CR-123782

(NASA-CR-123782) FABRICATION, TEST AND DEMONSTRATION OF CRITICAL ENVIRONMENT MONITORING SYSTEM Final Report K.W. Heimendinger (Lockheed Missiles and Space Co.) Jun. 1972 114 p CSCL 14B G3/14

N72-30389

Unclas 16072

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HREC-7300-5
LMSC-HREC D225985

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FABRICATION, TEST AND DEMONSTRATION OF CRITICAL ENVIRONMENT MONITORING SYSTEM

FINAL REPORT

June 1972

Contract NAS8-27300

Prepared for National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

by

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FOREWORD

This document presents the results of a 12-month, four-phase effort to "Design and Fabricate an Analytical System for the Evaluation of Certain Environmental Constituents in Critical Environmental Areas." This effort was performed under Contract NAS8-27300 by the Lockheed Huntsville Research & Engineering Center, Inc., for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama. Work was performed during the period 23 June 1971 to 23 June 1972 by the Lockheed-Huntsville Aeromechanics department, G.D. Reny, Manager. Project Engineer was K.W. Heimendinger, Research Engineer, Systems Engineering Section.

The NASA Contracting Officer's Representative (COR) for the contract was B. H. Nerren of the Quality and Reliability Assurance Laboratory.

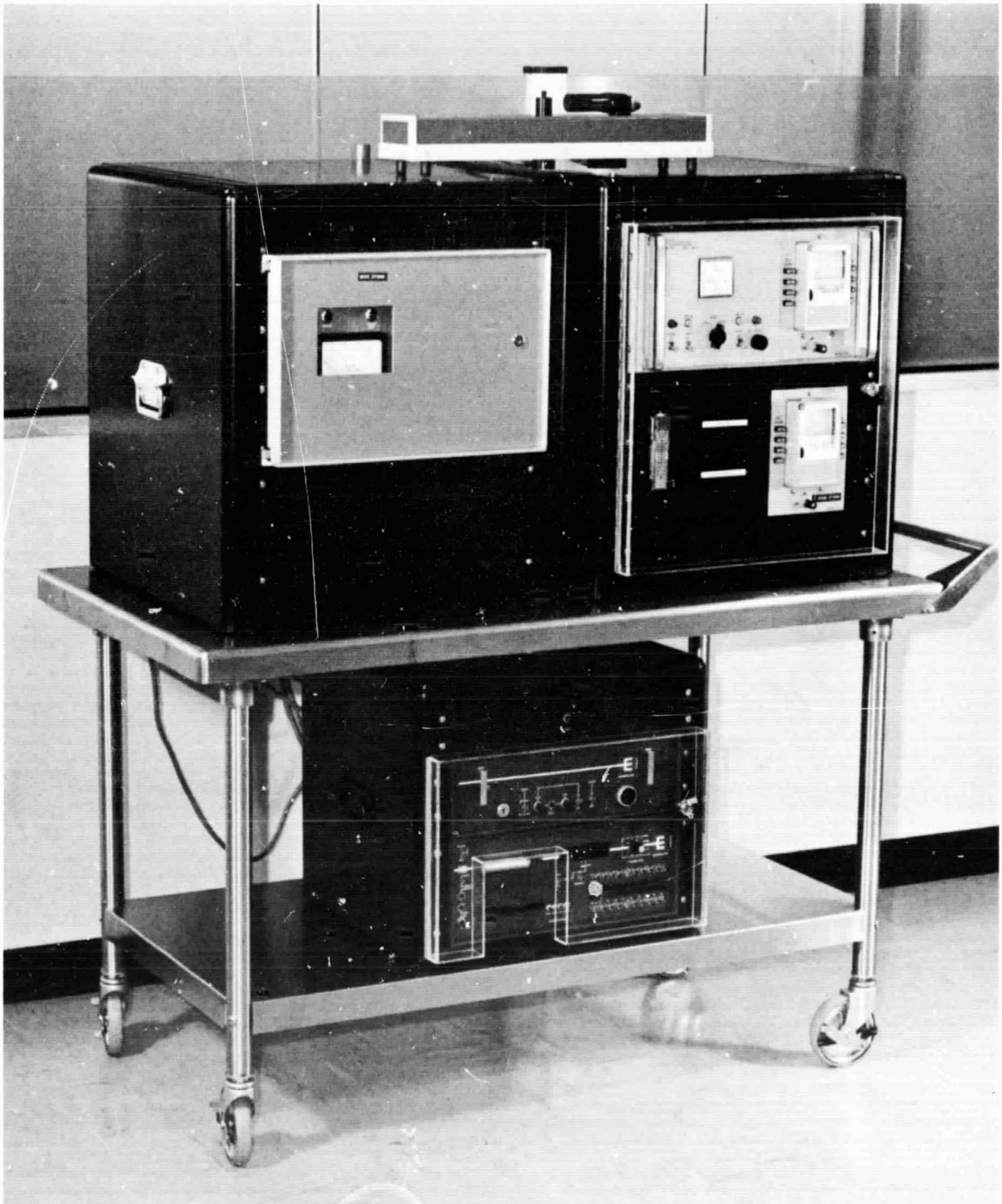
Achnowledgment is given to R.B. Wysor, R.A. Wyman, N.O. Wages, G.D. Robinson, and R.L. Chaney for their contributions to the work.

SUMMARY

This report summarizes work performed under Contract NAS8-27300, "Design and Fabrication of an Analytical System for the Evaluation of Certain Environmental Constituents in Critical Environmental Areas." The work documented encompasses a technological survey, conceptual, preliminary, and final designs, system fabrication, installation and demonstration of the Critical Environment Monitoring System (CEMS).

The Critical Environment Monitoring System (CEMS) as shown in the attached figure, is a versatile and flexible system to monitor and analyze humidity, temperature, hydrocarbons, particle size and particle count within prescribed clean areas. The system can monitor particulate matter in four size ranges (0.5 to 2.0 μ; 2.0 to 5.0 μ; 5.0 to 20.0 μ; and 20 μ and larger) to a total count of 100,000 particles per cubic foot with an accuracy of $\pm$ 10% full scale. Hydrocarbons are monitored from 0 to 40 parts per million, with an accuracy of $\pm$ 5% full scale. Temperature is monitored from $4^{\circ}C$ to $38^{\circ}C$ $\pm$ $0.5^{\circ}C$ and relative humidity from 30 to 70 $\pm$ 1.5%. All of the data are monitored continuously by an alarm system. The alarm activates the digital printer as well as an audible signal. The digital printer is capable of recording at various selectable intervals. The CEMS also contains an automatic calibration unit (ACU) for self calibration and interfaces with a nine-track, 800 BPI incremental magnetic tape recorder.

The CEMS consists of three modules: two instrumentation modules (on top of the dolly in the figure) and a recorder-alarm (RA) module (on lower shelf in the figure). The two instrumentation modules are the HFI module (on left in the figure) which houses the hydrocarbon analyzer and its support equipment and the PC module (on right in the figure) which houses the particle counter, temperature sensor, and humidity sensor. The RA module houses



Critical Environment Monitoring System (CEMS) the data logging and alarm system as well as the ACU. The modules are painted black with equipment panel faces finished in a compatible color scheme to optimize the visual detection of particulate matter. The finishes are baked to ensure no hydrocarbon outgassing at ambient temperatures.

The versatility of the CEMS allows each instrumentation module to be operated independently of the other, with or without the RA module. The various pieces of equipment are described in detail in the appendix to this manual.

CONTENTS

Section 1
INTRODUCTION

The quality assurance of flight hardware for such programs as the Apollo Telescope Mount, Skylab, Space Shuttle, etc., has increased the monitoring requirements of the manufacturing and storage environments. Although the work is performed and materials are stored in qualified clean facilities, the fact that people work in these areas causes concern for contamination control. People generate contamination by their very presence, particularly particulate contamination. There is no way to know what contamination is generated at a work station without some form of monitoring. It is expensive to maintain manned monitoring equipment at each work station or clean facility. Therefore, the answer is an unmanned monitoring system capable of monitoring certain environmental constituents at the work stations and signaling whenever the preset limits of these constituents are exceeded.

Under the terms of this contract, Lockheed-Huntsville designed and fabricated an analytical system for the evaluation of certain environmental constituents in critical environmental areas for the Quality Reliability and Assurance Laboratory. The purpose of this effort was to provide a self-contained, integrated, minimum-sized unit which will detect, interrogate, and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures and special work benches.

This report presents the results of the CEMS program. The CEMS development summary (Phases A through C) are presented in Section 2. Section 3 provides the CEMS description and operation. Section 4 covers Phase D, Fabrication, Test and Demonstration. Conclusions and recommendations are presented in Section 5 with references in Section 6. CEMS specifications are included in the Appendix.

Section 2
CEMS DEVELOPMENT SUMMARY

2.1 BACKGROUND

The increased demand for more thorough control and timely analysis of environments in which space vehicle and payload hardware are manufactured, inspected and tested necessitates development and/or adaptation of more effective, less manpower-consuming techniques for analyzing such environments. To this end, NASA-MSFC Quality and Reliability Assurance Laboratory personnel initiated a Request for Proposal for the ultimate acquisition of a self-contained, integrated, portable unit which detects, interrogates, and records the environment parameters that are dictated for control in the controlled environments that exist in large storage facilities, clean rooms, temporary curtained enclosures, and special work benches. A portable unit precludes the need for permanent installation of many units that would not be in continuous use.

The system was to analyze the following constituents:

Constituent	Technique	Range	Accuracy
Particulates	Light Scattering	(in microns from) .5-5, 10-15, 20-25 30-35, 40-45, 50-55, 60-65, 70-75, 80-85, 90-95	± 10% full scale in both size and count (sampled at 1.0 ft^3/min)
Hydrocarbons	Flamionization	0-30 PPM	± 5% full scale
Humidity	Wet-dry bulb	30-70% RH	± 1% RH
Temperature	Dry bulb	4-38°C	± 0.5°C

The additional characteristics of the system were:

- Self calibrating
- Audible alarm system
- Digital recorder for simultaneous recording of each constituent
- Data presented directly in engineering units, ppm, % RH, ^{o}C, etc., as appropriate
- Compact, light, portable
- Remote output for hardline transmission of data
- Servicing frequency of less than one time per week.

The effort was to be a four-phase effort. Phase A was a technological survey of the currently available off-the-shelf equipment that could perform the desired analysis. Considerations were to be given to cost, size, weight, repackaging capability, commonality of basic components, etc. Utilizing the results of the survey and tradeoff considerations, several conceptual designs were to be developed and submitted to NASA-MSFC for review and concept selection. Phase B was to develop the preliminary design based on the selected concept. This preliminary design included expected operating specifications, characteristics, and requirements, together with sensor selection and proposed system integration. Upon completion of this phase, a preliminary design review (PDR) was held for Contracting Officer review and approval. Phase C was the final design. This phase was to develop a set of manufacturing drawings that incorporated the findings and recommendations of the PDR. The final phase, Phase D, was system fabrication, installation and demonstration.

The remainder of this section is a summary of the first three phases of the total effort. The final phase is discussed in Section 4.

2.2 PHASE A: TECHNOLOGICAL SURVEY AND CONCEPTUAL DESIGN

A comprehensive technological survey was made to locate available sensors and equipment that could meet the system specifications. The next step was to investigate repackaging of equipment to reduce size and weight of the overall system and to incorporate commonality of basic components (power supplies, air pumps, gas reservoirs, etc). The equipment identified for inclusion in the CEMS was:

Total hydrocarbon analyzer
Hydrogen generator or bottled hydrogen
Catalytic oxidizer or bottled zero gas and bottled combustion air
Bottled span gas
Temperature sensor
Humidity sensor
Particle counter
Sampling pump(s)
Automatic calibration unit
Data logger/printer
Alarm system

The critical pieces of equipment in the CEMS are the sensors.

The total hydrocarbon analyzer is a continuous monitoring instrument designed to detect and measure trace hydrocarbon contaminants. Its operation is based on the ionization of carbon atoms in a hydrogen flame; thus, the name hydrogen flamionization (HFI) analyzer. A flame of pure hydrogen in a pure atmosphere contains a negligible number of ions. The addition of traces of organic compounds results in a large number of ions in the flame. In the analyzer, the air sample is mixed with a hydrogen fuel and passed through a small jet. Pure air supplied to the annular space around the jet supports combustion. Any hydrocarbon carried into the flame causes carbon ions to form. An electrical potential across the flame jet and an "ion collector" electrode suspended above the flame produces an ion current proportional to the hydrocarbon count. The current is fed to an electronic circuit which provides an analog voltage proportional to the hydrocarbon count. The analyzer requires an air pump for sampling, hydrogen for fuel and pure air to support combustion. The hydrocarbon analyzer is calibrated by using zero gas (no hydrocarbon content) and span gas (known hydrocarbon content). This is a field calibration that is performed at prescribed intervals. Several companies manufacture HFI units that meet CEMS specifications. The units are very close in size, shape, weight, accuracy, etc. Upon comparison the HFI unit manufactured by the Mine Safety Appliance Company appeared to be the best choice and was recommended by Lockheed. The HFI analyzer has an analog meter on the face of the unit for direct reading of PPM. The analyzer is also provided with a flame-out alarm and an automatic hydrogen shut-off valve. A hinged door prevents tampering with pressure settings of the fuel and sample. Water formed by the hydrogen flame was to be routed to the hydrogen generator reservoir.

The particle counter utilizes light scattering of incident light on the particles and photo multipliers to size and count the number of particles in the air sample. The desired sample flow of 0.03 m^3 (1.0 ft^3) per minute ensure that a large enough sample will be secured to obtain an accurate count in a low concentration environment (i.e., clean room environment). However, in real life, particle counters do not size particles exactly - they equivocate to a standard - such as a 1.0 micron latex sphere. The counters can easily vary 10% on sizing. Although manufacturers claim a $\pm$ 10% sizing accuracy, this value is questionable. Thus, the operation of the clean room (especially the decision to shut down) becomes a problem of judgment. The counter is ideal to indicate trends so that corrective action can be taken.

A survey of the particle counter manufacturers shows that only two companies manufacture a particle counter capable of sampling at 0.03 m^3 (1.0 ft^3) per minute. Both of the manufacturers claimed they could provide a particle counter capable of meeting the sizing ranges, counting range and sample flow rate discussed in Section 2.1. However, the proposed cost of the dynamic range required for particle sizing resulted in a reevaluation of the particle size ranges. The resultant choice was: 0.5μ to 2.0μ ; 0μ to 5.0μ ; 5.0μ to 20.0μ ; and larger than 20.0μ . The system proposed by the Royco Instruments Company appeared to be the best choice and was recommended by Lockheed. The Royco system consists of a Model 245 mainframe, a Model 45 power supply, two Model 504 pulse conversion plug-in modules with twin channel strip chart recorders, a Model 242 sensor modified for a dynamic range of 40:1 and a Model 173 portable sampling probe. The strip chart recorders on the Model 504 plug-in modules provide the additional feature of real-time recording of particle concentrations. The Model 173 sampling probe provides a means for screening filters as well as a horizontal flow sampling station. The 242 sensor provides a vertical flow sampling station. The manufacturer designs the 242 sensor to operate up to 3.05 m (10 ft) away from the 245 mainframe.

The state-of-the-art in temperature sensors offered no problem in obtaining accurate temperature data with small, light-weight, inexpensive equipment. The Lockheed-recommended temperature sensor package consisted of the Rosemont Engineering Company's Model 414 linear bridge, a ceramic-coated platinum sensor, and an analog meter for direct temperature readout. This system was recommended because of the small size and weight, low cost and the inherent accuracy of the platinum sensor.

The state-of-the-art in humidity sensors ranges from expensive dew-point hygrometers with extremely high accuracies to carbon element relative humidity sensors having accuracies of ± 5 to ± 10% RH. In keeping with the desire for small, lightweight, reasonably priced equipment, the relative humidity sensor built by Phys-Chemical Research Corporation was recommended. The humidity sensor system consists of an electric hygrometric circuit element with temperature compensating platinum sensor housed in plastic shell and an electronic package with an analog meter for visual display. The humidity sensor element has an electric conducting surface on a non-conductive substrate. Changes in the relative humidity cause the surface resistivity to vary. Dust settling on the sensor surfaces will not affect performance except possibly to decrease the speed of response slightly. Such sensors indicate relative humidity with an accuracy better than ± 1.5% RH. over the range of 30 to 70% and over an ambient temperature range of 278 to 333°K (+ 5 to + 60°C).

The feasibility of using common power supplies was investigated. The equipment manufacturers quickly let it be known that they were very reluctant to sell their equipment without power supplies. The power supply is the key to the equipment's stability and, from the manufacturer's viewpoint, selling equipment without the built-in power supplies would result in uncalibrated, unguaranteed equipment. Another consideration of common power supplies is the potential for noise and crosstalk that exists between equipment. This noise could completely destroy the sensitivity and calibration of the equipment. It was decided at this time not to pursue further the common power supply but to maintain the integrity of each piece of equipment.

Another consideration was the use of a common sampling pump for both the total hydrocarbon analyzer and the particle counter. Such a pump must draw the sample through the particle counter (vacuum) and push the sample through the hydrocarbon analyzer (pressure). Such a pump must be a sealed diaphragm or bellows unit that produces no particulate or hydrocarbon contaminates, thus eliminating carbon vane pumps. The best choice appeared to be the Model MB-150 metal bellows pump by Metal Bellows Corporation and was recommended by Lockheed. Initial considerations indicated that a one-pump configuration might be marginal for both the HFI unit and the PC. Therefore a detailed flow and pressure drop analysis was to be performed to determine whether a single pump could be used.

The possibility of using common gas reservoirs was also considered. The total hydrocarbon analyzer uses hydrogen for fuel, pure air for combustion, pure air for zero gas, and span gas (gas with a known hydrocarbon content). In using gas bottles, the purity of the gas varies from bottle-to-bottle, which produces a calibration problem. All bottled gas except the span gas could be replaced by a hydrogen generator and catalytic oxidizer. The generator and oxidizer are larger in volume than the required gas bottles. Therefore, the consideration of gas purity and repeatability versus volume was considered. Since the accuracy and sensitivity of the equipment of the CEMS is of primary concern, the choice recommended was to use a hydrogen generator and catalytic oxidizer.

Changes in calibration occur from sensor deterioration, power fluctuations, and ambient temperature changes. The changes affect the resultant recorded output data. Although electronic equipment is calibrated against known standards, there normally is no way to know the gradual calibration changes that occur until the next time the equipment is calibrated. Thus, an automatic calibration unit (ACU) was needed that would switch in known calibration values to be read through the same electronic system as the sensors. These data would be digitized and recorded in the same manner as sensor data to provide calibration points. These recorded calibration points indicate the amount of calibration error. The operator can then refine the printed output data and decide when total calibration against known standards is necessary. Such a unit was not commercially available, and was to be designed and built by Lockheed.

There were many data logging and alarm systems on the market which could apparently fulfill the CEMS requirements. Specifications would be developed and a selection made in Phase B after sensor and instrumentation choices were firm.

