised of two 17-inch monitors working with the four cameras mounted in the test chambers provides the operator with a visual link to the test chamber and its occupants. The switching circuitry is arranged so that the test monitor may view occupants of either the fore or aft sections of the chamber on either television screen. It is also possible to use both screens simultaneously to view a subject located in either section of the chamber from two different angles.

The television equipment, supplied by Miratel Incorporated of New Brighton, Minnesota, consists of four 63AR Dage Cameras, two K59/17R 17-inch monitors, a regulated power supply, cables, and switching circuitry. The two monitors are panel-mounted in the turret section of the console, one on the left end and the other adjacent to it on the forward-facing section of the enclosure.

A complete complement of television controls is located on the same panels. These controls include optical focus, electrical focus, and camera selection, as well as the necessary adjustments for picture quality.

The K59 model monitors feature plug-in chassis construction for ease of maintenance. The plug-in units are listed below:

1. A "D" unit containing an 8-megacycle video amplifier section, d-c restorer, sync separator, sync amplifier, AFC detector, and internal-external sync control amplifier.
2. An "E" unit containing the vertical oscillator and vertical output stage.
3. An "F" unit containing the horizontal oscillators, horizontal output, high voltage rectifier, damper, flyback transformer, etc.
4. The main chassis containing the B plus supply and interconnecting wiring.

Contrails

Characteristics and features of the television monitor are outlined below:

Power Input -- 115 volts ac, 60 cycles, 200 watts. Fused.

Controls -- The monitor contains the following controls:

Front Panel -- Contrast, brightness, vertical hold, horizontal hold, vertical height, vertical linearity, on-off switch, and volume control (for use with audio models).

Rear Control -- Width sleeve for horizontal width adjustment.

Video Bandwidth-- Video response beyond 8 megacycles. Resolution better than 600 lines.

Tube Complement -- The following tubes are contained in the television monitor:

| | |
|------------------|--|
| 1 - 5U4GB | Low voltage rectifier |
| 4 - 12AU7A | Vertical oscillator, horizontal oscillator, sync Separator, and sync amplifier |
| 1 - 6CM6 | Vertical output |
| 1 - 6CB6 | Video amplifier |
| 1 - 6CL6 | Video amplifier |
| 2 - 6AL5 | DC restorer, and AFC detector |
| 1 - 6AX4GT | Damper |
| 1 - 6CU6 | Horizontal output |
| 1 - 1B3GT | High voltage rectifier |
| 1 - 17AVP4A Kine | Picture tube |

Recommended Spares -- For less than 10 monitors, the following spares are recommended:

- 1 - Set tubes
- 1 - Flyback transformer
- 1 - Yoke
- 1 - Vertical output transformer

Dimensions and Weights -- The Miratel Model No. K/59/17R has the following dimensions and weights:

| | |
|-----------------|----------------|
| Height | 15- 3/4 inches |
| Width | 19 inches |
| Depth | 17 inches |
| Shipping Weight | 52 pounds |

CONSOLE - TO - TEST CHAMBER AUDIO LINK

The evaluator console communications system is designed to provide three-way communication between console and both sections of the evaluator. The console panel contains a 6-inch speaker; on-off switches for forward and aft speakers; and base, treble, and volume control for the console speaker. A Bogen 35-watt amplifier powers the communications system.

An 8-inch speaker and ceramic microphone for each of the two chamber sections are part of the system instrumentation. Each speaker has a monitor on-off switch and a FORWARD or AFT on-off switch for switching the microphone output into either or both of these speakers. For instance, an operator or subject located at any of the three stations may talk to either of the other two stations by switching his microphone output to the desired stations and holding down the microphone TRANSMIT button. He may also receive from either or both of the other two stations if his station has been selected.

The same basic system may also operate with a "live microphone" arrangement. With both microphone buttons depressed or the equivalent permanent switching accomplished by a circuit modification, the operator located at the evaluator console may monitor conversations emanating from either section of the test chamber. Either mode of operation may be selected by actuation of a switch located on the console communications panel.

Subjects located in the test chamber may receive from the monitor provided the console operator has made the proper selection on the console panel.