Equipment was then identified that had repackaging potential (apparent excess space). This provides space savings but no weight savings. The equipment so identified was the total hydrocarbon analyzer, particle counter, catalytic oxidizer and hydrogen generator. An attempt was then made to obtain detailed data and drawings from the manufacturers to optimize repackaging. The fact that Lockheed would not declare that we would purchase their equipment and were obviously comparing one company against another or were competition ourselves prompted the companies in question to declare reluctance to release that proprietary information. A conference was held with NASA personnel. It was felt that wholesale repackaging would require a thorough study of electronic-electrical interference, thermal loads and equipment interference, and was beyond the scope of this effort. The decision was to utilize to the greatest extent possible off-the-shelf equipment modified only as necessary to meet the CEMS specifications.

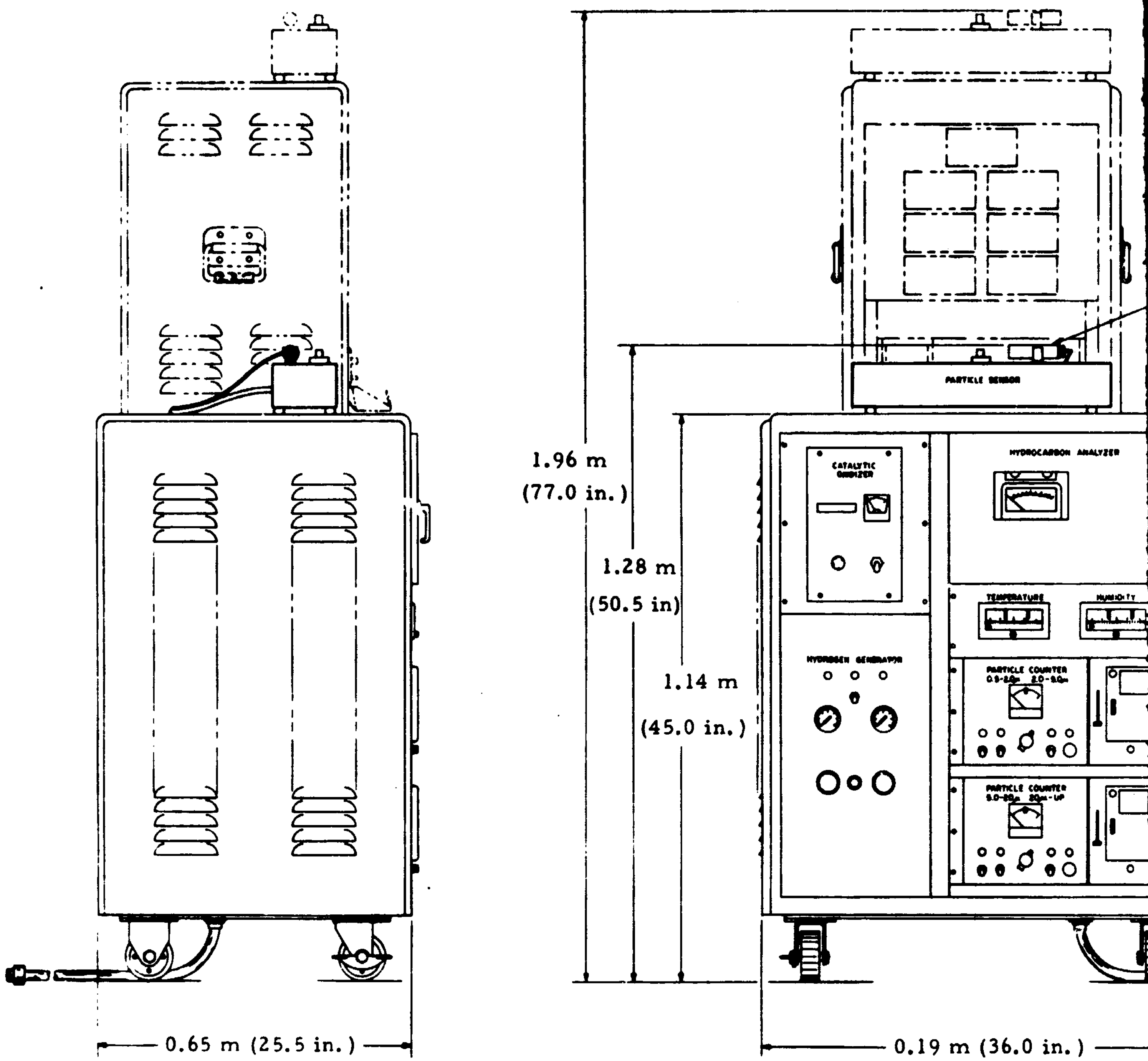
In keeping with the decision of individual equipment integrity (modularized equipment with self contained power supply) a CEMS configuration baseline was developed which uses standard off-the-shelf equipment as purchased from the manufacturer and standard equipment cabinets requiring minimum repackaging. The desire to maintain a small instrument package near the work station as well as to prevent particle contamination by the digital printer led to the initial choice of a two-console CEMS: The instrument console (IC) is shown in Fig. 2-1 and the recorder-alarm console (RAC) is shown in Fig. 2-2. This design also provided more flexibility in that the RAC could be operated completely outside a curtained enclosure or small clean room.

This configuration choice provided a fairly large, 0.91 m (36 in.) wide x 0.65 (25.5 in.) deep x 1.02 m (40 in.) high; and heavy, 90.7 kg (200 lb plus cabinet), console near the work station. Repackaging considerations could reduce the size of the console but not the weight. The single module console was too heavy to be readily lifted or hauled up and down stairs by two men. Therefore, Lockheed recommended the two-module instrument console (TMIC) configuration as shown in Fig. 2-3 together with the same RAC. The drawing shown developed the same CEMS baseline as that of Figs. 2-1 and 2-2. The TMIC resulted in two modules, each of which measures 0.61 m (24 in.) wide 0.69 m (27 in.) high and 0.66 m (26 in.) deep and weighs a maximum of 50 kg (110 lb) plus cabinet. Modules of such size and weight could easily be lifted and carried up and down stairs or loaded into a truck by two men. The potential for operating the modules independently of each other further enhanced the capability of the TMIC.

Lockheed findings and recommendations were documented and forwarded to NASA for review and approval. Results of the NASA review were:

- Three module system as shown in Fig. 2-2 and 2-3.
- Hydrogen generator by Milton Roy Co.
- Catalytic oxidizer by Mine Safety Appliance Co.

FOLDOUT FRAME



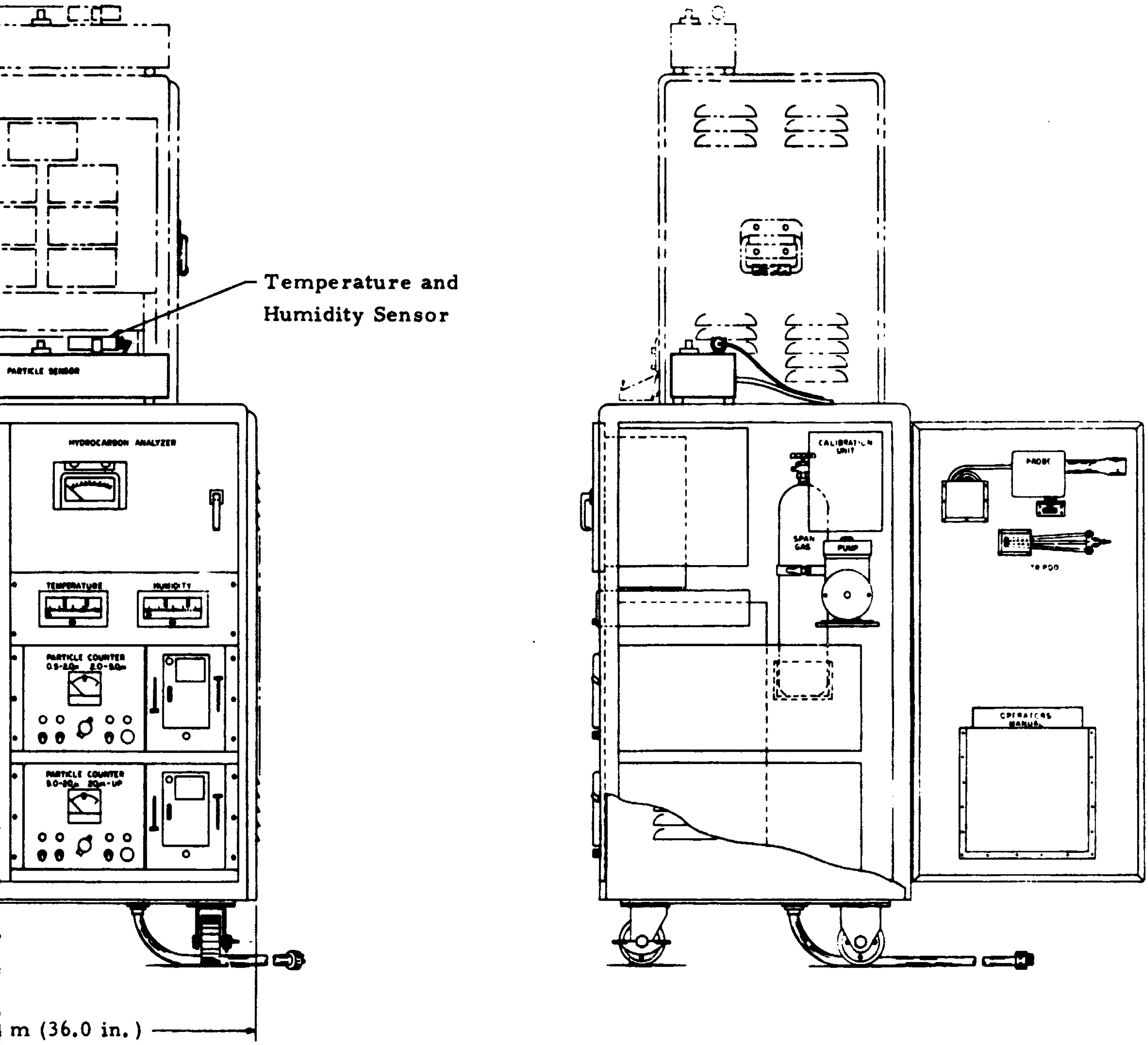


Fig. 2-1 - Instrument Console (IC)

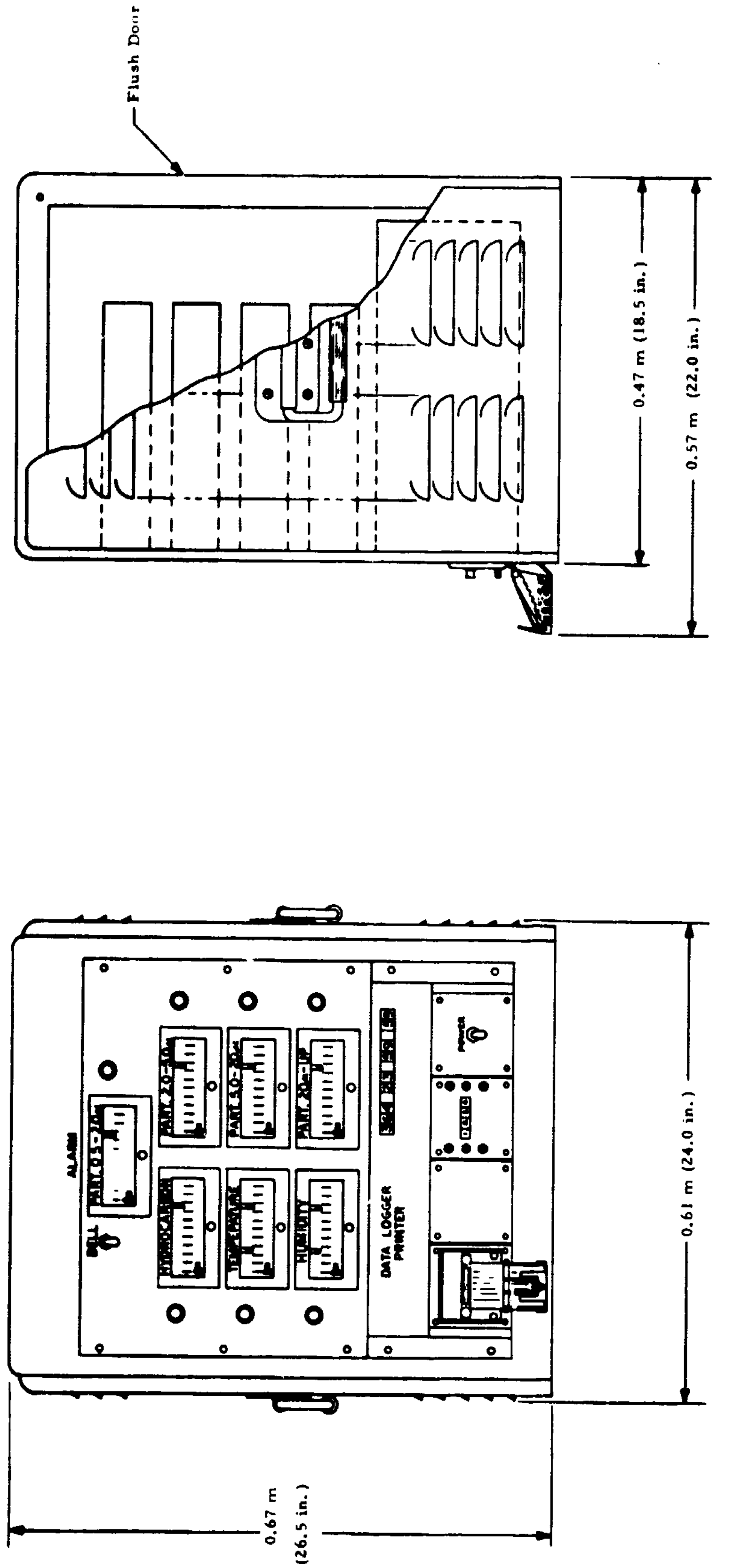
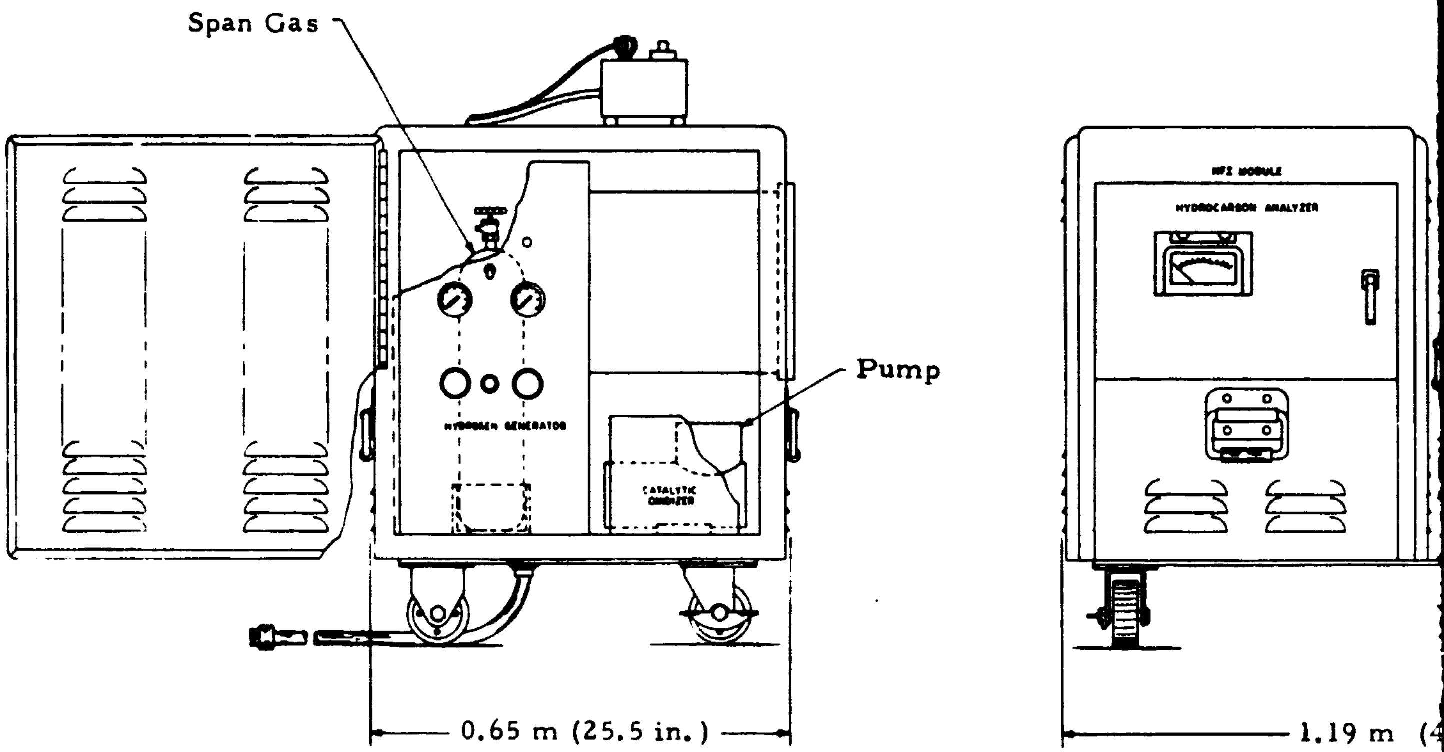


Fig. 2-2 - Possible Recorder-Alarm Console (RAC)


Span Gas
Pump
0.65 m (25.5 in.)
HYDROCARBON ANALYZER
1.19 m

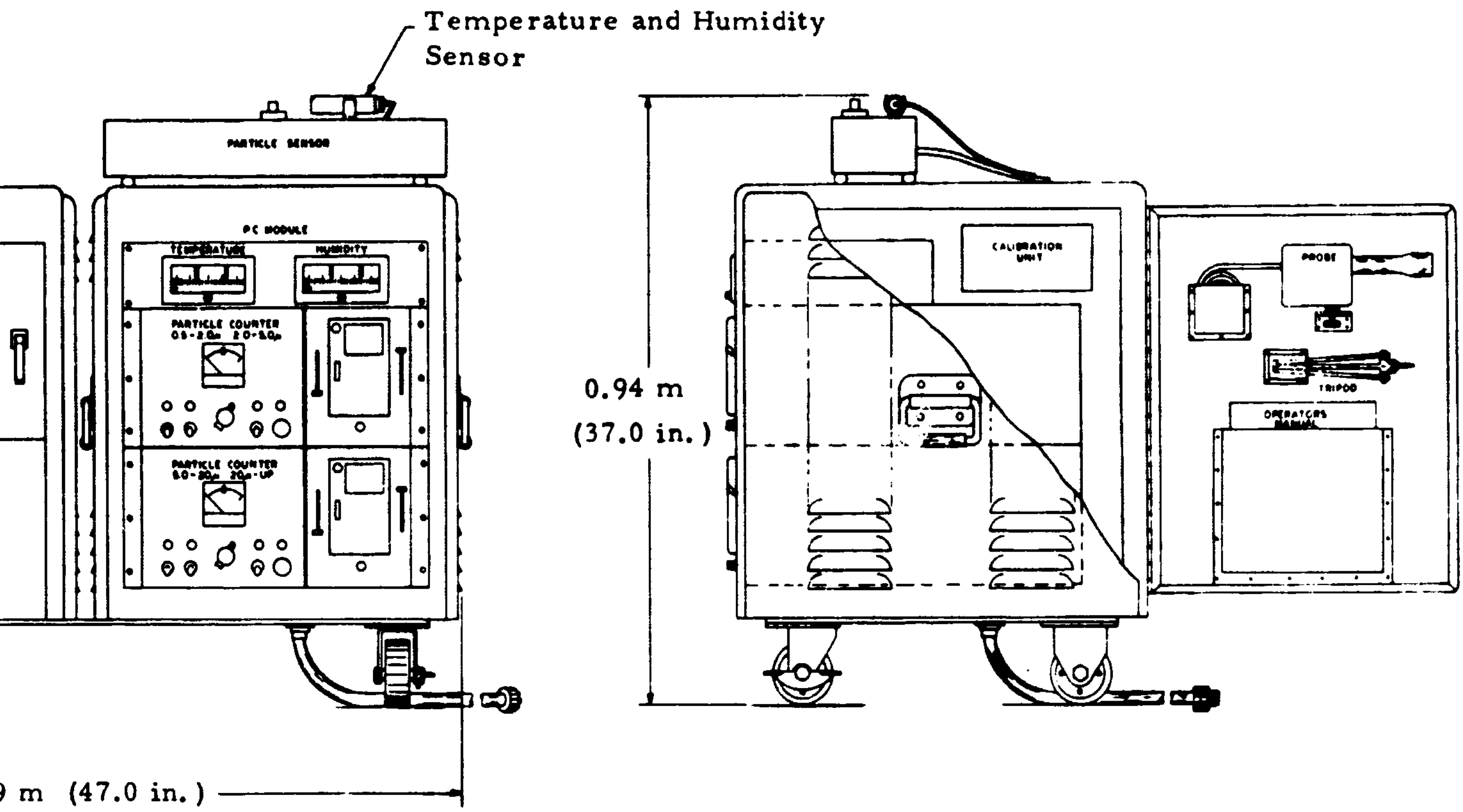


Fig. 2-3 - Two-Module Instrument Console (TMIC)

- Hydrocarbon analyzer by Mine Safety Appliance Co.
- Particle counter by Royco Instrument Co.
- Temperature sensor by Rosemont Engineering Co.
- Humidity sensor by Phys-Chemical Research Corp.
- The use of an instrumentation module dolly large enough to carry the two instrument modules and the recorder-alarm module.
- Surface finishes shall be such as to not outgas at ambient conditions and of a color to optimize visual detection of particulate matter.

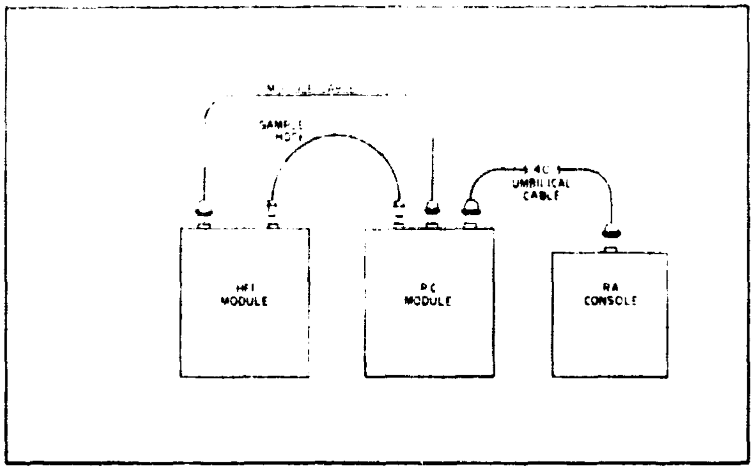
2.3 PHASE B: PRELIMINARY DESIGN

Upon reciept of approval and recommendations of Phase A, Phase B was initiated. During this phase a set of CEMS specifications was developed, design analysis was performed, and a set of preliminary design drawings completed. The resultant configuration is shown in Fig. 2-4.

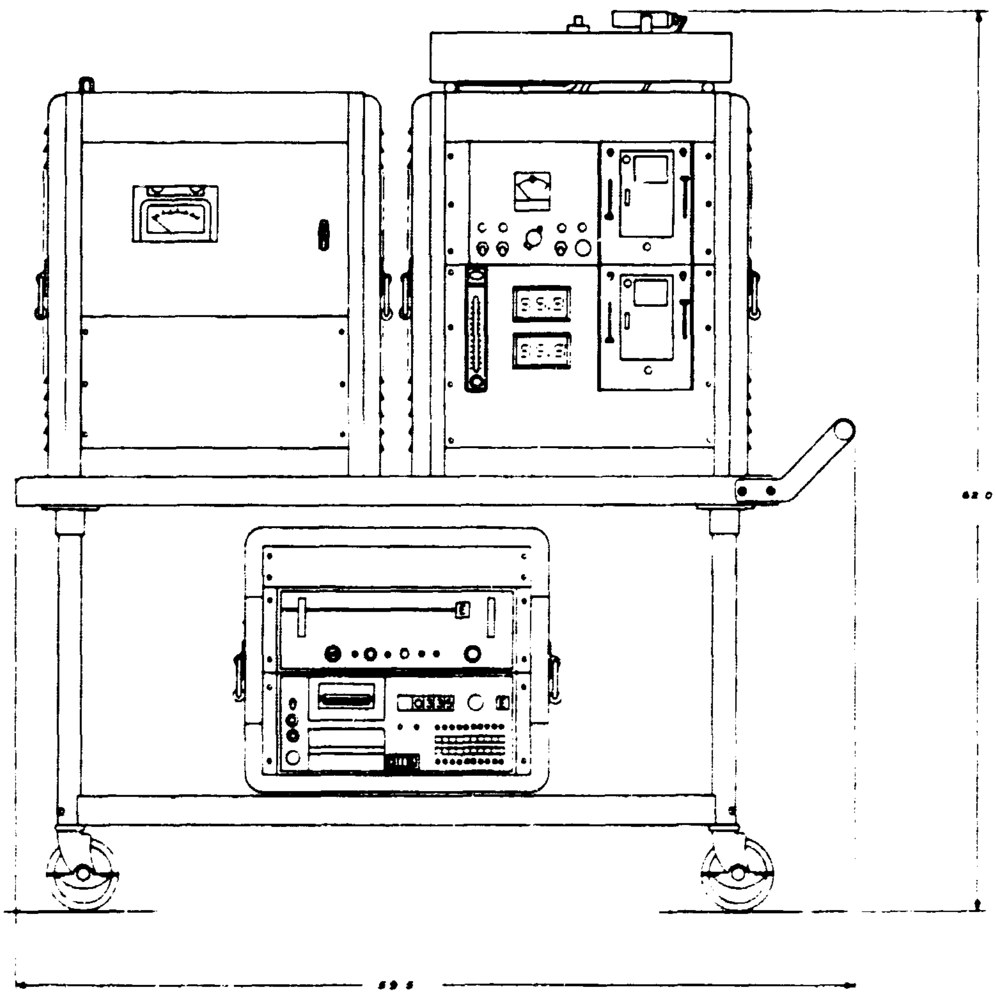
A study of the instrumentation modules was performed to determine the ventilation requirements. Since the HFI module contained the greatest heat producer, the catalytic oxidizer, a study was performed to determine the catalytic oxidizer's effect on the temperature of the HFI module. The catalytic oxidizer uses 300 watts power to maintain a catalytic oxidizer filter bed at $600^{\circ}F$ maximum. A computer-programmed thermal analysis was performed on the case of the oxidizer. Under normal room conditions in a non-ventilated cabinet with no fan, the oxidizer case would remain between 585 to $610^{\circ}K$ (125 to $150^{\circ}F$). An air flow of only 0.23 cubic meters/minute (8 cubic feet/minute) will maintain the case below $570^{\circ}K$ ($110^{\circ}F$) and the air in the module at $540^{\circ}K$ ($80^{\circ}F$).

As a result of this study, all modules were to have louvered side panels to provide adequate exchange of air, with the HFI module utilizing a small fan capable of a flow of 2.8 cubic meters/minute (100 cu ft/min). Thus, all modules were expected to maintain an internal air temperature of only a few degrees above the temperature of the area in which they are operating.

FOLDOUT FRAME 1



INTERCONNECT DIAGRAM



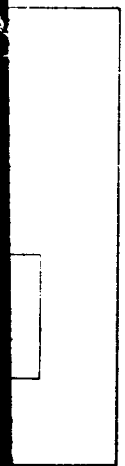
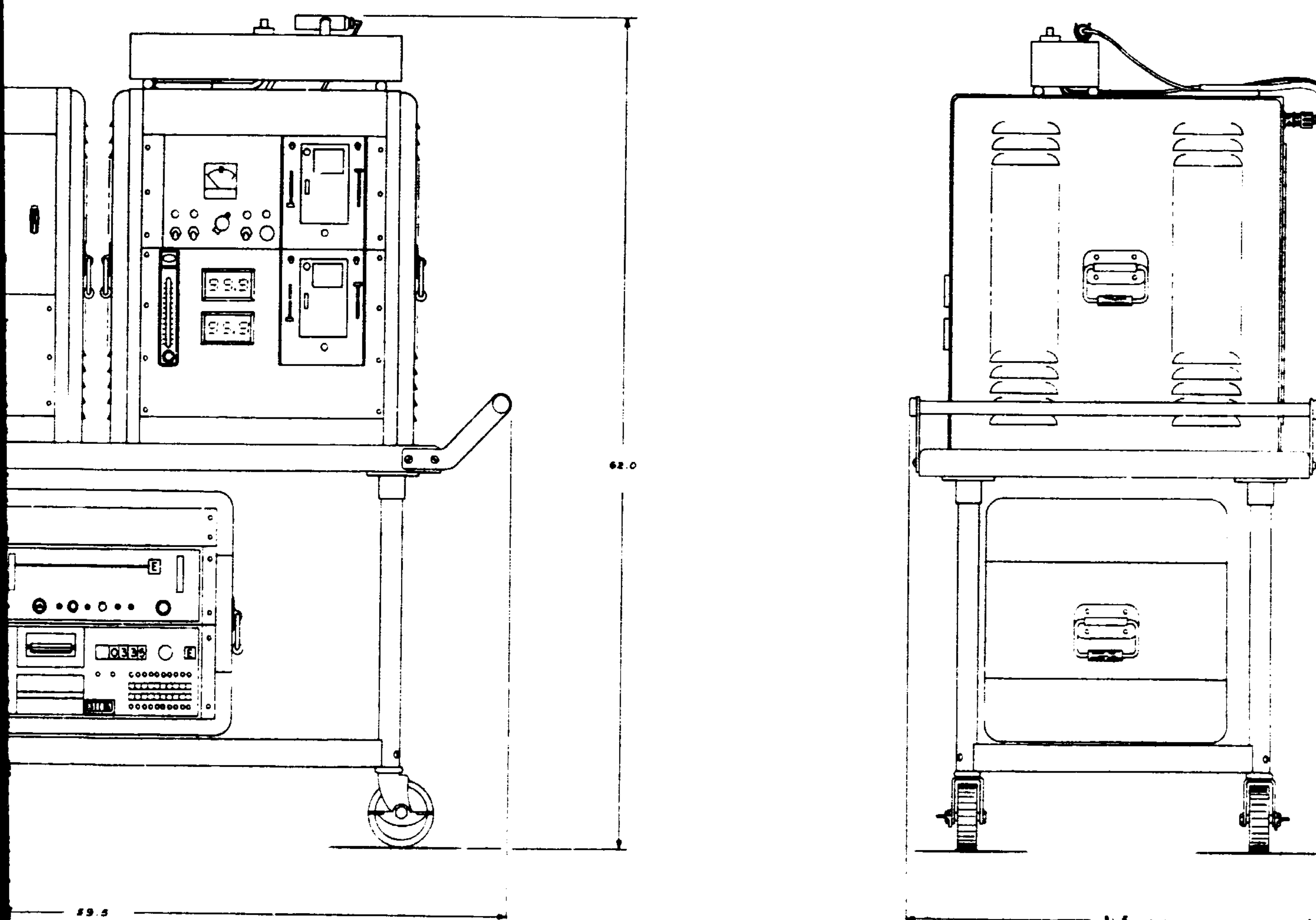


Fig. 2-4 - Critical Environment Monitoring Systems



As a result of the choice of the two-module instrument console concept with each module capable of independent operation, an analysis to determine single sampling pump requirements was not required. Each module has its own sampling pump. The tubing size used in each module is the same as that used in the original equipment so as not to impair sample flow. The pressure-flow capabilities of the pump selected met the requirements of the pump normally supplied with the particle counter. An added feature of the modified system was the flowmeter and flow control valve that provided adjustment of the flow to exactly 0.28 cubic meters/minute (1.0 cu ft/min).

The electronic interface between the sensors and the data logger and alarms was of major concern, because it was necessary to ensure that no additional error was introduced into the system by the data logger or alarms loading the sensor signals. A study of the various systems shows that the load impedance offered by the various data-logger/alarm systems ranges from 100K ohms to 100M ohms. Since the output impedance of the selected data-logger/alarm system was 100M ohms and since the output impedance of the sensors was all low (100 ohms or less) no significant error would be introduced in the system.

A study of the ACU showed that it could use time delay relays more economically than an electromechanical programmer. Since the flow rates of the HFI analyzer are large enough for fairly fast response (several-second response), no long time delays are required before the data logger scans the calibration data. The time delay relays also offer the flexibility of changing the calibration timing to provide optimum calibration data.

The components were reviewed and studied to reduce their weight and volume, which reduces the weight of each module. Such reviews led to the redesign of the Model 245 particle counter to completely eliminate the need for the Model 45 power supply (at virtually no price change) and thus operate both model 504 plug-in modules from the single 245 main frame. This provided a 9.1 to 13.6 kg (20 to 30 lb) weight savings in the PC module. The hydrocarbon analyzer vendors are firmly against repackaging, because the electrical shielding and temperature control are very critical for an analyzer having high sensitivity. Also, the vendor warranty will not apply if the component parts are rearranged in any other way than specified in the original design and construction.

Other components, although their cabinets may not be completely removed because of the necessity for electronic shielding, can be lightened by removing non-essential parts of the cabinet. The weight distribution within the modules was considered in component location, although physical size was the prime factor. Components will be continuously reviewed throughout the contract for repackaging to minimize volume and weight.

Detailed discussions with seven different data-logger vendors about sensor accuracy, system requirements (such as fullscale signal level, printer format, and printer control), and cost resulted in the following data:

- Signal levels will be 0-100 mV fullscale when feasible with lesser values (0-10 mV or 0-1 mV) when required.
- Sensor accuracy alone requires only 4 columns of printout instead of 5.
- Twisted pair signal wires allow consoles to be separated by up to 40 feet.
- No two vendors handle the data printout and format the same way (different format and control signals requiring different number of signal wires).
- Modification to the standard off-the-shelf equipment to provide similar format proves to be expensive (standard $4K systems increase to $7.5K to $10K).
- Systems offer typical accuracies of $\pm$ 0.1% reading, one digit, or 5 microvolts, whichever is greater $\pm$ 1 digit.

Competitive bids were received from the data-logger vendors. The low bid was Esterline Angus.

Although white has always been standard equipment color for clean rooms in the past, the U.S. Air Force has begun to use other colors. According to Mr. Philip R. Austin of Contamination Control Laboratories, the Air Force closed one of its largest clean rooms as a health hazard. Everything (including portable equipment) within the room was white. As a result, personnel experienced the loss of depth perception ("white-out" or "snow-blindness") when they were in the room, resulting in personnel injury and equipment damage (dropped or knocked over).

Obviously, if the colors are changed this problem would be eliminated, but further consideration of the particulate size within the clean room (mostly less than 0.3μ) showed that accumulations of these particles would appear white to the naked eye and thus white equipment would tend to mask the accumulation rather than reveal it. Only particles of much larger size would reveal color to the naked eye and they should be rare in the clean room. Thus, a dark color should more readily reveal particulate accumulation. It was therefore recommended that the CEMS be black.

Lockheed findings and recommendations were documented and forwarded to NASA for approval. A PDR was also held. Results of the PDR and NASA review were:

- Configuration shown in Fig. 2-4 to be used in final design.
- Data-logger and alarm system by Esterline Angus.
- Internal interface for nine-track 800 BPI incremental magnetic tape recorder.
- Covered side panels for instrumentation modules.
- Cooling fan in HFI module.
- Sampling pump for each instrumentation module.
- Black module cabinets be used.
- Allow for span gas recharging without disassembly of span gas bottle.

- Provide protective face covers on data-loggers to prevent "knob twittling".
- Provide common-key locks on all hinged access doors.

2.4 PHASE C: FINAL DESIGN

Upon receipt of approval and recommendations of Phase B, Phase C was initiated. A complete set of manufacturing drawings incorporating the results and recommendations of Phase B was developed. A complete set of system specifications was finalized, which are provided in Appendix A. The only major changes were the recommendations that (1) plain side panels be used on the instrumentation models rather than louvered ones so that carrying handles could be mounted more easily, and (2) digital panel meters be used rather than analog meters for temperature and humidity. The configuration was the same as that shown in Fig. 2-4 except for louvered side panels.

A set of drawings together with Phase C report was forwarded to NASA for approval. The design as submitted was approved without exception. Results of Phase D are discussed in Section 4.

Section 3
CEMS DESCRIPTION AND OPERATION

3.1 FUNCTIONAL DESCRIPTION

The CEMS (Fig. 3-1) consists of three modules housing equipment to monitor and record particle count and size, hydrocarbon content, temperature, and humidity of a clean room environment. Two modules are instrumentation modules and the other a recorder-alarm (RA) module. The two instrumentation modules are the PC module (Fig. 3-2) and the HFI module (Fig. 3-3). The PC module houses the particle counter, temperature sensor, and humidity sensors. The HFI module houses the total hydrocarbon analyzer and its support equipment. Each module houses a sampling pump, allowing each module to operate independently of the other or together as a single console. The RA module (Fig. 3-4) connects to the instrumentation modules by a single 40-foot long umbilical cable. The umbilical cable consists of shielded, twisted pair wires. Thus, both ac power and analog dc signals can be transmitted to the RA module without cross-talk. Quick connect electrical and pneumatic connectors are used to interconnect the modules and consoles. Protective covers on the connectors minimize contamination or damage during transporting or storage. Figure 3-5 provides the electrical block diagram and Fig. 3-6 provides the pneumatic diagram.

An umbilical cable and flexible pneumatic hose connect the HFI module to the PC module. The RA module may be connected either to the HFI module or to the PC module, or the two modules can be operated independently of the other. This allows the critical environment monitor equipment to be utilized for particle count analysis (including temperature and humidity) and total hydrocarbon analysis at different locations. Such a concept provides two modes of operation (standard and alternate) as shown in Fig. 3-7. If two RA modules were available, then both modules would have alarm, calibration and printer capabilities when operated in the alternate mode.

Fig. 3-1 - Critical Environment Monitoring System (CEMS)

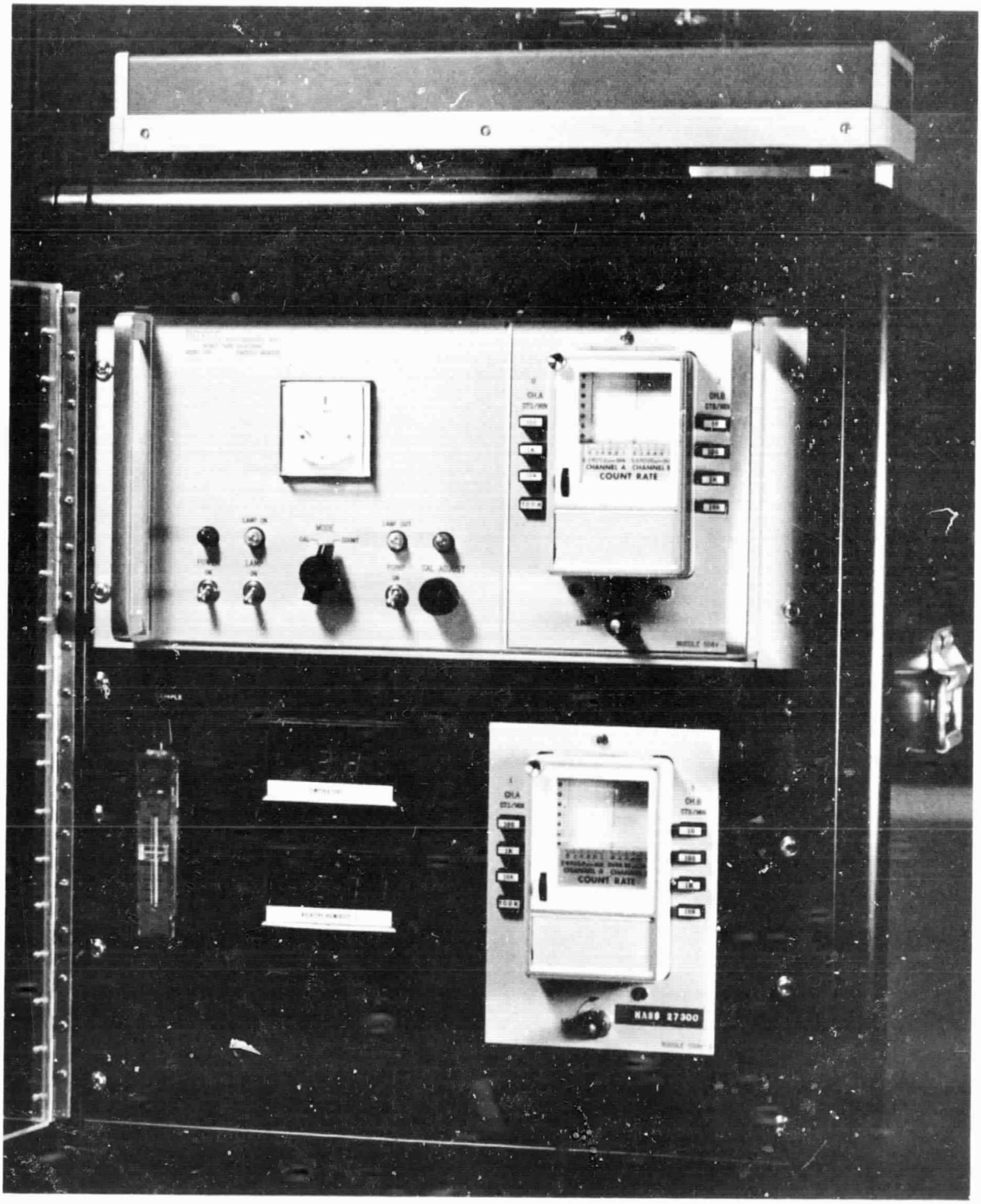


Fig. 3-2 - PC Module

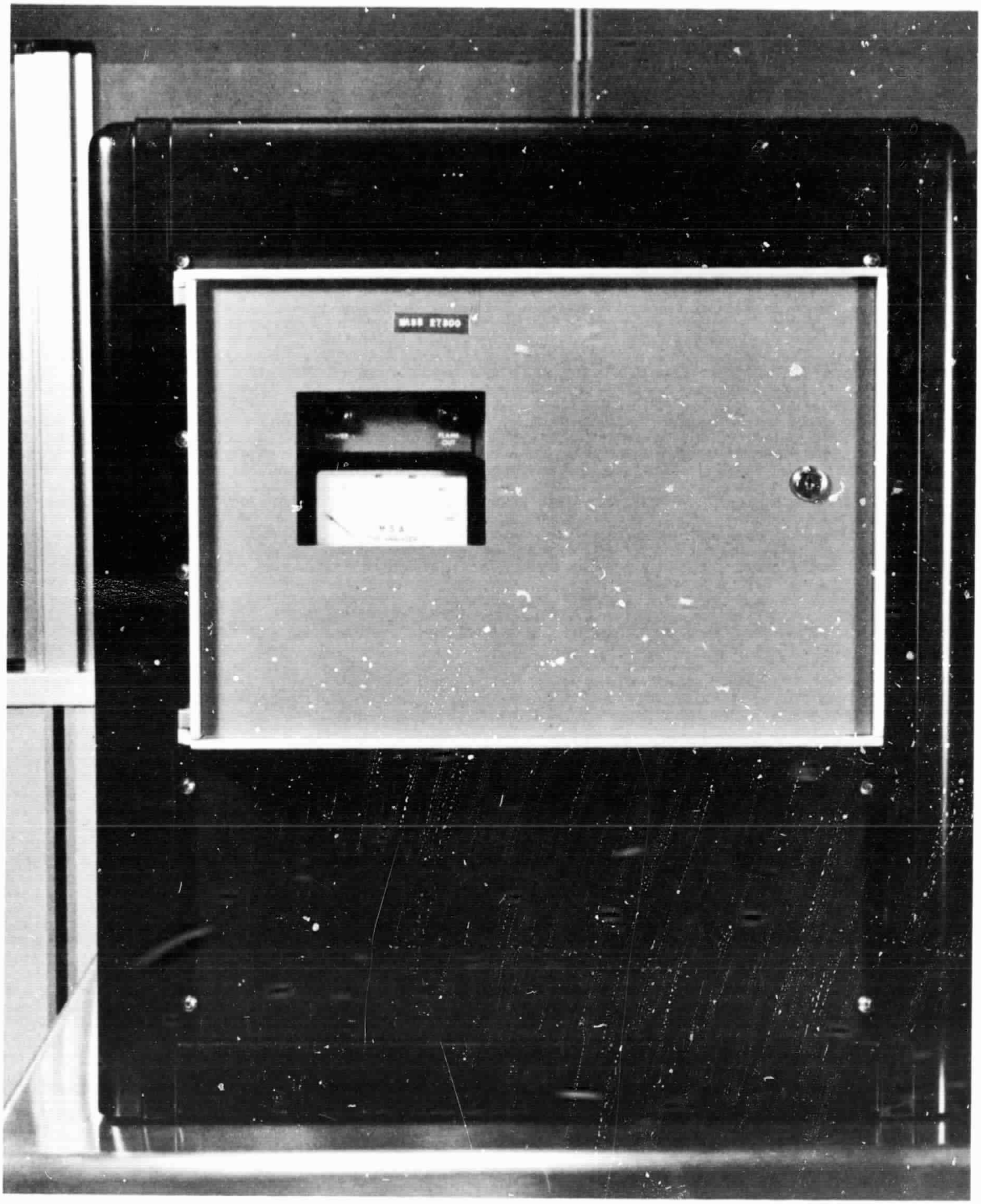


Fig. 3-3 - HFI Module

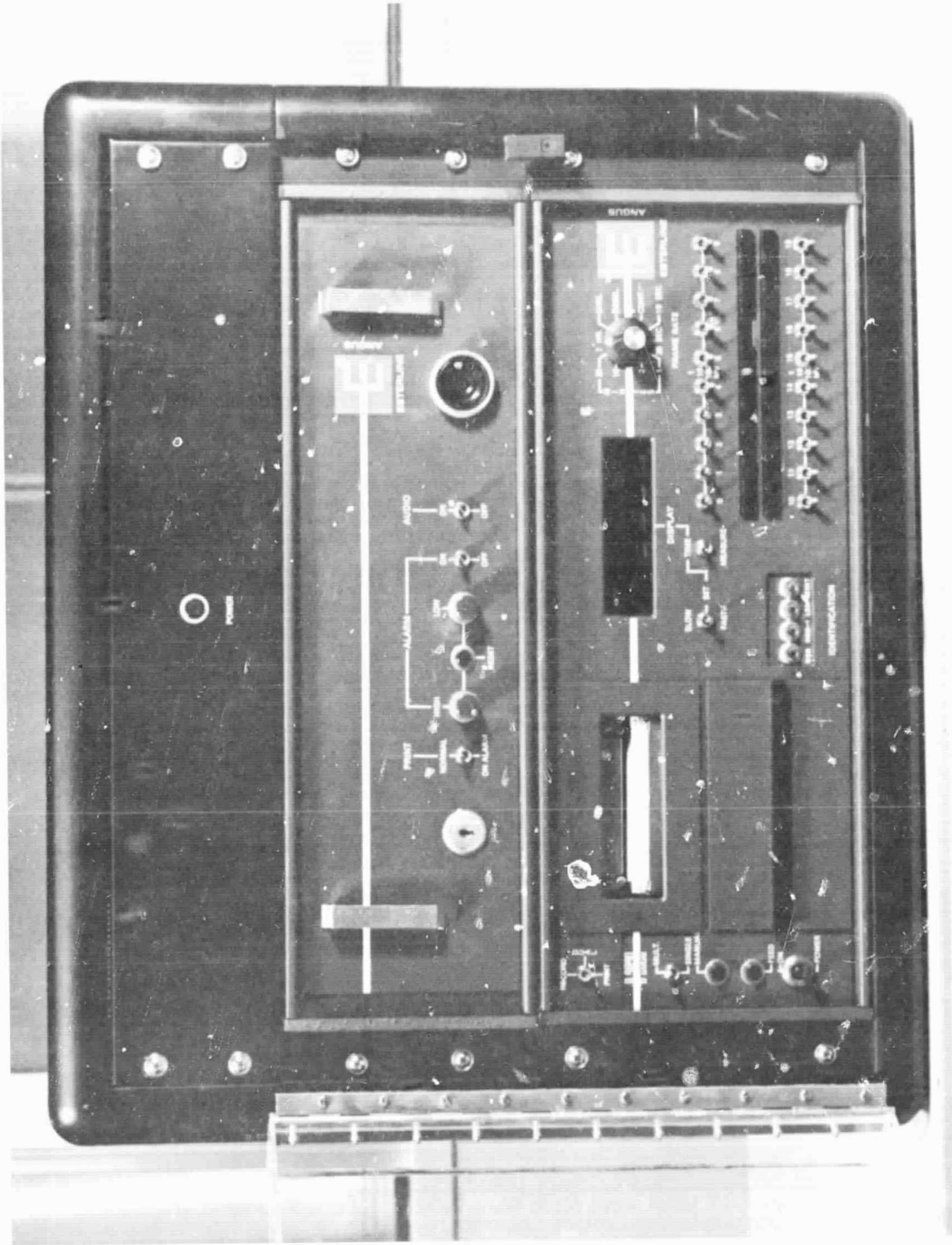


Fig. 3-4 - RA Module

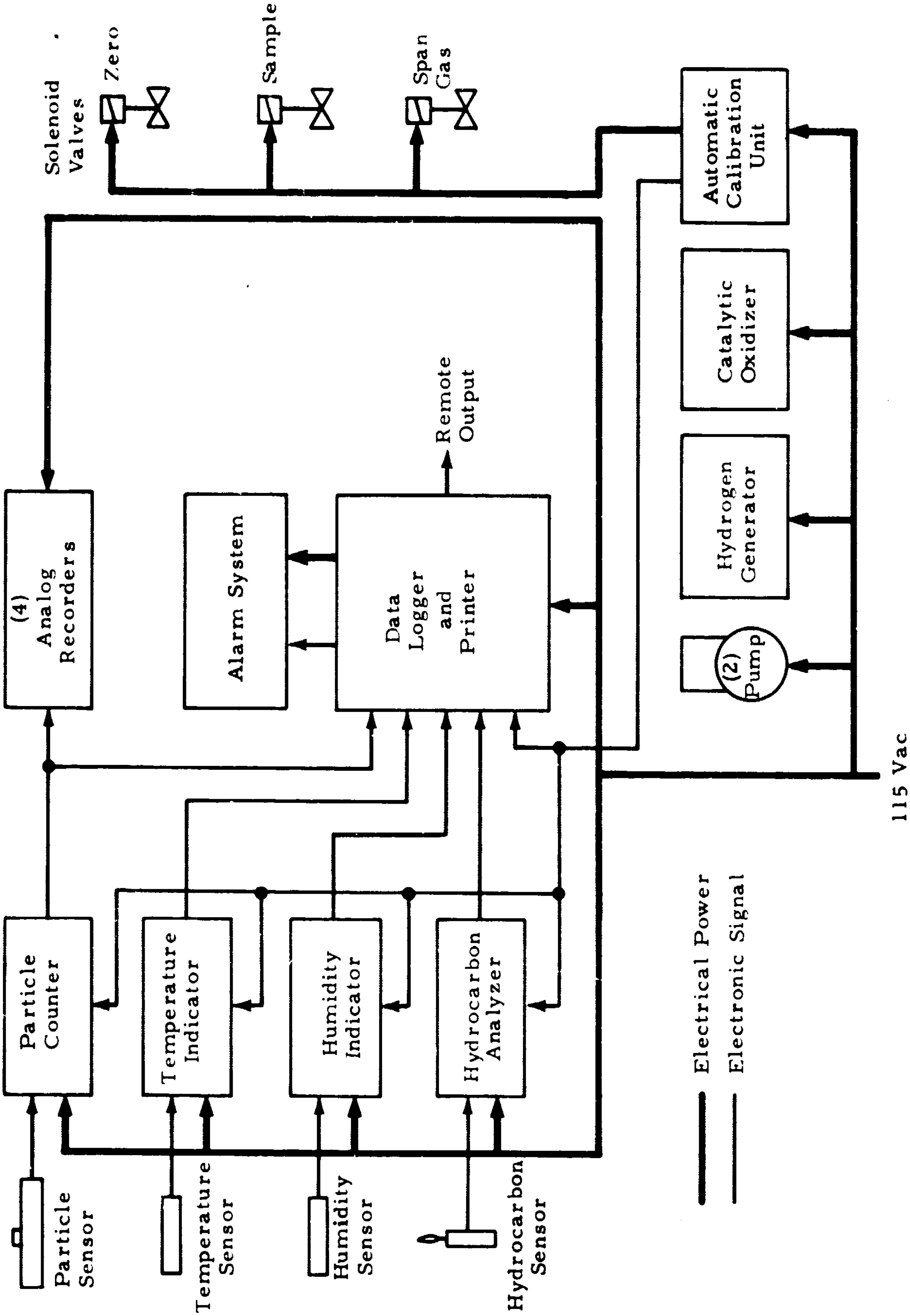


Fig. 3-5 - Electrical/Electronic Block Diagram CEMS

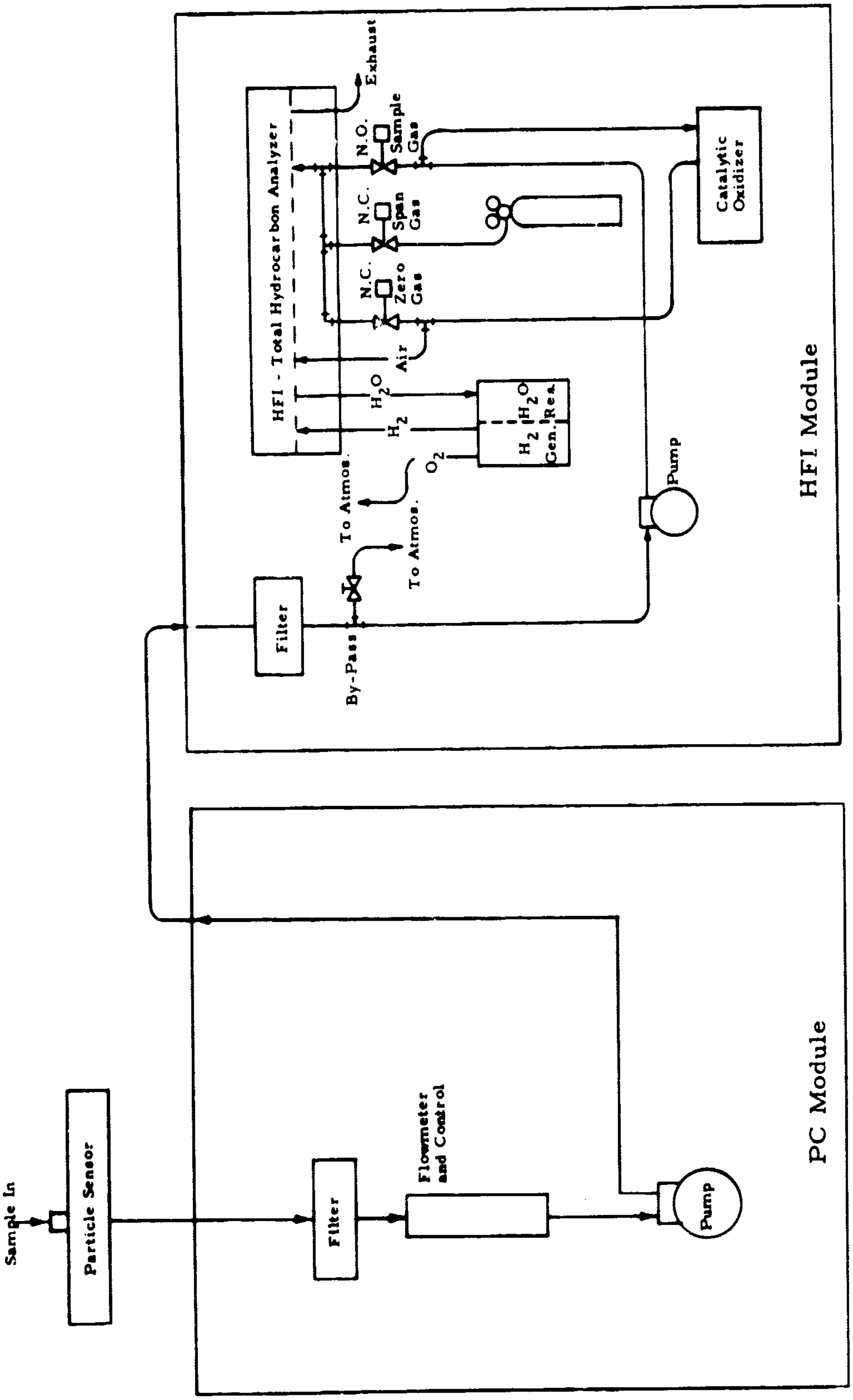
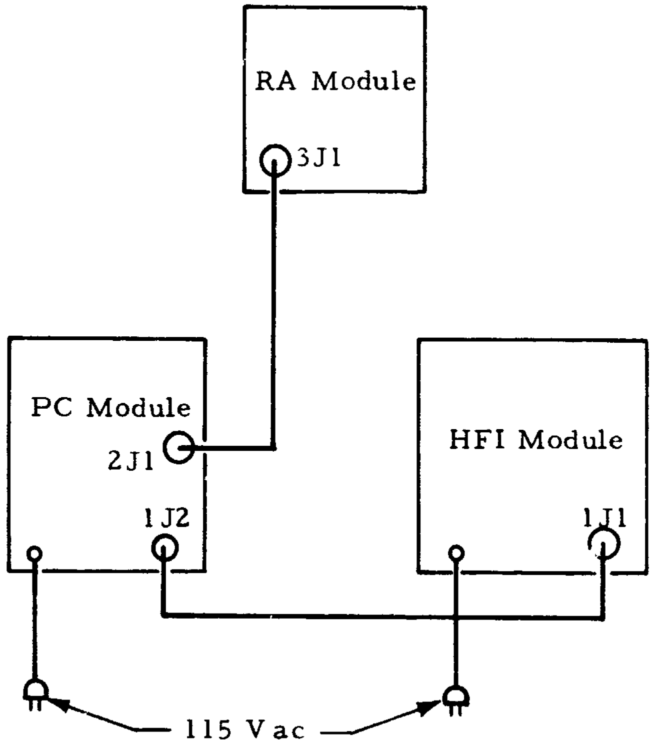
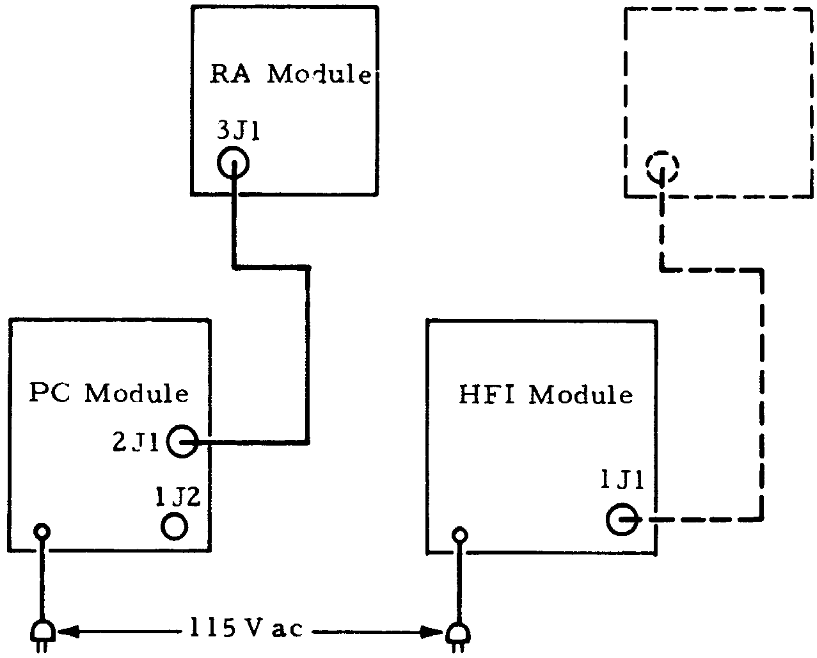


Fig. 3-6 - Pneumatic Diagram Critical Environment Monitoring System



Standard Operating Mode



Alternate Operating Mode

Fig. 3-7 - Operating Modes

Since each piece of equipment has its own power supplies, 115 Vac power must be provided to the system. The HFI and PC modules each have a standard power cord. The RA module obtains power from the module to which it is connected. A switch and circuit breaker mounts in each module and provides master power control to that module.

The dolly shown in Fig. 3-1 is of all stainless stell construction. The paint selected for the exterior painted surfaces of the console and equipment will be an enamel or acrylic paint sufficiently baked so as not to outgas at ambient conditions. The black color selected will provide optimum visual detection of particular matter.

The PC module samples the environment at a sampling rate of 0.03 m^3/min (1.0 ft^3/min). The sample is drawn through a particle sensor and then a particle filter to the pump. The temperature and humidity sensors in a common housing are mounted on top of the particle sensor. In the standard operating mode, the sampled air is pumped to the HFI module. In the HFI module the sample is pumped to the total hydrocarbon analyzer and the catalytic oxidizer. All excess sampled air is released prior to the HFI pump by a manually regulated by-pass valve. In the alternate mode of operation, the by-pass valve is closed and the HFI pump draws its own sample. In the PC module the pump expels its sample to atmosphere.

The RA module houses the data acquisition and the automatic calibration unit. The data acquisition continuously monitors the various constituents and prints out data at manually set intervals or on alarm. A typical data frame is shown in Fig. 3-8. Alarm limits are manually set for each data channel. In the alarmed condition, a buzzer sounds. The channel which exceeds limits is printed in red. The data acquisition system also provides interval interface for a 9-track, 800 BPI incremental magnetic tape recorder.

The ACU consists of a 24-hour timer having variable settings and two time delay relays with variable settings. The ACU:

Channel Number

Data

English Units - Meaning:

Channel Number	Data	English Units	Meaning
Ch06	007.2	P/M	7.2 parts per million
Ch05	025.2	^{o}C	25.2 degrees Celsius
Ch04	051.3	RH	51.3% relative humidity
Ch03	.702	PA	7 part/ft^3 (20μ - larger)
Ch02	.247	PB	24 part/ft^3 (5.0μ - 20μ)
Ch01	5.17	P	5170 part/ft^3 (2.0μ - 5.0μ)
Ch00	047.6	P	47,600 part/ft^3 (0.5μ - 2.0μ)
312	01:29	HR	1:29 hours

Day of Year   Time   Frame Heading

NORMAL DATA

NOTE 1: All channel data printed in red indicates calibration mode. Alarm mode is indicated by alarmed channel printed in red. Low sample flow rate indicated by frame heading (day-time-hour) printed in red.

NOTE 2: Selector ranges for particle counts are:

100 mV full scale - 100 K part/cu ft

10 mV full scale - 10 K part/cu ft

1 mV full scale - 1 K, 100, and 10 part/cu ft

NOTE 3: All particle count readouts are in K particles/cu ft when P appears. When PA or PB appears: PA - 10 part/cu ft (read 2 MSD only); PB - 100 part/cu ft (read 3 MSD only).

NOTE 4: Temperature, humidity and hydrocarbons are always set on 0 - 100 mV fullscale range.

Fig. 3-8 - Typical Data Frame Printout

1. Switches in a precision, temperature-insensitive resistor in place of the temperature and humidity sensor elements;

2. Switches the particle counter into the calibrate mode;

3. Turns off the sample gas solenoid valve to the hydrocarbon analyzer and turns on the zero gas solenoid valve;

4. Switches the frame rate of the printer to continuous scan;

5. Allows time (15 seconds) for the hydrocarbon analyzer to be purged by the zero gas;

6. Turns off the zero gas to the hydrocarbon analyzer and turns on the span gas;

7. Allows time (15 seconds) for the analyzer to read the span gas;

8. Turns off span gas to hydrocarbon analyzer, turns on sample gas and switches the printer frame rate back to original scan rate;

9. Turns off ACU until new signal received from 24-hour timer.

The timing sequence is shown in Fig. 3-9. The ACU can be used in either the standard or alternate operation mode.

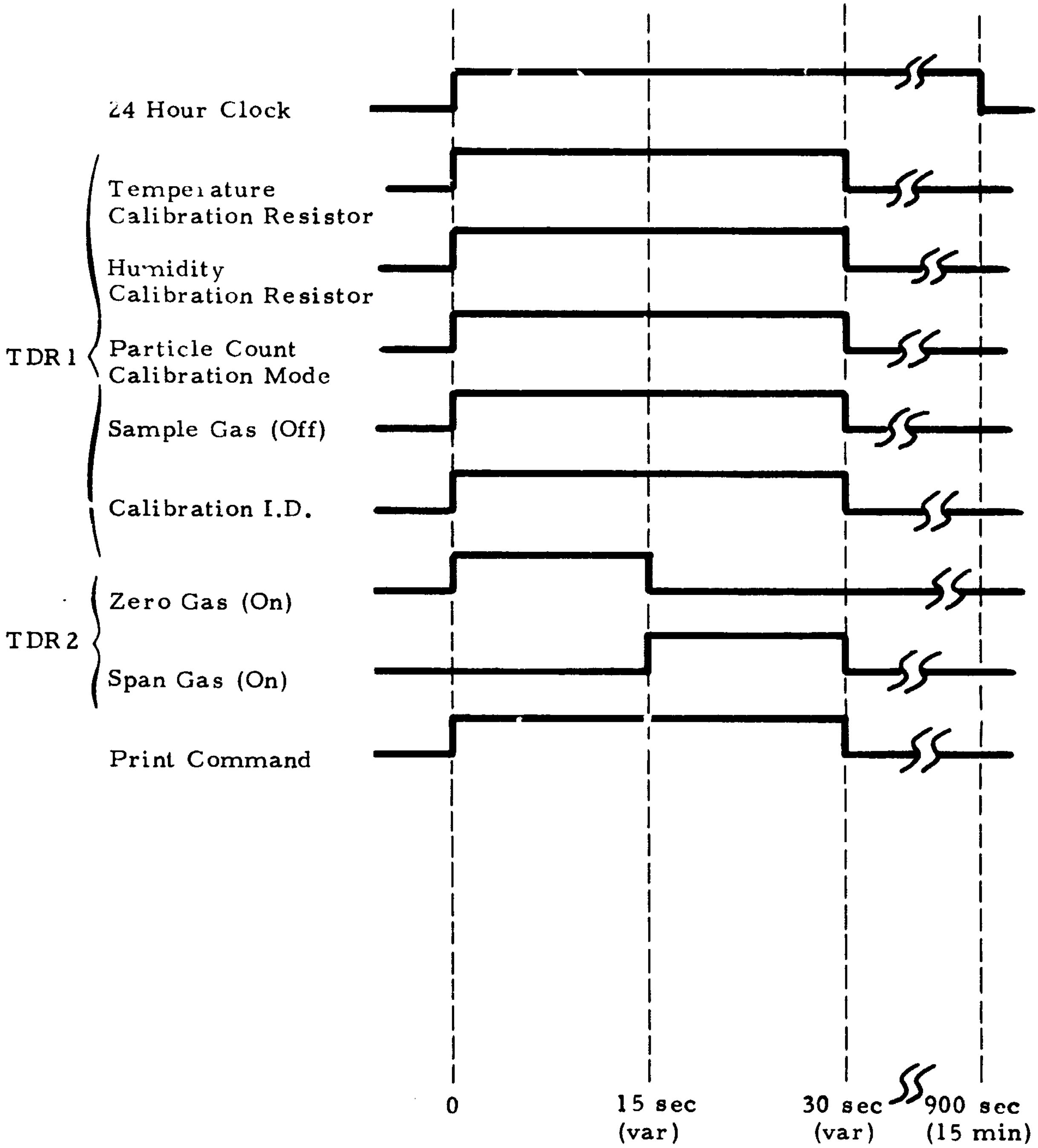


Fig. 3-9 - ACU Timing Sequence

3.2 CEMS OPERATION

These CEMS operating procedures are based on the assumption that personnel are thoroughly familiar with the detailed operating procedures found in the operations manual for each piece of equipment. Proper packaging procedures, such as cleaning and double-bagging, must be followed so that the CEMS can be taken into clean areas. The following procedure takes place after the equipment is unbagged:

- Place HFI and PC modules on instrumentation dolly.
- Place RA module at desired location.
- Place master power switch in HFI and PC module to OFF.
- Connect long (40 foot) umbilical cable from RA module to PC module.
- Connect short (3 foot) umbilical cable and pneumatic hose from HFI module to PC module.
- Place sensor package at desired location and connect to PC module.
- Ensure all equipment, pump and solenoid valve power switches in all modules are off. Plug in PC module and HFI module power cords to 110 Vac power source.
- Open back door and turn on master power switch of PC and HFI modules.
- Open door of Hydrocarbon Analyzer (HC), turn on main power.
- Open HFI module back door and turn on catalytic oxidizer. Turn on hydrogen (H_2)generator (ensure H_2 output valve is closed).
- Turn on main power of particle counter.
- Turn on particle counter lamp.
- Switch to "calibrate" and adjust to red line.
- Switch to "count" and select desired count rate for particle size channels.
- Open top door of HFI module and ensure sample bypass valve is fully open. Turn on particle counter pump and adjust flow to 60 scfh.
- Open HFI module top door and check to make certain flow valve on span gas bottle is closed (fully clockwise). Open bottle valve for span gas.
- On hydrogen generator adjust interstage pressure regulator to 70 psig and output pressure regulator to 30 psig. Open H_2 output valve fully.

- Open HC door. Turn on pump. Turn on sample solenoid. Fully open valve on top of sample flow meter.
- Open top of HFI module and adjust sample inlet valve on back of HC for sample flow of 4 scfh.
- Open HC inner door, adjust air pressure regulator to 7 psig. Set attenuator switch to X300.
- Press ignite button and while holding depressed adjust hydrogen pressure to 15 psig. After setting pressure release ignite button. If ignition occurs, flame out light will go out and up-scale meter deflection will be observed. If not H_2 pressure will begin to drop. Push ignite button and hold for 3 seconds. If ignition still does not occur repeat above procedure and increase H_2 pressure to 20 psig.
- After ignition set air pressure to 20 psig, H_2 pressure to 10 psig and sample flow (using sample valve in back of HC) to about 4 scfh.
- Turn attenuator switch to X10.
- If HC has not been used for several weeks, no calibration adjustment should be made for several hours.
- Turn off sample switch and turn on zero switch. Adjust meter to zero if necessary with zero trimpot.
- Turn off zero switch and turn on span switch. Open span gas flow valve on pressure regulator and adjust flow to 4 scfh on front flow meter. Allow system to flush for several minutes. Adjust span reading with span trimpot if necessary.
- Turn off span switch and turn on sample switch. HC is now in full operation.
- Check H_2 generator for proper water level and empty condensate bottle.
- Check power light on RA module to ensure power is available.
- Turn on data logger.
- Open alarm drawer, set desired alarm levels, close drawer, set print switch to "normal" or "on alarm" as desired, and set audio switch to desired position.
- Set digital clock to proper time and day identification to proper day.
- Set frame mode toggle switch to MULT.
- Set frame rate switch to desired rate.
- Set voltage level toggle switches for each channel to proper level.

Ch	Parameter	Range (mV)
0	0.5μ to 2.0μ	100 K - 100
1	2.0μ to 5.0μ	10 K - 10
2	5.0μ to 20.0μ	1 K - 1
3	20μ and larger	100, 10 - 1
4	Humidity	100
5	Temperature	100
6	Hydrocarbon	100

100 part/min prints PB indicator – read 3 MSD on printout

10 part/min prints PA indicator – read 2 MSD on printout

- Depress channel 6 pushbutton.
- Push manual print button for sample printout.
- Open top of RA module. Remove cover plate of ACU. Set 24-hr timer to proper time and set calibration timer according to instructions on inside of ACU cover. Replace ACU cover.
- Switch manual override switch to ON for sample calibration printout. When printout is complete, return manual override switch to OFF.
- WARNING – if manual override switch left in ON position, ACU will not operate.
- The CEMS is now in full operation.

Section 4

FABRICATION, TEST AND DEMONSTRATION

4.1 FABRICATION

Approval to commence Phase D was received on 14 January 1972 and all equipment necessary to fabricate the CEMS was ordered by 20 January 1972. Fabrication was delayed until most of the equipment was received so as to eliminate fabrication interruptions and learning curve losses which can cost manhours. Only four items had promised delivery dates that caused concern. However, the hydrocarbon analyzer delivery date slipped, which caused much concern about meeting the contract completion date of 23 April 1972. Since slippages were expected in other deliveries, the contract was extended to 23 June 1972. A summary of the delivery problems is as follows:

Item	Promised Del. (1972)	Actual Del. (1972)
Hydrocarbon Analyzer	3 March	31 March
Connectors	25 March	15 May
Particle Counter	27 March	4 April
Temperature Sensor	10 April	22 February
Data Logger	15 April	13 May

As equipment delivery began, checks were performed for compliance with specifications. During this same time a class 100 clean bench was installed at Lockheed for use with the CEMS' performance tests. The bench was certified by MSFC Quality and Reliability and Assurance Laboratory.

During fabrication, several changes became necessary. The particle probe that was to be mounted on the inside of the rear access door to the PC Module was mounted inside the module (Fig. 4-1). The filling valve and tee

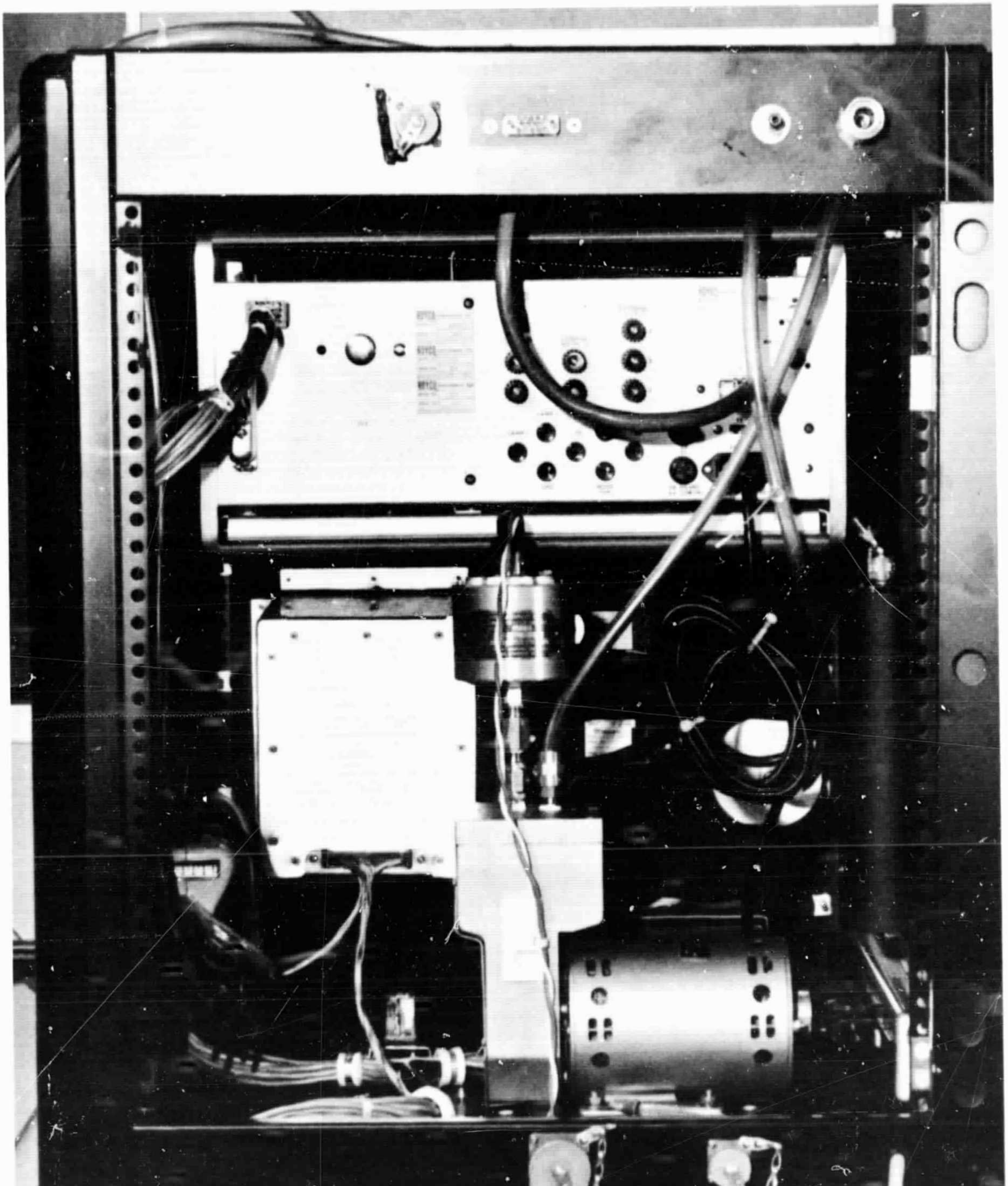


Fig. 4-1 - PC Module Inside Rear View

that were to be used to fill the span gas bottle without disconnecting it could not be used because space inside the cabinet was limited. The technique to pump the condensate resulting from the hydrogen flame in the hydrocarbon analyzer into the hydrogen generator reservoir became questionable. Because of the requirement for ultra-pure water for the generator, the condensate was collected first in a plastic bottle. The condensate was then to be checked for purity. The size and weight and the need for ready access made it necessary to have a mounting bracket for the filter (Fig. 4-2). Also, a terminal strip was mounted on top of the hydrocarbon analyzer (Fig. 4-2) for access to the wiring for the pump and solenoids. The remaining equipment and components were fabricated and assembled in compliance with the final design drawings.

4.2 CHECKOUT AND TEST

Upon completion of each module a checkout and operation test was performed. Before the module system was put in operation, each piece of equipment was checked out according to the procedures provided in the individual operations manual.

The HFI Module was the first to be completed. During checkout, it became apparent that several changes were needed. First, a throttle valve was installed on the sample inlet to the analyzer to control the sample flow rate and to provide the proper air pressure. An automatic moisture separator and filter were installed on the pump output to prevent moisture from entering the catalytic oxidizer. Flexible "impolene" (polyethelene) tubing was installed to isolate the pump vibrations. A test of the collected contents of the condensate bottle showed that the condensate was questionable, and the condensate was therefore not reused. The condensate bottle (Fig. 4-3) is also used to collect the output of the automatic moisture separator. The condensate collects at a rate slow enough so as to need emptying only at the regular servicing intervals.

The PC Module was completed next. The checkout went smoothly with one exception. While the module was being calibrated, only one channel of the

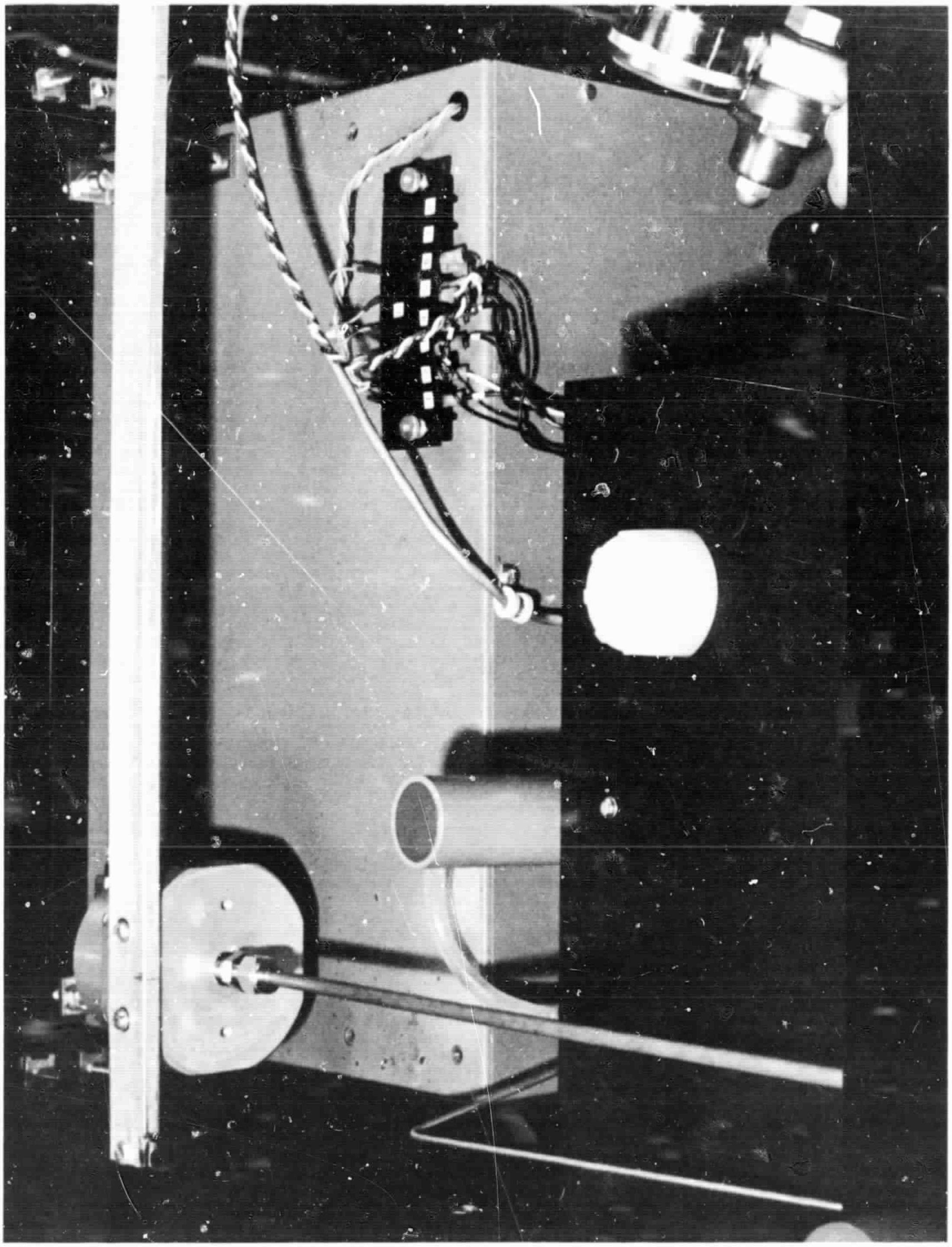


Fig. 4-2 - HFI Module (Inside Top View)

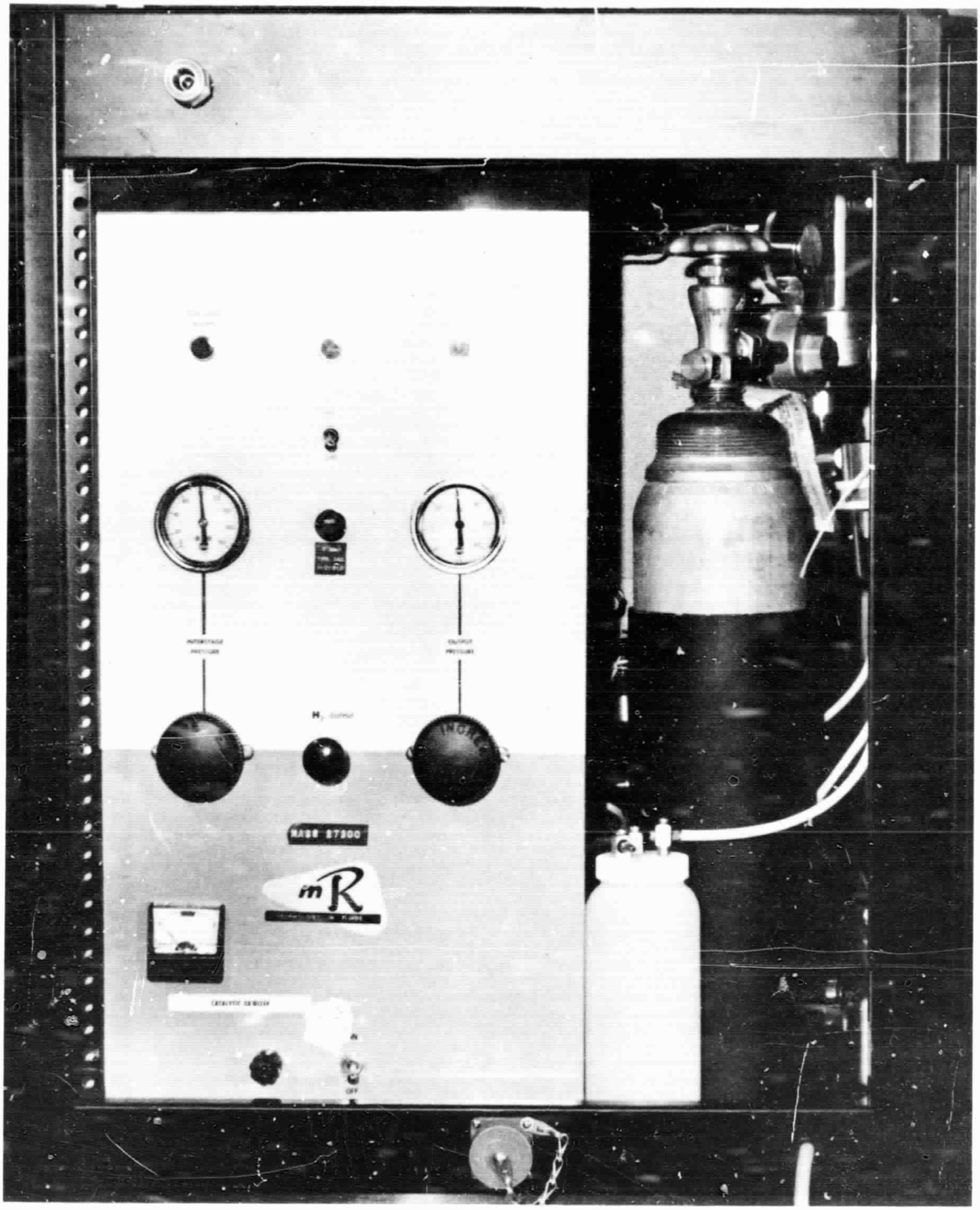


Fig. 4-3 - HFI Module (Inside Back View) particle counter was to have a readout, but all four channels had readings. A conference with the factory personnel indicated that a field change was necessary to correct the problem. The change was performed and all checkouts proceeded smoothly.

The RA Module was the last to be completed. Checkout of the equipment went smoothly. However, during checkout it became apparent that a safety problem regarding 115 Vac power existed. With the umbilical cable connected and the data logger off, there was no way to tell whether 115 Vac were being supplied; i.e., whether the master switch in the supplying module was on or off. This was remedied by installing a power light on the front of the RA Module (Fig. 3-4). The light is on as long as power is supplied to the RA Module.

The modules were then set up as a total system and a final system checkout and test performed. Everything performed well except the data logger clock. The clock time changed radically every time the ACU operated. A faulty switch in the ACU's 24-hour time appeared to be the culprit. A 24-hour operational test was performed with no further problems. The CEMS was then readied for shipment to MSFC.

4.3 DEMONSTRATION

The CEMS was delivered to MSFC and set up in a clean room for a two-week demonstration. During the first few days of the demonstration, the ACU-induced clock problem reappeared. A thorough check of the system located the problem in two capacitors on the clock board. The board was returned to the factory for repair. An available spare board allowed the system to continue operation. The humidity sensor when checked against other instruments appeared to read low by 4% RH. However, a calibration check of the CEMS sensor in a test chamber proved the calibration to be correct.

Near the end of the demonstration the particle counter appeared to have a component failure. The readouts suddenly appeared to be very noisy with a repetitive signal occurring every 12 minutes, indicating that the clean room was out of specs. The daily particle count of the clean room showed it to be within specs. A thorough checkout of the particle counter electronics produced no cause for such a problem. A thorough check of other equipment in the area provided no further clues as to the cause. A test with pure nitrogen was then performed and a test in a clean bench verified the findings. The clean room air supply had experienced a failure and the particle count was indeed exceeding specifications every 12 minutes. These findings verify the need for the CEMS.

Section 5
CONCLUSIONS AND RECOMMENDATIONS

A reliable Critical Environment Monitoring System has been designed and developed. The hardware has been fabricated which meets the NASA specifications. The particle counter episode during the demonstration, discussed in Section 4.3, verifies the need for using the CEMS in critical clean areas.

Several recommendations are presented for future CEMS as a result of the Phase D effort:

- Copper tubing and brass fittings should be used throughout the system.
- The digital data logger should obtain the day-of-year signal from the same source as the 24-hour print rate signal for printer. (This precludes the necessity of modifying the clock board, thus simplifying the problem of replacement parts.)
- The Royco provided cable for connecting the two 504 units together should have longer leads for the Molex connector (36 inches). (This allows more flexibility during fabrication.)
- Additional slack in leads and tubing to lower front panel on PC Module should be provided for easier access to equipment without a major disassembly.
- All nut and bolt installations to the module floors should utilize "Pem" nuts to simplify installation and repair.
- Louvered back doors having fans mounted on the doors should be used on both the PC Module and HFI Module. (This precludes the need for cutting holes in the floor, and both modules are maintained at room temperature.)
- The total number of wires needed in the 40 foot umbilical cord should be reduced since the data logger provides a single common wire for all indicators. Thus, the extra, two-wire cable would not be necessary.

Section 6
REFERENCES

1. Heimendinger, K.W., "Technological Survey and Preliminary Design of Critical Environment Monitoring System, Phase A Report," LMSC-HREC D225302, Lockheed Missiles & Space Co., Inc., Huntsville, Ala., August 1971.

2. Heimendinger, K.W., "Preliminary Design of Critical Environment Monitoring System, Phase B Report," LMSC-HREC D225418, Lockheed Missiles & Space Co., Inc., Huntsville, Ala., October 1971.

3. Heimendinger, K.W., "Final Design of Critical Environment Monitoring System, Phase C Report," LMSC-HREC D225574-A, Lockheed Missiles & Space Co., Inc., Huntsville, Ala., December 1971.

Appendix A

SPECIFICATIONS

SPECIFICATION

CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

PREPARED BY: K. W. Heimendinger
Research Engineer

APPROVED BY: G. D. Reny, Manager
Aeromechanics Department

Specification

CRITICAL ENVIRONMENT MONITORING SYSTEM

SUMMARY

This specification establishes the requirements for a Critical Environment Monitoring System (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm module. Such a system will be portable and easily handled, as well as flexible for positioning the equipment for monitoring various work stations.

CRITICAL ENVIRONMENT MONITOR SYSTEM REQUIREMENTS

1.0 CONFIGURATION

1.1 The CEMS shall consist of three module consoles (Fig. 1): two instrumentation modules and the recorder-alarm module.

1.2 The modules shall be of minimum size and weight consistent with performance. Each module will be no larger than 0.66 meters (26 inches) wide, 0.69 meters (27 inches) high and 0.66 meters (26 inches) deep so that two men can negotiate stairways and equipment bays as necessary for transporting the equipment.

1.3 The modules shall have plastic doors where necessary to prevent tampering.

1.4 All locks shall have a common key.

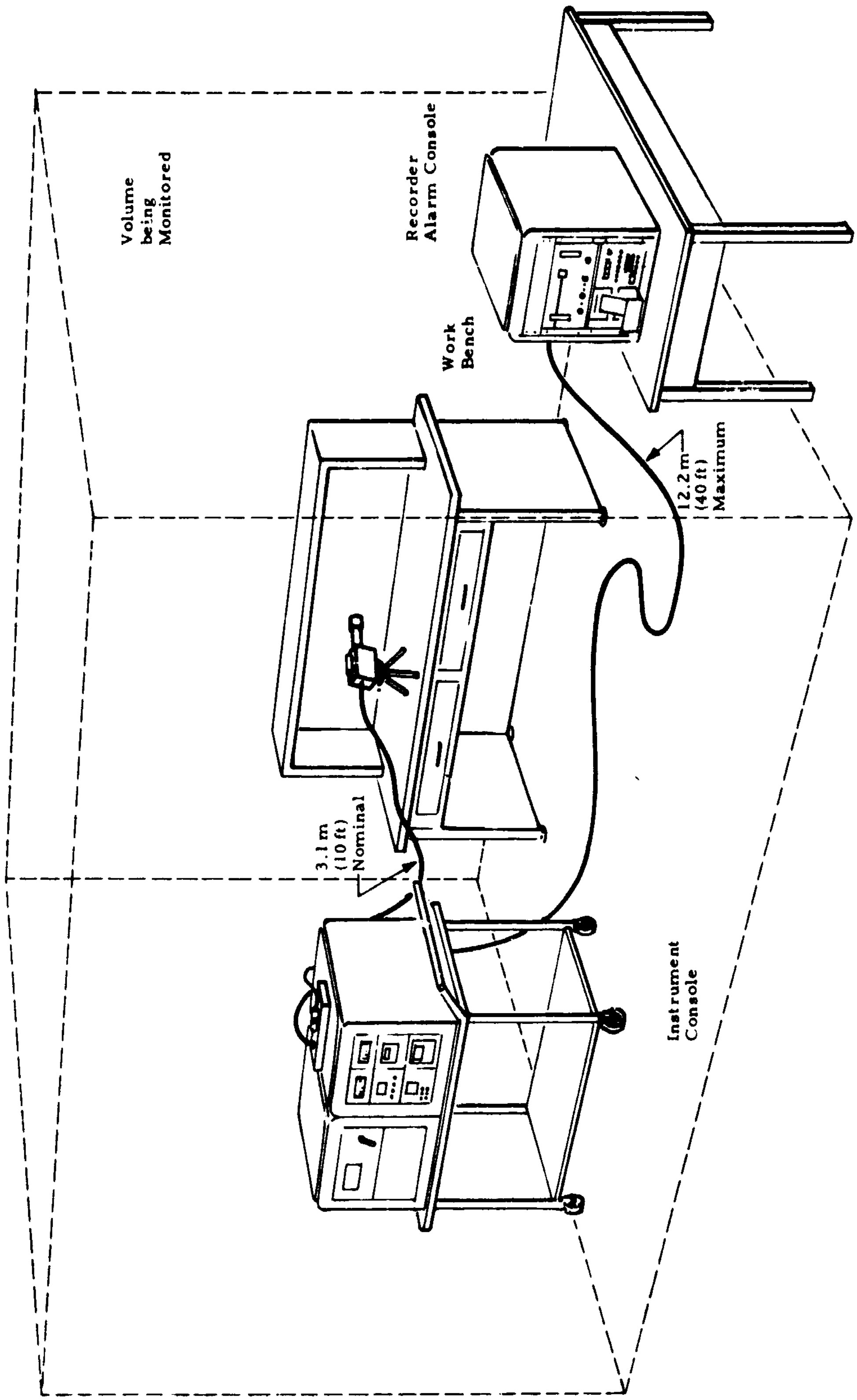


Fig. 1 - Critical Environment Monitoring System Configurations

1.5 The instrument modules shall be interconnected by a short umbilical cable with miniature type connectors and quick-connect pneumatic fittings to facilitate ease of interconnecting power and sampling hose.

1.6 The RA module shall be connected to the instrument modules by a single umbilical cable with miniature type connectors that will allow the consoles to be separated by 12.2 meters (40 feet) (maximum).

1.7 The RA module shall contain

Automatic Calibration Unit (ACU)
Alarm system
Data logger/printer with remote output plug (digital)
Chassis
Accessory and mounting hardware

1.8 The PC module shall contain

Particle counter with probes and sensors
Humidity sensor
Temperature sensor
ACU relay
Sampling pump
Chassis
Accessory and mounting hardware

1.9 The HFI module shall contain

Total hydrocarbon analyzer
Hydrogen generator
Catalytic oxidizer
ACU solenoids
Sampling pump
Chassis
Accessory and monitoring hardware

2.0 ELECTRICAL REQUIREMENTS

2.1 The equipment shall be connected as shown in Fig. 2.

2.2 The total power budget at 115 Vac shall be 24 amperes (amp) maximum. Approximate distribution shall be as listed as follows:

Instrumentation Modules

PC Module		HFI Module	
Particle counter	5.0 amp	Hydrocarbon analyzer	1.0 amp
Humidity	0.1	Hydrogen generator	1.0
Temperature	0.3	Catalytic oxidizer	3.0
Pump	2.6	Pump	3.0
Total	8.0 ± 1.0 amp	Total	8.0 ± 1.0 amp

Recorder-Alarm Module

ACU	1.0 amp
Alarms	1.0
Data logger/printer	3.0
Total	5.0 ± 1.0 amp

2.3 A power outlet box with a 15 amp circuit breaker and master switch shall be mounted inside the rear access door of each module.

3.0 PNEUMATIC SYSTEM AND PLUMBING

3.1 The pneumatic system shall consist of the necessary tubings and fittings for sampling and calibrating as shown in Fig. 3.

3.2 All tubing fittings shall be of materials that offer no contamination to the sample. Corrosion resistant tubing and fittings shall be used for all pneumatic lines in contact with sample or calibration gas, and drain line for return H_2O.

3.3 The piping layout shall minimize sharp bends and irregularities that may trap particles or other contaminants in the sample flow.

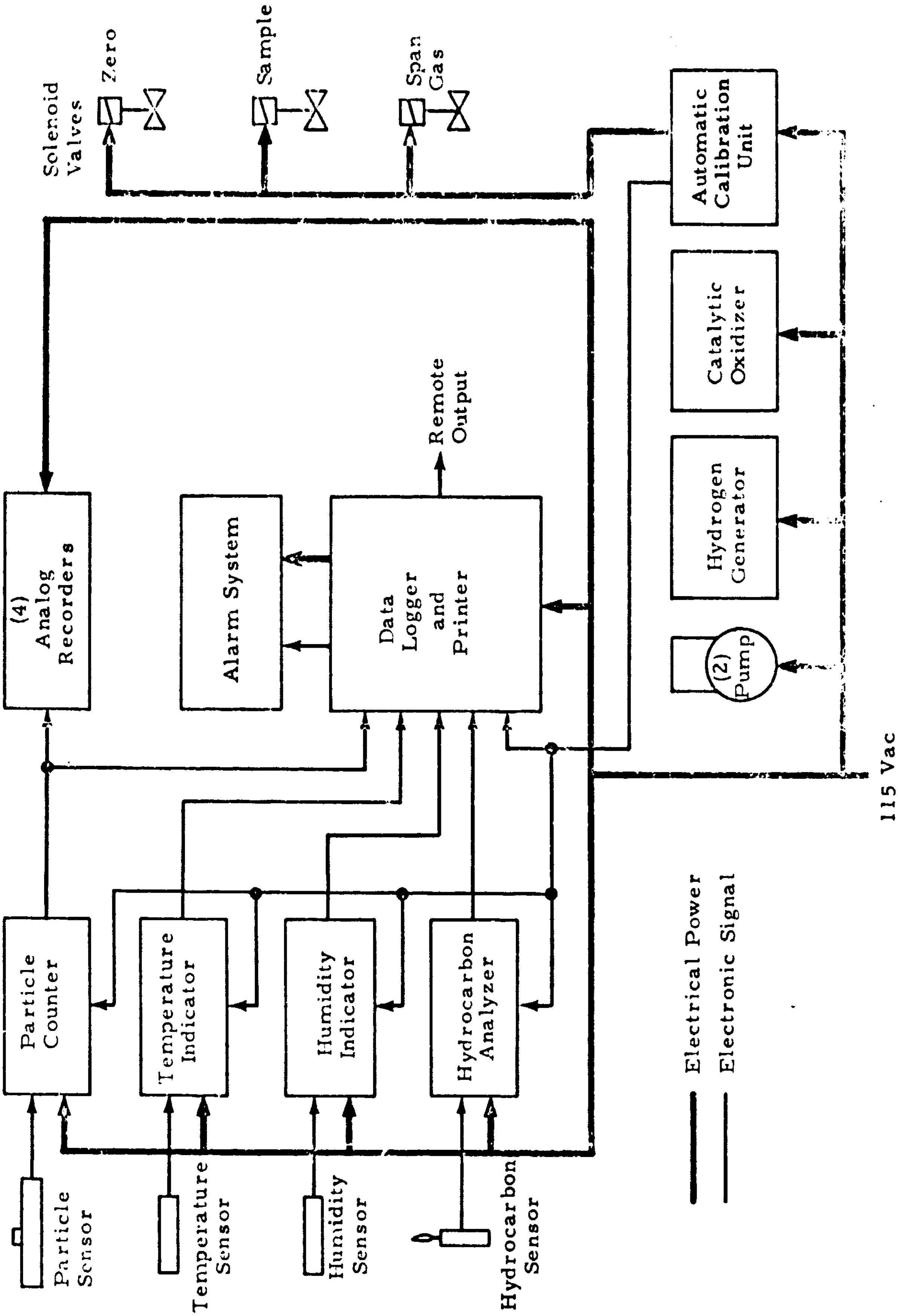


Fig. 2 - Electrical/Electronic Block Diagram CEMS

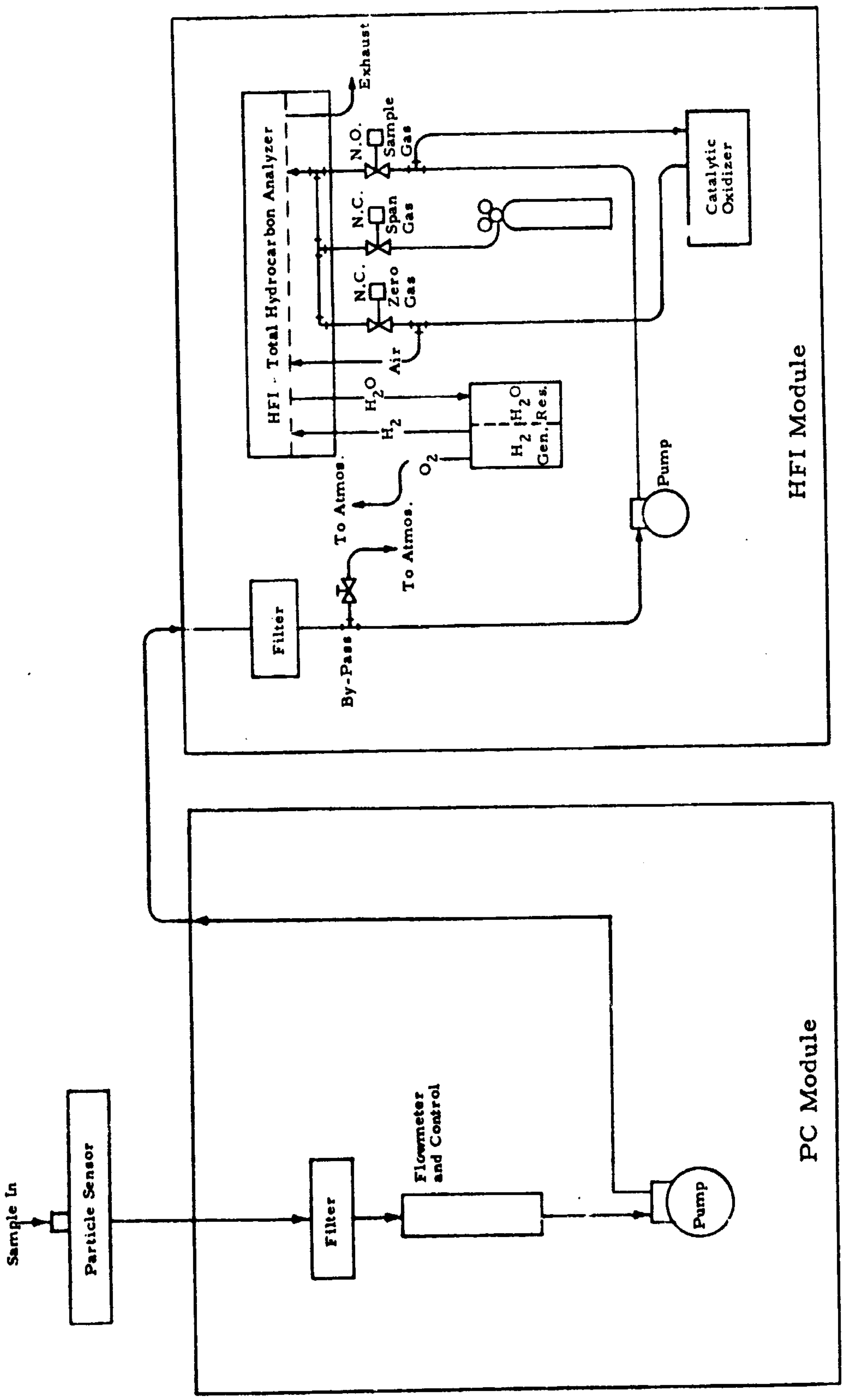


Fig. 3 - Pneumatic Diagram Critical Environment Monitoring System

4.0 INSTRUMENTATION DOLLY (LMSC-HREC Spec. 5150725-A)

4.1. The instrumentation dolly shall measure 0.76 meters (30 inches) wide, 1.37 meters (54 inches) long and 0.76 meters (30 inches) high.

4.2 The dolly shall be so constructed to meet clean room requirements, handle the equipment weight, and equipped with 0.13 meter (5 inch) diameter casters (with locking brakes) for ease of transporting.

4.3 The dolly shall have a lower shelf capable of storing the RAC for ease in transporting the CEMS.

4.4 The dolly shall be constructed of polished stainless steel and will require no further protective coating.

5.0 PC MODULE

5.1 Particle Counter (LMSC-HREC Spec. 5150729-D)

5.1.1 The particle counter shall utilize the light scattering technique for sizing and counting.

5.1.2 The counter shall have four sizing ranges with a sizing accuracy of $\pm 10\%$ full scale:

0.5 to 2.0 microns
2.0 to 5.0 microns
5.0 to 20.0 microns
20.0 microns and larger

5.1.3 The counter shall be capable of counting up to 100,000 particles per cubic foot with an accuracy of $\pm 10\%$ full scale.

5.1.4 The counter shall have a remote sensing probe capable of monitoring remote work stations at a nominal length of 10 feet.

5.1.5 The counter shall continuously monitor all four sizing ranges and provide an analog strip chart recording of the count in each range.

5.1.6 The counter shall sample at 0.03 cubic meters (1.0 cubic foot) per minute.

5.1.7 The counter shall have a sample flow rate control capability to ensure proper flow to maintain counting accuracy as specified in 4.1.3.

5.1.8 The particle counter envelope shall be 0.48 meters (19 inches) wide by 0.56 meters (22 inches) deep by 0.23 meters (9 inches) high and weigh 32.0 kilograms (66 pounds) maximum.

5.1.9 The finish of the counter face shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

5.2 Humidity Sensor (LMSC-HREC Spec. 5150726-B)

5.2.1 The humidity sensor shall utilize an all-electric hygrometric circuit element to provide readings of relative humidity.

5.2.2 The sensor shall have a range of 30 to 70% relative humidity with an accuracy of $\pm 1\%$ relative humidity (R.H.) over an ambient temperature range of 278 to 333°K (+5 to +60°C).

5.2.3 The relative humidity shall be displayed in tenths of a percent R.H. by a digital panel meter mounted on the front of the PC module.

5.2.4 The humidity sensor envelope shall be 0.15 meters (6 inches) wide by 0.33 meters (13 inches) deep by 0.08 meters (3 inches high) and weigh 2.3 kilograms (5 pounds) maximum.

5.2.5 The finish of the humidity sensor panel meter face shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

5.3 Temperature Sensor (LMSC-HREC Spec. 5150727-B)

5.3.1 The temperature sensor shall be a platinum resistance sensor utilizing a linear bridge system for direct temperature readings.

5.3.2 The sensor shall have a range of 277 to 311°K (4 to 38°C) with an accuracy of $\pm$0.5°K.

5.3.3 Temperature shall be displayed in tenths of a degree Celsius by a digital panel meter mounted on the front of the PC module.

5.3.4 The temperature sensor envelope shall be 0.08 meters (3 inches) square by 0.10 meters (4 inches) high and weigh 1.4 kilograms (3 pounds) maximum.

5.3.5 The finish of the temperature sensor panel face shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

5.4 Sampling Pump

5.4.1 The pump shall have vacuum/pressure capabilities.

5.4.2 The pump shall be capable of drawing the sample through the particle counter at a rate of 0.03 m^3/min (1.0 ft^3/min) minimum.

5.4.3 The pump shall be so constructed as to cause no hydrocarbon or particulate contamination.

5.4.4 The pump envelope shall be 0.23 meters (9 inches) wide by 0.10 meters (4 inches) deep by 0.18 meters (7 inches) high and weigh 5.0 kilograms (11 pounds) maximum.

5.5 PC Module Chassis

5.5.1 The chassis shall be of the construction capable of handling the weight and volume of the rack-mounted instrumentation equipment. The chassis corners and edges shall be rounded for safety.

5.5.2 The chassis shall have side handles for hand carrying and a flush door on the back to provide easy access to the equipment.

5.5.3 The finish of the chassis shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

6.0 HFI MODULE

6.1 Total Hydrocarbon Analyzer (HFI) (LMSC-HREC Spec. 5150728-B)

6.1.1 The total hydrocarbon analyzer shall utilize the hydrogen flamionization (HFI) technique.

6.1.2 The analyzer shall have a range of 0 - 40 parts per million (ppm) with an accuracy of $\pm 5\%$ full scale.

6.1.3 The analyzer shall have flow rate control capability to meet the accuracy requirements of 4.3.1.2.

6.1.4 The analyzer shall be equipped with flame-out alarm and automatic hydrogen shut-off for maximum safety.

6.1.5 The analyzer envelop shall be 0.48 meters (19 inches) wide by 0.33 meters (13 inches) deep by 0.30 meters (12 inches) high and weigh 15.9 kilograms (35 pounds) maximum.

6.1.6 The finish of the analyzer face and cover door shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

6.2 Hydrogen Generator

6.2.1 The hydrogen generator shall produce ultrapure hydrogen (less than 0.01 ppm hydrocarbons).

6.2.2 The generator shall have a capacity of 0.009 cubic meters (0.31 cubic feet) per hour maximum.

6.2.3 The generator shall be capable of an output pressure 0 to 4.22 kilograms per square centimeter (0 to 60 psig).

6.2.4 The generator shall fit within an envelop of 0.30 meters (12 inches) wide by 0.36 meters (14 inches) deep by 0.58 meters (23 inches) high and weigh 15.9 kilograms (35 pounds) maximum.

6.3 Catalytic Oxidizer (LMSC-HREC Spec. 5150728-B)

6.3.1 The catalytic oxidizer shall produce zero gas and combustion air with a hydrocarbon content of less than 0.1 ppm (measured as methane).

6.3.2 The flow rate shall be 0.28 cubic meters (10 cubic feet per hour) maximum.

6.3.3 The oxidizer envelop shall be 0.20 meters (8 inches) wide by 0.18 meters (7 inches) deep by 0.30 meters (12 inches) high and weigh 4.5 kilograms (10 pounds) maximum.

6.4 Sampling Pump

6.4.1 The pump shall have vacuum/pressure capabilities.

6.4.2 The pump shall be capable of drawing the sample through the in-line particle filter at a rate and pressure sufficient to provide a sample flow of 0.11 to 0.28 cubic meters per minute (4 - 10 cubic feet per minute) at a pressure of 0.18 kg/cm^2 (2.5 psig).

6.4.3 The pump shall be so constructed as to cause no hydrocarbon or particulate contamination.

6.4.4 The pump envelope shall be 0.23 meters (9 inches) wide by 0.10 meters (4 inches) deep by 0.18 meters (7 inches) high and weigh 5.0 kilograms (11 pounds) maximum.

6.5 HFI Module Chassis

6.5.1 The chassis shall be of the construction capable of handling the weight and volume of the rack-mounted instrumentation equipment. The chassis corners and edges shall be rounded for safety.

6.5.2 The chassis shall have side handles for hand carrying and a lift door on the top and a flush door on the back to provide easy access to the equipment.

6.5.3 The finish of the chassis shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

7.0 RECORDING-ALARM (RA) MODULE

7.1 DIGITAL DATA ACQUISITION SYSTEM (LMSC-HREC Spec. 5150724)

7.1.1 Alarm System

7.1.1.1 An alarm system shall be provided for continuous monitoring of each of the seven (7) data channels.

7.1.1.2 Each channel shall have both high and low settable limits.

7.1.1.3 All channels shall be connected to a common audio alarm with red indicator light.

7.1.1.4 An alarm signal from any channel shall command the printer to print out the data with the alarmed channel printed in red.

7.1.1.5 The alarm system envelope shall be 0.48 meters (19 inches) wide by 0.42 meters (16.5 inches) deep by 0.15 meters (6 inches high) and weigh 9.1 kilograms (20 pounds) maximum.

7.1.1.6 The finish of the meters and the panel shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

7.1.2 Data Logger/Printer

7.1.2.1 The data logger/printer shall scan, digitize, and print the analog data.

7.1.2.2 The system shall scan the data at the desired interval (continuous to one-per-day) at a rate of two channels per second.

7.1.2.3 The system shall be capable of handling seven (7) analog channels plus one (1) time channel.

7.1.2.4 The data logger/printer shall be capable of recording four columns of data for a maximum count of 100.0K particles.

7.1.2.5 The data logger/printer shall have an output plug to provide remote output for hardline transmission of digital data.

7.1.2.6 The data logger/printer envelope shall be 0.48 meters (19 inches) wide by 0.44 meters (17.2 inches) deep by 0.18 meters (7 inches high) and weigh 11.3 kilograms (25 pounds) maximum.

7.1.2.7 The finish of the data logger/printer face shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

7.2 AUTOMATIC CALIBRATION UNIT (ACU)

7.2.1 Automatic calibration shall be performed on all sensors and electronics including the particle counter, by the automatic calibration unit (ACU) at least once every 24 hours.

7.2.2 The ACU shall consist of a 24-hour timer-sequencer, two time delay relays, a relay and a small bottle of span gas with three solenoid valves and appropriate plumbing.

7.2.3 The ACU shall switch in resistors to the temperature and humidity circuits, switch the particle counter for a "red-line" calibration readout, control the solenoids of the HFI analyzer and control the printer to properly identify and record the calibration.

7.2.4 The ACU envelope shall be 0.20 meters (8 inches) wide by 0.15 meters (6 inches) deep by 0.10 meters (4 inches) high and weigh 4.5 kilograms (10 pounds) maximum.

7.3 RA MODULE CHASSIS

7.3.1 The chassis shall be of the construction capable of handling the weight and volume of each mounted equipment. The chassis corners and edges shall be rounded for safety.

7.3.2 The chassis shall have side handles for hand carrying, and a hinged top to provide easy access to the equipment.

7.3.3 The finish of the chassis shall be an enamel or acrylic paint sufficiently baked so as to produce no hydrocarbon or particulate contamination. The color shall be selected to provide optimum visual detection of particulate matter.

Revision B to:
LMSC-HREC 5150724

SPECIFICATION

DIGITAL DATA ACQUISITION SYSTEM
FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

PREPARED BY: K. W. Heimendinger
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APPROVED BY: R. B. Wysor, Supervisor
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Aeromechanics Department

Specification

DIGITAL DATA ACQUISITION SYSTEM FOR CRITICAL ENVIRONMENT MONITORING SYSTEM

SUMMARY

This specification established the requirements for the digital data acquisition system for the Critical Environment Monitoring system (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

DIGITAL DATA ACQUISITION SYSTEM REQUIREMENTS

1.0 SYSTEM CONFIGURATION

1.1 The digital data acquisition system shall consist of the necessary components to scan, digitize, and print out ten (10) channels of analog data and one channel of real time. The system shall also have settable high and low alarm limits for each data channel.

1.2 The system envelope shall be no larger than 19 inches wide by 18 inches deep by 14 inches high and weigh 40 pounds maximum. The system shall have suitable hardware for rack mounting.

1.3 The finish of the case and panel face shall be enamel, baked at 300°F for twenty (20) minutes so as to produce no hydrocarbon contamination at normal ambient conditions.

1.4 The case and panels of the system shall be painted a flat charcoal color so as to provide optimum visual detection of particulate matter in a clean room environment.

1.5 Power provided shall be 120 Vac ± 10% at 60 Hz.

2.0 DATA LOGGER/PRINTER

2.1 The system shall be capable of handling ten (10) analog channels and one time channel.

2.2 Channel scan rate shall be 2.5 channels per second.

2.3 Frame scan rate shall be variable from continuous to one frame per 24 hours.

2.4 Visual data presentation shall be a visual display in $3\frac{1}{2}$ digits with floating decimal. Visual display shall read time and/or data.

2.5 An internal, digital, real time clock shall provide time readout in days, hours, and minutes.

2.6 A printed record of the data and time shall be provided by the self-contained printer.

2.7 A typical printed data frame shall provide: time in days, hours and minutes; channel identification; and data with proper engineering units.

2.8 System Inputs shall be:

Ch. 05 Temperature: 0 to 50°C = 0 to 50 mV, read to 0.1°C

Ch. 04 Humidity: 0 to 100% = 0 to 100 mV, read to 0.1%

Ch. 06 Hydrocarbons: 0 to 40 ppm = 0 to 40 mV, read to 0.1 ppm

Particle count (four channels with 4 ranges each as follows):

Ch. 00, 01 0-100K particles = 0 to 100 mV, read to 0.1K particles
0-10K particles = 0 to 10 mV, read to 0.01K particles
0-1K particles = 0 to 1 mV, read to 0.001K particles
0-100 particles = 0 to 1 mV, Range indicated by remote (40-50 ft. away) switch closure activating coded character in engineering units column.

Ch. 02, 03 0-10K particles = 0 to 10 mV, read to 0.01K particles
0-1K particles = 0 to 1 mV, read to 0.001K particles
0-100 particles = 0 to 1 mV
0-10 particles = 0 to 1 mV
Range indicated by remote (40-50 ft away) switch closure activating coded character in engineering units column.

2.9 Engineering units code shall be:

Temperature = °C

Humidity = RH

Hydrocarbon = P/M

Particles: 100K = P
10K = P
1K = P
100 = PB
10 = PA

2.10 A contact closure by a Lockheed furnished remote (40-50 ft. away) pressure switch shall cause red printing of the frame header line to indicate an "alarm" condition in the CEMS Sampling rate.

A contact closure by a Lockheed furnished remote (3-4 ft. away) relay shall cause red printing of the entire data printout to indicate a "calibrate" condition.

2.11 System accuracy shall be $\pm 0.1\%$ of reading, one digit, or 5 microvolts, whichever is greater, $\pm$ one digit.

2.12 System remote output shall have internal interface for 9-tracks, 800 BPI incremental magnetic tape recorder.

3.0 ALARM SYSTEM

3.1 The alarm system shall provide high-low set points for each of the ten (10) data channels.

3.2 Alarm accuracy shall be plus or minus one count in the least significant position of display.

3.3 The alarm system shall provide normal printing, print on alarm, and continuous scanning with variable print intervals up to once per 24 hours.

3.4 The alarmed channel printout shall be in red.

3.5 The alarm system shall have high-low alarm lights and an audible alarm with a switch for silencing the alarm.

Channel Number

Data

English Units - Meaning:

Channel	Data	Units	Meaning
Ch06	007.2	P/M	7.2 parts per million
Ch05	025.2	°C	25.2 degrees Celsius
Ch04	051.3	RH	51.3% relative humidity
Ch03	.702	PA	7 part/ft^3 (20μ - larger)
Ch02	.247	PB	24 part/ft^3 (5.0μ - 20μ)
Ch01	5.17	P	5170 part/ft^3 (2.0μ - 5.0μ)
Ch00	047.6	P	47,600 part/ft^3 (0.5μ - 2.0μ)
312	01:29	HR	1:29 hours

Day of Year   Time   Frame Heading

NORMAL DATA

NOTE 1: All channel data printed in red indicates calibration mode. Alarm mode is indicated by alarmed channel printed in red. Low sample flow rate indicated by frame heading (day-time-hour) printed in red.

NOTE 2: Selector ranges for particle counts are:

100 mV full scale - 100 K part/cu ft

10 mV full scale - 10 K part/cu ft

1 mV full scale - 1 K, 100, and 10 part/cu ft

NOTE 3: All particle count readouts are in K particles/cu ft when P appears. When PA or PB appears: PA - 10 part/cu ft (read 2 MSD only); PB - 100 part/cu ft (read 3 MSD only).

NOTE 4: Temperature, humidity and hydrocarbons are always set on 0 - 100 mV fullscale range.

Typical Data Frame Printout

SPECIFICATION

INSTRUMENTATION DOLLY FOR CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

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Specification

INSTRUMENTATION DOLLY FOR CRITICAL ENVIRONMENT MONITORING SYSTEM

This specification establishes the requirements for the instrumentation console dolly for the Critical Environment Monitoring System (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

INSTRUMENTATION DOLLY REQUIREMENTS

1.0 The instrument console dolly configuration and dimensions shall be as per LMSC-HREC drawing R72151.

2.0 The top shall be constructed of stainless steel with all edges rolled down 90 deg. with at least a 2 in. flange and made with rounded corners. The underside shall be properly reinforced to support at least 400 lbs. of equipment and properly sound deadened with vinyl material.

3.0 The undershelf shall be constructed of stainless steel with all edges rolled down 90 deg. with at least a 2 in. flange and made with rounded corners. The undershelf shall be capable of supporting at least 200 lbs. of equipment and shall be properly sound deadened with vinyl material.

4.0 The legs shall be constructed of stainless tubing and mounted on 5 in. diameter N.S.F. swivel casters with locks capable of supporting the specified loads in 2.0 and 3.0.

5.0 The handle shall be constructed of stainless steel with all sharp edges broken with a minimum 0.03 in. radius.

6.0 The table assembly shall be constructed and the joints reinforced to allow no more than 1/8 inch deflection in the top and undershelf or 1 degree relative deflection of the legs under normal transporting loads (Para. 2.0 and 3.0).

Revision B to:
LMSC-HREC 5150726

SPECIFICATION

RELATIVE HUMIDITY INSTRUMENT
FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

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Specification

RELATIVE HUMIDITY INSTRUMENT FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

This specification establishes the requirements for the relative humidity instrument for the Critical Environment Monitoring system (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

RELATIVE HUMIDITY INSTRUMENT REQUIREMENTS

1.0 The relative humidity instrument shall utilize an electric hygrometric circuit element to provide readings of relative humidity.

2.0 The instrument shall have a range of 0 to 100% relative humidity (RH) with a linear output voltage of 0 to 100 millivolts. No analog readout meter is required.

3.0 The instrument shall have an accuracy of $\pm 1\%$ for the range of 30 to 70% RH over the temperature range of $+5^{\circ}C$ to $+60^{\circ}C$.

4.0 The resistance value of the humidity sensor at 50% RH shall be provided by the vendor to Lockheed-HREC to assist in overall system calibration.

5.0 The sensing probe shall be the Phys-Chemical Research Corporation's standard PCRC-11HP sensing probe with two spare pins for mounting an additional temperature sensor. The probe cable shall be 6 feet long.

6.0 The relative humidity instrument shall be provided with a plug for the linear output voltage jack.

7.0 The relative humidity instrument envelope shall be no larger than 6 inches wide by 12 inches deep by 3 inches high and shall weigh no more than 5 pounds.

8.0 Power provided shall be 120 Vac $\pm 10\%$ at 60 Hz.

Revision B to:
LMSC-HREC 5150727

SPECIFICATION

TEMPERATURE INSTRUMENT
FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

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Specification

TEMPERATURE INSTRUMENT FOR CRITICAL ENVIRONMENT MOINTORING SYSTEM

This specification establishes the requirements for the temperature instrument for the Critical Environment Monitoring System (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

TEMPERATURE INSTRUMENT REQUIREMENTS

1.0 The temperature instrument shall consist of Rosemont Engineering Company's Model 414L 3AXH Linear Bridge and Model 14U100A Platinum Sensor.

2.0 The instrument shall read zero at $0^{o}C$ and have an output slope of 1 millivolt per ^{o}C for the range of $0^{o}C$ to $50^{o}C$.

3.0 The instrument shall have an accuracy of $\pm 0.5^{o}C$ and a non-linearity of better than $\pm 0.1^{o}C$ over the temperature range of $4^{o}C$ to $38^{o}C$.

4.0 The resistance value of the temperature sensor at $17^{o}C$ shall be provided by the vendor to Lockheed-HREC to assist in overall system calibration.

5.0 The load resistance of the bridge shall be 91 meg ohms.

6.0 The linear bridge envelope shall be no larger than 4 inches high and 3 inches square and weigh no more than 3 pounds.

7.0 Power provided shall be 120 Vac $\pm 10\%$ at 60 Hz.

Revision B to:
LMSC-HREC 5150728

SPECIFICATION

TOTAL HYDROCARBON ANALYZER
FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

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Specification

TOTAL HYDROCARBON ANALYZER FOR CRITICAL ENVIRONMENT MONITORING SYSTEM

This specification establishes the requirements for the total hydrocarbon analyzer for the Critical Environment Monitoring System (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

TOTAL HYDROCARBON ANALYZER REQUIREMENTS

1.0 Total Hydrocarbon Analyzer

1.1 The total hydrocarbon analyzer shall be Mine Safety Appliances Company's total hydrocarbon analyzer utilizing the hydrogen flamionization technique.

1.2 The analyzer shall have a range of 0 to 40 PPM with an accuracy of at least $\pm$ 5% full scale and shall provide a matching linear output signal of 0 to 40 mv.

1.3 The analyzer shall be equipped with flame-out alarm and automatic hydrogen shut-off for maximum safety.

1.4 The analyzer envelope shall be no larger than 19 inches wide by 13 inches deep by 12 inches high and shall weigh 35 lbs. maximum. The analyzer shall have suitable hardware for rack mounting.

1.5 The finish of the case and panel face shall be Sherwin-Williams Company's "Polatex" No. F6317 Nitro-Blue.

1.6 Power provided shall be 120 vac $\pm$ 10% at 60 Hz

2.0 Support Equipment

2.1.0 Catalytic Oxidizer

2.1.1 Combustion air and zero gas shall be provided by MSA's Catalytic Oxidizer.

2.1.2 Hydrocarbon content of the air shall be less than 0.1 ppm (measured as methane.

2.1.3 Maximum flow rate shall be 10 cubic feet per hour.

2.1.4 The oxidizer envelope shall be no larger than 8 inches wide by 7 inches deep by 12 inches high and weigh 10 lbs. maximum.

2.1.5 Power provided shall be 120 vac $\pm$ 10% at 60 Hz.

2.2.0 Span Gas Bottle

2.2.1 An empty 16 cubic foot (4 in. dia. by 17 in. long) cylinder for span gas complete with regulator and flow meter assembly shall be provided.

Revision D to:
LMSC-HREC 5150729

SPECIFICATION

PARTICLE COUNTER
FOR
CRITICAL ENVIRONMENT MONITORING SYSTEM

5 June 1972

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Specification

PARTICLE COUNTER FOR CRITICAL ENVIRONMENT MONITORING SYSTEM

This specification establishes the requirements for the particle counter system for the Critical Environment Monitoring system (CEMS). The end product shall be a self-contained, integrated, minimum-sized unit which will detect, interrogate and record those parameters of the environment dictated for control in such controlled environments as those of large storage facilities, clean rooms, temporarily curtained enclosures, and special work benches.

The system will consist of three modules: two instrumentation modules, and a recorder-alarm (RA) module. Such a system will be portable and easily handled, as well as be flexible for positioning the equipment for monitoring various work stations.

PARTICLE COUNTER SYSTEM REQUIREMENTS

1.0 Particle Counter System

1.1 The particle counter system shall be the Royco Model 245 Airborne Particle Counter System, consisting of: a Model 245 mainframe (modified) (Para. 2.1), a Model 242 sensor (modified) (Para. 2.2), two Model 245 recorder modules (modified) (Para. 2.3) and a Model 173 sampling probe (standard).

1.2 The particle counter system shall have four simultaneous sizing ranges with a sizing accuracy of $\pm$ 10% or better as follows:

Module 504-1 Mounted in Model 245 Main Frame
- Ch A 0.5 to 2.0 microns
- Ch B 5.0 microns

Module 504-2 Remote, for mounting in Lockheed's constructed housing
- Ch A 2.0 to 5.0 microns
- Ch B 20.0 microns and greater

1.3 The system shall be capable of counting 10 to 100,000 particles per cubic foot with an accuracy of ± 10% of full scale or better as referenced to the following size ranges:

Module 504-1	Ch A	0.5-2.0 μm	100 - 100,000 particles per Ft^3
	Ch B	5.0-20.0 μm	10 - 10,000 particles per Ft^3
Module 504-2	Ch A	2.0-5.0 μm	100 - 100,000 particles per Ft^3
	Ch B	20.0 μm & greater	10 - 10,000 particles per Ft^3

See 1.2 for size range/count range referenced.

1.4 The system shall continuously monitor all four size ranges and provide analog strip chart recording in each range as follows:

	Ch A		Ch B
Recording No. 1	*0.5 to 2.0 microns	&	5.0 to 20 microns
Recording No. 2	2.0 to 5.0 microns	&	20.0 & greater

*Ch A will record calibrate meter indication Red Line = Center Scale

1.5 The mainframe envelope shall be 19 inches wide by 22 inches deep by 9 inches high and the total system shall weigh 66 pounds maximum. The mainframe shall have suitable hardware for rack mounting.

1.6 The finish of the case shall be vinyl clad (blue) and the front panels shall be enamel (gray) sufficiently baked so as to produce no hydrocarbon contamination at normal ambient conditions.

1.7 Power provided shall be 120 vac ± 10% at 60 Hz.

2.0 Equipment Modifications

2.1 Model 245 Main Frame

2.1.1 The Model 245 main frame vacuum pump and motor assembly shall be removed.

a) Standard product front panel switch and rear panel aerosol sample fitting shall be installed and rendered inoperative.

b) Lockheed shall provide sample flow rate of 1.0 cubic ft. per minute ($\pm 5\%$).

2.1.2 An auxiliary cable 36 inches long with fittings (Cinch 50 pin) shall be provided to permit operating 504-2 module from Model 245 Main Frame.

a) Include rear panel interface for connecting and disconnecting cable from Model 245 (50 pin Cinch)

b) Module 504-2 termination of cable shall provide 22 gauge, color coded, 24" wires for remote metering of 2.0 to 5.0 um and 20.0 um and greater channels (1.0 ma full scale) and form "C" *alarm contacts.

See 2.3.3c

*Module 504 does not provide alarm function. Compatibility to alarm type interchangeable module will exist at rear panel of Lockheed constructed housing for 504-2 when wired.

2.1.3 A special signal and control cable shall be provided to interconnect the Standard 242 sensor cable plug to the 245 mainframe through the Lockheed provided console. The special cable shall be 18 inches long and shall consist of the cable, a 14 pin panel mount receptacle (Royco P/N 545-082) with mounting plate (Royco P/N 545-083) and a 14 pin plug (Royco P/N 545-084).

2.1.4 The main frame shall provide a "red-line" calibration and/or deviation readout to the 504 module 0.5 to 2.0 micron channel during calibration adjustment. The "red-line" shall occur at mid scale of the 504.

2.2 Model 242 Sensor

2.2.1 The Model 242 sensor shall have an extended (40:1) dynamic range of 0.5 microns to 20.0 microns and greater.

2.2.2 The 242 sensor shall be provided with the standard signal and control cable assembly.

2.3 Model 504 Recorder Modules

2.3.1 The four position-two pole lever switches (Royco P/N 240-021) used for range selection shall be replaced with four pole pushbutton switches to provide the same count range selection. The third pole shall be utilized by Lockheed in the data acquisition system. The following interfaces shall be provided to maintain interchangeable module capability.

a) <u>504-1 and 504-2 Modules</u>
   The additional third pole and four positions for each channel shall be wired to the 50 pin connector on the rear deck of both modules.
b) The Model 245 Main Frame shall provide a separate interface connector on the rear panel to provide Data Acquisition connection to the third pole and four positions of the two sets of pushbuttons of 504-1.
c) Auxiliary Cable (Ref. 2.1.2) shall provide similar 24 pin Molex fitting for 504-2.

3.0 Two 0.3 micron, 47 mm filters, with 50 microns, 47 mm backup filters mounted in aluminum holders and including input and output fittings (quick-disconnect) to 5/16" tubing shall be provided.